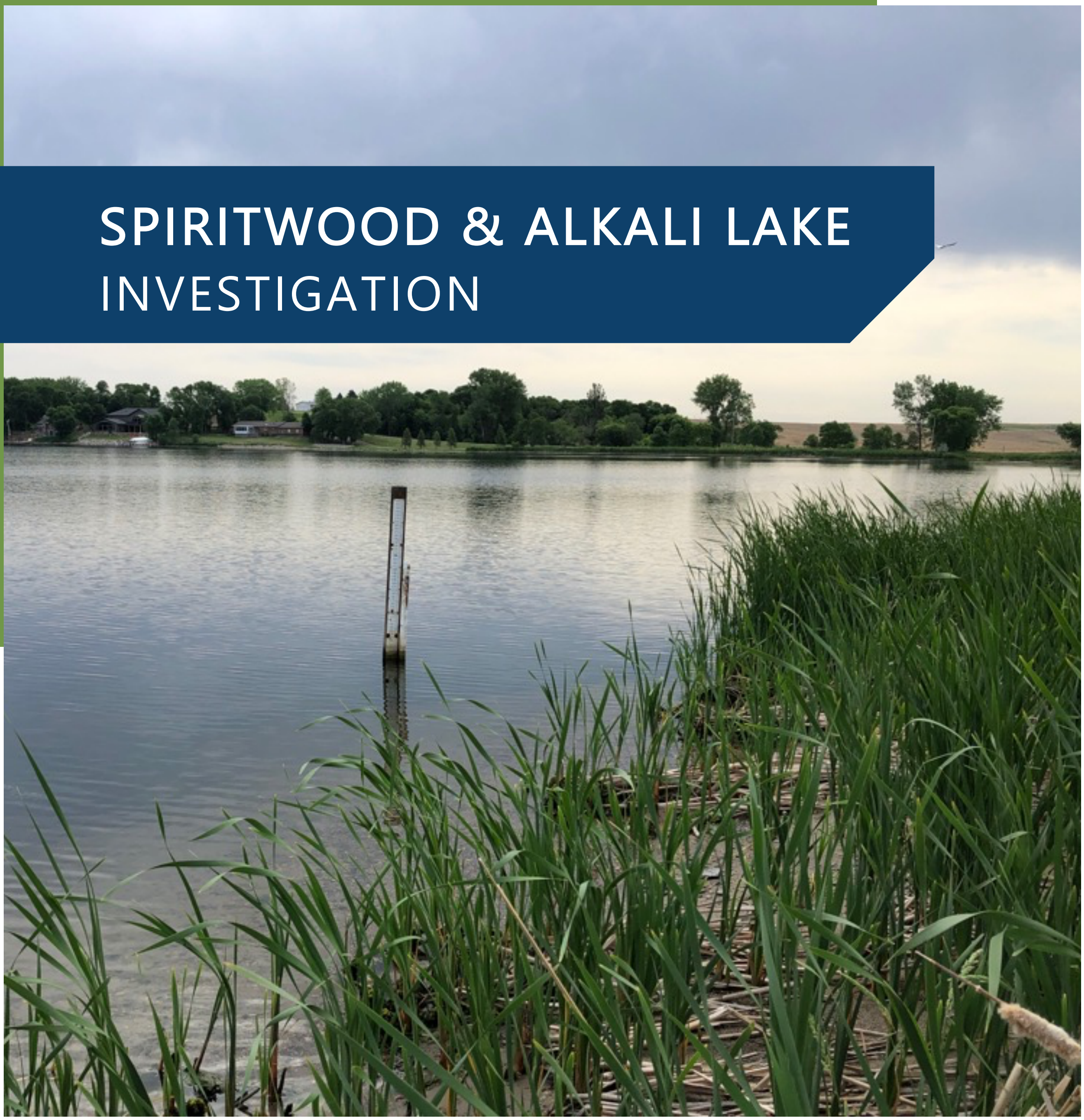
SPIRITWOOD & ALKALI LAKE INVESTIGATION



DEPARTMENT OF WATER RESOURCES

DWR Project #461
January 2023

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1200 Memorial Highway
Bismarck, ND 58504

Prepared For
Stutsman County Water Resource District
Spiritwood Lake, North Dakota, Stutsman County
January 2023

DWR Project #461

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1.0 PURPOSE

The purpose of this report is to document the findings of an investigation that evaluated flood risk reduction measures at Spiritwood and Alkali Lakes. The study was completed between 2020 and 2022 under an Investigation Agreement between the North Dakota State Water Commission (NDSWC) and the Stutsman County Water Resource District (District). The NDSWC was renamed North Dakota Department of Water Resources (NDDWR) by the North Dakota's 67th Legislative Assembly through the House Bill 1353, which became effective on August 1, 2021.

The Investigations Section of the NDDWR conducts feasibility studies, or preliminary engineering evaluations, for public entities on various surface water issues. NDDWR's responsibilities outlined in the agreement include the following:

a. Conduct topographic surveys and field observations to collect necessary data.
b. Examine the hydrology of Spiritwood Lake and Alkali Lake basins.
c. Evaluate options that could be implemented to mitigate damages on Spiritwood Lake.
d. Evaluate impacts of potential alternatives on Seven Mile Coulee.
e. Complete a written report with findings, including cost estimates.

The Investigation Agreement and Scope of Work are included in **Appendix A**.

1.1 Site Location

Spiritwood and Alkali Lakes are located on the eastern edge of Stutsman County, northeast of the City of Jamestown (**Figure 1**). The City of Spiritwood Lake surrounds Spiritwood Lake, while Alkali Lake is located to the south. Spiritwood Lake discharges into Alkali Lake across several county roads. Alkali Lake discharges into Seven Mile Coulee on the west side of the lake. Seven Mile Coulee eventually discharges into the James River, south of Jamestown, North Dakota.

Figure 1. Spiritwood and Alkali Lakes (site map).

2.0 BACKGROUND

This section summarizes past efforts to alleviate flooding issues at Spiritwood Lake, along with actions taken related to water quality and invasive species.

2.1 Spiritwood Lake Background

Spiritwood Lake has an extensive history of water resource issues dating back to the 1920s. Cabin owners on Spiritwood Lake formed an association in the early 1940s to explore alternatives that would raise the lake to levels seen in the 1920s. Inquiries to raise Spiritwood Lake were received by the NDSWC, now known as NDDWR, until the late 1960s, at which point the lake level started to rise naturally.

In 1969, there were two conflicting water management ideas to improve Spiritwood Lake. One group wanted to lower the lake, while the other wanted to reduce losses from the lake. An informal hearing was held on March 10, 1969, at which time landowners agreed that Spiritwood Lake should be lowered to 1439.8 feet msl. On August 28, 1969, an Investigation Agreement was signed between the NDSWC and the District to investigate the loss of water from the lake and explore the potential to replenish water from the north, with the main focus of the project to improve water quality and reduce algae blooms on the lake.

In 1975, the water surface of the lake continued to rise, stemming efforts to reduce the lake's water surface elevation. On July 9, 1975, an Investigation Agreement was signed between the NDSWC and the District to study the management of water resources on Spiritwood Lake, Alkali Lake, and Seven Mile Coulee. A hearing was held on October 6, 1975, in Jamestown, regarding establishment of a water surface elevation for Spiritwood Lake. At the time of the hearing, the lake was at 1443.5 feet msl and those at the hearing determined that an equitable water surface elevation for Spiritwood Lake would be 1442 feet msl. Vern Fahy, the State Engineer at the time, described the water level as:

> *No water surface level could be selected that would satisfy all interests. However, the most equitable level whereby everyone would perhaps "share the misery" and "share the benefits" would be to establish a lake level at an elevation of 1442.0 msl and with removable flashboard down to elevation 1440.0 msl allowing two feet to obtain a greater flexibility in regulating discharges from the lake.*

The City of Spiritwood Lake applied for authorization to partially drain Spiritwood Lake in late 1975. On April 15, 1976, State Engineer Fahy made a final determination and provided authorization for an outlet structure on the southwest side of Spiritwood Lake that would allow drainage to Seven Mile Coulee. This determination also provided that the authorized structure would only permit drainage of water to an elevation of 1442.0

feet msl on Spiritwood Lake. This authorization of the State Engineer had an expiration date of April 14, 1979. The District asked the State Engineer to consider the following items prior to approving the partial drainage application:

- Whether the quantity of water which will be drained from the lake will exceed the capacity of the natural watercourse, draw, natural drainway, or ditch into which the water will be drained;
- Whether the drainage of the lake will cause flooding or otherwise adversely affect the drainage of lands of lower proprietors;
- The report of the Game and Fish Department;
- The report of the Department of Health;
- Aesthetic values;
- The effect of drainage on improvements in and around the lake;
- The effect of the drainage on commercial and farming operations adjacent to the lake;
- The effect of the drainage on roads and other transportation facilities;
- The cost of constructing any drainage structures.

State Engineer Fahy issued acceptable alternatives for controlling the lake elevation and the City of Spiritwood Lake received an extension until April 15, 1981. This project and the other acceptable alternatives identified in the authorization were never developed.

Upon request by the District, NDDWR completed a study in 1976 of four alternatives for the purposes of lowering Spiritwood Lake. These alternatives were presented in 1977 and included the following:

- Pumping into Schock Lake ($224,000)
- Pumping into Seven Mile Coulee ($232,000)
- Channelization from Spiritwood Lake to Seven Mile Coulee ($975,000)
- Creating a dam on the Northeast corner of the lake, which had two options
    - Option 1 – full sized dam ($650,000)
    - Option 2 – dam designed for a 2-year event ($12,200)

Of the alternatives, pumping into Schock Lake was deemed to be the most feasible solution. In September of 1982 a pump with an approximate capacity of 1,900 gpm was installed. Conditions for pumping were set as follows:

- Condition 1 – If Schock Lake is below elevation 1440 feet msl and Spiritwood Lake is above elevation 1443.4 feet msl, then Spiritwood would be pumped continuously until Schock Lake's level reached 1443.5 feet msl.
- Condition 2 – If Schock Lake is between elevations 1443.5 feet msl and 1400 feet msl, Spiritwood Lake would be pumped for water quality reasons only.
- Condition 3 – No pumping would be allowed if Spiritwood Lake is below 1440 feet msl.

- Condition 4 – Water could be pumped into Schock Lake when its level is below 1440 feet msl.
- Condition 5 – Schock Lake levels can be increased from 1440 feet msl to 1442 feet msl for Spiritwood Lake water quality reasons only.

Pumping occurred from 1982 to approximately 1998. On June 1, 1998, a meeting was held between the NDSWC, District, North Dakota Department of Health (The North Dakota Department of Health was restructured in April of 2019 and a new State agency North Dakota Department of Environmental Quality (NDDEQ) was formed and NDDEQ is currently responsible for regulation of water quality), North Dakota Game and Fish Department (NDGF), and others to discuss the easements from the Spiritwood Lake pumping project expiring. It was deemed that the project could not continue operation unless the easements were obtained. Ultimately, the group decided not to renew the easements since Schock Lake's elevation at the time was 1446 feet msl.

In 1989, the NDGF made a one-time effort to stock Zander in Spiritwood Lake. Ontario's Invading Species Awareness Program (OISAP, 2020) identifies the Zander as follows:

> *Zander, also commonly known as Pike-Perch, European Pike-Perch and European Walleye, is a fish from freshwater and brackish habitats in western Eurasia. This species is very similar to its North American cousin, Walleye. Like Walleye, this is a very popular game fish, and has been intentionally introduced in thousands of lakes in Europe outside of its native range to establish sport and commercial fisheries.*

On March 5, 1997 the Spiritwood Lake Association applied for a permit to drain water from Spiritwood Lake with Stutsman County Water Resource District. The proposal was to drain excessive water from Spiritwood Lake to Alkali Lake and establish a permanent outlet at 1443 feet msl. On March 17, 1997 the District denied the application with an unanimous vote.

Figure 2 illustrates the lake level record from 1948 until 1997 (typo in the historical figure saying 1977), which documents the high-water levels Spiritwood Lake was enduring during the flooding in 1997. It was approximately 1-foot higher in 1997 than the previous flood of record in 1979.

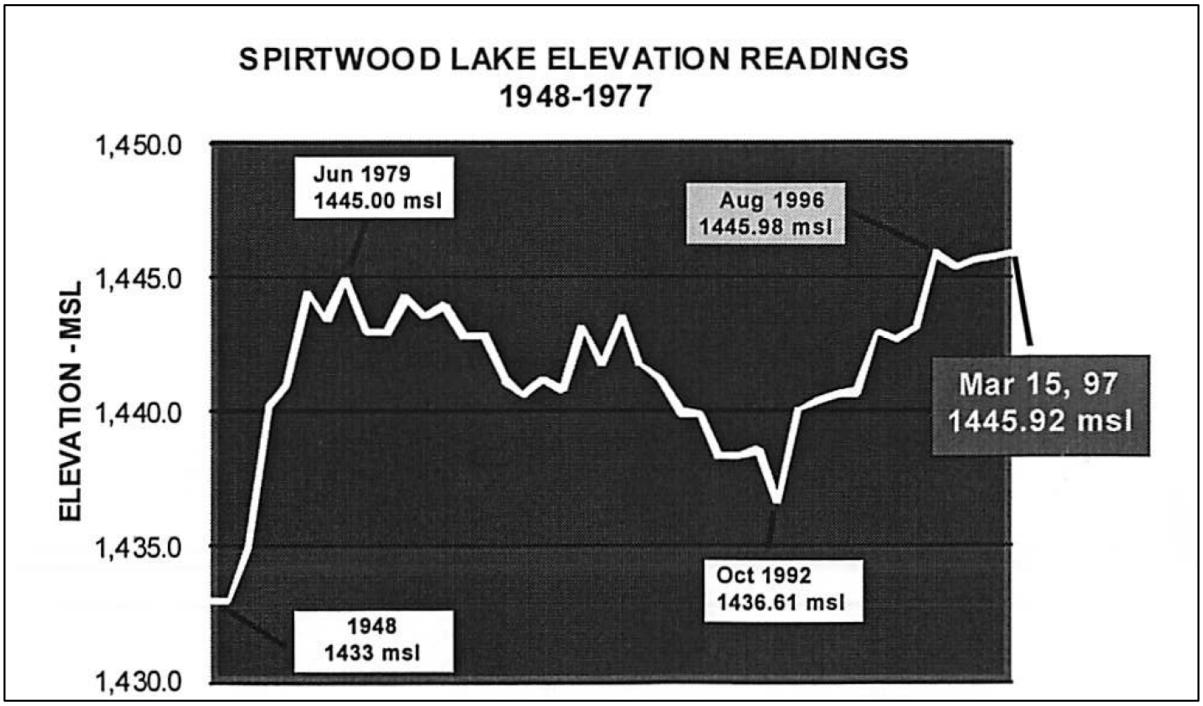

Figure 2. Spiritwood Lake historic gage record (1948-1997).

2.2 Spiritwood Lake Water Quality

In the summer of 2013, the Spiritwood Lake Association Inc. and the City of Spiritwood Lake approached North Dakota Department of Health (currently NDDEQ) with the idea of monitoring Spiritwood Lake to identify the lake's condition and track seasonal and long-term trends of water quality. The trends analysis eventually led to the proposed Spiritwood Lake Watershed Project. The hypolimnetic drawdown being proposed by this project would move nutrient rich water from Spiritwood Lake into Alkali Lake, which would eventually flow into Seven Mile Coulee. The operating conditions for the project are as follows:

- If Spiritwood Lake is above elevation 1442 feet msl, discharge from the hypolimnetic drawdown will occur continuously.
- If Spiritwood Lake is between 1442 feet msl and 1440 feet msl, discharge will occur only when necessary for water quality purposes.
- If Spiritwood Lake is at 1440 feet msl or below, no discharge would occur.

Additionally, on December 21, 2016, the National Resources Conservation Service (NRCS) proposed a $375,000 investment to improve water quality of Spiritwood Lake. The funding would support the Spiritwood Lake Water Quality Improvement Project, led by the City of Spiritwood Lake and local partners. The project would work by engaging landowners in a variety of conservation practices, including riparian improvements, nutrient and grazing management, no-till farming, use of cover crops, and more diverse crop rotation.

This feasibility study will not look at improving water quality on Spiritwood or Alkali Lakes. The hypolimnetic drawdown project would likely still be able to operate with changes to the operating conditions or conditions lower than designed alternatives.

2.3 Spiritwood Lake Invasive Species

The NDGF is working to keep Zander in Spiritwood and Alkali Lakes, and out of Seven Mile Coulee. The Ontario's Invading Species Awareness Program (OISAP, 2020) identifies that the Zander can impact food and habitat by out competing native fish species. Another noted concern is that Zander may be able to hybridize with native walleye. This feasibility study will not propose alternatives to keep Zander in Spiritwood and Alkali Lakes, but NDDWR will work with the NDGF to ensure that any identified cost-effective alternatives proposed through this feasibility study do not impact the NDGF's work.

The NDGF is also trying to keep grass carp out of Spiritwood Lake. Currently, the NDGF has installed a fish weir to prevent grass carp from moving from Alkali to Spiritwood Lake as seen in **Figure 3**.

Figure 3. Spiritwood Lake fish weir.

3.0 NDDWR INVESTIGATION

3.1 Topographic Analysis

The drainage basin for the Spiritwood Lake includes several historically non-contributing waterbodies namely Schock Lake, and Cysewski Slough. Light Detection and Ranging Data (LiDAR) was utilized to determine each waterbody's drainage area and evaluate the topography of the Spiritwood Lake region. The LiDAR data utilized for this study consisted of a bare earth 1-meter Digital Elevation Model (DEM) extracted from the NDDWR's LiDAR Map Service (NDDWR, 2020). The LiDAR elevations in the model are based on the North American Vertical Datum 1988 (NAVD88), GEOID03, with a horizontal coordinate system being the NDSPCS, South Zone, units in international feet, based on the North American Datum of 1983 (NAD83). Individual LiDAR tiles obtained from the NDDWR's LiDAR web service were merged using GIS. The DEM used for this study is included electronically with this report in **Appendix B**.

A 30-times exaggerated hillshade was developed from the DEM to show the topography of the region. Hillshading is a GIS technique for visualizing terrain that enhances its three-dimensional appearance and makes it easier to identify landscape features. **Figure 4** displays the 30-times exaggerated hillshade overlaying the DEM. The 30-times exaggeration was chosen based on visual inspection. Higher elevations are shown in tans/grays and the lower elevations are shown in blue. A scale for elevations was not developed for **Figure 4**, as it is only meant to show the relative topography of the region, not specific elevations. More detailed elevation data will be displayed and discussed later in this report.

Historically, Schock Lake, Cysewski Slough, Spiritwood Lake, and Alkali Lake Basins were closed lakes and runoff from these basins did not leave their respective lakes. Based on observations and the topographic analysis, it appears currently the only basin to remain closed off is Schock Lake Basin. In current conditions, Cysewski Slough contributes to Spiritwood Lake at 1516.0 feet (NAVD88), Spiritwood Lake contributes to Alkali Lake through the west end outlet at 1444.9 feet (NAVD88), and Alkali Lake discharges into Seven Mile Coulee at 1443.8 feet (NAVD88). Flow from Seven Mile Coulee eventually discharges into the James River downstream of the City of Jamestown. **Figure 5** illustrates the approximate stream paths of each basin and how they are interconnected. A streamline that shows the path Schock Lake would contribute after filling and reaching an outlet elevation of 1469.0 feet (NAVD88) is also included in **Figure 5**.

Based on Schock Lake's size and relative volume, it is unlikely that this basin will contribute to Spiritwood Lake through open channel flow for some time. Since Schock Lake is currently noncontributing and does not have a gaged water surface record, it would be difficult to include in a hydrologic analysis while having confidence in the modeled results. For this reason, Schock Lake was excluded from further analysis when examining flow contributions to Spiritwood and Alkali Lakes.

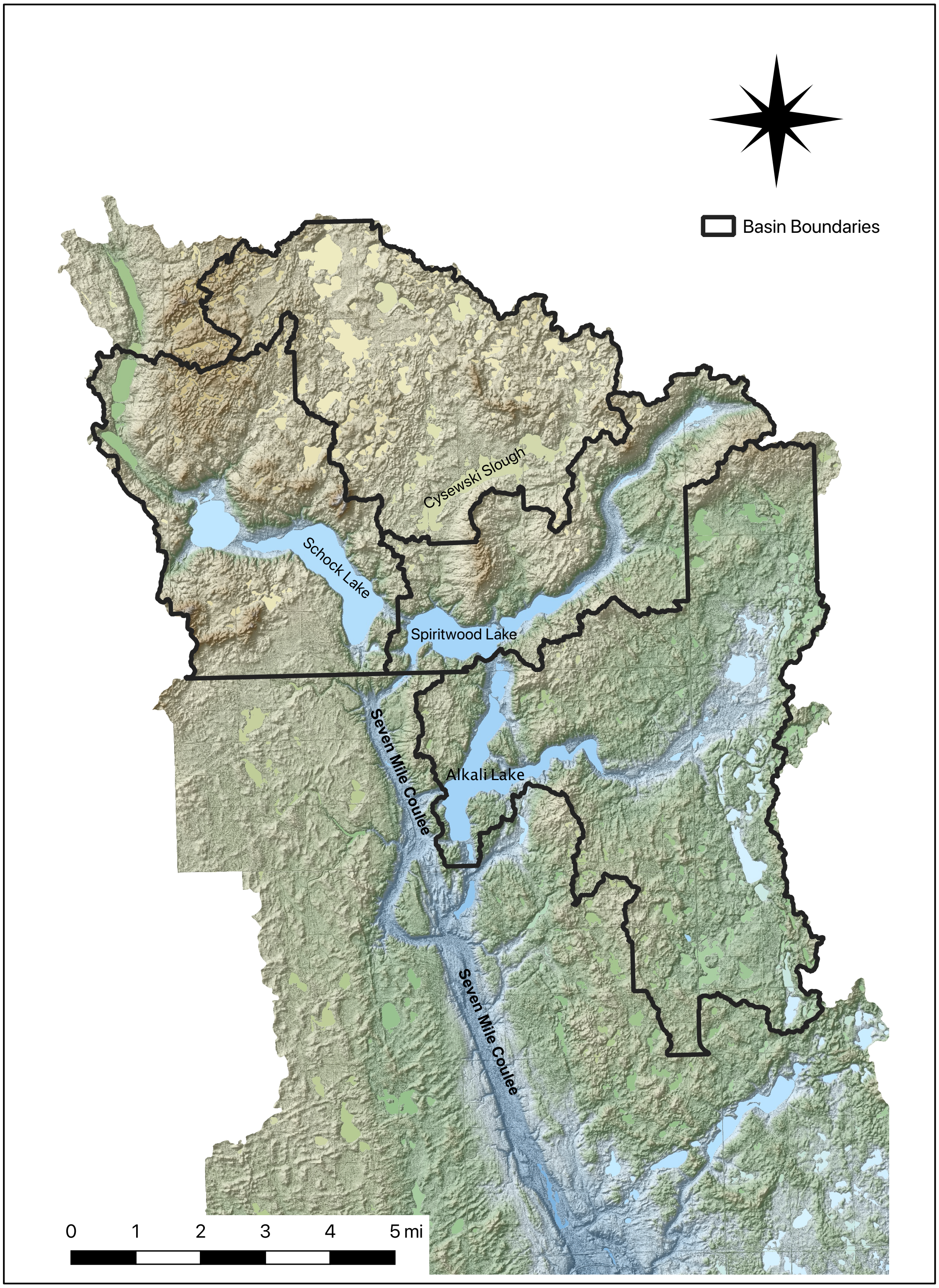

Figure 4. Exaggerated hillshade for the Spiritwood Lake region.

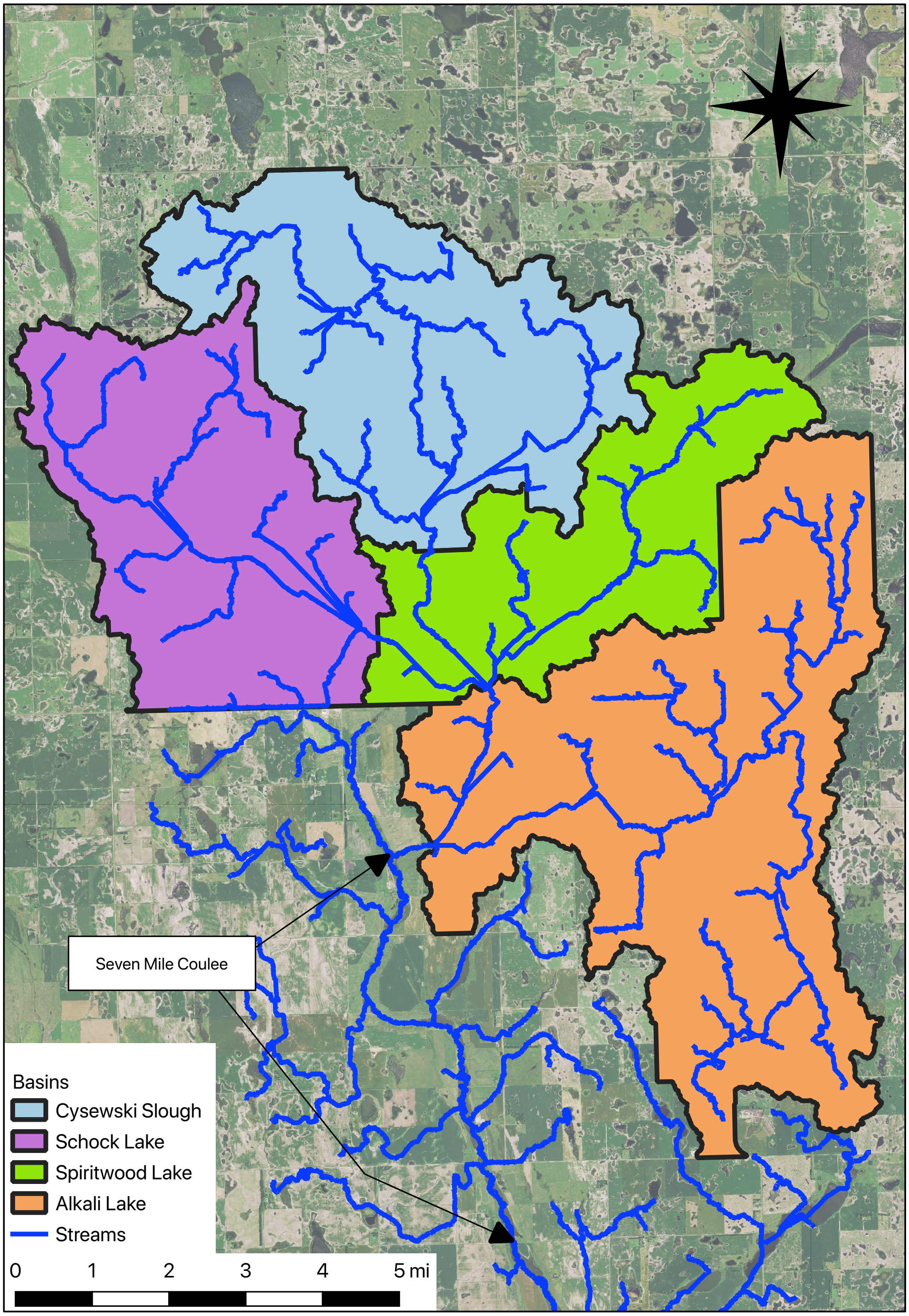

Figure 5. Spiritwood Lake Basin Complex.

Elevation-volume-area curves were developed for Cysewski Slough, Spiritwood Lake, and Alkali Lake. The curves for Spiritwood Lake and Alkali Lake were developed using NDGF contour data and the LiDAR DEM, while Cysewski Slough was developed using only the LiDAR DEM. The NDGF contour data was used to develop the elevation-volume-area curves below the elevations shown on the LiDAR DEM. The LiDAR DEM was used to develop elevation-volume-area relationships beyond the spill points in regions where the NDGF contour data did not exist. No NDGF contour data was available for Cysewski Slough, so elevation-volume-area relationships were estimated below the LiDAR DEM. **Figures 6**, **7**, and **8** illustrate the elevation-volume-area curves for Cysewski Slough, Spiritwood Lake, and Alkali Lake, respectively.

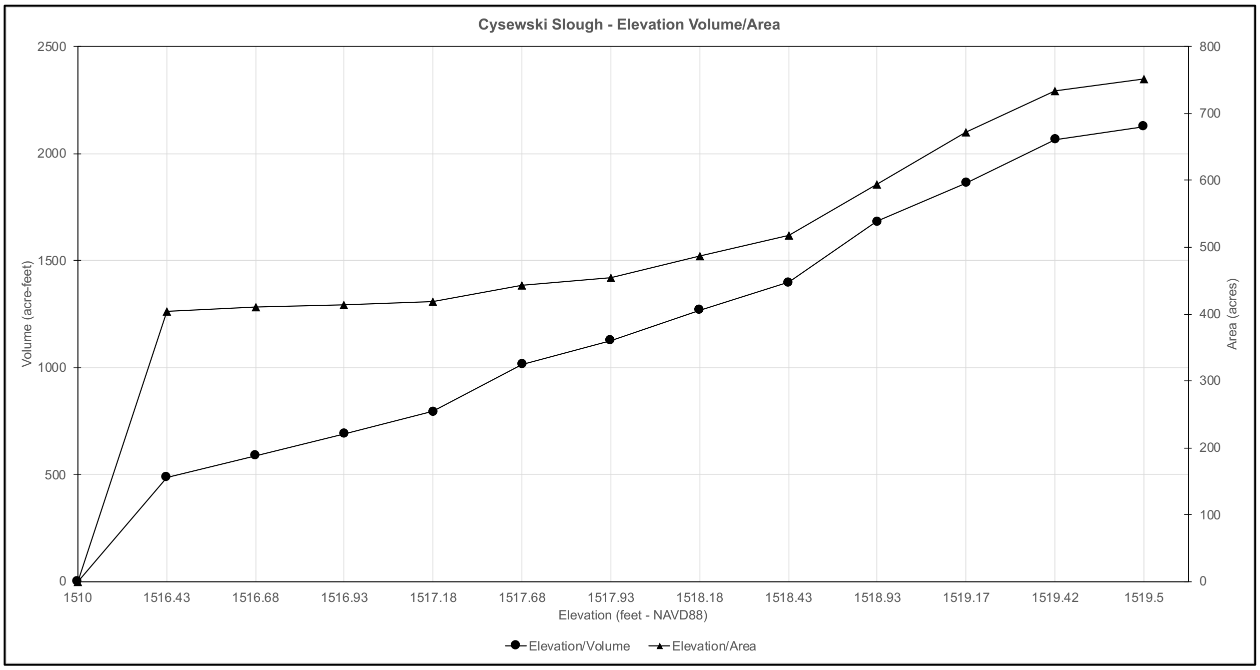

Figure 6. Cysewski Slough elevation-volume-area curve.

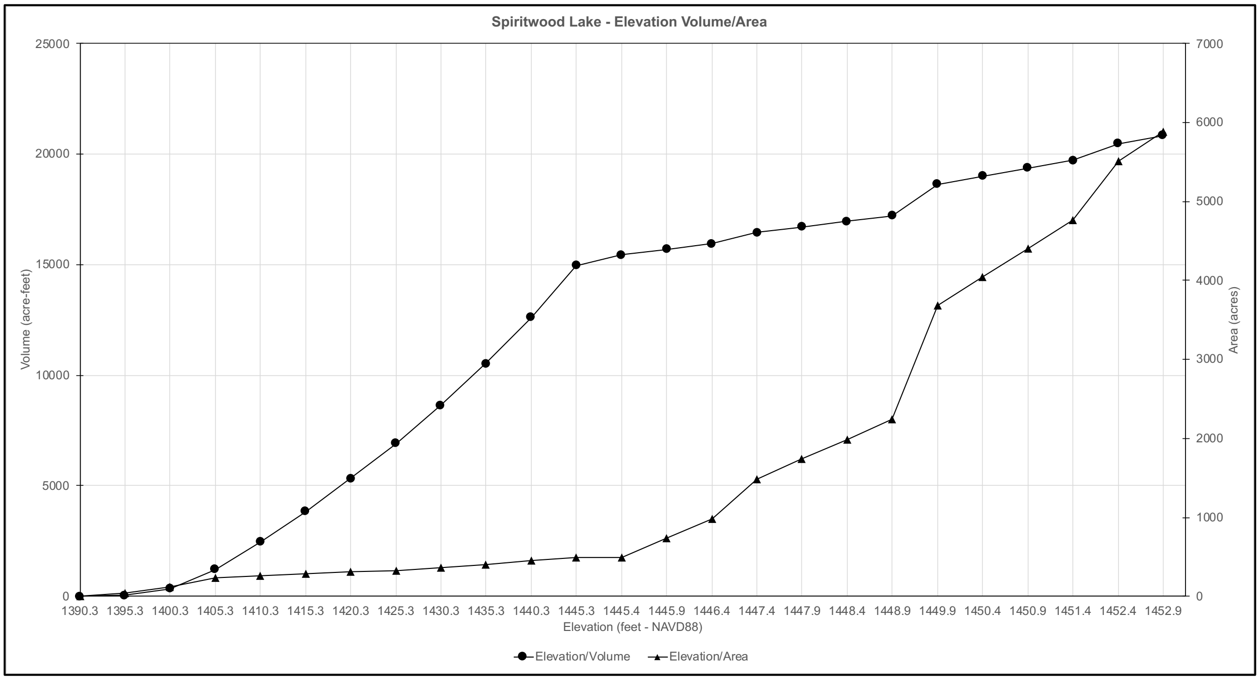

Figure 7. Spiritwood Lake elevation-volume-area curve.

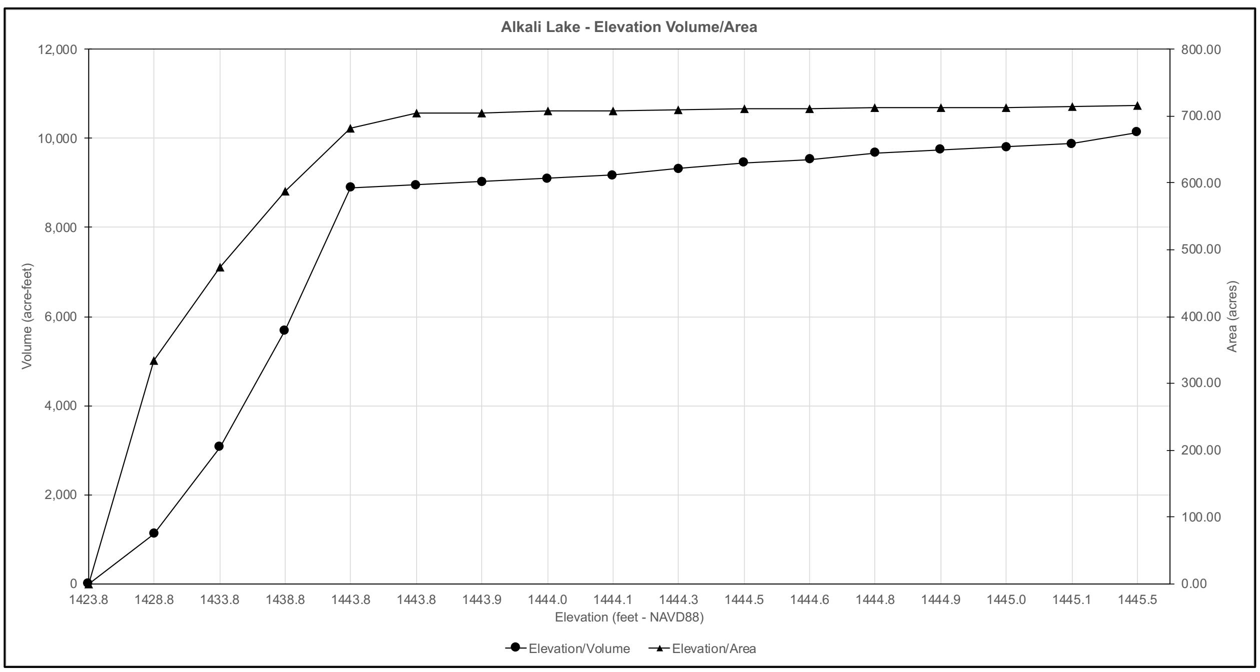

Figure 8. Alkali Lake elevation-volume-area curve.

3.2 Spiritwood Lake Geology and Soils

3.2.1 Spiritwood Lake Geology

The lakes that make up the Spiritwood Basin complex are remnants of the glacial age. Recession of and glacial movement left large poorly drained regions throughout central North Dakota. The outlet of meltwater from the Spiritwood Basin complex likely created Seven Mile Coulee. The Soil Survey of Stutsman County, North Dakota (NRCS, 1995), states the following:

> *With the retreat of glacial ice sheet for the north, meltwater flowing to the south created Pipestem River and James River systems. Minor meltwater channels, such as Minneapolis Flats Creek, Beaver Creek, and Seven Mile Coulee, also were created.*

3.2.2 Spiritwood Lake Soils

The NRCS Soil Survey Geographic Data (SSURGO) was analyzed to learn more about the region’s soils. SSURGO contains information about soils throughout the United States that has been collected by the NRCS over the course of a century. The information is broken down into separate classifications and provides a variety of different information that can be utilized. For the purpose of this study, the drainage characteristics, hydrologic soil group for the region’s soils, and soil parameters were examined.

The drainage characteristics in SSURGO are organized into 5 categories including somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. **Figure 9** illustrates the drainage characteristics of the Spiritwood Lake drainage complex. The illustration shows that the drainage classification in the Spiritwood Lake complex is generally well drained. Well drained areas occur in each of the basins until runoff makes its way into each basin’s noncontributing waterbody (Cysewski Slough, Spiritwood Lake, and Alkali Lake). It can also be seen through the illustration that Alkali Lake Basin has the least well drained areas, but majority of the basin is still made up with well drained or moderately well drained areas.

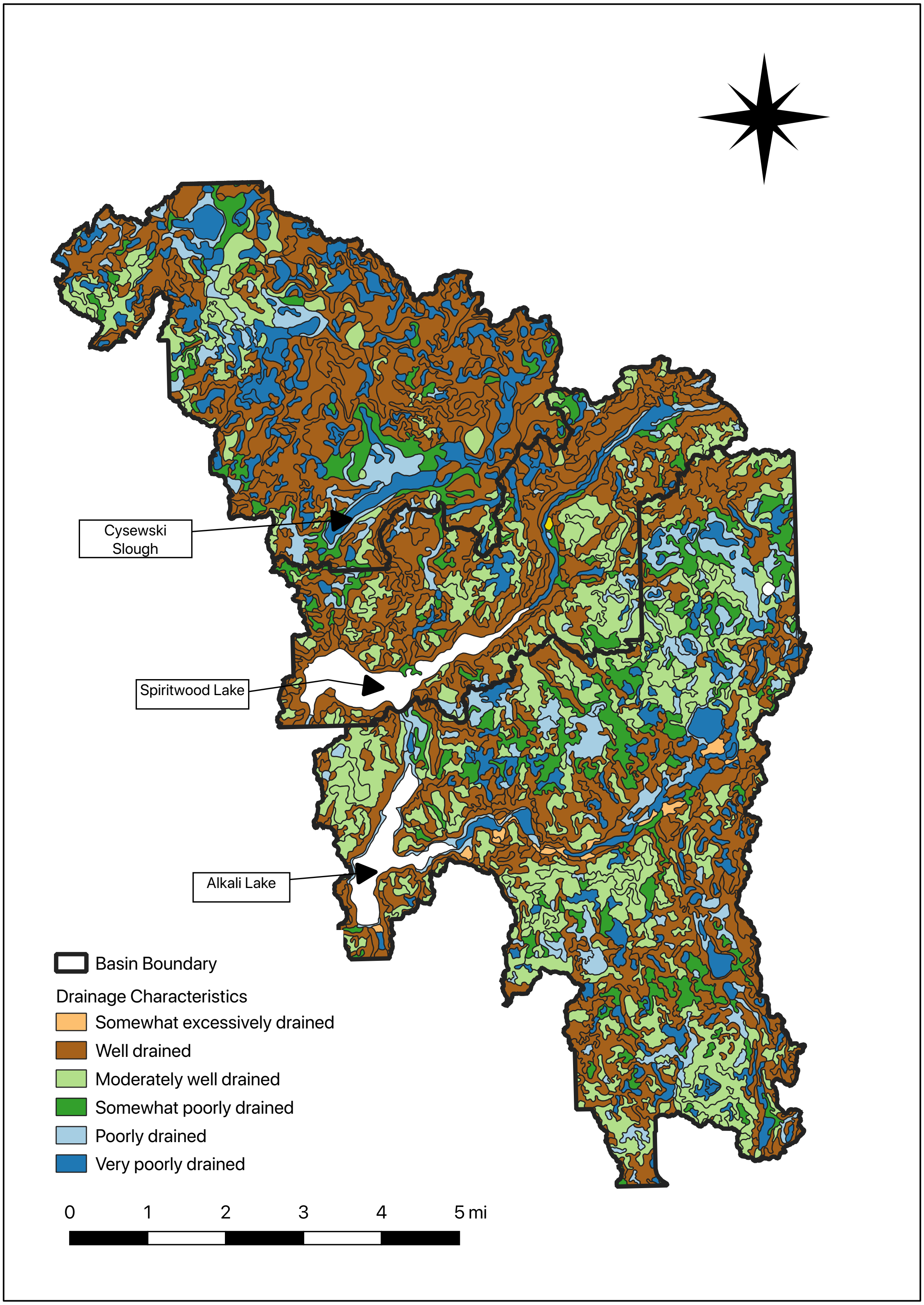

Figure 9. Spiritwood Drainage Complex, drainage characteristics.

The hydrologic soil group classification from SSURGO was also examined within the Spiritwood Lake drainage complex. The hydrologic soil groups are based on estimates of runoff potential (like the runoff classification), but it provides more information in the description of each classification. In the United States, four groups are assigned, and three dual classes exist within each group. The groups and definitions are defined on the NRCS's Web Soil Survey (NRCS, 2020) as follows:

> *Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have high rate of water transmission.*
>
> *Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.*
>
> *Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.*
>
> *Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high-water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.*
>
> *If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes (web soil survey).*

Figure 10 illustrates the hydrologic soil groups in the Spiritwood Lake drainage complex. As illustrated in **Figure 10**, the hydrologic soil groups surrounding Spiritwood Lake indicate each basin having moderate infiltration when thoroughly wet and that the soils have a moderate rate of water transmission (Group B). This suggests that a primary mode of water transmission to the lakes could be conducted via groundwater. Since each of the non-contributing lakes (Cysewski Slough, Spiritwood Lake, and Alkali Lake) are the lowest point in each of their respective basins, it is likely that runoff and groundwater discharge would move toward these locations.

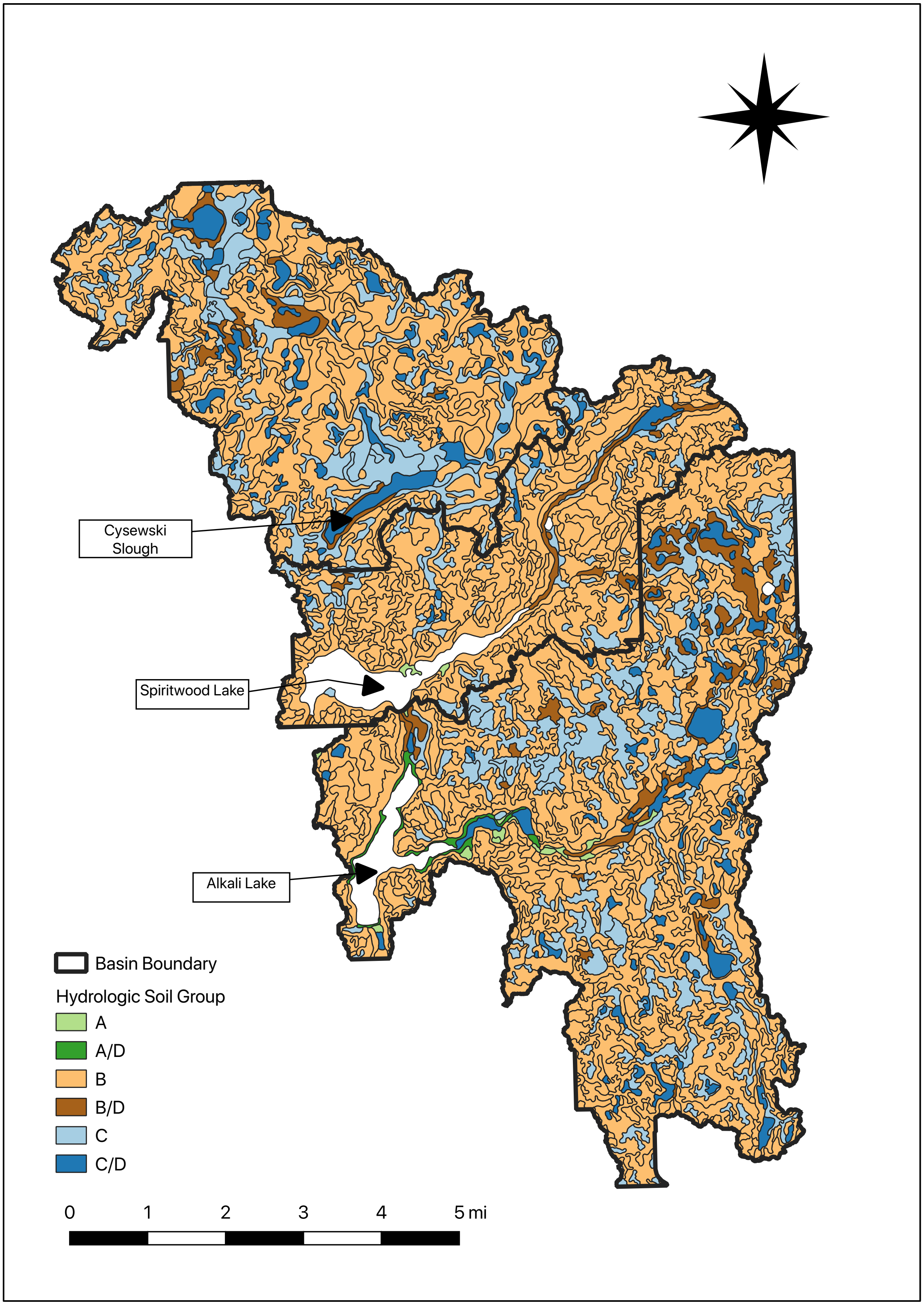

Figure 10. Spiritwood Lake Drainage Complex, hydrologic soil group.

SSURGO's soil satiated metric, soil and clay percentages, and the amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient were also analyzed to parameterize the hydrologic model later in this report.

3.3 Hydrologic & Hydraulic Modeling

A series of hydraulic and hydrologic models were created as part of this study. A hydrologic model was created to determine inflow conditions into Cysewski Slough, Spiritwood Lake, and Alkali Lake for the purpose of determining potential lake level rise. The hydrologic model was calibrated to the existing Spiritwood Lake water surface gage for the period from September 2010 until December 2019. **Figure 11** illustrates the water surface elevation at Spiritwood Lake for the calibrated hydrologic model compared to the existing gage. A detailed description of the hydrologic model is available in **Appendix C** along with an electronic copy of the model.

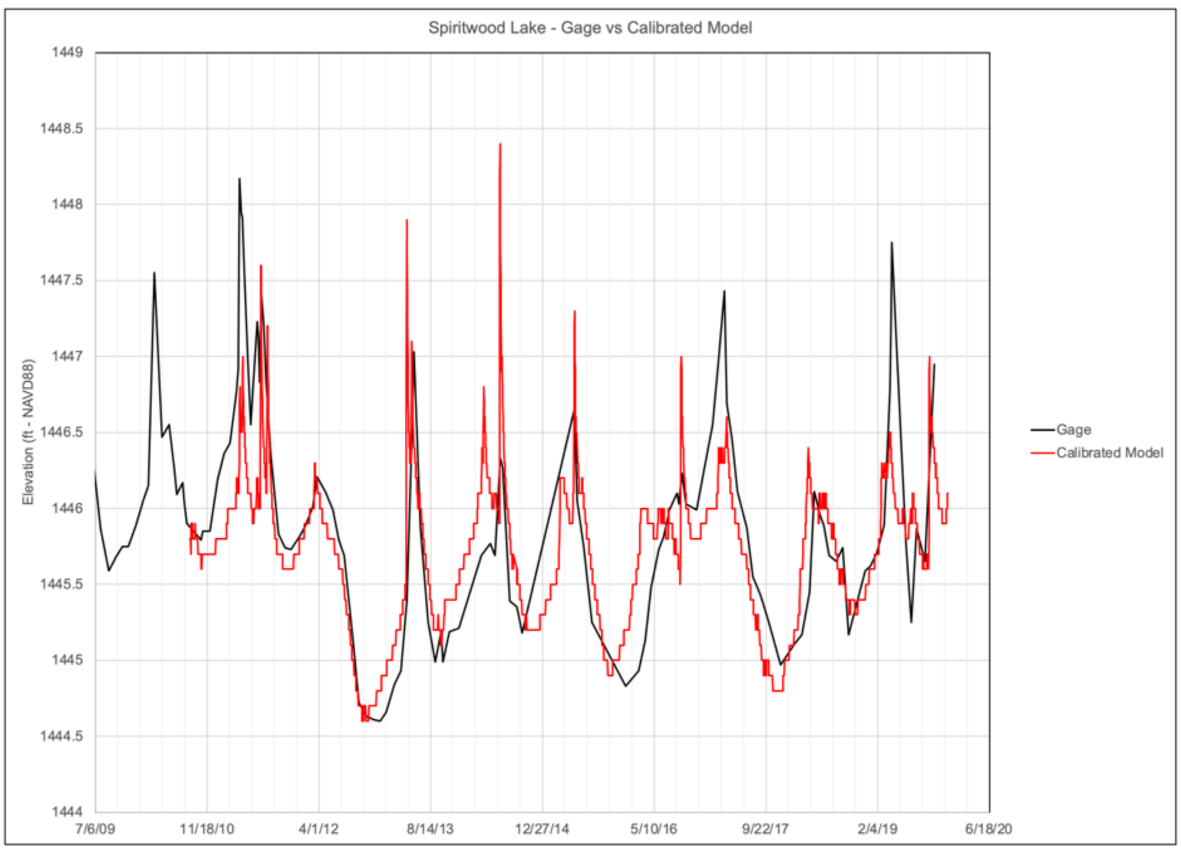

Figure 11. Spiritwood Lake Calibration Results.

A total of five hydraulic models were created as part of this study. Three of which were used to develop hydraulic rating curves for the outflow from Cysewski Slough, Spiritwood Lake, and Alkali Lake. The rating curves where then input into the hydrologic model. The other two hydraulic models were used to evaluate impacts. One was used to evaluate the effects downstream of Spiritwood and Alkali Lakes on Seven Mile Coulee, while the other was used to simulate the water surface elevations of Spiritwood and Alkali Lakes during extreme high flow events.

The hydraulic model for the Seven Mile Coulee extends from Spiritwood and Alkali Lakes downstream until the Seven Mile Coulee meets U.S. interstate I-94. This was decided as the downstream extent of the model based on discussions with the Stutsman County Water Resources Board on downstream boundary conditions. The purpose of this model is to evaluate the impacts that potential alternatives have on Seven Mile Coulee compared to existing conditions for large flood events.

A detailed writeup that includes documentation on each hydraulic model is available in **Appendix D**, along with an electronic copy of each model.

3.3.1 Potential Future Improvements

Calibration of the Spiritwood hydrologic model was extremely difficult due to the effect of stacking errors from each dataset used to develop the hydrologic model and the lack of observed data that existed for the system. Ideally, a calibrated hydrologic model would have a NSE (Nash-Sutcliffe Efficiency) value greater than 0.5, but it is unrealistic to assume it would ever reach a value near 1 due to the inherent error in the available datasets. The NSE for the calibrated model was 0.44. As part of this project, continuous water surface monitoring sites were installed at Spiritwood and Alkali Lakes that provides greater detail than the manual readings collected on Spiritwood Lake. Installation of these two gages will help develop a better understanding of the relationship between these two lakes overtime as they continue to collect water surface elevations, but more information could be collected to better understand the system as the whole and improve calibration in the future. The additional information that could be collected includes:

- Installing a continuous gage to collect the outflow from Spiritwood Lake.
- Installing a continuous gage to collect the outflow from Alkali Lake.
- Installing a continuous gage to collect water surface elevations at Cysewski Slough.
- Collection of bathymetric data for Cysewski Slough.

It is suggested that if no solution is implemented at Spiritwood and Alkali Lakes to alleviate flooding, that future calibration efforts include the newly collected data and that serious consideration should be given to installing gages and collecting bathymetric data at the site listed above.

3.3.2 Frequency Events

Frequency events for the Spiritwood and Alkali Lake model were originally modeled with the calibrated hydrologic model (HEC-HMS), but after review of the backwater effects on Spiritwood Lake, a 1-Dimensional hydraulic model (HEC-RAS) was made to determine the effects of frequency events at each lake. Table 1 provides the comparison of frequency events between the two models. The results from the 1-D HEC-RAS model was deemed to be a more appropriate representation conditions Spiritwood and Alkali Lakes would experience during a given frequency event based on its ability to account for backwater conditions and was ultimately used for alternatives assessment.

Table 1. Frequency Event Comparison, HEC-HMS vs HEC-RAS 1D model.

Waterbody	10 year	10 year	25 year	25 year	50 year	50 year	100 Year	100 Year	500 Year	500 Year
	HMS (ft)	1D Model (ft)	HMS (ft)	1D Model (ft)	HMS (ft)	1D Model (ft)	HMS (ft)	1D Model (ft)	HMS (ft)	1D Model (ft)
Spiritwood	1447.9	1448.05	1448.3	1448.5	1448.5	1448.8	1448.8	1449.23	1449.5	1450.78
Alkali	1446.6	1446.72	1447.5	1447.76	1448.3	1448.52	1449	1449.2	1450.6	1450.76

3.3.3 Seven Mile Coulee Hydraulic Model

A two-dimensional hydraulic model was developed for Seven Mile Coulee to evaluate downstream effects on outflows from Spiritwood and Alkali Lakes. The two-dimensional hydraulic model was then utilized to determine the relative impact specific flood risk reduction alternatives could have on downstream landowners and infrastructure. As illustrated in **Figure 12**, the two-dimensional hydraulic model of Seven Mile Coulee extends from Spiritwood and Alkali Lakes to Interstate I-94.

Details on model development are available in **Appendix D**. Outflow hydrographs for the existing conditions were utilized to determine the water surface profile and depths that could be experienced along Seven Mile Coulee. The model did not factor in local inflows, but only the contribution that Spiritwood and Alkali Lake complex had on Seven Mile Coulee. **Figure 13** illustrates the existing conditions water surface profiles for the frequency events for the extent of the model.

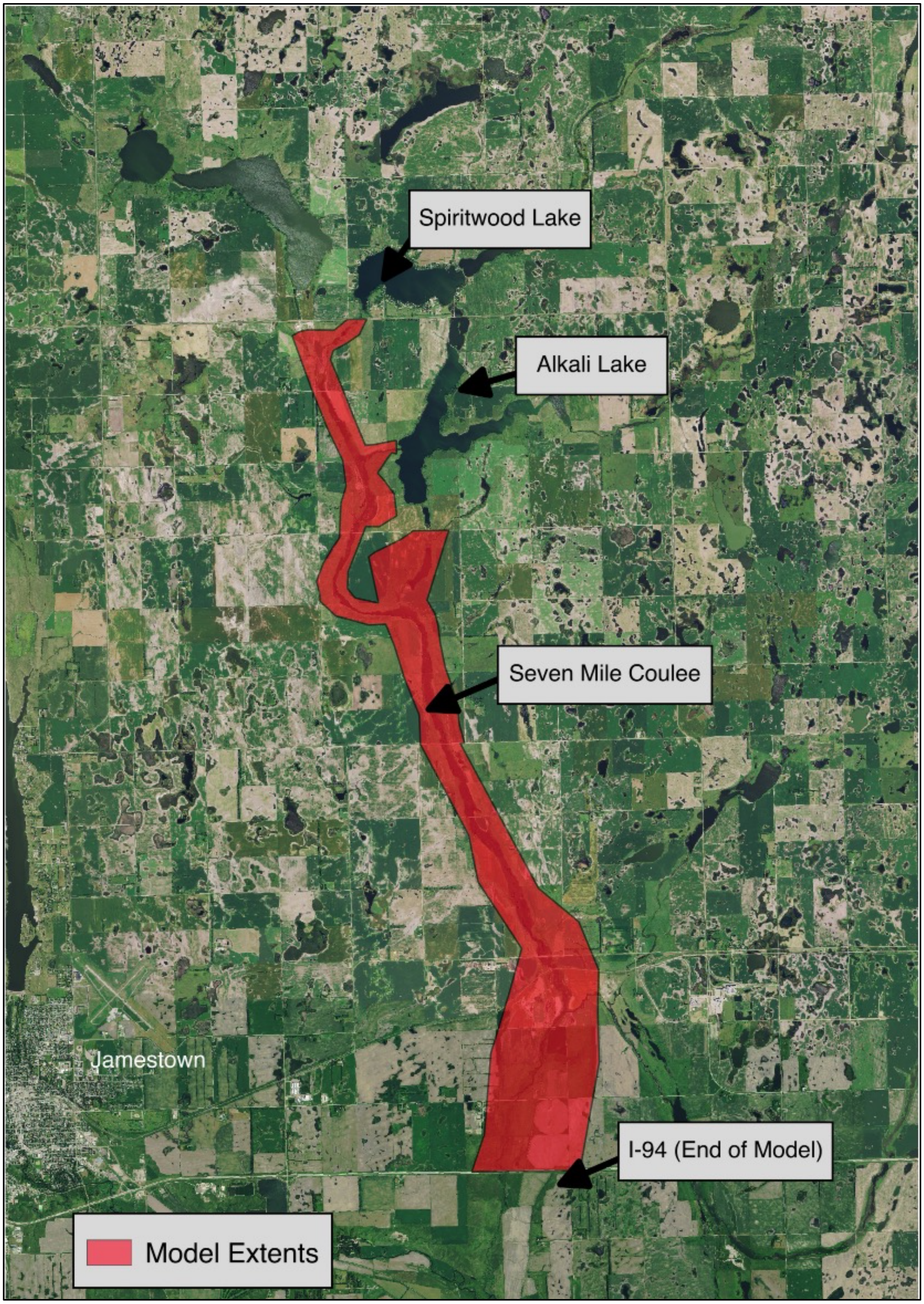

Figure 12. Seven Mile Coulee hydraulic model extents.

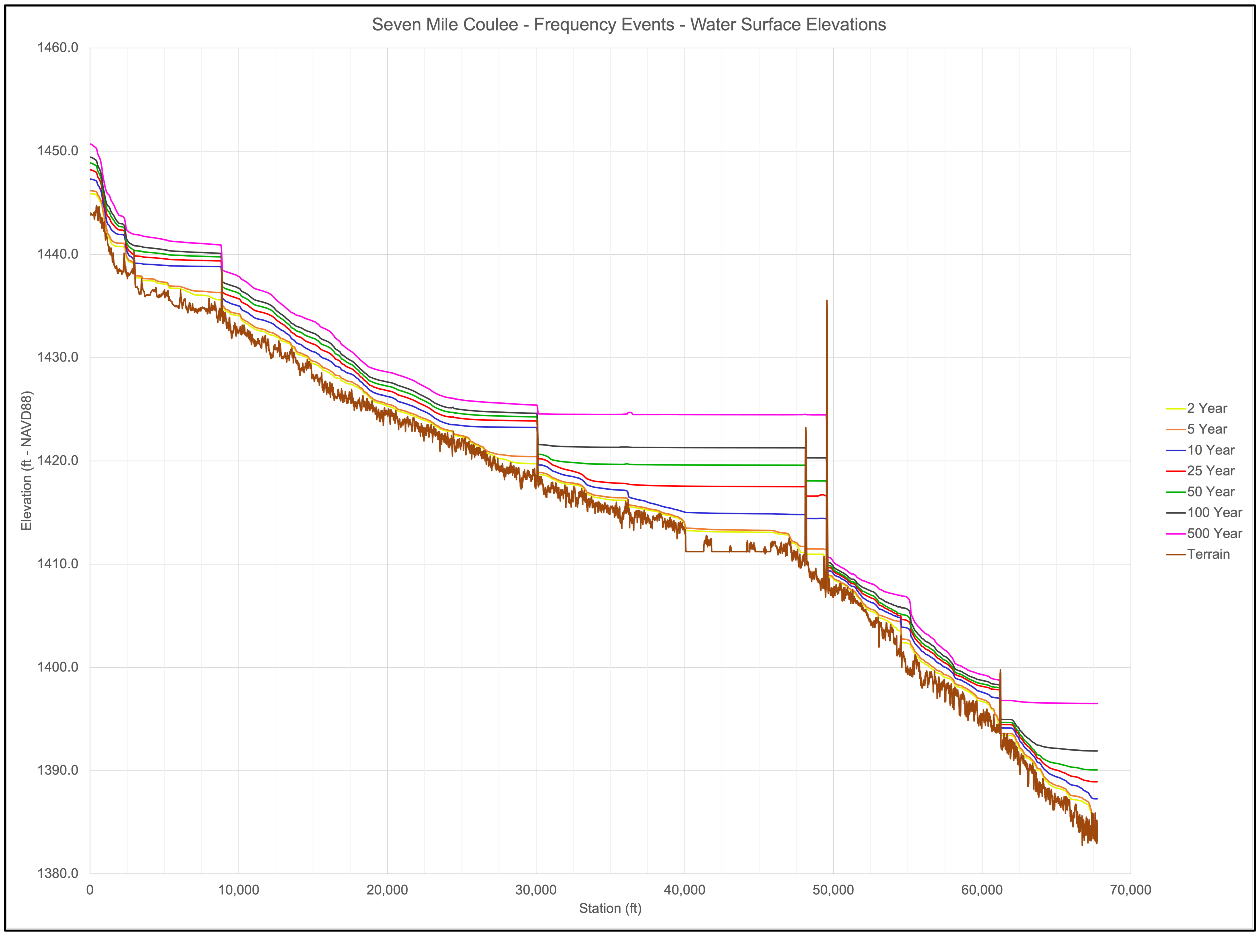

Figure 13. Existing conditions water surface profiles along Seven Mile Coulee.

3.4 Alternatives Assessment

In general, closed water bodies fill until they spill and finding cost effective solutions for removing that water and relieving impacts is extremely difficult. Typically, options for reducing flood impacts from closed water bodies falls into two categories: buying out the impacted structures or finding a way to evacuate floodwaters (e.g., open channel outlets or pumping). Pumping was not analyzed as part of this study due to the immediate availability of Seven Mile Coulee to use as a discharge point and the experience with previous pumping alternatives. The only identifiable sink or outlet locations for Spiritwood discharge is Schock Lake immediately west of Spiritwood Lake or Seven Mile Coulee to the south. Pumping water from Spiritwood into Schock Lake was utilized in the past, but landowners surrounding Schock Lake ultimately decided against the project after Schock Lake's elevation began impacting the surrounding land.

Many types of alternatives were analyzed to remove water from Spiritwood and Alkali Lakes and are documented in **Appendix E**. The viability of these alternatives was determined by comparing the cost of construction and reduction in damages to the value of structures inundated if the project was not in place. For the purpose of this report, only the primary findings will be described. Additional findings are summarized in **Appendix E**.

3.4.1 No Action Alternative

The No Action alternative represents existing conditions and will allow the current state of Spiritwood Lake's flood impacts to continue. Flooding impacts from Spiritwood and Alkali Lakes primarily include flooding of structures, roads, and land.

A process for determining the lowest elevation of each structure and determining a frequency of inundation is described in **Appendix E**. **Table 2** provides the number of structures inundated for each frequency event for the No Action alternative. The structure values were obtained from Stutsman County's online tax information (Stutsman County, 2022) and were utilized in the economic analysis for evaluated alternatives.

Table 2. Structures inundated by each frequency event for the No Action Alternative.

Event	Event Elevation (ft - NAVD88)	Number of Structures Inundated	Total Structure Value
10 Year	1448.1	4	$ 358,400
25 Year	1448.5	5	$ 472,900
50 Year	1448.8	5	$ 472,900
100 Year	1449.2	6	$ 798,200
500 Year	1450.8	14	$ 1,535,600

3.4.2 Individual Alternatives

A series of individual alternatives, or single actions, were analyzed and described in **Appendix E**. These individual alternatives did not offer substantial flood protection for the system but lead to a greater understanding of system dynamics. It was found that if the goal was to remove water through the east outlet of Spiritwood Lake, no improvement would be identifiable without also improving conveyance through 91st Avenue SE and 24th Street SE, and lowering and improving conveyance at Alkali Lake's natural outlet. Akali Lake's natural outlet was found to be one of the main constraints in moving water through the system, as the outlet is naturally high enough to prevent conveyance measures upstream from functioning as designed. Key findings from the individual alternative analysis include:

- Conveyance improvements at Spiritwood Lake's east outlet, 91st Avenue SE, and 24th Street SE should not be considered unless Alkali Lake's natural outlet is lowered and improved.
- Road raises at 91st Avenue SE and 24th Street SE should not be considered regardless of designed conveyance through the roadways due to the constraint at Alkali Lake (i.e., road raises would ultimately lead to greater risk of flooding at Spiritwood Lake).

- The dam on the downstream end of Alkali Lake's natural outlet (described in **Appendix E**) does not affect the water surface elevation of Alkali Lake or Spiritwood Lake.

3.4.3 Combination Alternatives

Because each individual alternative on its own resulted in minimal change from current conditions, these single actions were combined. This resulted in two combination alternatives, which are fully described in **Appendix E** and briefly summarized below. **Figure 14** illustrates the location of the components that were combined for these alternatives.

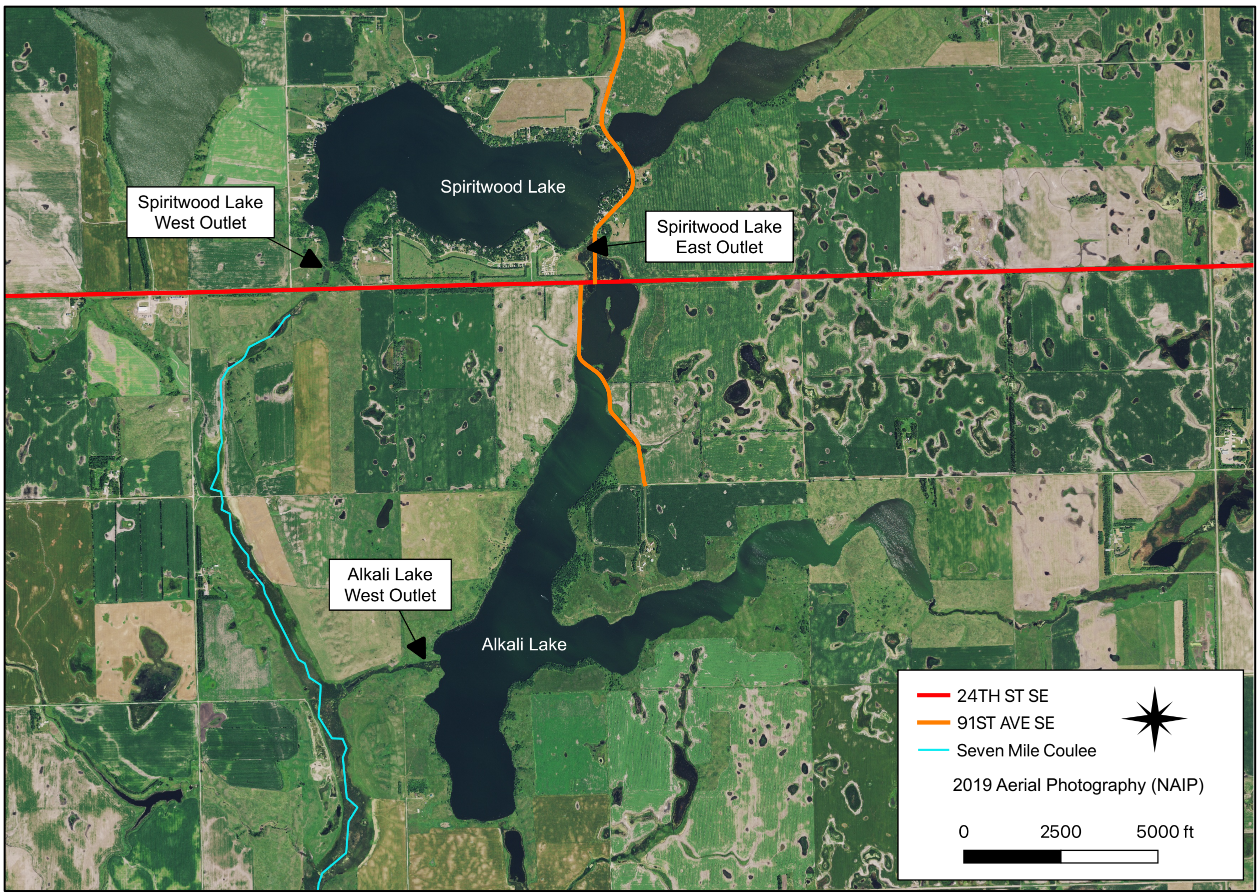

Figure 14. Spiritwood Lake layout.

Combination 1

Combination 1 would convey water through the east outlet of Spiritwood Lake into Alkali Lake and then to Seven Mile Coulee. The alternative includes the following features:

- Lowering Alkali Lake to elevation 1440 ft (NAVD88)
- Improving Alkali Lake's natural outlet with a 20-foot-wide trapezoidal channel with the invert elevation of 1440 ft (NAVD 88)

- Improving conveyance through 91st Avenue SE (two crossings) and 24th Street SE (one crossing) by adding an 8-foot by 8-foot box culvert through each crossing
- Lowering Spiritwood Lake to elevation 1442 ft (NAVD88)
- Adding a 100-foot-wide weir at the east outlet of Spiritwood Lake with an invert elevation of 1442 ft (NAVD 88)

This alternative reduces the water surface elevation at Spiritwood Lake from elevation 1449.2 ft (NAVD88) to 1447.4 ft (NAVD88) during the 100-year frequency event. This reduction in the 100-year water surface elevation prevents five structures, with an estimated value of $672,200, from being inundated. **Table 3** provides the number of structures inundated for each frequency event for the Combination 1 alternative.

Table 3. Structures inundated by each frequency event for the Combination 1 alternative.

Event	Event Elevation (ft - NAVD88)	Number of Structures Inundated	Total Structure Value
10 Year	1445.1	0	$ -
25 Year	1446.3	1	$ 126,000
50 Year	1446.8	1	$ 126,000
100 Year	1447.4	1	$ 126,000
500 Year	1449.1	5	$ 472,900

Combination 1 alternative was estimated to cost about $4.6 million and has an estimated benefit-to-cost ratio of 0.006. More detail about the cost estimate and economic analysis are included in **Appendix E**.

Combination 2

Combination 2 would convey water from the west outlet of Spiritwood Lake to Seven Mile Coulee. The alternative includes the following features:

- Lowering Spiritwood Lake to elevation 1442 ft (NAVD88)
- Adding a 20-foot-wide weir with an invert elevation of 1442 ft (NAVD88) at the west outlet of Spiritwood Lake
- Placing a 20-foot-wide span bridge through 24th Street SE
- Improving Seven Mile Coulee with a 20-foot-wide trapezoidal channel from Spiritwood Lake's west outlet past approximately Alkali Lake's outlet

It should be noted that the weir, bridge, and channelizing of Seven Mile Coulee as described for this combination were not evaluated as individual alternatives or single actions. The process of directly modeling many iterations of individual alternatives (referenced in Section 3.4.2), along with numerous combinations of alternatives, provided knowledge on the responsiveness of the system. This knowledge informed what actions to combine to create this alternative.

The alternative was not as effective as Combination 1 at reducing Spiritwood Lake's water surface elevation to prevent flooding of homes and structures along the lake. It reduced the water surface elevation at Spiritwood Lake from elevation 1449.2 ft (NAVD88) to 1448.3 ft (NAVD88) during the 100-year frequency event. This reduction in water surface elevation prevents one structure, with an estimated value of $325,300, from being inundated. **Table 4** provides the number of structures inundated for each frequency event for the Combination 2 alternative.

Table 4. Structures inundated by each frequency event for the Combination 2 alternative.

Event	Event Elevation (ft - NAVD88)	Number of Structures Inundated	Total Structure Value
10 Year	1446.1	0	$ -
25 Year	1446.9	1	$ 126,000
50 Year	1447.6	1	$ 126,000
100 Year	1448.3	5	$ 472,900
500 Year	1450	8	$ 1,018,600

The cost of the Combination 2 alternative was estimated to be about $4.1 million and has a benefit-to-cost ratio of 0.005. **Appendix E** contains more detail regarding the cost estimate and economic analysis.

3.4.4 Alternative Conclusions

Based on the study, Combination 1 alternative performs better than Combination 2 alternative in reducing flood risk. During the 100-year event, Combination 1 prevents five structures from sustaining flood damage, while Combination 2 prevents damages to one structure. According to the economic analysis, neither alternative is economically efficient. Based on this information, the District could consider offering optional buyouts to homeowners at risk of flooding as another option.

If the district was to consider structural flood options, Combination 1 would be the best option, based on this investigation. Implementation of Combination 1 should start at the most downstream component, remedying Alkali Lake's outlet, and progressively moving upstream. Each combination alternative required outflows into Seven Mile Coulee. Downstream impact maps of Seven Mile Coulee for Combination 1 versus No Action alternatives are included in **Appendix E1** (attached to **Appendix E**).

The overall water surface elevations of the lakes during large scale events were less with the alternatives than for existing conditions. However, the alternatives require the lakes to be drawn down, which would discharge water into Seven Mile Coulee during construction that would have normally been stored in the lakes. This initial one-time drawdown was not modeled because of the preliminary analysis nature of this study. If one of the evaluated alternatives was implemented, the details of completing this drawdown would be determined during the design phase or later. In addition, there is also a likelihood that maintaining the lakes at lower elevations as proposed in the alternatives would result in discharges to Seven Mile Coulee more frequently, which could also cause additional impacts downstream. It should be mentioned that conveyance along Seven Mile Coulee appears to be inadequate based on field assessments and hydraulic analysis during this study.

4.0 CONCLUSION

In conclusion, the No Action alternative or offering buyouts is recommended for the District's consideration, based on the results of the economic analysis. For next steps, in addition to considering this study's alternatives, the District may want to consider intermediary measures, such as actions listed in Section 5.1, a clean out of Seven Mile Coulee, or modifications to flood-prone structures. As stated earlier in this report, Alkali Lake's natural outlet is the main constraint. As such, actions implemented at Spiritwood Lake's east outlet, 91st Avenue SE, and 24th Street SE should not be considered unless Alkali Lake's natural outlet is addressed.

Submission of this report constitutes completion of the Investigation Agreement between NDDWR and the District.

5.0 REFERENCES

(NRCS, 1995) National Resources Conservation Service. “Soil Survey of Stutsman County, North Dakota – Indiana State Library.” Soil survey of Stutsman County, North Dakota, United States Department of Agriculture, link.library.in.gov/portal/soil-survey-of-Stutsman-County-North-Dakota/gVotdhzKeQQ/

(NRCS, 2020) Web Soil Survey, 2020. National Resources Conservation Service, http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

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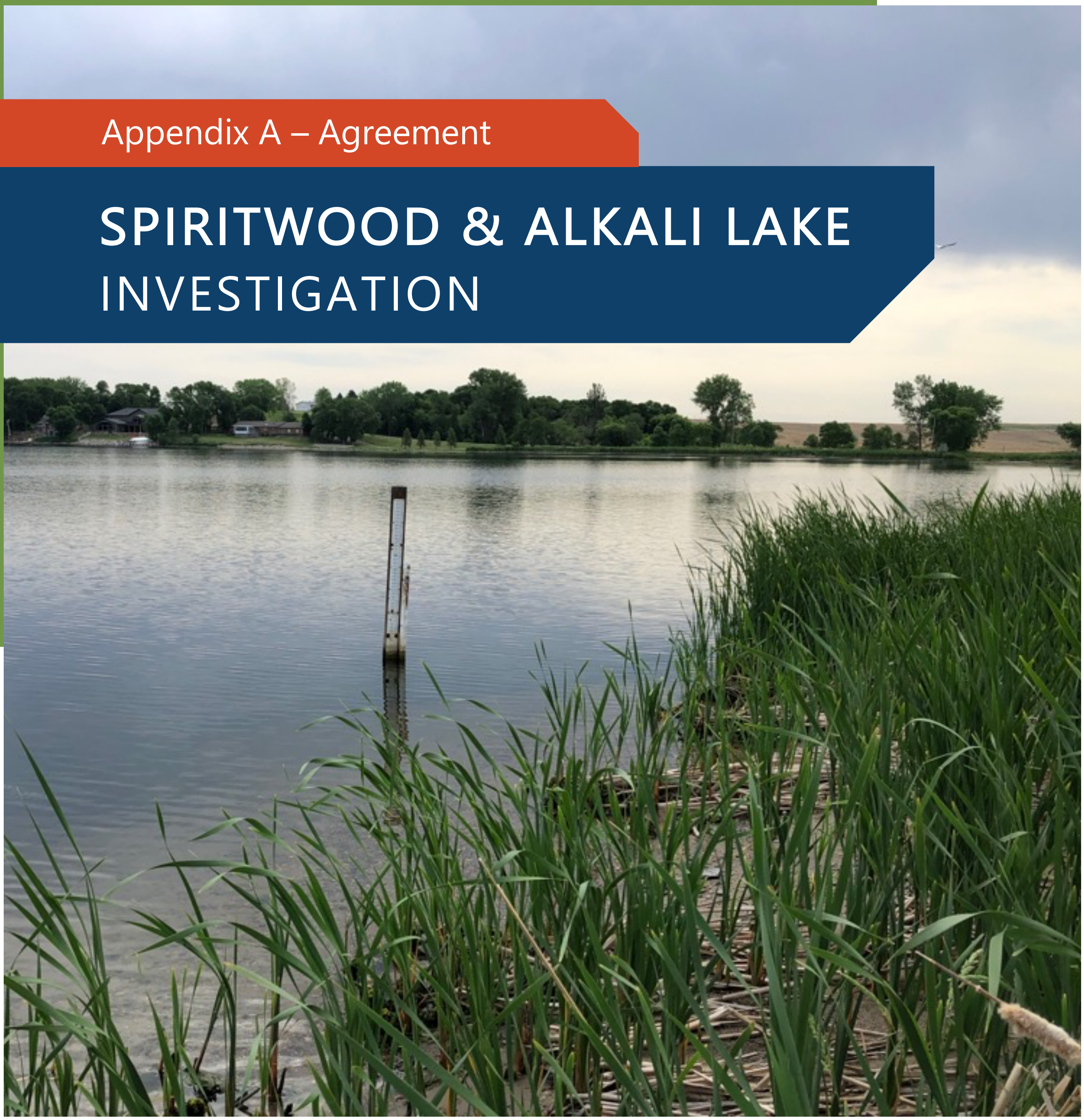
(OISAP, 2020) Ontario Invasive Species Awareness Program, 2020. http://www.invadingspecies.com/zander/

Appendix A – Agreement

SPIRITWOOD & ALKALI LAKE INVESTIGATION



DEPARTMENT OF WATER RESOURCES

DWR Project #461
January 2023

TEL: 701.328.2750
1200 Memorial Hwy
Bismarck, ND 58504

NORTH Dakota Be Legendary. | Water Resources

SWC Project #461
Project Manager: Ckorkowski
February 2020

Investigation Agreement

1. **Parties.** This agreement is between the State of North Dakota (State), acting through the State Water Commission, 900 East Boulevard Avenue, Bismarck, ND 58505 (Commission) and the Stutsman County Water Resource District, a North Dakota political subdivision, P.O. Box 1727, Jamestown, ND 58402-1727 (District).

2. **Project Description.** Commission will perform the tasks as outlined in the attached Scope of Work and incorporated into this Agreement.

3. **Commission's Responsibilities.** Commission will:

   a. Conduct topographic surveys and field observations to collect necessary data.

   b. Examine the hydrology of Spiritwood Lake and Alkali Lake basins.

   c. Evaluate options that could be implemented to mitigate damages on Spiritwood Lake.

   d. Evaluate impacts of potential alternatives on Seven Mile Coulee.

   e. Complete a written report with findings, including cost estimates.

4. **District's Responsibilities.** District must:

   a. Use best efforts to acquire written permission from landowners to access property for data collection. The parties understand failure to obtain permission may impact Commission's ability to provide accurate survey data for that property. Commission agrees to use other available data and highlight any deficiencies in its report.

   b. Use best efforts to acquire written permission from landowners to install real-time water level gages on Spiritwood Lake and Alkali Lake. The parties understand failure to obtain permission may impact Commission's ability to provide accurate water levels. Commission agrees to use other available data and highlight any deficiencies in its report.

   c. Pay $2,305 to Commission prior to commencement of work. This amount constitutes one-half of the field survey costs anticipated for the work.

5. **Term.** This agreement terminates on June 30, 2021, unless otherwise agreed to in writing by the parties.

6. INSURANCE. State and District each shall secure and keep in force during the term of this agreement, from an insurance company, government self-insurance pool, or government self-retention fund authorized to do business in North Dakota, commercial general liability with minimum limits of liability of $250,000 per person and $500,000 per occurrence.

7. AGREEMENT BECOMES VOID. This agreement is void if not signed and returned by District within 60 days of Commission's signature.

8. TERMINATION.

a. Either party may terminate this agreement upon thirty days' written notice.
b. Commission may terminate this agreement effective upon delivery of written notice to District, or a later date as may be stated in the notice, under any of the following conditions:
   (1) If Commission determines an emergency exists.
   (2) If funding from federal, state, or other sources is not obtained and continued at levels sufficient to provide the funds necessary to comply with this agreement. The parties may modify this agreement to accommodate a reduction in funds.
   (3) If federal or state laws or rules are modified or interpreted in a way that the services are no longer allowable or appropriate for purchase under this agreement or are no longer eligible for the funding proposed for payments authorized by this agreement.
   (4) If any license, permit, or certificate required by law, rule, or this agreement is denied, revoked, suspended, or not renewed.
   (5) If Commission determines that continuing the agreement is no longer necessary or would not produce beneficial results commensurate with the further expenditure of public funds.

c. Any termination of this agreement shall be without prejudice to any obligations or liabilities of either party already accrued prior to termination.
d. In the event this agreement is terminated prior to Commission providing a report to District, District may request any draft or final materials prepared by Commission. Commission shall return any unused portion of funds paid by District. The parties may discuss and agree to other reasonable terms and conditions based on the level of completeness of the information/data at the time of termination.
e. The rights and remedies of any party provided in this agreement are not exclusive.

9. APPLICABLE LAW AND VENUE. This agreement is governed by and construed in accordance with the laws of the State of North Dakota. Any action to enforce this agreement must be brought in the District Court of Burleigh County, North Dakota.

10. SEVERABILITY. If any term of this agreement is declared by a court having jurisdiction to be illegal or unenforceable, the validity of the remaining terms must not be affected, so long as the remaining rights and obligations of the parties are not substantially affected by the omitted term.

11. SPOLIATION – NOTICE OF POTENTIAL CLAIMS. The parties agree to promptly notify each other of all potential claims that arise or result from this agreement. The parties shall also take all reasonable steps to preserve all physical evidence and information that may be relevant to the circumstances surrounding a potential claim, while maintaining public safety, and grants to each other the opportunity to review and inspect the evidence, including the scene of an accident.

12. MERGER. This agreement constitutes the entire agreement between the parties. There are no understandings, agreements, or representations, oral or written, not specified within this agreement. This agreement may not be modified, supplemented, or amended in any manner except by written agreement signed by both parties.

NORTH DAKOTA STATE WATER COMMISSION

By: Garland Erbele

Garland Erbele, P.E.
Chief Engineer and Secretary

Date: 2.27.2020

STUTSMAN COUNTY WATER RESOURCE DISTRICT

By: Arlyn Schmidt

Arlyn Schmidt
Vice Chairman

Date: 2-26-2020

NORTH
Dakota | Water Commission
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To: Stutsman County Water Resource Board

From: Chris Korkowski, P.E., Water Resources Engineer

Subject: Scope of Work – Spiritwood and Alkali Lakes Investigation

Date: January 30, 2020

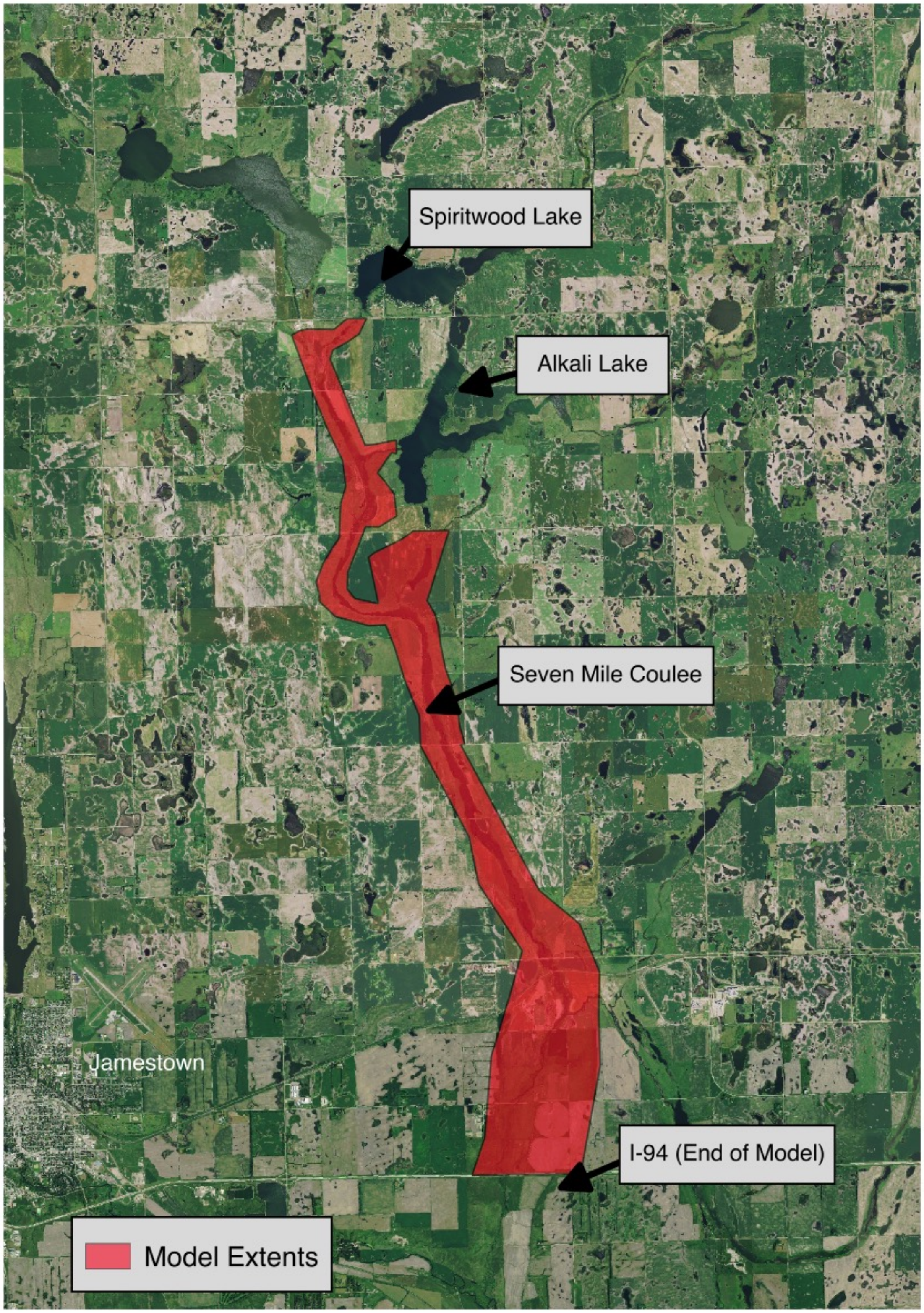
Background:
The Stutsman County Water Resource Board (Board) reached out to the North Dakota State Water Commission (Commission) about conducting a feasibility level investigation of drainage alternatives to reduce flooding on Spiritwood Lake. High water has been a concern for local interests in 1951, 1969, 1975, 1997, and throughout our current wet cycle. Numerous studies have been conducted on Spiritwood Lake, including several drainage studies.

Project Scope and Approach:
Below is a scope of work for an investigation of Spiritwood and Alkali Lakes.

1. Site survey, including potential installation of real-time water level gages on Spiritwood and Alkali Lakes
2. Identify the contributing drainage area of each lake
3. Estimate potential runoff volumes to each lake
    i. Calibrate hydrologic model to Spiritwood Lake's gage
    ii. Simulate frequency events to determine potential inflow volumes
4. Analyze potential outlet alternatives
    a. Preliminary analysis of outlet alternatives at Spiritwood and Alkali Lakes, including cost estimates
    b. Evaluate Seven Mile Coulee's ability to convey the new project
        i. Coarse hydraulic analysis of downstream impacts, as shown in the attached figure
5. Deliver report and supporting data

In total, based on the scope of work developed for this study, the Spiritwood and Alkali Lakes Investigation would cost approximately $33,125. The Investigations Section of the Commission charges fifty percent of the total estimated fieldwork costs to conduct an Investigation, which would make the Board's share of this study approximately $2,305.

Task	Total ($)
Site Survey	$ 4,610.74
Contributing Area Determination	$ 1,173.00
Volume Update/Lidar Integration	$ 1,173.00
Hydrologic Model Development	$ 7,038.00
Hydrologic Model Calibration	$ 4,692.00
Approximation of potential runoff	$ 1,173.00
Alternative Development	$ 3,519.00
Seven Mile Coulee Impacts	$ 4,692.00
Documentation	$ 3,519.00
Update Meetings	$ 938.40
Review	$ 597.50
Study Total	**$ 33,125.64**
WB Total	**$ 2,305.37**


Spiritwood Lake
Alkali Lake
Seven Mile Coulee
Jamestown
I-94 (End of Model)
Model Extents

June 11, 2021

Mr. Joel Lees, Chairman
Stutsman County Water Resource District
P.O. Box 68
Jamestown, ND 58402-1727

Dear Chairman Lees:

The Spiritwood and Alkali Lake Investigation Agreement is set to expire on June 30th, 2021. The project is nearing completion but will not be completed by the agreement expiration date. I have attached an amendment to the Spiritwood and Alkali Lake Investigation Agreement for your signature. This amendment extends our agreement into the next biennium, which is standard practice for extension of our agreements. The expectation is that the project would still be completed in 2021. Please sign and return a copy of the amendment to me by email at ckorkowski@nd.gov or by mail at the address below.

North Dakota State Water Commission
900 East Boulevard Ave.
Bismarck, ND 58505

I plan on attending your District's meeting on June 30th to provide you with a progress update on the project. I look forward to continuing working with you on this project. If you have any questions concerning this correspondence, please contact me at (701) 328-2762 or ckorkowski@nd.gov.

Sincerely,

Chris Korkowski

Chris Korkowski, P.E.
Investigations Section Chief

CK:pp/461

SWC Project #461
Project Manager: Chris Korkowski
June 2021

AMENDMENT I to the Investigation Agreement

1. **BACKGROUND.** In February 2020, the State of North Dakota (State), by and through the State Water Commission (Commission), and the Stutsman County Water Resource District (District) entered into an agreement to conduct an investigation of flood prevention and mitigation measures at Spiritwood and Alkali Lakes.

2. **INTENT**. The intent of the parties here is to amend the Agreement to extend the term.

3. **AGREEMENT**. Commission and District agree to amend the Agreement by replacing the language in paragraph 5 with the following:

> 5. **TERM.** This agreement terminates on June 30, 2023, unless otherwise agreed to in writing by the parties.

NORTH DAKOTA STATE WATER COMMISSION

By: [signature]

John Paczkowski, P.E.
Interim Chief Engineer and Secretary

Date: 06/10/2021

STUTSMAN COUNTY WATER RESOURCE DISTRICT

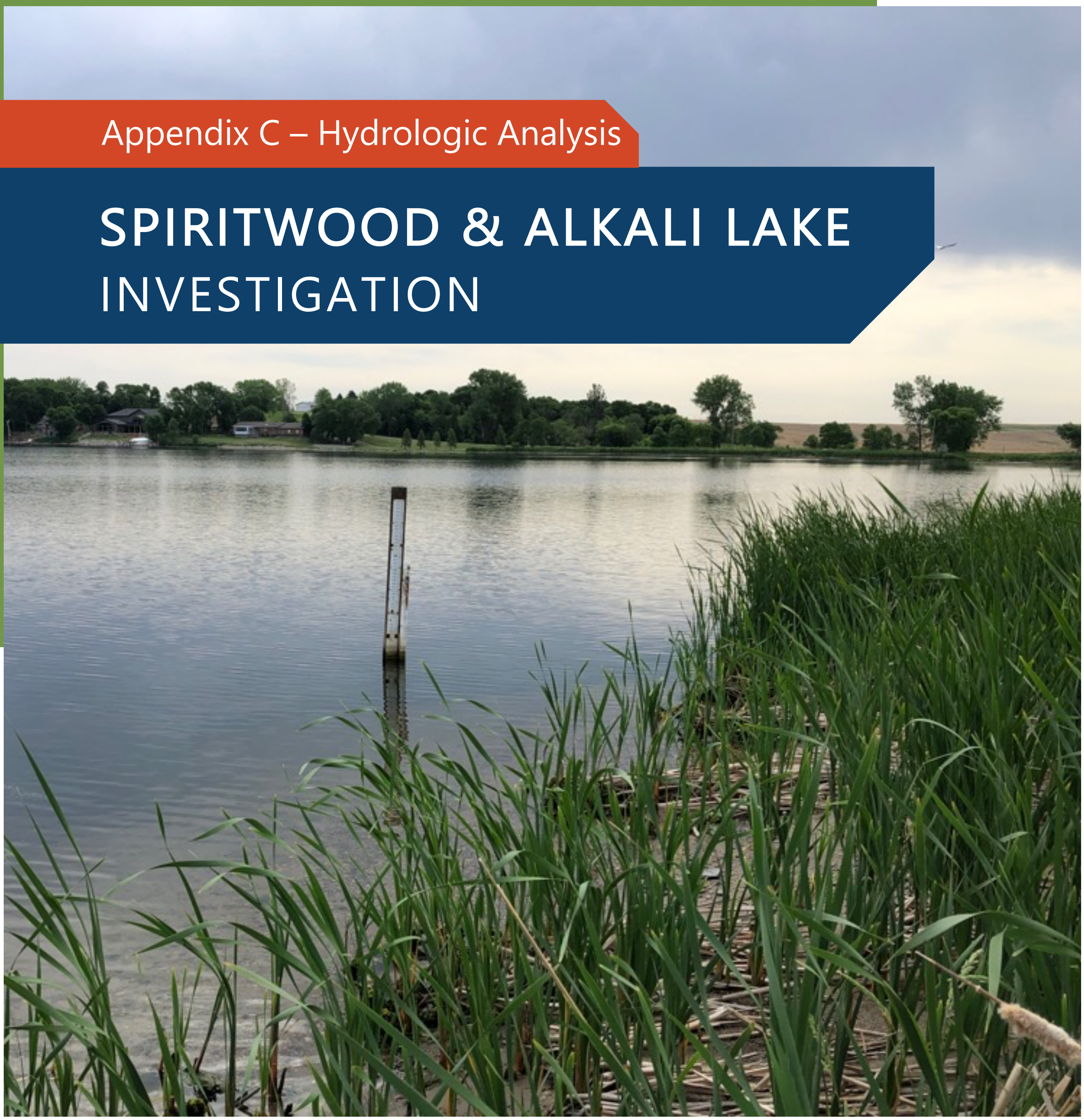
By: [signature]

Joel Lees
Chairman

Date: 7-1-2021

Appendix C – Hydrologic Analysis

SPIRITWOOD & ALKALI LAKE INVESTIGATION



DEPARTMENT OF WATER RESOURCES

DWR Project #461
January 2023

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SPIRITWOOD & ALKALI LAKE INVESTIGATION

North Dakota Department of Water Resources
1200 Memorial Highway
Bismarck, ND 58504

Prepared For
Stutsman County Water Resource District
Spiritwood Lake, North Dakota, Stutsman County
January 2023

DWR Project #461

Prepared By

REGISTERED PROFESSIONAL ENGINEER
CHRISTOPHER KORKOWSKI
PE-27993
DATE 1/23/23
NORTH DAKOTA

Chris Korkowski, P.E.
Investigations Section Chief

REGISTERED PROFESSIONAL ENGINEER
LAURA C. ACKERMAN
PE-7861
DATE 1/23/23
NORTH DAKOTA

Laura Ackerman, P.E.
Water Resource Engineer

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APPENDICIES

1.0 HYDROLOGIC MODEL SETUP

A hydrologic model was developed for the Spiritwood/Alkali Lake watershed complex using the United States Army Corps of Engineers' (USACE) Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) version 4.4 (USACE, 2020). Initial model parameters were developed and calibrated to match the continuous gage record from 2010 to the end of 2019. **Figure 1** illustrates the layout of the HEC-HMS model which includes 6 subbasins, 3 reservoirs, 3 routing reaches, and 1 sink.

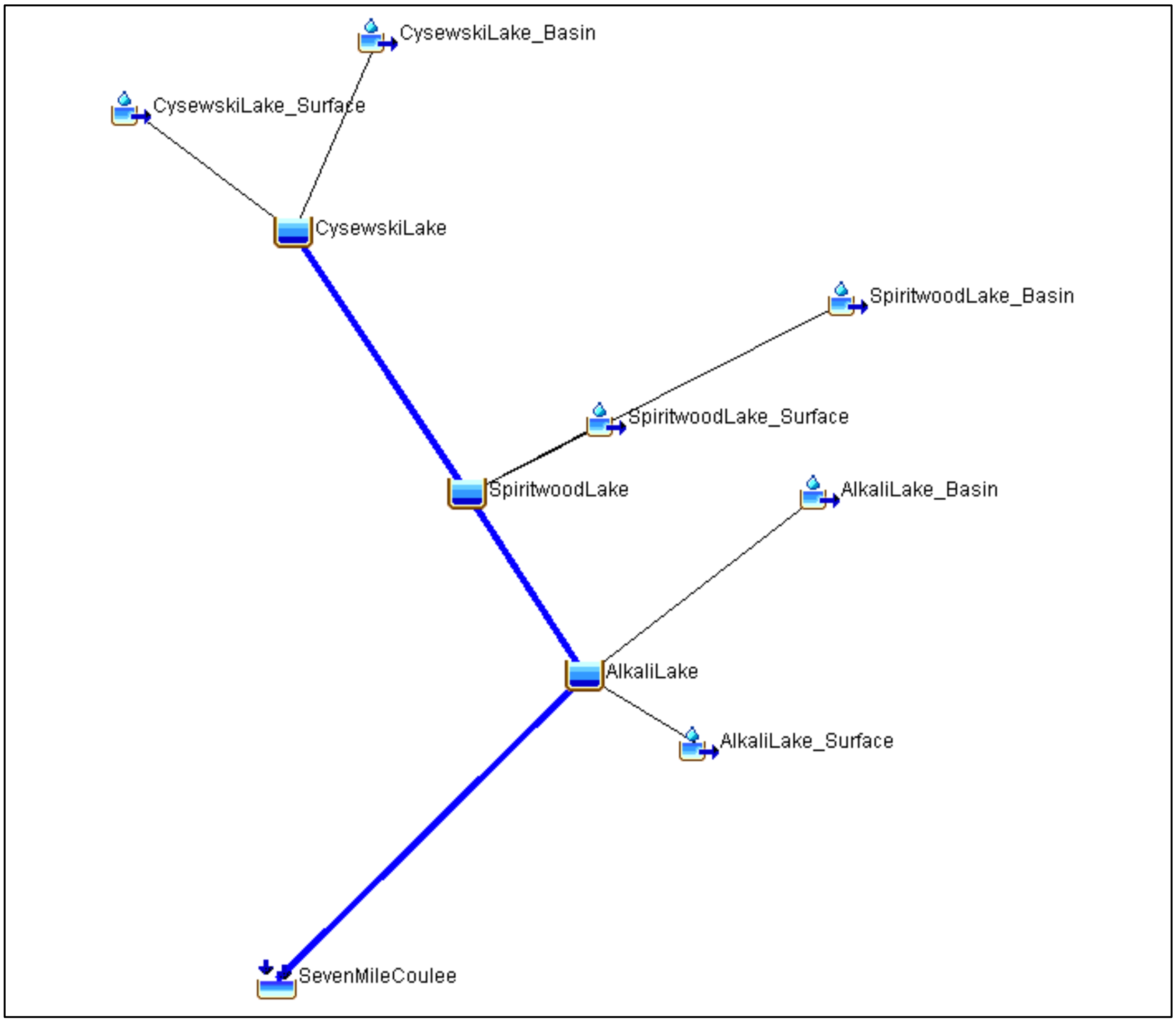

Figure 1. HEC-HMS model layout.

1.1 Subbasin & Reach Elements

1.1.1 Watershed Drainage Area

The drainage area for Cysewski Slough, Spiritwood Lake, and Alkali Lake were delineated for the hydrologic model as described in Section 3 of the main report. The three watersheds were included in the hydrologic model with stream connections shown in **Figure 1**. HEC-HMS requires drainage areas to be entered as subbasins. In order to calibrate a hydrologic model for a series of closed basin lakes, the surface area of the lake was entered as its own subbasin. **Table 1** provides the subbasin area in square miles for each subbasin within HEC-HMS.

Table 1. Subbasin area.

Subbasin Area	Area (Square Miles)
Cysewski Slough Basin	18.122
Cysewski Slough Surface	0.653
Spiritwood Lake Basin	12.106
Spiritwood Lake Surface	0.764
Alkali Lake Basin	28.904
Alkali Lake Surface	1.066

1.1.2 Loss Method

Loss methods in a hydrologic model determine how much infiltration and surface runoff will take place during a precipitation event. There are twelve loss methods in HEC-HMS, but Soil Moisture Accounting is one of five that can handle continuous hydrologic modeling, as opposed to event based hydrologic modeling. Continuous hydrologic modeling is necessary for modeling water surface elevation changes of a gaged lake because the water surface is often dependent on multiple factors rather than a single event. Factors that affect a lake's water surface include seepage, evaporation, and runoff into the lake. Soil Moisture Accounting was selected for this hydrologic model based on engineering experience.

Soil Moisture Accounting main parameters include maximum infiltration, imperviousness, soil storage, soil tension, and soil percolation. Parameters for the model were estimated based on the Natural Resources Conservation Service's (NRCS) Soil Survey Geographic Data (SSURGO) data (NRCS, 2020). SSURGO contains information about soils throughout the United States that has been collected by the NRCS over the course of a century. The information is broken down into separate classifications and provides a variety of information that can be utilized. The NDDWR's SSURGO dataminer GIS plugin was utilized to obtain information about the soils in each basin. Zonal statistics was utilized by the dataminer plugin to determine the average parameter value for each subbasin. The parameters were then adjusted to calibrate the hydrologic model to the Spiritwood Lake gage. **Table 2** provides the final Soil Moisture Accounting parameters utilized in HEC-HMS model.

Table 2. Calibrated Soil Moisture Accounting parameters.

Subbasin	Soil	Groundwater 1	Maximum Infiltration	Impervious	Soil Storage	Tension Storage	Soil Percolation	Groundwater 1 Storage	Groundwater 1 Percolation	GW 1 Coefficient
	%	%	(IN/HR)	%	(IN)	(IN)	(IN/HR)	(IN)	(IN/HR)	(HR)
CysewskiLake_Basin	0.5	0.5	0.1	0.266	21.496	14.544	0.759667	5	0.01	40
CysewskiLake_Surface	100	0	0.01	100	0	0	0.1	0	0	120
SpiritwoodLake_Basin	0.5	0.5	0.1	0.43	20.64	14.544	0.759667	5	0.01	40
SpiritwoodLake_Surface	100	0	0.01	100	0	0	0.1	0	0	120
AlkaliLake_Basin	0.5	0.5	0.1	0.32	21.723	14.544	0.759667	5	0.01	40
AlkaliLake_Surface	100	0	0.01	100	0	0	0.1	0	0	120

1.1.3 Transform Method

The Clark Unit Hydrograph Transform Method (Clark Method) was selected as the transform method for the hydrologic model. The Clark Method uses time of concentration (Tc) and a storage coefficient (R) to develop a time-area curve, which translates a hydrograph from precipitation. Tc was estimated using stream length and the 10-85 stream slope method estimated from the LiDAR DEM in GIS. The R was estimated based on a ratio of R/(Tc+R)=0.67. Subbasins representing the lake surfaces were given a Tc of 0.1 hours and R of 0.1 hours to represent direct rise from precipitation on the surface of the lakes. **Table 3** provides the calibrated Clark Method parameters for the hydrologic model.

Table 3. Calibrated Clark Method parameters.

Subbasin	Time of Concentration (HR)	Storage Coefficient (HR)
CysewskiLake_Basin	20	40
CysewskiLake_Surface	0.1	0.1
SpiritwoodLake_Basin	15	30
SpiritwoodLake_Surface	0.1	0.1
AlkaliLake_Basin	20	40
AlkaliLake_Surface	0.1	0.1

1.1.4 Baseflow Method

Baseflow represents the shallow subsurface flow within a basin. A total of six different baseflow methods are provided in HEC-HMS. The constant monthly baseflow method was selected for the hydrologic model. The rate of constant monthly baseflow was adjusted to calibrate the hydrologic model to the Spiritwood Lake gage. A constant baseflow of 1 cfs for each month of the calendar year for Cysewski Slough, Spiritwood Lake, and Alkali Lake basins was utilized to calibrate the hydrologic model.

1.1.5 Surface Method

The surface component in HEC-HMS is a subbasin element that is intended to represent the ground surface where water may accumulate in surface depression storage. The simple surface method was selected and a max storage of 0.07 inches with an initial storage of 50-percent was utilized for each subbasin. These values were chosen based on experience modeling similar environments in North Dakota.

1.1.6 Canopy Method

A canopy method is a subbasin component that represents the presence of plants in the landscape. Plants reduce the amount of precipitation that contacts the ground surface, which is either taken up by the plant or evaporated between precipitation events. A simple canopy method was utilized for the hydrologic model. The simple canopy method utilizes parameters for max storage, initial storage percentage, crop coefficient, evapotranspiration, and uptake method. Initial storage was set at 50-percent, maximum storage was set to 0.1 inches, the crop coefficient was set to 1.1, evapotranspiration was set for only dry periods, and the uptake method was set to simple for each subbasin in the hydrologic model.

1.1.7 Routing Method

Three routing reaches were created for the hydrologic model; Cysewski Slough to Spiritwood Lake, Spiritwood Lake to Alkali Lake, and Alkali Lake to Seven Mile Coulee. Hydrologic routing moves basin runoff between different elements of the hydrologic model, conceptually representing a stream. HEC-HMS provides nine different routing methods. The Lag Routing Method was selected for the Spiritwood/Alkali hydrologic model based on the short routing reaches needed for the hydrologic model and the simplicity of the method. The Lag Routing Method only requires a lag time parameter, which is the amount of time it takes for inflow to pass through the routing reach. Lag time was set at 15 minutes for the Cysewski to Spiritwood and Alkali to Seven Mile Coulee reaches, and 5 minutes for Spiritwood to Alkali reaches.

1.2 Reservoir Elements

Three reservoir elements were utilized in the hydrologic model to represent Cysewski Slough, Spiritwood Lake, and Alkali Lake. The elevation-area-storage method was utilized to represent the elevation-storage relationship of each lake. This method was selected due to it being required in order to allow evaporation calculations to be utilized by the HEC-HMS model. Elevation-area-volume curves were developed using methodology outlined in Section 3 of the main report and are illustrated in **Figures 6**, **7**, and **8** of that report.

1.2.1 Evaporation

In order to calibrate a continuous hydrologic model to lake levels, evaporation must be incorporated. Lake discharge, evaporation, and seepage make up the volume losses that lower a reservoir's water surface elevation. Seepage is often neglected in hydrologic models due to its difficulty to measure and replicate, and losses to seepage are often made up by slightly exaggerating evaporative losses. Monthly constant evaporative losses were utilized for this hydrologic model and were estimated based on the Strasburg Slough and Twin Lake hydrologic model (NDSWC 2, 2020). **Table 4** represents the calibrated constant monthly evaporative losses utilized for this hydrologic model for each reservoir.

Table 4. Constant monthly evaporative losses (inches).

Month	Evaporation (IN)
January	0
February	0
March	0
April	1.9
May	3
June	4.5
July	6.1
August	6.8
September	5.4
October	3.6
November	1.4
December	0

1.2.2 Elevation-Discharge Method

Elevation-discharge curves were developed for Cysewski Slough, Spiritwood Lake, and Alkali Lake for use in the hydrologic model. Elevation-discharge curves represent the discharge from the lake based on a given elevation of the lake. Two-dimensional HEC-RAS (USACE 2, 2020) models were created to develop the elevation-discharge curves for each lake. A constantly increasing inflow hydrograph was set at the upstream end of each lake which continuously filled the reservoir and outflow was then recorded at each lake's outlet. **Figure 2** illustrates the layout of the two-dimensional grid for the Spiritwood Lake elevation-discharge model. The two-dimensional elevation-discharge models for Cysewski Slough, Spiritwood Lake, and Alkali Lake are available in electronic **Appendix D**. Elevation-discharge curves for Cysewski Slough, Spiritwood Lake, and Alkali Lake developed from the two-dimensional hydraulic models are provided in **Figures 3**, **4**, and **5**.

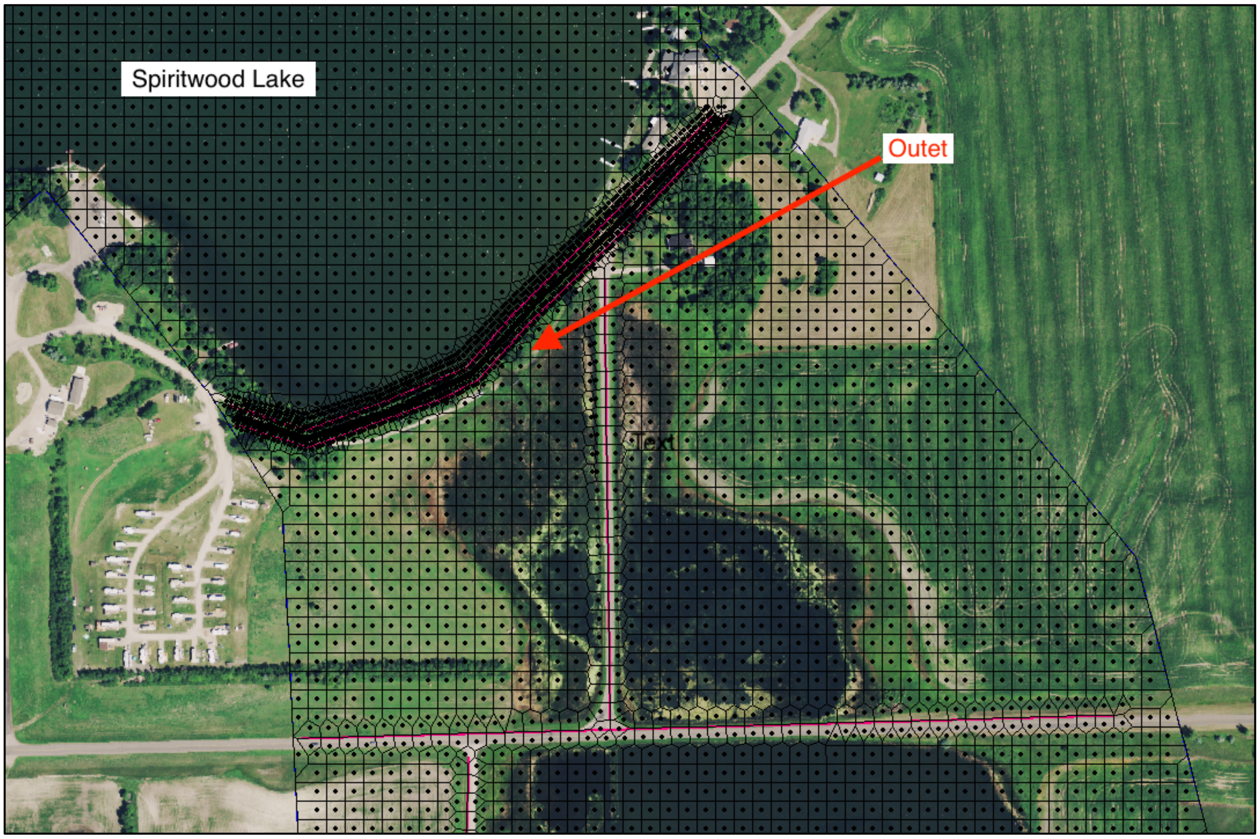

Figure 2. Spiritwood Lake elevation-discharge two-dimensional model.

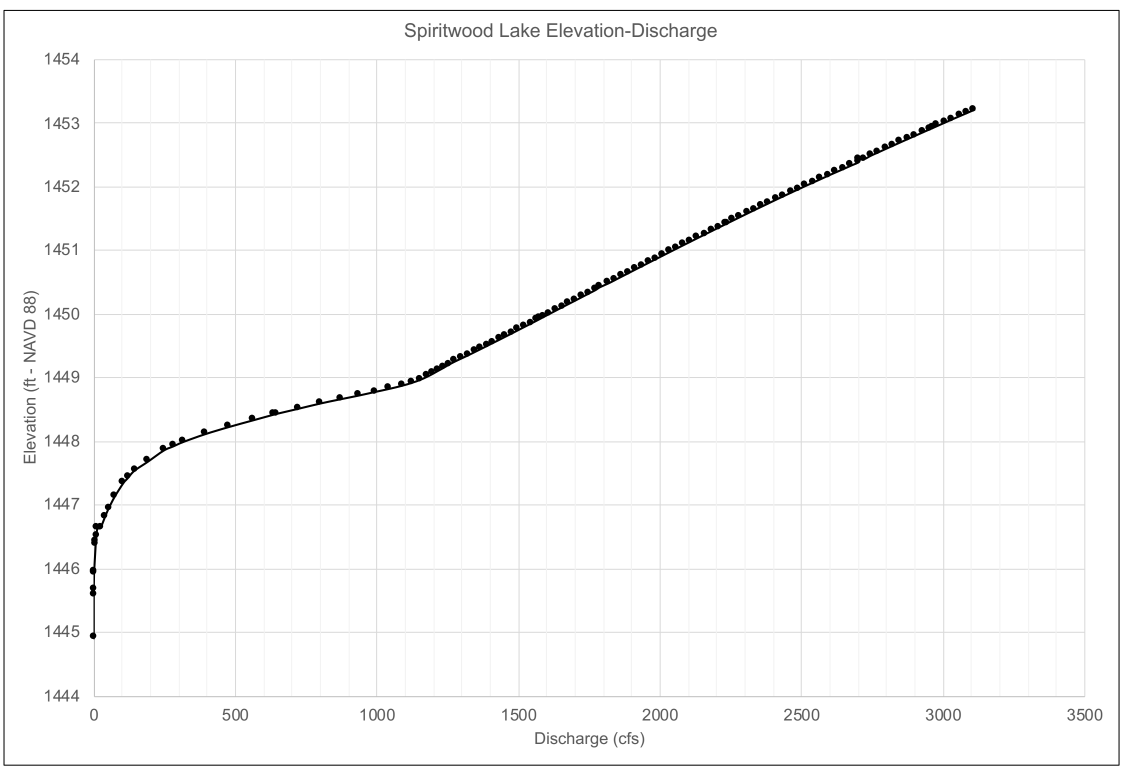

Figure 3. Spiritwood Lake elevation-discharge curve.

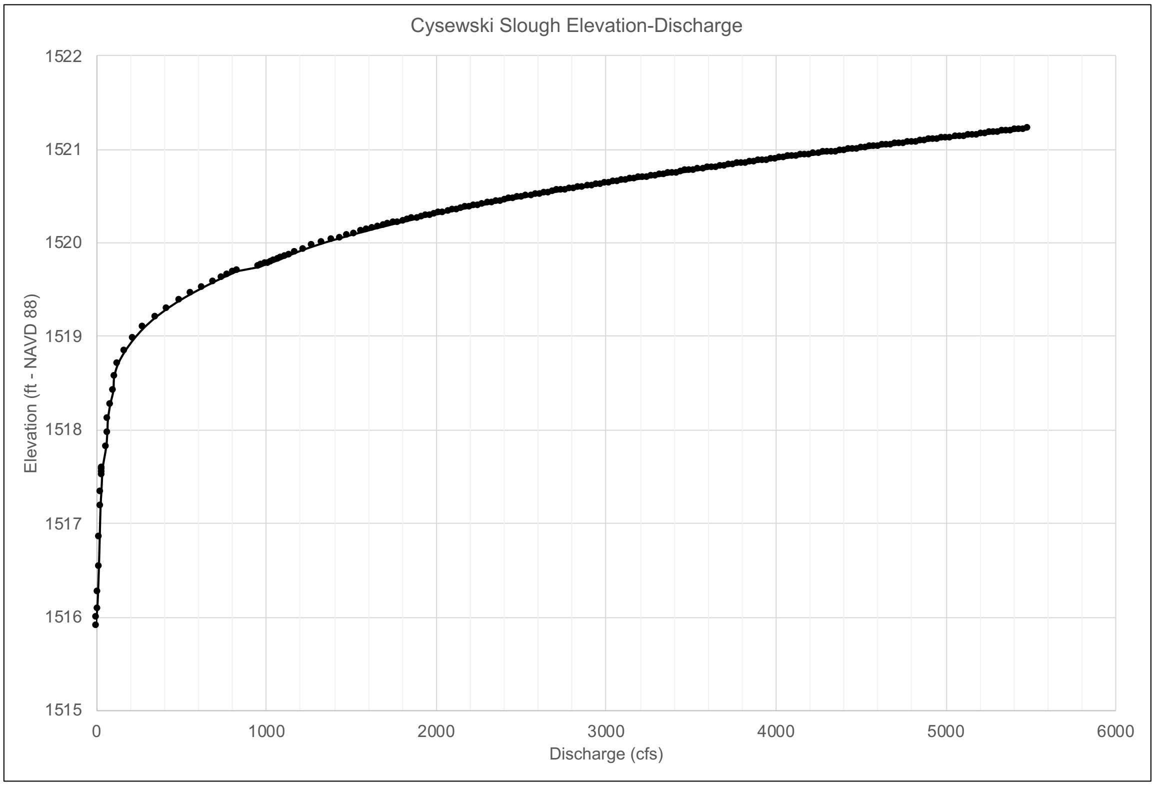

Figure 4. Cysewski Slough elevation-discharge curve.

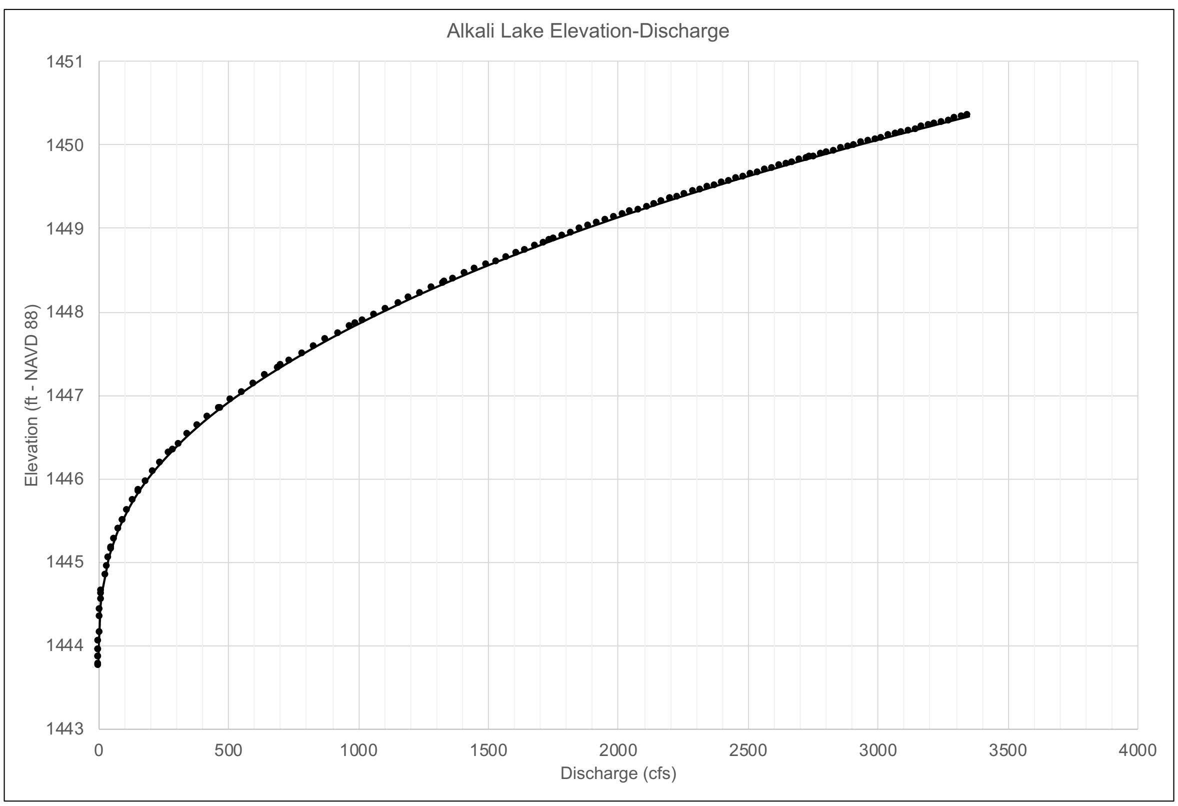

Figure 5. Alkali Lake elevation-discharge curve.

2.0 PRECIPITATION & OBSERVED DATA

This section of the appendix describes the observed water surface elevation and precipitation datasets utilized in the hydrologic model.

2.1 Observed Data

Observed water surface data was only available for Spiritwood Lake. Manual readings were obtained from the NDGF for the period from 1992 until 2019. **Figure 6** provides the manual observed water surface elevations for Spiritwood Lake.

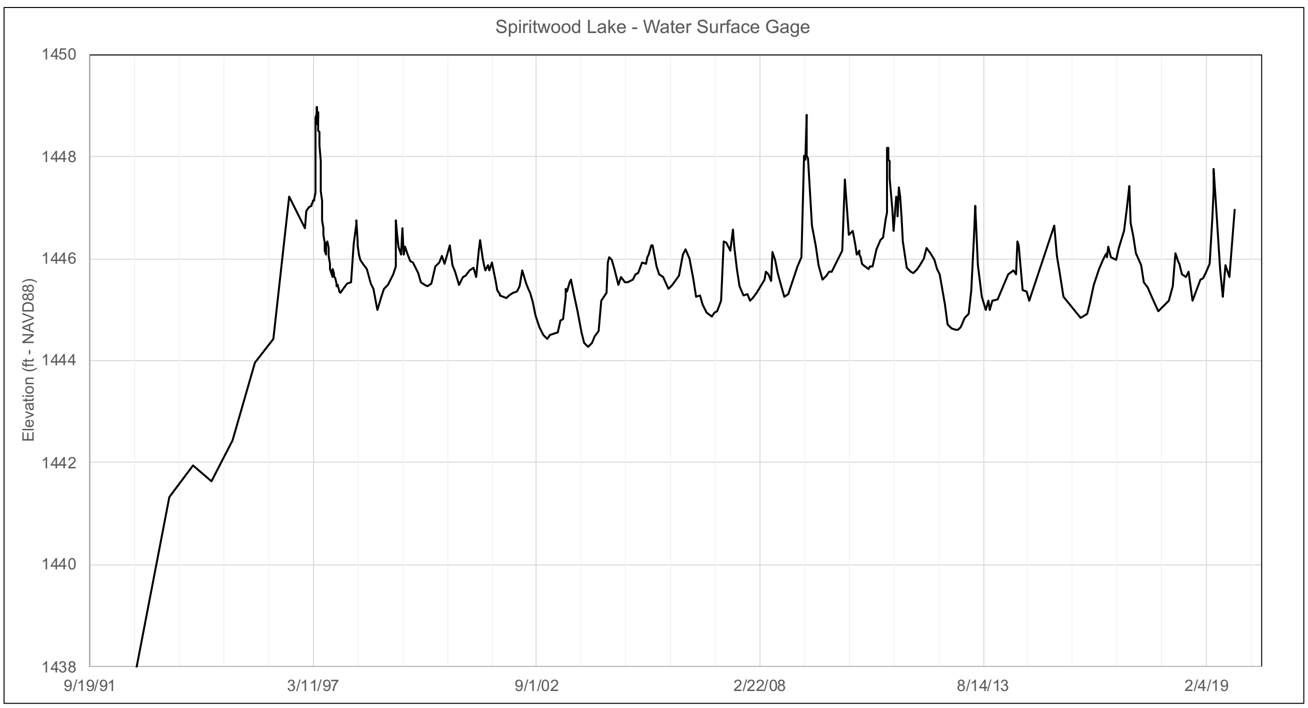

Figure 6. Manual observed water surface elevations for Spiritwood Lake.

In order to better understand the water resource in the future, NDDWR's Pushing Remote Sensors (PRESENS) units were installed on Spiritwood (**Figure 7**) and Alkali (**Figure 8**) Lakes in the spring of 2020. PRESENS delivers real-time environmental data from sensors located in remote locations to publicly accessible databases with the NDDWR. The PRESENS units were placed with sensors to collect the water surface elevations on each lake in real time. The data is uploaded in real time to the NDDWR's map service, located at Map Service.

Figure 7. Spiritwood Lake PRESENS unit.

Figure 8. Alkali Lake PRESENS unit.

2.2 Precipitation and Snowmelt Data

Precipitation data was obtained from the PRISM Climate Group (PRISM, 2020). The PRISM Climate Group gathers climate observations from monitoring networks and develops spatial climate datasets. PRISM precipitation data collected from January 2005 to December 2019 was used in the study for the purpose of calibrating the hydrologic model to the Spiritwood Lake water surface gage. **Figure 9** illustrates the annual precipitation data from 2005 to 2019.

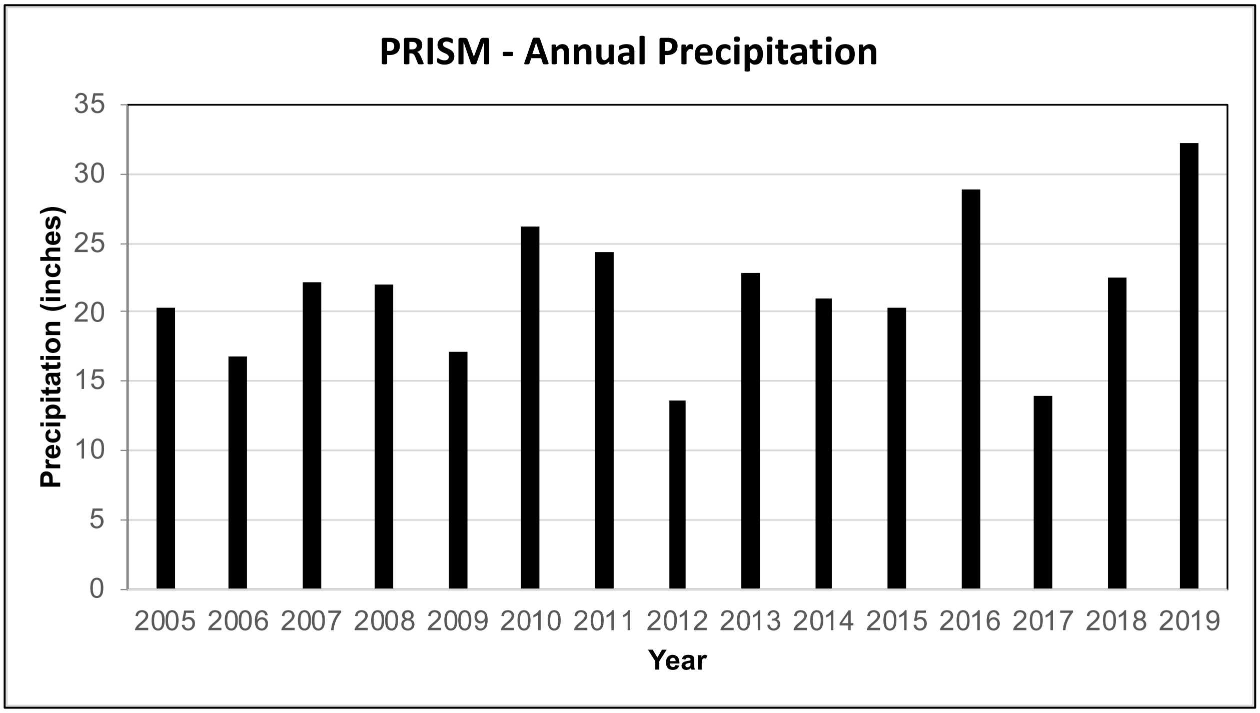

Figure 9. PRISM annual precipitation data for the Spiritwood Lake Basin.

The PRISM precipitation dataset was utilized to represent the rainfall data for the model. PRISM dataset included information for all throughout the year. From the PRISM dataset, data for the period of May through November was extracted, which served as the rainfall data for the modeling efforts. Snowmelt data was collected from the National Operational Hydrologic Remote Sensing Center (NOHRSC, 2020). Maximum and mean snow water equivalent (SWE) data was gathered from NOHRSC for Stutsman County, ND. The maximum and mean SWE data was then manipulated into snowmelt datasets by calculating the difference between SWE data for each day in the period of record to determine daily snowmelt in inches. The daily snowmelt was estimated for the period of January 2005 to December 2019. Based on initial calibration efforts, the maximum snowmelt data better represented the total runoff of the basin and was utilized for calibration of the hydrologic model. **Figure 10** provides the maximum snowmelt dataset that was used for calibration of the hydrologic model.

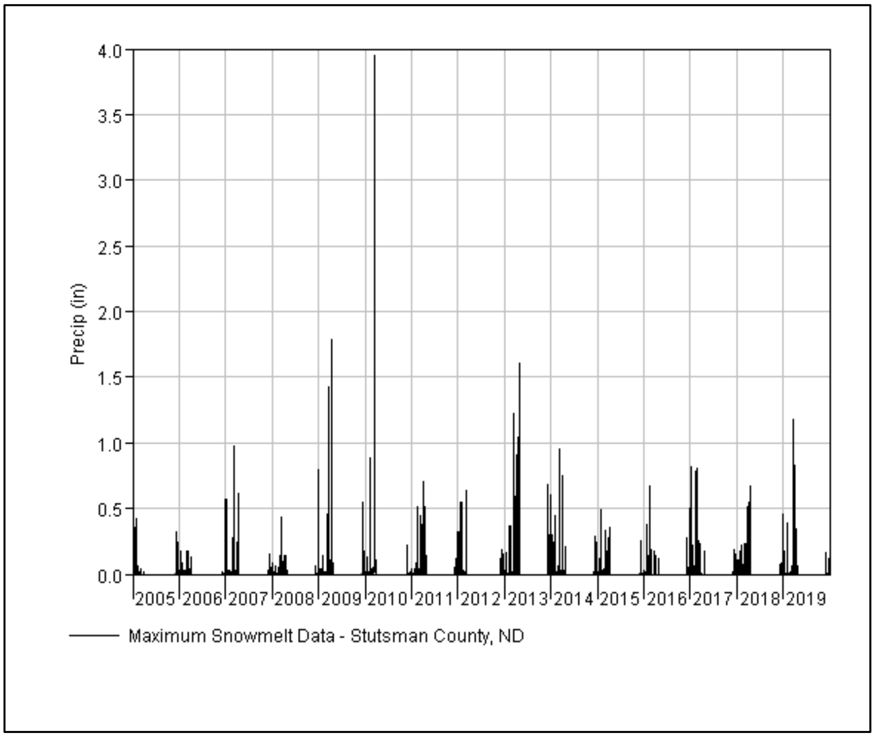

Figure 10. Maximum snowmelt data from December to April, Stutsman County, ND.

The combined precipitation dataset, using the PRISM rainfall data and maximum snowmelt dataset was ultimately used for calibration of the hydrologic model. The combined precipitation dataset is provided in **Figure 11**.

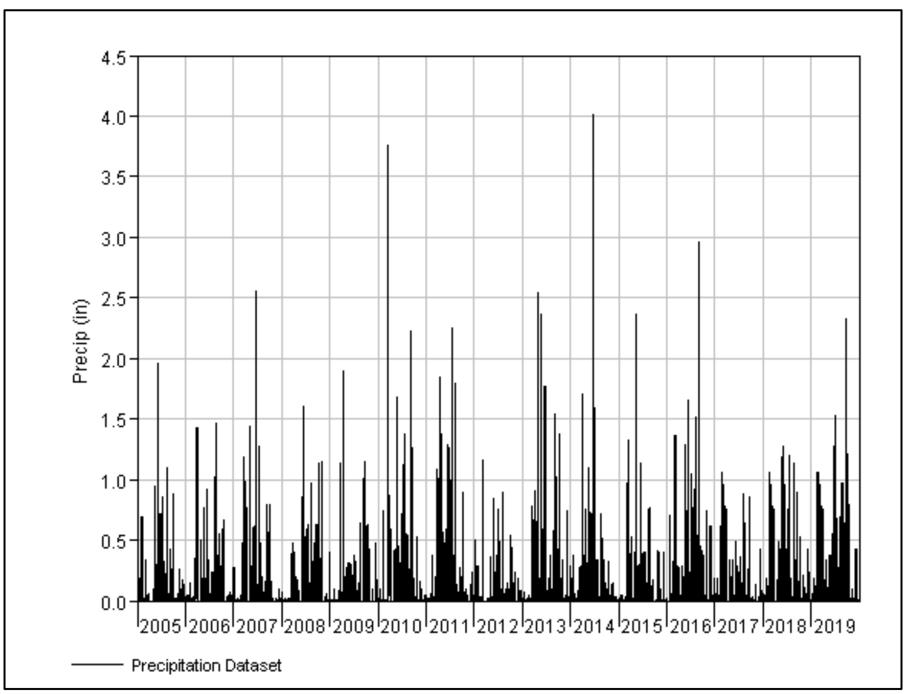

Figure 11. Combined precipitation dataset used for calibration of the hydrologic model.

3.0 HYDROLOGIC MODEL CALIBRATION

The HEC-HMS model was calibrated for the period of September 2010 to December 2019. Prior to September 2010, a roadway existed between Spiritwood and Alkali Lakes, which changed the elevation-discharge relationship of the Spiritwood Lake outlet. Historic data related to the roadway was not available to recreate the road to calibrate to the portion of the record prior to 2010.

3.1 Calibration Effort

Calibration of the hydrologic model was completed by changing the maximum infiltration value, monthly evaporation, and baseflow to represent what occurred throughout the period of record. The calibrated values for each of these parameters are provided in their corresponding sections above.

3.2 Calibration Results

The hydrologic model was calibrated using the water surface elevations collected at the Spiritwood Lake gage site from September 2010 to December 2019. The Spiritwood Lake gage site was the only available water surface data available to calibrate the hydrologic model over this period. Though water surface elevation data was available for the period prior to September 2010, the Spiritwood Lake's outlet elevation and conveyance were different than the current condition making calibration prior to 2010 difficult.

Figure 12 illustrates the calibrated model's water surface elevations compared to the observed data. The Nash-Sutcliffe efficiency (NSE) was calculated to estimate the performance of the hydrologic model. The NSE is a normalized statistic that determines the relative magnitude of the residual variance compared to the measured data variance (Nash, 1970). **Equation 1** was utilized to compute NSE to compare the observed (obs) and simulated (sim) data. An NSE equal to 1 means that the observed and simulated data are a perfect match. An NSE equal to or less than zero means choosing the mean value of the observed is a better prediction than the simulated data. Computed NSE for the calibrated hydrologic model was 0.44.

Equation 1. Nash-Sutcliffe efficiency (NSE).

$$\mathbf{NSE = 1 - (sum((obs - sim)^2)/sum(obs - mean(obs))^2)}$$

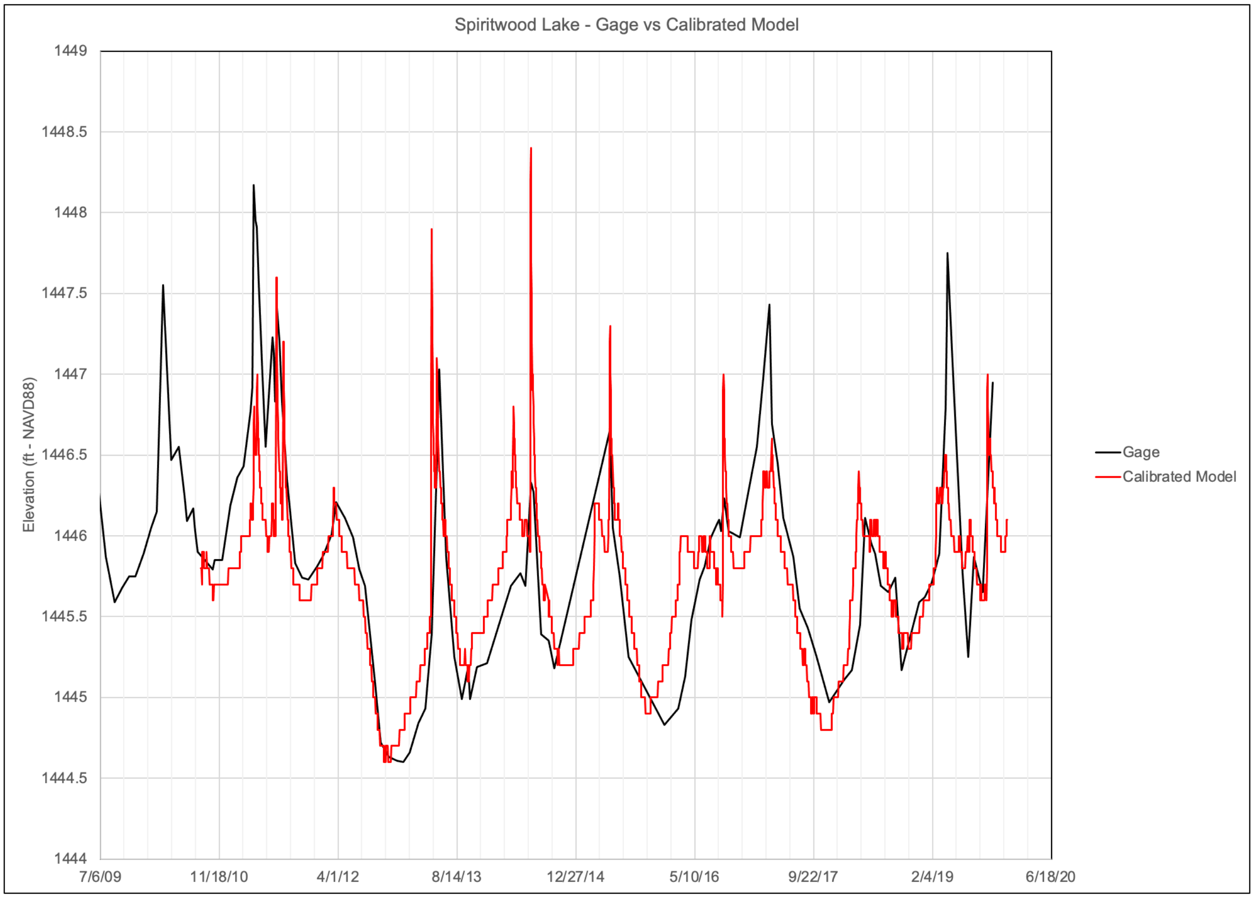

Figure 12. Spiritwood Lake Model Calibration vs Observed.

3.3 Potential Future Improvements

Calibration of the Spiritwood hydrologic model was extremely difficult due to the effect of stacking errors from each dataset used to develop the hydrologic model and the lack of observed data that existed for the system. Ideally, a calibrated hydrologic model would have an NSE value greater than 0.5, but it is unrealistic to assume it would ever reach a value near 1 due to the inherent error in the available datasets. As part of this project, continuous water surface monitoring sites were installed at Spiritwood and Alkali Lakes that provides greater detail than the manual readings collected on Spiritwood Lake. Installation of these two gages will help develop a better understanding of the relationship between these two lakes overtime as they continue to collect water surface elevations, but more information could be collected to better understand the system as a whole and improve calibration in the future. The additional information that could be collected includes:

- Installing a continuous gage to collect the outflow from Spiritwood Lake.
- Installing a continuous gage to collect the outflow from Alkali Lake.
- Installing a continuous gage to collect water surface elevations at Cysewski Slough.
- Collection of bathymetric data for Cysewski Slough.

It is suggested that if no solution is implemented at Spiritwood and Alkali Lakes to alleviate flooding at this time, that future calibration efforts include the newly collected data and that serious consideration should be given to installing gages and collecting bathymetric data at the site listed above.

4.0 FREQUENCY EVENTS

Inflows to each lake for a given frequency event was developed using the National Weather Service's Precipitation Frequency Data Server (NOAA, 2020). Atlas 14 precipitation data was downloaded for the Spiritwood Lake region using the data server and uploaded to HEC-HMS as frequency events. The depth-duration table for each frequency event obtained from the data server is provided in **Table 5**.

Table 5. Atlas 14 depth-duration frequency event data.

Duration	Frequency Events						
	2 Year (in)	5 Year (in)	10 Year (in)	25 Year (in)	50 Year (in)	100 Year (in)	500 Year (in)
5-min:	0.37	0.48	0.575	0.713	0.825	0.941	1.23
10-min:	0.542	0.703	0.842	1.04	1.21	1.38	1.8
15-min:	0.661	0.857	1.03	1.27	1.47	1.68	2.2
30-min:	0.904	1.17	1.4	1.74	2.01	2.29	3
60-min:	1.13	1.45	1.74	2.15	2.49	2.85	3.74
2-hr:	1.35	1.74	2.08	2.57	2.98	3.4	4.49
3-hr:	1.48	1.89	2.25	2.79	3.24	3.71	4.9
6-hr:	1.7	2.18	2.61	3.23	3.75	4.3	5.71
12-hr:	1.96	2.53	3.03	3.76	4.37	5.01	6.66
24-hr:	2.25	2.85	3.4	4.22	4.9	5.63	7.51

Once each frequency event was uploaded to the hydrologic model, the model was run using a frequency storm meteorologic model. Each frequency event included TP40 area reduction, a storm intensity position of 50-percent, and a storm area of 61.39 square miles.

The frequency events were modeled in HEC-HMS to obtain the inflow data to Spiritwood and Alkali Lakes. Once the inflow data was obtained, it was transferred to a 1-dimensional HEC-RAS model to produce realistic water level data for the larger frequency events. Backwater effects occur between each lake during the large frequency events. Because HEC-HMS is not able to handle backwater effects, a HEC-RAS model was used to estimate the resulting water surface level. A detailed writeup on the hydraulic model and the corresponding water surfaces for Spiritwood and Alkali Lake for each frequency event is provided in **Appendix D**.

5.0 REFERENCES

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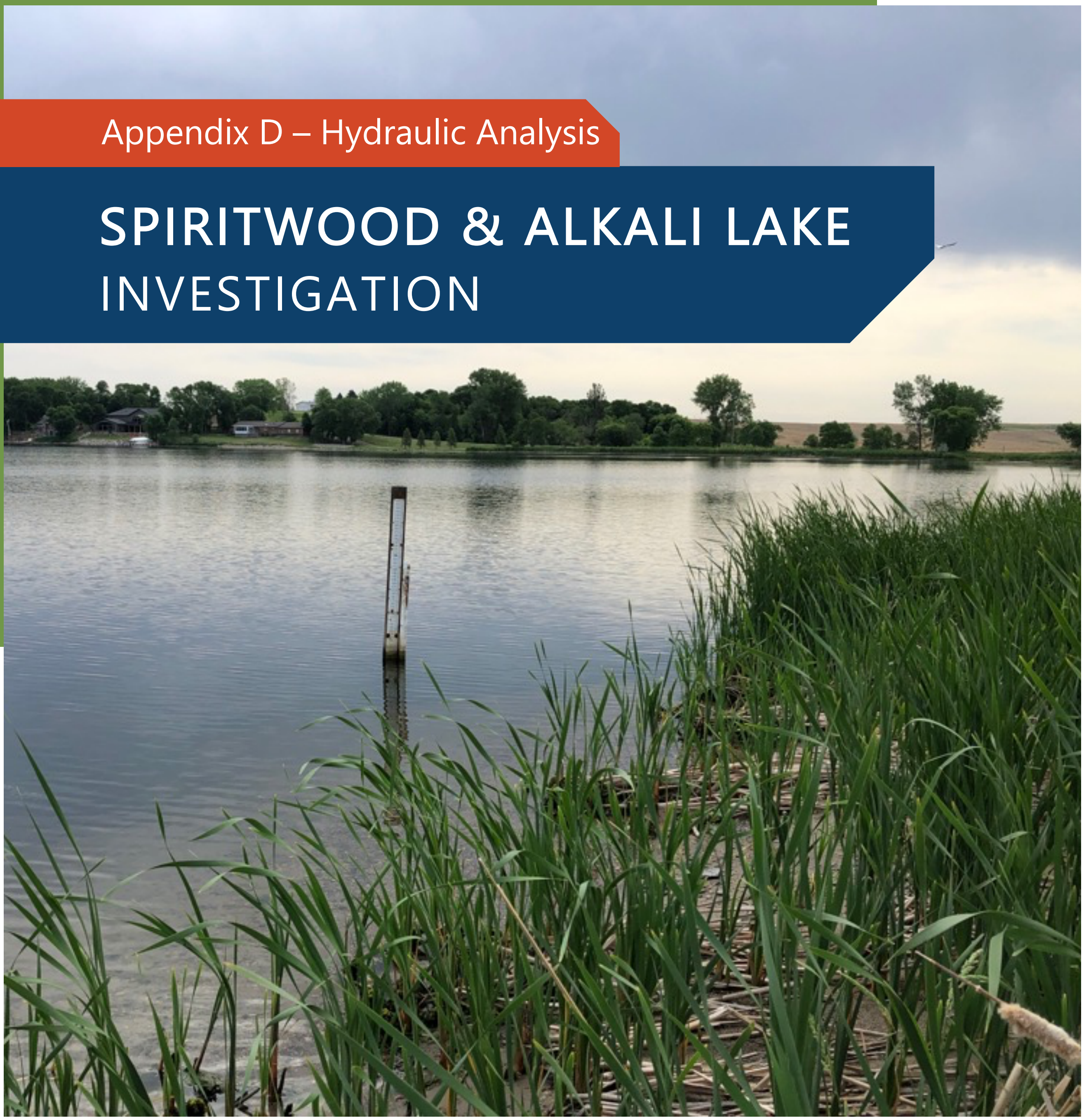
(USACE 2, 2020) United States Army Corps of Engineers’ Hydrologic Engineering Center, 2020. Hydrologic Engineering Center’s River Analysis System version 5.0.7.

(USDOC, 2005) US Department of Commerce, et al. *PF Map: Contiguous US*, US Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, 7 Nov. 2005, https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html

Appendix D – Hydraulic Analysis

SPIRITWOOD & ALKALI LAKE INVESTIGATION



DEPARTMENT OF WATER RESOURCES

DWR Project #461
January 2023

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SPIRITWOOD & ALKALI LAKE
INVESTIGATION

North Dakota Department of Water Resources
1200 Memorial Highway
Bismarck, ND 58504

Prepared For
Stutsman County Water Resource District
Spiritwood Lake, North Dakota, Stutsman County
January 2023

DWR Project #461

Prepared By

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Investigations Section Chief

Laura Ackerman, P.E.
Water Resource Engineer

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APPENDICIES

1.0 SPIRITWOOD & ALKALI LAKE INVESTIGATION'S HYDRAULIC MODELS

Five hydraulic models were developed as part of the Spiritwood and Alkali Lake Investigation. The hydraulic models were created using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 5.0.7 (USACE 2, 2020). Three hydraulic models were developed to produce elevation-discharge curves for Cysewski Slough, Spiritwood Lake, and Alkali Lake represented in the HEC-HMS model (USACE, 2020). The fourth hydraulic model was to determine the water surface elevation on Spiritwood and Alkali Lakes for large flood events. The final hydraulic model was created to determine the impacts of outflow from Alkali Lake on Seven Mile Coulee and the effect of proposed alternatives on Alkali Lake's outflow.

1.1 Topographic Data

Light Detection and Ranging Data (LiDAR) was utilized as the base to develop a terrain for each of the two-dimensional hydraulic models. The LiDAR data utilized for this study consisted of a bare earth 1-meter Digital Elevation Model (DEM) collected from the NDDWR's LiDAR Map Service (NDDWR, 2020). The LiDAR elevations in the model are based on the North American Vertical Datum 1988 (NAVD88), GEOID03, with a horizontal coordinate system being the NDSPCS, South Zone, units in international feet, based on the NAD83 (1986). Individual LiDAR tiles obtained from the NDDWR's LiDAR web service were merged using Quantum Geographic Information System (QGIS). The LiDAR DEM used for this study is included electronically with this report in **Appendix B**.

Survey data was added to the LiDAR DEM to improve each hydraulic model's accuracy. Survey of bridges and other structures was also completed and used to accurately depict the structures in each hydraulic model. The survey elevations in the model are based on the NAVD88, GEOID03, with a horizontal coordinate system being the NDSPCS, South Zone, units in international feet, based on the NAD83 (1986). The survey used for this study is included electronically with this report in **Appendix B**.

1.2 Elevation-Discharge Models

Three two-dimensional hydraulic models were created as part of this study. Each model was used to develop elevation-discharge curves for each of the lakes in the hydrologic model.

1.2.1 Cysewski Slough

A two-dimensional hydraulic model was created to develop an elevation-discharge curve for Cysewski Slough. Cysewski Slough has a subbasin area of 18.1 square miles that contributes to the slough. At approximately 1516.0 feet (NAVD88), it discharges through the southwest outlet (**Figure 1**) and spills into Spiritwood Lake. At 1519.4 feet (NAVD88) Cysewski Slough contributes to Spiritwood Lake from the outlet located southeast.

An elevation-discharge curve was developed using profile lines in HEC-RAS's RAS Mapper. Once the profile line was drawn across the outlet locations, the rating curve feature was utilized to develop the lake's elevation-discharge curve. **Figure 2** provides the elevation-discharge curve for Cysewski Slough.

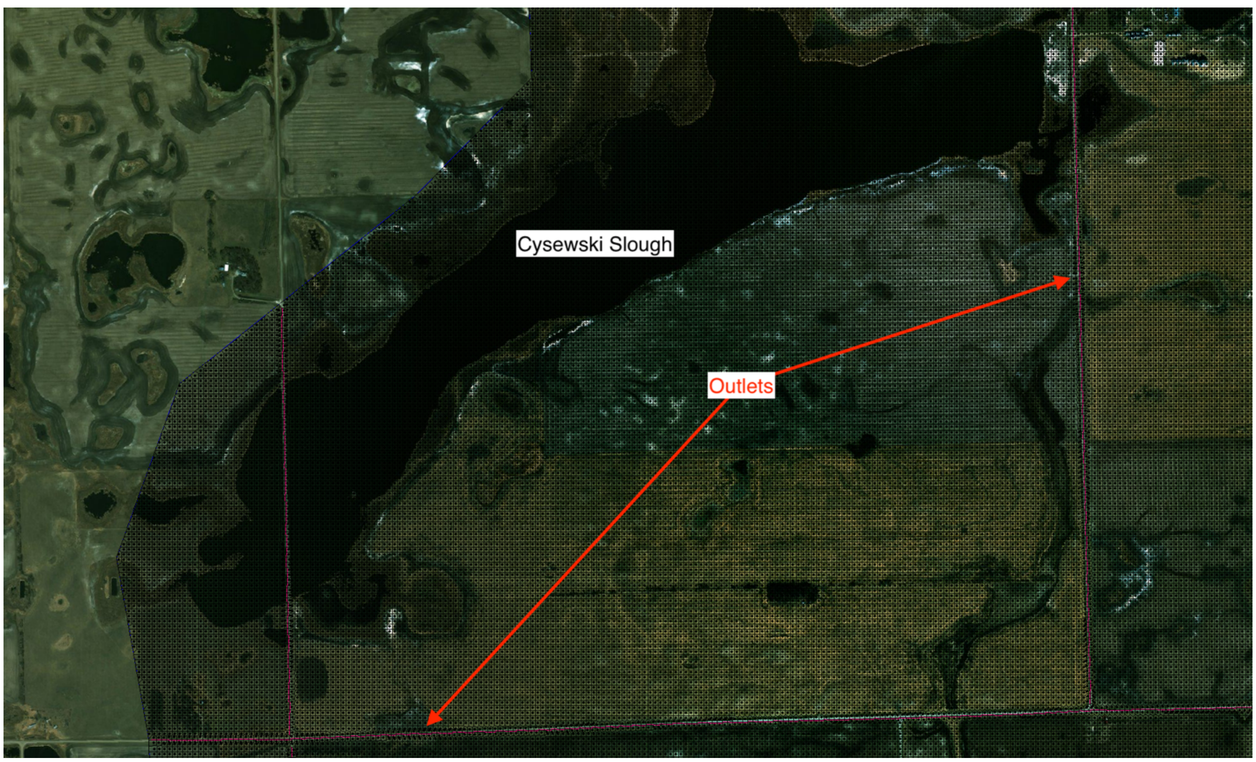

Figure 1. Cysewski Slough outlet locations.

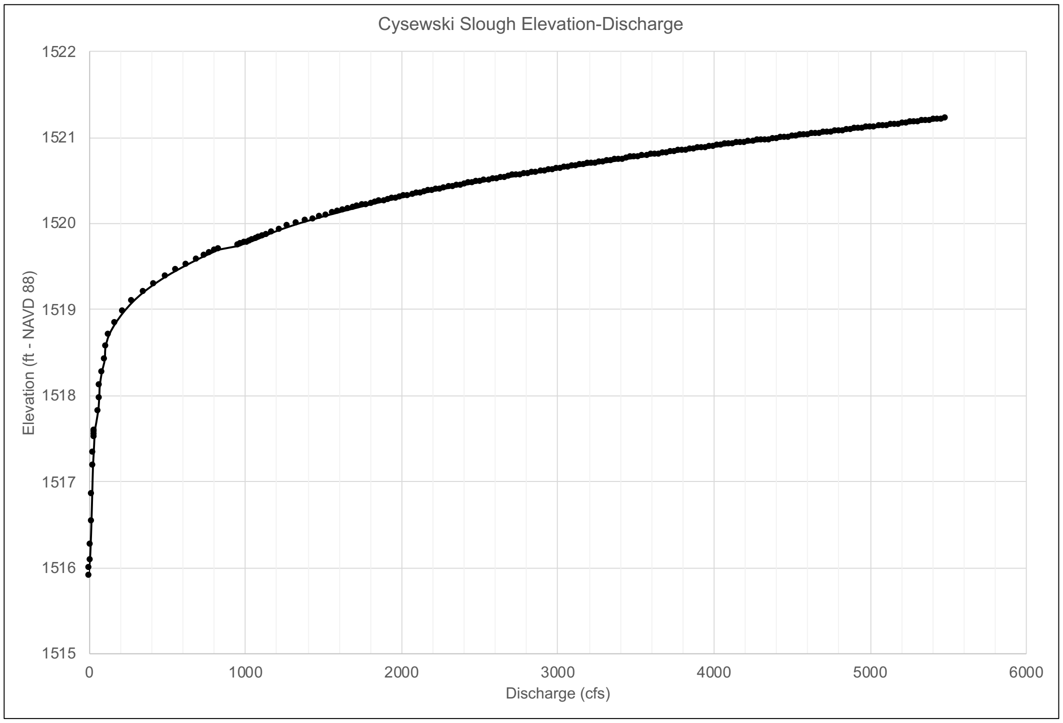

Figure 2. Cysewski Slough elevation-discharge curve.

1.2.2 Spiritwood Lake

A two-dimensional hydraulic model was created to develop an elevation-discharge curve for Spiritwood Lake. Spiritwood Lake has a subbasin area of 12.1 square miles that directly contributes to the lake, and Cysewski Slough subbasin, which can contribute if the slough is above elevation 1516.0 feet (NAVD88). Once Spiritwood Lake rises to approximately 1444.9 feet (NAVD88), it discharges through the southeast outlet (**Figure 3**) and spills into Alkali Lake. Spiritwood's west end outlet, that flows directly into Seven Mile Coulee at elevation 1449.5 feet (NAVD88), was not included in rating curve development because it has not been active during Spiritwood Lake's period of record due to its higher elevation. The two-dimensional rating curve models were only used in hydrologic model development.

An elevation-discharge curve was developed using profile lines in HEC-RAS's RAS Mapper. Once the profile line was drawn across the outlet location, the rating curve feature was utilized to develop the elevation-discharge curve. **Figure 4** provides the elevation-discharge curve for Spiritwood Lake.

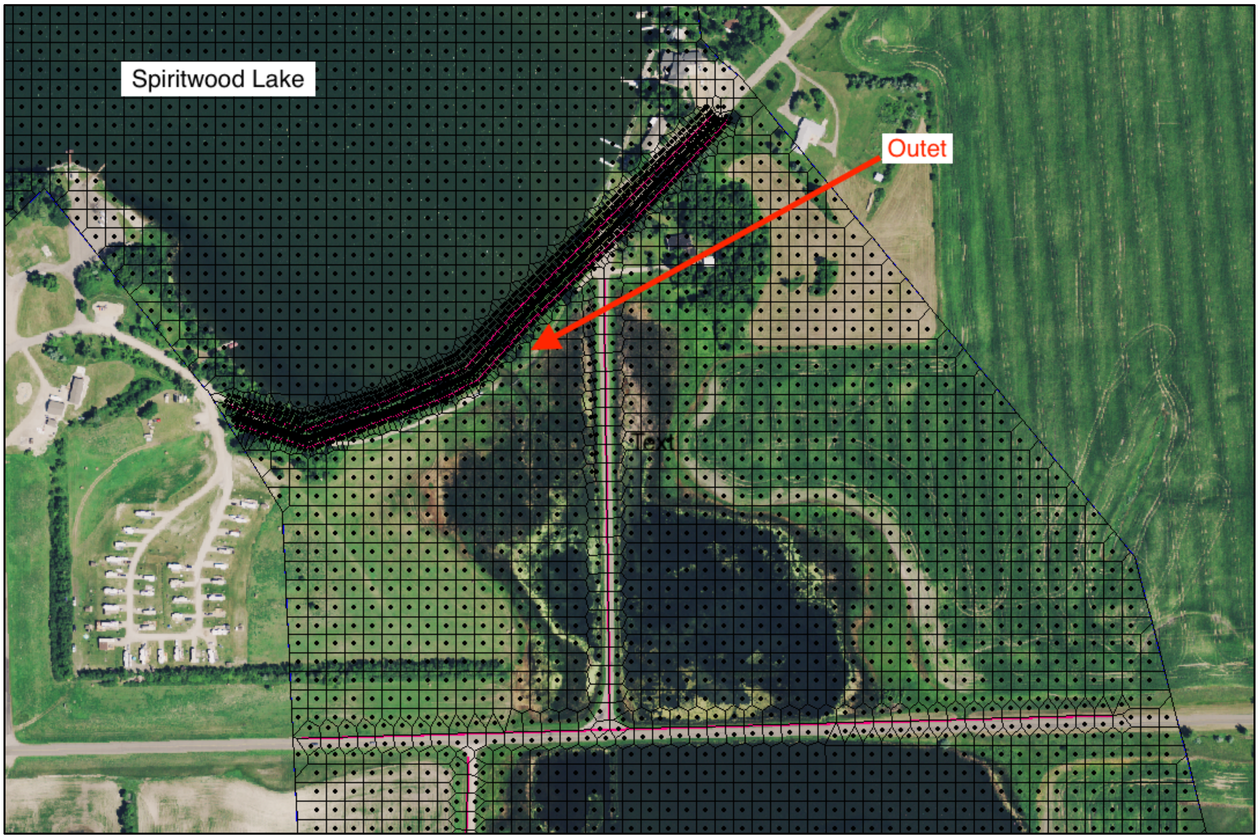

Figure 3. Spiritwood Lake outlet.

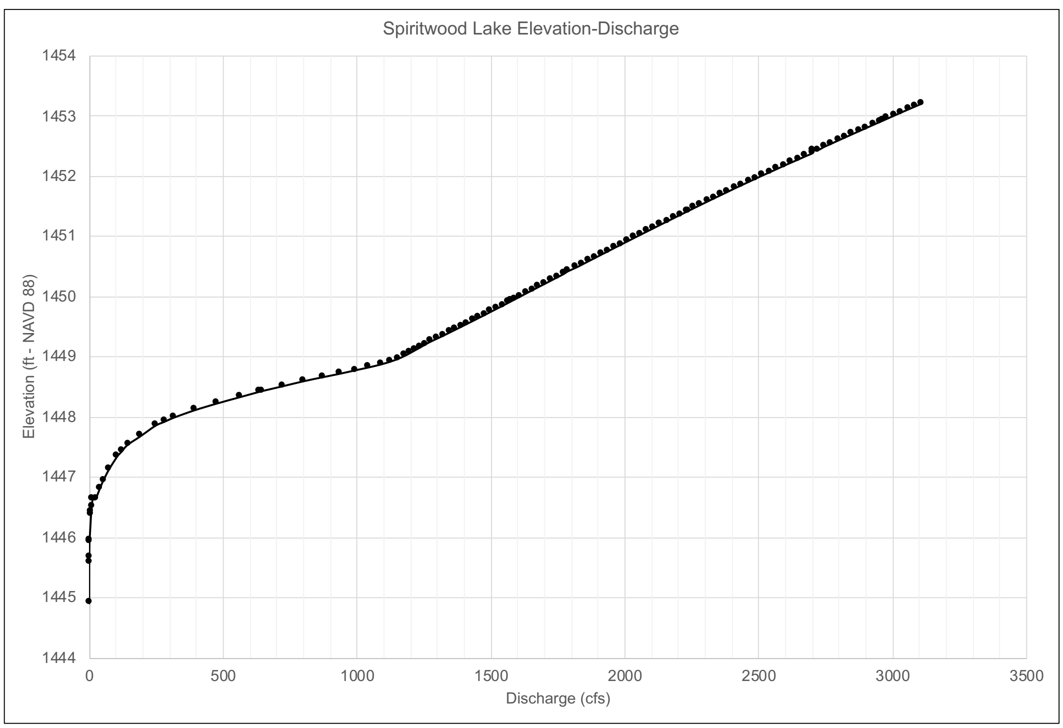

Figure 4. Spiritwood Lake elevation-discharge curve.

1.2.3 Alkali Lake

A two-dimensional hydraulic model was created to develop an elevation-discharge curve for Alkali Lake. Alkali Lake has a subbasin area of 28.9 square miles that directly contributes to the lake, and Spiritwood Lake subbasin, which can contribute if the lake is above elevation 1444.9 feet (NAVD88). Once Alkali Lake rises to approximately 1443.8 feet (NAVD88), it discharges through the southeast outlet (**Figure 5**) and spills into Seven Mile Coulee.

An elevation-discharge curve was developed using profile lines in HEC-RAS's RAS Mapper. Once the profile line was drawn across the outlet locations, the rating curve feature was utilized to develop the elevation-discharge curve. **Figure 6** provides the elevation-discharge curve for Alkali Lake. Drone footage and aerial photographs of Alkali outlet can be found and downloaded at https://aerials.swc.nd.gov.

Figure 5. Alkali Lake outlet.

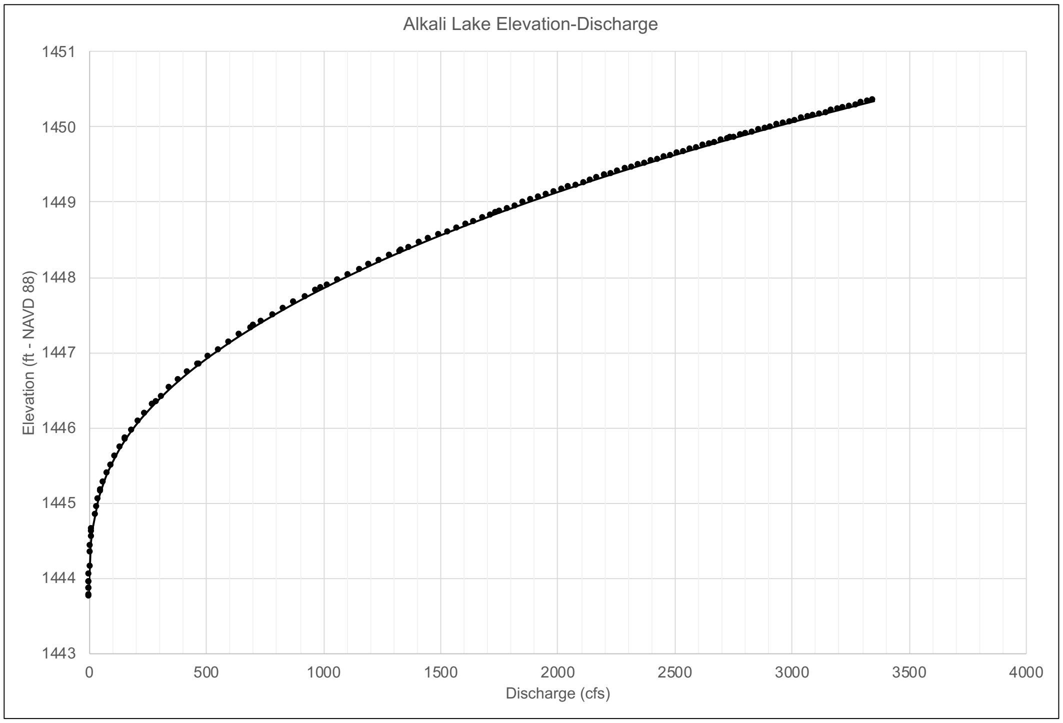

Figure 6. Alkali Lake elevation-discharge curve.

1.3 Spiritwood and Alkali Lakes One-Dimensional Hydraulic Model

The Spiritwood and Alkali Lakes one-dimensional hydraulic model was developed using HEC-RAS, version 5.0.7 (USACE, 2020), for the purpose of evaluating high flow frequency events and modeling alternative impacts and benefits.

1.3.1 Model Setup

A Digital Elevation Model (DEM) was created using North Dakota Game and Fish Department (NDGF) lake contour data (NDGF, 2020) for Spiritwood and Alkali Lakes, estimated depth for the regions between Spiritwood and Alkali Lakes, and the DEM created using LiDAR for the project (**Appendix B**). The DEM was used to develop elevation/volume curves for storage areas, elevation/station curves for cross sections, and elevation/station curves for storage areas. The layout of the one-dimensional HEC-RAS model is illustrated in **Figure 7**.

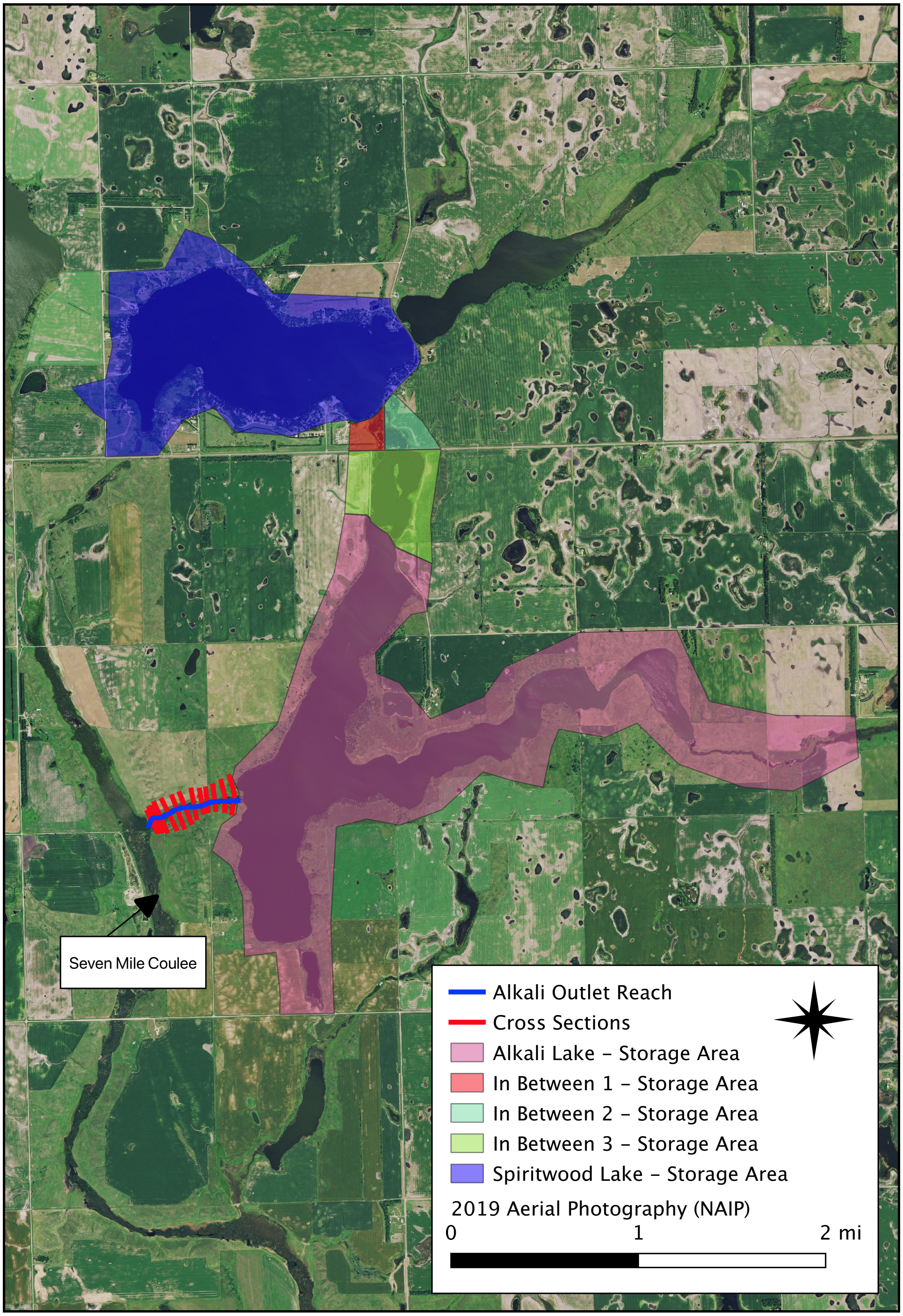

Figure 7. 1-Dimensional Model Layout.

The inputs into the hydraulic model include the lateral inflows into Spiritwood and Alkali Lakes, and a downstream boundary condition for the Alkali Outlet Reach. The lateral inflows for each lake were obtained from the hydrologic model for each frequency event. The downstream boundary condition for the Alkali Outlet Reach was set as normal depth with a value of 0.001 ft/ft.

Roughness coefficients for the Alkali Outlet Reach were based on engineering judgement and ranged from 0.045 to 0.1.

The water surface elevation for the Alkali Lake storage area and In Between 1 through 3 storage areas was set at 1442 feet (NAVD88). The water surface elevation of Spiritwood Lake was set at 1445 feet (NAVD88). The initial flow from Alkali Outlet Reach was set at 2 cubic feet per second.

Each model run was given a timestep of 1 minute and a detailed output interval of 1 hour.

1.3.2 Frequency Event Results

Due to the backwater effects Alkali Lake imposes on the Spiritwood Lake Outlet, the one-dimensional hydraulic model produces more realistic results for high flow events. **Table 1** provides the computed water surface elevations for each frequency event from the one-dimensional hydraulic model.

Table 1. Computed water surface elevations for Spiritwood and Alkali Lakes Frequency Events.

Waterbody	2 year	5 year	10 year	25 year	50 year	100 Year	500 Year
	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)	Elevation (ft)
Spiritwood	1447.07	1447.65	1448.05	1448.5	1448.8	1449.23	1450.78
Alkali	1445.05	1445.97	1446.72	1447.76	1448.52	1449.2	1450.76

1.4 Seven Mile Coulee Model

A two-dimensional hydraulic model for Seven Mile Coulee was developed to evaluate impacts of outflows from Spiritwood and Alkali Lakes. The two-dimensional hydraulic model was utilized to determine the relative impact specific flood mitigation alternatives could have on downstream landowners and infrastructure. As illustrated in **Figure 8**, the two-dimensional hydraulic model of Seven Mile Coulee extends from Spiritwood and Alkali Lakes to Interstate I-94.

Impacts can be evaluated using quasi-steady flow of pre and post alternative conditions. Using quasi-steady flow to evaluate these impacts allows comparison of the relative difference, while acknowledging that imperfections in the terrain exist and ignoring volume change over time. For instance, Seven Mile Coulee is impeded with cattails, which limited the viability of survey and affects the accuracy of LiDAR.

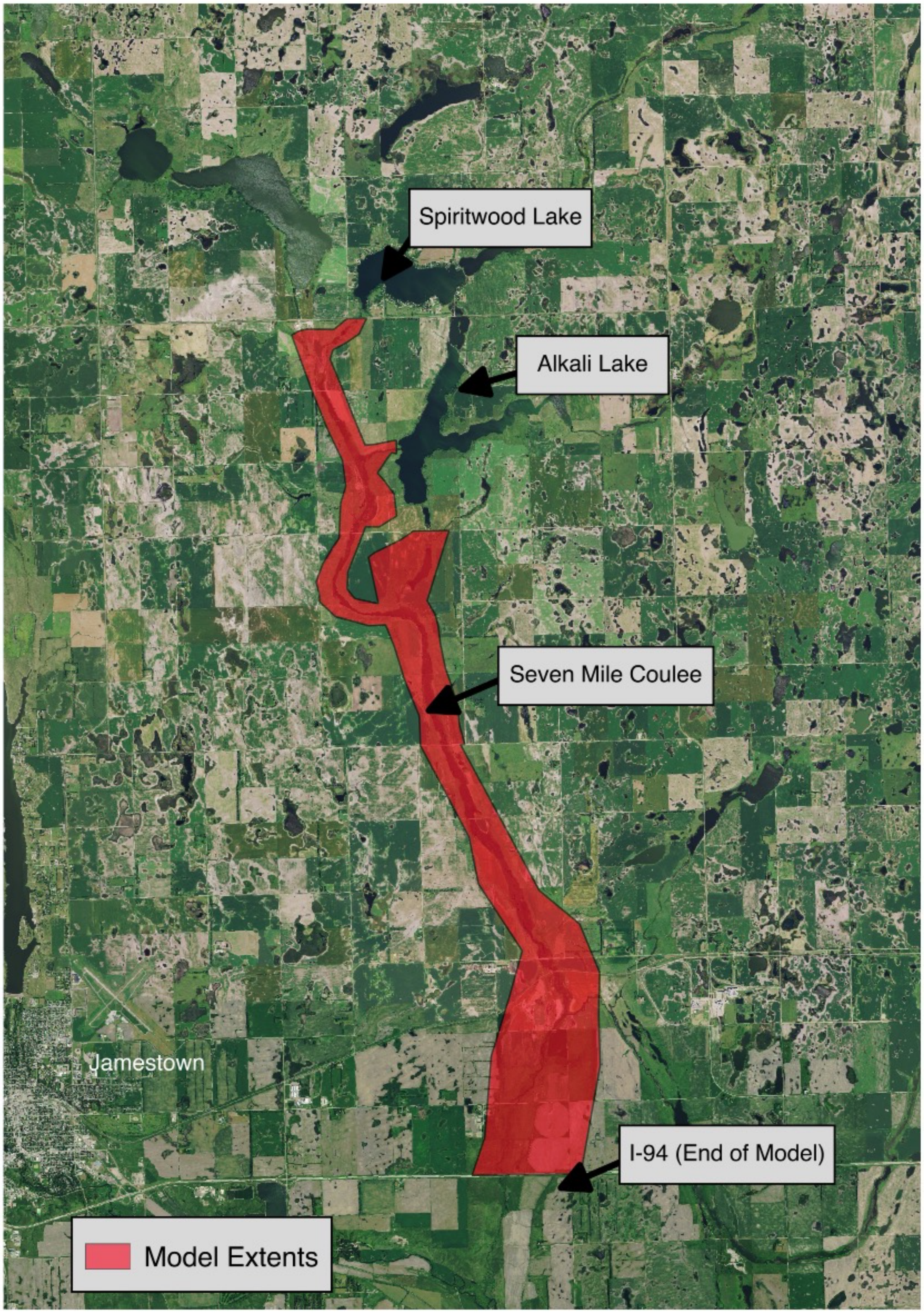

Figure 8. Seven Mile Coulee model extents.

1.4.1 Model Setup

HEC-RAS two-dimensional model setup requires creation of a Terrain/DEM, model extents, grid size, roughness coefficient, boundary conditions, and timestep. This section of the report documents how each required component of the HEC-RAS model was setup.

A DEM was created for the Seven Mile Coulee model utilizing the LiDAR and survey data described in section 1.1 of this report. The LiDAR served as the base of the DEM and the survey was utilized to tie in existing culverts and bridges to represent the crossings throughout Seven Mile Coulee. The DEM was entered into RAS Mapper as a RAS Terrain to represent the topography in the hydraulic model. Break lines were added to the hydraulic model to represent high spots such as roads and natural ridges that naturally block flow.

The hydraulic model extents were defined based on input from a Stutsman County Water Resource District Board Meeting in early 2020. Members of the Stutsman County Water Resource Board felt that impacts of a project at Spiritwood Lake could affect landowners along Seven Mile Coulee and in order to adequately understand impacts of a project, the model must extend to Interstate I-94.

Development of a computational mesh that can solve hydraulic problems requires selection of a grid size. Each cell of the grid develops a detailed elevation-volume-area relationship that represents the terrain developed as part of the model. HEC-RAS requires rectangular cells to develop the elevation-volume-area relationships. In order to get the detail desired from the hydraulic model, the average grid cell size selected for this model was 50 by 50 feet. The initial time step selected for the hydraulic model was 12 seconds, which was chosen based on engineering judgement and the grid size.

Roughness coefficients, represented as Manning's n values, were selected for the Seven Mile Coulee two-dimensional model by using the National Land Cover 2016 Database (MRLC, 2020). The National Land Cover 2016 Database was entered into RAS Mapper to serve as a land cover file and represent changes in roughness through the model extents. The roughness from each land cover type was estimated based on engineering judgement and guidance from the NRCS's "Recommendations and Cautions, Manning's n Values for Various Land Covers to Use for Dam Breach Analysis" (NRCS, 2016).

Two-dimensional hydraulic models require an upstream and downstream boundary condition. Upstream boundary conditions utilized in the Seven Mile Coulee two-dimensional model are flow hydrographs or modified quasi-steady state hydrographs from the Spiritwood and Alkali Lakes 1-dimensional hydraulic model. A rating curve representing the outflow capabilities of two 9.5-foot culverts was developed to serve as the downstream boundary condition. The rating curve for the two culverts was developed using the Federal Highway Administration's HY-8 program (FHWA, 2020). HY-8 is a hydraulic analysis tool for culvert and bridge crossings. The survey data collected for each of the culverts was entered into the program to develop the rating curve illustrated in **Figure 9**.

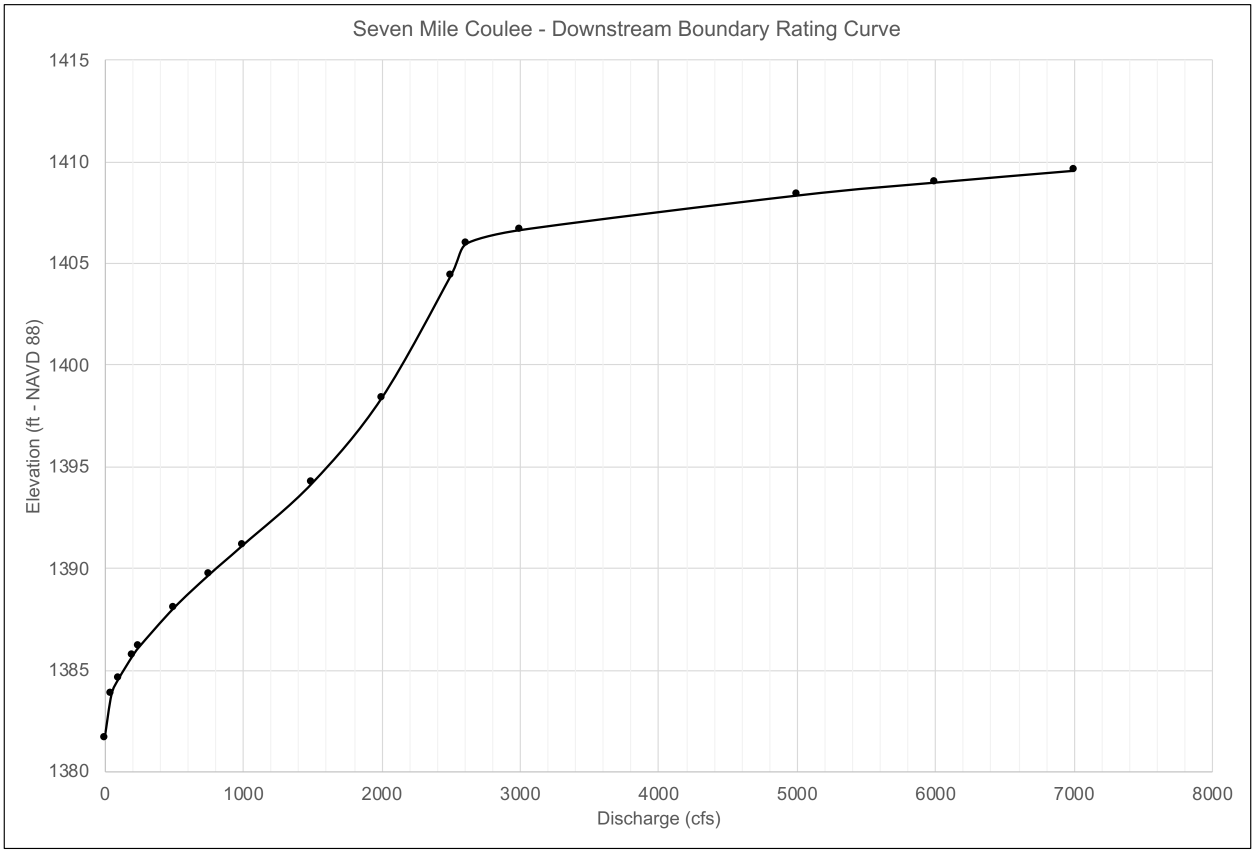

Figure 9. Seven Mile Coulee downstream boundary conditions - rating curve.

1.4.2 Model Results

The Seven Mile Coulee two-dimensional hydraulic model was run using outflows from the frequency event model to develop hydraulic profiles along Seven Mile Coulee. **Figure 10** illustrates the water surface profile of each frequency event along Seven Mile Coulee. For reference, it should be noted the large rise in terrain near station 50,000 is the railroad embankment just downstream of 33rd Street SE. It can also be noted based on the hydraulic profile, that large events at the terminus of the model, which is the I-94 culvert rating curve, may create significant backwater from the roadway acting as a dam. A catalog of water surface and depth maps created based on the results of the two-dimensional hydraulic model are available in the attached **Appendix D1**.

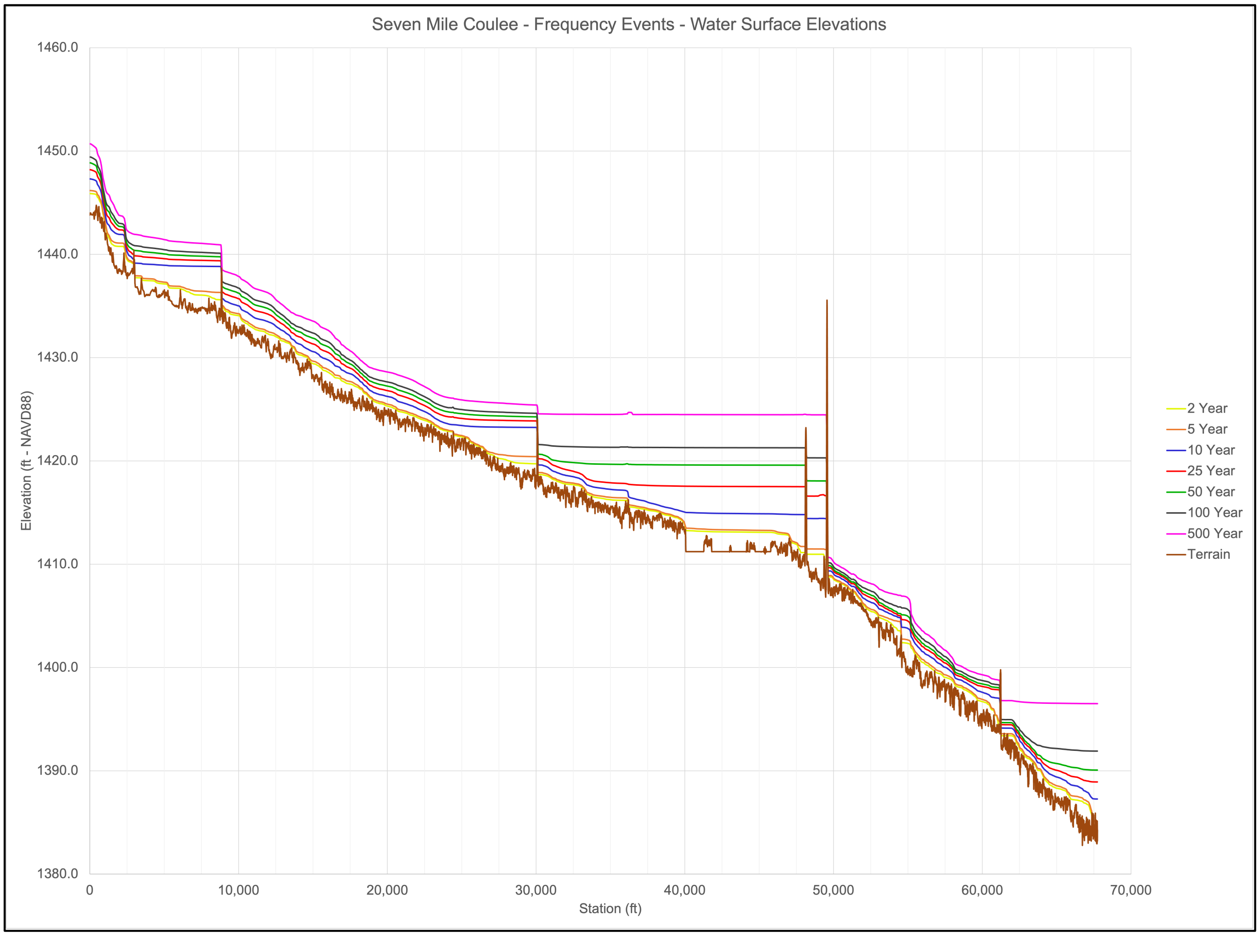

Figure 10. Seven Mile Coulee Water Surface Profile.

1.4.3 Sensitivity Analysis

A brief sensitivity analysis was completed as part of this study for the Seven Mile Coulee hydraulic model. Typically, model downstream boundary conditions, computational timestep, roughness coefficients, bridge parameterizations, and computational solvers are adjusted to see if they have high sensitivity to the model's results. Due to the lack of data on the downstream model, roughness coefficients were set based on engineering judgement and no sensitivity analysis was completed on them. A sensitivity analysis was completed by varying the computational timestep and selecting different computational solvers.

The sensitivity analysis on the model's computational solver was completed by changing the two-dimensional solver from diffusion wave to full momentum. Changing the computational solver had little to no effect on the modeled results, thus the model was found to not be sensitive to which computational solver was selected.

The model was also found to not be sensitive to varying the computational timestep. The original timestep selected for the model was 12 seconds. The sensitivity analysis was completed by comparing the 12 second run with two other runs with timesteps of 6 seconds and 20 seconds respectively. This had little to no effect on the modeled results.

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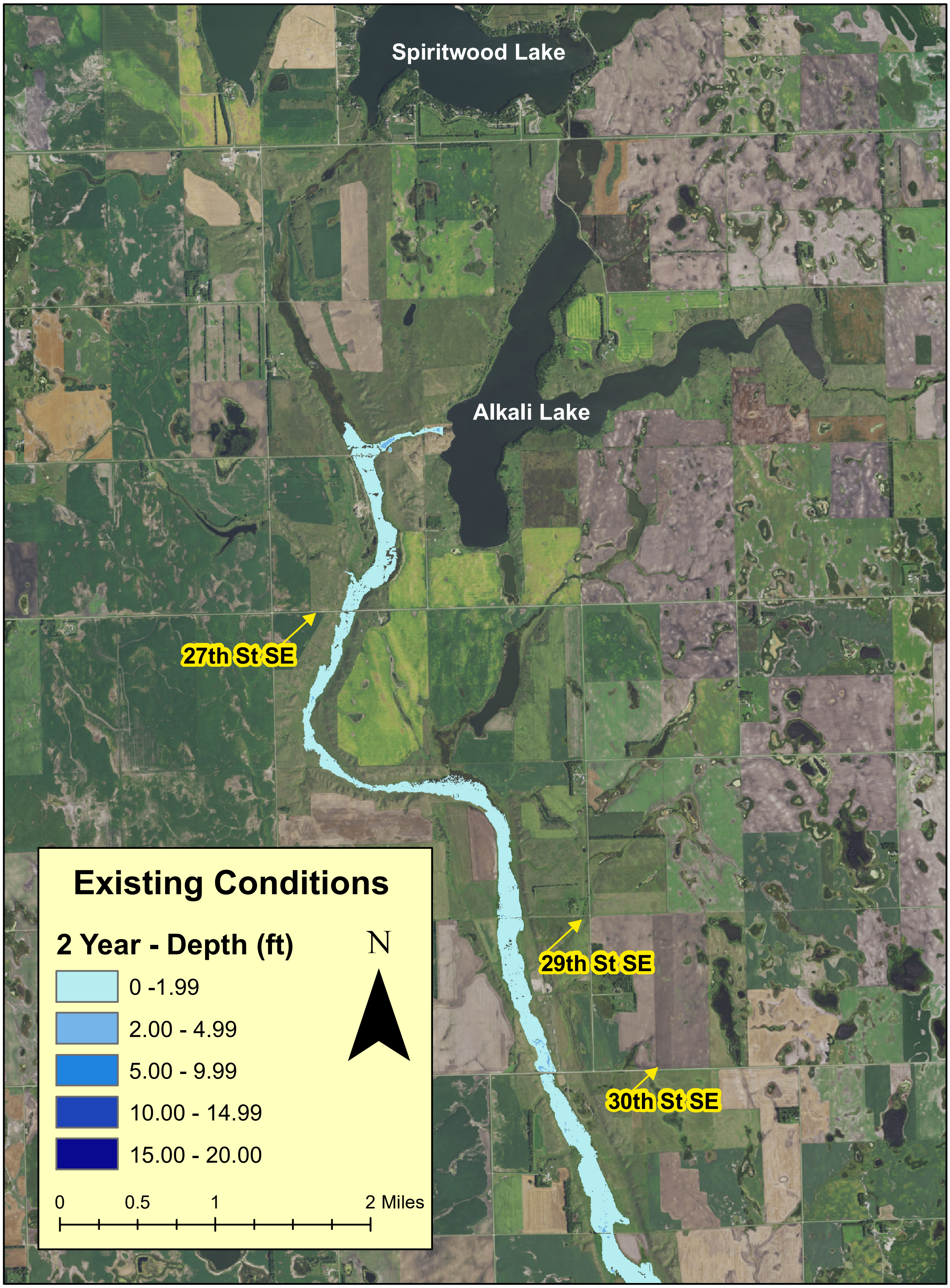
(USACE 2, 2020) United States Army Corps of Engineers' Hydrologic Engineering Center, 2020. Hydrologic Engineering Center's River Analysis System version 5.0.7.

APPENDIX D1

Frequency Events Water Surface/Depth Maps for Seven Mile Coulee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Alkali Lake
27th St SE
29th St SE
30th St SE
Existing Conditions
2 Year - Depth (ft)
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5.00 - 9.99
10.00 - 14.99
15.00 - 20.00
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0
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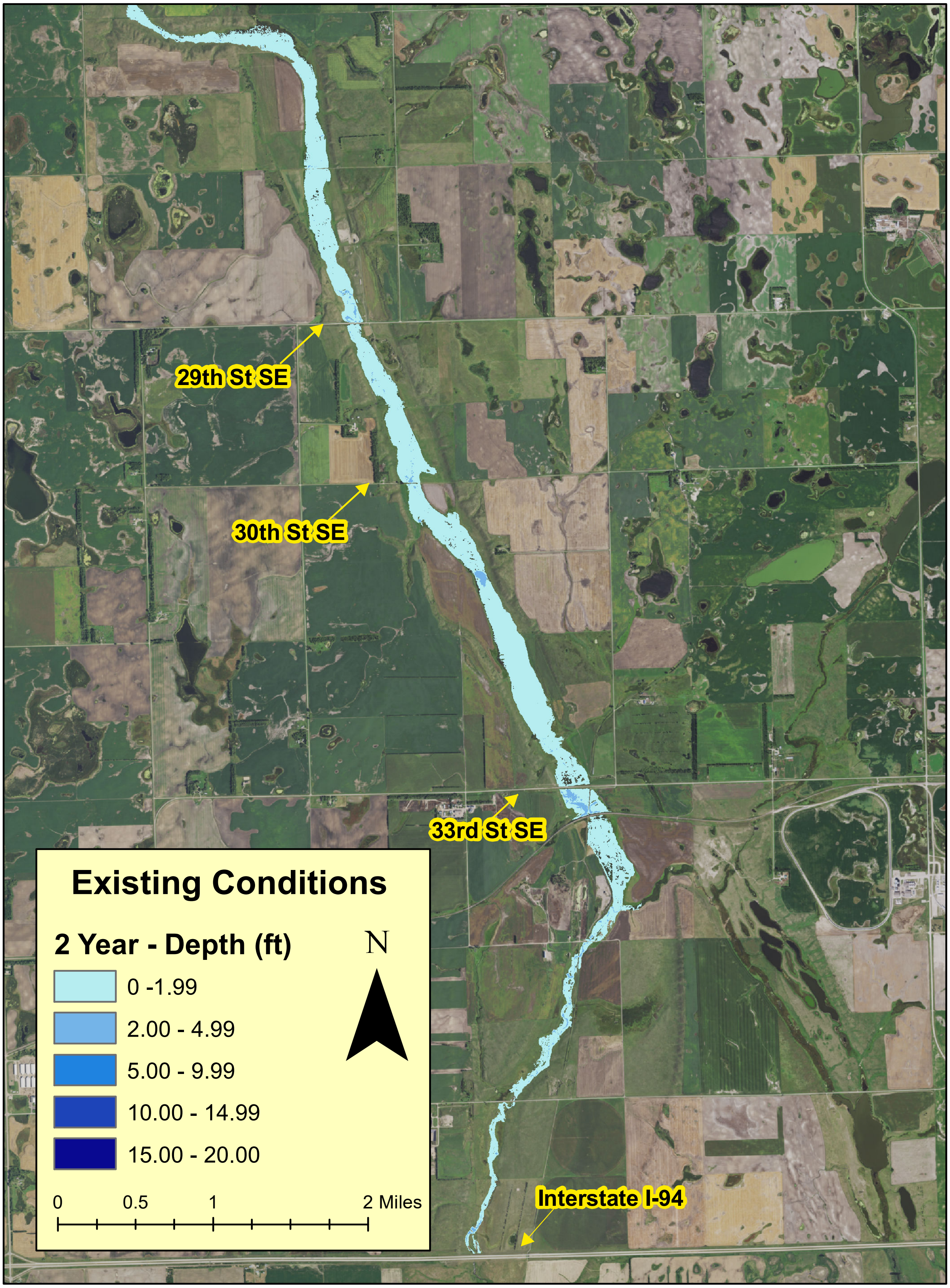
1
2 Miles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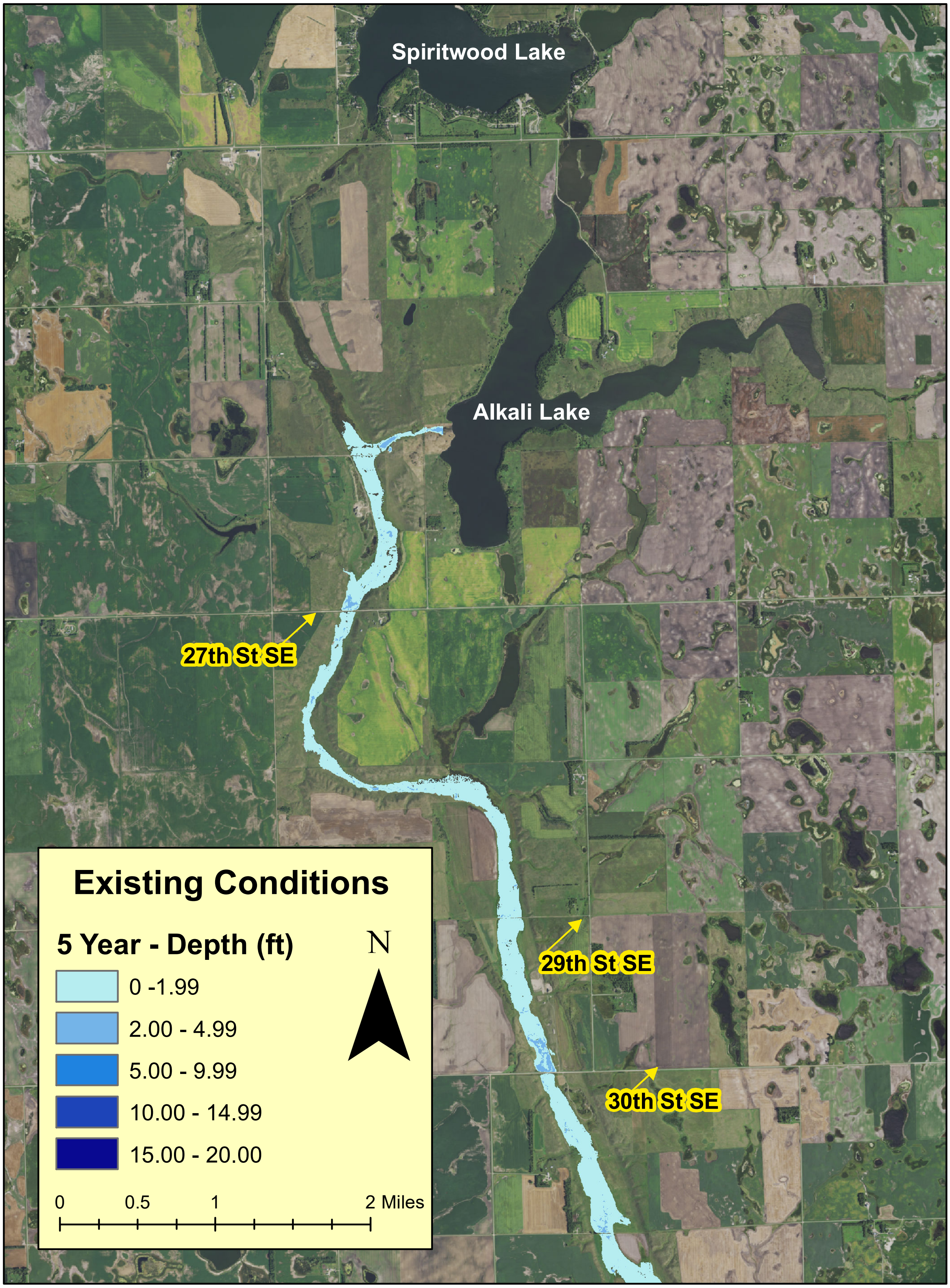
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Existing Conditions
5 Year - Depth (ft)
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5.00 - 9.99
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0.5
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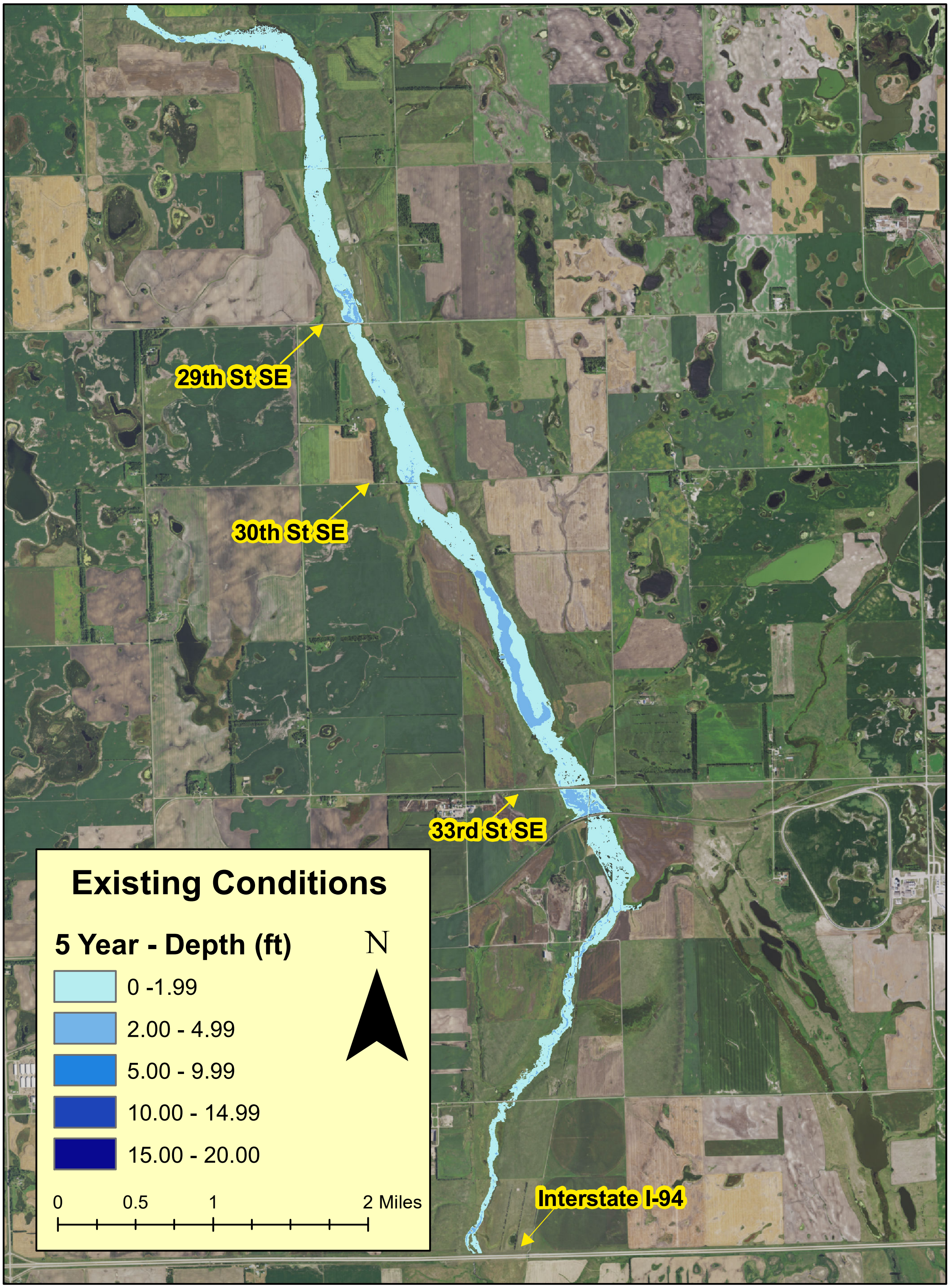
2 Miles


29th St SE
30th St SE
33rd St SE
Interstate I-94
Existing Conditions
5 Year - Depth (ft)
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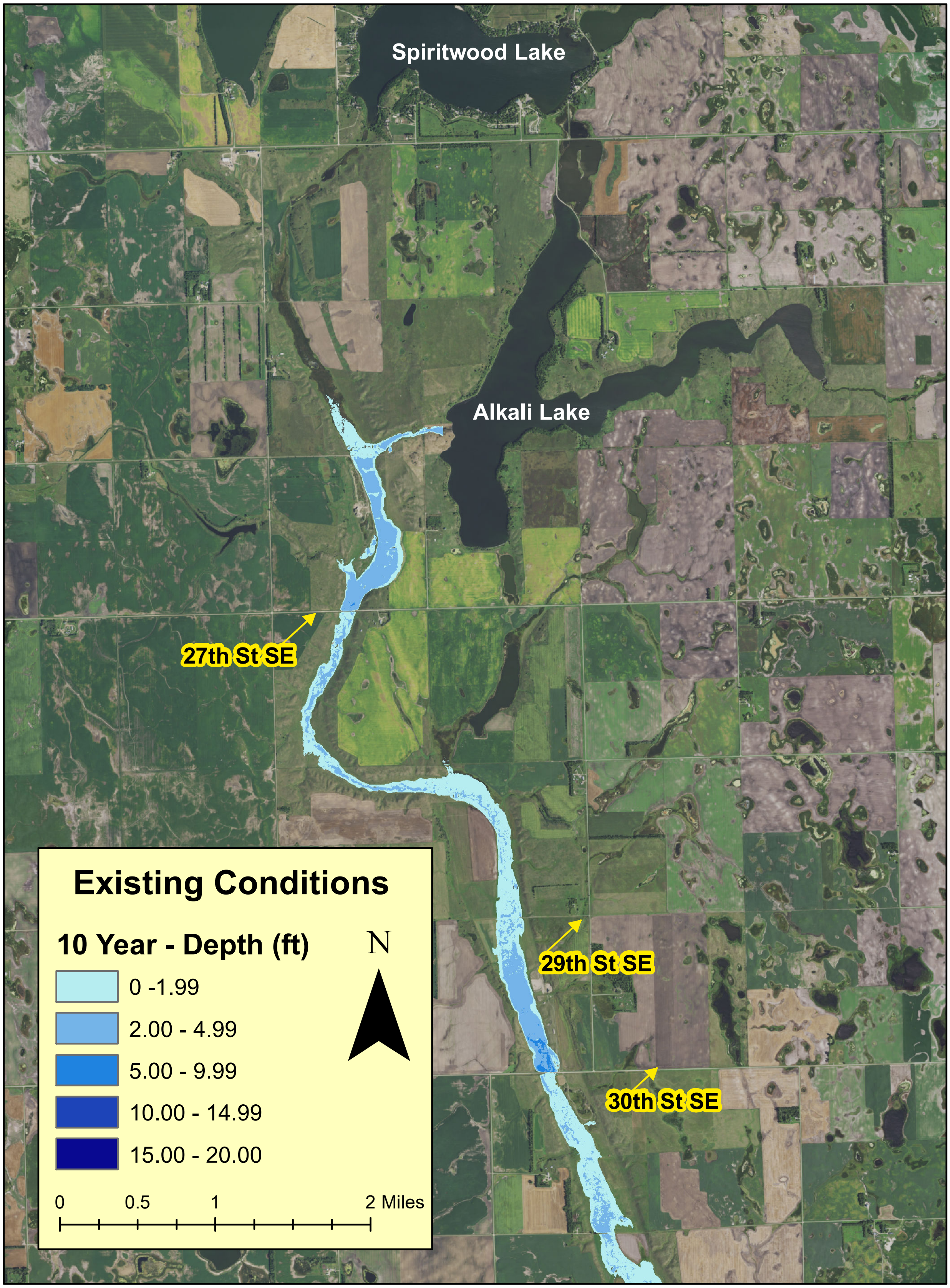
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5.00 - 9.99
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15.00 - 20.00
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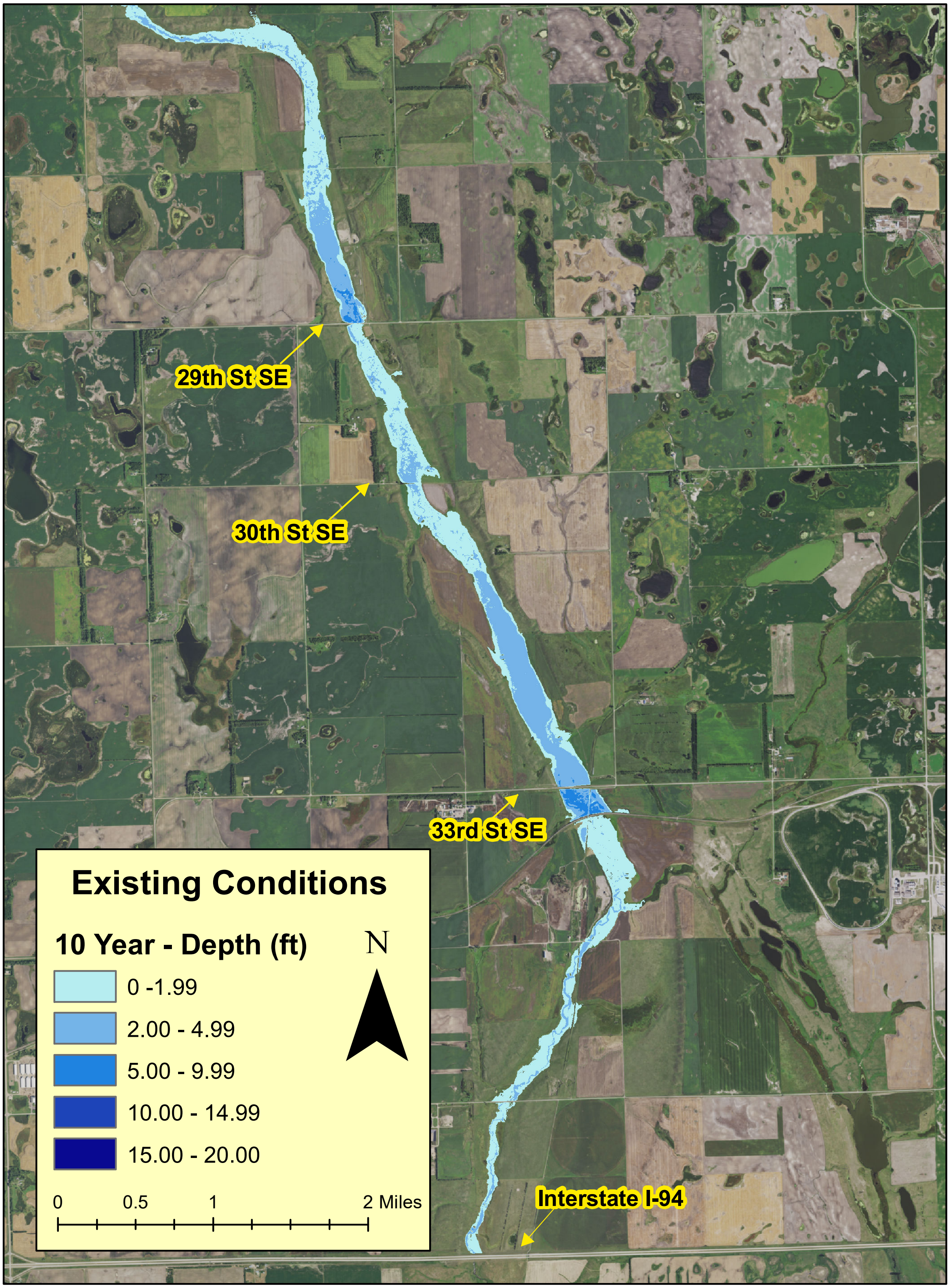
2 Miles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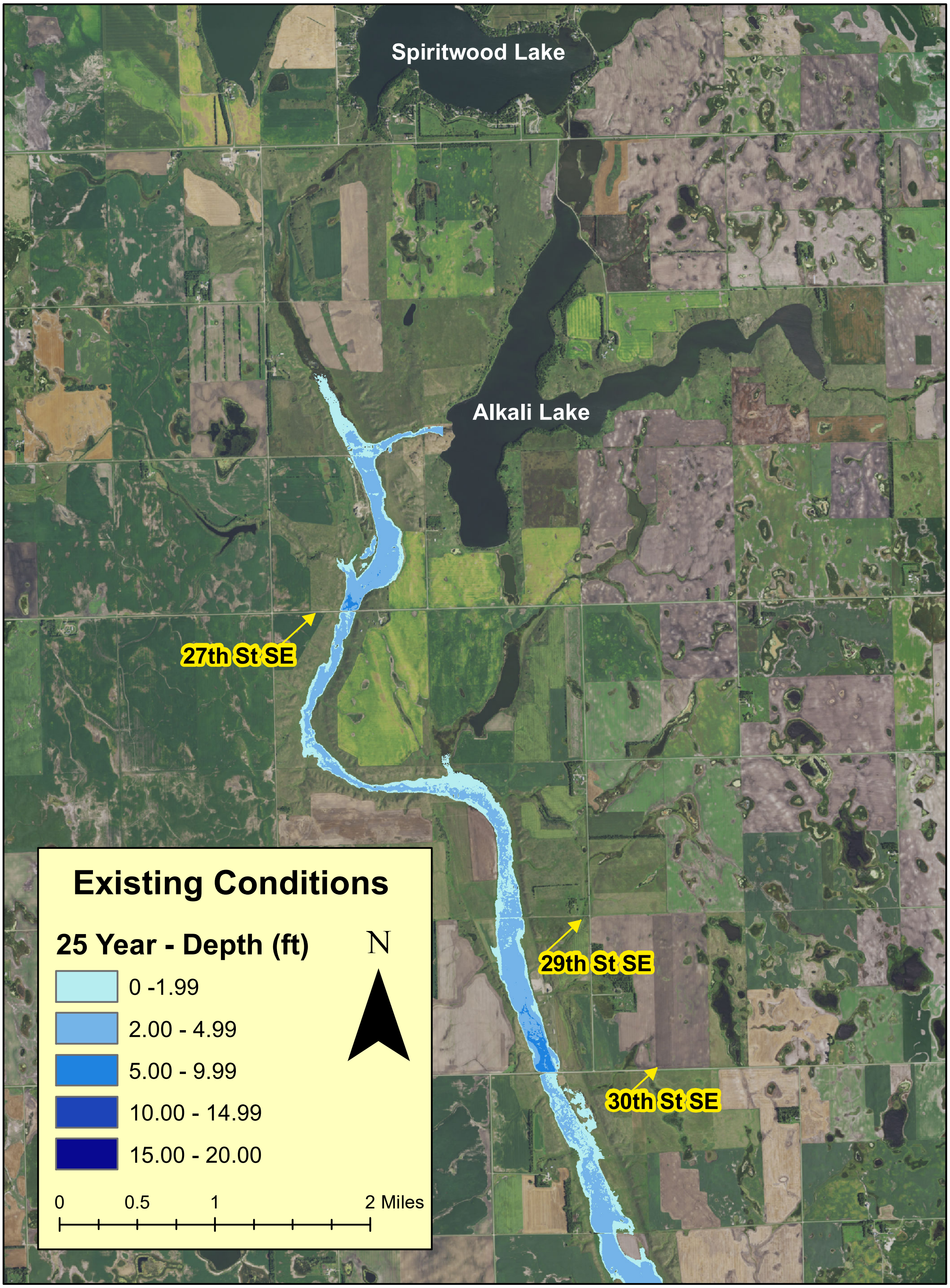
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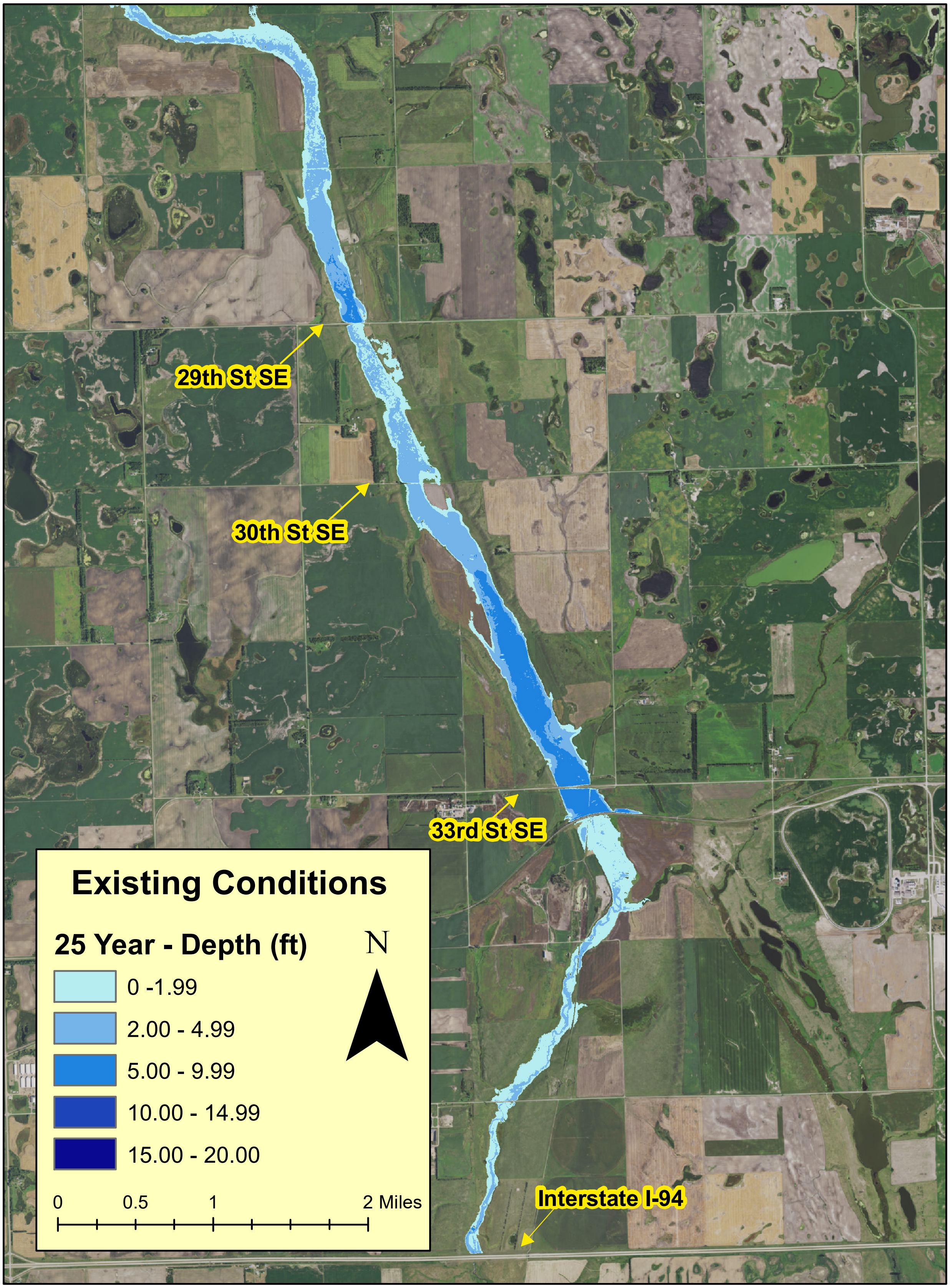
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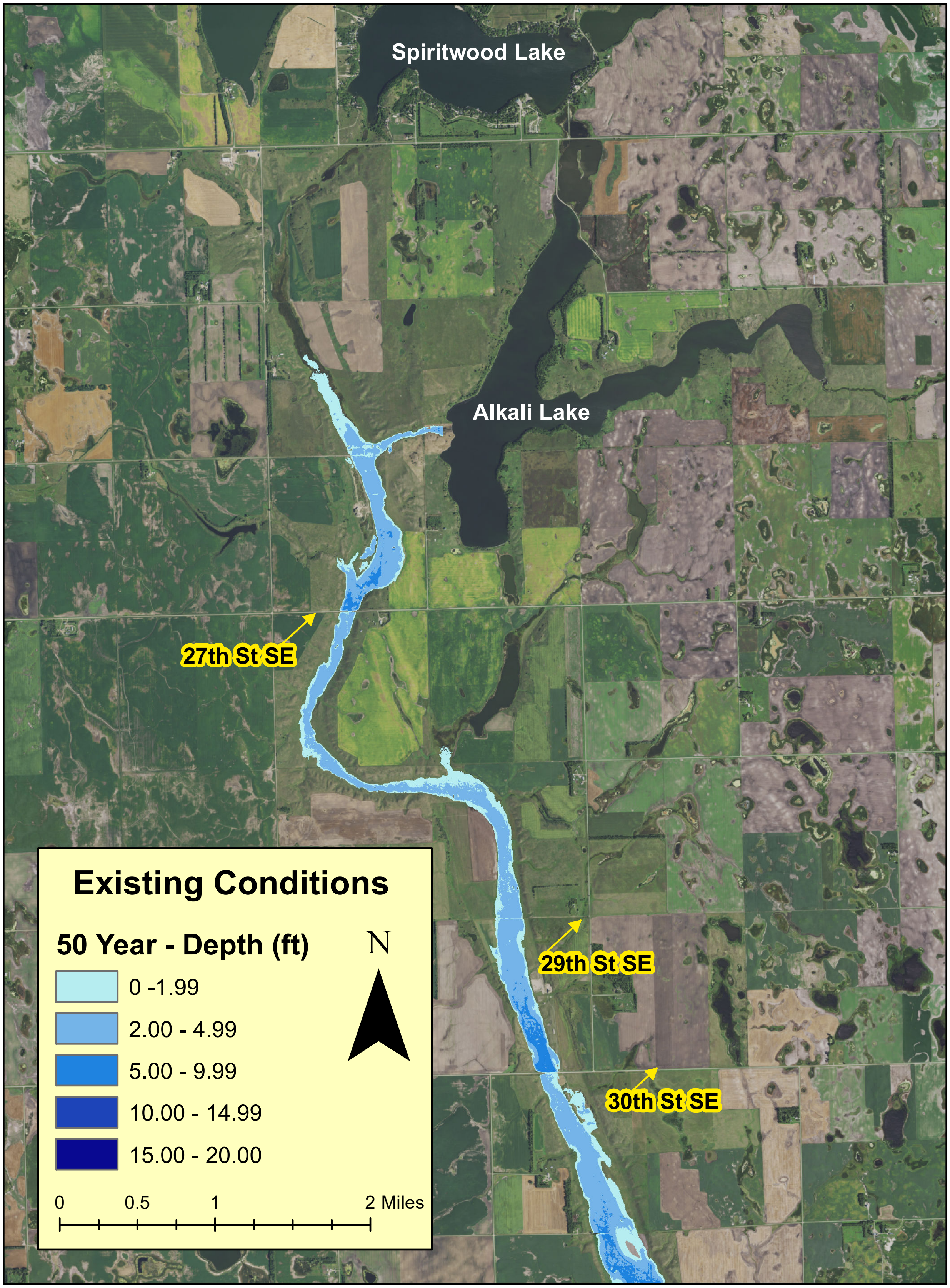
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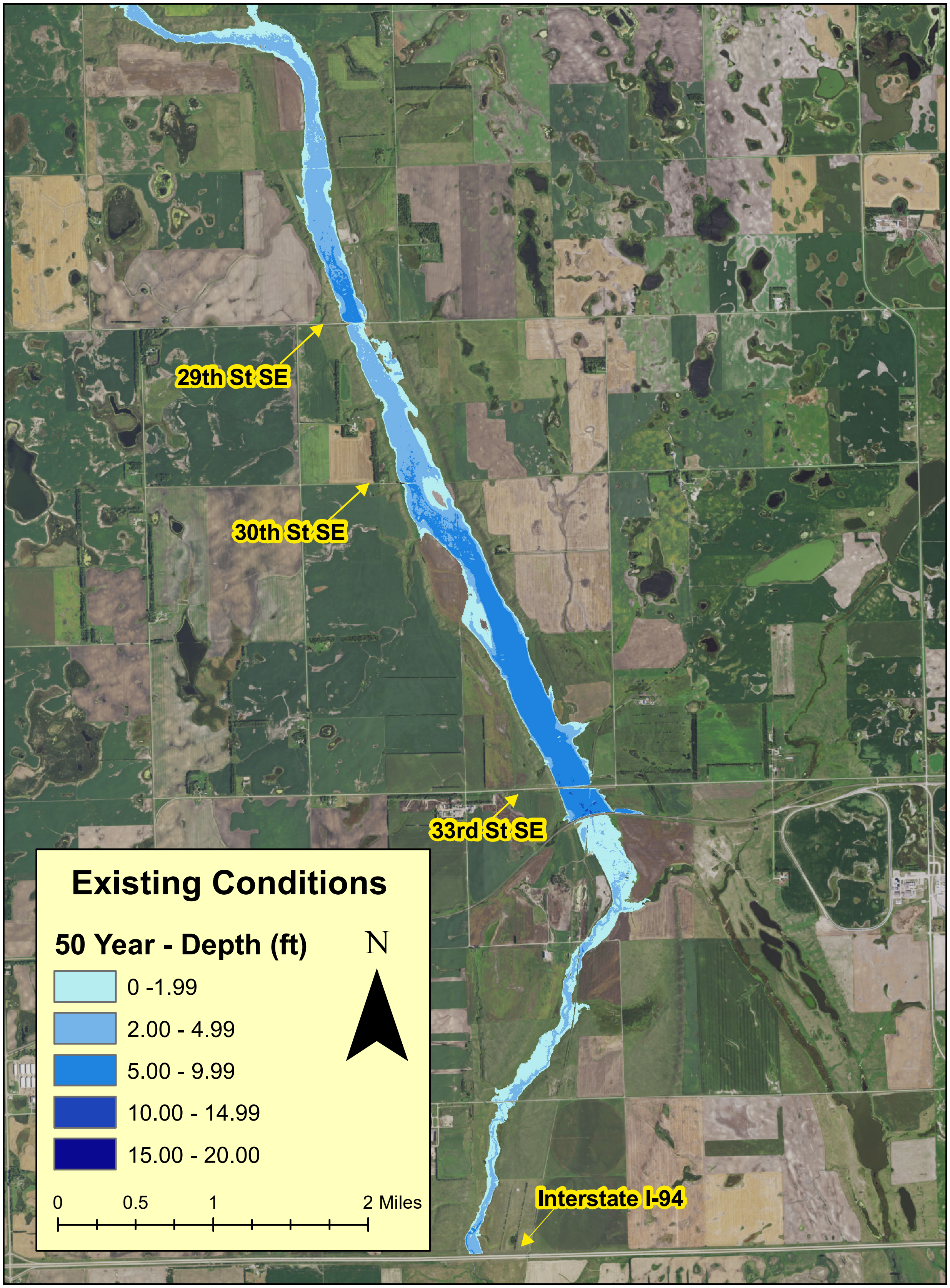

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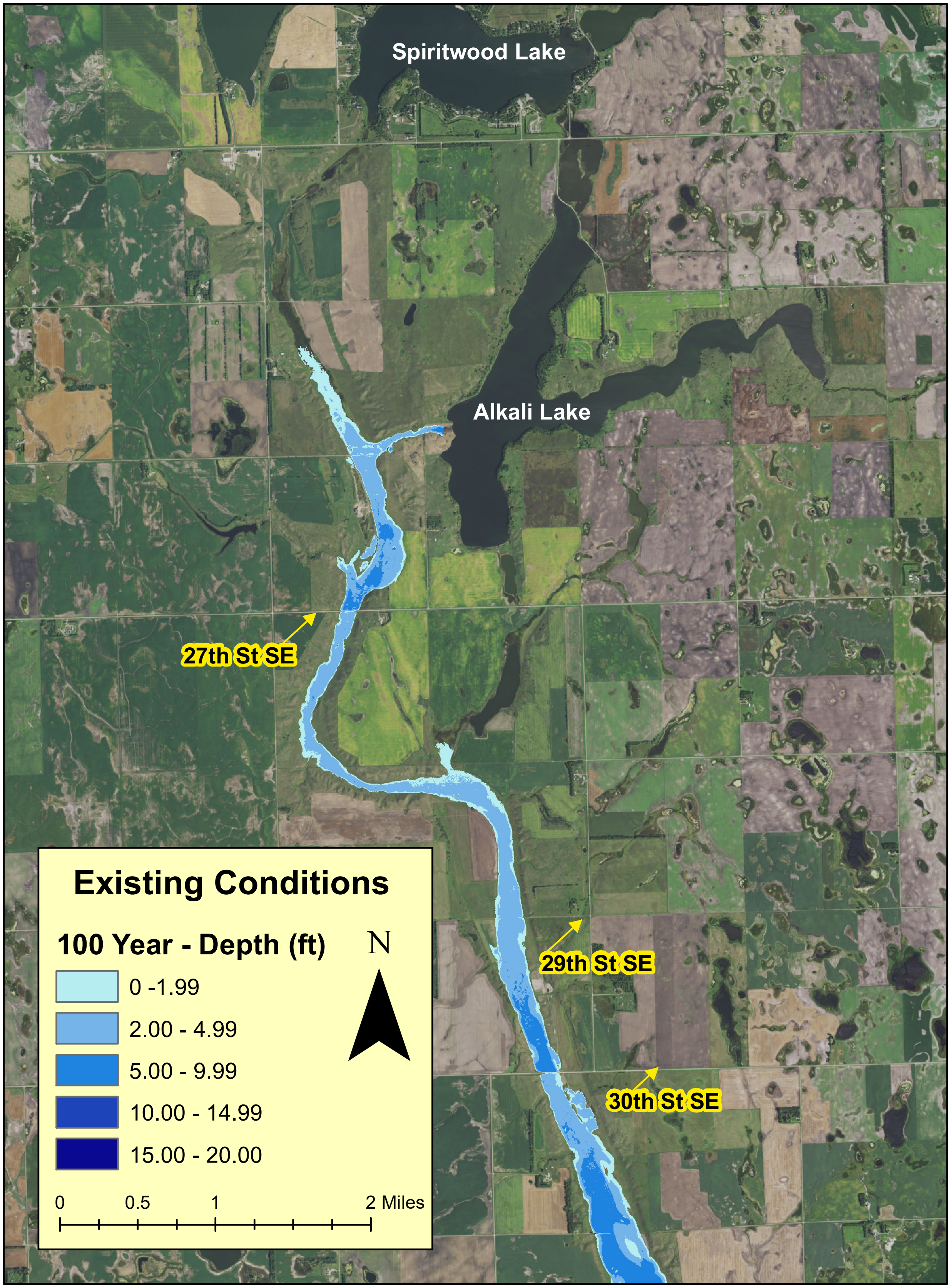
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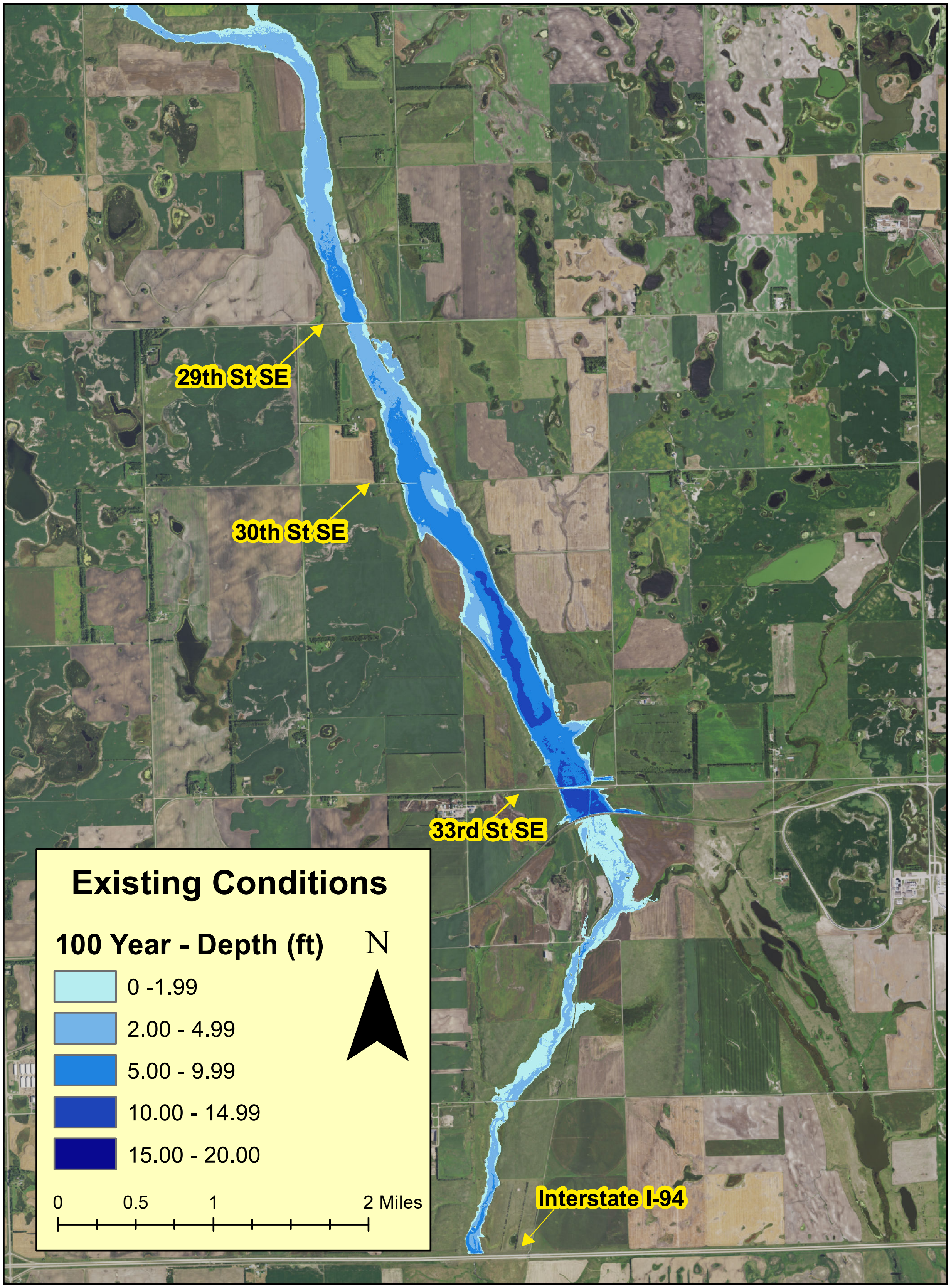
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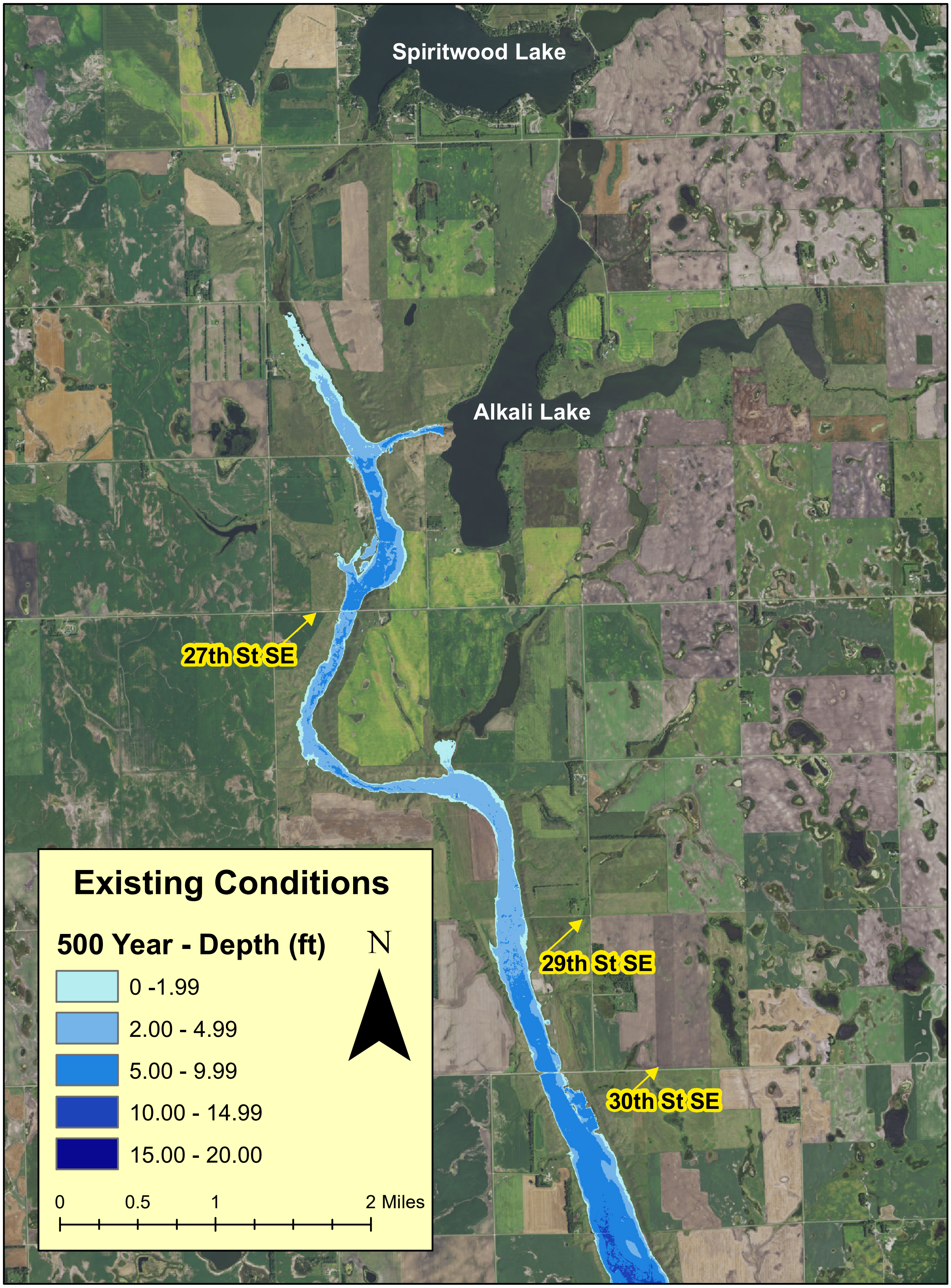
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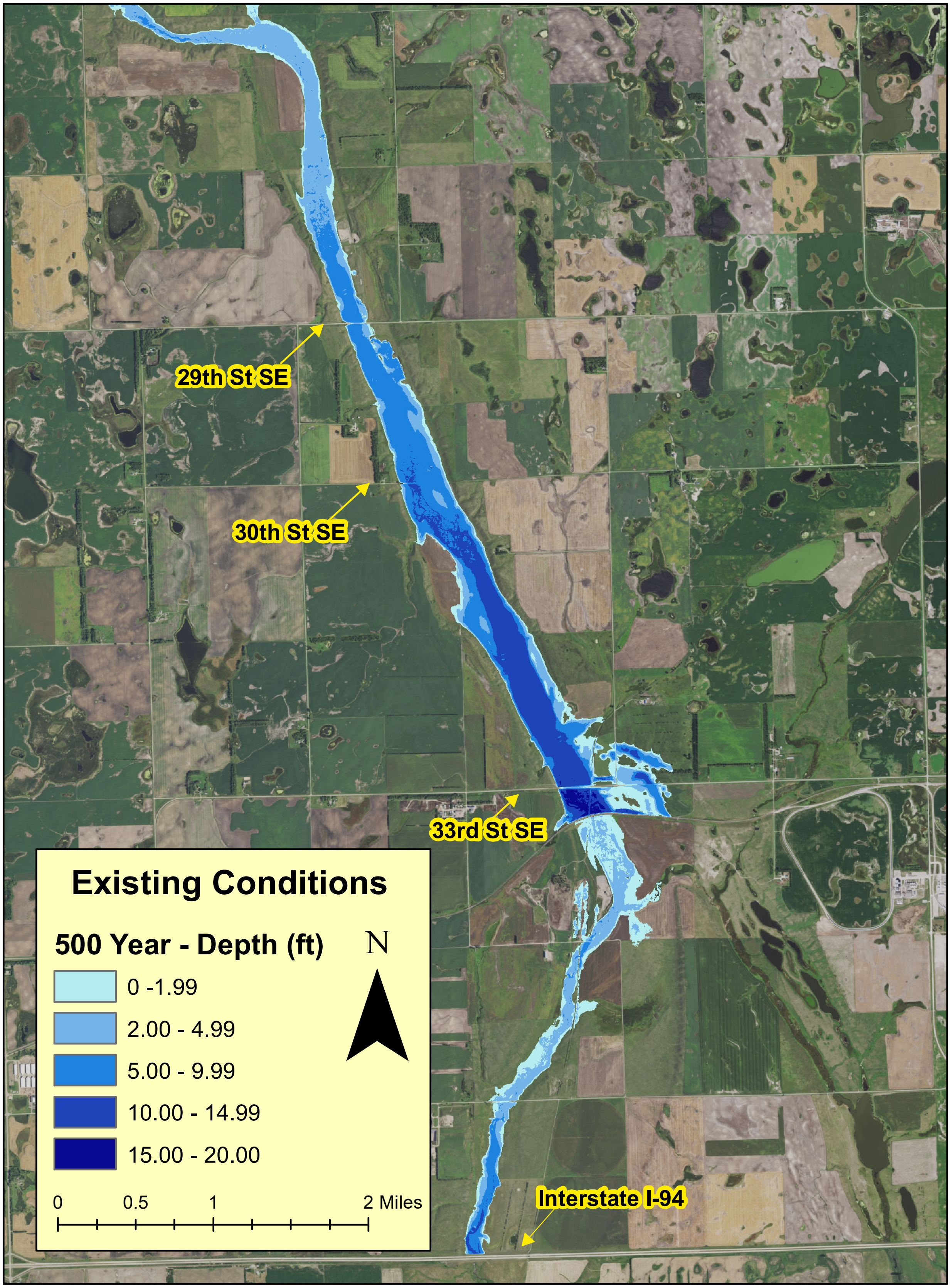
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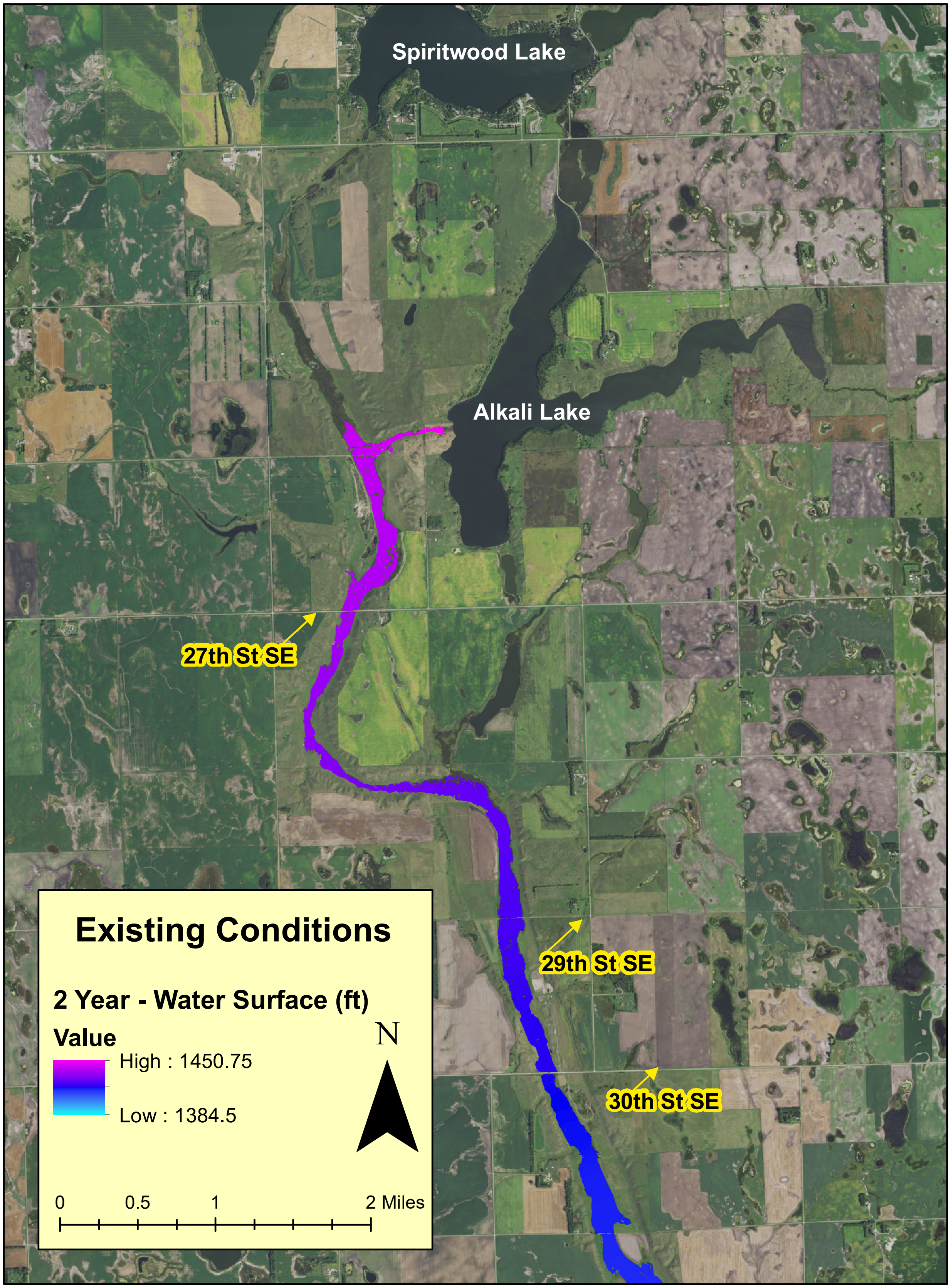
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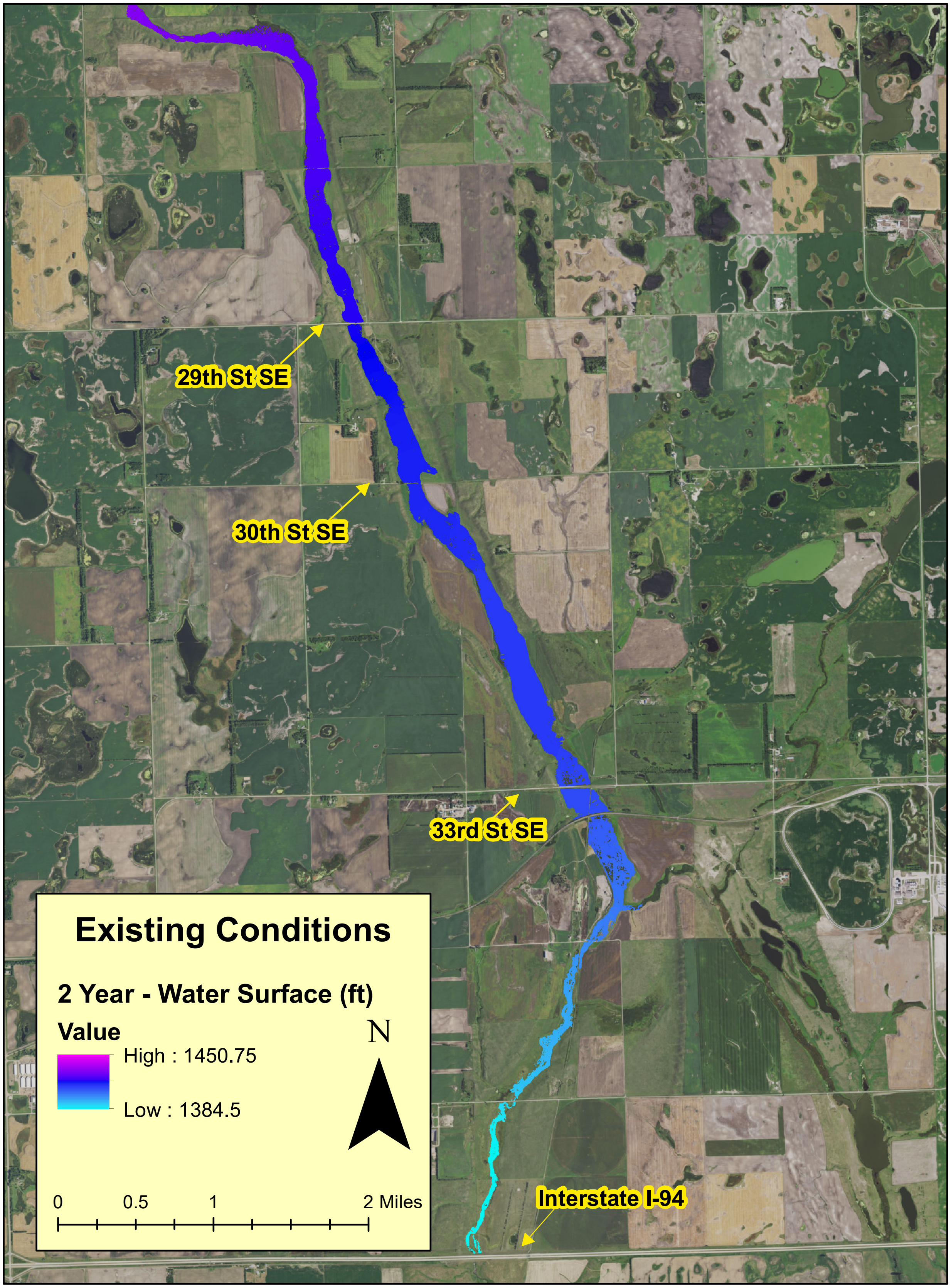
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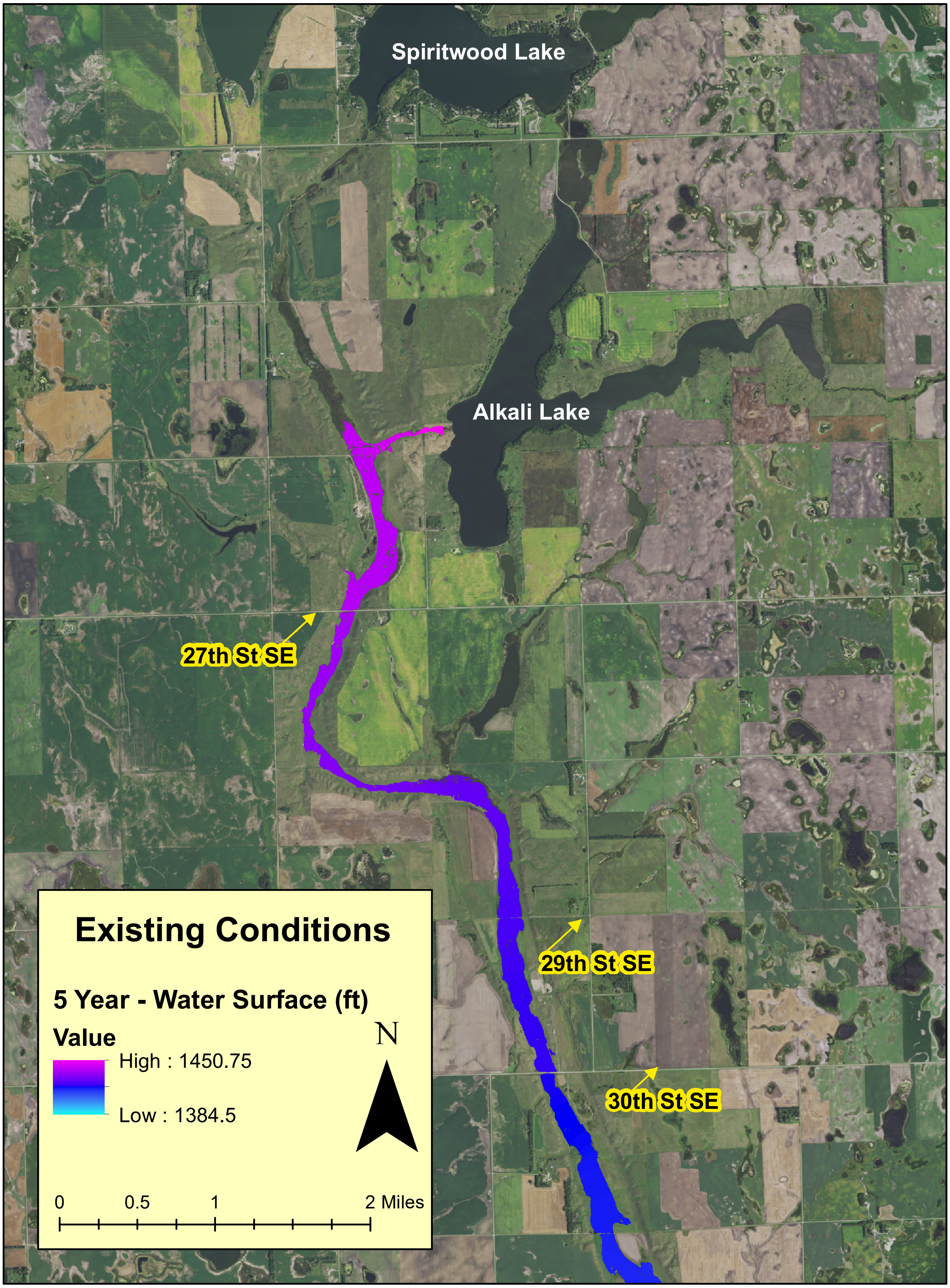
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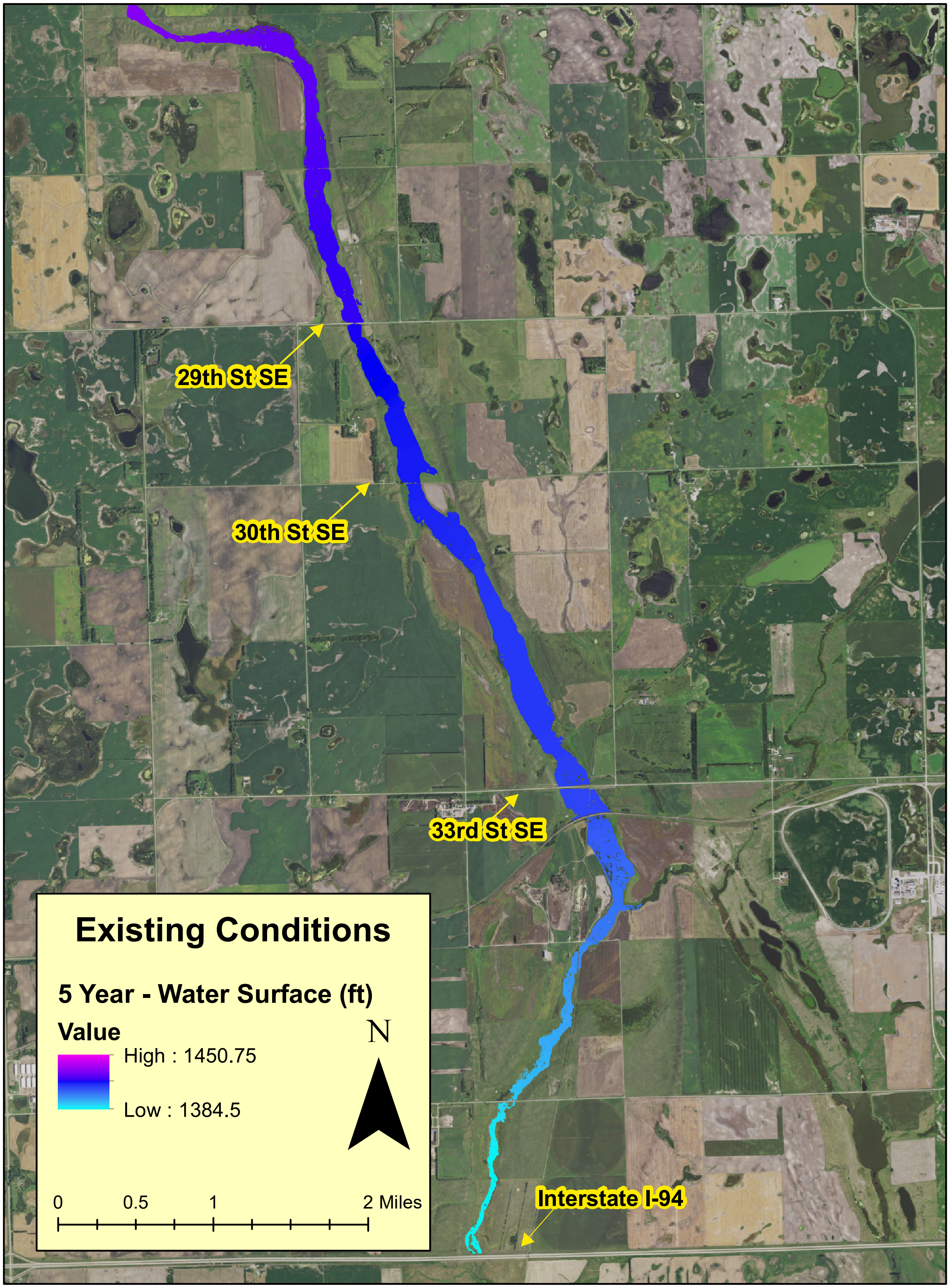
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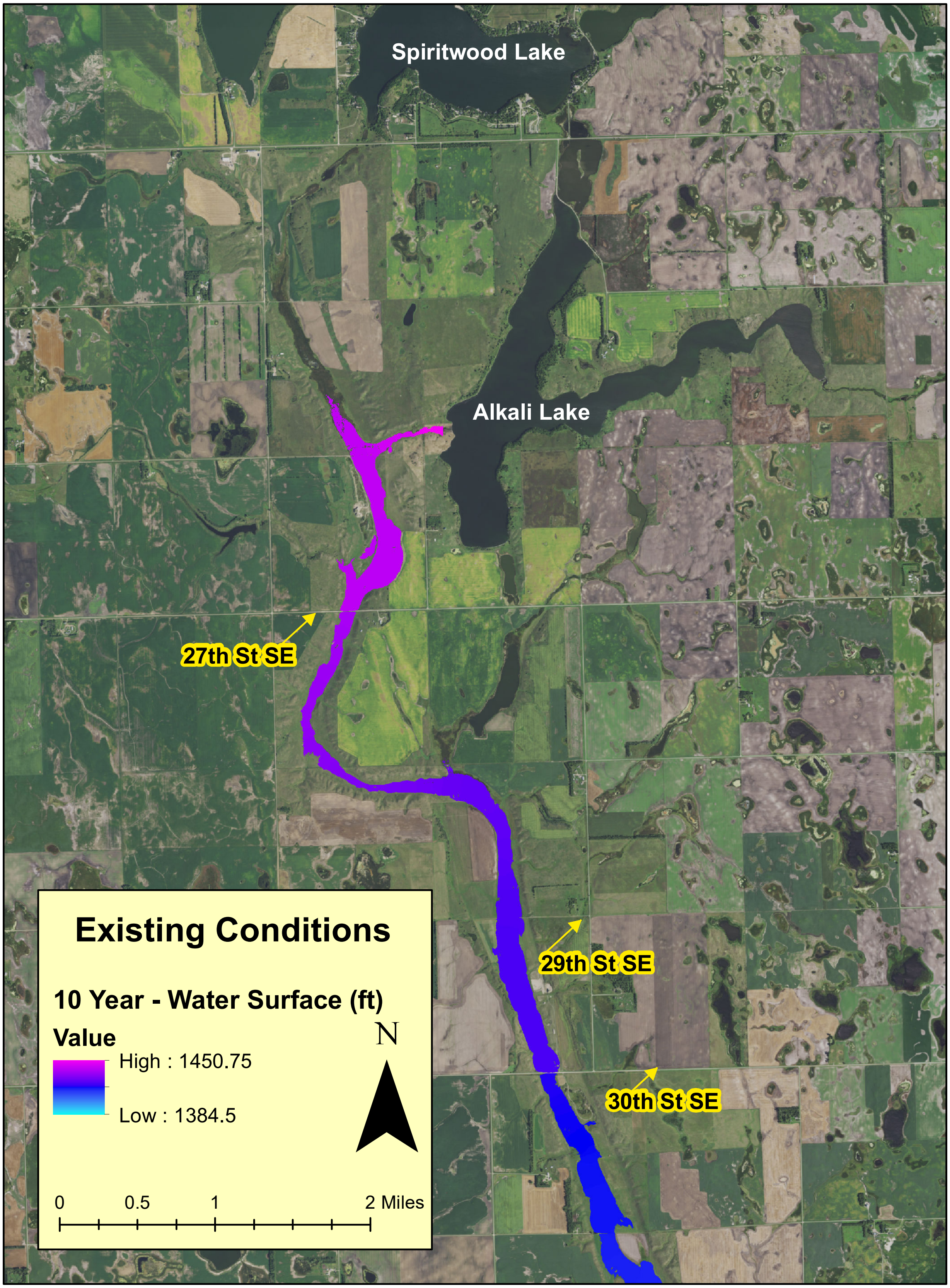
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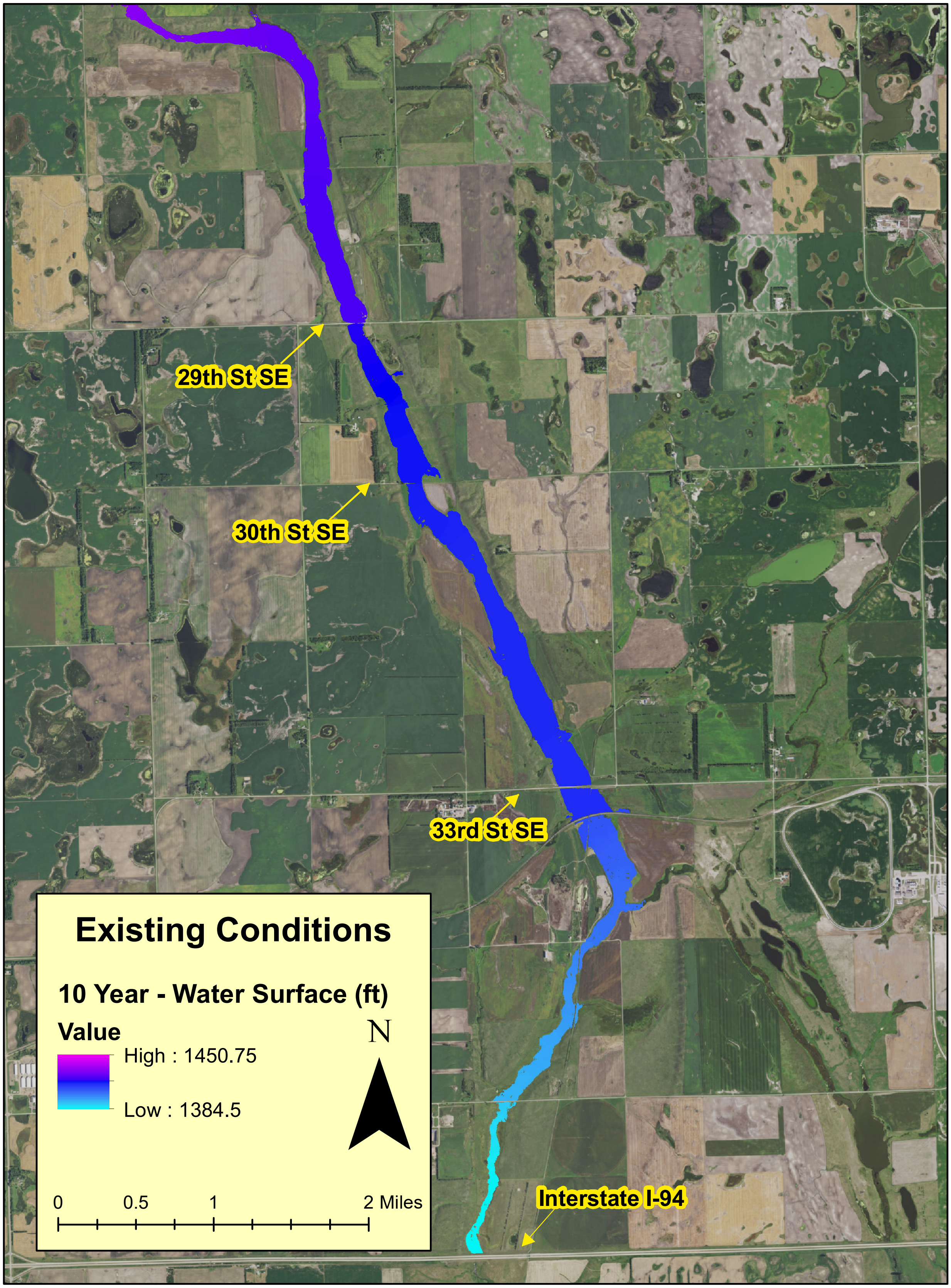
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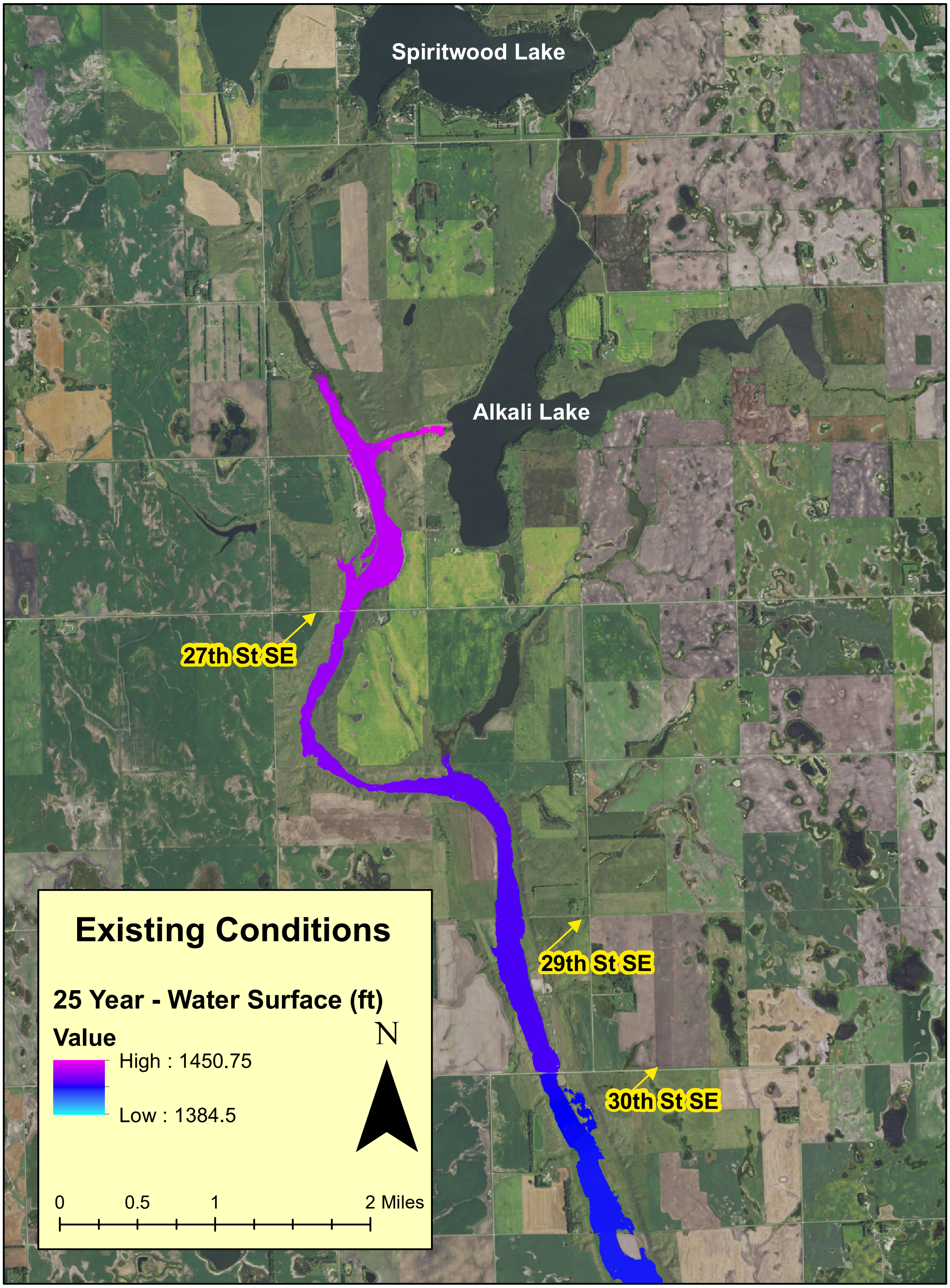
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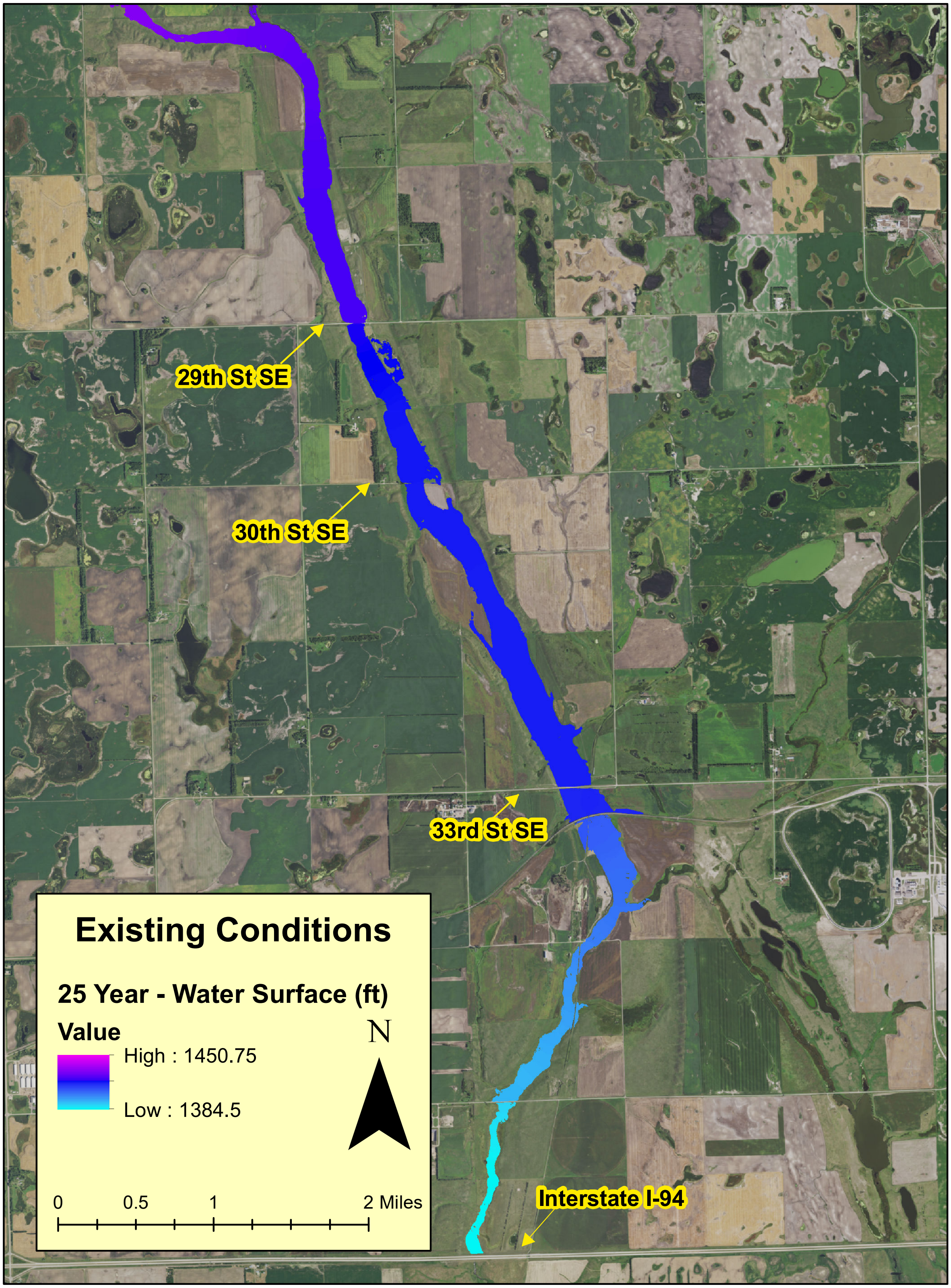
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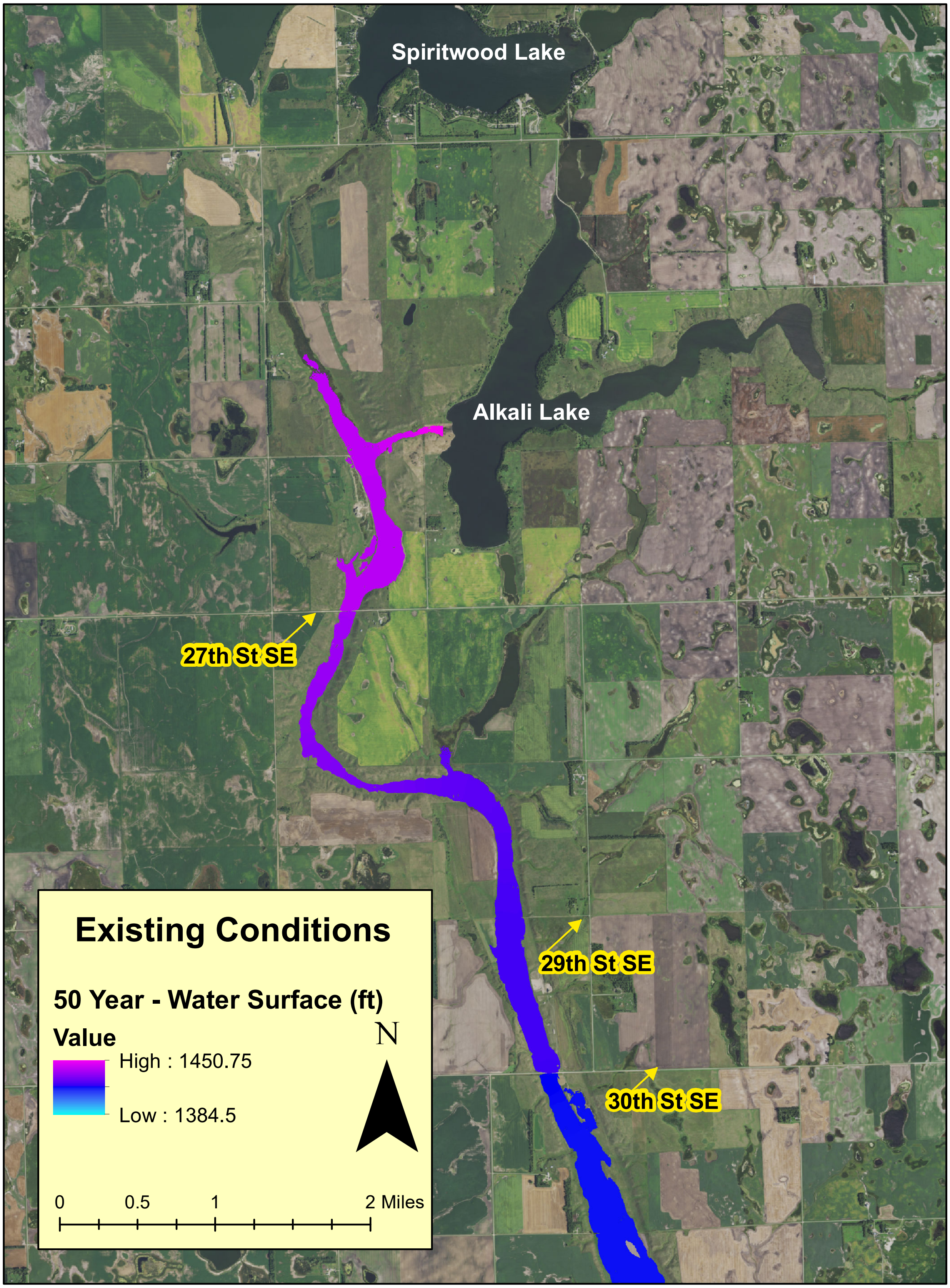
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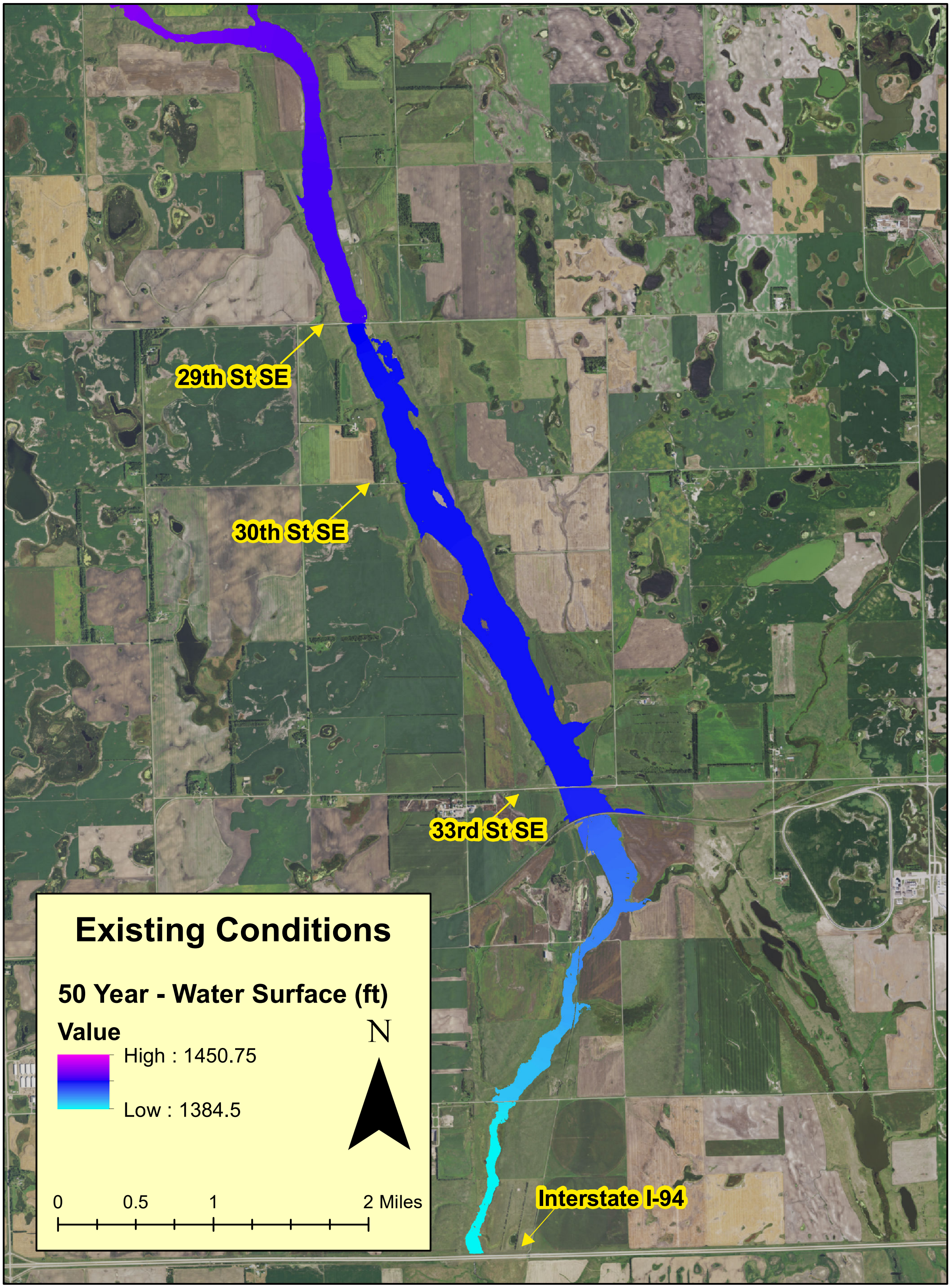
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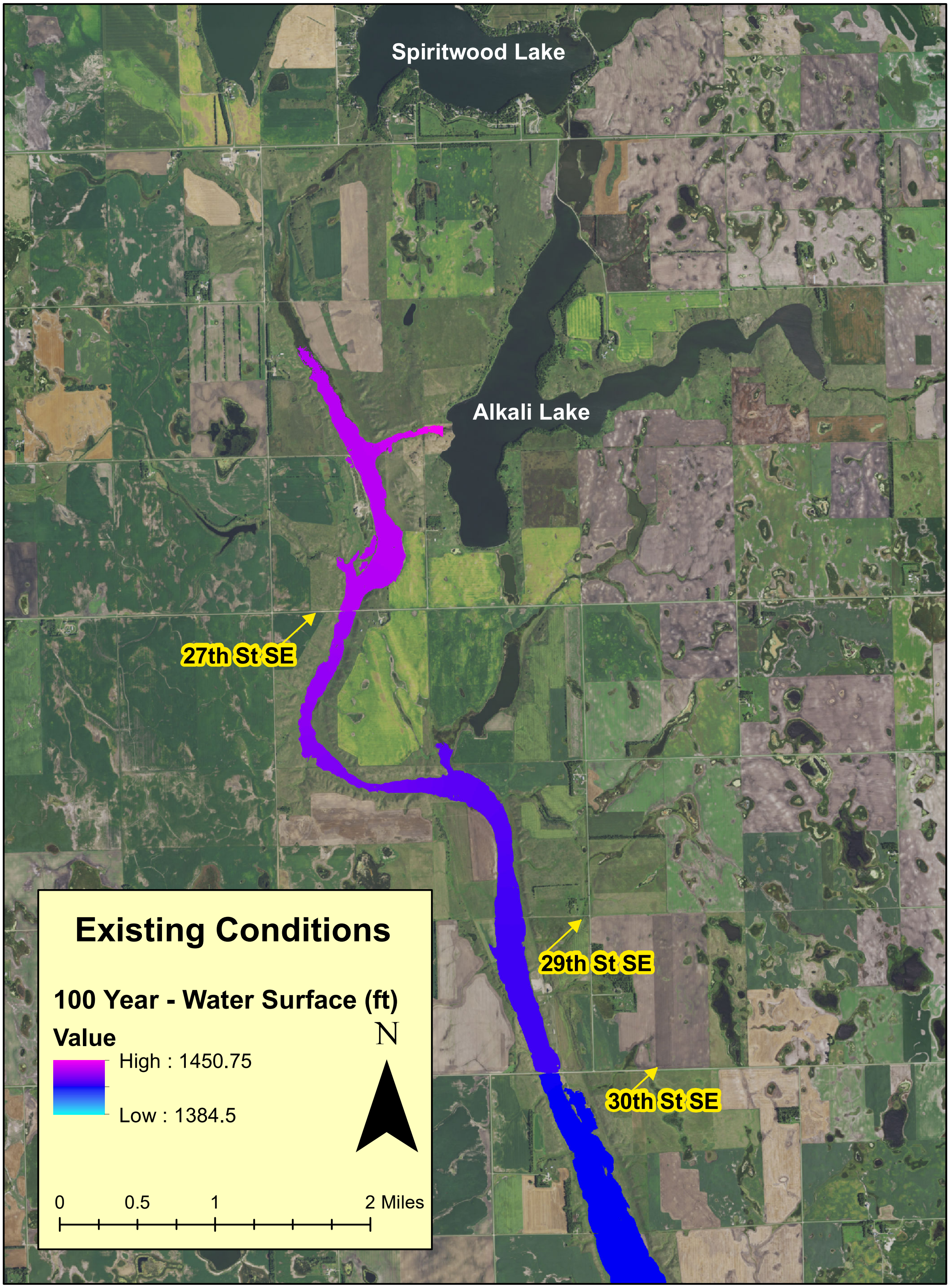

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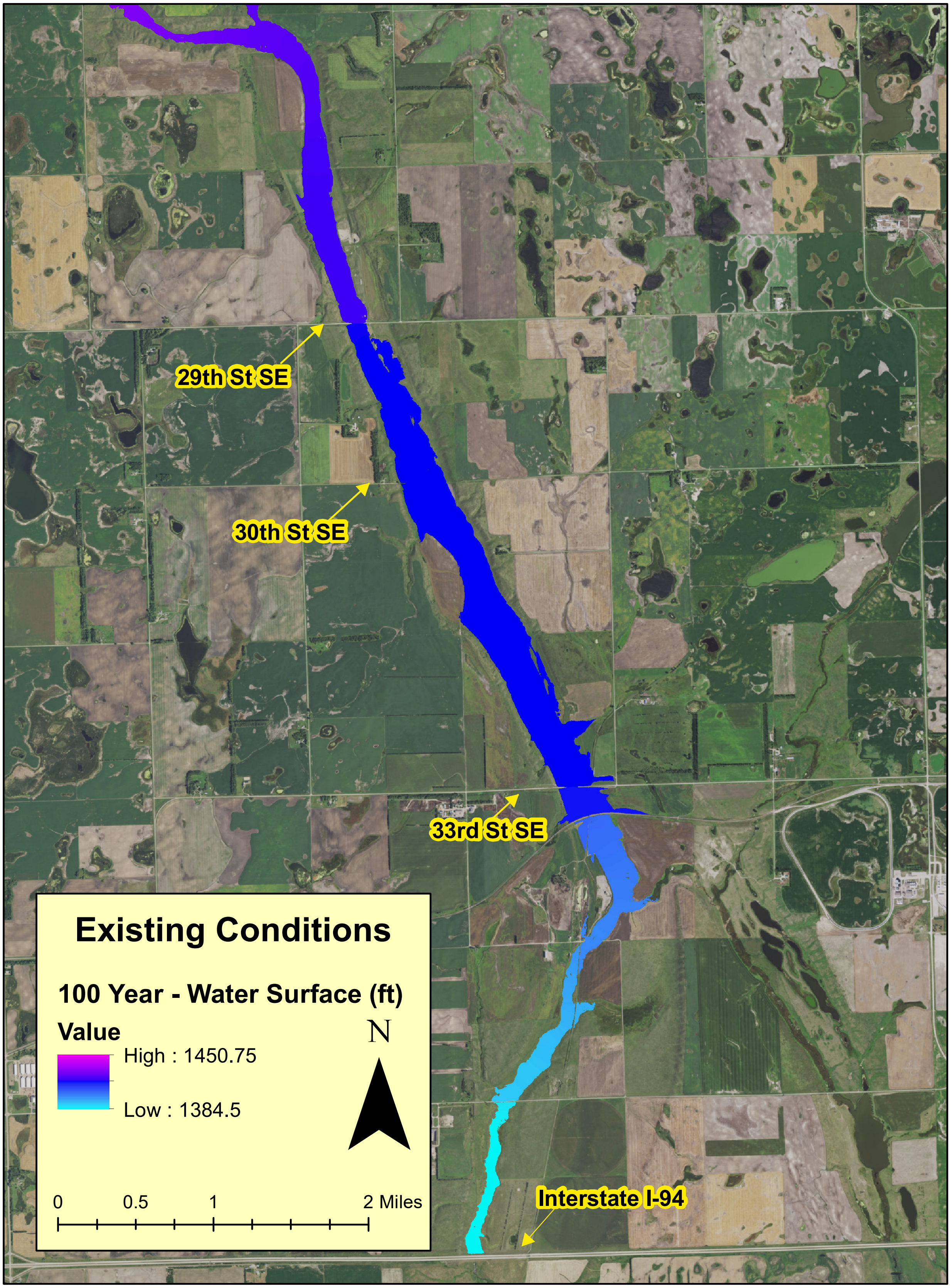
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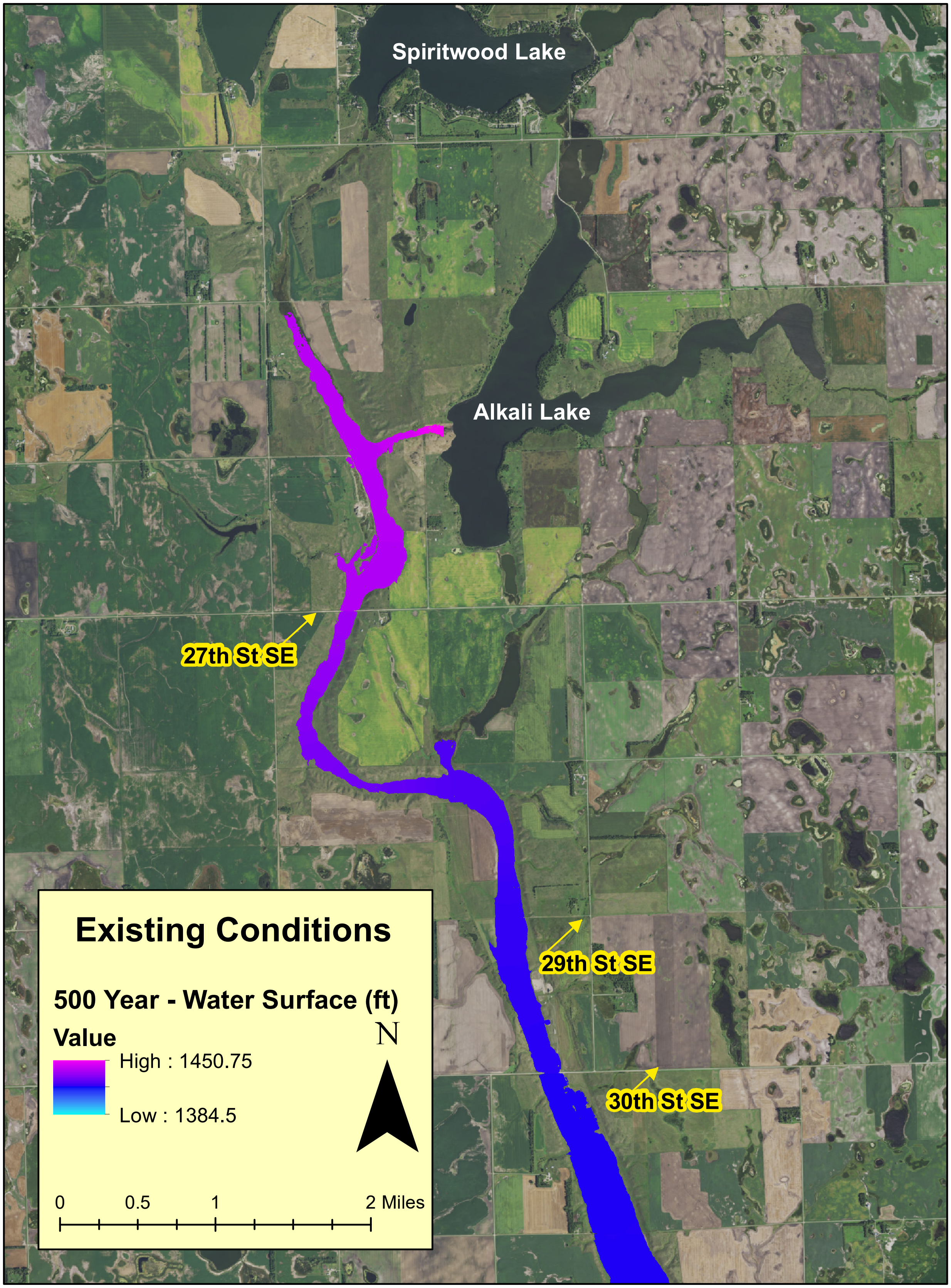
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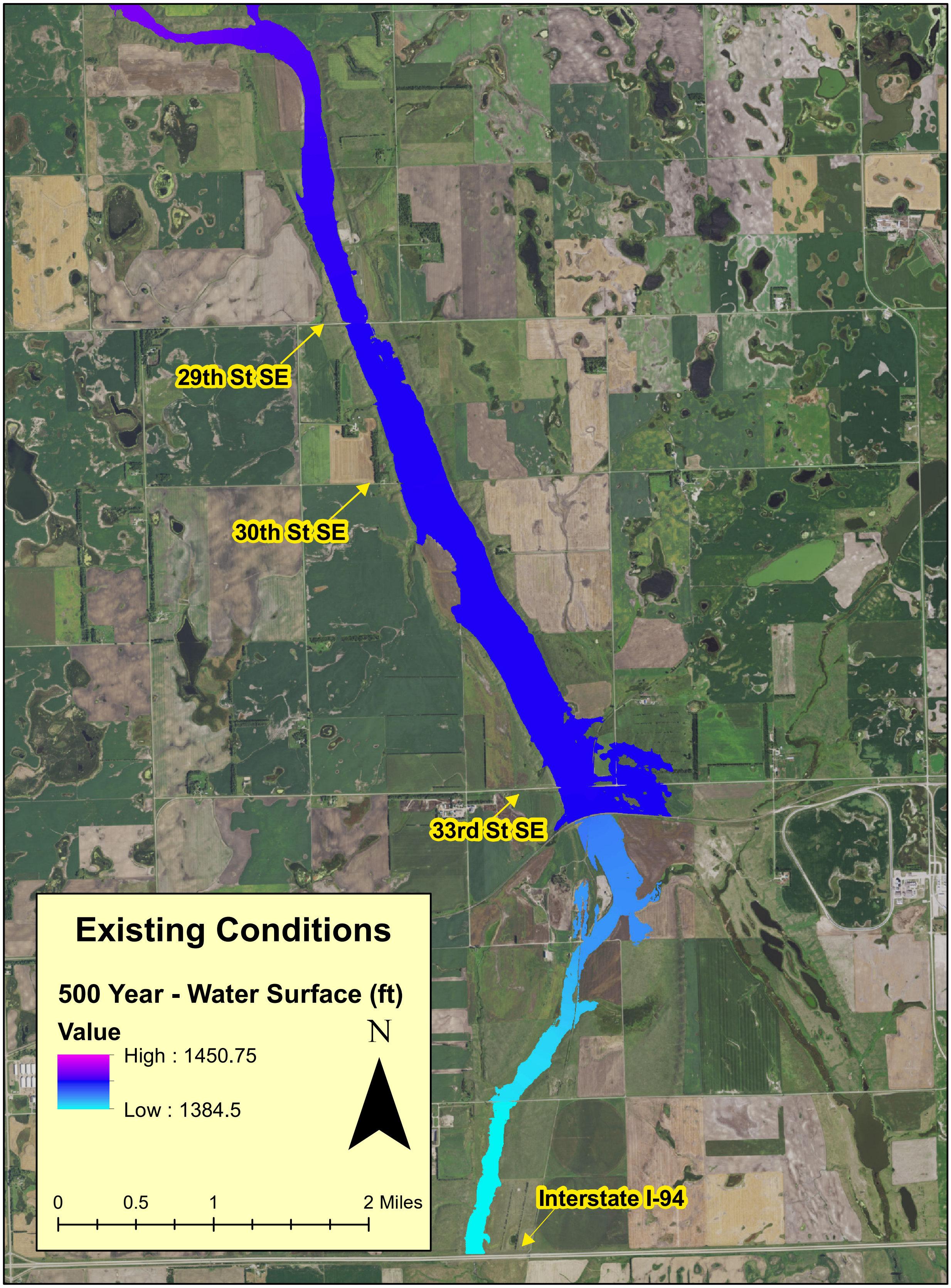
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Interstate I-94
Existing Conditions
500 Year - Water Surface (ft)
Value
High : 1450.75
Low : 1384.5
N
0
0.5
1
2 Miles

Appendix E – Alternatives Analysis

SPIRITWOOD & ALKALI LAKE INVESTIGATION

DEPARTMENT OF WATER RESOURCES

DWR Project #461
January 2023

TEL: 701.328.2750
1200 Memorial Hwy
Bismarck, ND 58504

North Dakota Be Legendary. | Water Resources

SPIRITWOOD & ALKALI LAKE
INVESTIGATION

North Dakota Department of Water Resources
1200 Memorial Highway
Bismarck, ND 58504

Prepared For
Stutsman County Water Resource District
Spiritwood Lake, North Dakota, Stutsman County
January 2023

DWR Project #461

Prepared By

Chris Korkowski, P.E.
Investigations Section Chief

Laura Ackerman, P.E.
Water Resource Engineer

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1.0 INTRODUCTION

This investigation reviews and develops structural alternatives for prevention or mitigation of flooding at Spiritwood and Alkali Lakes. The west end outlet of Spiritwood Lake is impeded by high ground and 24th Street SE prior to being discharged into Seven Mile Coulee (**Figure 1**). The east end outlet is impeded by a narrow outlet, 24th Street SE, 91st Avenue SE twice, and once discharged into Alkali Lake, the water must reach Alkali Lake's outlet elevation to discharge into Seven Mile Coulee (**Figure 1**).

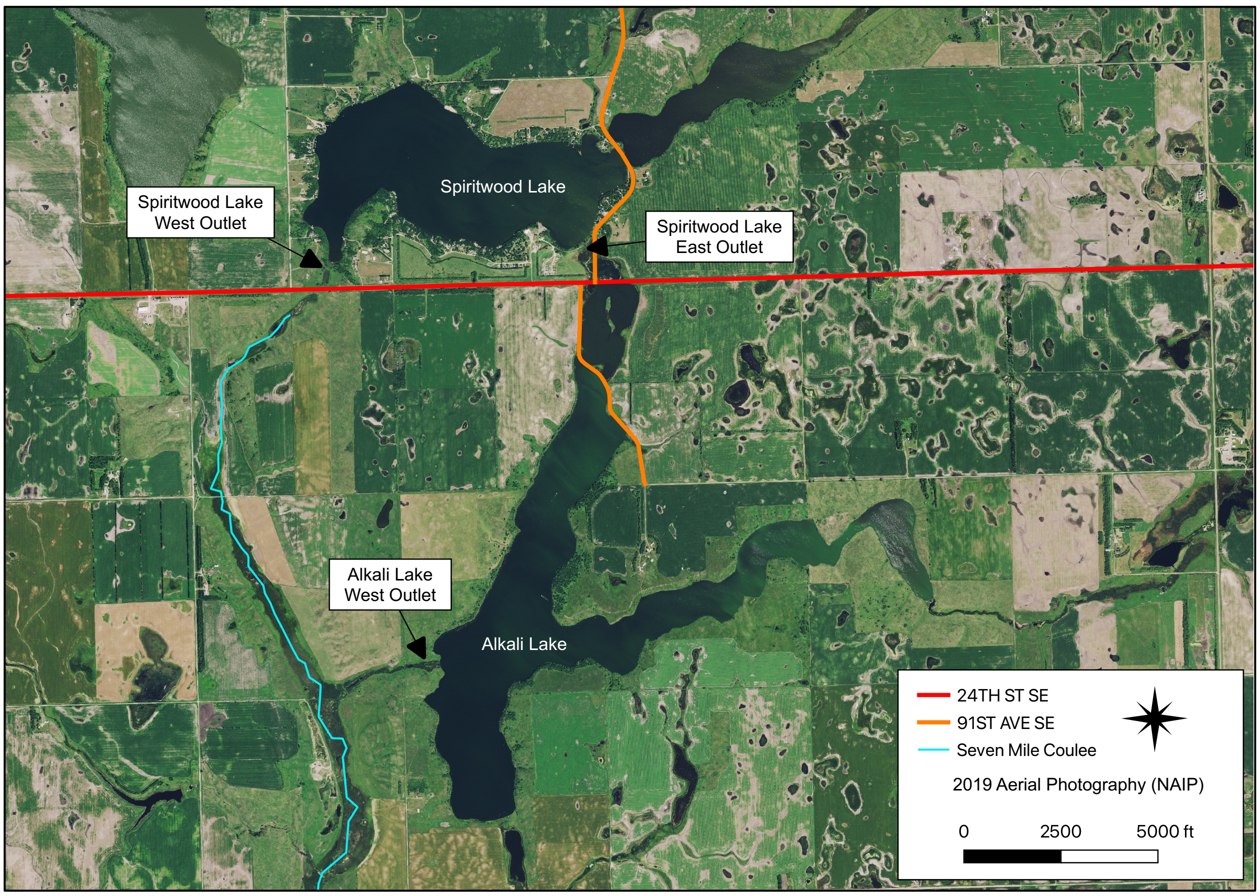

Figure 1. Spiritwood Lake layout.

A balance of storage and discharge capability in a given alternative is critical to mitigate flooding on Spiritwood Lake while also preventing undo damage downstream on Seven Mile Coulee. Several structural alternatives were developed as part of this study, the details of which are documented in this appendix.

2.0 ALTERNATIVE EVALUATION

Non-contributing water bodies fill until they spill and finding cost effective solutions for removing that water and relieving impacts is extremely difficult. Typically, options for reducing flood impacts from non-contributing water bodies falls into two categories: buying out the impacted structures or finding a way to evacuate floodwaters (e.g., open channel outlets or pumping). Pumping was not analyzed as part of this study due to the immediate availability of Seven Mile Coulee to use as a discharge point and the region's experience with pumping alternatives. The only identifiable sink or outlet locations for Spiritwood discharge is Schock Lake immediately west of Spiritwood Lake or Seven Mile Coulee to the south. Pumping water from Spiritwood into Schock Lake was utilized in the past, but landowners surrounding Schock Lake ultimately decided against the project after the lake's elevation began impacting the surrounding land.

2.1 No Action Alternative

The No Action alternative represents existing conditions and will allow the current state of Spiritwood Lake's flood impacts to continue. Flooding impacts from Spiritwood and Alkali Lakes primarily include flooding of structures, inundation of roads, and inundation of land.

Light detection and ranging data (LiDAR) and aerial photography was used to identify the lowest elevation of each structure around Spiritwood Lake. The lowest elevation of each structure was then compared to the results of the frequency events from the 1-dimensional hydraulic model. **Table 1** provides the number of structures inundated for each frequency event. It should be noted that there are uncertainties related to the LiDAR, selection of the lowest point around each structure due to vegetation in the aerial photography, and uncertainty related to the hydrology. According to the structure inundation analysis, the first one floods at approximately 1446.1 feet (NAVD88).

Table 1. Structures inundated by each frequency event for the No Action alternative.

Event	Event Elevation (ft - NAVD88)	Number of Structures Inundated	Total Structure Value
10 Year	1448.1	4	$ 358,400
25 Year	1448.5	5	$ 472,900
50 Year	1448.8	5	$ 472,900
100 Year	1449.2	6	$ 798,200
500 Year	1450.8	14	$ 1,535,600

Information on parcels and structures was obtained from North Dakota Information Technology's statewide parcels website (NDIT, 2022) and Stutsman County's tax website (Stutsman County, 2022). The locations of the inundated structures are illustrated in **Figure 2**. The value of the inundated structures for each frequency event was utilized in the economic analysis for evaluated alternatives.

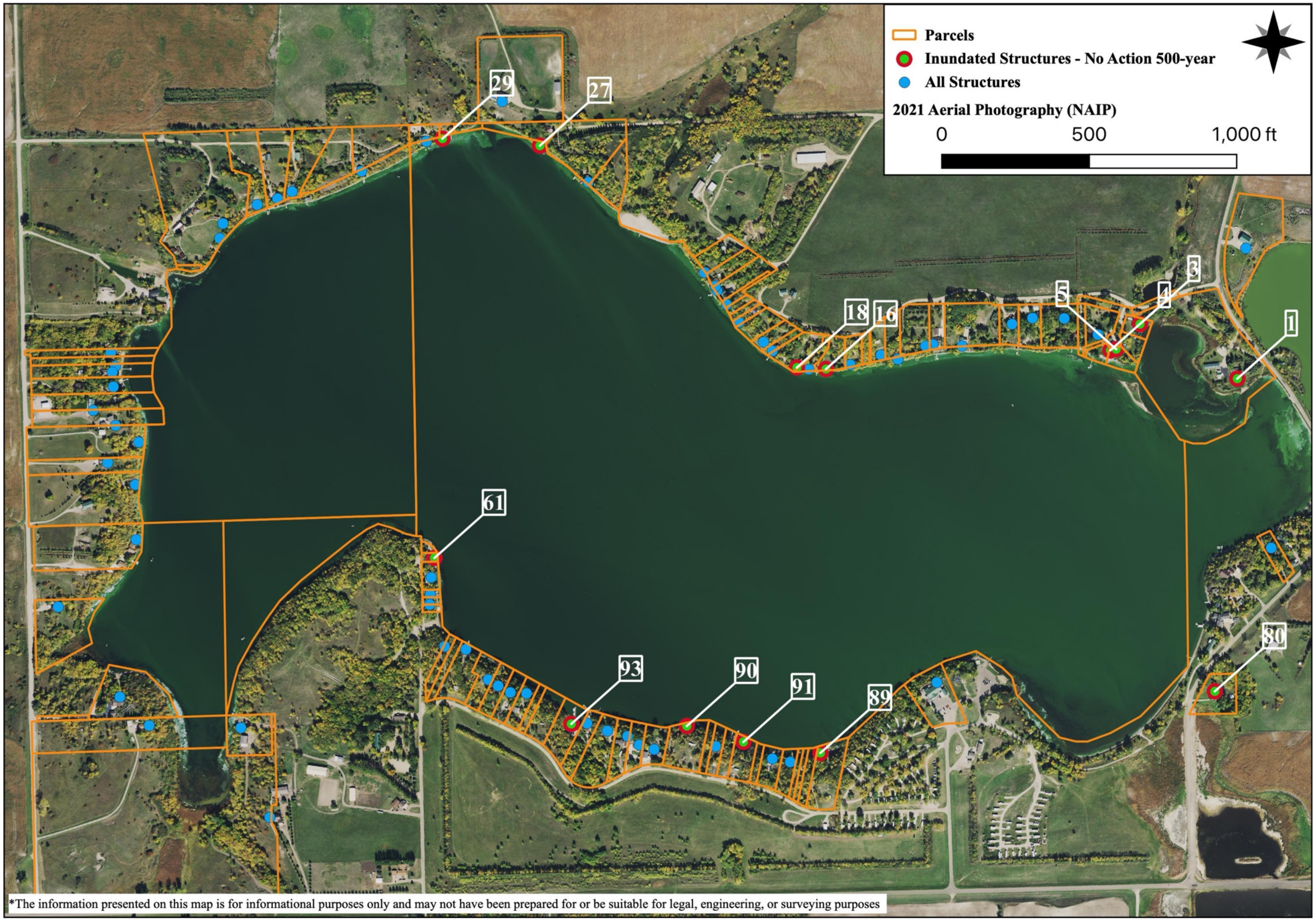

Figure 2. Inundated structures up to the 500-year event for the No Action alternative.

2.2 Individual Alternative Evaluation

Throughout the alternative evaluation, many individual alternatives were evaluated to prevent or mitigate flooding at Spiritwood Lake. It was found that the individual alternatives did not produce sufficient effects of mitigating/reducing flood impacts at Spiritwood Lake due to the complexities of the region. These individual alternatives were later combined to produce well-rounded alternatives for mitigating flood impacts, but documentation of the individual alternatives is necessary to show the effects these can have on the system and why any alternative that could reduce flood impacts on Spiritwood Lake would need multiple components.

2.2.1 Spiritwood East Outlet Weir

The Spiritwood East Outlet is a starting point for discharging water from the lake as it is currently discharging water into Alkali Lake. Increasing the outlet capacity at the east outlet could have substantial benefits if the flow is able to move unobstructed downstream. The purpose of evaluating this operational change first was to determine how obstructed the downstream reaches are if adequate discharge capacity was added at Spiritwood Lake.

A simple analysis was conducted to determine whether a weir at elevation 1442.0 feet (NAVD88) would be effective in discharging flood waters from the 100-year event using the weir equation. This simple analysis does not factor in downstream constraints, but it allows for simple sizing to be determined prior to advancing the design into the hydraulic model, which would factor in such constraints. **Figure 3** illustrates the head/discharge relationship for a simple 100-foot-wide weir calculated using Kindsvater-Carter rectangular weir equation with a P-value of 3 feet.

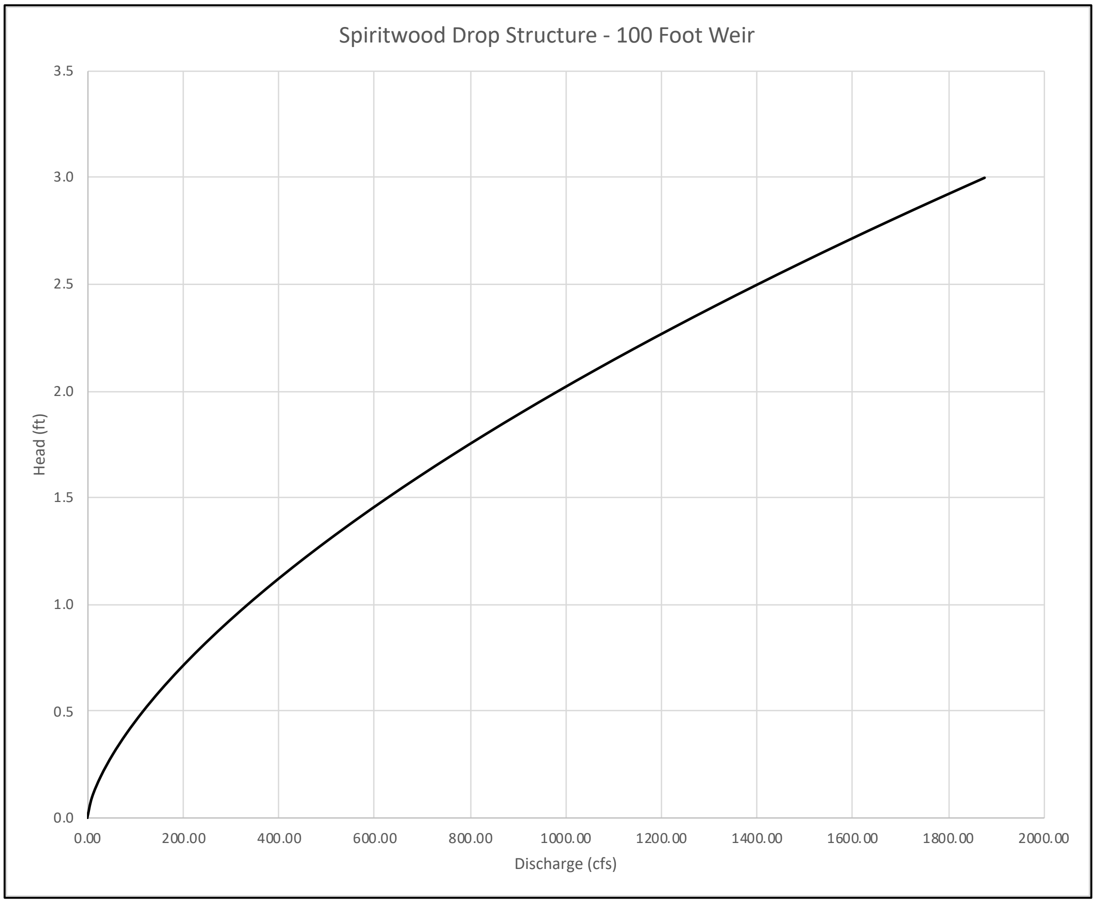

Figure 3. Rating curve for 100-foot weir at Spiritwood East Outlet.

The weir was then placed into the 1-dimensional hydraulic model and the starting elevation for both Spiritwood and Alkali Lakes was set to 1442.0 feet. This system was likely to be more beneficial if downstream constrictions were removed and if Alkali Lake had a starting water surface elevation lower than Spiritwood Lake, but was run as a stand-alone solution to better understand what increasing the conveyance at this location would accomplish. The 100-year event was utilized to determine the benefits and detriments of this alternative. **Figure 4** provides the 100-year hydrograph of Spiritwood Lake for the No Action alternative, a 100-foot weir at elevation 1442.0 feet (NAVD88), and a 200-foot weir at elevation 1442.0 feet (NAVD88). The 200-foot weir was added to better understand if the water surface differences between the 100-foot weir and No Action alternative were caused by the increase in conveyance or from the lower starting water surface elevations of the lakes between the two modeled runs. The model results show that the difference in water surfaces between the existing conditions and the two alternatives was due to the lower lake elevations, meaning the increased outlet capacity is not effective due to downstream constrictions/restrictions.

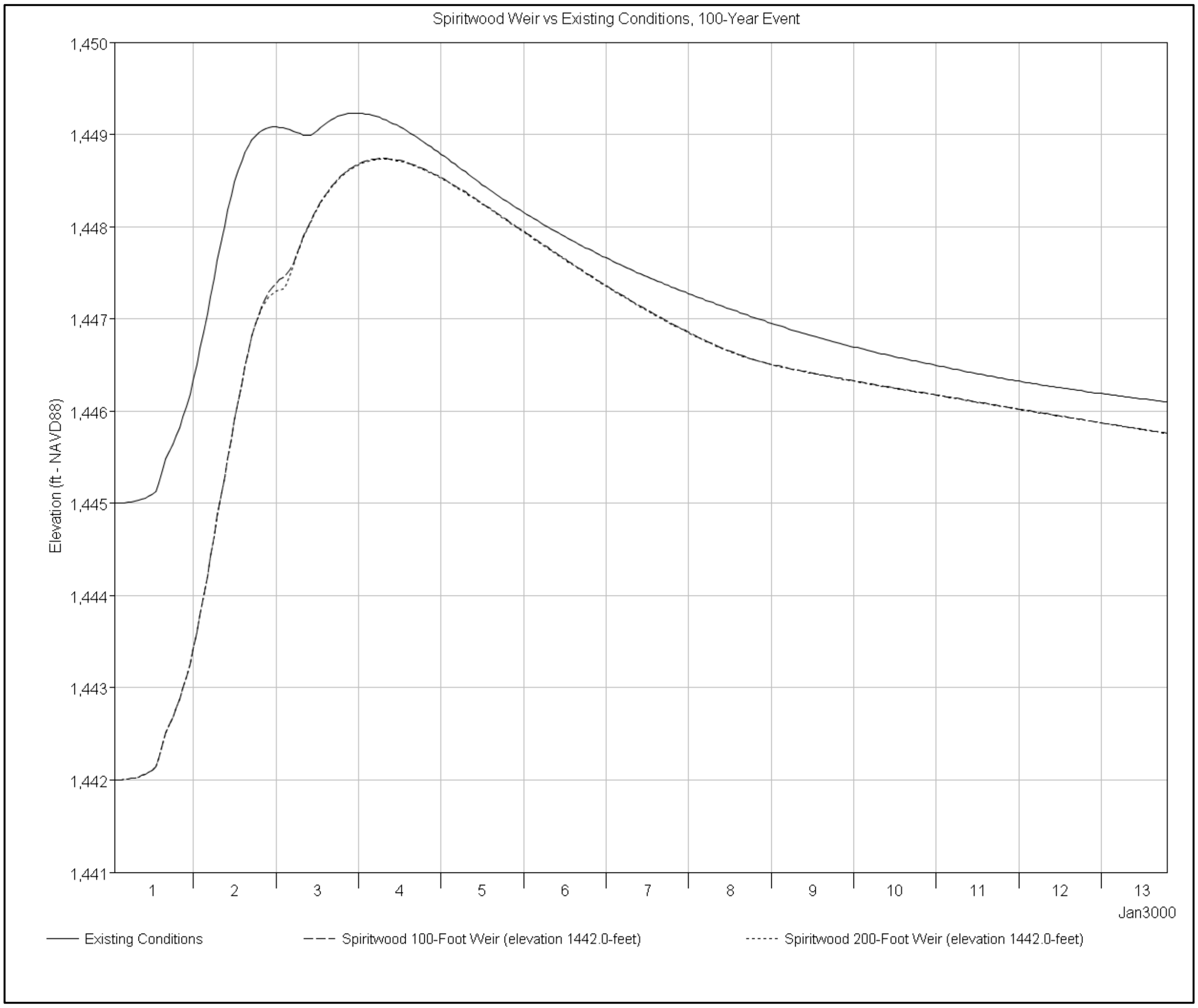

Figure 4. 100-Year Event, Spiritwood Lake No Action alternative versus weir alternatives.

Based on the simulations, it was determined that placing a weir on Spiritwood Lake's east outlet at elevation 1442.0 feet (NAVD88) is not an adequate stand-alone solution. Placement of the weir and lowering the lake does have immediate effects on the 100-year water surface elevation, but it was felt that the change was not drastic enough to pursue this option alone. It was also likely that the lake could remain at a higher elevation due to the downstream restrictions impeding the conveyance of water out of the system.

2.2.2 Roadway Conveyance

Several stand-alone roadway conveyance alternatives were examined as part of this study. The first roadway stand-alone alternative (labeled Box 1) examined was placing one 8-foot by 8-foot box culvert through 91st Avenue SE (two crossings) and 24th Street SE (one crossing). Existing culverts in 24th Street SE include one 4-foot corrugated metal pipe with an invert elevation of 1439.37 feet (NAVD 88). Existing culverts in the first crossing at 91st Avenue SE include two 3.5-foot diameter pipes at an invert of 1441 feet (NAVD88) and one 3-foot diameter pipe with an invert of 1443.09 feet (NAVD88).

No culverts were identified in the second crossing at 91st Avenue SE, meaning they were well below the Alkali outlet invert elevation and were likely ineffective at moving flow during high water conditions. For this reason, no culverts were included in the second crossing at 91st Avenue SE. Each culvert was set at the lowest invert elevation of the existing culverts. The Box 1 alternative was compared against each frequency event to determine if it had stand-alone benefits. **Figure 5** illustrates the results of the 100-year and 10-year frequency events for the No Action and Box 1 alternatives at Spiritwood Lake.

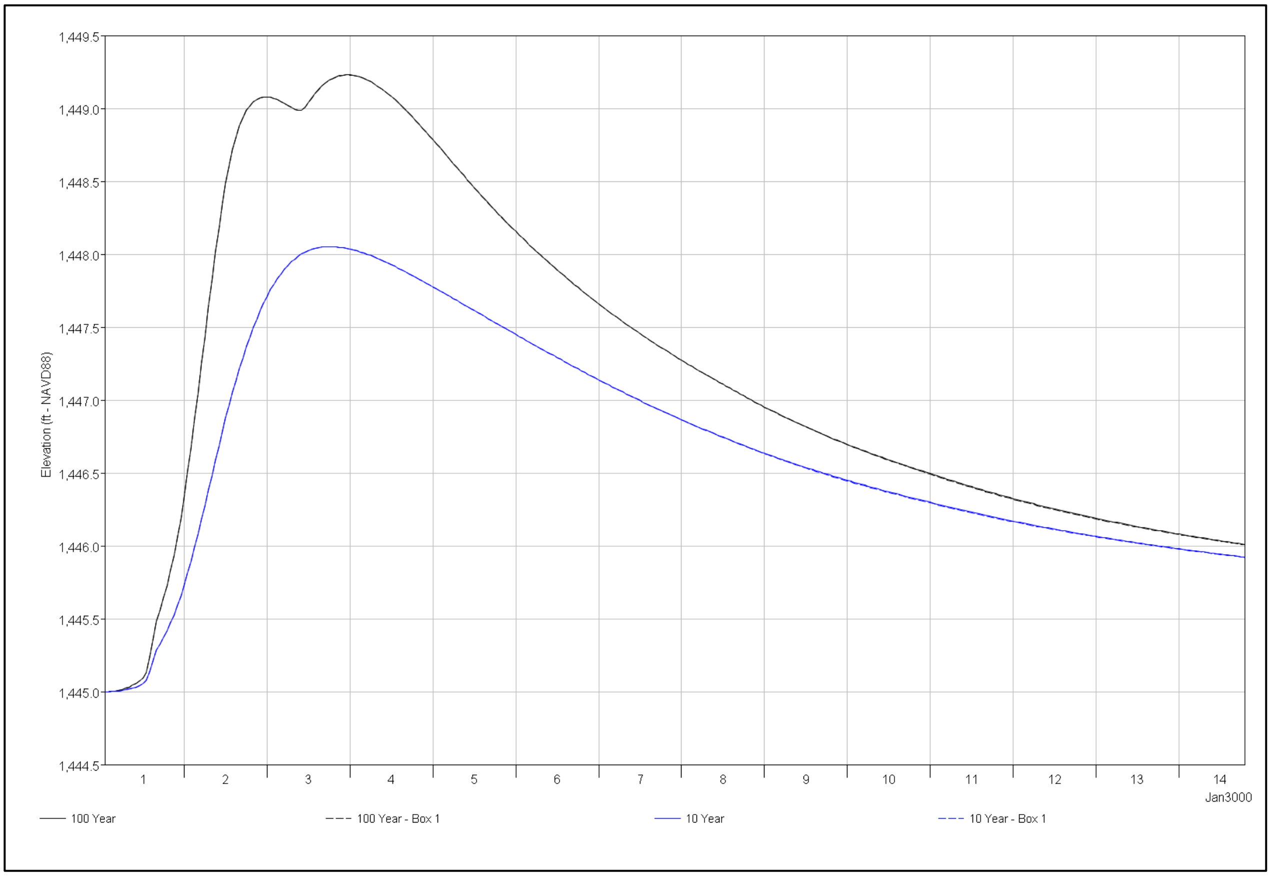

Figure 5. Box 1 alternative versus No Action alternative at Spiritwood Lake.

As illustrated in **Figure 5**, there is no difference between the No Action and Box 1 alternatives. This demonstrates that the Spiritwood Outlet is not controlled by the downstream road constrictions, but likely by its outlet and Alkali Lake's Outlet.

To demonstrate that the outlets of Spiritwood and Alkali Lakes are truly the impediment on flows leaving the system, 91st Avenue SE and 24th Street SE were removed from the system in a stand-alone alternative, labeled Roads Removed. **Figure 6** illustrates the results of the stand-alone alternative Roads Removed versus the No Action alternative at Spiritwood Lake. The results illustrate that the downstream constraint, Alkali Outlet, is still controlling water leaving the system.

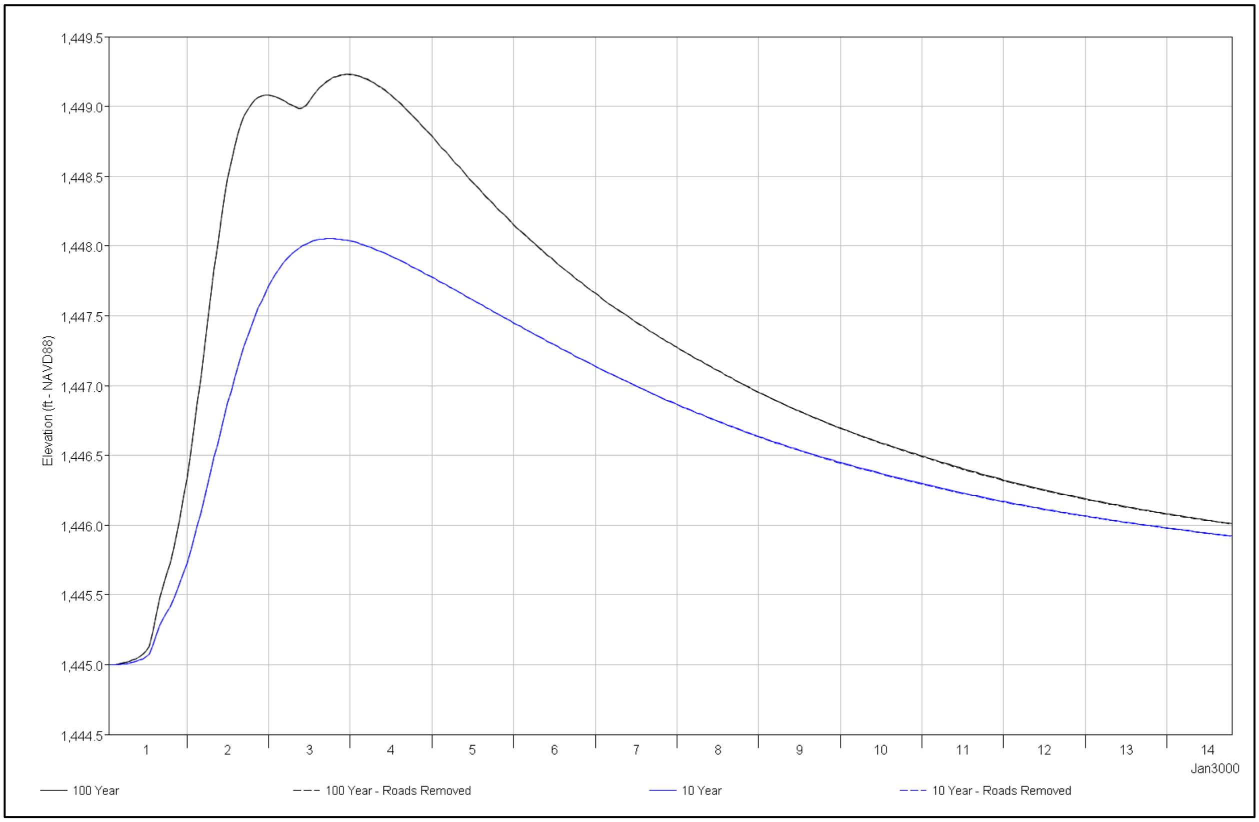

Figure 6. Roads Removed alternative versus No Action alternative at Spiritwood Lake.

2.2.3 Alkali Outlet Open Channel

Alkali Outlet is the most downstream constriction of the Spiritwood and Alkali Lake complex. A stand-alone alternative looked at placing a 10-foot-wide trapezoidal channel with 3 to 1 side slopes on Alkali Outlet, with an invert elevation of 1440.0 feet (NAVD88). The existing invert elevation of the Alkali Outlet is at elevation 1443.8 feet (NAVD88). **Figure 7** provides the cross section of Alkali Outlet with both the No Action and the 10-foot Alkali Outlet alternatives.

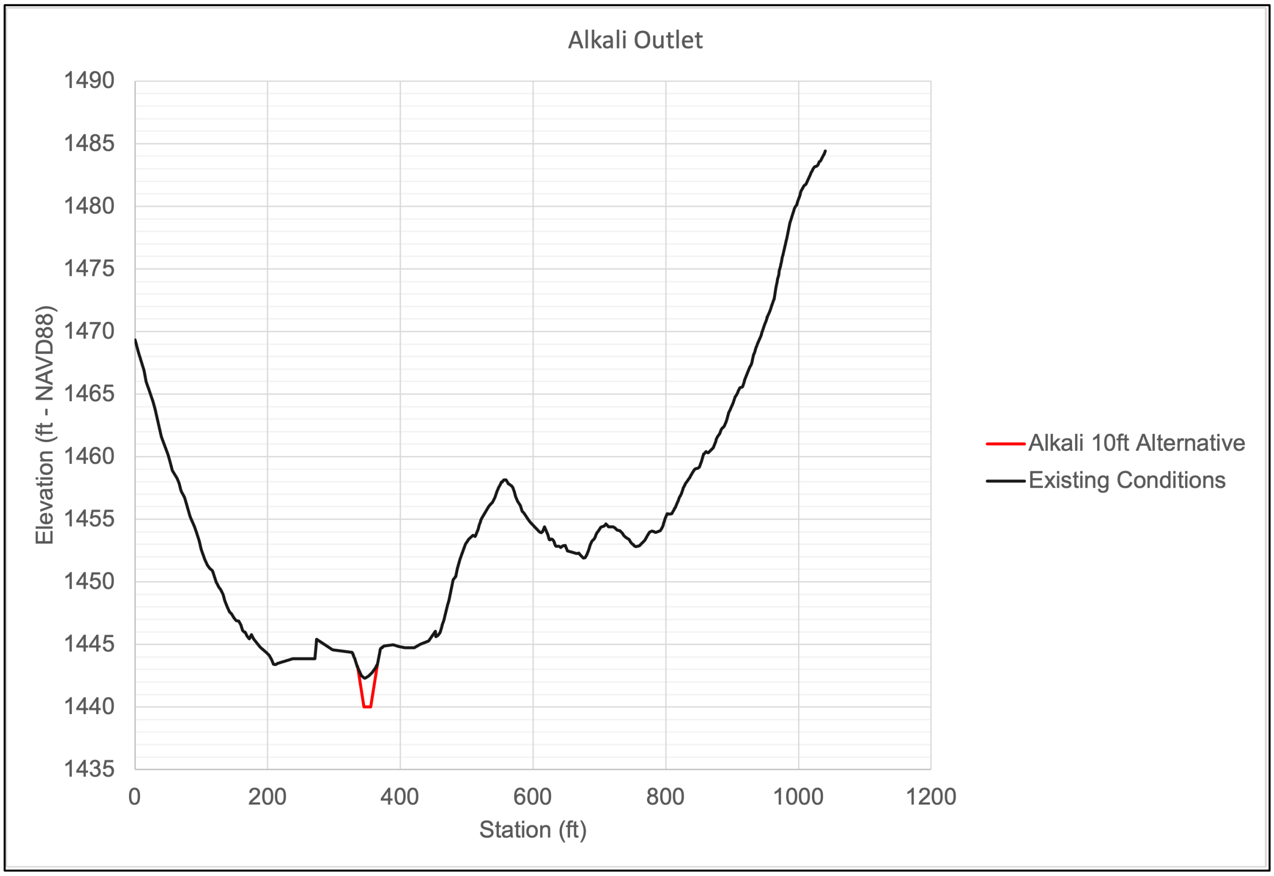

Figure 7. No Action and 10-ft Alkali Outlet alternative cross sections.

The results of the 10-foot trapezoidal channel at Alkali Outlet have significant effects on the water surface elevation on Alkali Lake. **Figure 8** illustrates the effects that the channel has on the water surface of Alkali Lake for various frequency events.

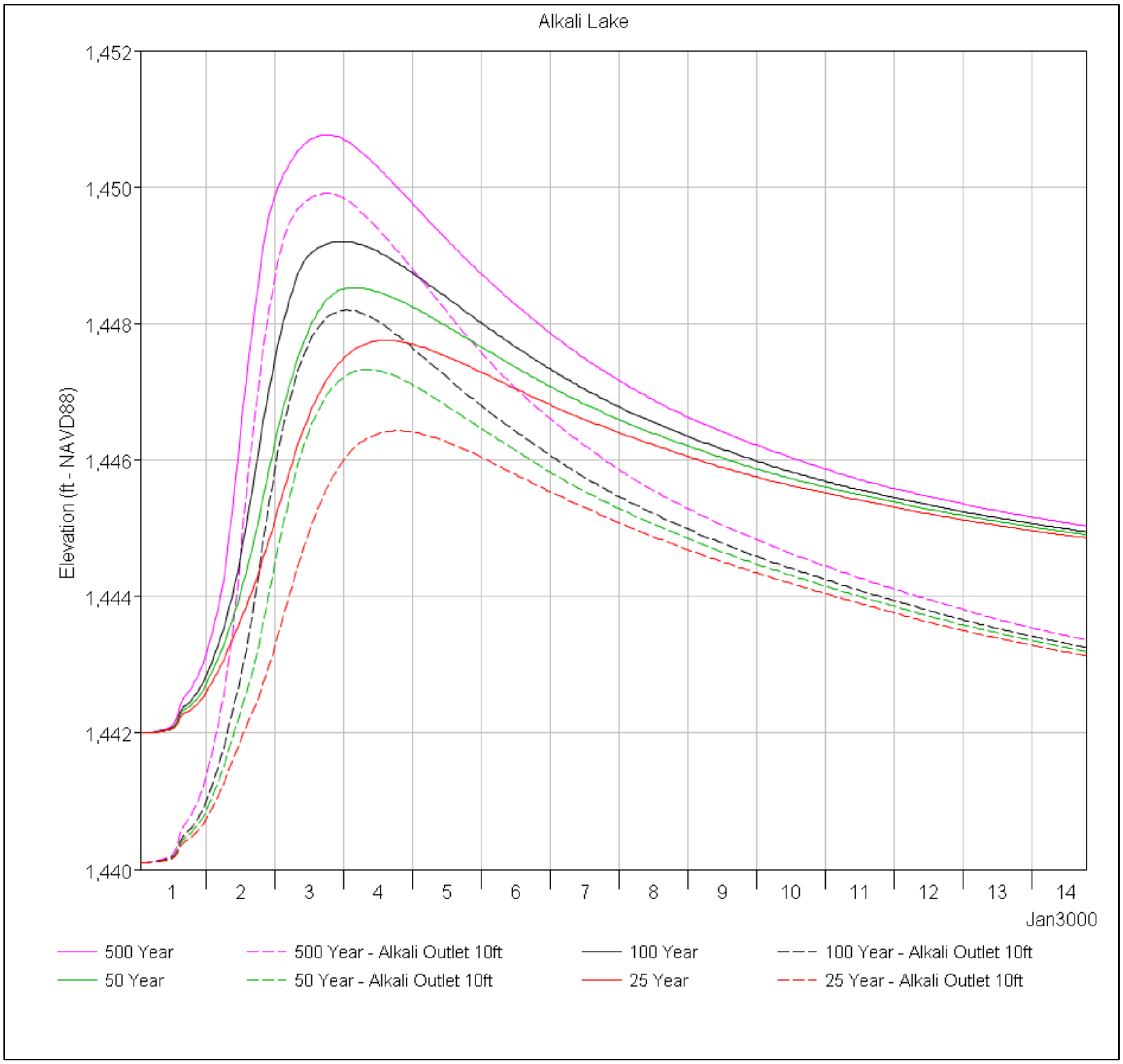

Figure 8. Alkali Outlet 10-ft Alternative Effects on Alkali Lake.

2.2.4 Alkali Outlet Dam Removal

At the downstream end of the Alkali Outlet a small dam exists for the purpose of environmental benefit. **Figure 9** illustrates the location of the dam. Several locals have expressed concern about the dam impeding outflow from Alkali Lake, thus worsening the flooding issues between Spiritwood and Alkali Lakes. The dam was removed from the Seven Mile Coulee downstream impacts model to better understand its effects. A 900 cfs outflow was entered into the model to evaluate the No Action versus Dam Removed alternatives. **Figure 10** compares the water surface elevation profiles for the two alternatives. As illustrated in **Figure 10**, the water surface elevations converge downstream of Alkali Lake, thus proving that the Alkali Outlet dam has little to no effect on Alkali Lake's water surface elevation.

Figure 9. Alkali Outlet Dam Location.

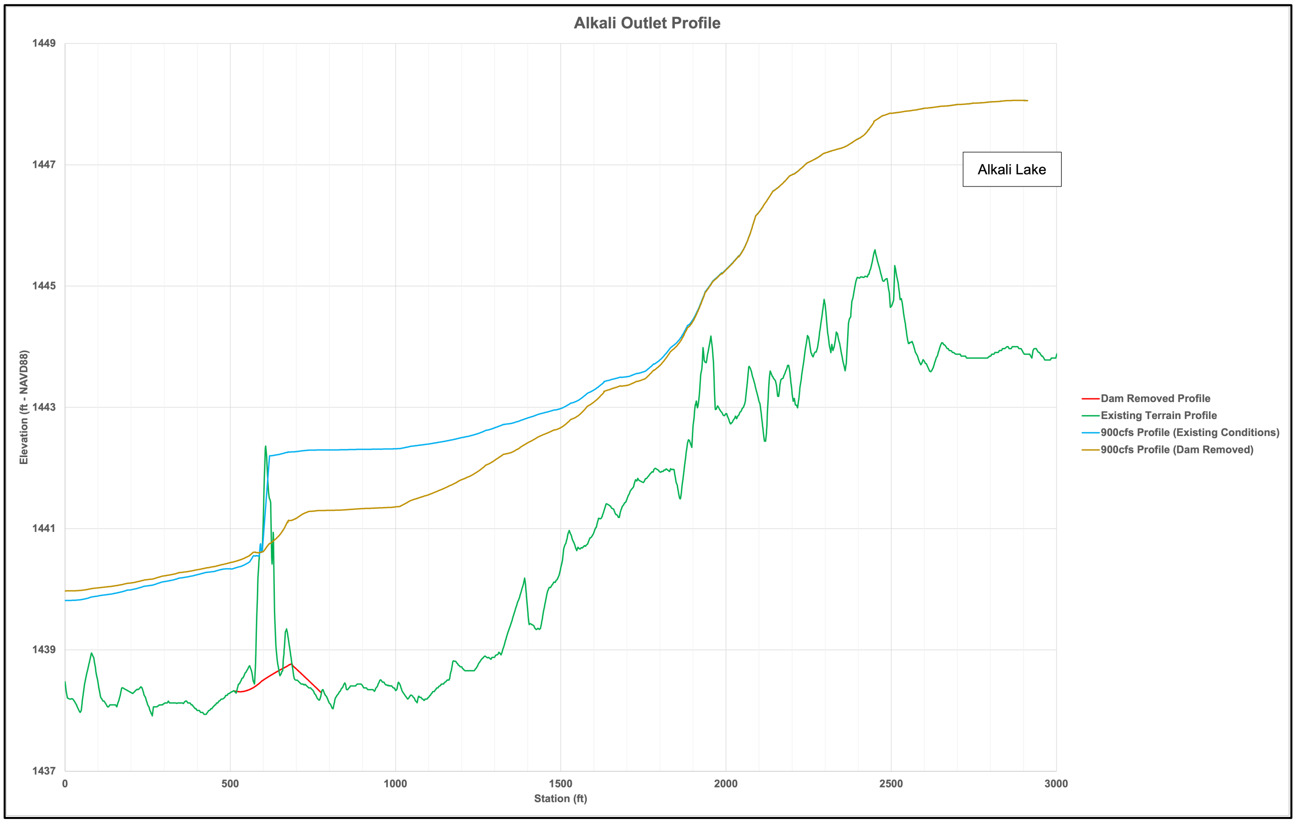

Figure 10. Water surface elevation profiles for No Action versus Alkali Outlet Dam Removal alternatives.

2.3 Combination Alternative Evaluation

A series of combined alternatives were evaluated as part of this study. Two combination alternatives were identified based on the individual alternative assessment. Each combination alternative is described in Sections 2.3.1 and 2.3.2.

2.3.1 Combination 1

Combination 1 would convey water through the east outlet of Spiritwood Lake into Alkali Lake and then to Seven Mile Coulee. The alternative includes the following features:

- Lowering Alkali Lake to elevation 1440 ft (NAVD88)
- Improving Alkali Lake's natural outlet with a 20-foot-wide trapezoidal channel
- Improving conveyance through 91st Avenue SE (two crossings) and 24th Street SE (one crossing) by adding an 8-foot by 8-foot box culvert through each crossing
- Lowering Spiritwood Lake to elevation 1442 ft (NAVD88)
- Adding a 100-foot-wide weir at the east outlet of Spiritwood Lake

Combination 1 reduces the water surface elevations of both Spiritwood and Alkali Lakes by actively managing the lakes at lower elevations than in current conditions. The alternative improves flow throughout the system allowing large frequency events to be discharged without drastically inundating property at Spiritwood Lake. **Figure 11** illustrates the hydrographs for each frequency event for the No Action and Combination 1 alternatives.

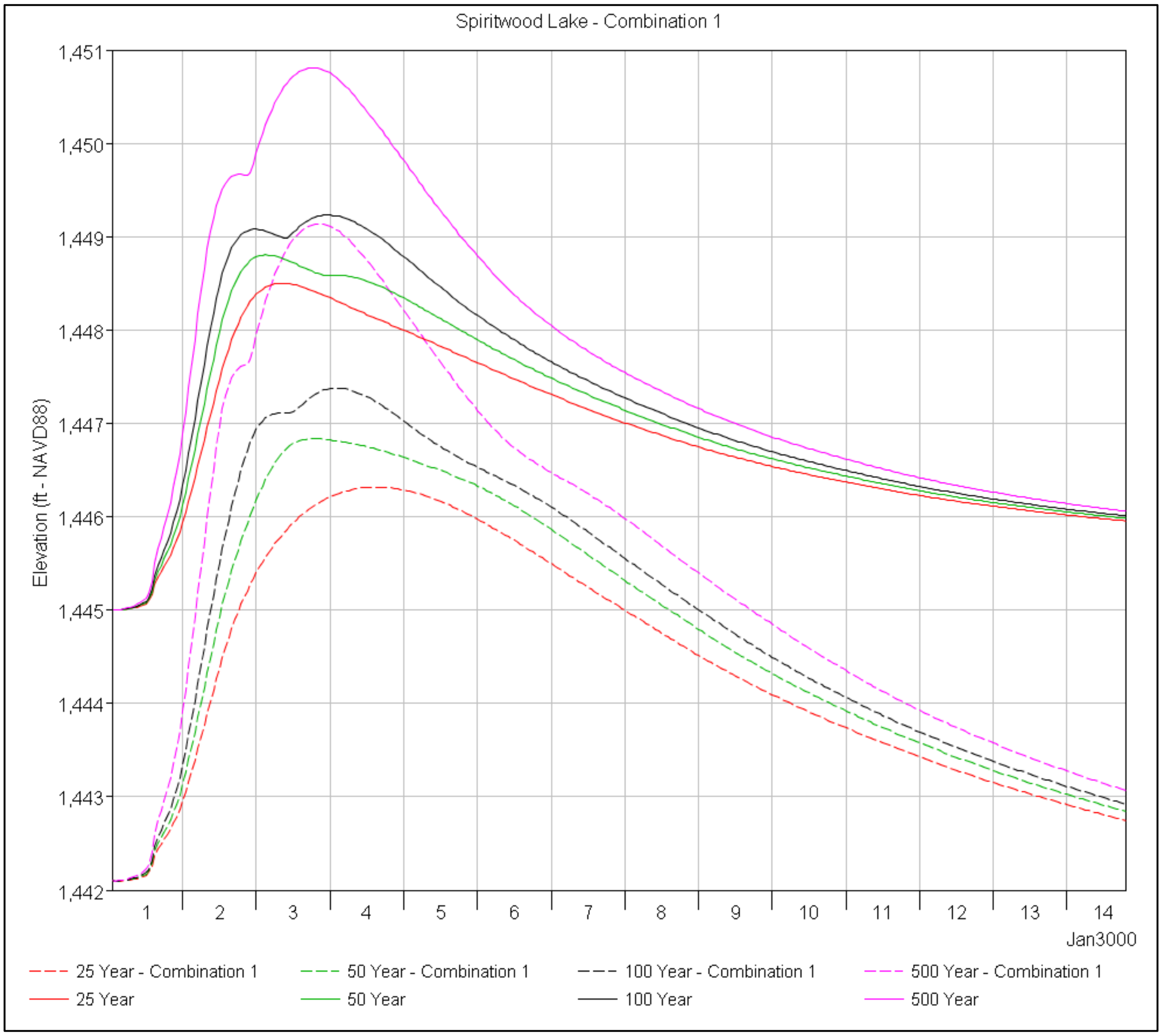

Figure 11. Spiritwood Lake frequency event hydrographs for No Action versus Combination 1 alternatives.

This alternative reduces the water surface elevation at Spiritwood Lake from elevation 1449.2 ft (NAVD88) to 1447.4 ft (NAVD88) during the 100-year frequency event. This reduction in the 100-year water surface elevation prevents five structures, with an estimated value of $672,200, from being inundated. **Table 2** provides the number of structures inundated for each frequency event for the Combination 1 alternative.

Table 2. Structures inundated by each frequency event for the Combination 1 alternative.

Event	Event Elevation (ft - NAVD88)	Number of Structures Inundated	Total Structure Value
10 Year	1445.1	0	$ -
25 Year	1446.3	1	$ 126,000
50 Year	1446.8	1	$ 126,000
100 Year	1447.4	1	$ 126,000
500 Year	1449.1	5	$ 472,900

Cost estimates were completed for the Alkali Lake natural outlet channelization, box culverts, 100-foot-wide weir at the east outlet of Spiritwood Lake, and excavation upstream and downstream of the weir.

RS Means Heavy Construction Cost Data (RSMeans, 2014) was used to estimate channelization costs of Alkali Lake's natural outlet. The length of channelization was calculated to be about 3,000 feet, with a total cut volume of about 8,700 cubic yards. The estimated cost was determined to be about $98,000, which accounts for a cumulative inflation rate of 24.5% since 2014 (US Inflation Calculator, 2022). The cost estimate includes excavation, topsoil replacement, grading, and seeding.

The cost estimates for installing 8-foot by 8-foot box culverts through 91st Avenue SE and 24th Street SE was completed by comparing the project to similar projects that have occurred around the state. In 2021, the North Dakota Department of Transportation (NDDOT, 2021) completed construction of a large box culvert that required creation of a coffer dam for proper installation. The NDDOT project is included as a reference in electronic **Appendix E**. This project also included the resurfacing of an asphalt roadway which is applicable to one site on 91st Avenue SE and to the site at 24th Street SE. Removing nonapplicable costs for the paved sites puts the cost of installation of a large box culvert at approximately $1.1 million per site. The estimate was not lowered for the gravel site on the section of 91st Avenue SE that crosses Alkali Lake due to the large uncertainty that comes with this type of estimate. The total cost estimate for installing the three crossings is approximately $3.6 million, which accounts for a cumulative inflation rate of 9.5% since 2021 (US Inflation Calculator, 2022).

Ducks Unlimited provided information for estimating weir costs (DU, 2022). While bids for weirs have been erratic lately, for cost estimating purposes they recommended using a rate of $40 per square foot for materials and $30 per square foot for installation. Based on their experience in North Dakota, they recommend using steel sheet piles, rather than vinyl sheeting, which has a higher tendency to break or shatter during installation. Their rule of thumb for estimating the depth of sheet pile is 2/3 in the ground and 1/3 out. Based on this information, the cost was estimated to be about $42,000. This is based on a weir approach height of 2 feet, with 4 feet of sheeting in the ground (6-foot height total), and a width of 100 feet. This design would most likely change based on soil tests, groundwater levels, and other onsite conditions.

Finally, a cost estimate was completed for excavation of an approach channel upstream of the weir and downstream channelization. This estimate included the same components as channelization of Alkali Lake's natural outlet. It was assumed that the width of the excavation would be 100 feet, similar to the weir width, and it was determined to have a length of about 300 feet, based on topography. The cut volume was calculated to be approximately 8,200 cubic yards, with a cost of about $77,000, which accounts for a cumulative inflation rate of 24.5% since 2014.

The total cost of the Combination 1 alternative is about $4.6 million, which includes a 20% contingency. A summary of the estimate is included in **Table 3**. There is uncertainty in this estimate related to engineering costs required for detailed design, permitting costs, legal costs for obtaining easements, or costs for buying out or modifying structures that remain prone to flooding.

Table 3. Cost estimate summary for Combination 1 alternative.

Alkali Outlet 20-ft Bottom Width Channel (Length about 3,000 ft)			
	Unit	**Quantity**	**Source**
Total Area	Acres	2.4	Calculated
Total Cut Volume	Cubic Yards	8,700	Calculated
Excavation Cost Per Unit	$ Per Bank Cubic Yard	$ 6.20	RS Means 31 23 16.50 1400
Excavation Subtotal	$	$ 53,940.00	Calculated
Topsoil Volume	Bank Cubic Yard	1,936	Calculated
Topsoil Replacement Cost Per Unit	$ Per Bank Cubic Yard	$ 6.15	RS Means 32 91 19.13 0400
Topsoil Replacement Subtotal	$	$ 11,906.39	Calculated
Seeding Cost Per Unit	$ Per Thousand Square Feet	$ 67.50	RS Means 32 92 19.14 2400
Seeding Subtotal	$	$ 7,056.72	calculated
Rough Grading Subtotal	$ for 75,100-100,000 S.F.	$ 5,050.00	RS Means 31 22 13.20 0280
	Alkali Outlet Total Cost =	$ 77,953.11	
	Inflation Since 2014 (25.4%) =	$ 97,753.20	
Crossing at 91st Ave SE and 24th St SE with 8-ft x 8-ft Box Culverts			
Crossing Cost Per Unit	$	$ 1,100,000.00	ND Dept. of Transportation
Number of Culverts	-	3	Calculated
	Culvert Total Cost =	$ 3,300,000.00	
	Inflation Since 2021 (9.5%) =	$ 3,613,500.00	
100-ft Wide Steel Sheet Pile Weir at Spiritwood Lake's East Outlet			
Total Sheet Pile Area	Square Feet	600	Calculated
Sheet Pile Materials	$ Per Square Foot	$ 40.00	Ducks Unlimited
Materials Subtotal	$	$ 24,000.00	Calculated
Sheet Pile Installation	$ Per Square Foot	$ 30.00	Ducks Unlimited
Sheet Pile Installation Subtotal	$	$ 18,000.00	Calculated
	Materials/Install Total Cost =	$ 42,000.00	

100-ft Wide Excavation for Sheet Pile Weir Location (Length about 300 ft)			
Total Area	Acres	1	Calculated
Total Cut Volume	Cubic Yards	8,200	Calculated
Excavation Cost Per Unit	$ Per Bank Cubic Yard	$ 6.20	RS Means 31 23 16.50 1400
Excavation Subtotal	$	$ 50,840.00	Calculated
Topsoil Volume	Bank Cubic Yard	807	Calculated
Topsoil Replacement Cost Per Unit	$ Per Bank Cubic Yard	$ 6.15	RS Means 32 91 19.13 0400
Topsoil Replacement Subtotal	$	$ 4,961.00	Calculated
Seeding Cost Per Unit	$ Per Thousand Square Feet	$ 67.50	RS Means 32 92 19.14 2400
Seeding Subtotal	$	$ 2,940.30	Calculated
Rough Grading Subtotal	$ for 40,100-45,000 S.F.	$ 2,275.00	RS Means 31 22 13.20 0250
	Weir Excavation Total Cost =	$ 61,016.30	
	Inflation Since 2014 (25.4%) =	$ 76,514.43	

Combination 1 Alternative Total =	$ 3,829,767.63
Total with 20% Contingency =	$ 4,595,721.16
Rounded Cost Estimate =	**$ 4,600,000**

2.3.2 Combination 2

Combination 2 would convey water from the west outlet of Spiritwood Lake to Seven Mile Coulee. The alternative includes the following features:

- Lowering Spiritwood Lake to elevation 1442 ft (NAVD88)
- Adding a 20-foot weir at the west outlet of Spiritwood Lake
- Placing a 20-foot-wide span bridge through 24th Street SE
- Improving Seven Mile Coulee with a 20-foot-wide trapezoidal channel from Spiritwood Lake’s west outlet past approximately Alkali Lake’s outlet

It should be noted that the weir, bridge, and channelizing of Seven Mile Coulee as described for this combination were not evaluated as individual alternatives or single actions. The process of directly modeling many iterations of individual alternatives, along with numerous combinations of alternatives, provided knowledge on the responsiveness of the system. This knowledge informed what actions to combine to create this alternative.

This alternative reduced Spiritwood Lake’s water surface elevation less compared to Combination 1. **Figure 12** illustrates the hydrographs for each frequency event for the No Action and Combination 2 alternatives.

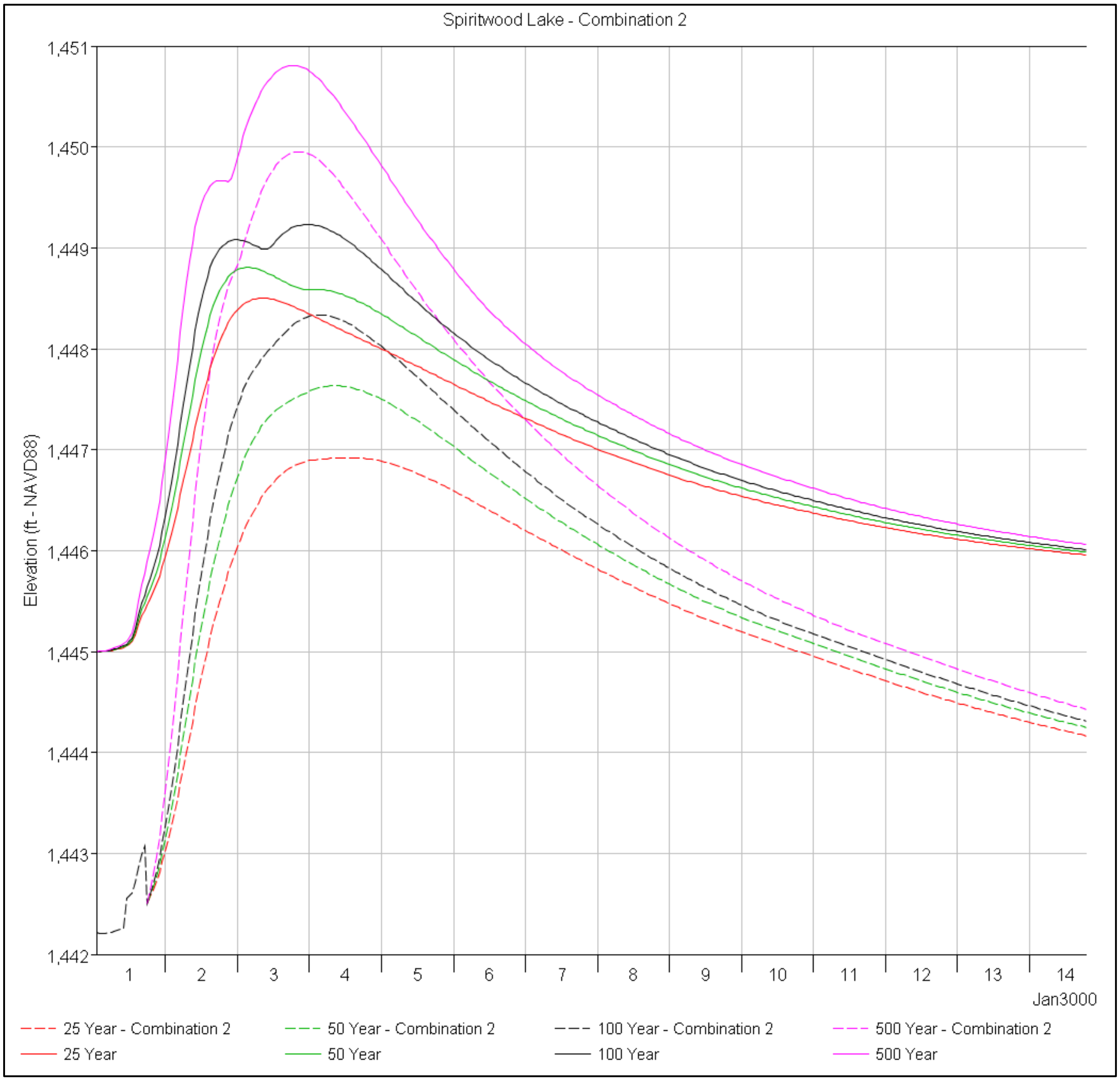

Figure 12. Spiritwood Lake frequency event hydrographs for No Action versus Combination 2 alternatives.

The alternative reduced the water surface elevation at Spiritwood Lake from elevation 1449.2 ft (NAVD88) to 1448.3 ft (NAVD88) during the 100-year frequency event. This reduction in water surface elevation prevents one structure, with an estimated value of $325,300, from being inundated during this frequency event. **Table 4** provides the number of structures inundated for each frequency event for the Combination 2 alternative.

Table 4. Structures inundated by each frequency event for the Combination 2 alternative.

Event	Event Elevation (ft - NAVD88)	Number of Structures Inundated	Total Structure Value
10 Year	1446.1	0	$ -
25 Year	1446.9	1	$ 126,000
50 Year	1447.6	1	$ 126,000
100 Year	1448.3	5	$ 472,900
500 Year	1450	8	$ 1,018,600

Cost estimates were completed for the Seven Mile Coulee channelization, bridge, and weir at the west outlet of Spiritwood Lake.

RS Means Heavy Construction Cost Data (RSMeans, 2014) was used to estimate channelization costs of Seven Mile Coulee, starting at the west outlet of Spiritwood Lake past the point where Alkali Lake outlets into the coulee. The length of channelization was based on topography and calculated to be about 2.7 miles, with a total cut volume of about 115,600 cubic yards. It should be noted that LiDAR downstream of Spiritwood Lake's west outlet is highly affected by channel vegetation, and realistically, channelization or cleanout may need to go further. The estimated cost was determined to be about $1.2 million, which accounts for a cumulative inflation rate of 24.5% since 2014 (US Inflation Calculator, 2022). The cost estimate includes excavation, topsoil replacement, grading, and seeding.

The cost estimate for placing a 20-foot-wide span bridge at 24th Street SE was obtained through personal communication with NDDOT staff (NDDOT 2, 2021). NDDOT staff confirmed that the cost of a bridge would be approximately $2 million. Accounting for a cumulative inflation rate of 9.5% since 2021, the cost of the bridge would be about $2.2 million (US Inflation Calculator, 2022).

The same Ducks Unlimited information (DU, 2022) was utilized for estimating the cost of a weir at the west outlet of Spiritwood Lake. Based on that information, the cost was estimated to be about $8,400. This is based on a weir approach height of 2 feet, with 4 feet of sheeting in the ground (6-foot height total), and a width of 20 feet. This design would most likely change based on soil tests, groundwater levels, and other onsite conditions.

The total cost of Combination 2 alternative is about $4.1 million, which includes a 20% contingency. A summary of the estimate is included in **Table 5**. There is uncertainty in this estimate related to engineering costs required for detailed design, permitting costs, legal costs for obtaining easements, or costs for buying out or modifying structures that remain prone to flooding.

Table 5. Cost estimate summary for Combination 2 alternative.

Seven Mile Coulee 20-ft Bottom Width Channel (Length about 2.7 miles)			
	Unit	**Quantity**	**Source**
Total Area	Acres	16.4	Calculated
Total Cut Volume	Cubic Yards	115,600	Calculated
Excavation Cost Per Unit	$ Per Bank Cubic Yard	$ 6.20	RS Means 31 23 16.50 1400
Excavation Subtotal	$	$ 716,720.00	Calculated
Topsoil Volume	Bank Cubic Yard	13,229	Calculated
Topsoil Replacement Cost Per Unit	$ Per Bank Cubic Yard	$ 6.15	RS Means 32 91 19.13 0400
Topsoil Replacement Subtotal	$	$ 81,360.32	Calculated
Seeding Cost Per Unit	$ Per Thousand Square Feet	$ 67.50	RS Means 32 92 19.14 2400
Seeding Subtotal	$	$ 48,220.92	Calculated
Grading	$ Per Square Yard	$ 0.91	RS Means 31 22 16.10 0100
Grading Subtotal	$	$ 72,232.16	Calculated
	Spiritwood West Outlet Total Cost =	$ 918,533.40	
	Inflation Since 2014 (25.4%) =	$ 1,151,840.88	

20-ft Wide Span Bridge at 24th St SE			
Bridge Cost Per Unit	$	$ 2,000,000.00	ND Dept. of Transportation
Number of Bridges	-	1	Calculated
	Bridge Total Cost =	$ 2,000,000.00	
	Inflation Since 2021 (9.5%) =	$ 2,190,000.00	

20-ft Wide Steel Sheet Pile Weir at Spiritwood Lake's West Outlet			
Total Sheet Pile Area	Square Feet	120	Calculated
Sheet Pile Materials	$ Per Square Foot	$ 40.00	Ducks Unlimited
Materials Subtotal	$	$ 4,800.00	Calculated
Sheet Pile Installation	$ Per Square Foot	$ 30.00	Ducks Unlimited
Sheet Pile Installation Subtotal	$	$ 3,600.00	Calculated
	Materials/Install Total Cost =	$ 8,400.00	

Combination 2 Alternative Total =	$ 3,350,240.88
Total with 20% Contingency =	$ 4,020,289.06
Rounded Cost Estimate =	**$ 4,100,000**

2.3.3 Economic Analysis

An economic analysis was conducted for the purposes of determining a benefit-to-cost ratio for each combination alternative. The analysis followed the process developed by the North Dakota Department of Water Resources (NDDWR, 2022) for reviewing cost share requests.

The analysis only focused on flood damages to structures (i.e., urban damages) and required the following information:

- Structure square footage
- Structure value
- Structure type (e.g., 1 story with basement)
- Water depths at structures for each frequency event for No Action and Combination 1 and 2 alternatives
- Project cost

Structure square footage, value, and type was obtained from property sheets from Stutsman County's tax website (Stutsman County, 2022). The value was the 2021 building assessment value from the tax information. The square footage was the sum of the living area, basement, garages, and decks.

Water depths at structures for the 25, 50, 100, and 500-year events were obtained from the hydraulic model. A summary of the water depths for each affected structure for the No Action, Combination 1, and Combination 2 alternatives is shown in **Table 6**. The cost estimate for each combination alternative was used as the project cost. The structure ID numbers in **Table 6** correspond to **Figure 2**.

The parameters described above were entered into the economic analysis worksheet that is available on NDDWR's website (NDDWR, 2022). Using this information, the worksheet automatically calculates the net present value of flood control benefits over 50 years for each structure by calculating the difference between damages with and without the project. The economic analysis worksheet for each alternative is included in electronic **Appendix E**. The results summary sheets for both alternatives are shown in **Figures 13** and **14**. These figures show several categories of benefits that were calculated for this study, which are described in more detail in NDDWR's economic analysis guidance document (NDDWR, 2022). In general, they mean the following:

- Flood Mitigation Benefits: Present value of avoided structure damages avoided with the alternative.
- Flood Relocation: Estimated costs of disaster relief. Based on studies from the U.S. Army Corps of Engineers (USACE) (7% of expected annual damages).
- Flood Fighting: Estimated emergency costs for flood fighting and volunteer costs, and EMS response impacts. Based on USACE reports (9% of expected annual damages).

- Social Benefits: Value to society associated with mental well-being from reducing the risk of flooding. Based on FEMA guidance.

The benefits and costs are presented as both present value and average annual present value. The present value represents the total monetary value of a benefit or cost over the life of the project (default is 50 years), converted to present dollars using the time value of money and the USACE published discount rate for water projects. The discount rate is applied to future benefits and costs to convert those to present dollar values. The average annual value represents the average present value benefit or cost per year for the life of the project.

The benefits and costs are finally summarized into three performance metrics: benefit-to-cost ratio, net benefits, and payback year. These metrics illustrate the relationship between project benefits and costs and assist in determining the economic efficiency of each alternative.

The benefit-to-cost ratio is the ratio of present values of total benefits to costs. A benefit-to-cost ratio that is greater than one indicates that benefits exceed costs.

The net benefit of a project is the difference between the present values of total benefits and costs of a project. If this value is positive, the project benefits exceed its expected costs.

The payback period represents the number of years for the project benefits to repay initial project costs. A negative value means that the project never reaches a breakeven point during the life of the project between the benefits and costs.

The benefit-to-cost ratios for Combination 1 and Combination 2 alternatives were determined to be 0.006 and 0.005, respectively. In addition, for both alternatives, the net benefit was negative, and there was no payback period. Due to unfavorable performance metrics, it may be worth considering a non-structural alternative, such as a buyout of impacted structures. The total value of structures impacted by the No Action alternative is $1,535,600.

Table 6. Water depths for affected structures for each alternative and frequency event. Highlighted cells represent instances of structure flooding. Structure IDs correspond to Figure 2.

		Water Depth at Structures (ft)														
		No Action Alternative					**Combination 1 Alternative**					**Combination 2 Alternative**				
Structure ID	Structure Value ($)	10-year	25-year	50-year	100-year	500-year	10-year	25-year	50-year	100-year	500-year	10-year	25-year	50-year	100-year	500-year
90	126,000	2	2.4	2.7	3.1	4.7	-1	0.2	0.7	1.3	3	0	0.8	1.5	2.2	3.9
61	56,100	0.5	0.9	1.2	1.6	3.2	-2.5	-1.3	-0.8	-0.2	1.5	-1.5	-0.7	0	0.7	2.4
91	127,200	0.3	0.7	1	1.4	3	-2.7	-1.5	-1	-0.4	1.3	-1.7	-0.9	-0.2	0.5	2.2
89	49,100	0.1	0.5	0.8	1.2	2.8	-2.9	-1.7	-1.2	-0.6	1.1	-1.9	-1.1	-0.4	0.3	2
1	114,500	0	0.4	0.7	1.1	2.7	-3	-1.8	-1.3	-0.7	1	-2	-1.2	-0.5	0.2	1.9
4	325,300	-1	-0.6	-0.3	0.1	1.7	-4	-2.8	-2.3	-1.7	0	-3	-2.2	-1.5	-0.8	0.9
80	133,200	-1.1	-0.7	-0.4	0	1.6	-4.1	-2.9	-2.4	-1.8	-0.1	-3.1	-2.3	-1.6	-0.9	0.8
27	87,200	-1.8	-1.4	-1.1	-0.7	0.9	-4.8	-3.6	-3.1	-2.5	-0.8	-3.8	-3	-2.3	-1.6	0.1
5	131,100	-2	-1.6	-1.3	-0.9	0.7	-5	-3.8	-3.3	-2.7	-1	-4	-3.2	-2.5	-1.8	-0.1
29	36,500	-2.2	-1.8	-1.5	-1.1	0.5	-5.2	-4	-3.5	-2.9	-1.2	-4.2	-3.4	-2.7	-2	-0.3
3	24,900	-2.3	-1.9	-1.6	-1.2	0.4	-5.3	-4.1	-3.6	-3	-1.3	-4.3	-3.5	-2.8	-2.1	-0.4
18	23,700	-2.3	-1.9	-1.6	-1.2	0.4	-5.3	-4.1	-3.6	-3	-1.3	-4.3	-3.5	-2.8	-2.1	-0.4
93	250,800	-2.3	-1.9	-1.6	-1.2	0.4	-5.3	-4.1	-3.6	-3	-1.3	-4.3	-3.5	-2.8	-2.1	-0.4
16	50,000	-2.6	-2.2	-1.9	-1.5	0.1	-5.6	-4.4	-3.9	-3.3	-1.6	-4.6	-3.8	-3.1	-2.4	-0.7

5 - Results Summary

This worksheet serves as the summary for all outputs created in the model. For the given inputs, the Results Summary provides an overview of present value and average annual benefits and costs. The Results Summary also presents project performance metrics including: Benefit-to-Cost Ratios, Net Benefits, Internal Rate of Return, and Payback Year.

Scenario Analysis - Benefit Summary

Urban Flood Control Benefits	Present Value ($1K)	Average Annual ($1K)
Flood Mitigation Benefits	$21	$1
Flood Relocation	$1	$0
Travel Time Delays	$0	$0
Flood Fighting	$2	$0
Social Benefits	$1	$0
Subtotal	$25	$1
Other Benefits		
Other Benefits	$0	$0
Consumptive	$0	$0
Non-Consumptive	$0	$0
Rural Flood Conveyance and Other Benefits		
Rural Flooding Benefit	$0	$0
Bank Erosion Benefit	$0	$0
Cleanup Cost Benefit	$0	$0
Sediment Removal Benefit	$0	$0
Stored Water Benefit	$0	$0
Detour Benefit	$0	$0
Total Rural Mitigation Benefits	$0	$0
Subtotal	$0	$0
Grand Total	$25	$1

Project Costs	Present Value ($1K)	Average Annual ($1K)
Capital Costs	$4,549	$152
Annual O&M	$0	$0
Total	$4,549	$152

Project Performance Metrics	Present Value ($1K)	Average Annual ($1K)
Benefit-to-Cost Ratio	0.006	
Net Benefits	-$4,524	-$152
Payback Year	None	

Figure 13. Economic analysis results summary sheet for Combination 1 alternative.

5 - Results Summary

This worksheet serves as the summary for all outputs created in the model. For the given inputs, the Results Summary provides an overview of present value and average annual benefits and costs. The Results Summary also presents project performance metrics including: Benefit-to-Cost Ratios, Net Benefits, Internal Rate of Return, and Payback Year.

Scenario Analysis - Benefit Summary

Urban Flood Control Benefits	Present Value ($1K)	Average Annual ($1K)
Flood Mitigation Benefits	$18	$1
Flood Relocation	$1	$0
Travel Time Delays	$0	$0
Flood Fighting	$2	$0
Social Benefits	$1	$0
Subtotal	$21	$1
Other Benefits		
Other Benefits	$0	$0
Consumptive	$0	$0
Non-Consumptive	$0	$0
Rural Flood Conveyance and Other Benefits		
Rural Flooding Benefit	$0	$0
Bank Erosion Benefit	$0	$0
Cleanup Cost Benefit	$0	$0
Sediment Removal Benefit	$0	$0
Stored Water Benefit	$0	$0
Detour Benefit	$0	$0
Total Rural Mitigation Benefits	$0	$0
Subtotal	$0	$0
Grand Total	$21	$1

Project Costs	Present Value ($1K)	Average Annual ($1K)
Capital Costs	$4,055	$136
Annual O&M	$0	$0
Total	$4,055	$136

Project Performance Metrics	Present Value ($1K)	Average Annual ($1K)
Benefit-to-Cost Ratio	0.005	
Net Benefits	-$4,034	-$135
Payback Year	None	

Figure 14. Economic analysis results summary sheet for Combination 2 alternative.

2.3.4 Impacts to Seven Mile Coulee from combination alternatives

Only Combination 1 was run through the downstream impacts hydraulic model, due to Combination 2 having a lackluster impact on Spiritwood Lake's water surface. The effects of Combination 1 on water surface elevations along Seven Mile Coulee appear to be less than during existing conditions. However, with each lake starting to discharge earlier and perhaps more frequently into Seven Mile Coulee, many unknowns still exist regarding the impacts of this type of project. It should also be noted that implementation of any combination alternative requires a one-time drawdown of the lakes, which would have impacts that are not shown through modeling in this report. **Figure 15** illustrates the hydrograph comparison of the No Action and Combination 1 alternatives at the Alkali Lake outlet.

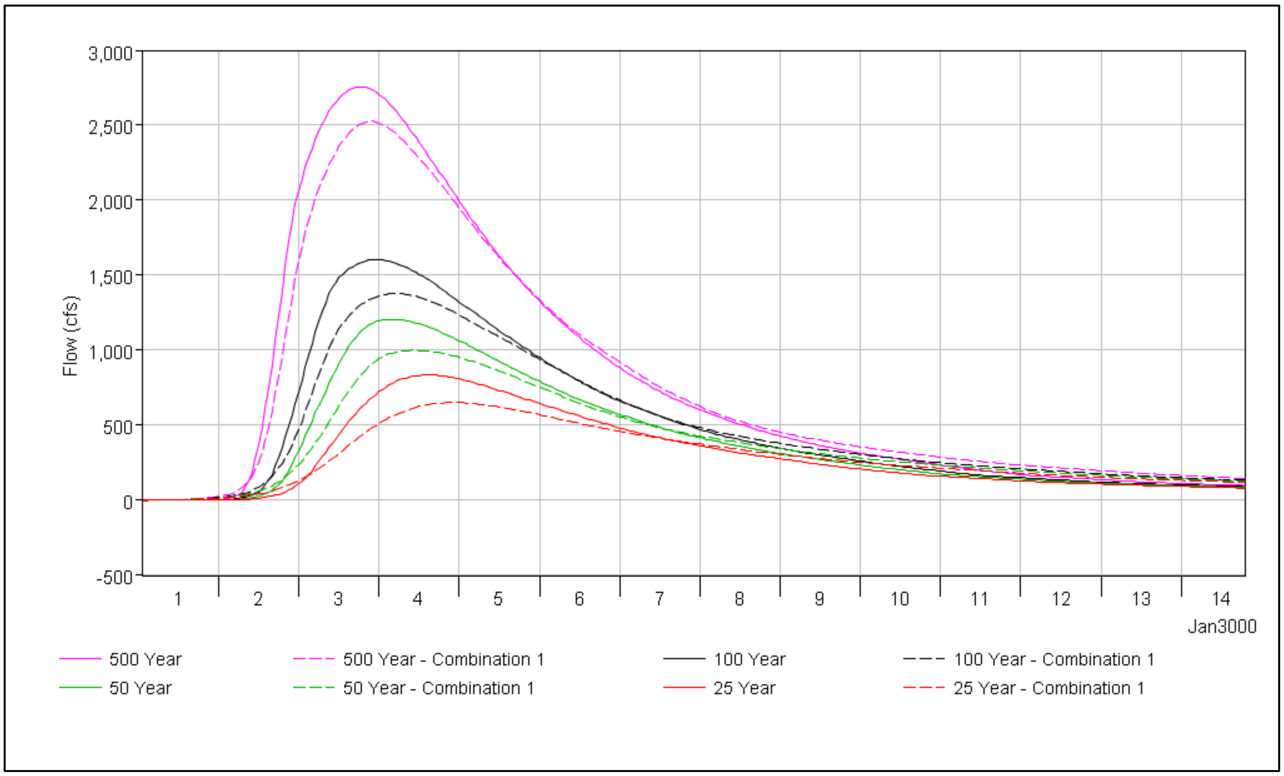

Figure 15. Hydrograph comparison of No Action versus Combination 1 alternatives at Alkali Lake Outlet.

Additional maps comparing the water surface differences between the No Action and Combination 1 alternatives are provided in the attached **Appendix E1**.

3.0 REFERENCES

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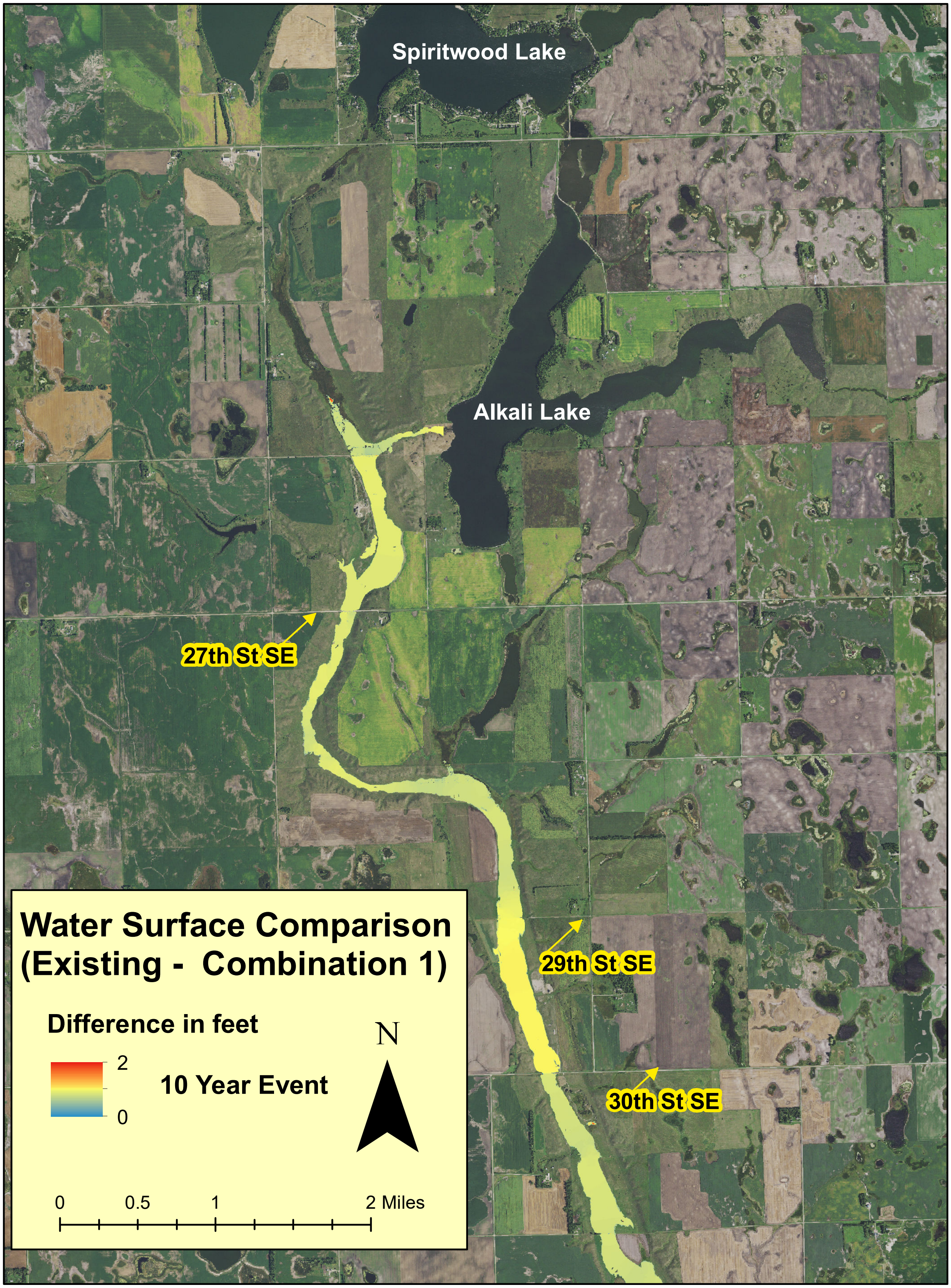
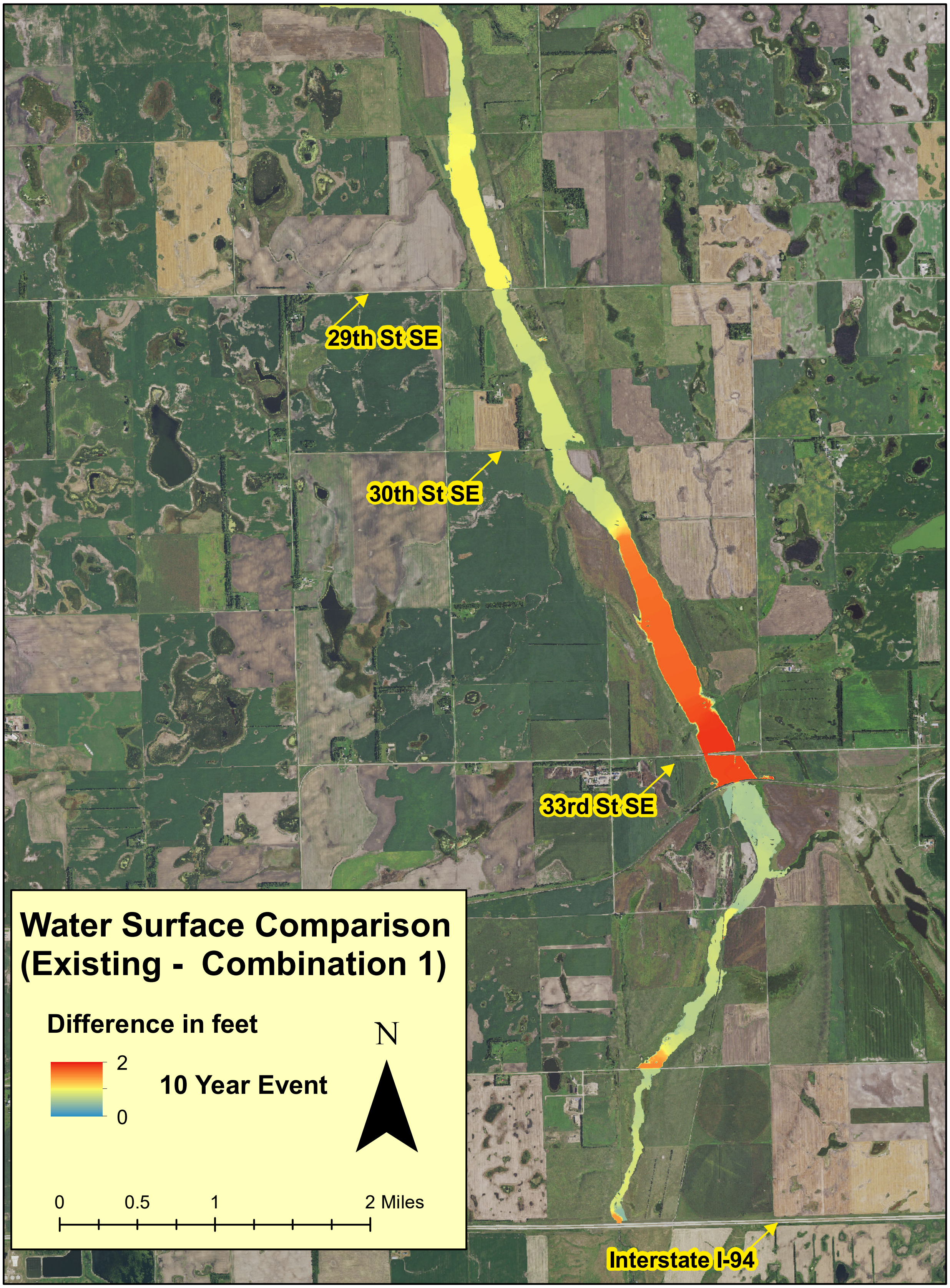
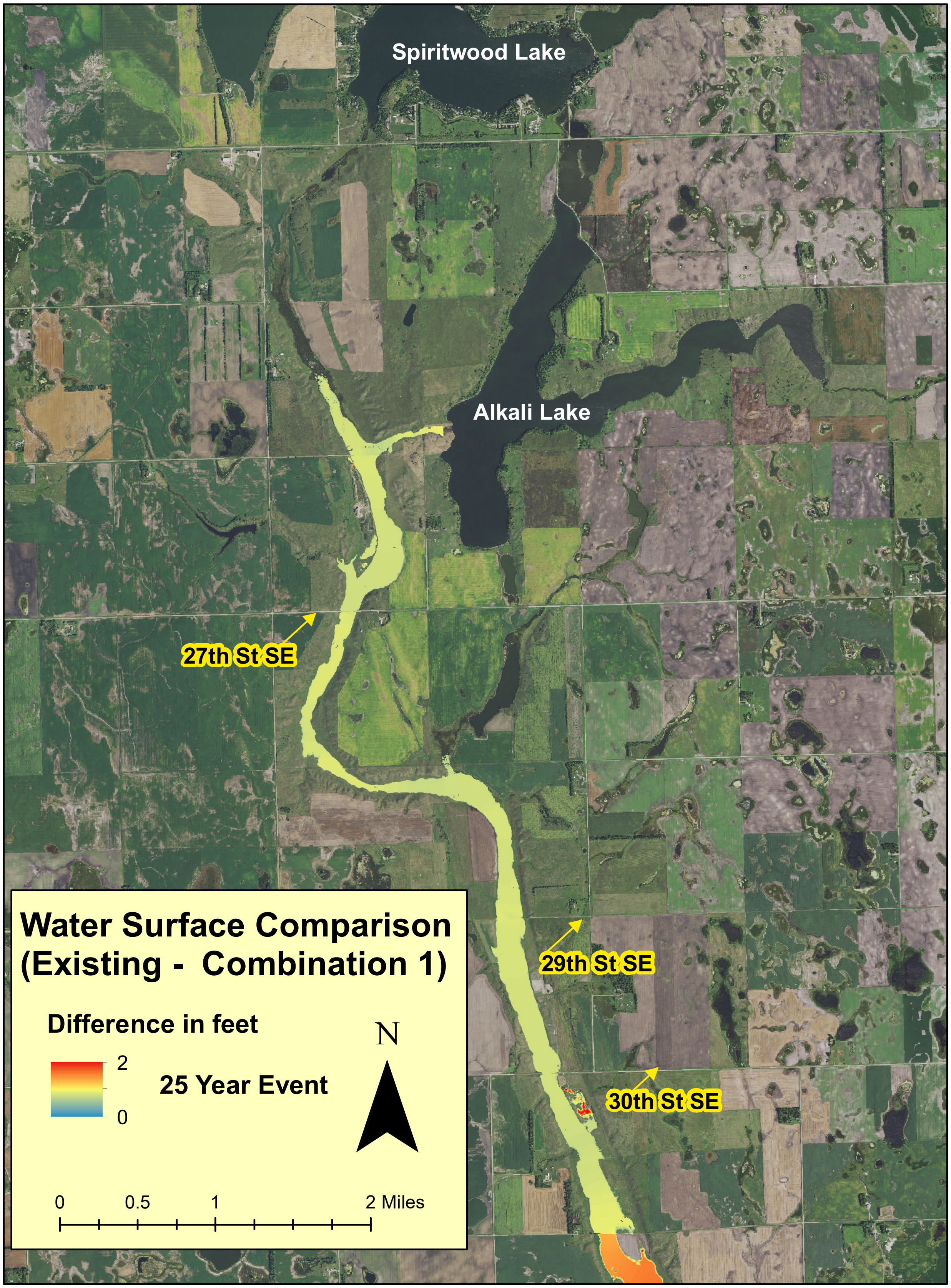
APPENDIX E1

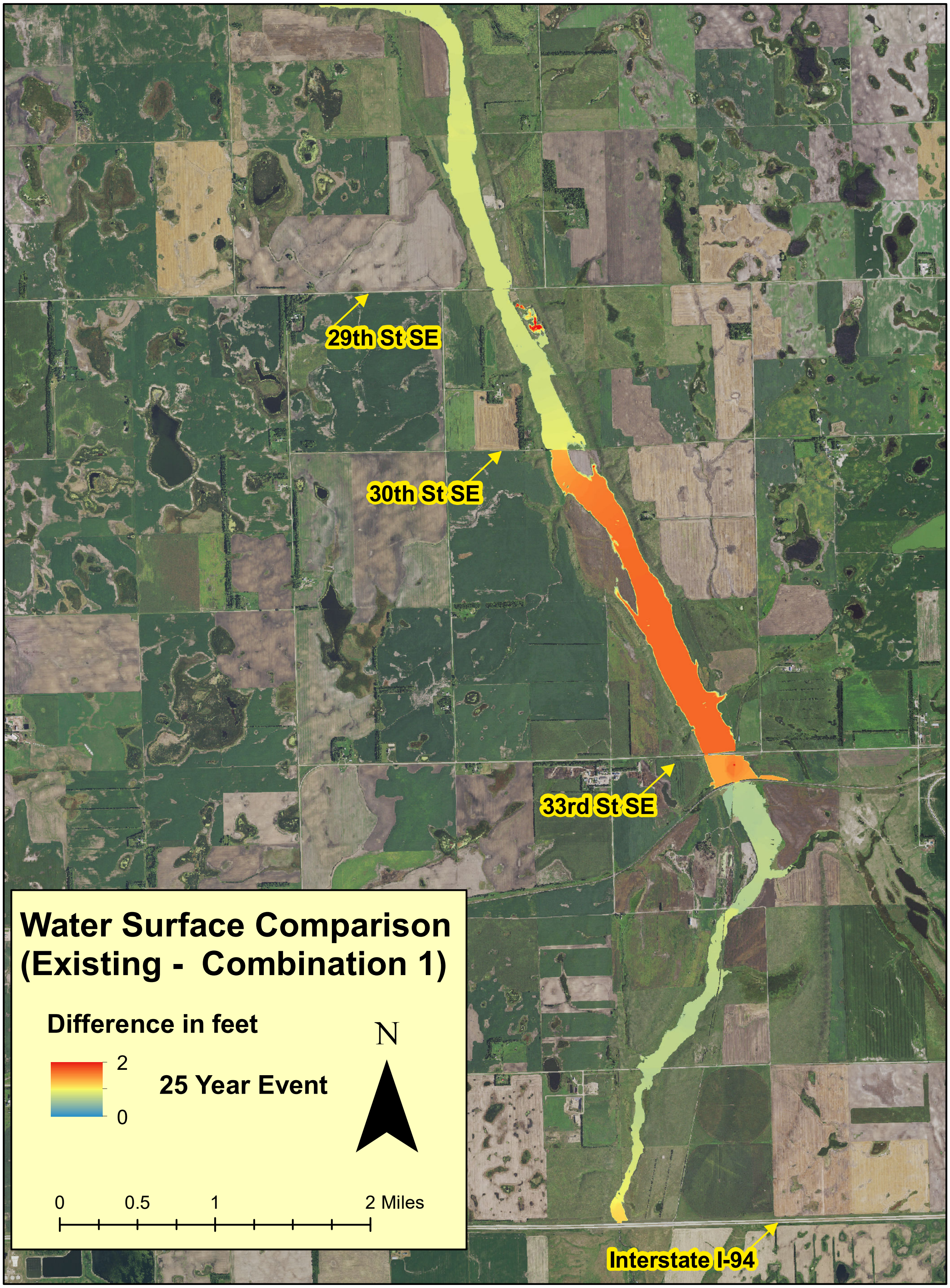
Downstream Impact Maps of Seven Mile Coulee for Combination 1 alternative: Water Surface Differences between No Action (existing conditions) and Combination 1 alternatives for 10, 25, 50, 100, and 500-year events

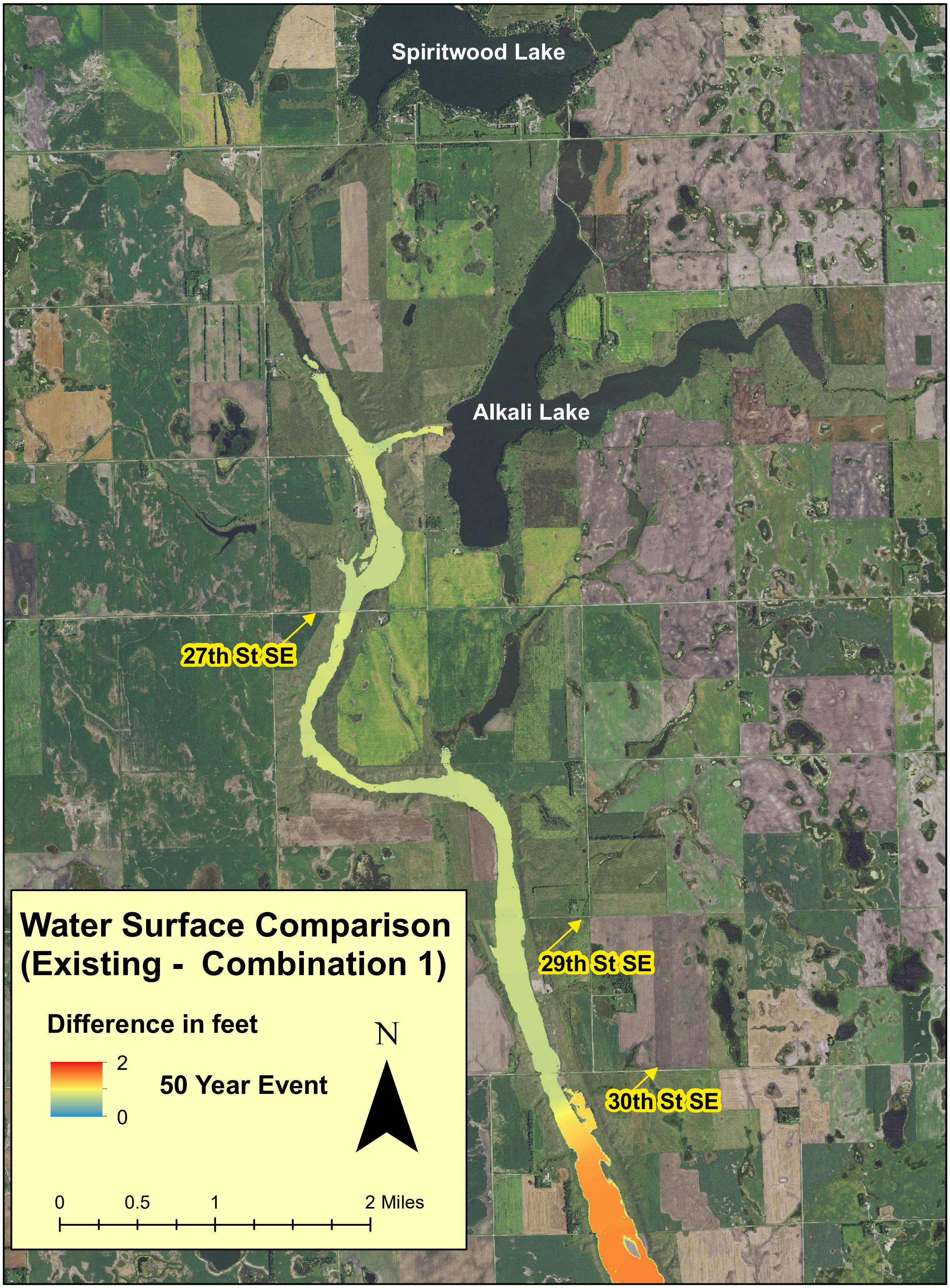

Spiritwood Lake
Alkali Lake
27th St SE
29th St SE
30th St SE
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
10 Year Event
N
0
0.5
1
2 Miles

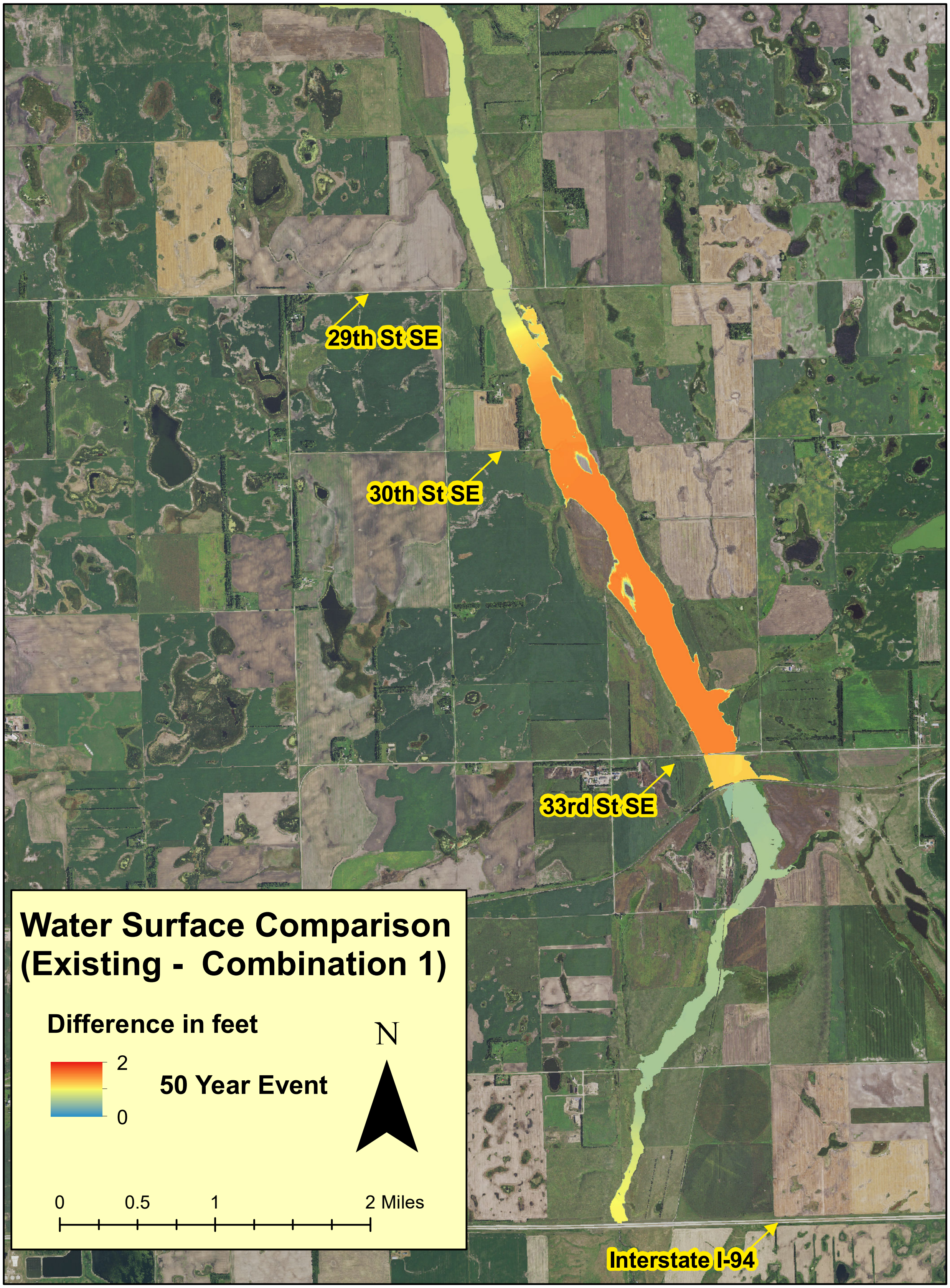


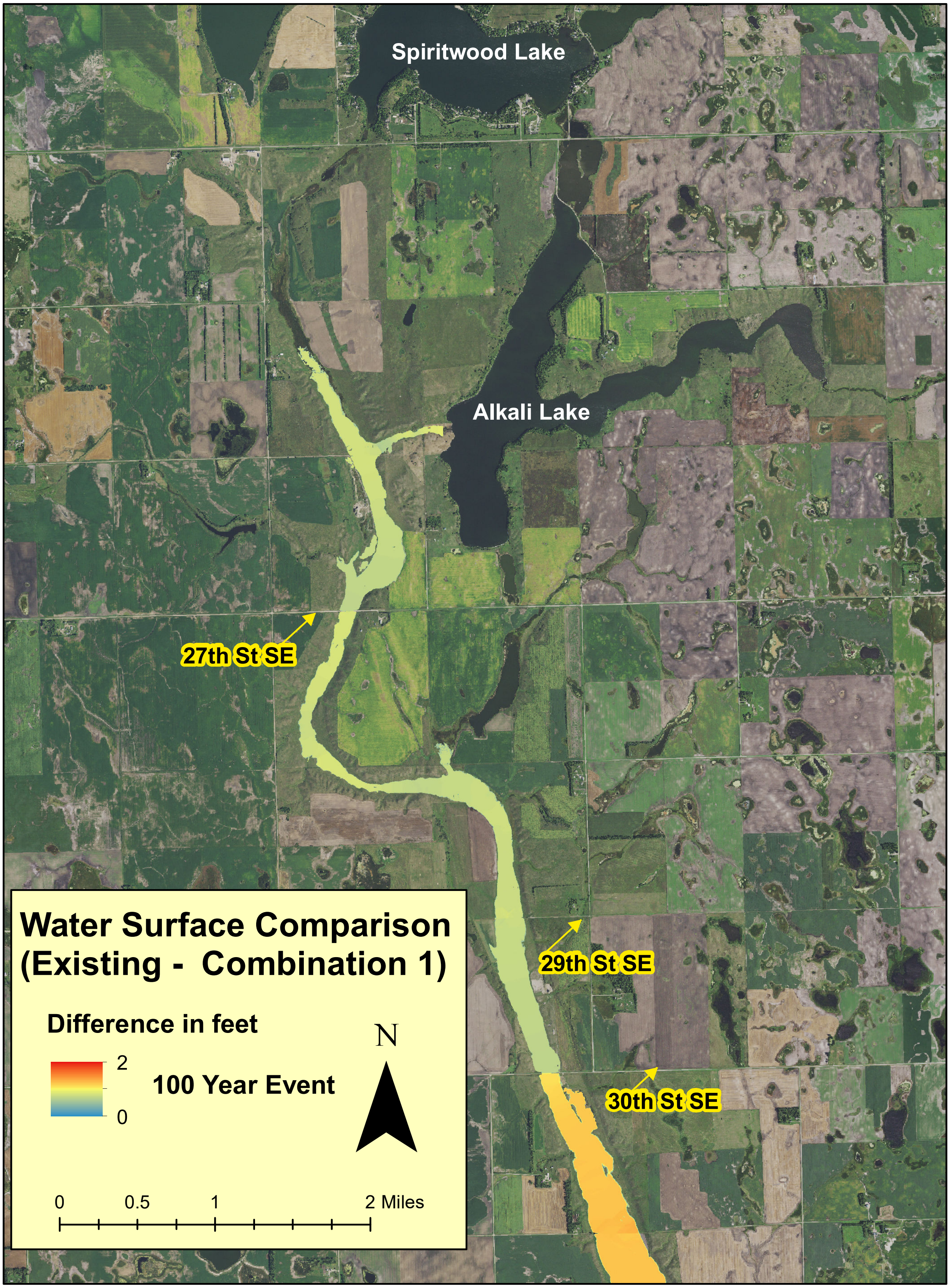
29th St SE
30th St SE
33rd St SE
Interstate I-94
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
10 Year Event
N
0
0.5
1
2 Miles

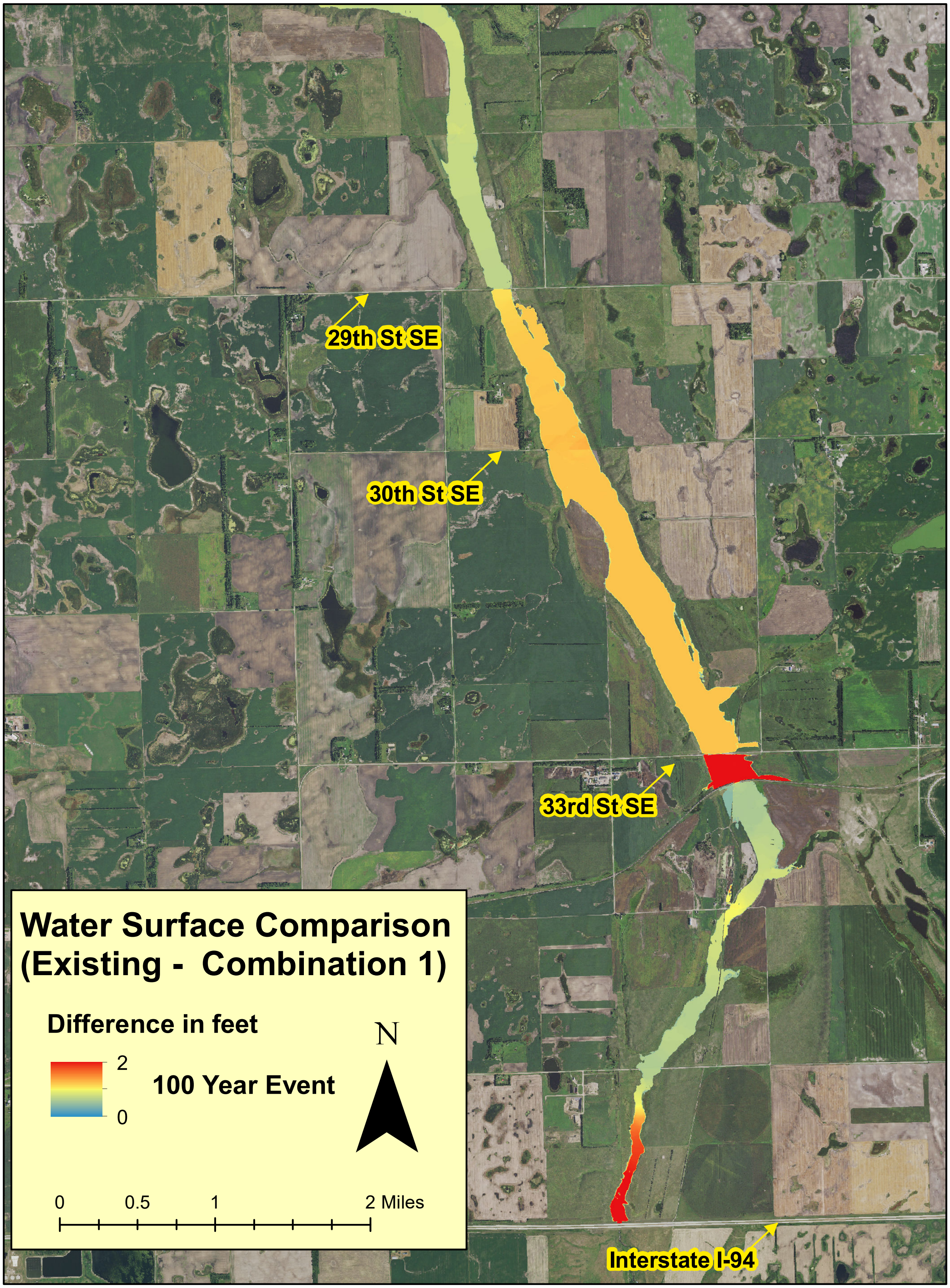

Spiritwood Lake
Alkali Lake
27th St SE
29th St SE
30th St SE
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
25 Year Event
N
0
0.5
1
2 Miles

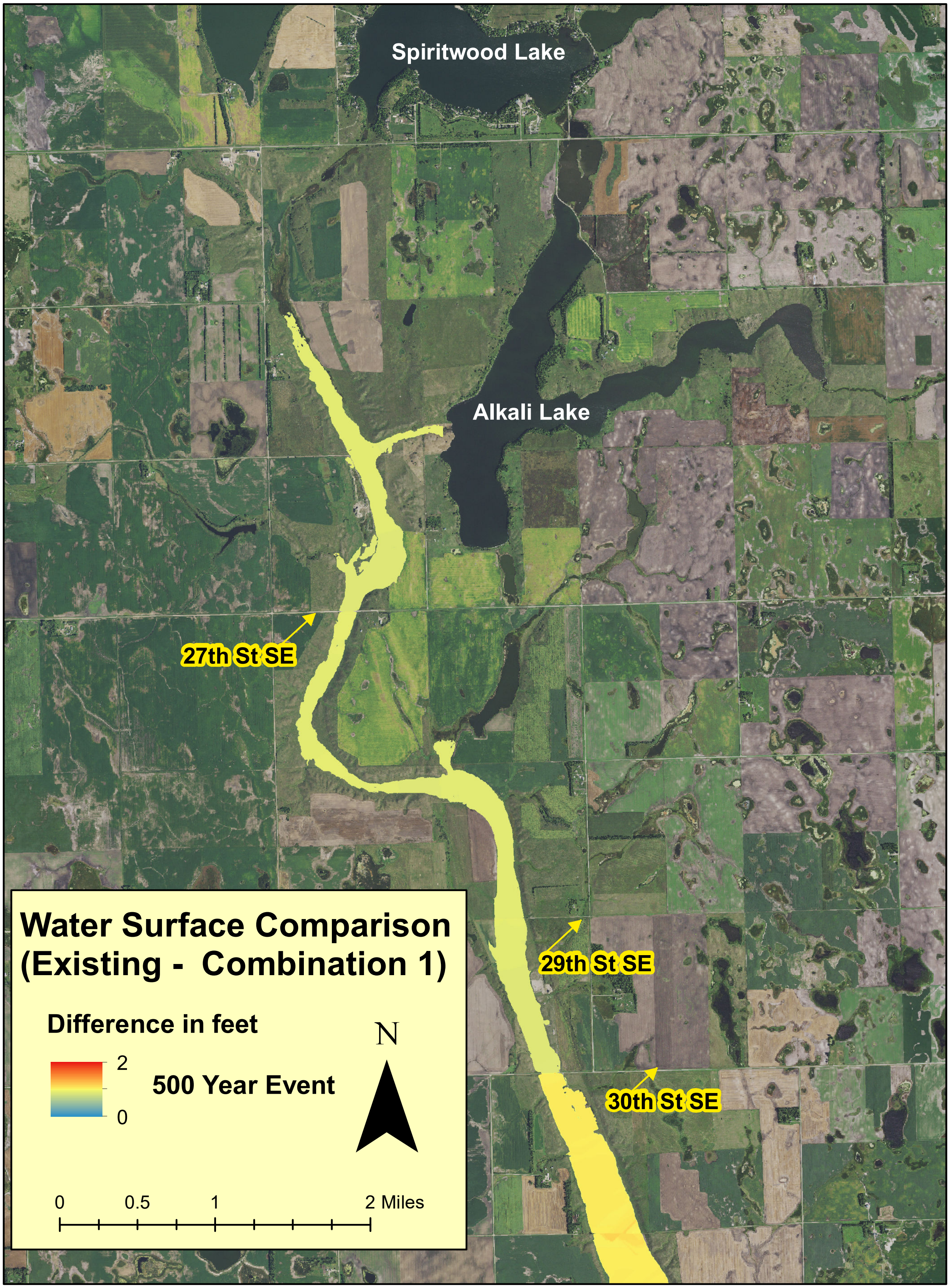

29th St SE
30th St SE
33rd St SE
Interstate I-94
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
25 Year Event
N
0
0.5
1
2 Miles

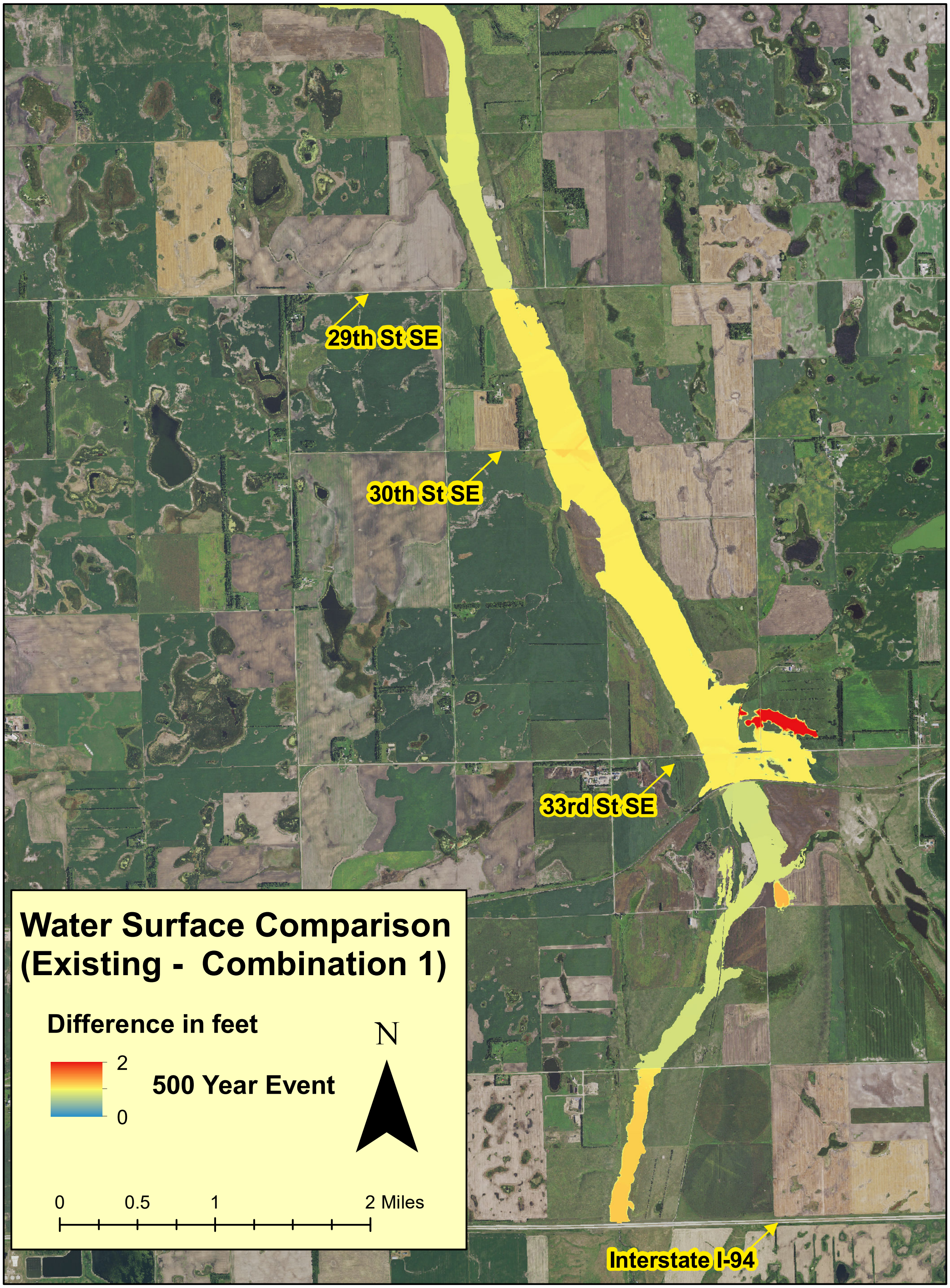

Spiritwood Lake
Alkali Lake
27th St SE
29th St SE
30th St SE
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
50 Year Event
N
0
0.5
1
2 Miles


29th St SE
30th St SE
33rd St SE
Interstate I-94
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
50 Year Event
N
0
0.5
1
2 Miles


Spiritwood Lake
Alkali Lake
27th St SE
29th St SE
30th St SE
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
100 Year Event
N
0
0.5
1
2 Miles


29th St SE
30th St SE
33rd St SE
Interstate I-94
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
100 Year Event
N
0
0.5
1
2 Miles


Spiritwood Lake
Alkali Lake
27th St SE
29th St SE
30th St SE
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
500 Year Event
N
0
0.5
1
2 Miles


29th St SE
30th St SE
33rd St SE
Interstate I-94
Water Surface Comparison
(Existing - Combination 1)
Difference in feet
2
0
500 Year Event
N
0
0.5
1
2 Miles