LB1023 (JEDI) IMPACT EVALUATION FOR CITY OF LINCOLN WATER SYSTEM AND METROPOLITAN UTILITIES DISTRICT: ANALYSIS SUMMARY AND FINAL REPORT

CITY PROJECT NO. 702309

OLSSON PROJECT NO. 021-01559

BLACK & VEATCH PROJECT NO. 413017

PREPARED FOR

LINCOLN
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METROPOLITAN
UTILITIES DISTRICT

CITY OF LINCOLN WATER SYSTEM
METROPOLITAN UTILITIES DISTRICT
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Project Name: LB 1023 (JEDI) Impact Evaluation for City of Lincoln Water System and Metropolitan Utilities District
Project Address/Location: Cass, Dodge, Douglas, Sarpy, and Saunders Counties

ACRONYMS AND ABBREVIATIONS

AEM..Aerial Electromagnetic (Survey)
CLOMR...Conditional Letter of Map Revision
DEM...Digital Elevation Model
FEMA... Federal Emergency Management Agency
JEDI...Jobs and Economic Development Initiative
LPMT...Lower Platte Missouri Tributaries Model
LWS... City of Lincoln Water System
MODFLOW .............U.S. Geological Survey Modular Finite-difference Groundwater Flow Model
MODPATH...U.S. Geological Particle-tracking Model for MODFLOW
MUD .... Omaha Metropolitan Utilities District
NDED ....Nebraska Department of Economic Development
NDEE.. Nebraska Department of Environment and Energy
NeDNR ....Nebraska Department of Natural Resources
STARWARS .. Statewide Tourism And Recreational Water Access and Resources Sustainability
USGS ....U.S. Geological Survey
WhAEM...Wellhead Analytic Element Model
WHPA... Wellhead Protection Area

TABLE OF CONTENTS

Executive Summary 1
1. Project Historical Context 1
  1.1 LB406 (2021): The STARWARS Committee 1
  1.2 LB1023 (2022) and the Jobs and Economic Development Initiative (JEDI) Act 2
2. Scope of Study 4
  2.1 City of Lincoln Water System, (Omaha) Metropolitan Utilities District, and State of Nebraska Involvement 4
  2.2 Study Purpose 4
  2.3 Summary of Analytical Reports 5
3. Development in Area of Interest 6
  3.1 Water Supply and Users 6
  3.2 Sandpit Lakes through Time 8
  3.3 Comprehensive Plans and Zoning 9
4. Overview of Analytical Processes and Results 11
  4.1 Possible Lake Location Selections 11
  4.2 Iterative Hydrologic Modeling Process and Results 16
  4.3 Water Balance Modeling Process and Results 21
  4.4 Desktop Geotechnical Analysis 23
  4.5 Geomorphic Analysis 24
  4.6 Additional Analysis 26
5. Conclusions 27
Appendix A: Groundwater Modeling Summary Report .... A-i
Appendix B: Surface Water Flood Modeling Report .... B-i
Appendix C: Water Balance Modeling Report .... C-i
Appendix D: Desktop Geotechnical Analysis Summary Report .... D-i
Appendix E: Geomorphic Analysis Report .... E-i

LIST OF FIGURES

Figure 1: Cover page of the STARWARS special committee final report.................................... 1
Figure 2: Lakes as conceptualized by HDR, Inc. in STARWARS Committee's final report.[3] 2
Figure 3: Wellhead protection areas in the study area.. 7
Figure 4: Progression of sandpit lake development in the study area... 9
Figure 5: Wellhead protection areas and originally conceptualized lake location.......................12
Figure 6: Example of reverse particle tracking scenario conducted for this study......................13
Figure 7: Lake locations initially considered in this study..15
Figure 8: JEDI groundwater model extent within the Lower Platte Missouri Tributaries model. .17
Figure 9: Boundaries of the surface water flood model developed for this study. 19
Figure 10: Example illustration of mass balance for a water balance analysis...........................22
Figure 11: Example of channel and floodplain velocities along the Platte River.........................25

LIST OF TABLES

Table 1: Major Conclusions of LB1023 (JEDI) Impact Analysis for City of Lincoln Water System and Metropolitan Utilities District. 28

EXECUTIVE SUMMARY

In 2021 and 2022, the Nebraska legislature enacted LB406 and LB1023, respectively, which first established the Statewide Tourism And Recreational Water Access and Resources Sustainability (STAR WARS) special committee, and then the Lake Development Act which was codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (*Neb. Rev. Stat.* §61-401 to 61-404). In these pieces of legislation, the unicameral recognized the importance – in the wake of historic flooding in 2019 and the COVID-19 pandemic – for both flood control and major recreational opportunities in the state to attract and retain an increasingly remote workforce. The STAR WARS committee envisioned, in the lower Platte River corridor, a lake that would rival Iowa's Lake Okoboji as a tourist destination and hub for public-private partnerships to develop lakeside communities, a community town center, and a major resort. As outlined in the STAR WARS committee's report, a lake location northeast of the city of Ashland, Nebraska was contemplated and this informed the committee's recommendation that further analysis be conducted to inform viable locations for a lake of at least 3,600 acres, located in or near Sarpy County, and adjacent to – but not impounding – the Platte River.

Recognizing the potential for impacts to public water system wellfields, the legislature also appropriated funds to be administered through the Nebraska Department of Natural Resources (NeDNR) for further study on possible lake sites. The City of Lincoln Water System (LWS) already had its Water 2.0 project – investigating possibilities for additional source(s) of drinking water – underway with Black & Veatch and Olsson, and recognized that these consultants have the necessary expertise regarding the water system as well as expertise in the types of technical analysis needed for potential lake sites. Thus, LWS amended its Water 2.0 contract to include this study and entered into a memorandum of understanding with Omaha's Metropolitan Utilities District (MUD) to allow for MUD's wellfields and concerns to also be considered.

The scope of this study, then, was to: (1) construct and calibrate a subregional groundwater model and run scenarios to help inform where a lake of this scale should not be developed while considering wellfields and their associated wellhead protection areas (WHPAs); (2) develop and calibrate a two-dimensional surface water model of the Platte River and floodplain in the area of interest and use information from scenarios run with this model to inform further groundwater modeling to determine impacts of potential lakes on wellfields operated by the LWS and MUD; (3) evaluate impacts to local water balance resulting from lakes constructed at the identified potential locations, specifically estimating evaporation and evapotranspiration; (4) perform seepage analysis of potential lakes; and (5) evaluate geomorphic impacts of potential lakes, including impacts from flood events on geomorphology of the lake itself as well as fluvial geomorphology resulting from existence of a lake.

With LWS, MUD, and NeDNR serving as client advisors throughout this study, three potential lake sites were identified and analyzed: (1) a dammed lake on the Elkhorn River near Nickerson, Nebraska; (2) a dammed lake on Salt Creek between Greenwood and Ashland, Nebraska; and (3) an excavated lake along the Platte River downstream of Louisville, Nebraska. Midway through the study, the Nebraska Department of Economic Development (NDED) joined as a client advisor. Upon presentation of initial analytical results of these potential lake sites, the NDED also requested consideration of a small excavated lake along the Platte River upstream of Louisville – alongside the larger excavated lake downstream of Louisville that had already been analyzed – that had previously been eliminated from consideration. The purpose of considering both excavated lakes along the Platte River was to understand any change to the already-analyzed impacts for a total lake surface area, at these locations, that would be more similar to the legislatively envisioned 3,600+ acres (the combined acreage of both Platte River lakes in this study is roughly 3,000 acres).

For the Elkhorn River lake, which would have a footprint of approximately 4,100 acres, groundwater modeling indicated an increase in groundwater level of approximately 29.4 feet on the downstream end of the lake. Surface water modeling showed a decrease in the immediately downstream 100-year flood water surface elevations of up to 0.60 feet, and reduced 100-year flood water surface elevations along the Platte River of 0.01 foot or less. Water balance analysis indicated that, during exceptionally dry periods, water surface elevation of the lake would fluctuate but minimum flows (as defined by this analysis)[1] could be maintained downstream. The greatest concerns revealed by the desktop geotechnical seepage analysis were that foundation seepage rates could be highly variable and that relatively shallow bedrock could present concerns about karst conditions either being present or developing. Finally, the geomorphic analysis indicated substantial possible impacts on overall sediment, flow, and habitat downstream in the Platte River, and that negative impacts to water quality, habitat, fish passage, and flooding were possible for the Elkhorn River.

For the Salt Creek lake, which would also have a footprint of approximately 4,100 acres, groundwater modeling indicated an increase in groundwater level of approximately 41.8 feet on the downstream end of the lake. Surface water modeling showed a decrease in the immediately downstream 100-year flood water surface elevations of up to 0.30 feet, and reduced 100-year flood water surface elevations along the Platte River of 0.1 foot or less. Water balance analysis indicated that, during exceptionally dry periods, water surface elevation of the lake would

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[1] Required minimum flows were determined based on the monthly 10th percentile flows for each stream. Required minimum flows do not consider wellfield needs as defined by LWS or MUD or existing in-stream flow rights downstream of the lake locations. In addition, the Water Balance Analysis did not consider this recreational lake as a water supply and also assumed a minimum flow during drought conditions for releases to support biological integrity.

fluctuate significantly but minimum flows (as defined by this analysis)[1] could be maintained downstream. The greatest concern revealed by the desktop geotechnical seepage analysis was that foundation seepage rates could be highly variable. Finally, the geomorphic analysis indicated minimal possible impacts on overall sediment, flow, and habitat downstream in the Platte River, but that negative impacts to water quality, habitat, fish passage, and flooding were possible for Salt Creek. Most notably, adverse impacts are likely to creek bend stability and bridge scour through an infrastructure-dense portion of the city of Ashland.

For the Platte River lakes, which would have a combined footprint of approximately 3,000 acres, groundwater modeling indicated an increase in groundwater level of approximately 8.4 feet on the downstream end of the large lake, with an equal decrease on the upstream end; for the small lake, this increase/decrease was 6.8 feet. Surface water modeling showed increases of 1.37 feet and 1.89 feet, respectively, for the large and small lake in the immediately downstream 100-year flood water surface elevations along the Platte River; these conditions would require a Conditional Letter of Map Revision with the Federal Emergency Management Agency (FEMA). Water balance analysis indicated decreased average annual atmospheric water loss when comparing lake evaporation to existing land use evapotranspiration, and reduced demand on groundwater supplies. The greatest concern revealed by the desktop geotechnical seepage analysis was that foundation seepage rates were anticipated to be high and that, because of variable depth to bedrock, the possibility exists for karst conditions to be present or to develop. Finally, the geomorphic analysis indicated several concerns, including: (1) increased erosion due to elevated flood depths and associated increased risk of avulsion; (2) high sediment load in the lakes themselves would lead to a requirement for substantial dredging efforts; (3) removal of native vegetated floodplain would render proposed embankments/structures more vulnerable to damage from overbank flows; (4) negative impacts on water quality, habitat, fish passage, and flooding were possible for Buffalo Creek, Springfield Creek, and other tributaries that would be intercepted by the lakes; and (5) water quality and ecological concerns would exist within the lakes due to removal of wetlands, nutrient loading, and sedimentation. For the large lake, an increased scour threat would exist due to the location on the outside bend of the Platte River meander, requiring robust channel stabilization measures; for the small lake, the location on the inside bend of the Platte River meander would result in increased sedimentation. In addition, for the small lake, increased velocities and flood depths due to natural constriction of the floodplain could be further exacerbated.

General conclusions of the analyses included in this study are summarized in **Table 1** of this document, and details of each of the analyses are provided in the appendices.

1. PROJECT HISTORICAL CONTEXT

1.1 LB406 (2021): The STARWARS Committee

In 2021, the Nebraska legislature enacted LB406 which, in part, established the Statewide Tourism And Recreational Water Access and Resources Sustainability (STAR WARS) special committee. This committee was tasked with conducting studies that would investigate various needs, conditions, and opportunities around three areas of the state – including a stretch of the lower Platte River – focused on surface water-based development and recreation. The legislature noted the need to investigate opportunities to invest in these areas to help attract and retain an increasingly remote workforce.[2]

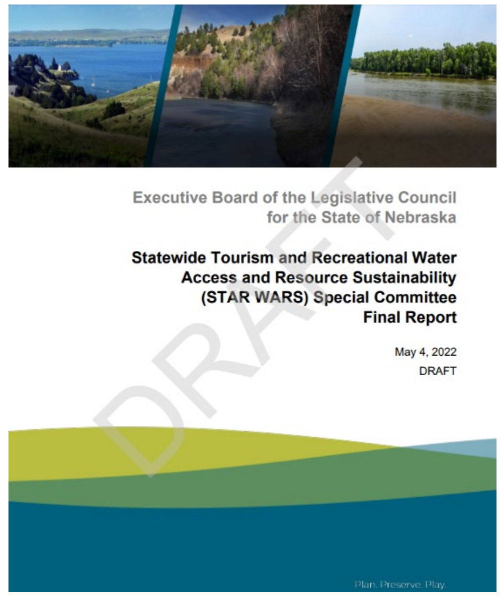

Figure 1: Cover page of the STAR WARS special committee final report

In the lower Platte River corridor particularly, the STAR WARS committee's study and report (**Figure 1**) focused on flood mitigation measures as well as identifying opportunities to maximize tourism and recreational opportunities, provide water supply resilience and increased habitat preservation opportunities, and improve water quality. In the course of the committee's study, a consultant evaluated impacts – at a conceptual level – of flood control/recreation projects in the lower Platte River corridor (**Figure 2**). The consultant conceptualized and evaluated two different 4,000-acre lake configurations: a dual-lake system split by a causeway; and a large, single lake. The general location of the conceptualized lakes was in the vicinity of the Metropolitan Utilities District (MUD)'s Platte West and City of Lincoln Water System (LWS)'s wellfields along the Platte River, generally northeast of Ashland, Nebraska.[3]

The committee envisioned that this lake would provide public access to outdoor recreation and rival out-of-state lakes, such as Lake Okoboji in Iowa, so that recreation dollars currently leaving Nebraska would remain in state. The committee's report also envisioned robust development around this lake, including residences, a community town center, and a destination resort. Recognizing the complexities of such a development between the state's two major

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[2] Legislature of Nebraska, 2022. Legislative Bill 1023. Retrieved July 25, 2024 from: https://nebraskalegislature.gov/FloorDocs/107/PDF/Intro/LB1023.pdf.
[3] Executive Board of the Legislative Council for the State of Nebraska, 2022. Statewide Tourism and Recreational Water Access and Resource Sustainability (STARWARS) Special Committee Final Report. Retrieved July 25, 2024 from: https://dnr.nebraska.gov/lb-1023-water-recreation-enhancement-act.

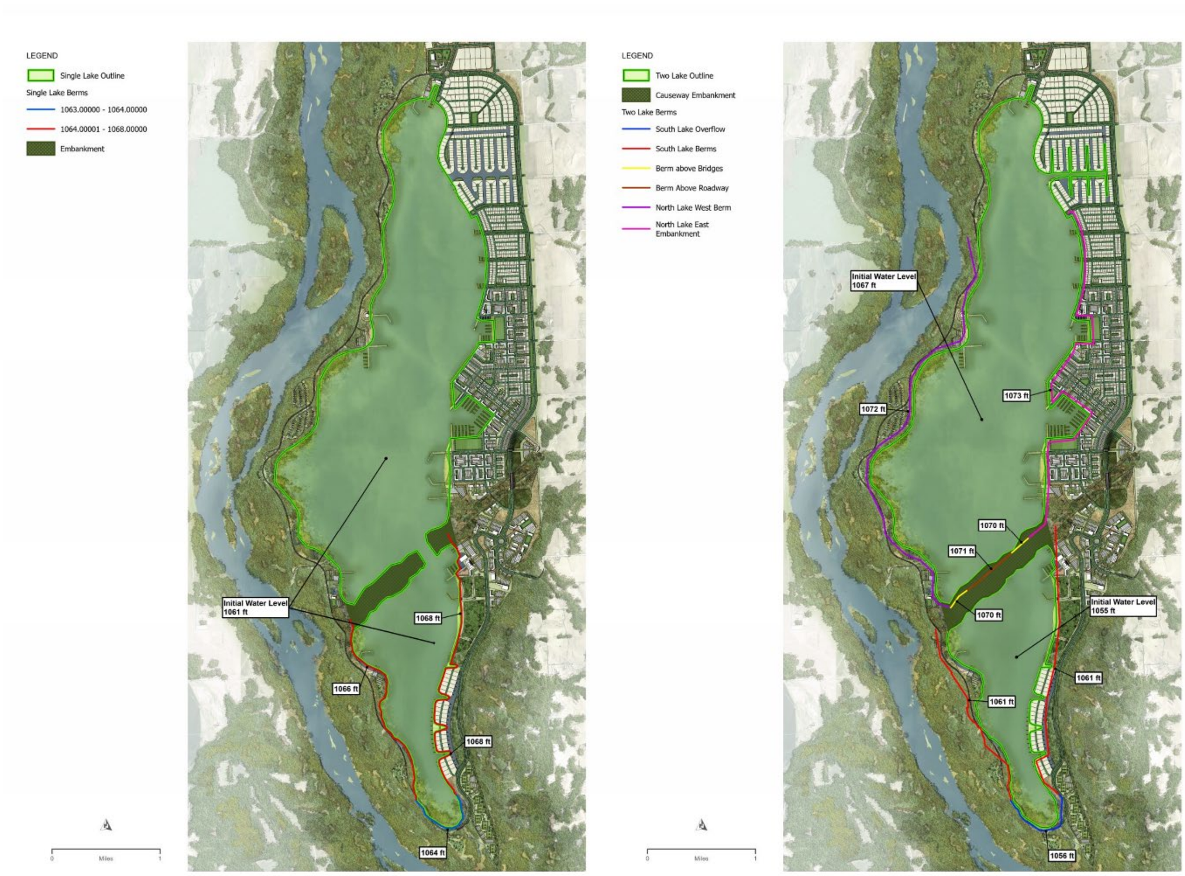

Figure 2: Lakes as conceptualized by HDR, Inc. in STAR WARS Committee's final report.[3]

metropolitan areas (and noting that both cities have municipal wellfields in the area), the committee also recommended further assessment and analysis of the feasibility of such a lake.[3]

1.2 LB1023 (2022) and the Jobs and Economic Development Initiative (JEDI) Act

In 2022, as the STAR WARS committee's report was being finalized, the Nebraska legislature enacted LB1023[2], a portion of which was later codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (*Neb. Rev. Stat.* §61-401 to 61-404)[4]. The legislation and statute granted several powers to the Nebraska Department of Natural Resources (NeDNR) related to implementing the Act, including the authority to select land upon which a lake would be built according to the following criteria:

1. Land shall be located in or near Sarpy County and within the floodplain or floodway of the Platte River;

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[4] Nebraska Revised Statutes Chapter 61. Retrieved July 25, 2024 from: https://nebraskalegislature.gov/laws/browse-chapters.php?chapter=61.

2. Preference shall be given to locations that were materially under water when the Platte River flooded in 2019;
3. It is the intent of the legislature that the lake be at least 3,600 acres in size;
4. No dam shall be constructed on the main channel of the Platte River in order to construct the lake;
5. No city or village, or any part thereof, shall be flooded in order to construct the lake.

2. SCOPE OF STUDY

2.1 City of Lincoln Water System, (Omaha) Metropolitan Utilities District, and State of Nebraska Involvement

Recognizing the potential for impacts to public water system wellfields, the Nebraska legislature also appropriated funds to be administered through NeDNR for further study on possible lake sites. LWS already had its Water 2.0 project - investigating possibilities for additional source(s) of drinking water - underway with Black & Veatch and Olsson, and recognized that these consultants have the necessary expertise regarding the water system as well as expertise in the types of technical analysis needed for potential lake sites. Thus, LWS amended its Water 2.0 contract to include this study and entered into a memorandum of understanding with MUD to allow for MUD’s wellfields and concerns to also be considered. LWS, MUD, and NeDNR provided guidance throughout the course of the study described in this report. Monthly progress meetings and workshops were held between LWS, MUD, NeDNR, Olsson, and Black & Veatch to discuss the progress of the modeling and evaluations. In addition, LWS, MUD, and NeDNR provided direction and feedback on assumptions and decisions throughout the study. In summer 2024, around the time the most critical pieces of analysis were completed and presented to the client advisory group, representatives of the Nebraska Department of Economic Development (NDED) joined the discussions as client advisors.

The following representatives participated in these meetings and comprised the client advisory group:

- Steve Owen, Assistant City Engineer, LWS
- Bob Taylor, Senior Design Engineer, Water Production, MUD
- Luca DeAngelis, Senior Hydrogeologist at Layne and Technical Advisor to MUD
- Jesse Bradley, Assistant Director, NeDNR
- Jenny B. Mason, Director of Community Development and Disaster Recovery, NDED
- Joseph Lauber, Deputy Director of Operations/Chief Legal Officer, NDED

2.2 Study Purpose

The purpose of this study, then, was to: (1) construct and calibrate a subregional groundwater model and run scenarios to help inform where a lake of this scale should not be developed while considering existing wellfields and their associated protection areas, and then use this groundwater model to examine impacts of the potential lakes to local groundwater levels and elucidate water quality concerns; (2) develop and calibrate a two-dimensional model of the Platte River and floodplain in the area of interest and use information from scenarios run with this model to inform further groundwater modeling to determine impacts of potential lakes on wellfields operated by LWS and MUD; (3) evaluate impacts to local water balance resulting from lakes constructed at the identified potential locations, specifically estimating evaporation and evapotranspiration; (4) perform seepage analysis of potential lakes; and (5) evaluate geomorphic impacts of potential lakes, including impacts from flood events on geomorphology of the lake itself as well as fluvial geomorphology resulting from existence of a lake.

2.3 Summary of Analytical Reports

Analytical reports were prepared outlining each area of analysis and are included here as appendices. The reports are as follows:

- **Groundwater Modeling Summary Report (Appendix A):** Discusses construction and calibration of the sub-regional JEDI groundwater model (JEDI model) and the results of particle tracking and water level assessment scenarios
- **Surface Water Flood Modeling Report (Appendix B):** Provides details on the construction and calibration of a two-dimensional surface water model of the applicable portion of the lower Platte River, as well as the modeled impacts of potential lakes resulting from various flood intensities
- **Water Balance Modeling Report (Appendix C):** Describes impacts of each potential lake on local water balances, especially the impacts to losses of water to the atmosphere through evapotranspiration
- **Desktop Geotechnical Analysis Summary Report (Appendix D):** Examines anticipated seepage through the embankments and beds of each potential lake to determine each lake's viability from a perspective of maintaining permanent pool
- **Geomorphic Analysis Report (Appendix E):** Summarizes the foreseeable impacts to local geomorphology from each potential lake, especially each lake's potential to induce head cutting upstream and/or downcutting and/or bank erosion downstream

3. DEVELOPMENT IN AREA OF INTEREST

3.1 Water Supply and Users

Black & Veatch and Olsson examined the development history of the alluvial valley/floodplain of the Platte River between North Bend, Nebraska, and the river's confluence with the Missouri River near Plattsmouth, Nebraska. This area – including the floodway and floodplain bounded by bluffs on both sides – is approximately 160,000 acres.

Within this area, there are fourteen wellhead protection areas (WHPAs), which provide water to around 930,000 people. The WHPAs in the area include those of LWS, MUD, and many smaller jurisdictions such as the Cities of Ashland and Papillion, Nebraska, as shown in **Figure 3**.

WHPAs are delineated to aid public water systems both in understanding where their source water comes from and potential sources of contamination, and to provide a basis from which to consider and implement protections against contamination of public water supply wells. WHPA boundaries are determined by the Nebraska Department of Environment and Energy (NDEE) and are based on hydrogeologic data gathered for the area. The data is incorporated into a numerical groundwater model using either the Wellhead Analytic Element Model (WhAEM) or the U.S. Geological Survey (USGS) modular finite-difference groundwater flow model (MODFLOW). Reverse particle tracking scenarios are used to simulate 20-year or 50-year time-of-travel lines that represent the path that hypothetical particles would take through the aquifer to a well pumping groundwater.

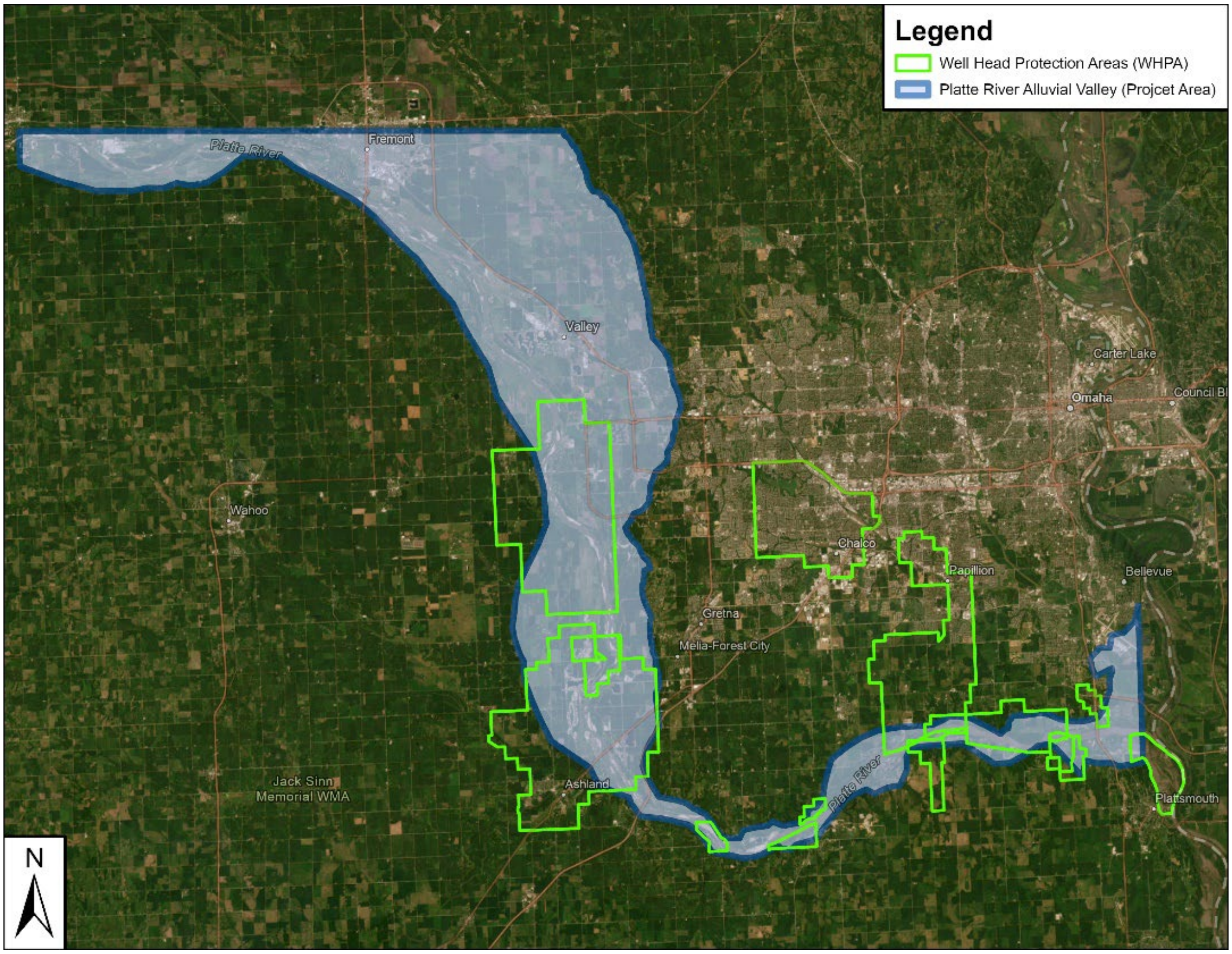

Figure 3: Wellhead protection areas in the study area.

While WhAEM times-of-travel have been historically used in Nebraska to determine 20-year time-of-travel zones for public water supply wells and therefore WHPAs, NDEE has begun to use MODFLOW simulations in recent years to verify and update WHPAs as necessary. A WHPA boundary is typically drawn around the 20-year time-of-travel lines to the nearest section, but some communities may choose to adopt the 50-year time-of-travel area. Communities and/or counties can place restrictions on land uses in the WHPA that could negatively impact water quality (e.g. confined animal feeding operations, landfills, etc.). Regulations within a WHPA are not consistent across Nebraska and are instituted at the jurisdictional authority's discretion.

Groundwater modeling results from this study (detailed in **Appendix A: Groundwater Modeling Summary Report**) confirmed the importance of the LWS and MUD WHPA boundaries. Particle tracking simulations showed that hypothetical particles placed around the municipalities' wellfields traveled to the boundaries of the already-established WHPAs in roughly twenty years. More details on the particle tracking scenarios and results can be found in **Appendix A: Groundwater Modeling Summary Report**.

3.2 Sandpit Lakes through Time

Manmade lakes that result from mining sand and gravel below the water table are generally referred to as sandpit lakes. The formation of these lakes along the Platte River is possible due to relatively shallow depth to groundwater. Sandpit lakes provide increased opportunity for water recreation and facilitate population growth across the state. The study area has seen an increase in the development of sandpit lakes over time, as outlined below. Many of the sandpit lakes have been developed into private communities with houses constructed around the lake perimeter.

Aerial imagery from 1984, 2003, and 2023 was used to understand the development of sandpit lakes in the project area over time. In 1984, there were about 131 lakes covering 3,390 acres within the project area. In 2003, there were about 200 lakes covering a total area of approximately 6,080 acres. In 2023, there were about 281 lakes covering a total area of 8,035 acres. The progression and location of lakes in the project area is shown in **Figure 4**. As shown, sandpit lake development has increased over time and is likely to continue into the future at a similar rate. It is reasonable to assume that, in the absence of a large lake such as that envisioned in the JEDI legislation, private sandpit lake development will continue in feasible areas.

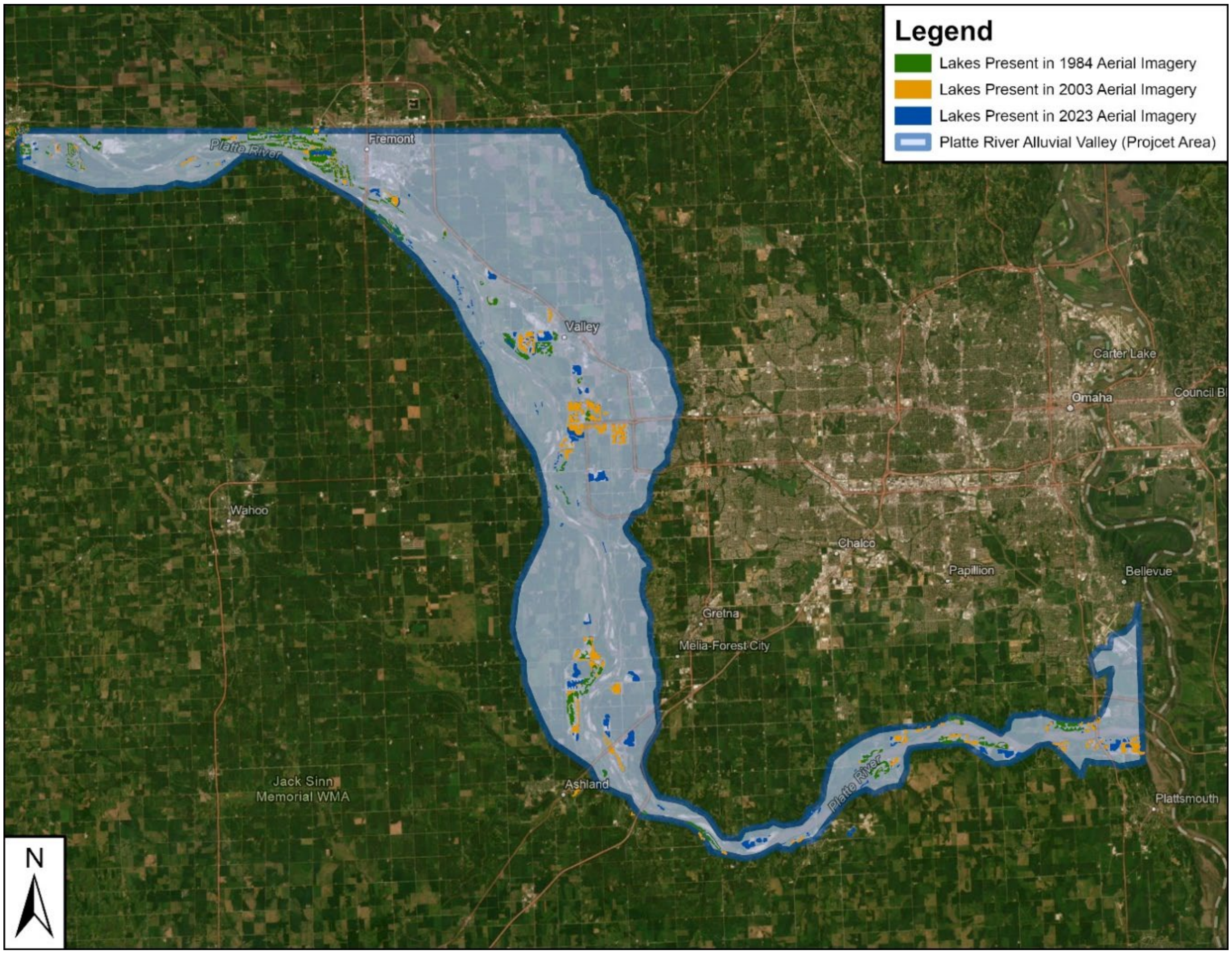

Figure 4: Progression of sandpit lake development in the study area.

3.3 Comprehensive Plans and Zoning

As outlined in the analytical summary reports (appendices to this document), the study area is located within portions of Cass, Dodge, Douglas, Sarpy, and Saunders Counties. For this reason, comprehensive plans and projected zoning maps were reviewed to understand both any planning or zoning policies or restrictions that would prevent development of the legislatively proposed lake, and any plans or policies for other development in these counties that would conflict with the proposed lake. Review of these documents indicated that there are no policies that conflict with the lake's development.

3.3.1 Cass County

Cass County zoning maps show that a large portion of the Cass County study area is zoned as agricultural and transitional agricultural land. Recreational facilities for use by the public for recreational activities including swimming are a conditional use of agricultural and transitional agricultural zones in Cass County.[5]

3.3.2 Dodge County

Dodge County zoning maps show that large portions of the Dodge County study area are zoned as Platte River corridor and agricultural land. Public and private parks and recreational areas are a conditional use of the Platte River corridor, and public parks and recreational areas are a principal permitted use of agricultural land in Dodge County.[6,7]

3.3.3 Douglas County

Within Douglas County, parks and recreation are a permitted use of all zoning districts.[8]

3.3.4 Sarpy County

Sarpy County zoning maps show that a large portion of the Sarpy County study area is zoned as agricultural land. Sarpy County agricultural farming district regulations specify private and public recreational lakes as a principal permitted use of agricultural land.[9]

3.3.5 Saunders County

Additionally, large portions of the project area within Saunders County are designated as agricultural and transitional agricultural districts. Private lakes are a permitted conditional use of land for both of these classifications in Saunders County, as well.[10]

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[5] Cass County Zoning Regulations. Retrieved July 24, 2024 from: https://www.cassne.org/plugins/show_image.php?id=929.

[6] Dodge County, Nebraska: Official Zoning Map. Retrieved July 24, 2024 from: https://dodgecounty.nebraska.gov/sites/default/files/doc/Dodge-Co-Official-Zoning-Map.pdf.

[7] Dodge County Zoning Regulations – 2015. Retrieved July 24, 2024 from: https://schmidguides.unl.edu/ld.php?content_id=61750699.

[8] Douglas County Zoning Regulations. Retrieved July 24, 2024 from: https://www.dceservices.org/images/Article_4_Zoning_Regulations.pdf.

[9] Sarpy County Zoning Regulations. Retrieved July 24, 2024 from: https://www.sarpy.gov/DocumentCenter/View/407/Zoning-Regulations---Section-9-AG---Agricultural-Farming-District-20-Acres-PDF.

[10] Saunders County, Nebraska Zoning Regulations – 2015 Update. Retrieved July 24, 2024 from: https://saunderscounty.ne.gov/pdfs/zoning/Zoning%20Regulations.pdf.

4. OVERVIEW OF ANALYTICAL PROCESSES AND RESULTS

4.1 Potential Lake Location Selections

As preliminarily evaluated during the STAR WARS committee's study, a conceptual lake location was identified in the floodplain of the Platte River on its east side, northeast of the city of Ashland. However, this location coincides directly with a portion of the WHPA delineated for the LWS wellfield and was thus determined during this study to not be a viable lake location (**Figure 5**), because a large recreational lake with residential and commercial development would stand to present threats to water quality in the local aquifer as well as the hydrologically connected Platte River. Reverse particle tracking scenarios using the groundwater model (JEDI model) constructed for this study and detailed in **Appendix A: Groundwater Modeling Summary Report** confirmed that the LWS and MUD WHPAs had been properly delineated and that contaminants within these areas could generally be expected to reach corresponding wells within 20 years' time. It was also noted that the originally conceptualized lake's boundaries extended into shorter times-of-travel for some of the LWS wells and that the hydrogeologic system is highly connected in the areas of the LWS and MUD wellfields. An example of a reverse particle tracking scenario is presented in **Figure 6**.

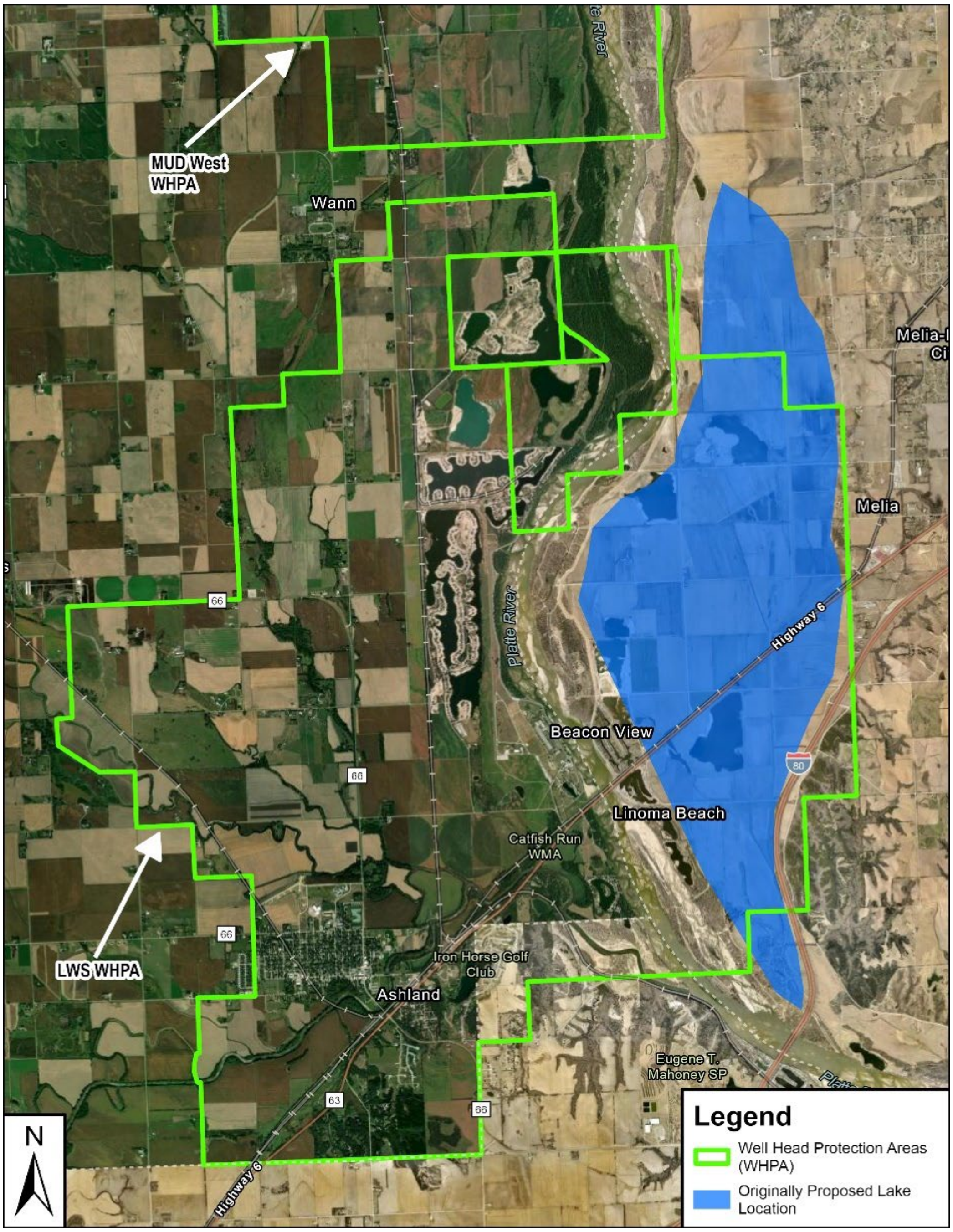

Figure 5: Wellhead protection areas and originally conceptualized lake location.

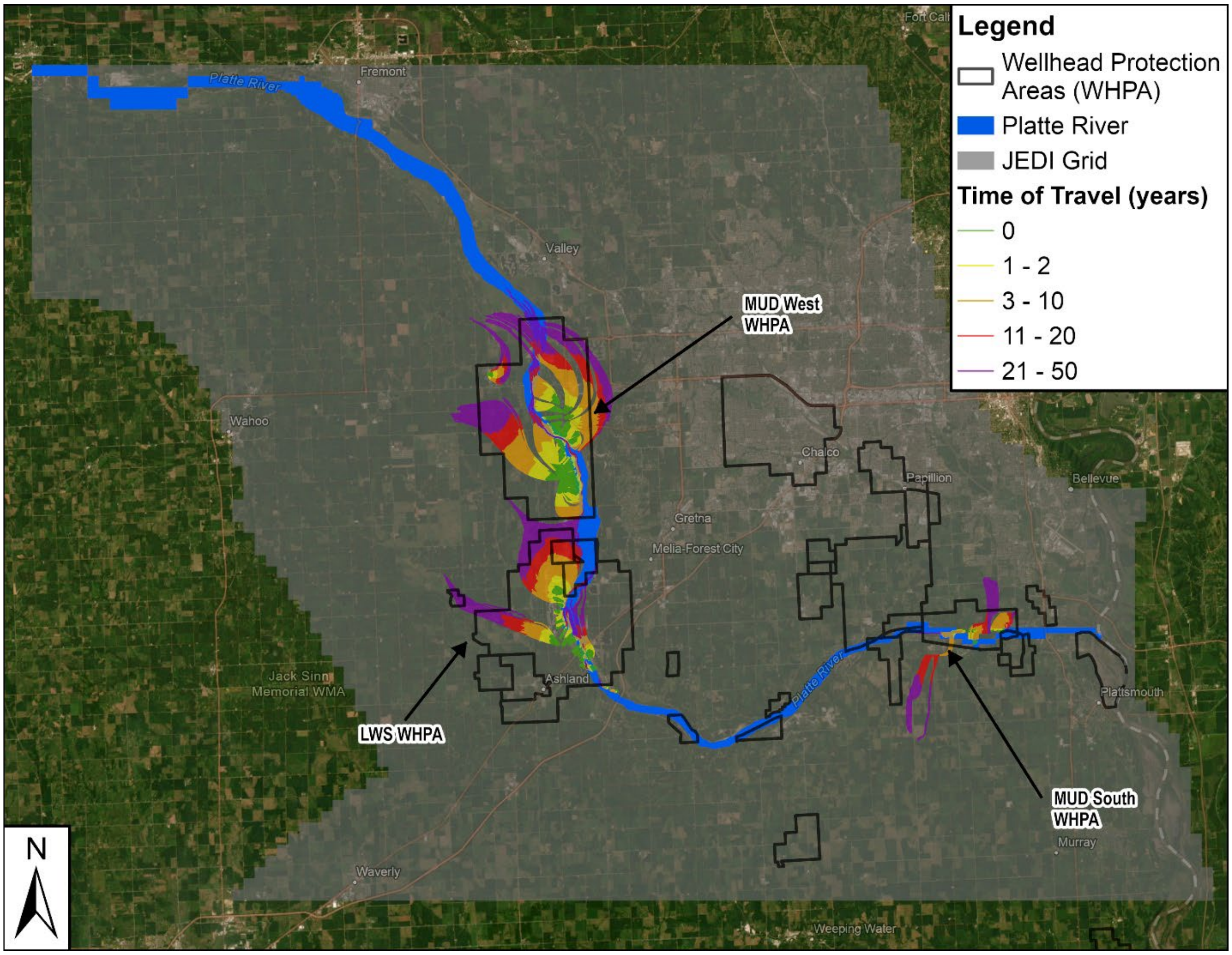

Figure 6: Example of reverse particle tracking scenario conducted for this study.

In consultation with the client advisory group, it was determined that Black & Veatch and Olsson would investigate lake locations within the lower Platte River floodplain assuming excavated lakes without dams, but also dammed and excavated lakes on Salt Creek and the Elkhorn River, if viable. While the original study scope did not include investigation of dammed lakes on Platte River tributaries, NeDNR requested that these areas also be considered in this study, as examples of sites chosen to examine initial feasibility, with the possibility that similar sites could be considered in the future.

To determine viable potential lake locations, then, Olsson and Black & Veatch first used the particle tracking scenarios from the JEDI groundwater model to clearly identify where a lake should not be constructed, particularly in terms of protecting existing wellfields/associated WHPAs. The surface water model (detailed in **Appendix B: Surface Water Flood Modeling Report**) was then used to provide further information about potential lake locations and configurations back to the groundwater model, which was used to determine impacts of potential lakes on wellfields operated by LWS and MUD; this iterative modeling process is described in greater detail in **Section 4.2**.

An initial set of five potential lake locations was considered and is shown in **Figure 7**:

- An excavated lake along the Elkhorn River, near Valley, Nebraska
- A small excavated lake along the Platte River, upstream of Louisville, Nebraska
- A large excavated lake along the Platte River, downstream of Louisville, Nebraska
- A dammed lake on the Elkhorn River, near Nickerson, Nebraska
- A dammed lake on Salt Creek, between Greenwood and Ashland, Nebraska

The excavated lake along the Elkhorn River was eliminated from further consideration due to existing development in the downstream end of the lake footprint, including homes, as well as some development at the upstream end. Additionally, it would require relocation/re-routing of roads, and would have a significant slope that would require extensive excavation and berming. The small excavated lake along the Platte River was also initially eliminated from further consideration due to inadequate size relative to the legislatively envisioned 3,600+ acres.

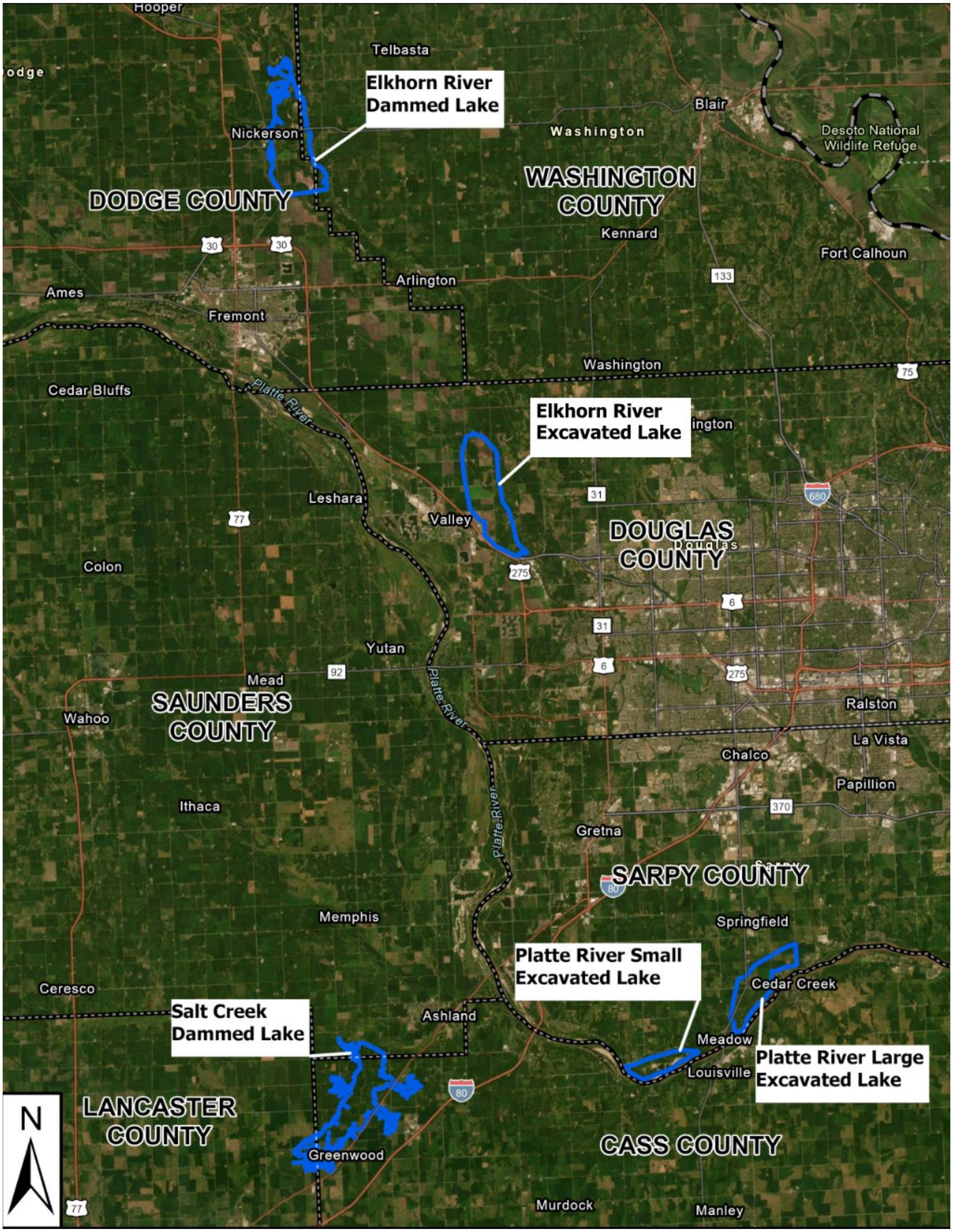

Figure 7: Lake locations initially considered in this study.

4.2 Iterative Hydrologic Modeling Process and Results

To use the JEDI groundwater model to determine where a lake should not be constructed, USGS particle-tracking model for MODFLOW (MODPATH) scenarios were run to track hypothetical particles and their interactions with the Platte River and municipal wellfields. To determine footprints of potential lakes, then, the surface water model was used to: (1) limit increases in water surface elevation during a 100-year flood event to no more than 1.0 feet for the Platte River excavated lake; and (2) compute the necessary dimensions for dams to impound roughly 4,000 acres if spanning the floodplains of the Elkhorn River and Salt Creek, without threatening existing development or major infrastructure. These lake footprints, then, were input in the groundwater model and scenarios were run to evaluate impacts to groundwater level elevations. Additionally, forward particle tracking scenarios were created to demonstrate times- and paths-of-travel from the Platte River excavated lakes to the Platte River. Each of the models, as well as results and conclusions, are summarized in the following sections.

4.2.1 Groundwater Model

The JEDI groundwater model (**Figure 8**) was constructed to be run as a standalone model but has the capability to be coupled with the regional Lower Platte Missouri Tributaries (LPMT) model. The JEDI model was constructed as a five-layer MODFLOW 6 model, using octree refinement.[11] The model cells are most refined along the Platte River in Layer 1 (the uppermost layer) and grow coarser as they move outward from the Platte River and move down through the layers. Most modeling inputs were borrowed from the regional LPMT model; however, aerial electromagnetic (AEM) survey data was used to refine aquifer properties, and flow-stage relationships were used to build the Platte River MODFLOW 6 package. Stream locations and pumping data were also refined based on the refinement of the JEDI model grid. Additionally, municipal pumping data was refined based on pumping data from The Flatwater Group, a consultant that has worked with NeDNR on the LPMT model which is the parent model to the JEDI model developed for this study.

[11] Langevin, C.D., J.D. Hughes, E.R. Banta, A.M. Provost, R.G. Niswonger, and S. Panday. 2017. MODFLOW 6 Modular Hydrologic Model: U.S. Geological Survey Software, https://doi.org/10.5066/F76Q1VQV

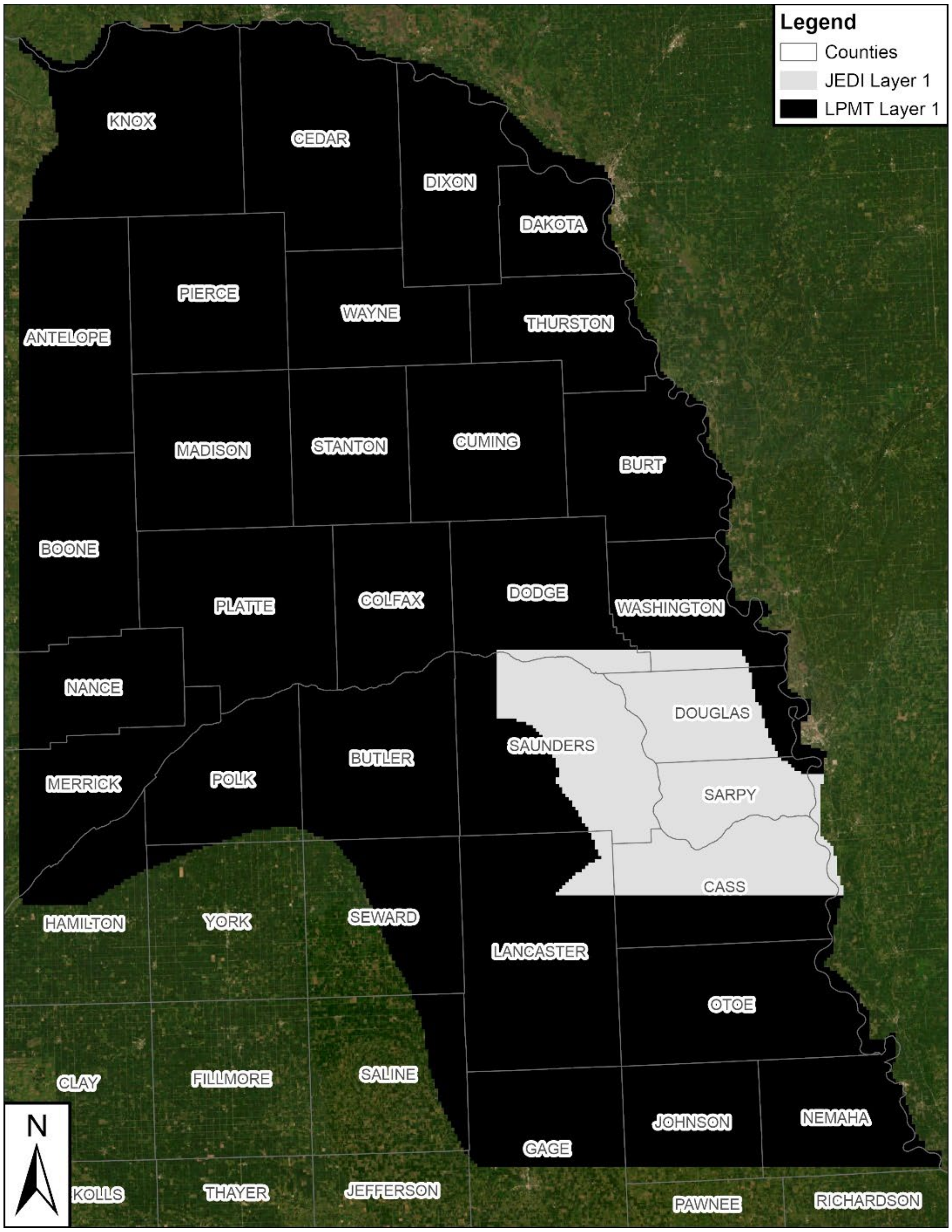

Figure 8: JEDI groundwater model extent within the Lower Platte Missouri Tributaries model.

MODPATH was used to complete reverse particle tracking scenarios using three climatic conditions – wet, dry, and normal. These climatic conditions were built to isolate the effects of the Platte River and municipal wellfield pumping rates on contaminant time of travel, i.e., the amount of time as determined by modeling for a single particle of a contaminant to move from one location to another. Particles traveled the farthest (largest radius of influence) when the Platte River was at a low stage and pumping rates were high; conversely, particles had the smallest radius of influence when the Platte River was at a high stage and pumping rates were low. As expected, then, when the Platte River and pumping rates were set to mean values (normal conditions), the radius of influence landed between these two extremes. Detailed figures illustrating these results are provided in **Appendix A: Groundwater Modeling Summary Report**. In general, the particle tracking scenarios confirmed that WHPAs as delineated by NDEE for public water systems in the area were properly identified; these scenarios also demonstrated that the LWS and MUD wellfields draw water both from the local aquifer and the Platte River in all climatic conditions, with greater reliance over greater distances on the local aquifer when conditions are dry – demonstrating that impacts to water quality and/or quantity resulting from construction of a lake would have potential to be rather significant.

4.2.2 Surface Water Flood Model

A surface water flood model was also developed for this study and consists of a model of the Platte River including the Elkhorn River and Salt Creek. The surface water model geometry is foundationally a digital elevation model (DEM) constructed from available topographic and bathymetric data from USGS, the Eastern Nebraska Lidar Download Application, and the Headwaters Corporation. The DEM extends along the Platte River from North Bend to the confluence with the Missouri River and includes a portion of the Missouri River, Elkhorn River, and Salt Creek. **Figure 9** shows the boundaries of the surface water model.

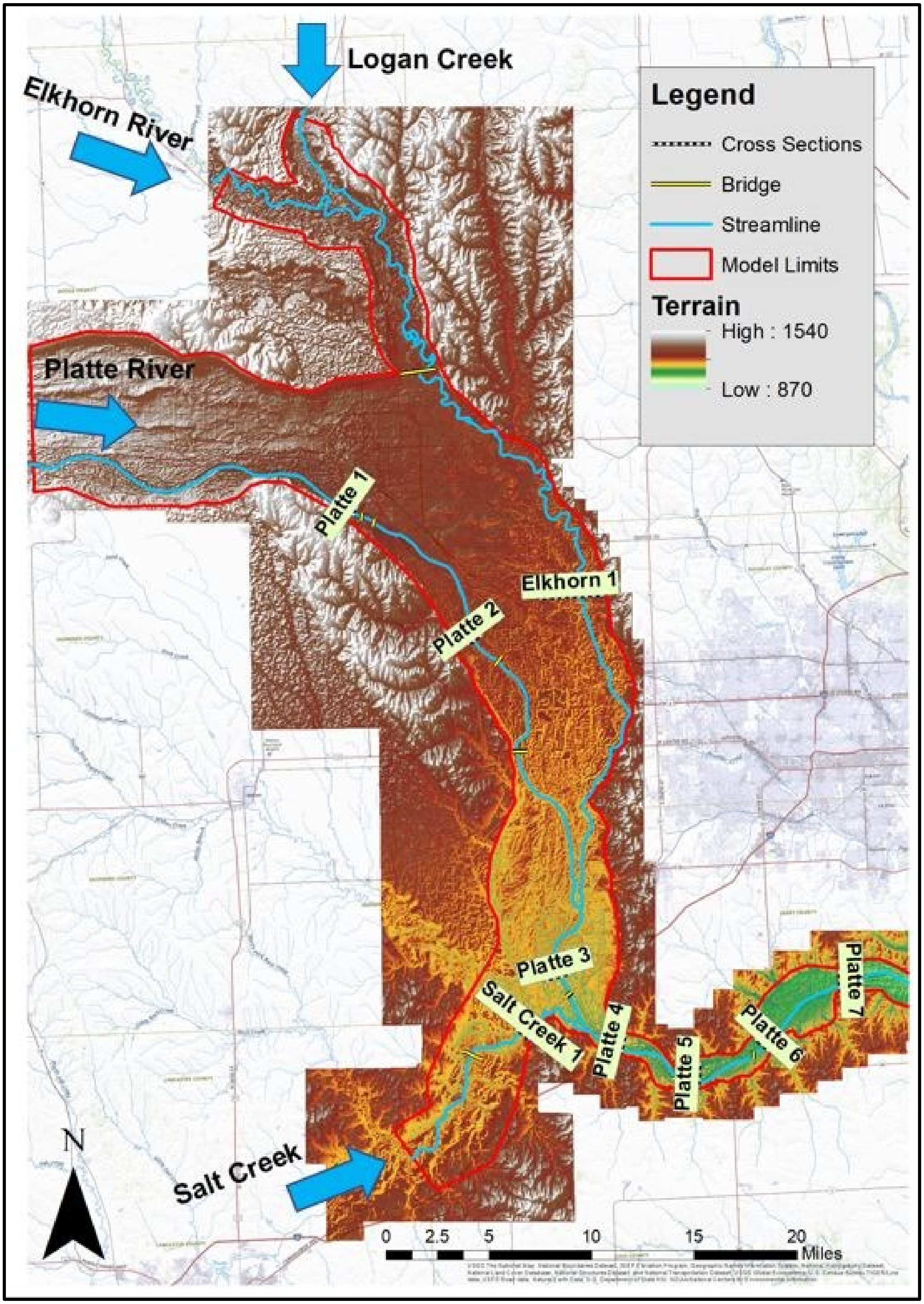

Figure 9: Boundaries of the surface water flood model developed for this study.

The surface water model was used to identify footprints of lakes that would come close to or meet the legislatively envisioned 3,600+ acres while avoiding major infrastructure and WHPAs. It was also used to evaluate potential impacts of excavating a lake in the floodplain of the Platte River or damming the Elkhorn River or Salt Creek. While the original study scope did not include investigation of dammed lakes on Platte River tributaries, it became apparent as this study progressed that an excavated lake along the Platte River would not be feasible at the size envisioned by the legislature, due to the presence of critical infrastructure and WHPAs designed to be protective of public water supplies, including those serving the state's two largest metropolitan areas. Thus, possible impacts of dammed lakes on the Elkhorn River and Salt Creek were also examined in this study.

Three potential lake locations from the original set of five were identified that were of appropriate size and did not inundate or threaten existing infrastructure, and were carried forward for full analysis. These included:

- The large excavated lake along the Platte River, downstream of Louisville, Nebraska
- The dammed lake on the Elkhorn River, near Nickerson, Nebraska
- The dammed lake on Salt Creek, between Greenwood and Ashland, Nebraska

The Platte River lake footprint was limited in spatial extent to roughly 2,100 acres because the area is confined by two WHPAs, the Platte River itself, and bluffs. The lake would need a berm constructed around it to prevent the entry of floodwaters. It is also notable that several small tributaries exist to the northwest of this potential lake footprint, and flow from these would either have to be allowed to enter the lake or be routed around it. The berm would be approximately 10 feet high. While the lake boundary was defined by attempting to limit increases in the water surface elevation (WSE) during the 100-year flood event to no more than 1.0 feet (as required by Federal Emergency Management Agency [FEMA] regulations), final modeling results indicate that the maximum increase in the 100-year WSE may be slightly above the regulatory threshold. Thus, the lake footprint would possibly need to be reduced; alternatively, a Conditional Letter of Map Revision (CLOMR) from FEMA could be sought to update the regulatory flood map(s) and/or provide regulatory comment on whether changes in hydrology resulting from the lake's construction would be acceptable under National Flood Insurance Program standards.

Both the Salt Creek and Elkhorn River dammed lakes, as modeled and analyzed, would be approximately 4,100 acres in size. The Salt Creek lake would have a dam height and length of approximately 50 feet and 5,500 feet, respectively, while the Elkhorn River lake would have a dam height and length of approximately 36 feet and 9,000 feet, respectively. Final modeling results indicate that the downstream reduction in WSE for the Salt Creek lake would be less than 0.1 foot; for the Elkhorn River lake, this reduction would be even smaller at less than 0.01 foot.

4.2.3 Additional Groundwater Modeling

From these lake footprints, then, additional groundwater modeling scenarios were carried out to evaluate the impacts of each potential lake on water table elevations. Modeling showed that each lake would locally produce declines and/or rises in water tables. The water table rises on the downstream end of the Elkhorn River and Salt Creek lakes would be 29.4 feet and 41.8 feet, respectively; the Platte River excavated lake would produce an upstream-end decline of 8.4 feet and a commensurate downstream-end rise. Figures detailing these changes are presented in **Appendix A: Groundwater Modeling Summary Report**.

Forward particle tracking scenarios were also carried out to examine times and paths of travel from the conceptual lakes and whether they would impact the existing municipal wellfields operated by LWS and MUD. These scenarios showed that the Platte River lake would contribute water over short periods of time – as little as 1 to 2 years – to the local aquifer and then to the river. Note, again, that previously discussed model scenarios showed that all three municipal wellfields draw water from the Platte River, with more water drawn from the surrounding aquifer during dry periods. The conceptual Platte River lake as analyzed is located upstream of the MUD Platte South wellfield.

4.3 Water Balance Modeling Process and Results

This study also included a water balance analysis (**Appendix C: Water Balance Modeling Report**) which includes water flowing into the lake from upstream and rainfall, and outflow leaving the potential lake from evaporation, groundwater infiltration, and downstream flows. **Figure 10** provides an example illustration of the mass balance for a water balance analysis.

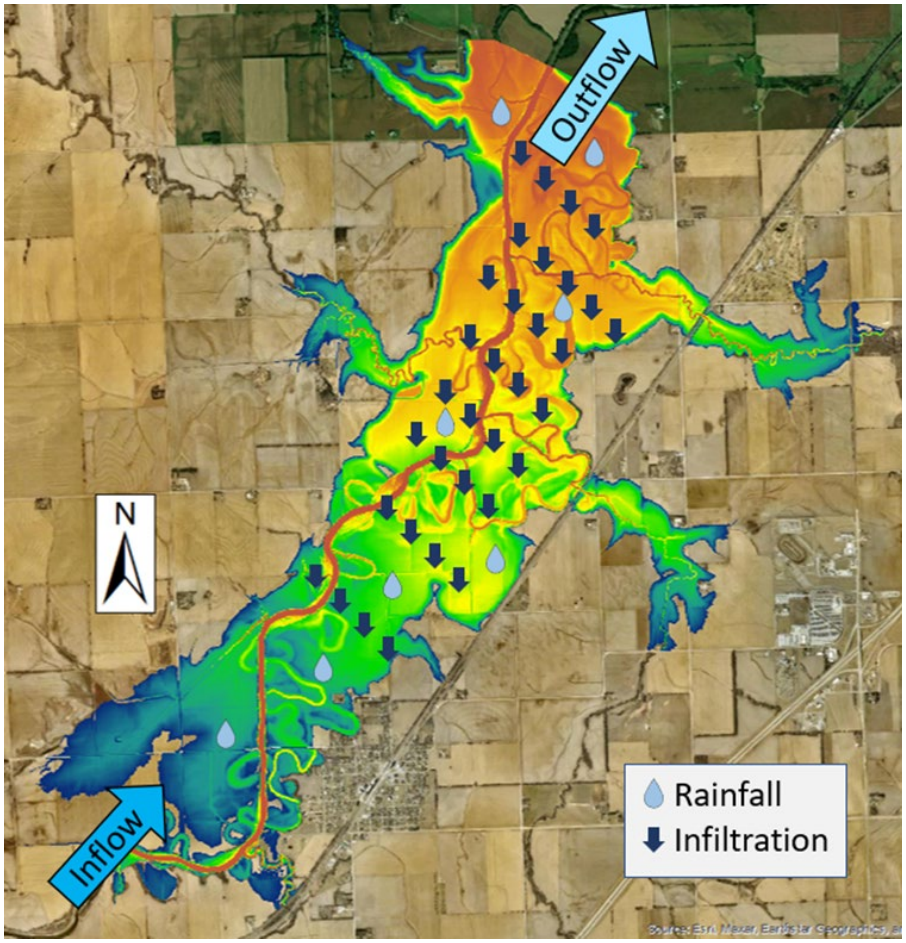

Figure 10: Example illustration of mass balance for a water balance analysis.

The purpose of the analysis was to estimate evaporation from the potential lakes, and the impacts of the lakes on changes in evapotranspiration within their footprints and evaporation from the river under low-flow conditions. While the conceptual lake was assumed to be for recreational purposes, its operation was not defined in this analysis. In addition, this analysis for outflows did not consider the lake as a water supply and also assumed a minimum flow during drought conditions for releases to support biological integrity. Because the lake would be for recreational purposes, releases were not assumed to be made for augmenting flows in the Platte River. Additional analysis and modeling will need to be completed to address the lake operation and augmenting of downstream flow requirements.

The Platte River excavated lake would represent reduced loss of water to the atmosphere from groundwater, as the evapotranspiration conditions in the area currently are greater than would be the evaporative loss from the lake surface. In other words, the Platte River lake would marginally increase the amount of groundwater retained in the local aquifer as compared to present conditions. Additionally, over half of the land within the footprint of the lake as modeled and analyzed is assumed to be irrigated, so conversion of these acres to permanent pool from irrigated row crops would reduce groundwater demand in the area.

For the two dammed lake locations, the Salt Creek lake would drain a much smaller land area compared to the Elkhorn River lake and would thus be more influenced by low-flow conditions. The Elkhorn River lake would drain an area of approximately 5,406 square miles, as compared to the Salt Creek lake's drainage area of approximately 1,119 square miles. As such, the relative impact of evaporative and groundwater losses would be less significant for the Elkhorn River lake. Results indicate that, under modeled conditions, the Salt Creek lake would result in passing approximately 99.0% of the upstream volume while the Elkhorn River lake would pass approximately 99.7% of the volume. Note that daily flows would be highly controlled by lake operation rules and requirements to maintain minimum environmental instream flows. The monthly assigned 10th percentile flows for the minimum flow did not take into account the potential needs of the LWS and MUD wellfields or existing instream flow rights.

4.4 Desktop Geotechnical Analysis

In addition, a desktop geotechnical analysis (**Appendix D: Desktop Geotechnical Analysis Summary Report**) was performed to examine likely seepage at each of the three identified potential lake locations.

For the Elkhorn River lake, on-site soils generally comprise four different complexes that vary from well/excessively drained to very poorly drained. Permeability rates in the upper five feet of soil could generally be between 0.039 cm per second to 0.000021 cm per second. It is also expected that on-site soils could include clay with varying silt or sand content overlying fine to coarse grained sands, with the possibility of intermittent layers of fine to coarse grained gravels as well. Estimated seepage rates through the embankment and foundation of the embankment were calculated as less than 0.1 to 2.0 cubic feet per day per linear foot, and less than 0.1 to 200 cubic feet per day per linear foot, respectively. Foundation seepage rates are anticipated to be highly variable, based on the likelihood of encountering intermittent layers of sands and gravel within the clay soil alluvial stratigraphy.

For the Salt Creek lake, soils at the site predominantly include two different complexes that are also described with variable drainage, but the permeability rates in the upper five feet of soil are expected to be within a smaller range than for the Elkhorn River lake at 0.00092 cm per second to 0.000025 cm per second. On-site soils could comprise clays with carrying silt and sand content or fine to coarse grained sands with varying silt and clay content; it is also possible that intermittent layers of clay soils could be encountered within the sand. In general, seepage through the lake bed at this location would not be expected to be as significant or variable as through the Elkhorn River lake. Additionally, limestone bedrock is generally encountered at depths ranging from approximately 40 to 116 feet below the surface, and Dakota sandstone or shale may be encountered at greater depths. Estimated seepage rates through the embankment and foundation of the embankment were calculated as less than 0.1 to 4.0 cubic feet per day per linear foot, and less than 0.1 to 300 cubic feet per day per linear foot, respectively. It is anticipated that seepage rates may be variable, as with the Elkhorn River lake, and also that limestone bedrock below a depth of about 40 feet could be encountered which could indicate existence or potential development of karst conditions.

For the Platte River lake location, soils at the site largely comprise two complexes, both of which are described as at least well drained (one is described as excessively drained). Permeability rates could generally be between 0.039 cm per second and 0.00014 cm per second. On-site soils could comprise clay with varying silt or sand content, and intermittent layers of fine to coarse grained sands and/or gravels may also be encountered. Sands and gravels may also be encountered with exposed sands more likely along the Platte River and near historic gravel pit areas. Layers of shale, sandstone, and ironstone were encountered in test holes in the area at depths as shallow as 125 feet and as deep as 205 feet below ground surface in the vicinity of this lake. Estimated seepage rates through the embankment and foundation of the embankment were calculated as less than 0.1 to 0.3 cubic feet per day per linear foot, and less than 0.1 to 20 cubic feet per day per linear foot, respectively. Seepage rates may be high, based on the likelihood of encountering shallow sands and gravels associated with the Platte River and nearby quarries. Like the Salt Creek lake, the potential for existence or development of karst conditions exists at this location due to the variable depth of limestone bedrock.

4.5 Geomorphic Analysis

Additionally, this study included a geomorphic analysis (**Appendix E: Geomorphic Analysis Report**) for each of the three potential lake locations. **Figure 11** provides an example of the channel and floodplain velocities along the Platte River, as these relate to fluvial geomorphology. The purpose of this analysis was to consider and describe the nature and magnitude of such changes in flood and erosion hazards in response to the scope and scale of different lake positions.

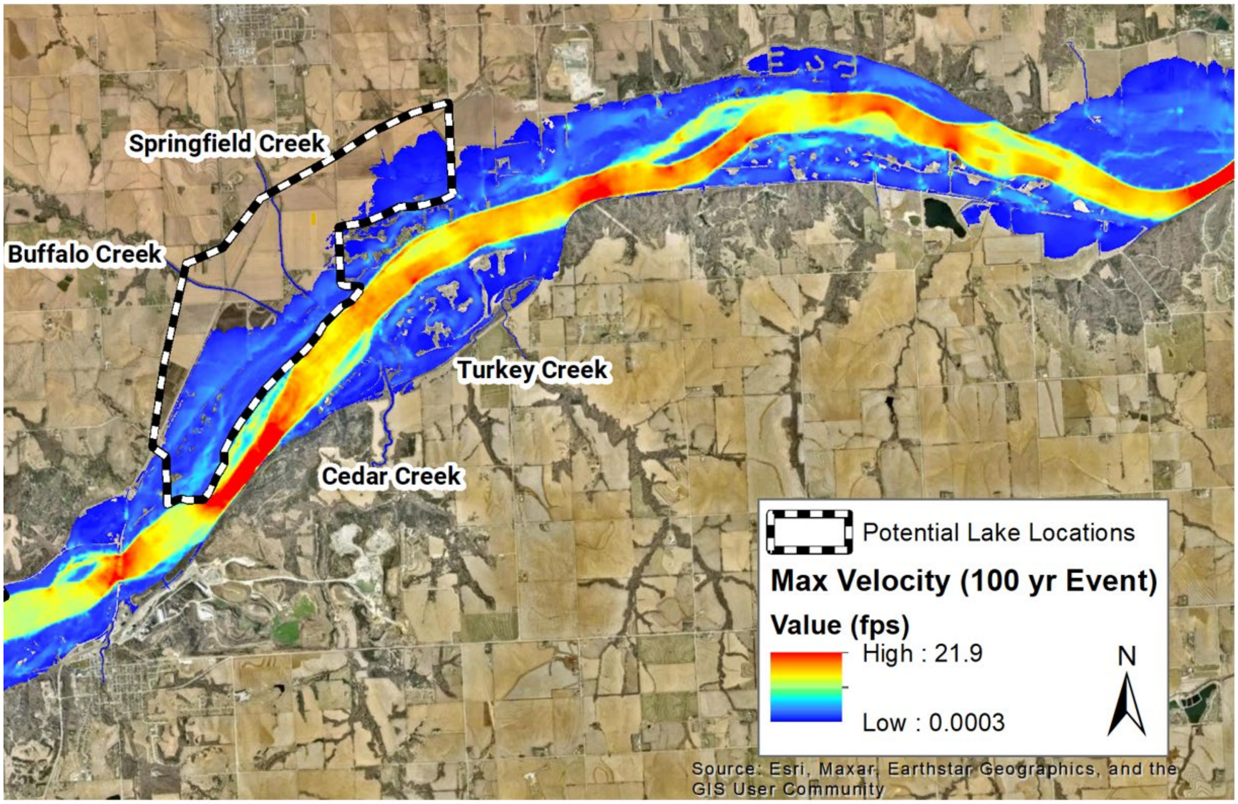

Figure 11: Example of channel and floodplain velocities along the Platte River.

The Platte River lake would require a berm isolating it from river floods to prevent the lake from eroding and capturing the normal river flow and filling with river sediment. The berm would displace natural floodplain surfaces where sediment normally is deposited and force that sediment downstream where it could have substantial unintended consequences and accumulations in areas that could acerbate downstream flooding. The narrowing of the floodplain would also accelerate flow during floods by constricting the floodplain, and the extra energy would increase erosion in the vicinity of the berm and beyond.

Two tributaries would be intercepted by the Platte River lake, lowering their confluence elevation with the Platte River floodplain by more than 10 feet. Without intervention, this lowering could lead to head cutting on those tributaries, leading to substantial bank failures and property loss well upstream of the lake boundary.

The two dammed lakes would produce different effects. The Elkhorn River lake would trap a significant volume of sediment, preventing its normal delivery to the Platte River. This would require dredging upstream of the dam to maintain lake volume. Without intervention, the trapping of this sediment would facilitate riverbed and bank erosion downstream of the dam and would likely increase localized erosion on portions of the Platte and Elkhorn Rivers, especially near their confluence. The Salt Creek lake would have less effect on the Platte River's stability because it normally delivers a less consequential sediment load to the Platte River. However, the lake would increase erosivity of Salt Creek itself where it runs through an infrastructure-dense area of Ashland, Nebraska.

While various structural and other strategies could mitigate most of the erosion impacts, building and maintenance of any structures are costly. Further, such structures can displace energy and create their own downstream impacts.

Each of the lake positions contemplated would likely create a variety of complex upstream and/or downstream property instabilities and risk management scenarios to a greater extent or in different positions from which they currently occur, especially at the locations in closest proximity to the lakes. Fluvial geomorphic modeling, including detailed numerical modeling of sediment transport and erosive forces will be necessary to determine the specific locations of project impacts and the magnitude of those impacts on flood risks, habitat loss, and asset erosion.

4.6 Additional Analysis

Upon discussion of the analyses completed in June 2024, representatives of NDED in the client advisory group asked whether both Platte River excavated lakes first identified as potential locations early in this study could be considered for construction to provide a total lake area (roughly 3,000 acres) closer to the targeted size mentioned in legislation. Black & Veatch and Olsson briefly revisited analyses to examine the extent to which a two-lake scenario would impact the analytical findings, and concluded that construction of both lakes would not significantly change the findings of the evaluation or the analyses that were completed. Impacts to the yield and water quality of the wellfields from the lakes would not change. The smaller Platte River lake would be further away from MUD's Platte South wellfield and several miles downstream of LWS's wellfield. Changes in flood elevations would be similar to those shown for the single-lake analyses and mitigation would likely be required to limit the rise in the 100-year flood elevation to one foot or less; alternatively, a CLOMR could be sought as in the single-lake scenario. The extent of the mitigation would likely be somewhat greater since more floodplain area would be taken by the second lake. The impacts to the geomorphology of the Platte River and its floodplain would increase; thus, careful consideration of the changes in sediment and erosion patterns in the Platte River as well as tributaries would be needed. Finally, the water balance of the Platte River small excavated lake would be the similar to the large excavated lake, where there would be a slight reduction in evapotranspiration overall.

5. CONCLUSIONS

While no fatal flaws were identified for any of the potential lake locations fully analyzed in this study, challenges and possible adverse impacts were identified for each lake. More detailed analysis would be needed to identify the extent to which possible impacts could be mitigated. Therefore, it is recommended that a full feasibility study be conducted on any site(s) selected for further consideration for development.

A matrix of major conclusions from each analysis is presented in **Table 1**. The analytical reports provided in **Appendices A – E** provide additional detail on these conclusions as well as the analyses leading to them.

Table 1: Major Conclusions of LB1023 (JEDI) Impact Analysis for City of Lincoln Water System and Metropolitan Utilities District.

	Salt Creek Dammed Lake	Elkhorn River Dammed Lake	Platte River Large Excavated Lake	Platte River Small Excavated Lake
Groundwater Modeling	• Increase in groundwater level of approximately 41.8 ft on downstream end of lake	• Increase in groundwater level of approximately 29.4 ft on downstream end of lake	• Potential contaminants introduced at lake would travel relatively quickly (on the order of 5 years or less) to source water for MUD's Platte South wellfield • Increase in groundwater level of approximately 8.4 ft on downstream end of lake • Decrease in groundwater level of approximately 8.4 ft on upstream end of lake	• Potential contaminants introduced at lake would travel relatively quickly (on the order of 5 years or less) to source water for MUD's Platte South wellfield • Increase in groundwater level of approximately 6.8 ft on downstream end of lake • Decrease in groundwater level of approximately 6.8 ft on upstream end of lake
Surface Water Modeling	• Decreased 100-year water surface elevations immediately downstream of up to 0.30 feet • Reduction in 100-year water surface elevations along Platte River of 0.10 foot or less	• Decreased 100-year water surface elevations immediately downstream of up to 0.60 feet • Reduction in 100-year water surface elevations along Platte River of 0.01 foot or less	• Increased 100-year water surface elevations of up to 1.11 feet, which would require a Conditional Letter of Map Revision and coordination with the Federal Emergency Management Agency	• Increased 100-year water surface elevations of up to 1.89 feet in combination with the large excavated lake, which would require a Conditional Letter of Map Revision and coordination with the Federal Emergency Management Agency
Water Balance Analysis	• During exceptionally dry periods, water surface elevation of the lake would fluctuate significantly but minimum flows (as defined by this analysis*) could be maintained downstream • Water surface elevation in the lake would frequently be controlled by minimum flows (as defined by this analysis*) required downstream	• During exceptionally dry periods, water surface elevation of the lake would fluctuate but minimum flows (as defined by this analysis*) could be maintained downstream	• Decreased average annual atmospheric water loss when comparing proposed lake evaporation to existing land use evapotranspiration • Reduced demand on groundwater supplies	• Decreased average annual atmospheric water loss when comparing proposed lake evaporation to existing land use evapotranspiration • Reduced demand on groundwater supplies
Geotechnical Seepage Analysis	• Shallow groundwater would affect earthwork operations and excavations • Foundation seepage rates anticipated to be highly variable based on likelihood of encountering intermittent layers of sands and gravels within the alluvium	• Shallow groundwater would affect earthwork operations and excavations • Foundation seepage rates anticipated to be highly variable based on likelihood of encountering intermittent layers of sands and gravels within the alluvium • Bedrock encountered at depths of around 40 feet could cause concern for karst conditions to be present or develop	• Shallow groundwater would affect earthwork operations and excavations • Seepage rates anticipated to be high based on likelihood of encountering shallow sands and gravels associated with the Platte River and nearby quarries • Depth to bedrock may be variable. Paired with shallow groundwater, karst conditions could be present or develop in the underlying limestone.	• Shallow groundwater would affect earthwork operations and excavations • Seepage rates anticipated to be high based on likelihood of encountering shallow sands and gravels associated with the Platte River and nearby quarries • Depth to bedrock may be variable. Paired with shallow groundwater, karst conditions could be present or develop in the underlying limestone.

Table 1: Major Conclusions of LB1023 (JEDI) Impact Analysis for City of Lincoln Water System and Metropolitan Utilities District.

	Salt Creek Dammed Lake	Elkhorn River Dammed Lake	Platte River Large Excavated Lake	Platte River Small Excavated Lake
Geomorphic Analysis	• Minimal impacts on overall sediment, flow, and habitat in downstream Platte River • Negative impacts on water quality, habitat, fish passage, and flooding to Salt Creek • Adverse impacts to creek bend stability and bridge scour through Ashland	• Substantial impacts on overall sediment, flow, habitat, and water quality in downstream Platte River • Negative impacts on water quality, habitat, and fish passage to the Elkhorn River	• Lake could erode and capture the river, changing its course. River would then fill lake with sediment • Lake would require substantial routine maintenance dredging, unless the lake is isolated from the river with berms • A bermed lake would displace flood flow energy locally and down valley, subjecting additional real estate and infrastructure to erosion • Negative impacts on stability, habitat, and fish passage to Buffalo Creek and Springfield Creek • Increased scour threat due to location on the outside bend of Platte River meander requiring robust channel stabilization measures to protect the lake • Water quality and ecological concerns within lake due to removal of wetlands, nutrient loading, and sedimentation	• Lake could erode and capture the river, changing its course. River would then fill lake with sediment • Lake would require substantial routine maintenance dredging, unless the lake is isolated from the river with berms • Lake is at a natural constriction of the floodplain at this location, and would displace and concentrate erosive forces along the opposite bank and down valley • Negative impacts on stability, habitat, and fish passage to three unnamed tributaries • Water quality and ecological concerns within lake due to removal of wetlands, nutrient loading, and sedimentation

*Required minimum flows were determined based on the monthly 10th percentile flows for each stream. Required minimum flows do not consider wellfield needs as defined by LWS or MUD or existing in-stream flow rights downstream of the lake locations. In addition, the Water Balance Analysis did not consider this recreational lake as a water supply and also assumed a minimum flow during drought conditions for releases to support biological integrity.

APPENDIX A: GROUNDWATER MODELING SUMMARY REPORT

LB 1023 (JEDI) IMPACT EVALUATION FOR CITY OF LINCOLN WATER SYSTEM AND METROPOLITAN UTILITIES DISTRICT: GROUNDWATER MODELING SUMMARY REPORT

CITY PROJECT NO. 702309

OLSSON PROJECT NO. 021-01559

BLACK & VEATCH PROJECT NO. 413017

PREPARED FOR

LINCOLN
Transportation and Utilities

METROPOLITAN
UTILITIES DISTRICT

CITY OF LINCOLN WATER SYSTEM
METROPOLITAN UTILITIES DISTRICT
18 OCTOBER 2024

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Project Name: LB 1023 (JEDI) Impact Evaluation for City of Lincoln Water System and Metropolitan Utilities District
Project Address/Location: Cass, Dodge, Douglas, Sarpy, and Saunders Counties

ACRONYMS AND ABBREVIATIONS

AEM.....Aerial Electromagnetic (Survey)
B&V.....Black & Veatch
DRN.....Drain (MODFLOW Cell/Package)
ENWRA.....Eastern Nebraska Water Resources Assessment
EVT.....Evapotranspiration (MODFLOW Cell/Package)
Lidar.....Light Dectection and Ranging
LPMT.....Lower Platte Missouri Tributaries (Model)
LTU.....Lincoln Transportation and Utilities
LWS.....Lincoln Water System
MUD.....Metropolitan Utilities District
NAD.....North American Datum
NDEE.....Nebraska Department of Environment and Energy
NeDNR.....Nebraska Department of Natural Resources
NHD.....National Hydrography Dateset
NPF.....Node Property Flow (MODFLOW Cell/Package)
PEST.....Model-Independent Parameter Estimation and Uncertainty Analysis
RCH.....Recharge (MODFLOW Cell/Package)
RIV.....River (MODFLOW Cell/Package)
RSWB.....Regional Soil Water Balance (Model)
SFR.....Streamflow Routing (MODFLOW Cell/Package)
STO.....Storage (MODFLOW Cell/Package)
USGS.....U.S. Geological Survey
WEL.....Well (MODFLOW Cell/Package)

TABLE OF CONTENTS

Executive Summary 1
1. Introduction 1
2. Methods 2
2.1 Hydrogeologic Data Assessment and Mapping 2
2.2 Subregional JEDI Groundwater Model Development 7
2.3 Transient Model Resultant Heads 26
3. Results: Calibration 32
3.1 Calibration Targets 32
3.2 Calibration Approach 32
3.3 Calibration Results 32
4. Scenarios 48
4.1 Reverse Particle Tracking Scenarios 48
4.2 Lake Scenarios 54
4.3 Forward Particle Tracking Scenario 61
5. References 62

LIST OF FIGURES

Figure 1: JEDI Model Domain 3
Figure 2: JEDI Land Use 4
Figure 3: Cultivated Crop Types Within the JEDI Model Domain (1960-2012; adapted from NeDNR 2023) 5
Figure 4: JEDI Soil Classifications 6
Figure 5: JEDI Layer 1 Horizontal Discretization 10
Figure 6: JEDI Layer 2 Horizontal Discretization 11
Figure 7: JEDI Layer 3 Horizontal Discretization 12
Figure 8: JEDI Layer 4 Horizontal Discretization 13
Figure 9: JEDI Layer 5 Horizontal Discretization 14
Figure 10: JEDI Boundary and Internal Cell Assignments 16
Figure 11: Layer 1 Resistivity Groups 21
Figure 12: Layer 2 Resistivity Groups 22
Figure 13: Layer 3 Resistivity Groups 23
Figure 14: Layer 4 Resistivity Groups 24
Figure 15: Layer 5 Resistivity Groups 25
Figure 16: Layer 1 Heads from Stress Period 446........ 27
Figure 17: Layer 2 Heads from Stress Period 446........ 28
Figure 18: Layer 3 Heads from Stress Period 446........ 29
Figure 19: Layer 4 Heads from Stress Period 446........ 30
Figure 20: Layer 5 Heads Stress Period 446........ 31
Figure 21: Residual Heads from Steady-State Model-Independent Parameter Estimation and Uncertainty Analysis (PEST) Run........ 33
Figure 22: Transient Water Level (WLE) Target Locations 34
Figure 23: Transient Water Level Hydrographs - Observations 1-5 35
Figure 24. Transient Water Level Hydrographs - Observations 6-10 36
Figure 25: Transient Water Level Hydrographs - Observations 11-15 37
Figure 26: Transient Water Level Hydrographs - Observations 16-20 38
Figure 27: Transient Water Level Hydrographs - Observations 21-25 39
Figure 28: Transient Water Level Hydrographs - Observations 26-30 40
Figure 29: Transient Water Level Hydrographs - Observations 31-35 41
Figure 30: Transient Water Level Hydrographs - Observations 36-40 42
Figure 31: Transient Water Level Hydrographs - Observations 41-45 43
Figure 32: Transient Water Level Hydrographs - Observations 46-50 44
Figure 33: Transient Water Level Hydrographs - Observations 51-55 45

Figure 34: Transient Water Level Hydrographs - Observations 56-60 46
Figure 35: Transient Water Level Hydrographs - Observations 61-65 47
Figure 36: Results from Wet Event - Particles Placed along Platte River 49
Figure 37: Results from Wet Event - Particles Placed around Municipal Well Cells...................50
Figure 38: Results from Normal Event - Particles Placed along Platte River 51
Figure 39: Results from Normal Event - Particles Placed around Municipal Well Cells..............52
Figure 40: Results from Dry Event - Particles Placed along Platte River 53
Figure 41: Results from Dry Event - Particles Placed around Municipal Well Cells 54
Figure 42: Changes in Head at Elkhorn River Lake Location 56
Figure 43: Changes in Head at Salt Creek Lake Location 57
Figure 44: Changes in Head at Upstream of Louisville Lake Location.......................................58
Figure 45.Changes in Head at Downstream of Louisville Lake Location 59
Figure 46: Changes in Head at Platte River Lake Locations...60
Figure 47: Forward Particle Tracking - Particles Placed in Platte River Lakes...........................61

LIST OF TABLES

Table 1: Development of Sandpit Lakes Along the Platte River... 5
Table 2: Temporal Discretization.. 8
Table 3: Horizontal Discretization by Layer 9
Table 4: Water Budget Terms 15
Table 5: Resistivity Grouping and Corresponding Hydraulic Conductivity.................................20
Table 6: Parameter Estimation and Uncertainty Analysis (PEST) Calibration Statistics.............33
Table 7: Stress Periods for Each Climatic Scenario 48
Table 8: Lake Scenario Details 55

EXECUTIVE SUMMARY

In 2021 and 2022, the Nebraska legislature enacted LB406 and LB1023, respectively, which first established the Statewide Tourism And Recreational Water Access and Resources Sustainability (STAR WARS) special committee, and then the Lake Development Act which was codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (*Neb. Rev. Stat.* §61-401 to 61-404). In these pieces of legislation, the unicameral recognized the importance – in the wake of historic flooding in 2019 and the COVID-19 pandemic – for both flood control and major recreational opportunities in the state to attract and retain an increasingly remote workforce. The STAR WARS committee envisioned, in the lower Platte River corridor, a lake that would rival Iowa's Lake Okoboji as a tourist destination and hub for public-private partnerships to develop lakeside communities, a community town center, and a major resort. As outlined in the STAR WARS committee's report, a lake location northeast of the city of Ashland, Nebraska was contemplated and this informed the committee's recommendation that further analysis be conducted to inform viable locations for a lake of at least 3,600 acres, located in or near Sarpy County, and adjacent to – but not impounding – the Platte River.

Recognizing the potential for impacts to public water system wellfields, the legislature also appropriated funds to be administered through the Nebraska Department of Natural Resources (NeDNR) for further study on possible lake sites. The City of Lincoln Water System (LWS) already had its Water 2.0 project – investigating possibilities for additional source(s) of drinking water – underway with Black & Veatch and Olsson, and recognized that these consultants have the necessary expertise regarding the water system as well as expertise in the types of technical analysis needed for potential lake sites. Thus, LWS amended its Water 2.0 contract to include this study and entered into a memorandum of understanding with Omaha's Metropolitan Utilities District (MUD) to allow for MUD's wellfields and concerns to also be considered.

As part of the work under the amended Water 2.0 contract, Olsson was tasked to construct a groundwater flow model (JEDI model). The JEDI model was constructed to be run as a standalone model but has the capability to be coupled with the regional Lower Platte Missouri Tributaries (LPMT) model, its "parent" model. The purpose of the JEDI model is to determine locations where a lake as envisioned in legislation should **not** be developed because of impacts to municipal wellfields, especially those operated by LWS and MUD.

The JEDI model was constructed as a five-layer MODFLOW 6 model, using octree refinement (Langevin et al. 2017). The model cells are most refined along the Platte River in Layer 1 (the uppermost layer) and grow coarser as they move outward from the Platte River and move down through the layers. Most modeling inputs were borrowed from the regional LPMT model; however, aerial electromagnetic (AEM) survey data was used to refine aquifer properties, and flow-stage relationships were used to build the Platte River MODFLOW 6 package. Stream locations and pumping data were also refined based on the refinement of the JEDI model grid.

Additionally, municipal pumping data was refined based on pumping data from The Flatwater Group.

Water level scenarios showed that for the Salt Creek lake location, an increase in groundwater level of approximately 41.8 feet could be expected on the downstream end of the lake; for the Elkhorn River lake location, this increase was approximately 29.4 feet. For the large Platte River lake, an increase in groundwater level on the downstream end of the lake of 8.4 feet was modeled, with a commensurate upstream decrease. For the small Platte River lake, this increase and decrease was 6.8 feet.

Reverse particle tracking scenarios were completed using wet, dry, and normal climatic conditions, which were built to isolate the effects of Platte River flow and municipal wellfield pumping rates on contaminant time of travel, i.e., the amount of time as determined by modeling for a single particle of a contaminant to move from one location to another. Particles traveled the farthest (largest radius of influence) when the Platte River was at a low-flow stage and pumping rates were high, and conversely had the smallest radius of influence when the Platte River was at a high-flow stage and pumping rates were low. When the Platte River flow stage and pumping rates were set to normal conditions (mean values), the radius of influence predictably landed between these two extremes. The reverse particle tracking scenarios both allowed for a more complete understanding of how groundwater and surface water interact in and near the lower Platte River and the importance of ensuring that any possible lake locations to be considered did not intersect with wellhead protection areas (WHPAs) or existing infrastructure. WHPAs are delineated to aid public water systems both in understanding where their source water comes from and potential sources of contamination, and to provide a basis from which to consider and implement protections against contamination of public water supplies.

Following identification of viable potential lake locations with feedback from the client advisory group consisting of LWS, MUD, and the Nebraska Department of Natural Resources (NeDNR), four total lakes – dammed lakes on the Elkhorn River and Salt Creek, and large and small excavated lakes along the Platte River – were modeled. It is noted that the small lake along the Platte River was originally not included in analyses, but was added upon request of the Nebraska Department of Economic Development once results of the original scenarios were presented. In all scenarios, generally, water table levels decreased at the upstream boundary and increased at the downstream boundary of each lake. Additionally, forward particle tracking scenarios were completed for the two lake locations along the Platte River. These scenarios demonstrated that contaminants in either of these two lakes would have short times of travel – on the order of five years or fewer – to the Platte River and, from there, to the MUD Platte South wellfield. It is noted that presence of either lake configuration along the Platte River (either the large lake alone or the large and small lake combined) would present a significantly different hydrologic regime than is present currently in the vicinity of these municipal wellfields and, thus, contaminants not yet encountered at these wellfields could become a concern.

1. INTRODUCTION

As part of the Legislative Bill (LB) 1023 (JEDI) Evaluation for the City of Lincoln Water System (LWS) and Omaha's Metropolitan Utilities District (MUD) project, Olsson constructed the JEDI groundwater model (JEDI model). The JEDI model is a "child" model of the Lower Platte – Missouri Tributaries (LPMT) model, which was commissioned by the Nebraska Department of Natural Resources (NeDNR) and constructed by HDR, The Flatwater Group, and TBirdie Consulting Inc. Olsson also separately completed work to convert the LPMT model to a MODFLOW 6 model and update it through 2020 (Olsson 2023).

The purpose of the JEDI model is to provide information for and receive information from the coupled surface water model, which was developed by project partner Black & Veatch (B&V). The JEDI model is used to determine areas where the proposed lake should **not** be developed because of potential impacts to existing wellfields (including through both contamination and altered water levels). These impacts are determined through particle tracking scenarios (via MODPATH software) that identify capture zones for these wellfields. From there, the surface water model is used to delineate potential lake locations in the remaining floodplain area by eliminating areas that don't have enough available area for the lake. Once these unsuitable areas are eliminated, the JEDI model is used to further refine potential lake locations based on bedrock elevations, which are used to determine the depths of potential lakes, and existing groundwater gradients. This modeling allows for the elimination of areas where bedrock is not deep enough to support the lake and determines necessary berm heights on the downstream end of the lakes. Finally, the groundwater model is used to model potential lakes and berms, identifying changes in water table elevation. Additionally, forward particle tracking is completed to demonstrate times of travel to the Platte River (and thence to municipal wellfields).

This report details the construction and calibration of the JEDI model. For information on the converted and updated LPMT model (the "parent" model), refer to Olsson's previous report (Olsson 2023). Development of the surface water model is detailed in the report titled "LB 1023 (JEDI) Impact Evaluation for City of Lincoln Water System and Metropolitan Utilities District: Surface Water Flood Modeling Report", authored by B&V. Implications of these modeling efforts, as well as the others carried out under the larger JEDI evaluation project, are detailed in the project's final summary report, to which this report is an appendix.

2. METHODS

The methods used to construct the JEDI model are outlined below.

2.1 Hydrogeologic Data Assessment and Mapping

The development of the conceptual model is outlined here, including the geographic setting and land use; the hydrology and hydrogeology; soils; and previous modeling efforts.

2.1.1 Geographic Setting and Land Use

The JEDI model domain is within the east central/southeast portion of the LPMT model, covering portions of Dodge, Washington, Saunders, Douglas, Sarpy, Lancaster, and Cass counties in Nebraska. **Figure 1** shows the extent of the JEDI model domain.

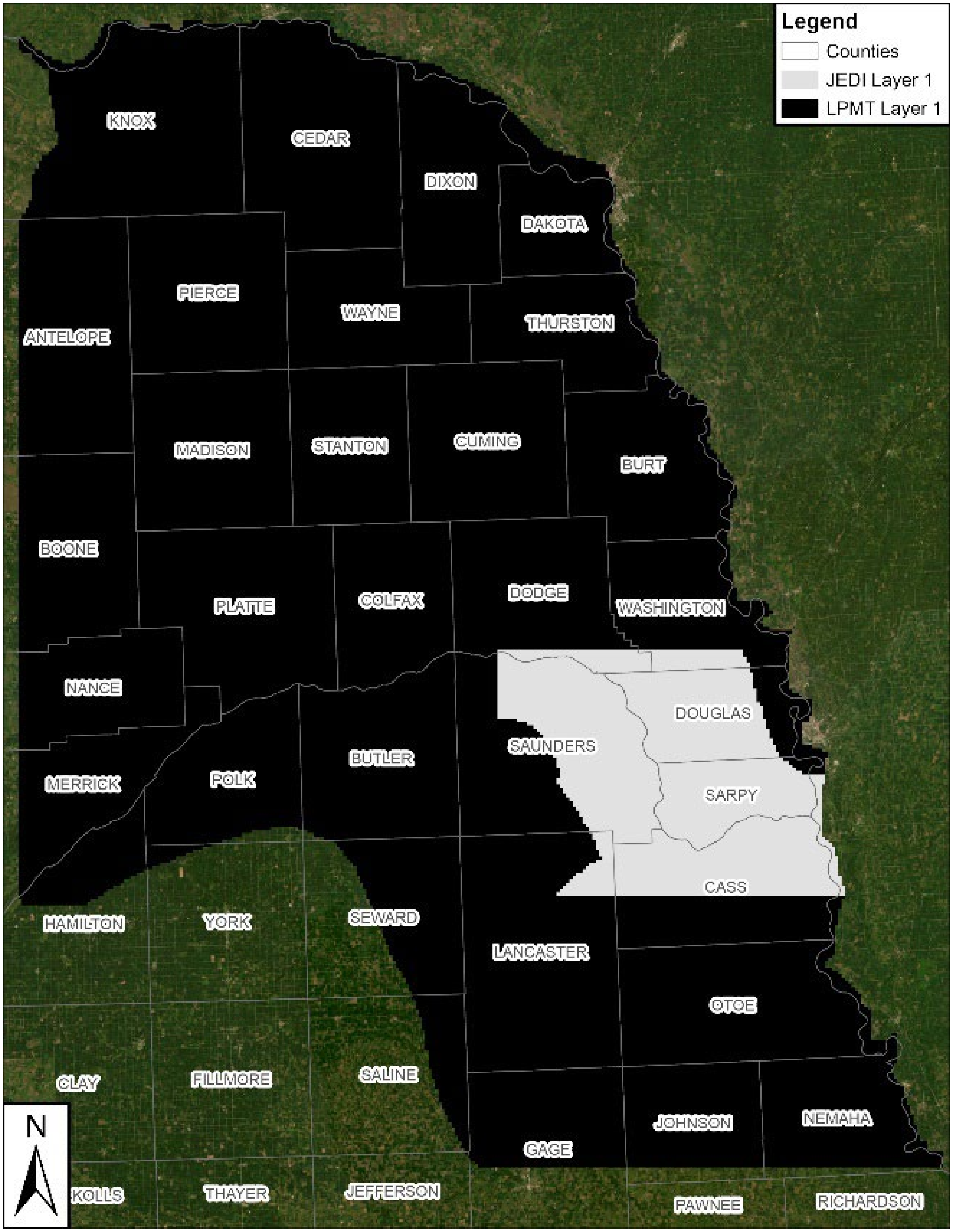

Figure 1: JEDI Model Domain

Land use within the JEDI model domain is a mix of agricultural, municipal, and small areas of forest (largely adjacent to surface water features). **Figure 2** shows land use classifications within the JEDI model domain (Dewitz 2021).

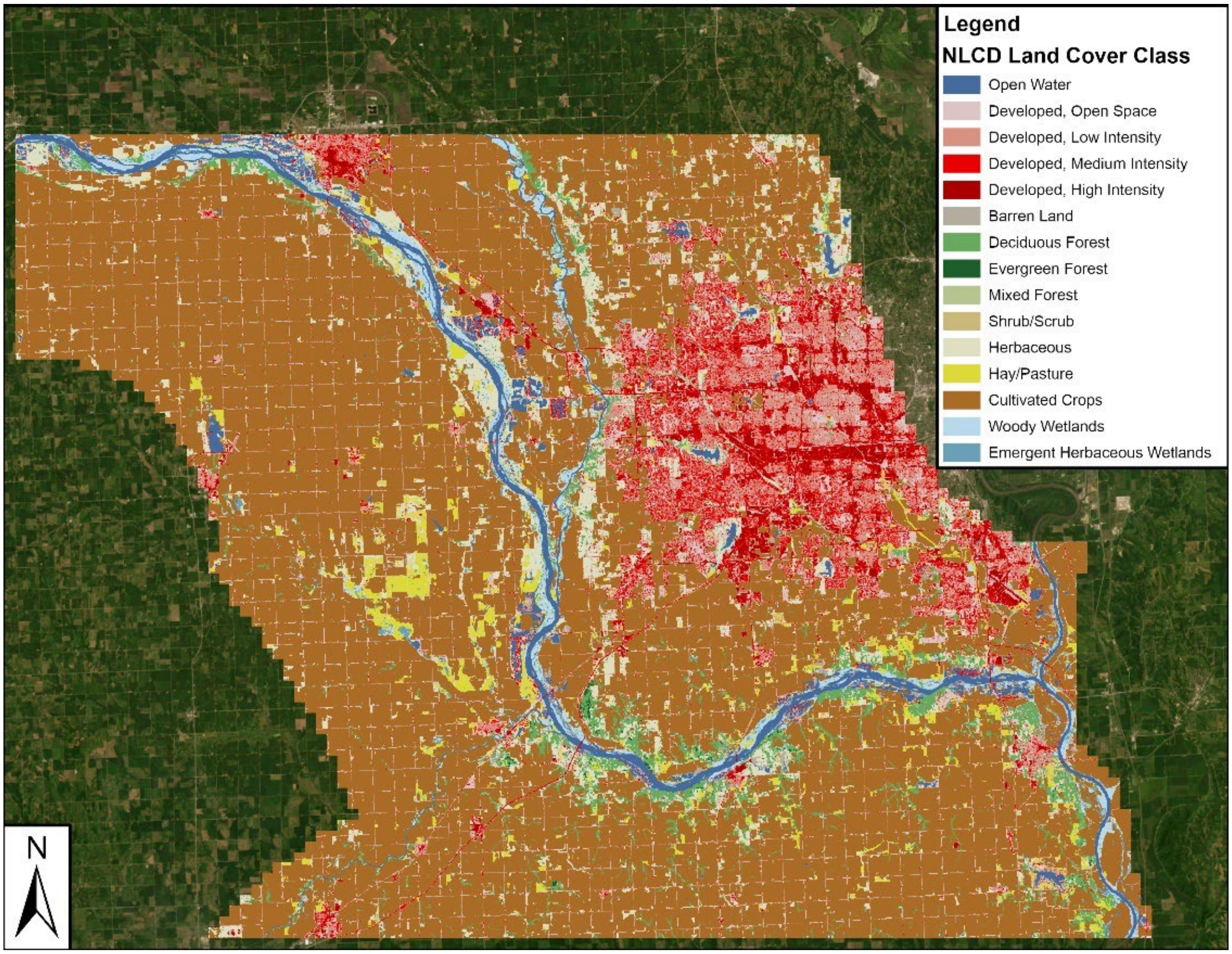

Figure 2: JEDI Land Use

Historic Trends in Land Use

Figure 3 shows the change in cultivated crop types from 1960 to 2012 within the JEDI model domain (NeDNR 2018). The bars, each representing a year, are expressed as a percentage of the model area, and each color corresponds to a different cultivated crop type.

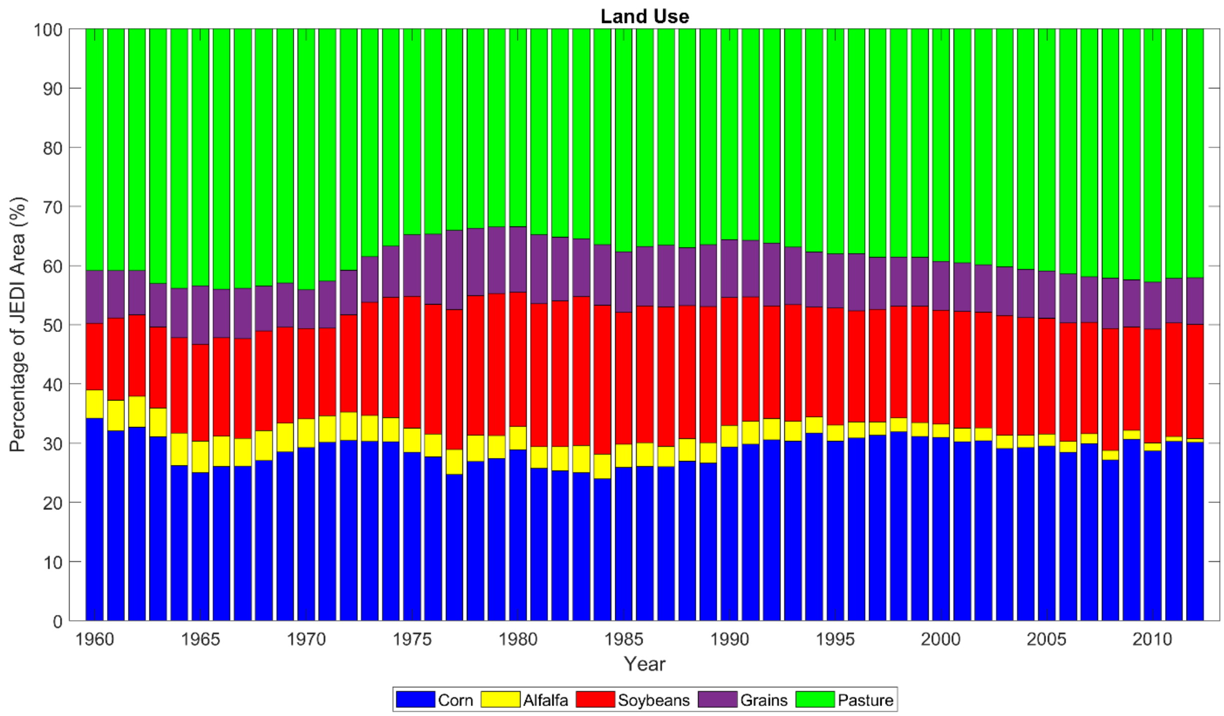

Figure 3: Cultivated Crop Types Within the JEDI Model Domain (1960-2012; adapted from NeDNR 2023)

Aerial imagery from the years 1984, 2003, and 2023 was used to outline the footprint and quantity of lakes present along the Platte River between North Bend and the confluence with the Missouri River. As shown in **Table 1**, the number of sandpit lakes has increased at a relatively constant rate since 1984. Several parcels are currently owned by sand and gravel mining companies according to the Sarpy County parcel boundary dataset (Sarpy County 2023). Considering the rate of development and parcel ownership, it is reasonable to assume that sandpit lakes will continue to be constructed along the Platte River.

Table 1: Development of Sandpit Lakes Along the Platte River

Aerial Year	Number of Sandpit Lakes
1984	131
2003	200
2023	281

2.1.2 Hydrogeology

In the model domain, the Dakota aquifer underlies the younger Cenozoic Era sediments; however, it is generally regarded as a minor contributor to the overall groundwater supply (Korus et al. 2013). The primary aquifer of interest supplies the municipal wells; it consists of younger, unconsolidated sediments and is explicitly delineated in the JEDI model. Vertical flow from the Dakota aquifer to the primary aquifer is determined by the regional LPMT model and incorporated as an input to the JEDI model.

2.1.3 Soils

Several soil classifications are present within the JEDI model domain, including large areas of Ponca-Marshall in the east; Sharpsburg, Sharpsburg-Fillmore, and Zook-Wabash-Kennebec in the west; and Luton-Gibbon, Inavale-Cass-Barney, Platte-Leshara-Inavale-Alda, and Monona-Ida along the Platte River (UNL 2009). Soil classifications are presented in **Figure 4**.

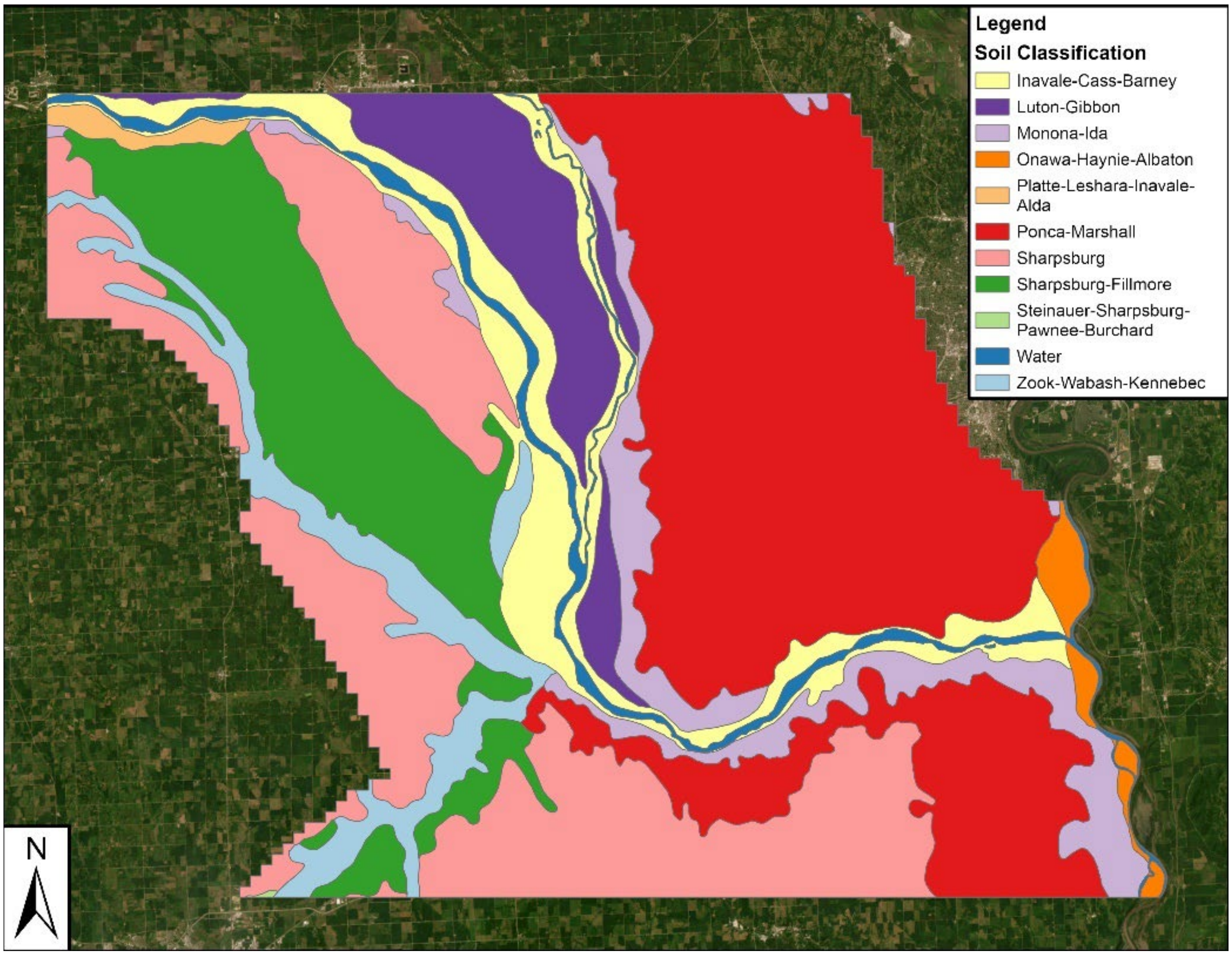

Figure 4: JEDI Soil Classifications

2.1.4 Previous Modeling Efforts

Under a separate contract with NeDNR, Olsson updated and extended the LPMT model (the "parent" model to the JEDI model). The LPMT model was updated from MODFLOW 2005 software to MODFLOW 6 software and extended to add the years 2014-2020. Of note is the use of quasi-3D confining layers (as included in the original model), which are not supported in MODFLOW 6 software; so, the updated LPMT model consists of three distinct layers instead of two. Sensitivity analysis was completed on specific storage and hydraulic conductivity terms, consisting of a suite of simulations that showed reducing both terms benefited the parallelism of the water budget between the two model versions, i.e., reducing both terms made the MODFLOW 6 water budget terms match the MODFLOW 2005 water budget terms most closely. The seven additional years simulated in the model were represented by 84 monthly stress periods. Finally, the WEL and RCH packages, which contain the pumping and recharge inputs, were extended using data taken from the Regional Soil Water Balance (RSWB) model; for the EVT and SFR packages, which simulate evapotranspiration and streams in the model, the data from 2006-2013 was repeated (NeDNR 2018).

2.2 Subregional JEDI Groundwater Model Development

The development of the JEDI model is outlined below, including the decision to use MODFLOW 6 software, the discretization of the model, the boundary conditions, and a description of how the model input files were constructed.

2.2.1 Model Code and Applications

The MODFLOW software suite of groundwater modeling codes published by the U.S. Geological Survey (USGS) are accepted as the industry standard for groundwater flow modeling. MODFLOW software uses a finite difference numerical solution to solve a system of equations using iterative numerical methods. MODFLOW 6 software (Langevin et al. 2017) is the most recent version of the MODFLOW software family and was selected for this modeling effort for the following reasons:

- MODFLOW 6 software supports multiple models and multiple types of models within the same simulation. This feature allows for tightly coupling the JEDI model with the regional LPMT model at the matrix level by adding them to the same numerical solution.
- MODFLOW 6 software supports unstructured grids and vertically varying discretization. This feature allows more flexible discretization of model inputs where irregular features need to be accurately represented and complex, highly heterogeneous aquifer properties exist.
- MODFLOW 6 software allows for a single design of the Newton-Raphson formulation for groundwater flow between connected, convertible groundwater cells. This feature prevents cells from going dry when computed water levels fall below the cell bottom and improves the solution of unconfined groundwater-flow problems where cell drying/rewetting is common. This is an important update because the occurrence of dry cells in simulations could cause models to produce unreliable results.
- MODFLOW 6 software can partition model packages of the same type to track water budgets individually. This feature allows for separate well pumping by group and by different river systems to be tracked individually.

MODFLOW 6 software was also chosen for the JEDI model because it supports groundwater model coupling. To accurately depict boundary conditions, two versions of the JEDI model were built: (1) a coupled version, and (2) a standalone version. In the coupled version, the JEDI (child) model is coupled with the LPMT (parent) model. An exchange file defines how parent and child models are spatially related and determines how they interact in a coupled model run; vertical and horizontal exchanges must be specified. All five layers of the JEDI model correspond to Layer 1 of the LPMT model. All five layers of the JEDI boundary cells were horizontally connected to Layer 1 of the bordering LPMT cells. All Layer 5 JEDI cells were vertically connected to the Layer 2 LPMT cells they overlayed. Layer schematics are provided below. On completion of the coupled model run, the amount and direction of water that is exchanged between the two models is specified as an output.

The flow exchanged between the two models is then specified as an input in the standalone JEDI model. The exchanges are specified as well files and referred to as "face flows" throughout this report. All face flows are input into Layer 5 of the standalone JEDI model and separated by vertical and horizontal flows. The magnitude and direction of flow from the coupled LPMT model is maintained in the face flow well files for the JEDI model. Flow into the JEDI model (from the LPMT model) is specified as an injection well, whereas flow out of the JEDI model (into the LPMT model) is specified as an extraction well.

The JEDI model was calibrated using Parameter Estimation and Uncertainty Analysis (PEST) as discussed further in Section 3. MODPATH software, a companion program to MODFLOW software, is also used for particle tracking to determine areas of influence for specific locations/cells within the JEDI model.

The coordinate system used for the JEDI model is the same as for the LPMT model, i.e., North American Datum (NAD) 1983 State Plane Nebraska Federal Information Processing Standards (FIPS) 2600 (NeDNR 2018).

2.2.2 Model Discretization

The temporal and horizontal discretization of the JEDI model are outlined below.

2.2.2.1 Temporal Discretization

The JEDI model is temporally discretized into 446 stress periods. The model begins in 1960 and ends in December 2020. The first 26 stress periods are annual and the remaining 420 stress periods are monthly, as outlined in **Table 2**. The temporal discretization of the JEDI model exactly reflects the temporal discretization of the extended LPMT MODFLOW 6 model (Olsson 2023).

Table 2: Temporal Discretization

Simulation Period	Number of Stress Periods	Length of Stress Period (days)
1960 - 1985 (annual)	26	365.25
1986 - 2020 (monthly)	420	30.43

2.2.2.2 Horizontal Discretization

The JEDI model is divided vertically into five layers and uses octree refinement. The model cells are most refined in Layer 1, within the Platte River alluvial valley where the minimum cell size is 82.5 by 82.5 feet. Cell faces double in length incrementally, moving outward from the Platte River, reaching a maximum cell size of 2,640.0 by 2,640.0 feet. The octree refinement is horizontally smoothed so that no more than two cells touch any particular face of a neighboring cell. Cell faces also double in length moving down layers, with a maximum of four cells overlaying a single cell of a lower layer. The number of cells and minimum cell size by layer is shown in **Table 3**. The spatial discretization by layer is shown in **Figures 5 - 9**.

Table 3: Horizontal Discretization by Layer

<table>
<tr><th>Layer</th><th>Number of Cells</th><th>Minimum Cell Size</th><th>Maximum Cell Size</th></tr>
<tr><td>1</td><td>311,851</td><td>82.5 x 82.5 feet = 0.160 acre</td><td rowspan="5">2,640.0 x 2,640.0 feet = 160 acres</td></tr>
<tr><td>2</td><td>80,761</td><td>165.0 x 165.0 feet = 0.625 acre</td></tr>
<tr><td>3</td><td>23,431</td><td>330.0 x 330.0 feet = 2.500 acres</td></tr>
<tr><td>4</td><td>9,592</td><td>660.0 x 660.0 feet = 10.000 acres</td></tr>
<tr><td>5</td><td>6,319</td><td>1,320.0 x 1,320.0 feet = 40.000 acres</td></tr>
</table>

Finally, note that all horizontal JEDI (child) model boundary cells are the same size as LPMT (parent) model boundary cells for ease of coupling.

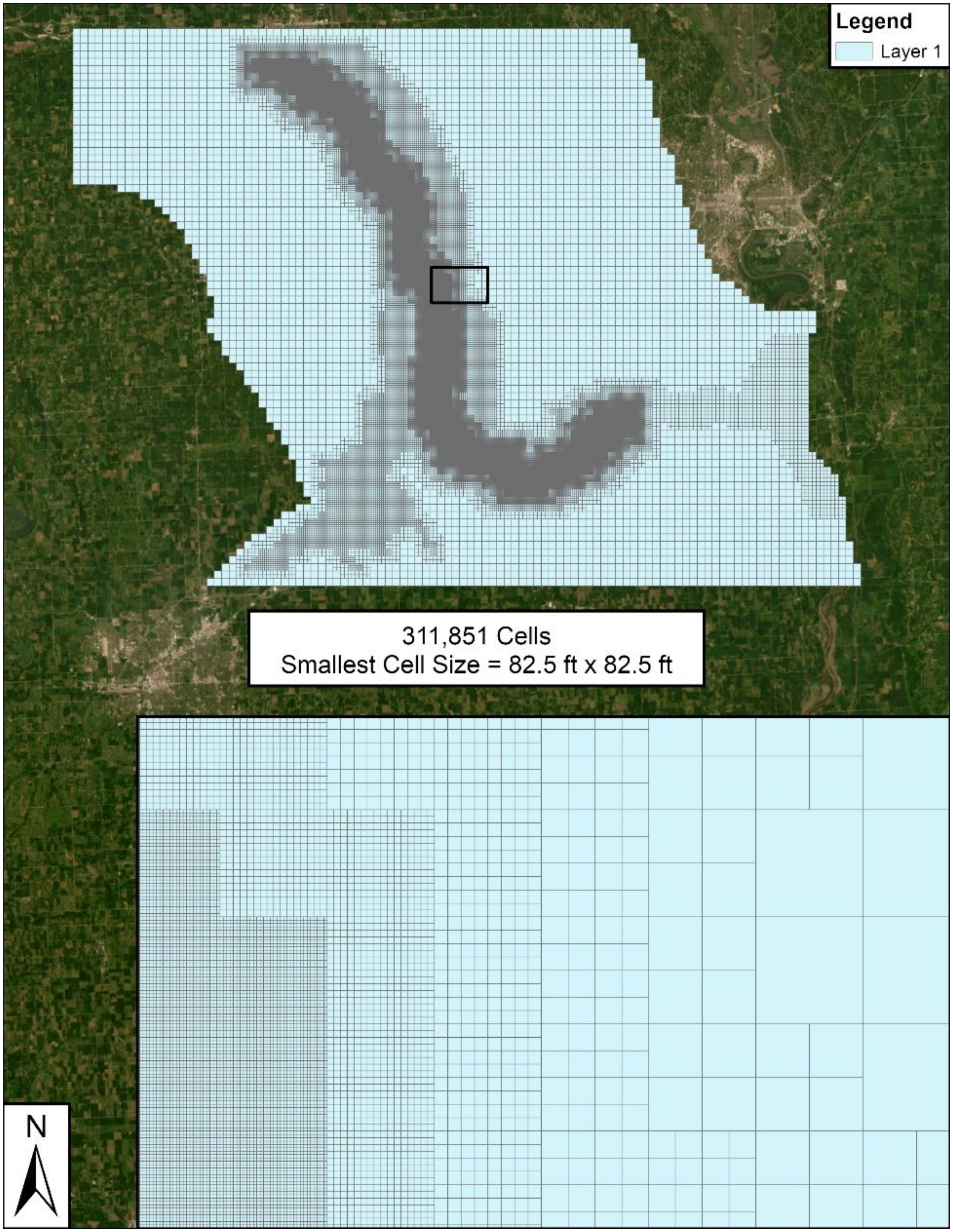

Figure 5: JEDI Layer 1 Horizontal Discretization

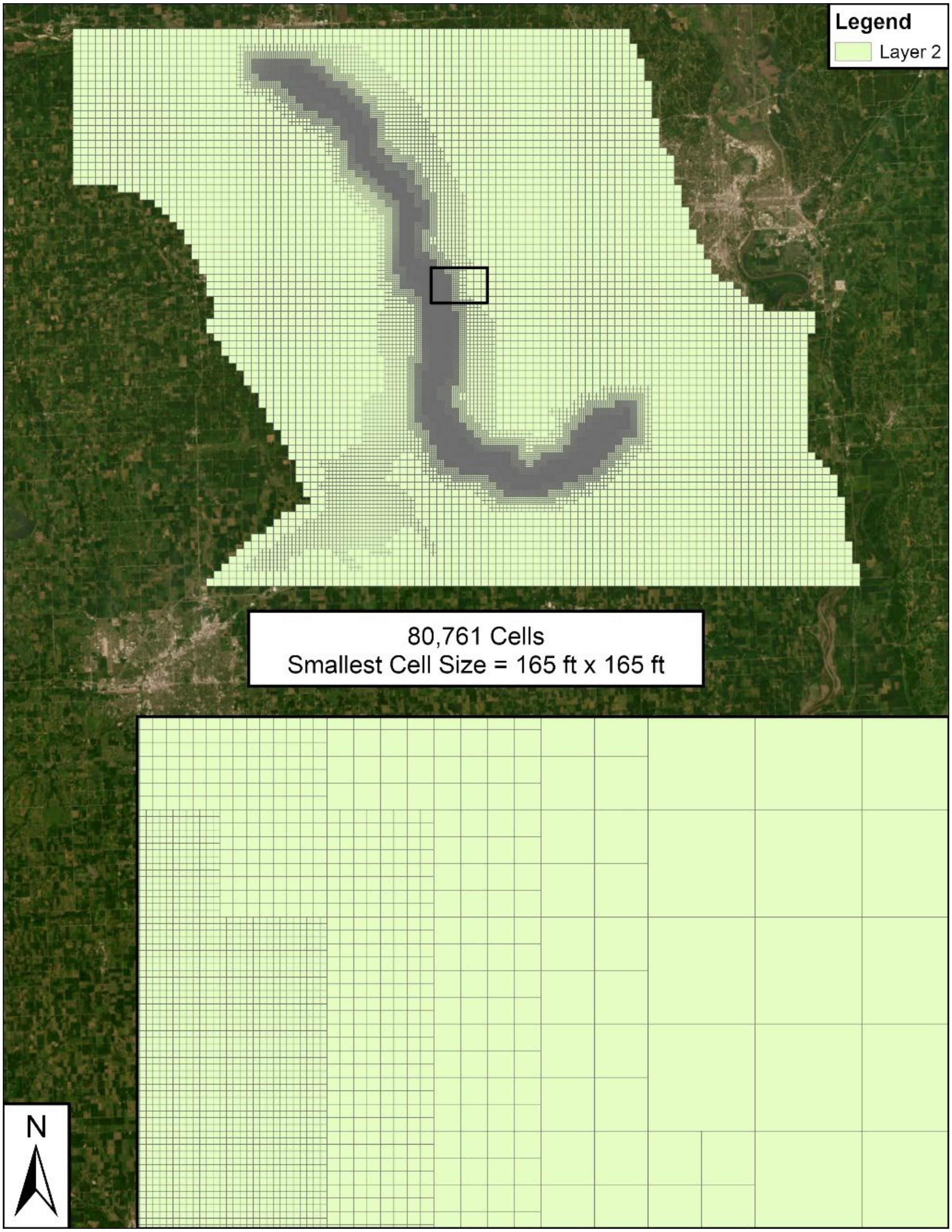

Figure 6: JEDI Layer 2 Horizontal Discretization

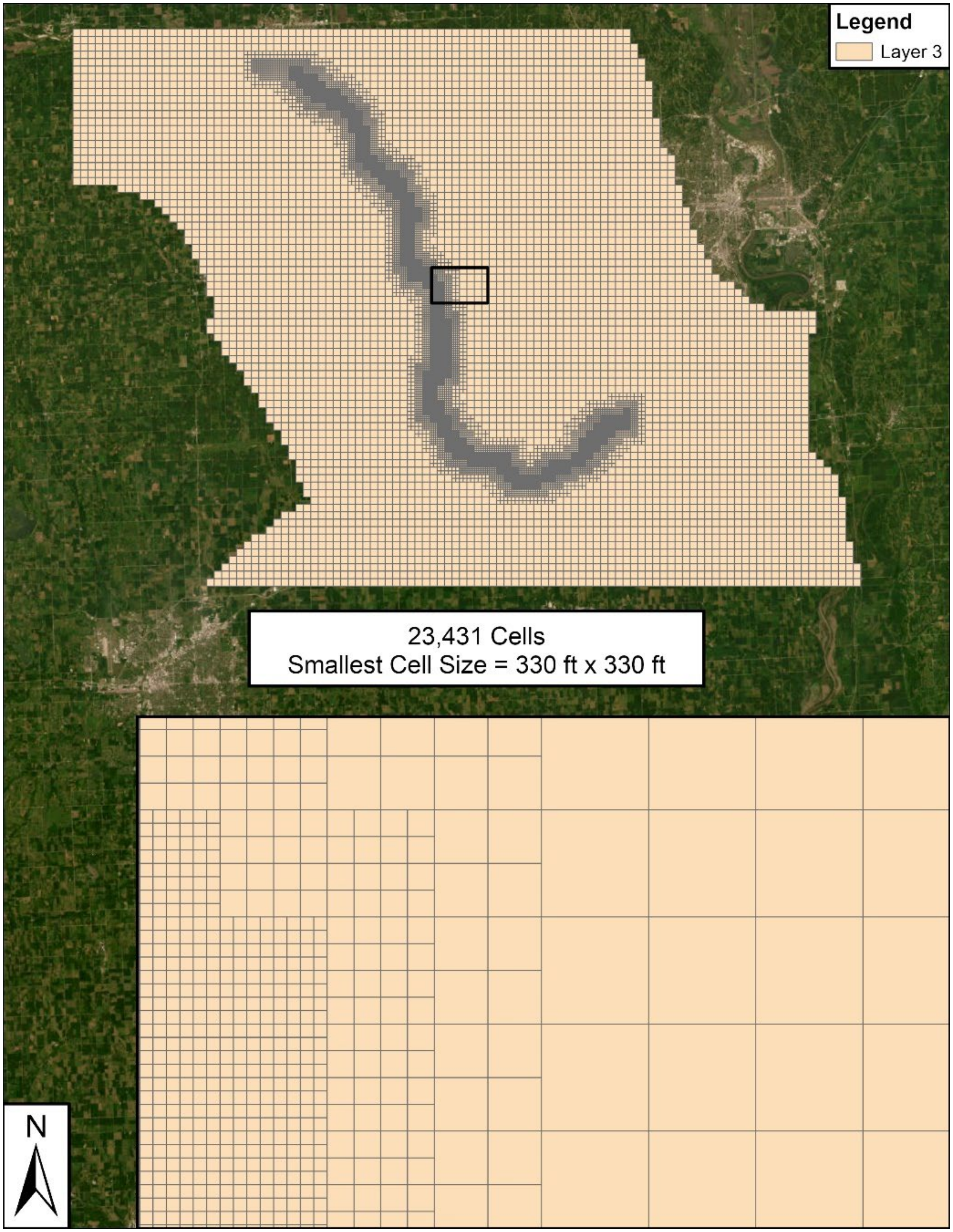

Figure 7: JEDI Layer 3 Horizontal Discretization

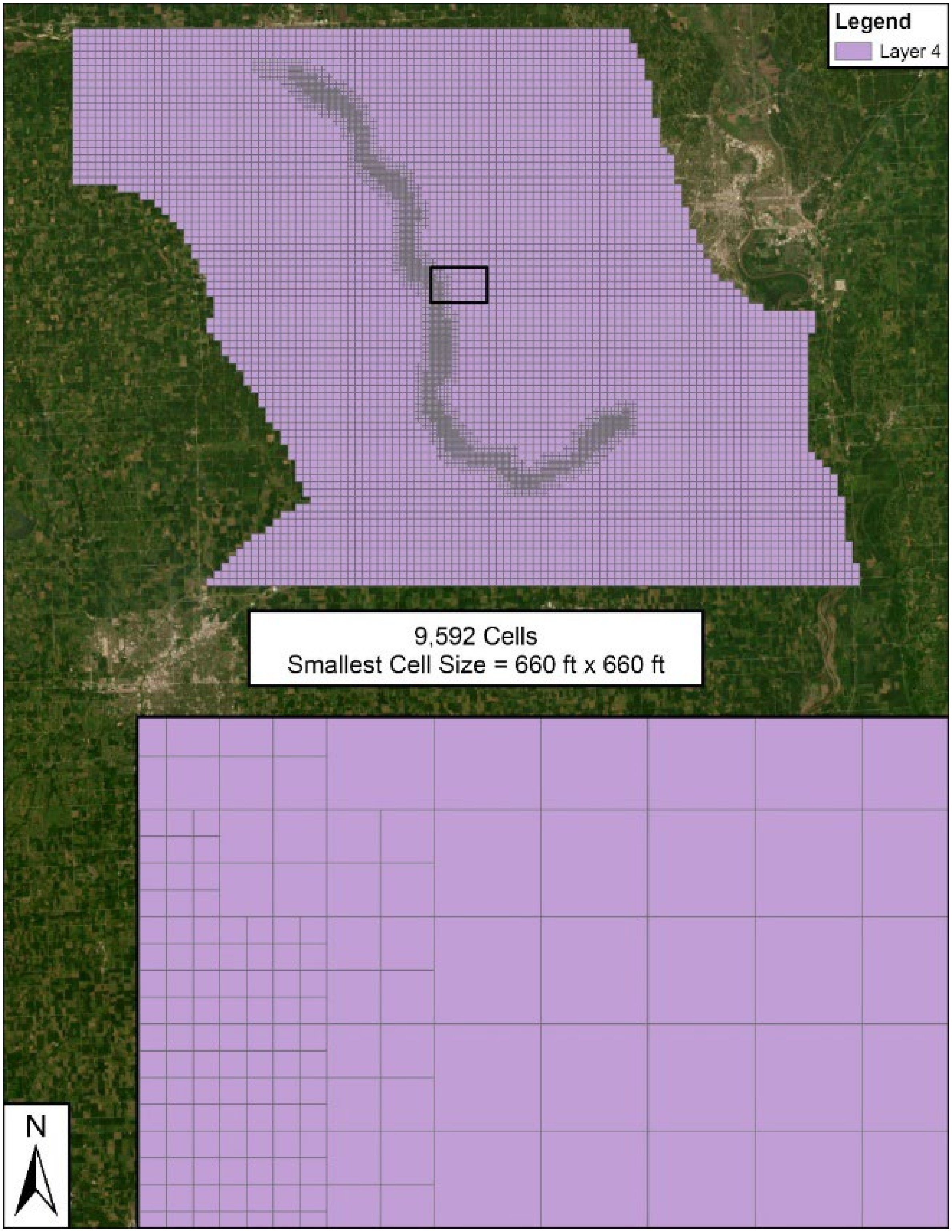

Figure 8: JEDI Layer 4 Horizontal Discretization

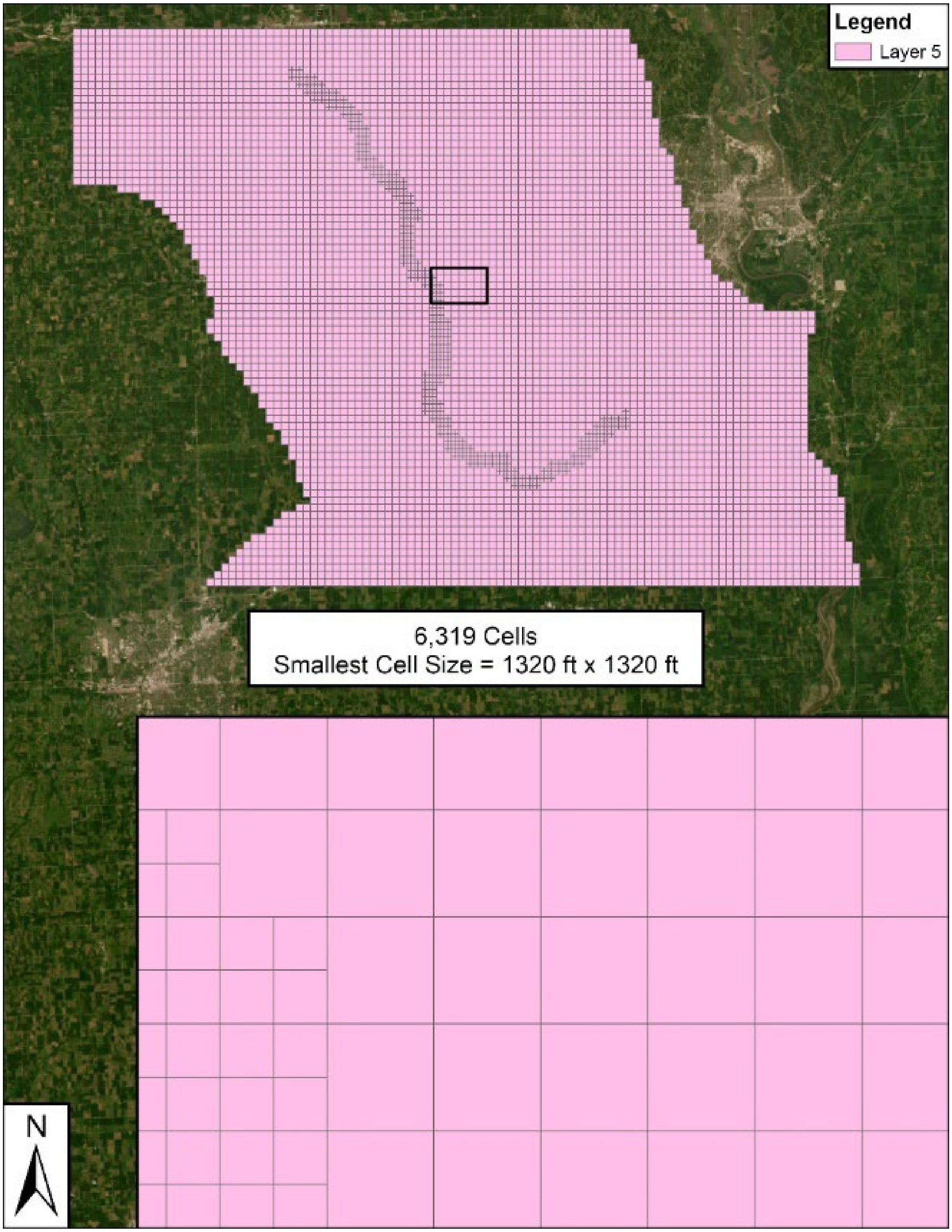

Figure 9: JEDI Layer 5 Horizontal Discretization

2.2.2.3 Vertical Discretization

The top of Layer 1 (model top) was defined using the average lidar surface elevation within each cell. The bottom of Layer 5 (model bottom) was defined based on the bottom of each corresponding cell in Layer 1 of the LPMT model. Horizontal discretization decreased with depth as outlined above. This was done to ensure a balance between a high level of refinement near areas of interest (i.e., the Platte River) while keeping the total number of cells - and therefore, model run times - manageable.

Layer Design

At each location within the model, the layers were initially set to equal thickness, using the difference between model top and model bottom. Adjustments were made to enforce a minimum layer thickness of two feet at all locations, forcing the top of the model up, above land surface, to maintain the bottom of the model equal to the bottom of LPMT Layer 1. The tops of lower layers are defined using the bottom of the layer above. For example, the top of a Layer 2 cell is defined based off the bottom of the Layer 1 cell that overlays it. Additional adjustments were made to assure that each lower-layer cell top was defined based on a continuous upper-layer bottom. In locations where four Layer 1 cells overlay a single Layer 2 cell, all four Layer 1 cells were assigned the same cell bottom. This process was repeated for consecutive layers. As a result of this process, thicknesses between layers at a single location deviated slightly and were not always equal.

2.2.3 Boundary Conditions and Cell Assignments

Table 4, below, provides a summary of water budget terms, the model packages used, and what each term simulates.

Table 4: Water Budget Terms

Package (Water Budget Term)	Simulating
EVT (EVT)	Evapotranspiration
WEL (WEL_1)	Lateral face flows from LPMT* model
WEL (WEL_2)	Vertical face flows from LPMT* model
WEL (WEL_3)	Wells located in the unrefined portion of the model
WEL (WEL_4)	Wells in the refined portion of the model that are neither MUD* nor LWS* wells
WEL (WEL_5)	MUD Platte South wellfield
WEL (WEL_6)	MUD Platte West wellfield
WEL (WEL_7)	LWS wellfield
RIV (RIV_1)	Missouri River
RIV (RIV_2)	Platte River
RCH (RCH)	Recharge
STO (STO_SS & STO_SY)	Aquifer storage

**LPMT = Lower Platte Missouri Tributaries (Model); MUD = Metropolitan Utilities District; LTU = Lincoln Transportation and Utilities*

Outer boundary cells (at the edges of the JEDI model domain) are specified flow cells, with flows specified from the LPMT parent model. As in the LPMT model, the Missouri River cells are assigned as river (RIV) cells and serve as the eastern boundary of the model. The Platte River cells are also assigned as RIV cells because this area is horizontally refined; it provides the ability to define stages on a stress-period-by-stress-period basis. The tributaries are assigned as Drain (DRN) cells because they are important to the water budget but are not our primary interest in the construction of the JEDI model. **Figure 10**, below, shows all cell assignments within the JEDI model domain.

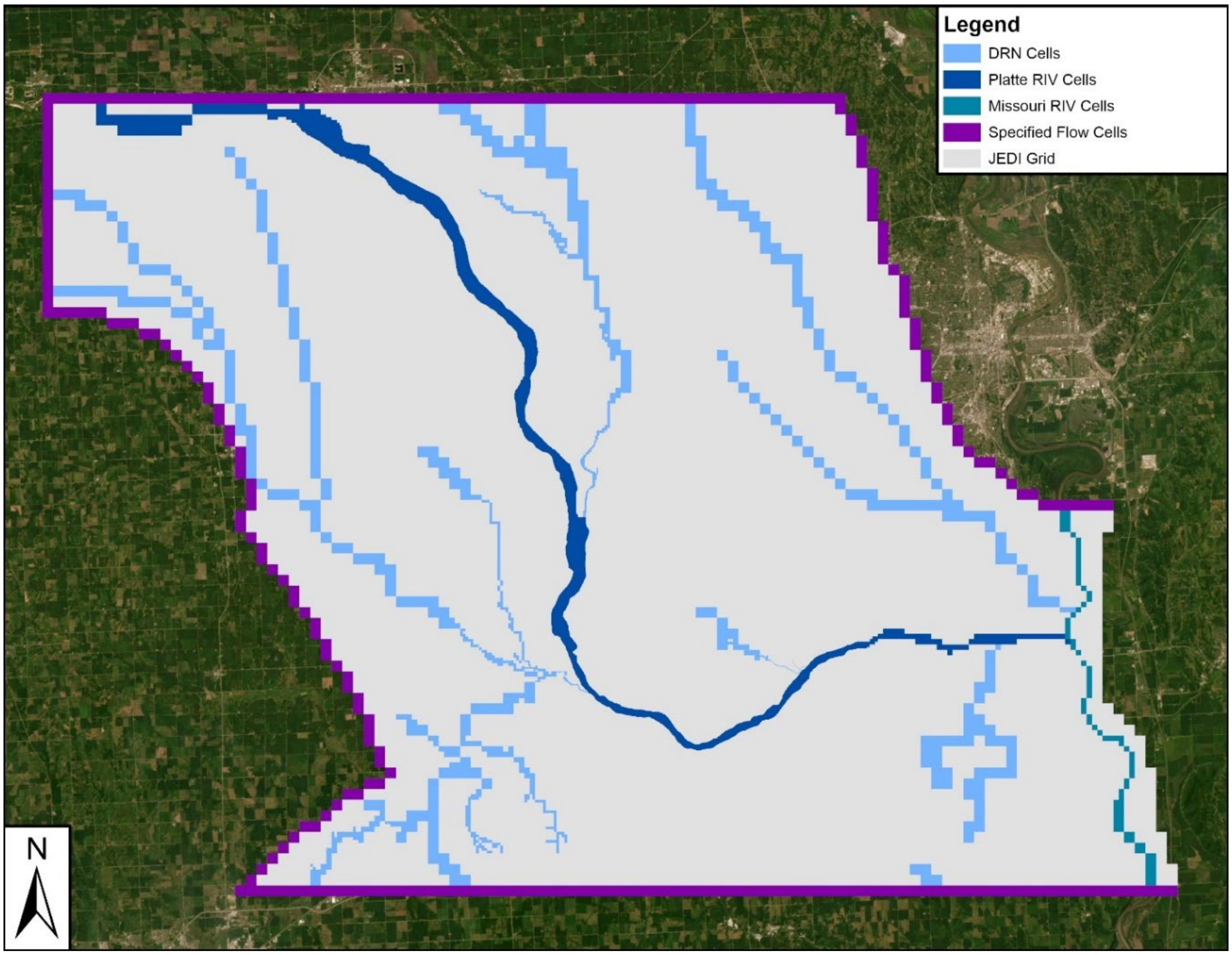

Figure 10: JEDI Boundary and Internal Cell Assignments

For the Missouri River package (RIV_1), the river bottom elevation, conductance, and stage were borrowed from corresponding LPMT RIV cells. The number of RIV cells was refined to reflect the location and footprint of the Missouri River, according to National Hydrography Dataset (NHD) flowlines (USGS 2017).

For the Platte River package (RIV_2), the maximum footprint of the Platte River (high-flow conditions) was defined based on all cells that lie between the levees along the Platte River; where levees are not present, aerial imagery was used to estimate the footprint of the Platte

River under high-flow conditions. River bottom elevation was assigned based on bathymetric data obtained from Headwaters Corporation, the consulting firm that operates the Platte River Recovery Implementation Program (NV5 2022). A moving mean function was used to smooth river bottom elevations to address uphill anomalies in the bathymetric data. Additionally, the river bottom was uniformly lowered by five feet to account for inaccurate measurements in turbid areas. Conductance for RIV cells was borrowed from streamflow routing (SFR) conductance, as was conductance for DRN cells (the DRN package is described below). A low-flow line to estimate a river centerline was established based on aerial imagery; along this low-flow line, river stationing was assigned based on cell size. River stations were assigned to the high-flow footprint of the Platte River, based on the low-flow cell they were nearest to, to simulate cross-sections. At each of the five USGS stream gages along the Platte River, Black & Veatch developed flow vs stage relationships and a natural log equation was used to interpolate the data. USGS stream gage data was used to determine an average flow rate at each gage location for each stress period of the JEDI model. Stages were assigned to the low-flow cells based on linear interpolation between gages while stages were assigned outward from the low-flow line to the footprint of the Platte River based on the previously established cross-sections. If the stage of a river cell fell below the river bottom for any stress period, this cell was not specified as a river cell for this stress period.

Two well files were created to represent boundary conditions for the standalone JEDI model. The WEL_1 package accounts for the horizontal face flows from the LPMT model (as discussed in Section 2.1.1). The WEL_2 package accounts for the vertical face flows from the LPMT model. All face flows were injected into or extracted from Layer 5 of the JEDI model. As discussed in Section 2.3, large areas of the upper layers of the model are dry at the end of the transient model solution. To ensure face flows were applied throughout the transient simulation, all face flows were applied to Layer 5.

The tributaries to the Platte River (LPMT SFR cells within the JEDI model domain) were assigned to be DRN cells. The SFR package was excluded from the JEDI model for two reasons. The tributaries to the Platte River do not serve as a significant source of water to the aquifers within the JEDI model area. Additionally, the routing of tributaries was not a primary concern in the construction of the JEDI model. Routed tributary flows were not necessary because Platte River flows were specified on a stress-period-by-stress-period basis. The DRN package serves as a water sink and provided an appropriate amount of complexity, outside the Platte River alluvial valley. The DRN cells were refined to reflect the location and footprint of the tributaries. The DRN elevation was defined based on the minimum lidar elevation present within each cell and the DRN conductance was calculated from LPMT SFR terms as the following:

DRN conductance = $\frac{SFR\ conductance}{number\ of\ JEDI\ cells\ within\ SFR\ cell}$

Where SFR conductance = $\frac{hydraulic\ conductivity * width\ of\ reach * length\ of\ reach}{thickness\ of\ streambed}$

2.2.4 Evapotranspiration, Recharge, and Pumping Inputs

For the EVT package, evapotranspiration (ET) extinction depth was duplicated from the LPMT model. The ET surface was assigned to be the top of JEDI model Layer 1; the surface was refined in accordance with the refinement of the Layer 1 cells. Using the LPMT ET rate in the JEDI model area, water budget plots showed that more ET was being extracted from the JEDI model as compared to the LPMT model. The final ET rate in the JEDI model is equal to 25 percent of the ET rate in the LPMT model, as it proved to provide the best match in the water budgets (comparing JEDI to the JEDI area of the LPMT model). When the water level elevation in any given cell of the model falls below the extinction depth of seven feet, no ET occurs in this cell. When the water level elevation is above the extinction depth, ET is extracted from the model.

For the recharge (RCH) package, recharge rates were duplicated from LPMT recharge rates, and all recharge was assigned to JEDI model Layer 3. As discussed in Section 2.3, there are many dry cells in JEDI Layers 1 and 2 at the end of the transient model run. To ensure that the majority of recharge was applied throughout the transient simulation, all recharge was assigned to JEDI Layer 3.

When constructing the WEL_3 package, corresponding to wells within the unrefined region of the JEDI model, borehole data was used to assign top and bottom elevations of well screens. Two rasters were created to cover the JEDI model domain by kriging borehole data according to top of screen, bottom of screen, and an enforced minimum screen length of 20 feet. Pumping was assigned to the layers using the following criteria: (1) where the screen fell entirely below the bottom of Layer 5, all pumping was assigned to Layer 5; (2) where the screen fell entirely above the top of Layer 1, all pumping was assigned to Layer 1; (3) where the screen fell fully within any layer, all pumping was assigned to that layer; and (4) where the screen spanned more than one layer, the weighted average pumping rate – based on the percentage of screen in each layer – was assigned to the corresponding layer. Scenarios 1 and 2 are possible because of the data processing methods. The screen rasters were created by interpolating point data at discrete locations within the JEDI model area, whereas the land surface raster used to assign layer elevations was a continuous, measured dataset. Finally, pumping was distributed to all JEDI model WEL cells that comprised the corresponding LPMT model WEL cell.

A separate well package (WEL_4) was created for the wells that fell within the refined region of the JEDI model but did not provide municipal water to LWS or MUD. Pumping data was obtained from The Flatwater Group and the well location and pump rates were refined to reflect the actual location and pump rates of the well. All pumping from these wells was assigned to

Layer 4. As discussed in Section 2.3, large portions of Layers 1 and 2 are dry at the end of the transient simulation. Layer 4 was chosen to maintain pump rates throughout the transient simulation.

Additionally, three separate well files were created for the MUD and LWS wellfields (WEL_5 for MUD South, WEL_6 for MUD West, and WEL_7 for LWS). For these three well files, the locations of the wells were updated to reflect the actual locations. The pumping data was obtained from The Flatwater Group. To ensure that pumping was distributed vertically throughout the aquifer where wells are generally screened, the pumping was allocated with 25 percent from Layer 3, 25 percent from Layer 4, and 50 percent from Layer 5.

2.2.5 Aquifer Parameters

To determine aquifer properties, AEM voxels were developed based on AEM flight lines as obtained from the Eastern Nebraska Water Resources Assessment (ENWRA), resulting in resistivity cubes measuring 500 feet by 500 feet by 2 feet (X by Y by Z directions, respectively). A group number was assigned to each AEM voxel in accordance with the values in **Table 5** below. The AEM voxels' resistivity group numbers were smoothed to remove outliers and anomalous data. In the X/Y plane, the centroid of each JEDI model Layer 1 node was found and used to determine in which AEM voxel this centroid fell. From here, a weighted average was calculated from all voxels falling between the Layer 1 top and bottom, and the resulting resistivity group was assigned to each Layer 1 node. This process was repeated for the remaining layers. Resistivity groups were used to control hydraulic conductivity ranges during calibration with PEST. In the node property flow (NPF) package, hydraulic conductivity was assigned based on each group as shown in **Table 5** below. Within the JEDI model domain, resistivity values are largely dependent on sediment grain size. Lower resistivity values correspond to silts and clays, which are less hydraulicly conductive relative to gravels, which have larger resistivity values.

Table 5: Resistivity Grouping and Corresponding Hydraulic Conductivity

Group	Minimum R* (Ohm-m)	Maximum R* (Ohm-m)	PEST Calibrated K (feet/day)	Minimum K (feet/day)	Maximum K (feet/day)
1	0	12	15	1	30
2	12	20	45	30	60
3	20	30	75	60	90
4	30	40	105	90	120
5	40	50	135	120	150
6	50	65	175	150	200
7	65	85	225	200	250
8	85		275	250	300

** R represents the resistivity ranges used to define each group. Hydraulic conductivity, K, was assigned based on each group as: $K = k_x = k_y$, $K_z = k_x/10$; minimum/maximum K represents the range used in calibration. PEST = Parameter Estimation and Uncertainty Analysis.*

The hydraulic conductivity groups by layer are shown in **Figures 11 - 15** below. As shown in the figures, the Platte River alluvium and Todd Valley aquifer are pronounced based on resistivity values. The remaining non-aquifer material within the model domain is also pronounced.

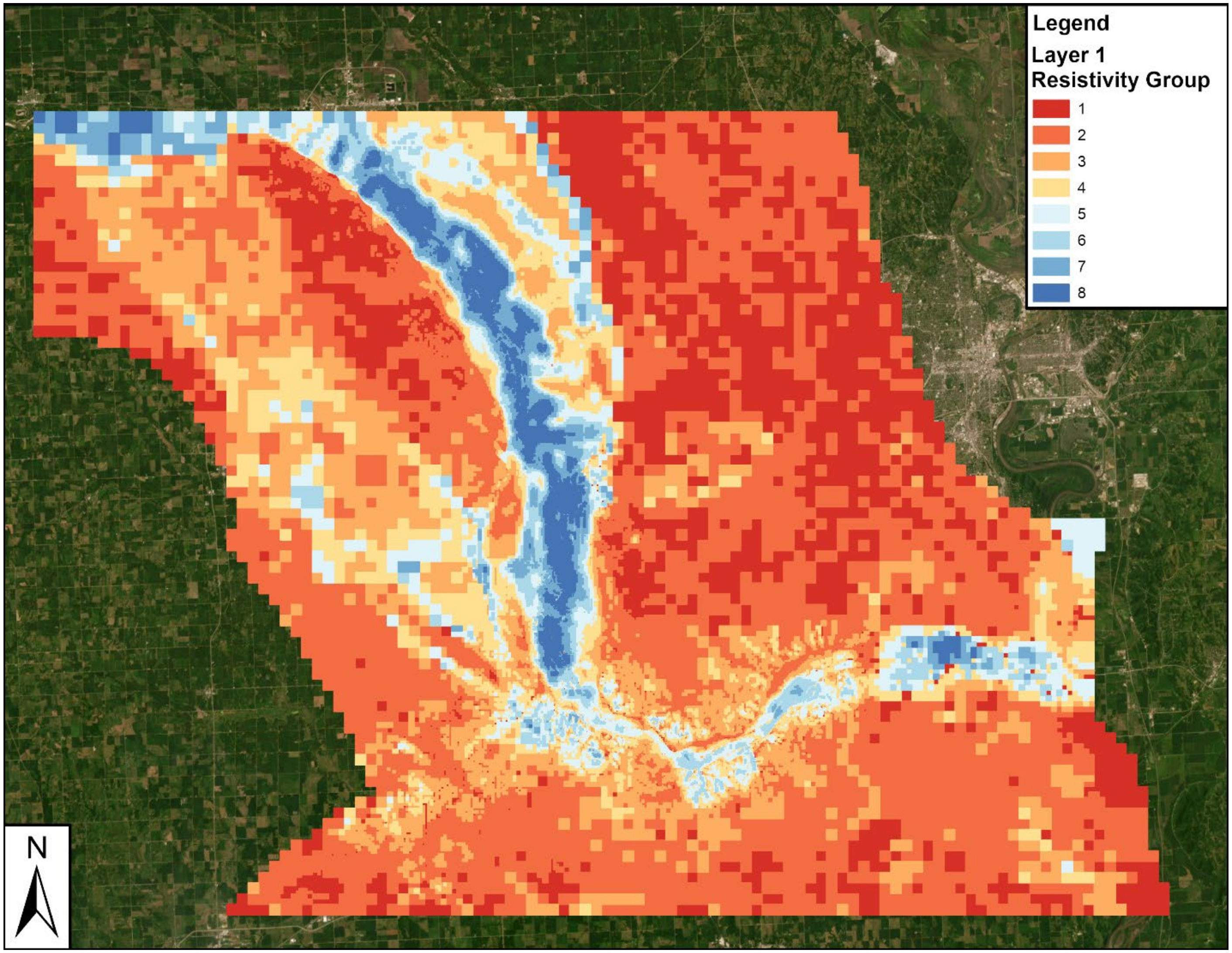

Figure 11: Layer 1 Resistivity Groups

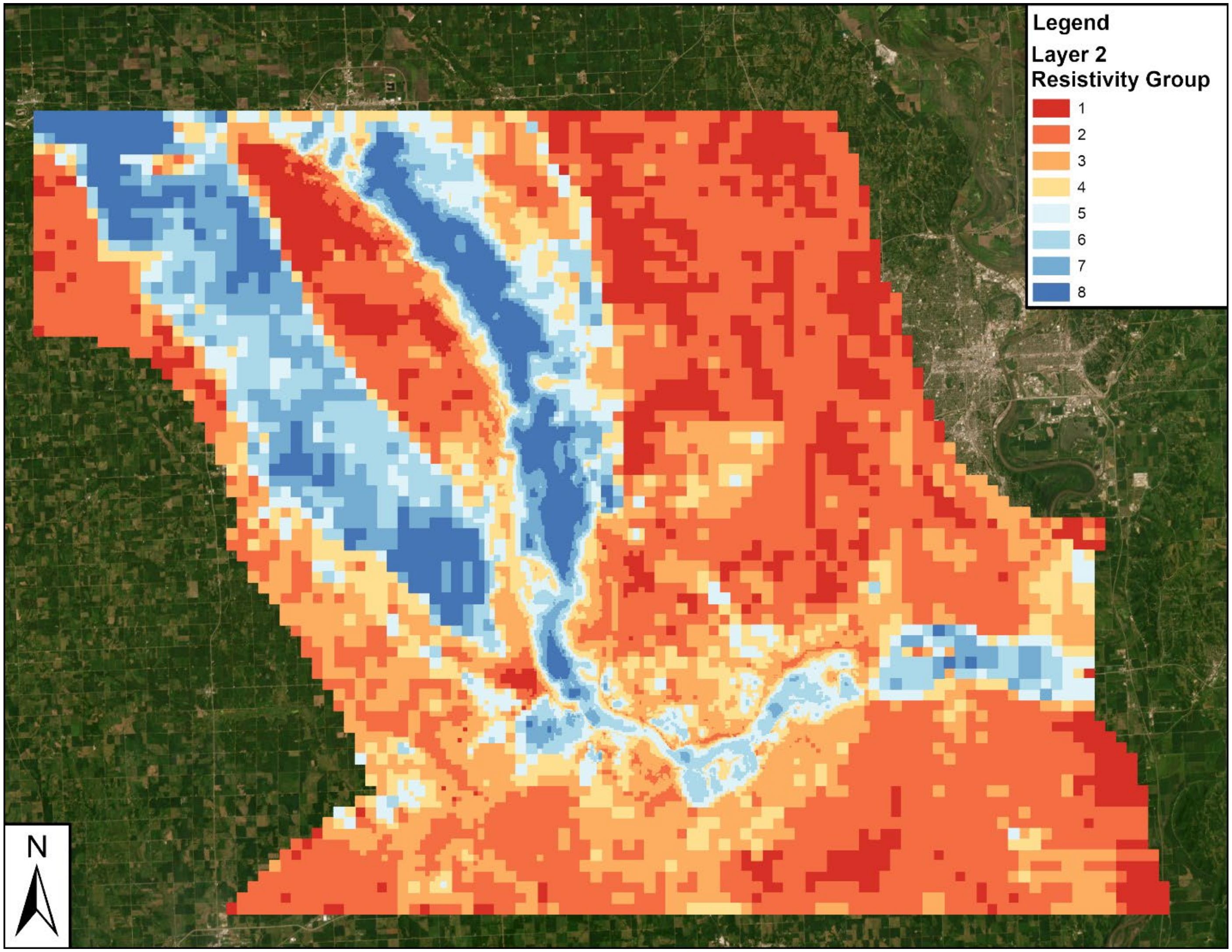

Figure 12: Layer 2 Resistivity Groups

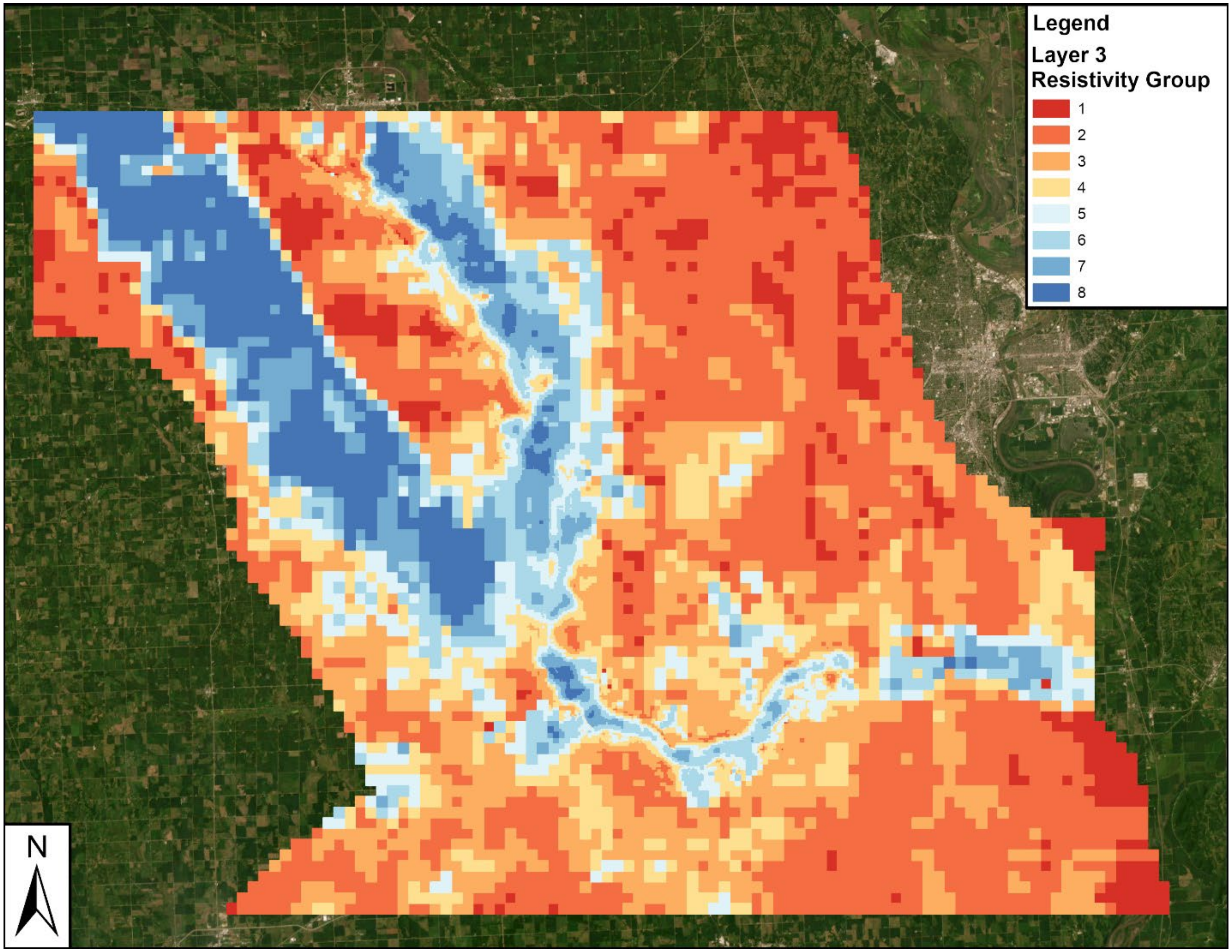

Figure 13: Layer 3 Resistivity Groups

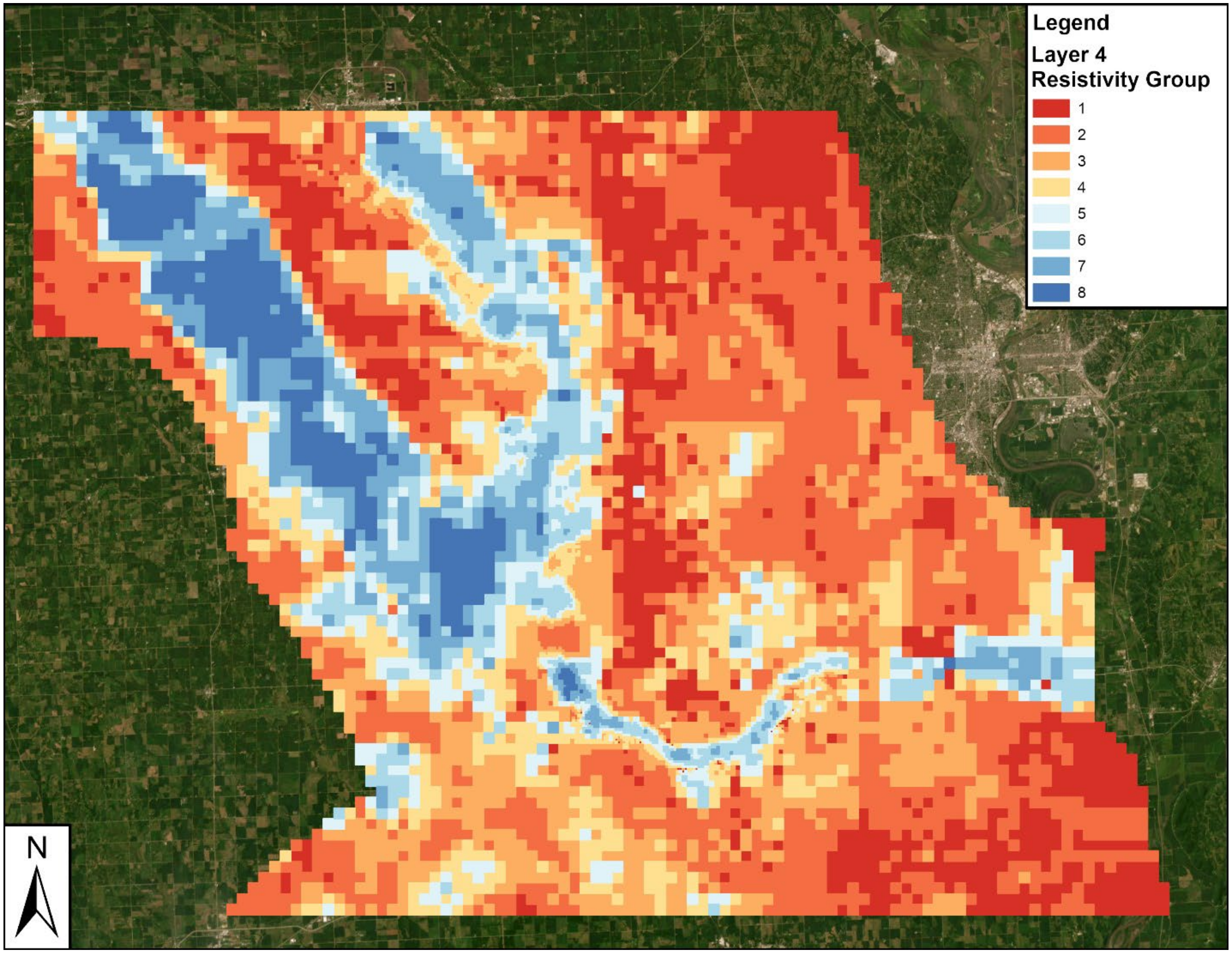

Figure 14: Layer 4 Resistivity Groups

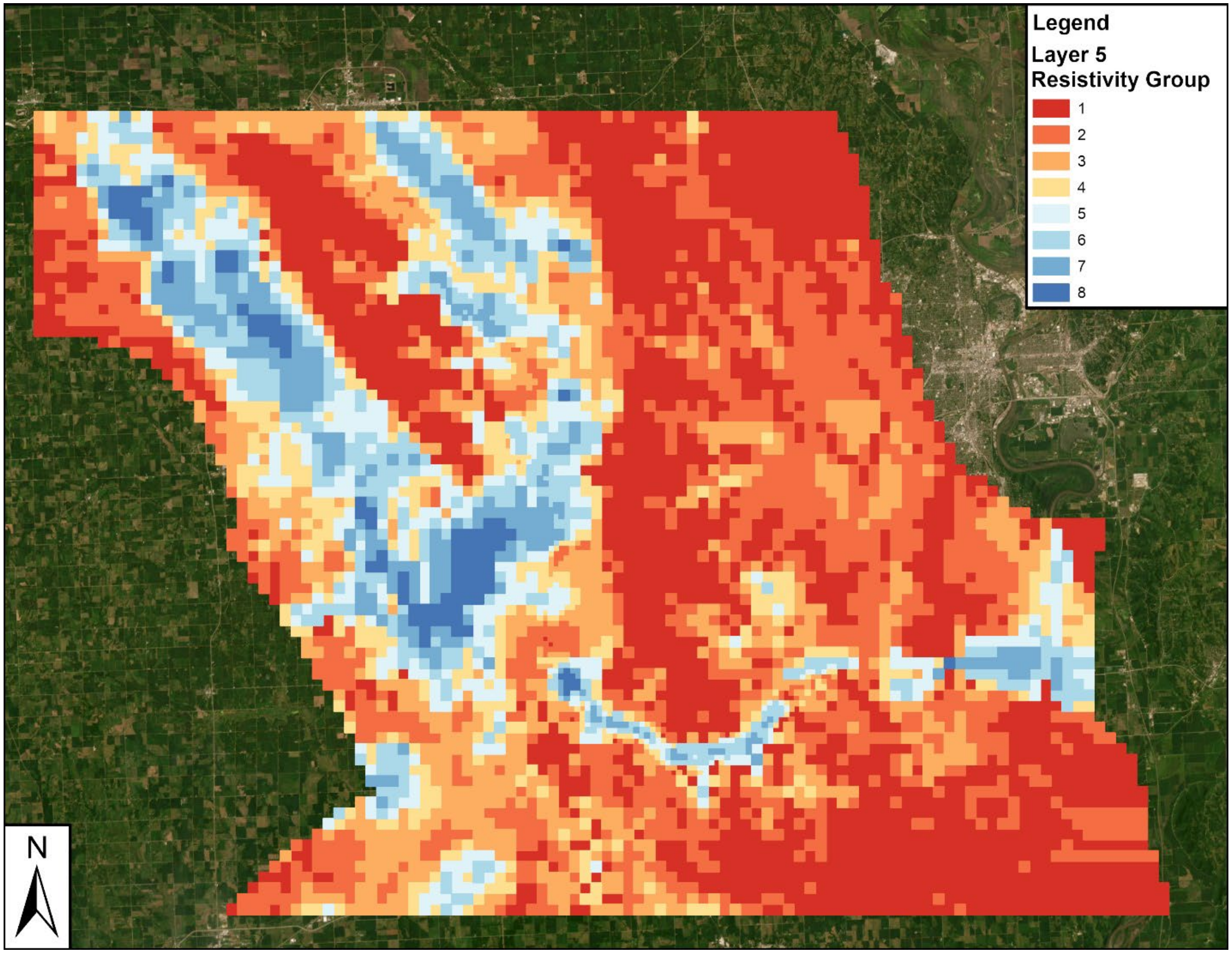

Figure 15: Layer 5 Resistivity Groups

For the storage (STO) package, specific yield was set as 0.14 for all cells in all layers, consistent with the LPMT model. Specific storage was set as 1 x 10^{-6} feet^{-1} for all cells in all layers, consistent with the LPMT model.

2.3 Transient Model Resultant Heads

At the end of the transient model simulation (stress period 446), dry cells appeared throughout the layers. The most dry cells can be seen in Layer 1 (**Figure 16**) and Layer 2 (**Figure 17**). The model was constructed as a five-layer model to provide a high level of detail and complexity throughout the aquifer. In many areas, the water table falls below the upper layers and therefore dry cells in upper layers are not a cause for concern. The majority of cells in Layer 3 (**Figure 18**), Layer 4 (**Figure 19**), and Layer 5 (**Figure 20**) are saturated throughout the transient model run.

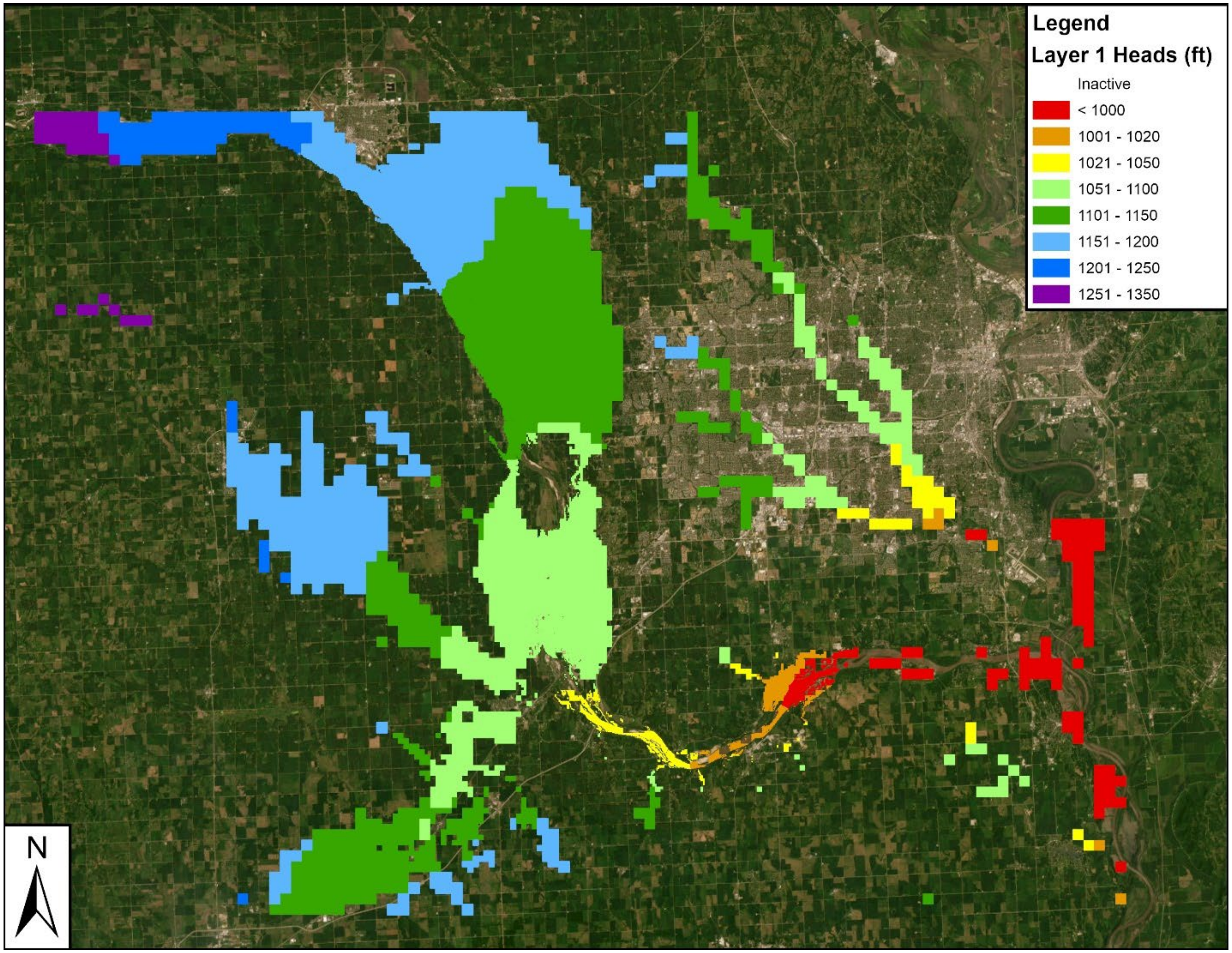

Figure 16: Layer 1 Heads from Stress Period 446

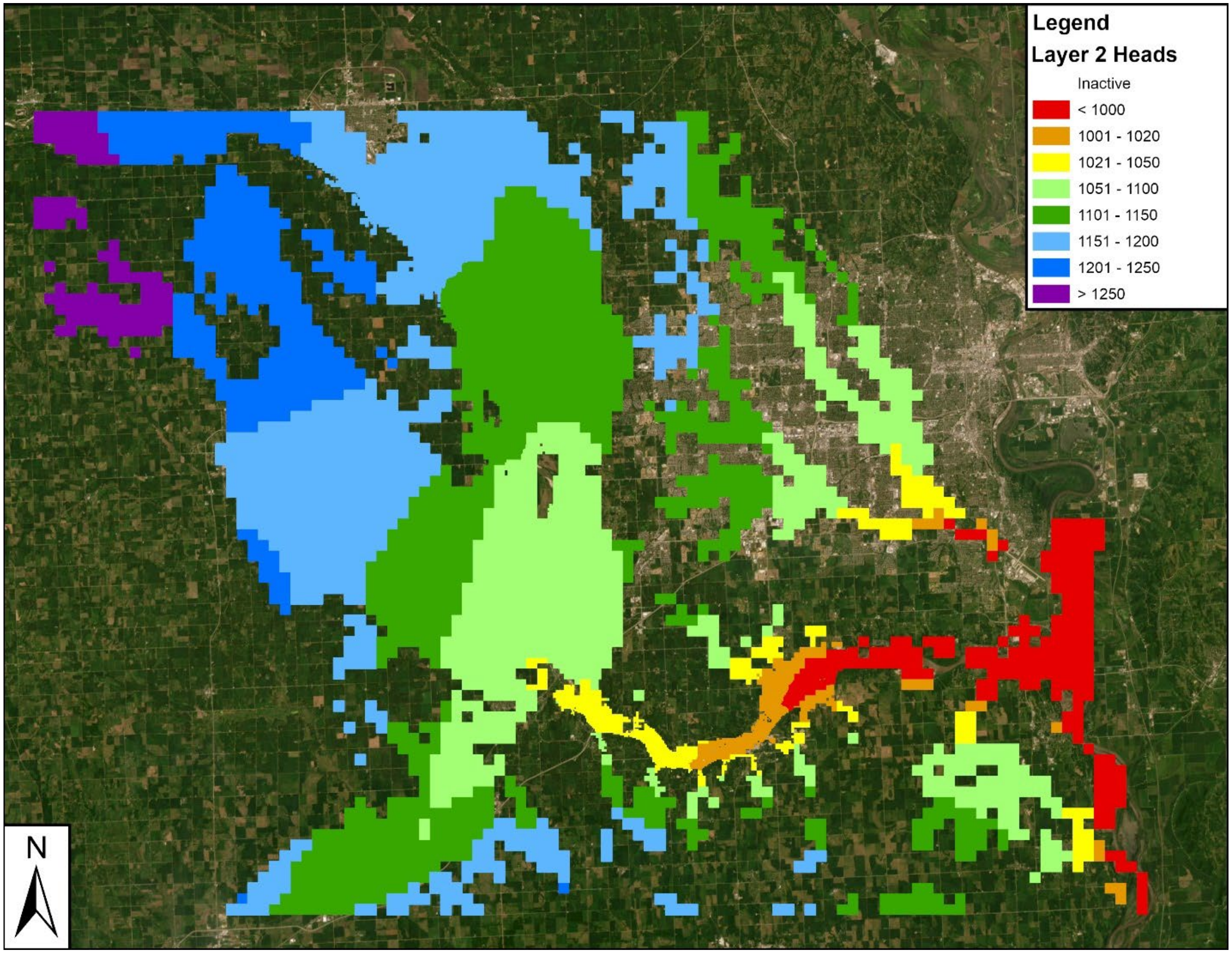

Figure 17: Layer 2 Heads from Stress Period 446

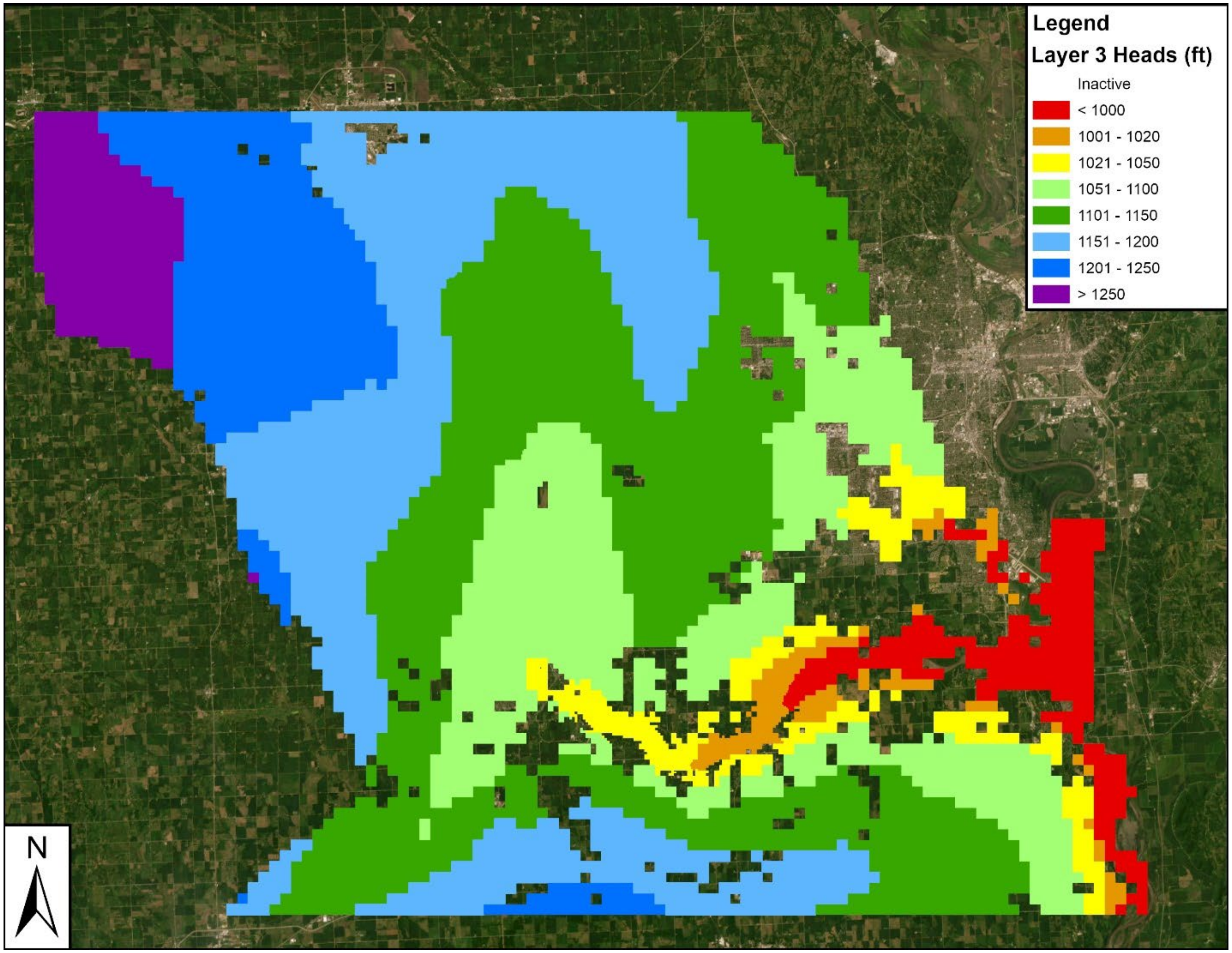

Figure 18: Layer 3 Heads from Stress Period 446

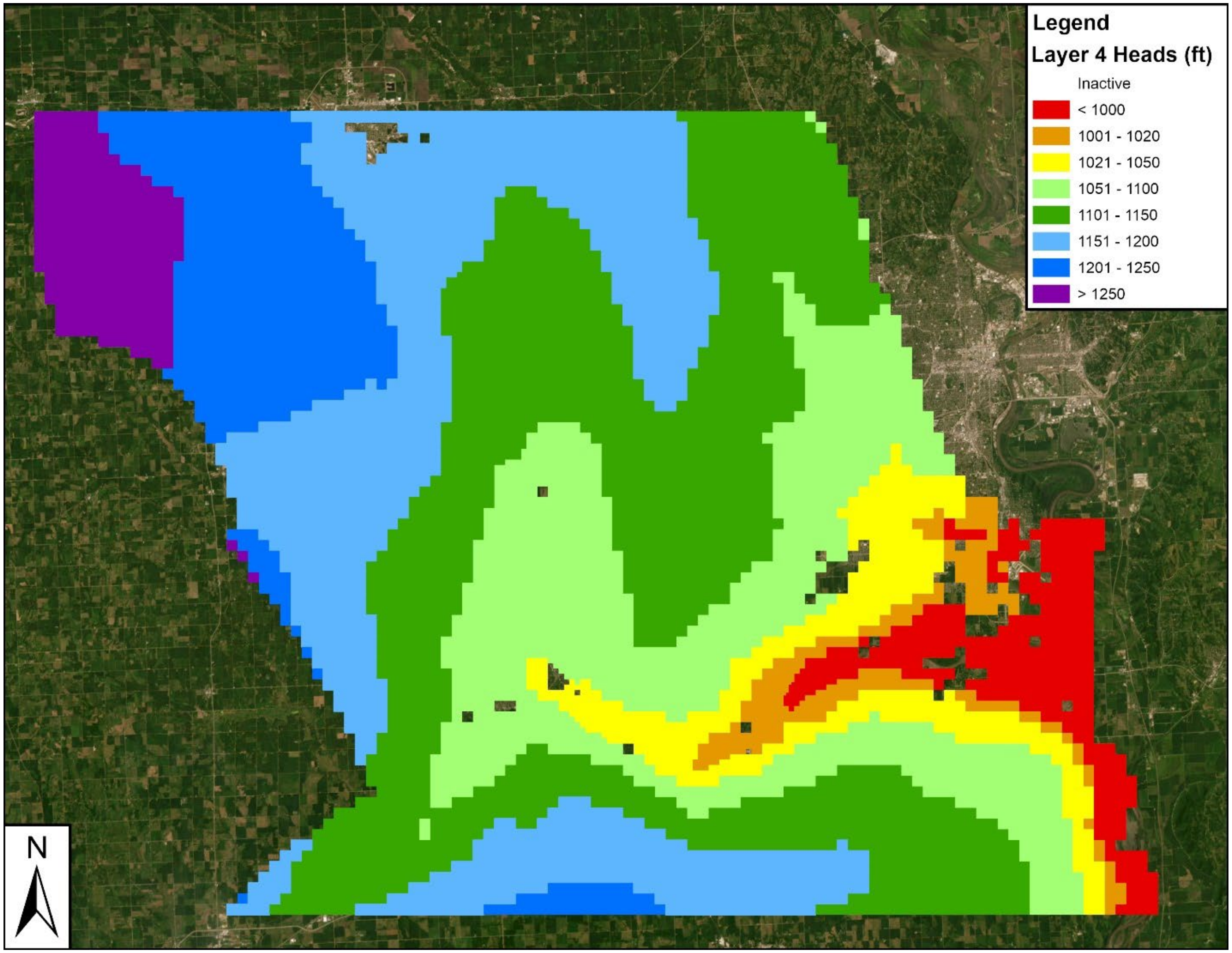

Figure 19: Layer 4 Heads from Stress Period 446

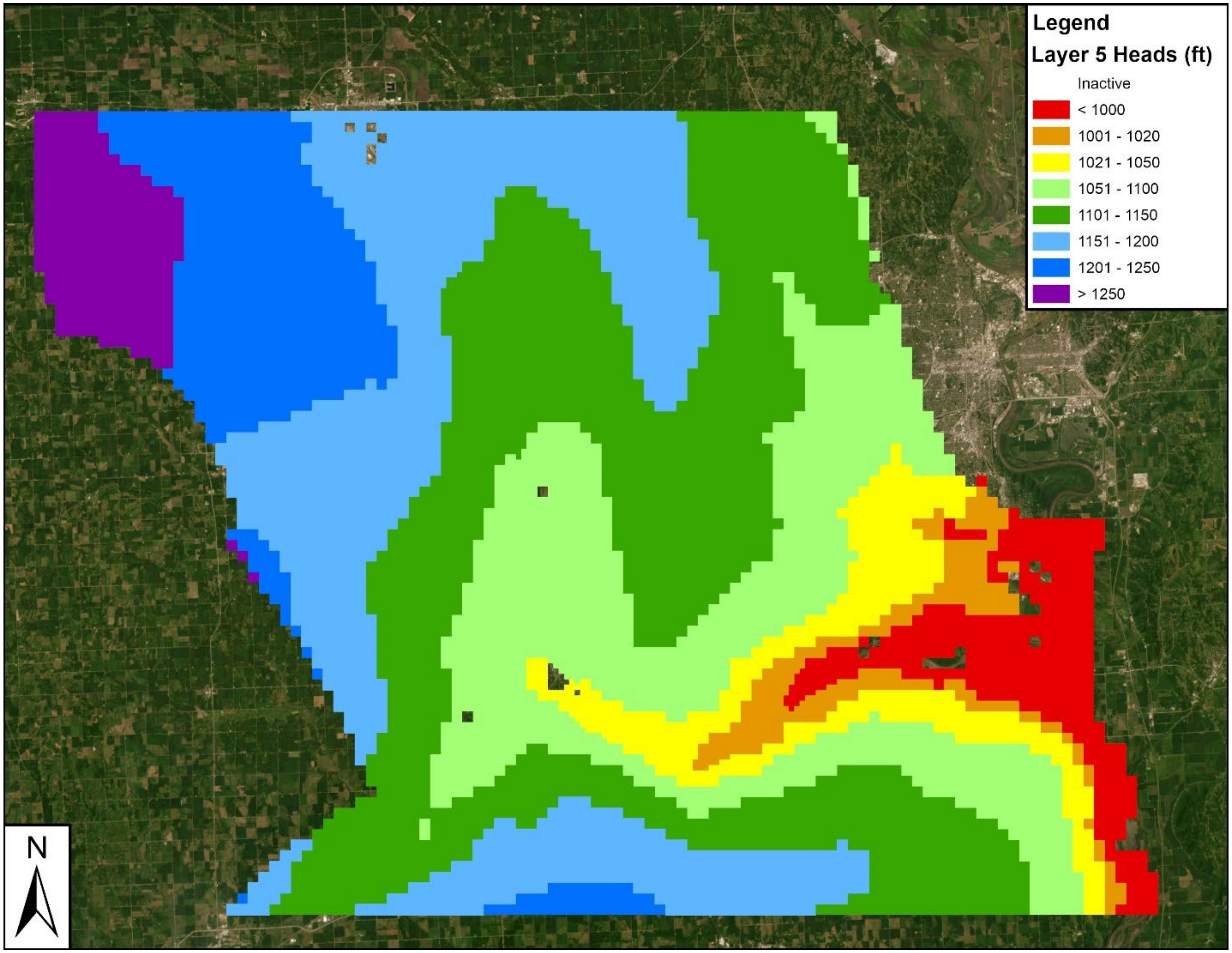

Figure 20: Layer 5 Heads Stress Period 446

3. RESULTS: CALIBRATION

The model was calibrated using Model-Independent Parameter Estimation and Uncertainty Analysis (PEST) (Doherty 2015). The goal of the calibration process was to produce simulated water levels comparable to the observed water levels. A steady state model was constructed for the purpose of calibration to simulate predevelopment conditions (prior to 1960).

3.1 Calibration Targets

For the steady state simulation, the primary calibration targets consisted of water level observation data from USGS (USGS 2023). Water level elevations for the years 1955 to 1965 were obtained and associated with the correct location within the model. The final calibration run in PEST with the steady state model had a total of 97 targets. All targets were placed in Layer 5 of the JEDI model. The targets provided a good spatial distribution throughout the area of interest (**Figure 21**); therefore, no weighting scheme was applied.

3.2 Calibration Approach

The calibration approach consisted of the use of PEST (Doherty 2015) to estimate the aquifer parameters that would result in the best fit between observed and modeled water levels. The PEST calibration used the eight resistivity groups discussed in Section 2.2.5. Each resistivity group was given a starting horizontal hydraulic conductivity and a range that it could vary between, shown in **Table 5**. Throughout the calibration process, the horizontal and vertical hydraulic conductivities were tied using a 10:1 ratio.

The aquifer and non-aquifer material is pronounced in the resistivity group assignments **(Figures 11 - 15)** and therefore assumed to be accurate. PEST calibration was largely constrained by the established resistivity groups and served as fine tuning for hydraulic conductivity values.

On completion of the steady-state calibration, the steady-state model was rerun with the calibrated hydraulic conductivity values. The resultant heads from the steady-state model run were defined as initial conditions for the transient run.

3.3 Calibration Results

The estimated final model parameters, obtained through the calibration process described above, produced a well-calibrated model. The final model simulation was conducted using the calibrated model parameters. Final calibration statistics for the steady-state model run, which compares modeled water levels to actual observed water levels, can be found in **Table 6**. **Figure 21** shows the spatial distribution of the calibration targets and residual head (measured minus the simulated water level elevation). The Platte River alluvial valley was the primary area of interest for this modeling effort. PEST calibration shows low residuals (good calibration) within the area of interest; the model is thus appropriately calibrated for scenario evaluation.

Table 6: Parameter Estimation and Uncertainty Analysis (PEST) Calibration Statistics

Statistic	Value
Phi	34,865.1475
Residual Mean	-5.0115
Absolute Residual Mean	12.9585

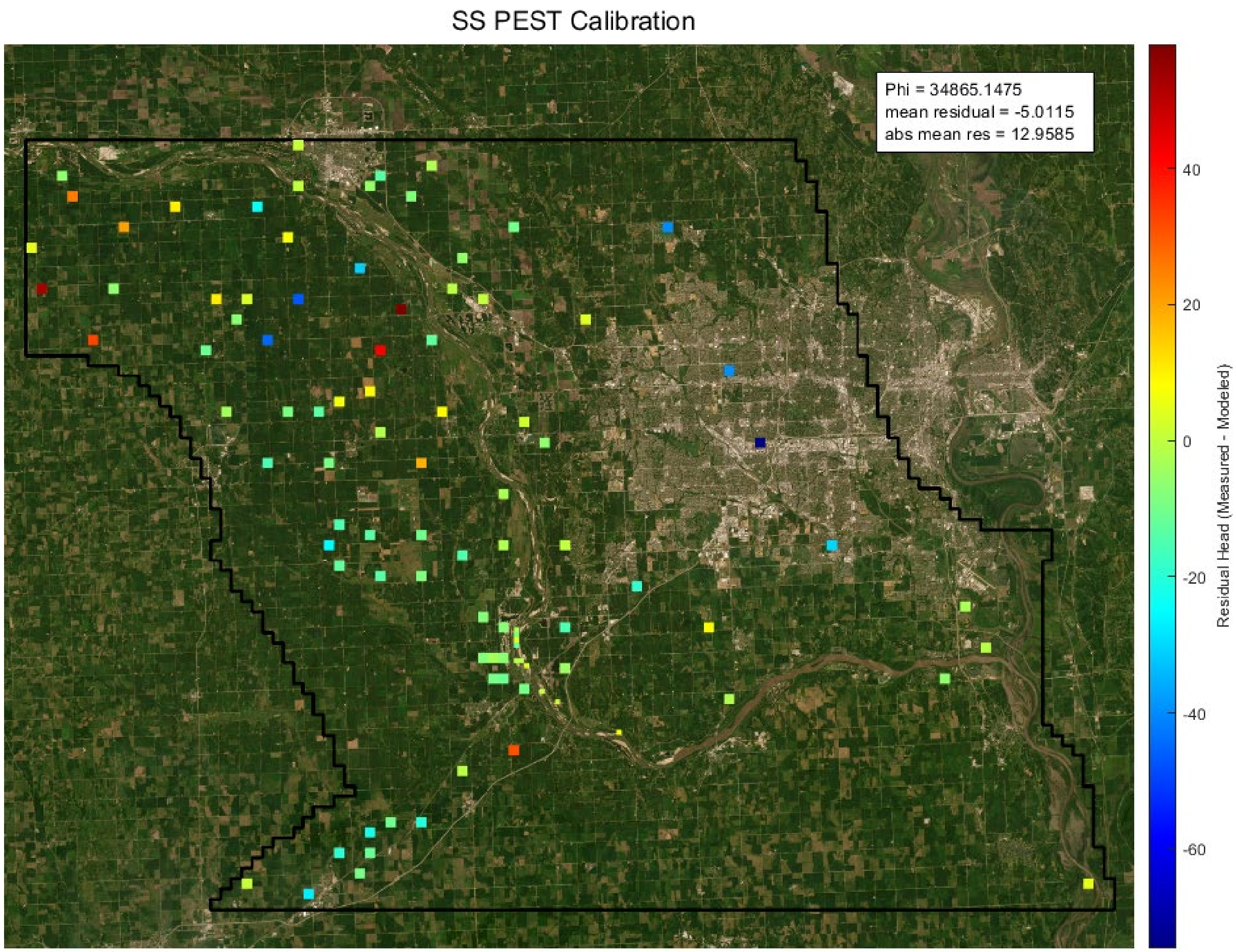

Figure 21: Residual Heads from Steady-State Model-Independent Parameter Estimation and Uncertainty Analysis (PEST) Run

The transient model was run using the calibrated hydraulic conductivity values and calibration was checked manually based on water level observations within the project area. The wells used for this calibration correspond to the wells within the JEDI model area that were used for LPMT model calibration, shown in **Figure 22**. There were 65 wells used in this calibration check, with water level data spanning from 1960 to 2020. The average number of observations per well was 167, with a maximum of 2,838 observations and a minimum of 12 observations. These water level hydrographs are shown in **Figures 23 - 35**. The hydrographs show that the trends in simulated water levels very closely match the trends in measured water levels. When there is an initial difference in measured versus simulated water levels, this difference is generally preserved throughout the transient model run. However, target locations within the Platte River alluvial valley show good calibration and therefore the model is well calibrated and suitable for use for scenario testing within the Platte River alluvial aquifer.

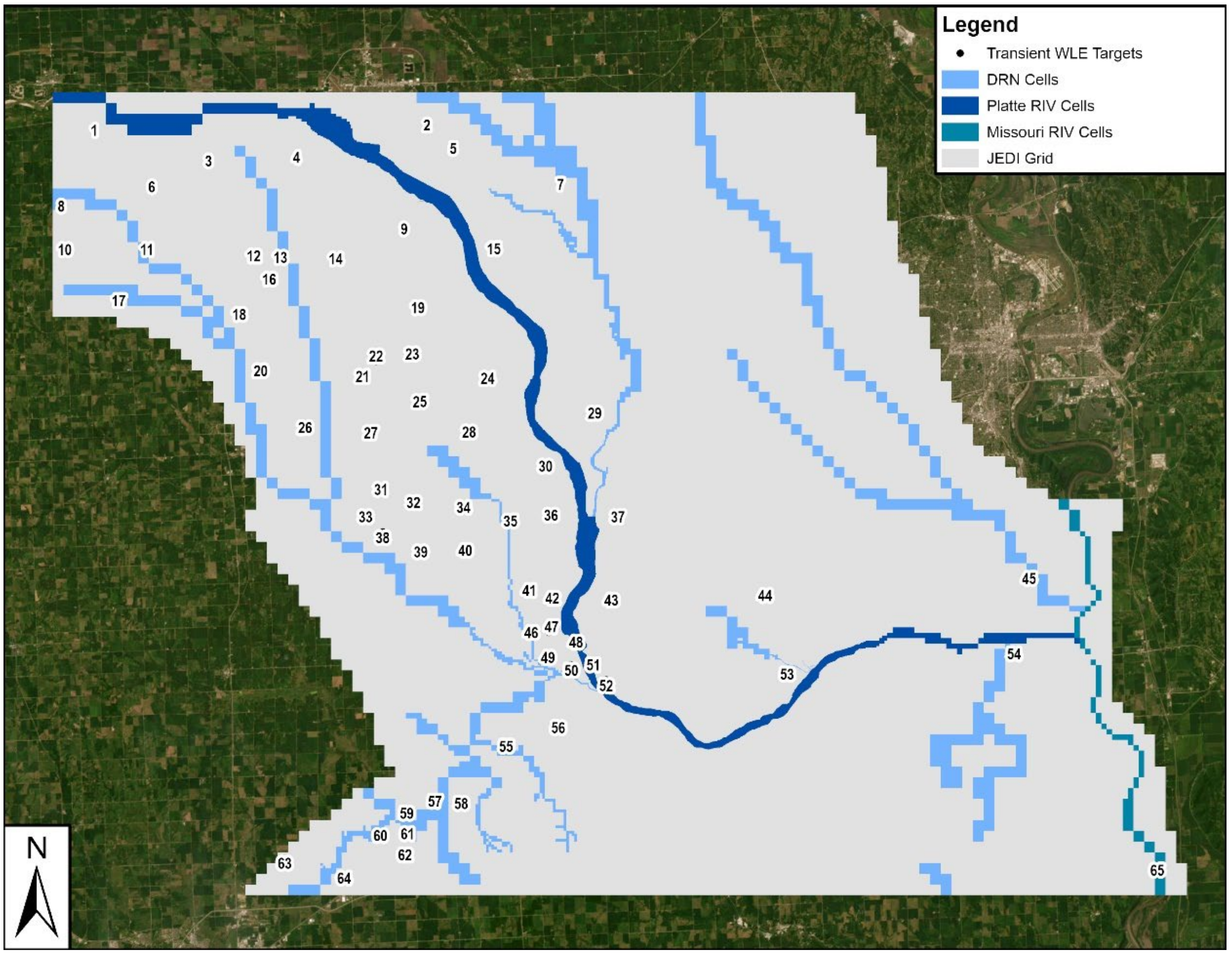

Figure 22: Transient Water Level (WLE) Target Locations

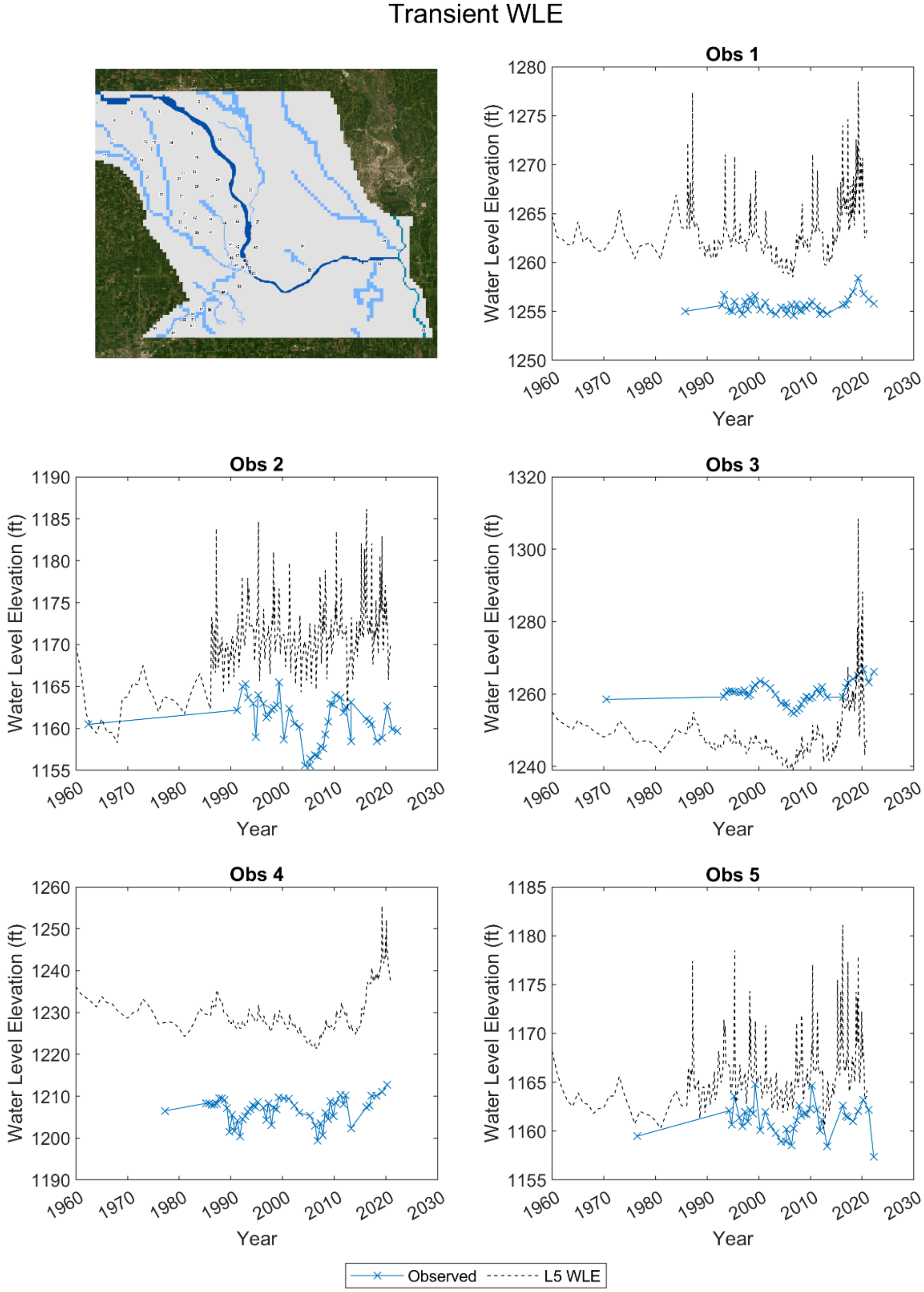

Figure 23: Transient Water Level Hydrographs - Observations 1-5

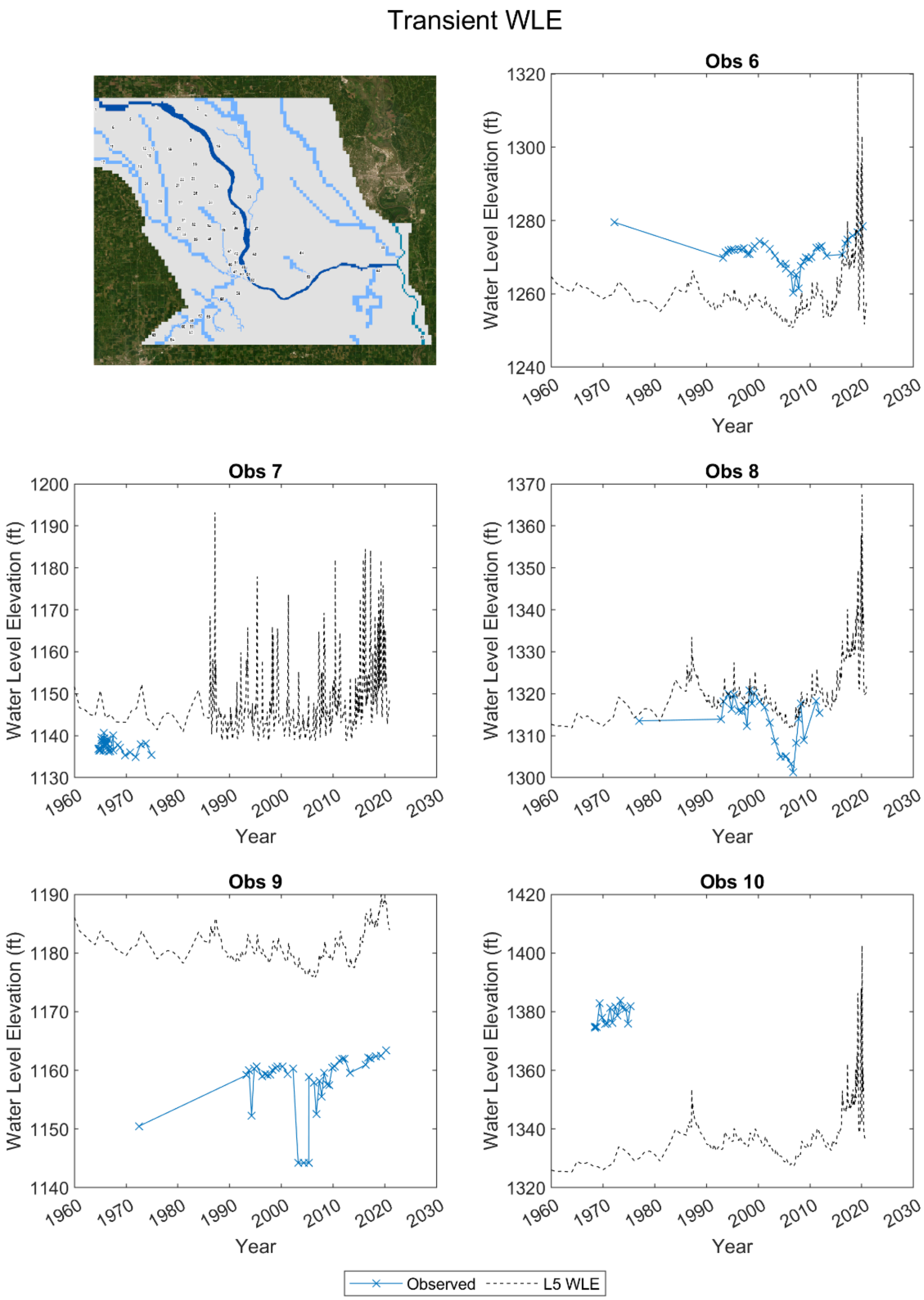

Figure 24. Transient Water Level Hydrographs - Observations 6-10

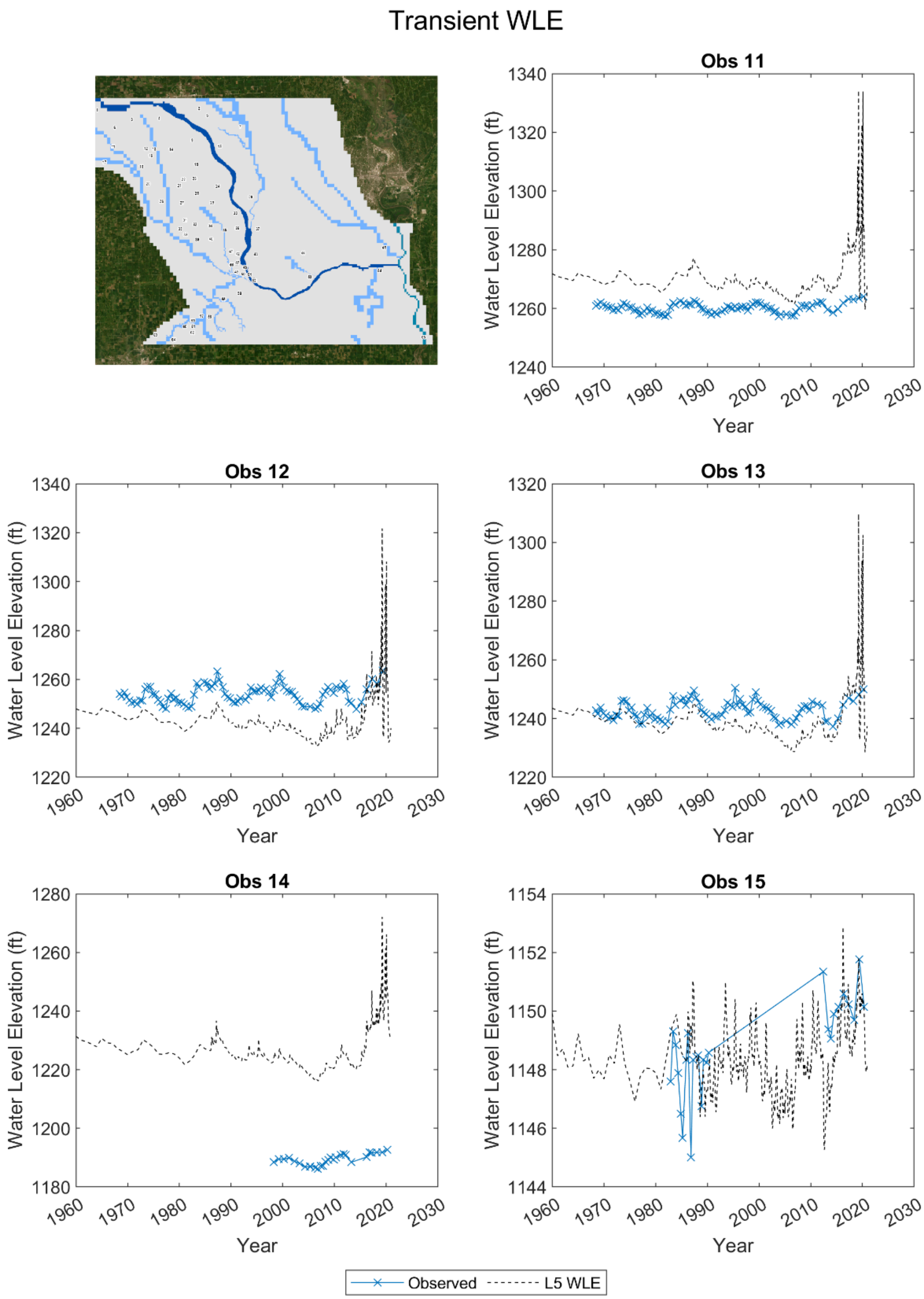

Figure 25: Transient Water Level Hydrographs - Observations 11-15

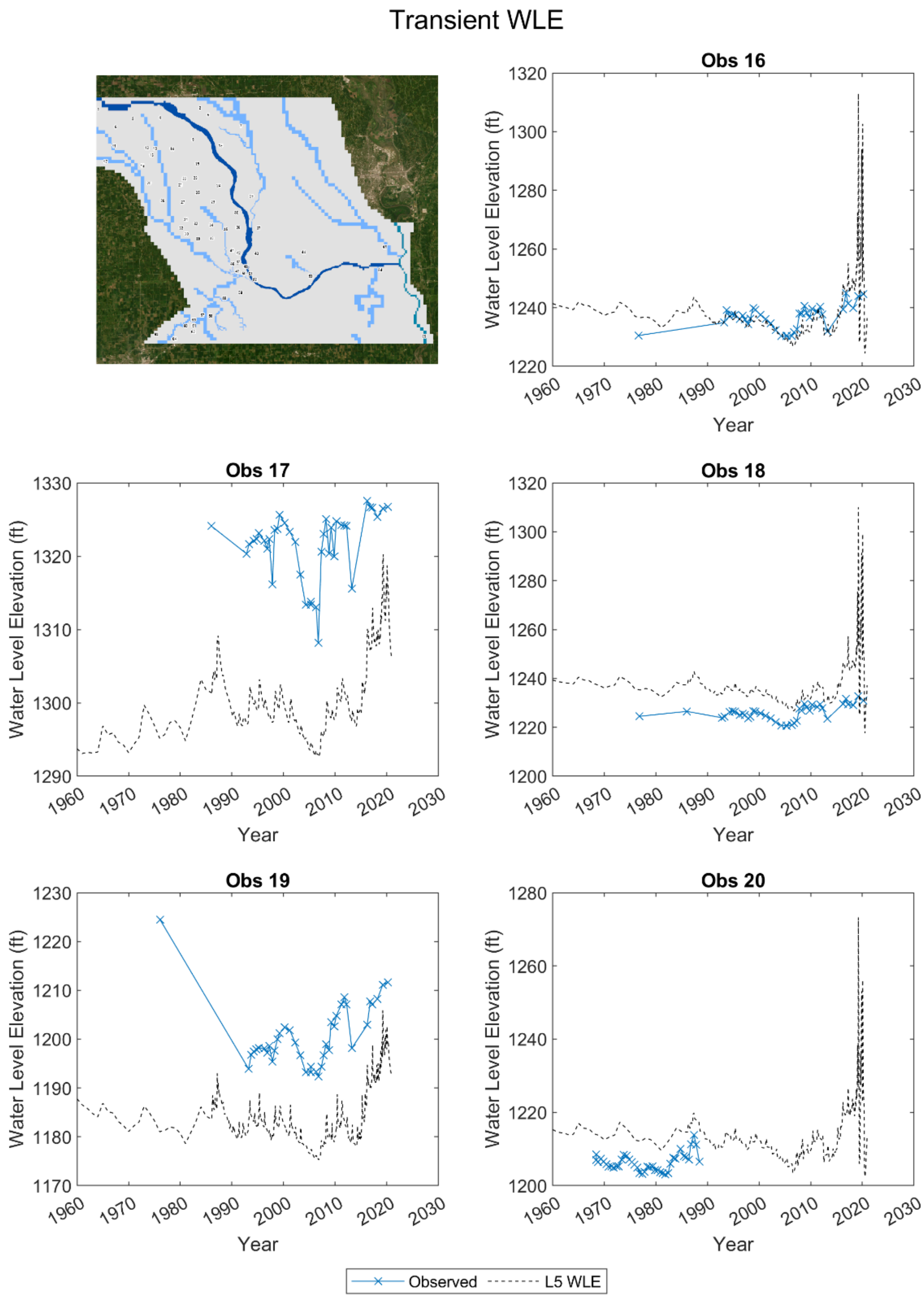

Figure 26: Transient Water Level Hydrographs - Observations 16-20

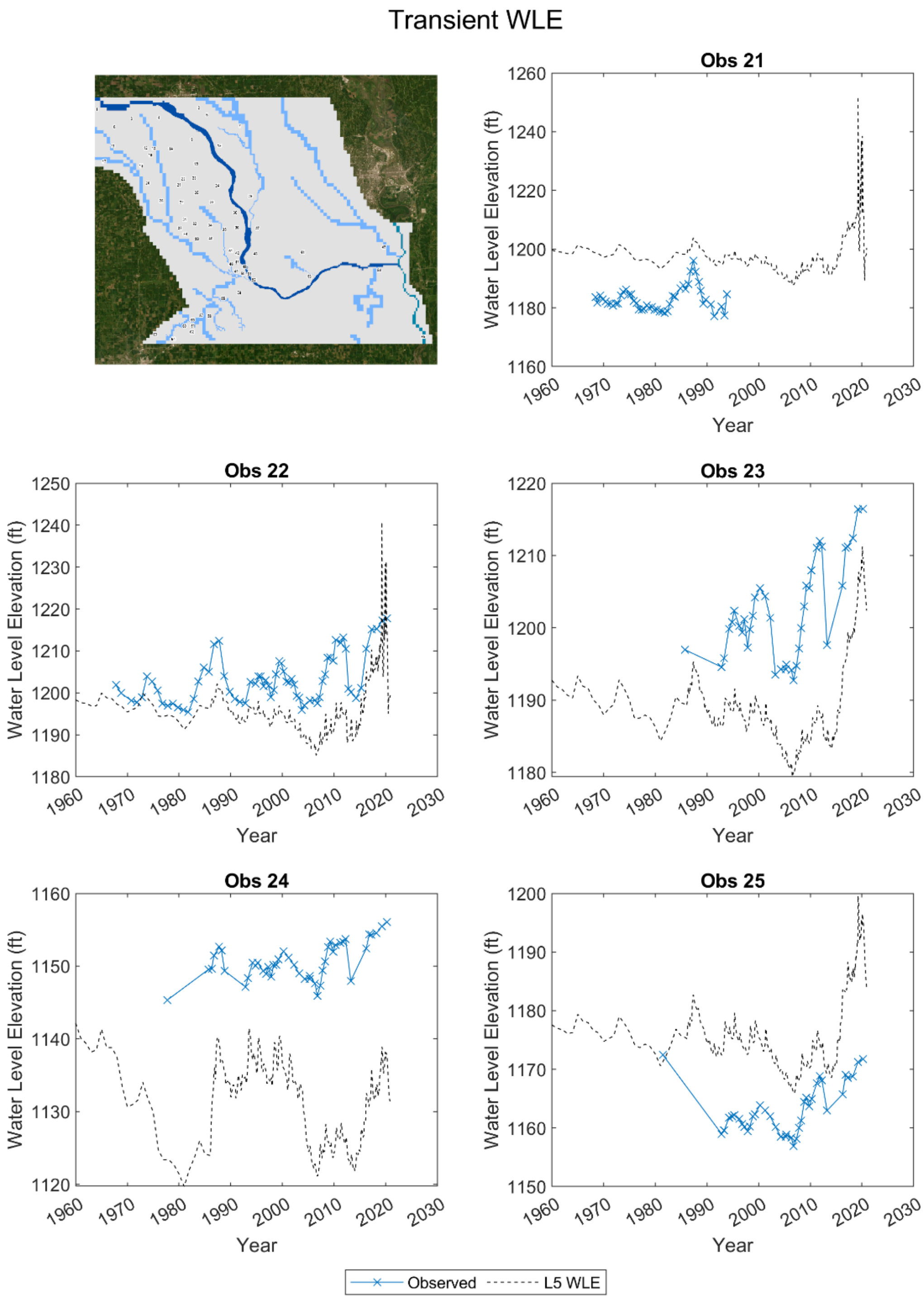

Figure 27: Transient Water Level Hydrographs - Observations 21-25

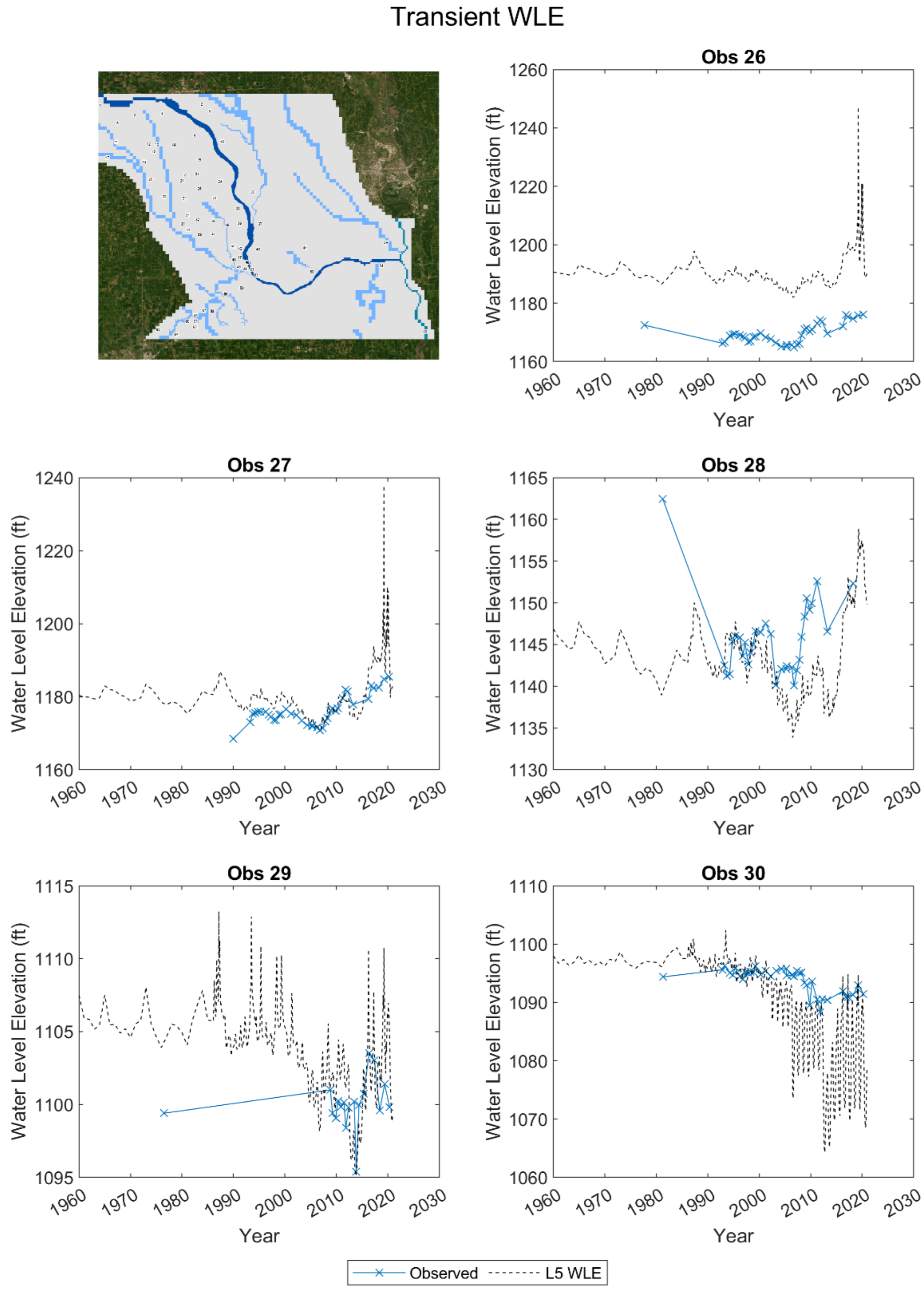

Figure 28: Transient Water Level Hydrographs - Observations 26-30

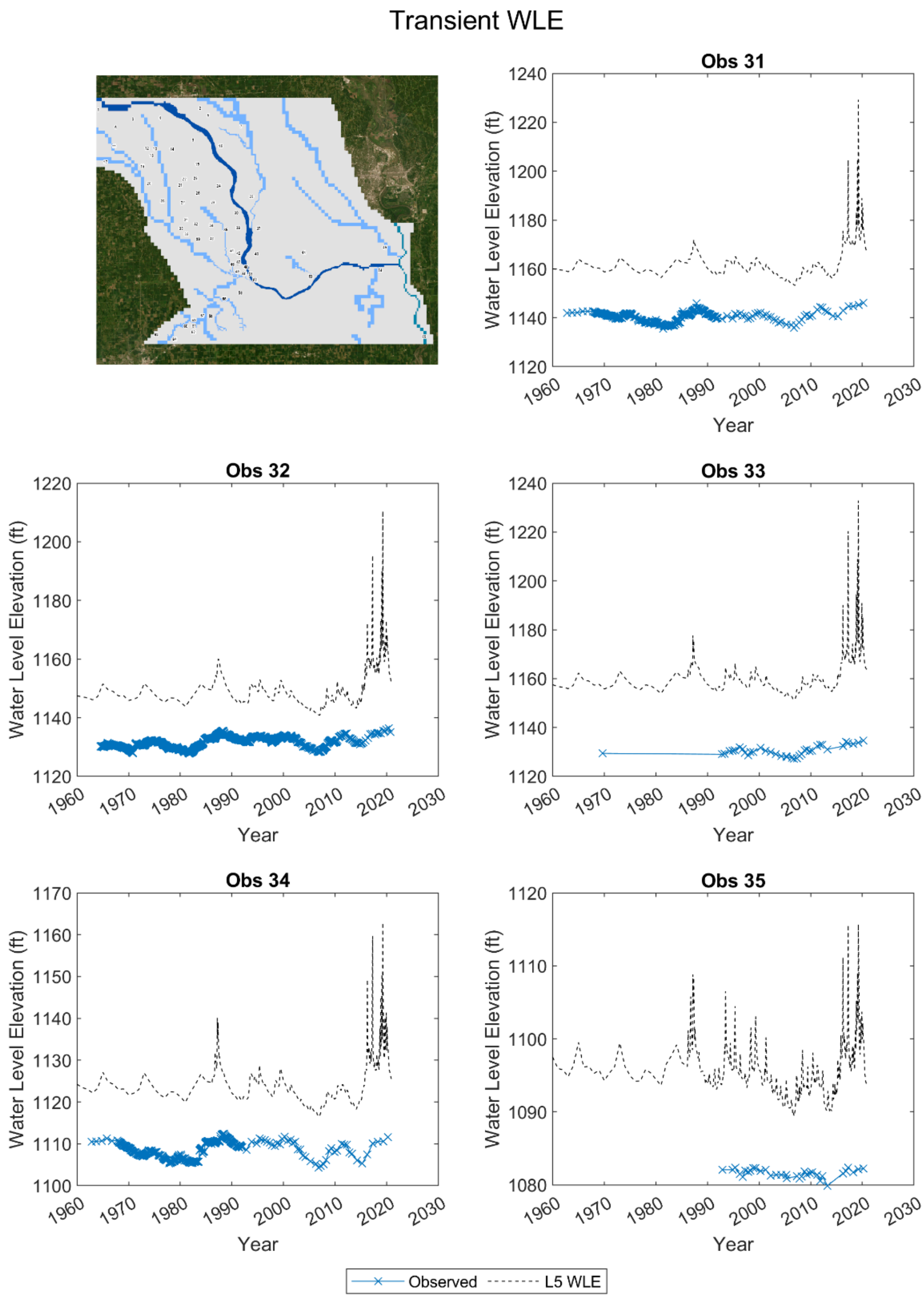

Figure 29: Transient Water Level Hydrographs - Observations 31-35

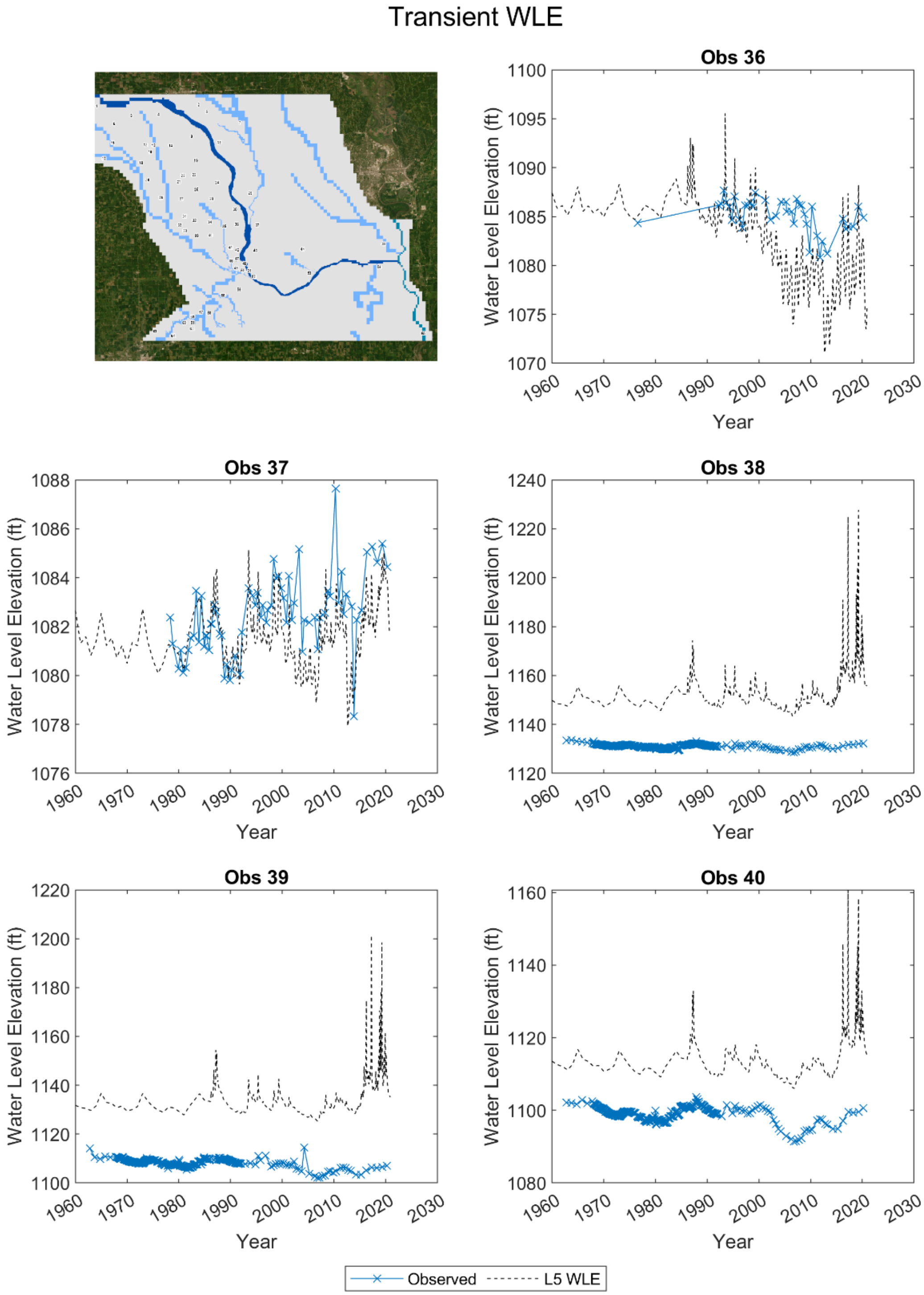

Figure 30: Transient Water Level Hydrographs - Observations 36-40

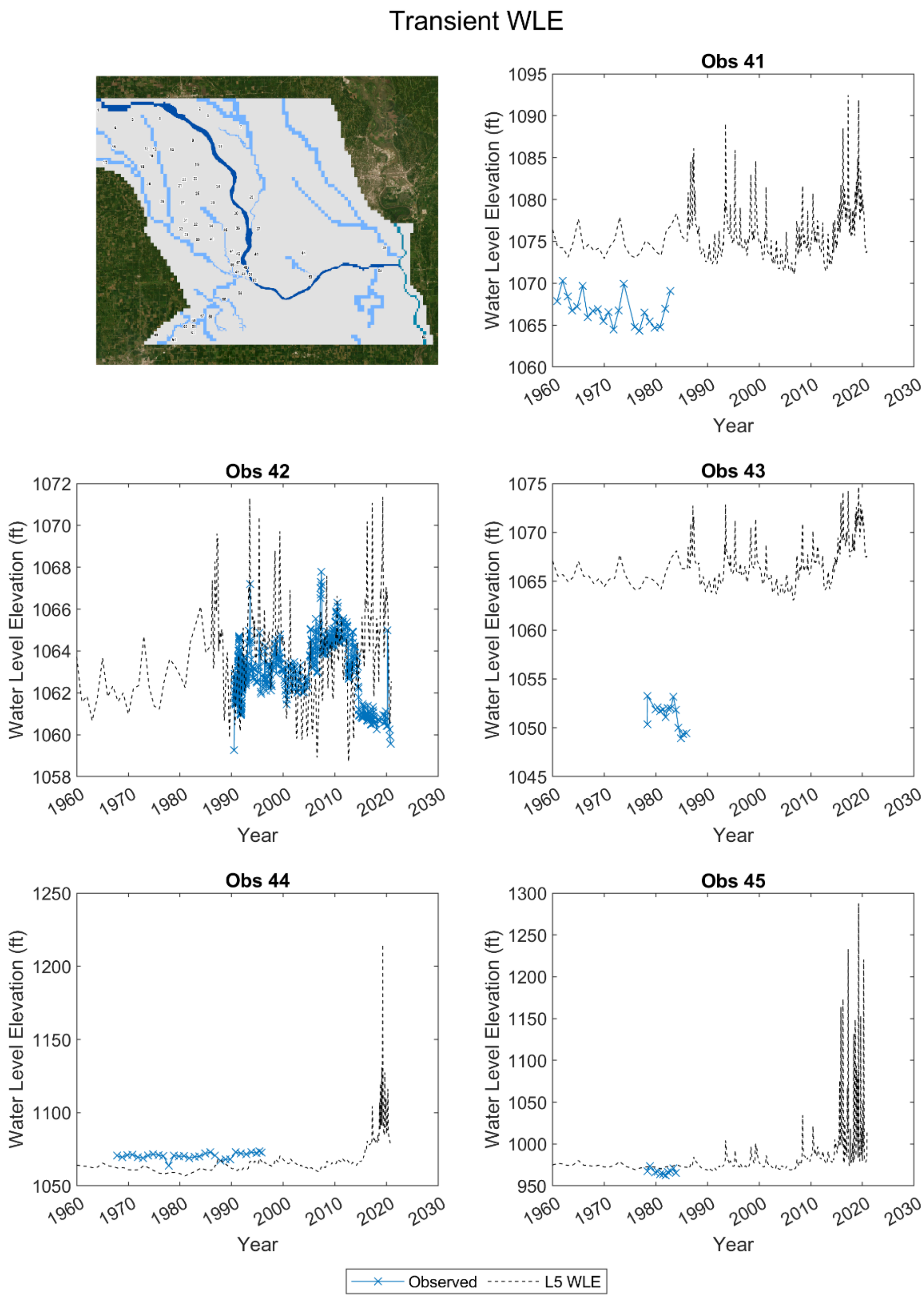

Figure 31: Transient Water Level Hydrographs - Observations 41-45

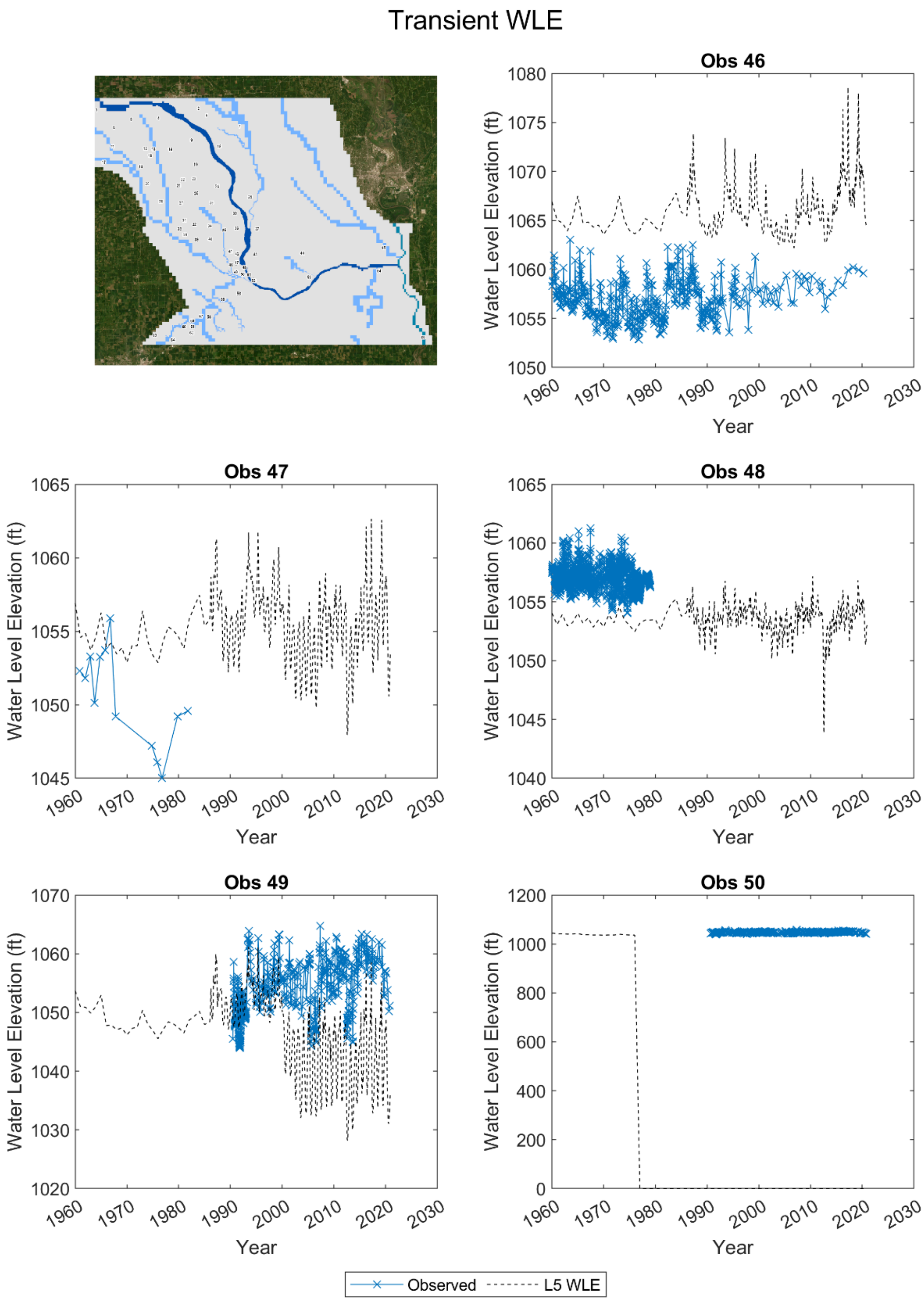

Figure 32: Transient Water Level Hydrographs - Observations 46-50

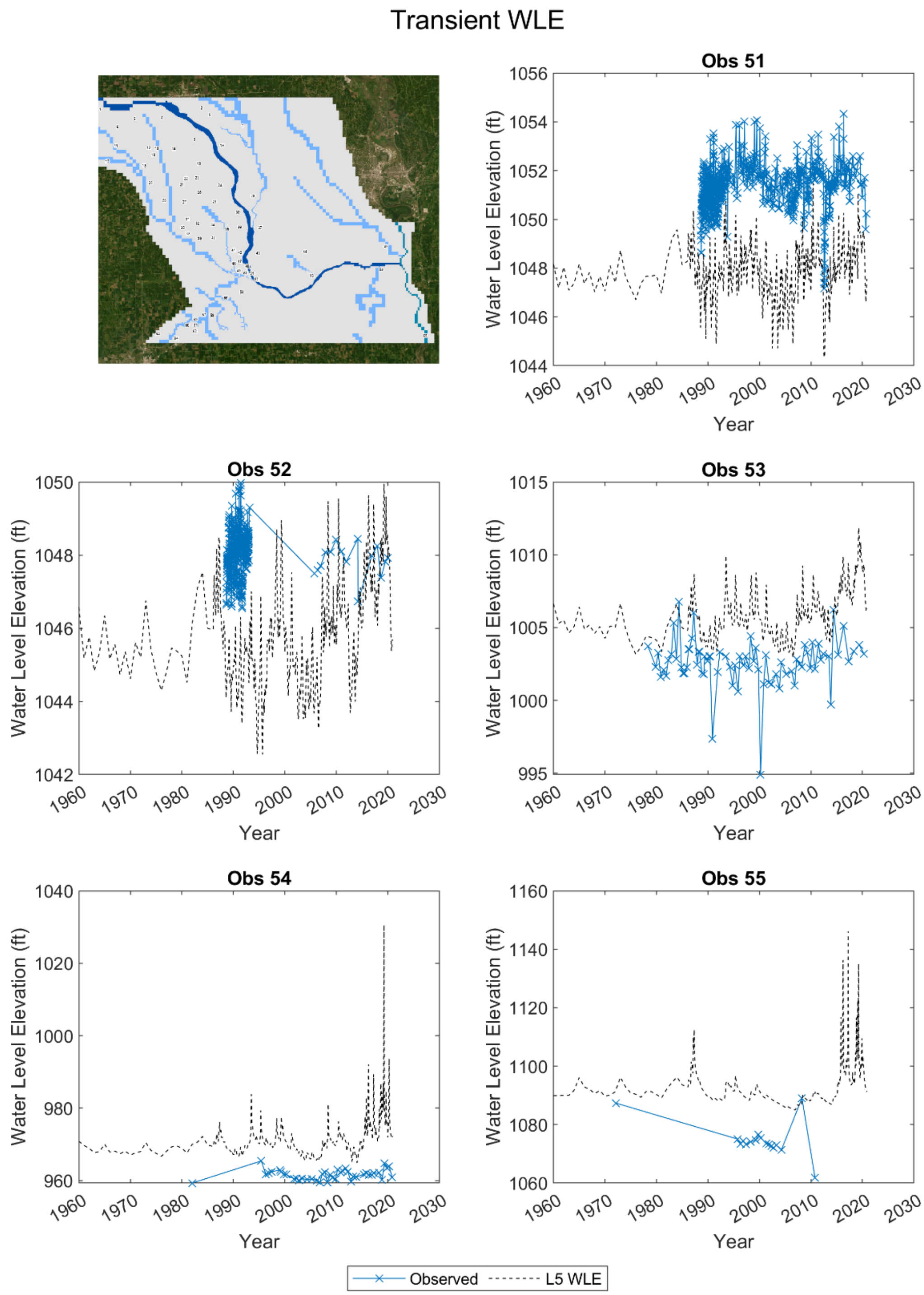

Figure 33: Transient Water Level Hydrographs - Observations 51-55

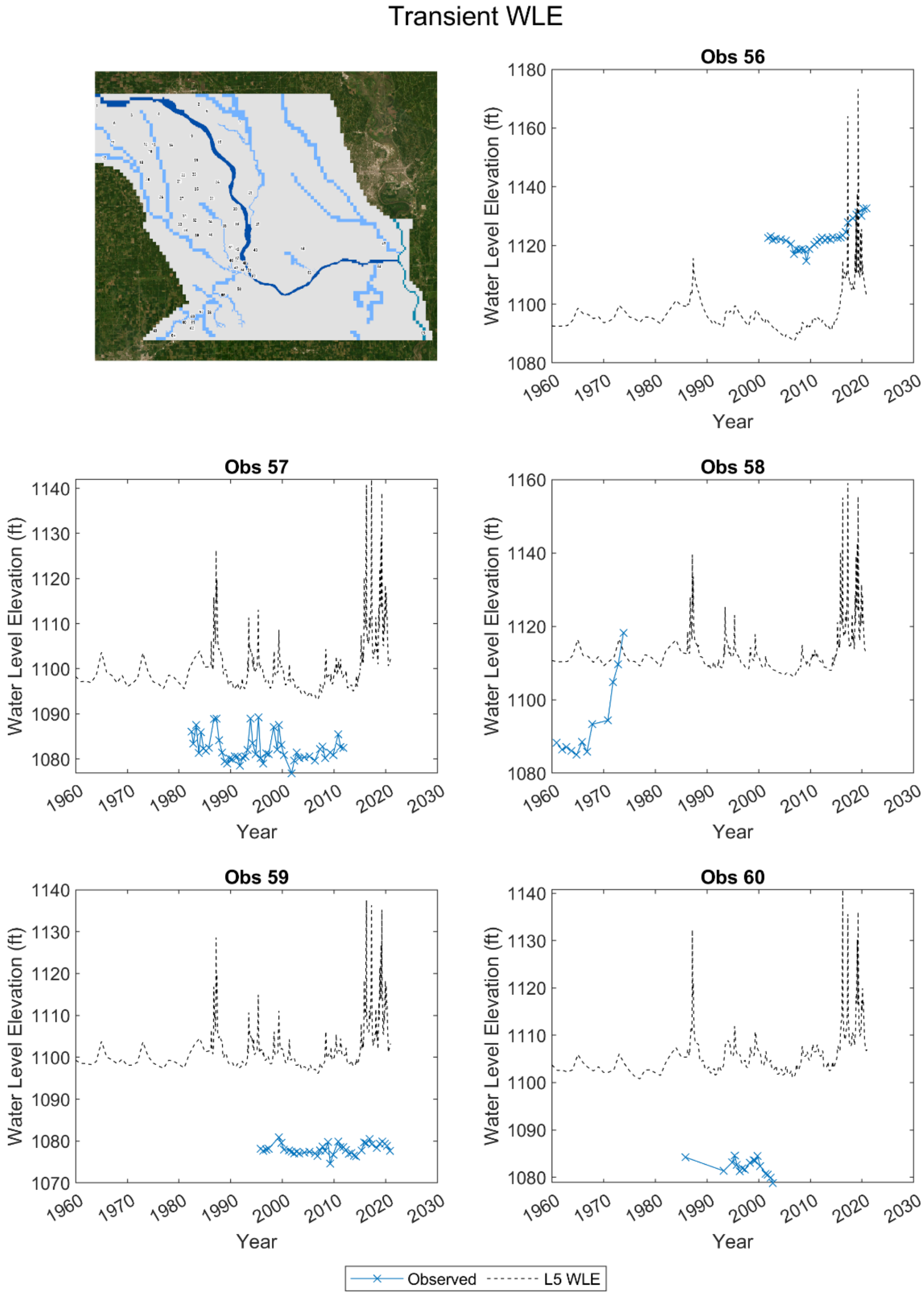

Figure 34: Transient Water Level Hydrographs - Observations 56-60

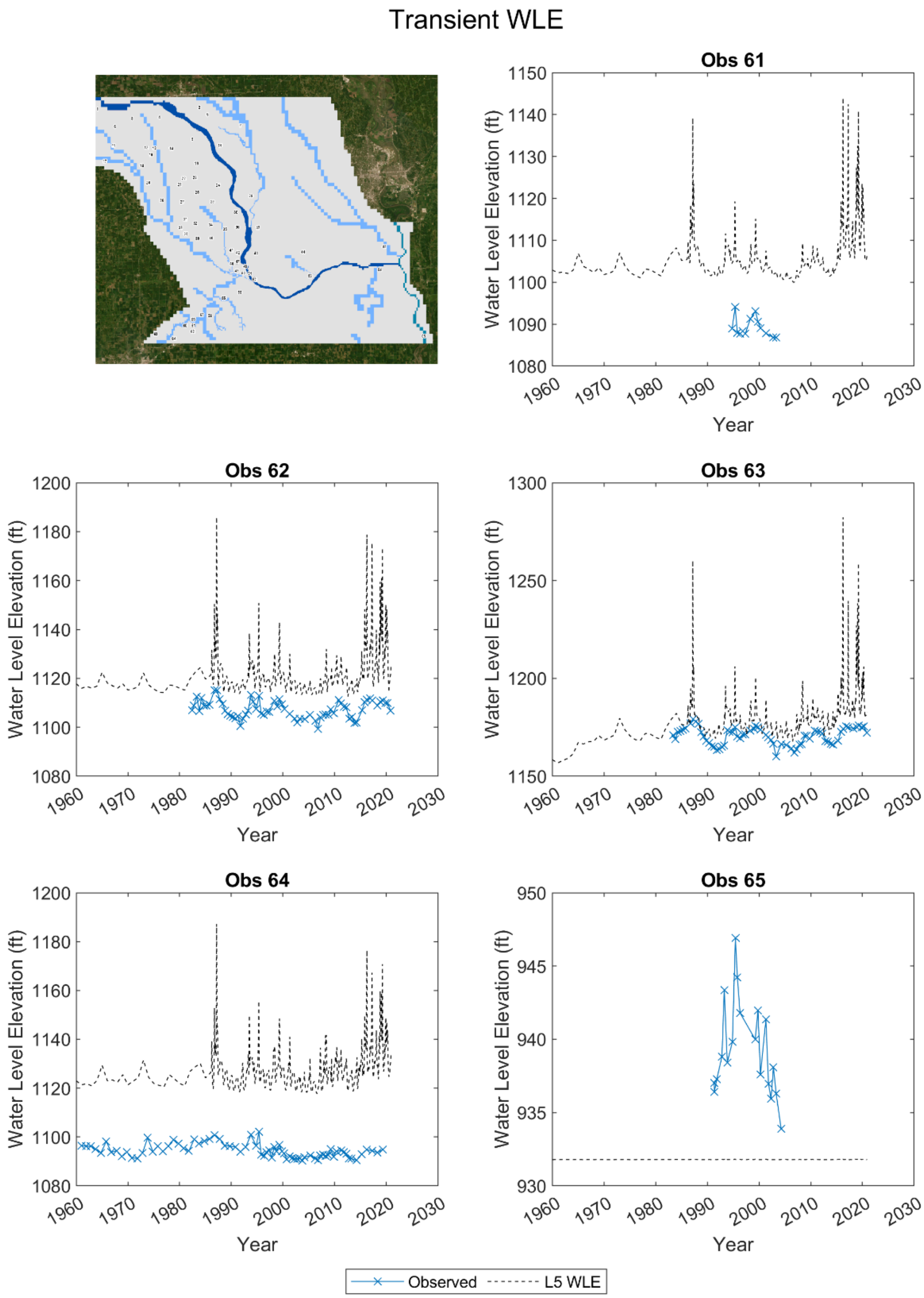

Figure 35: Transient Water Level Hydrographs - Observations 61-65

4. SCENARIOS

The purpose of the JEDI model is to determine locations where a lake as envisioned in legislation should **not** be constructed because of impacts to existing municipal wellfields, especially those operated by LWS and MUD. To evaluate these potential impacts, two different types of scenarios were set up. MODPATH software scenarios were set up to track particles and their interactions with the Platte River and LWS and MUD's wellfields. Lake scenarios were set up to evaluate impacts to the local water table if a lake were excavated.

4.1 Reverse Particle Tracking Scenarios

To examine possible water quality impacts, Olsson used MODPATH particle-tracking software to simulate flow paths and times of travel for hypothetical particles (representing contaminants) placed within MODFLOW model cells as desired, and then ran scenarios to demonstrate times and paths of travel for these particles. Three steady-state scenarios were created to track particles under different climatic events (wet, dry, and normal conditions). For each climate scenario, two particle tracking scenarios were completed: one where particles (one particle per cell per layer) were placed along the outer boundaries of the Platte River and a second where 300 particles were placed at a 250-foot radius from each municipal well. In both starting locations' files, particles were placed at the vertical midpoint of all five layers. The stress periods chosen for each climatic scenario are outlined in **Table 7**.

Table 7: Stress Periods for Each Climatic Scenario

Climatic Scenario	Pumping Stress Period	Cumulative Pumping from Municipal Wellfields (cubic feet per day)	River Stress Period	Average Flow from U.S. Geological Survey (USGS) Stream gage Platte River at Ashland (cubic feet per second)
Wet	364 (February 2014)	$1.29 * 10^7$	320 (June 2010)	$4.27 * 10^4$
Normal	438 (April 2020)	$1.91 * 10^7$	112 (February 1993)	$6.22 * 10^3$
Dry	441 (July 2020)	$4.66 * 10^7$	346 (August 2012)	$3.99 * 10^2$

The wet event is modeled by high-flow stage in the Platte River and low pump rates in the municipal wellfields. The Platte River stages are taken from stress period 320 (June 2010) of the JEDI model, because data from the USGS stream gage of Platte River at Ashland indicated this to be the stress period with the highest average flow rate across the month (USGS 2023). The three municipal well files (LWS, MUD South, and MUD West) were created using pump rates from stress period 364 (February 2014) of the model. This stress period was chosen because it had the least amount of municipal pumping in the last 10 years of the model. Results from the particles placed along the Platte River are shown in **Figure 36** below, and results from particles placed around the municipal well cells are shown in **Figure 37**.

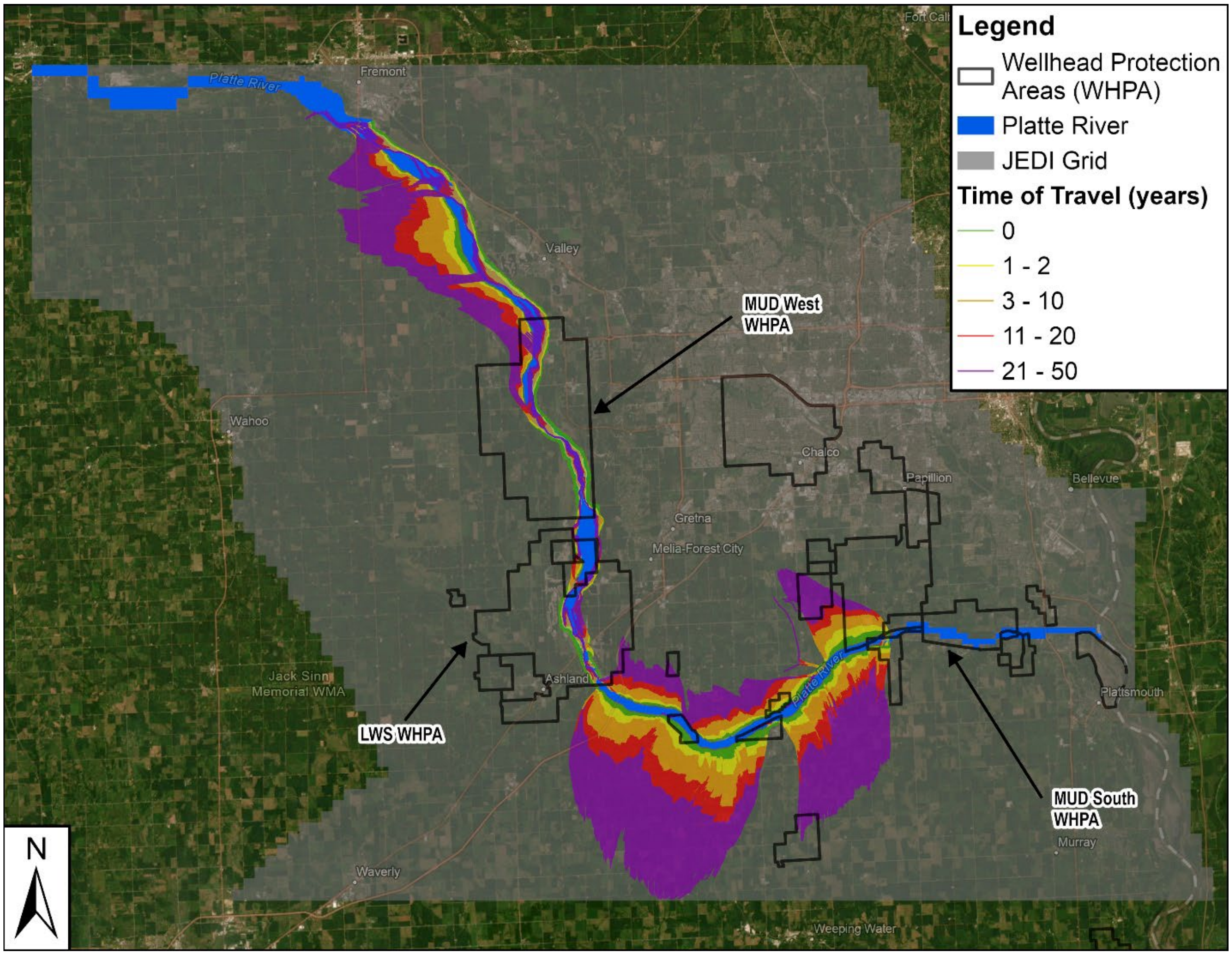

Figure 36: Results from Wet Event - Particles Placed along Platte River

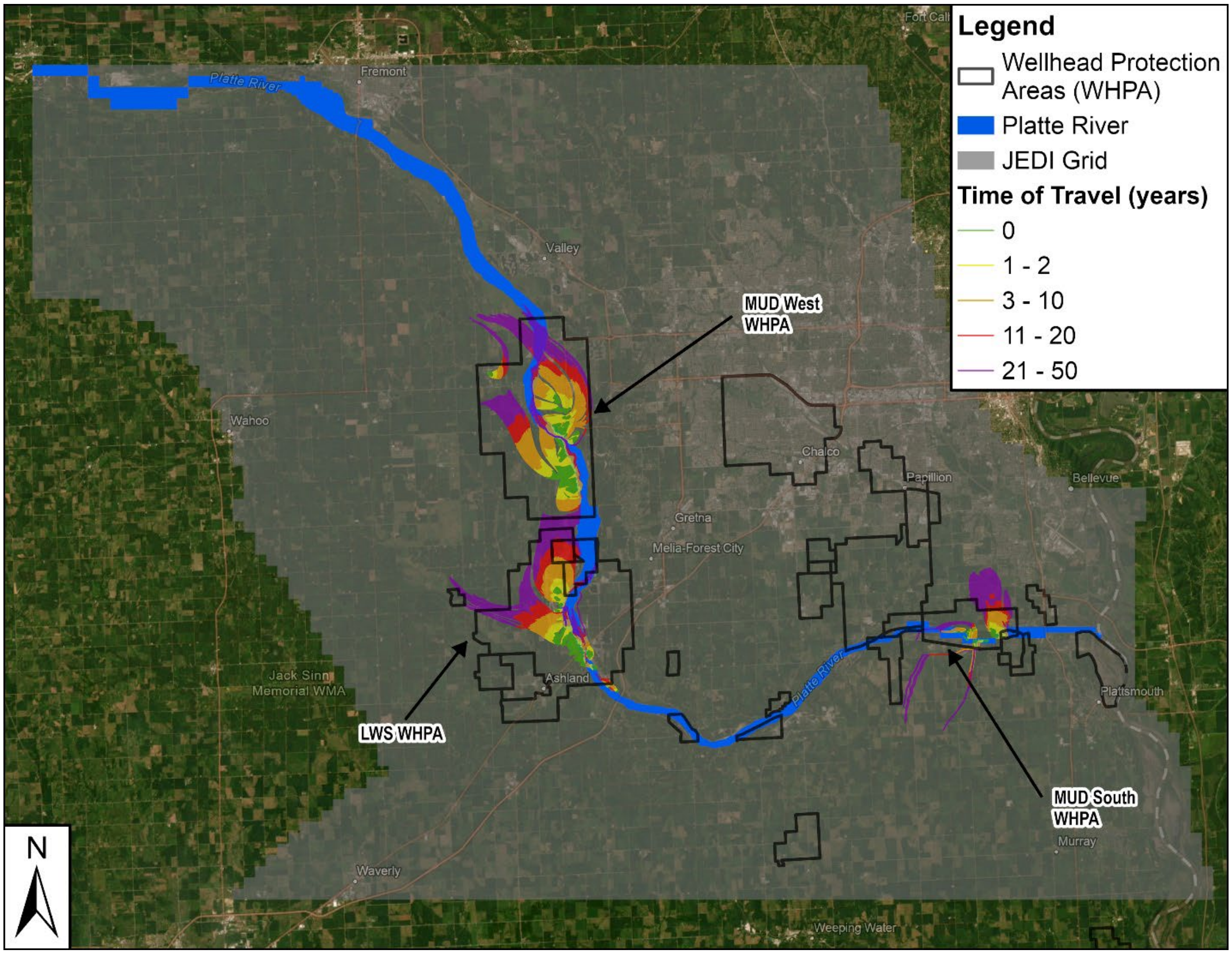

Figure 37: Results from Wet Event - Particles Placed around Municipal Well Cells

The normal event is modeled by median flow rates in the Platte River and median pumping rates in the municipal wellfields. The Platte River stages are taken from stress period 112 (February 1993) of the JEDI model, because USGS stream gage data indicated this to be the stress period with median average flow rates across the month (USGS 2023). The three municipal well files were created using pumping rates from stress period 438 (April 2020) of the JEDI model. This stress period was chosen because it had the median pumping rates across the last 10 years of the model. Results from the particles placed along the Platte River are shown in **Figure 38** below, and results from particles placed around the municipal well cells are shown in **Figure 39**.

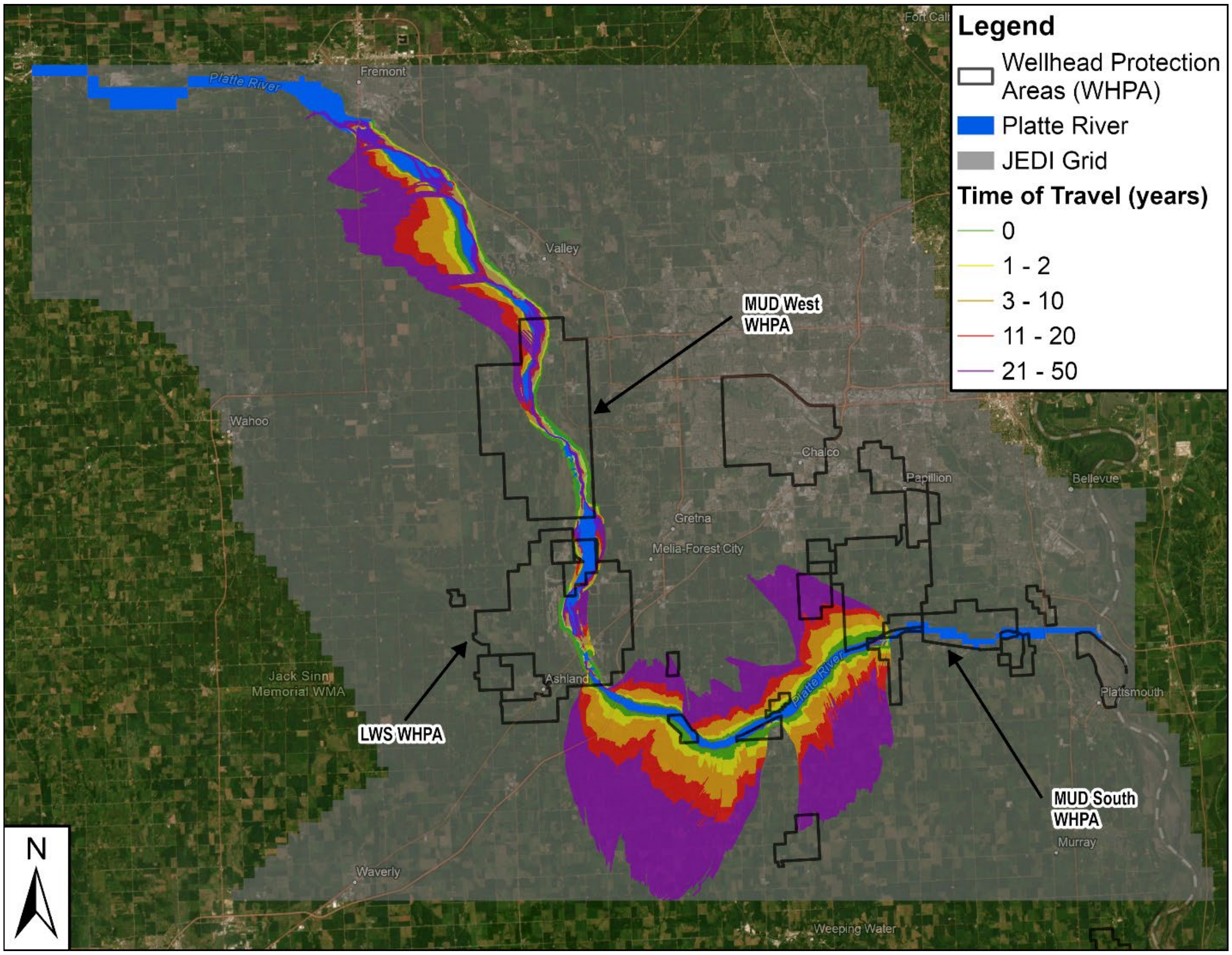

Figure 38: Results from Normal Event - Particles Placed along Platte River

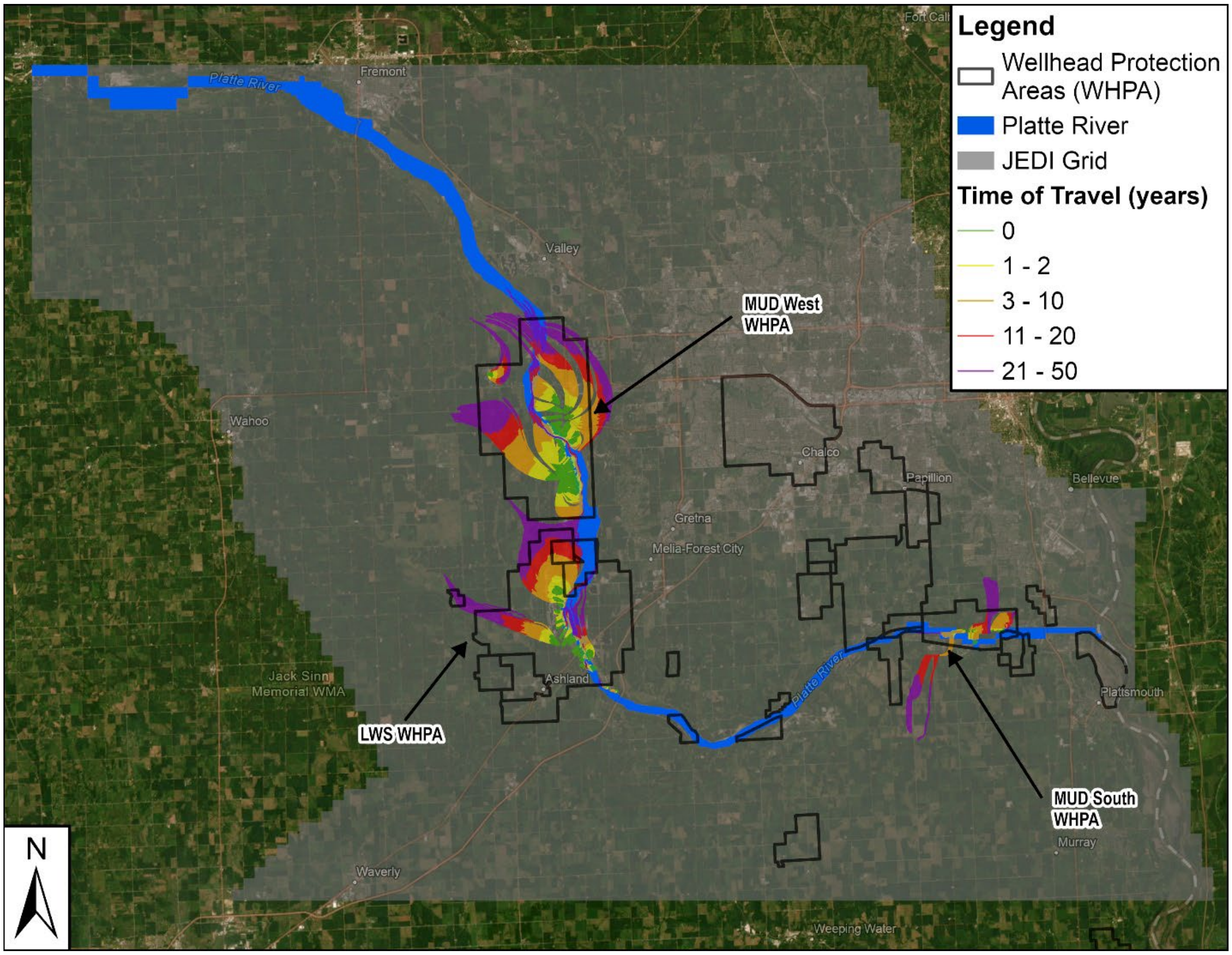

Figure 39: Results from Normal Event - Particles Placed around Municipal Well Cells

The dry event is modeled by low flow rates in the Platte River and high pumping rates in the municipal wellfields. The Platte River stages are taken from stress period 346 (August 2012) of the JEDI model, because USGS stream gage data indicated this to be the stress period with the lowest average flow rate across the month (USGS 2023). The three municipal well files were created using pumping rates from stress period 441 (July 2020) of the model. This stress period was chosen because it had the largest amount of municipal pumping in the last 10 years. Results from the particles placed along the Platte River are shown in **Figure 40** below, and results from particles placed around the municipal well cells are shown in **Figure 41**.

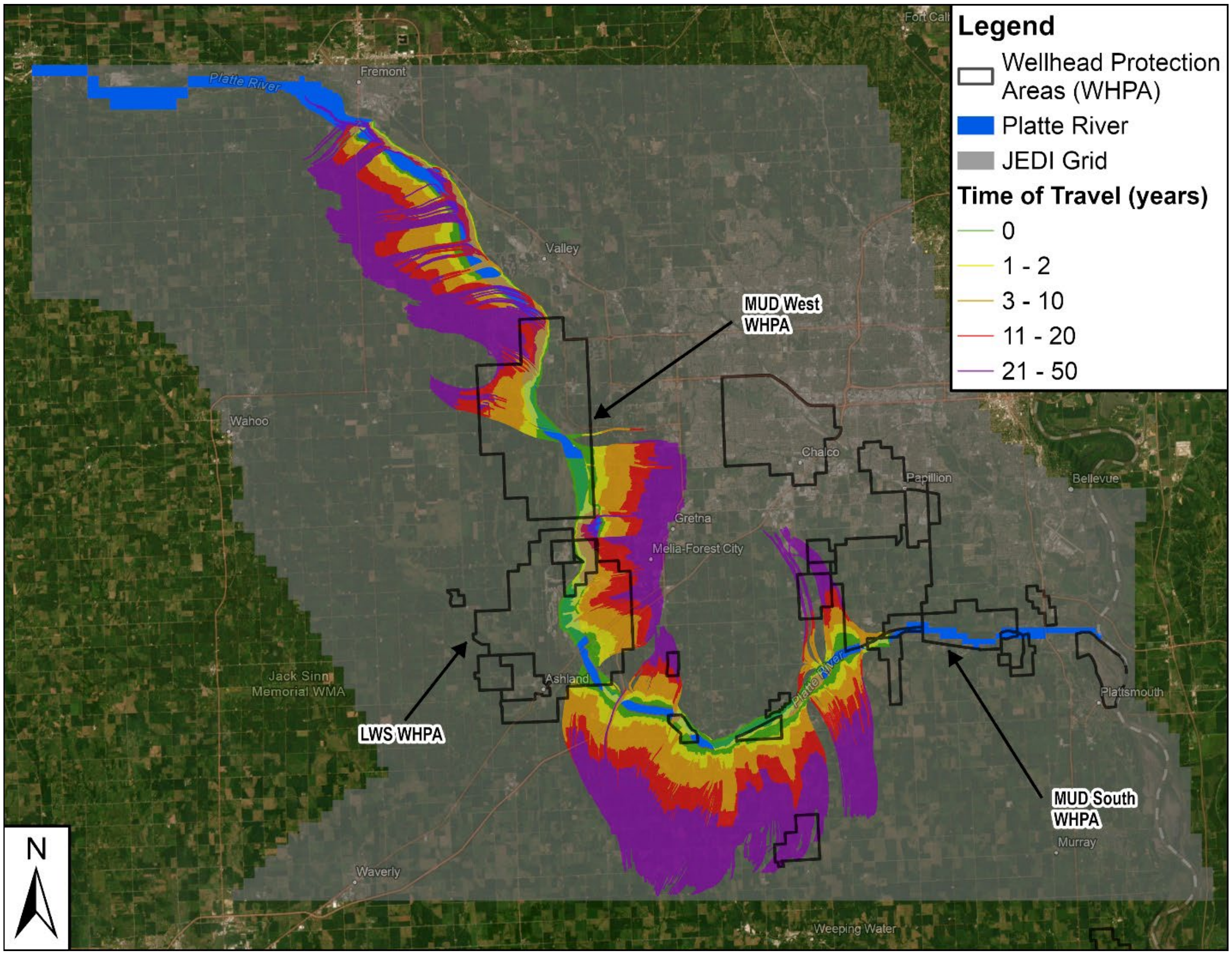

Figure 40: Results from Dry Event - Particles Placed along Platte River

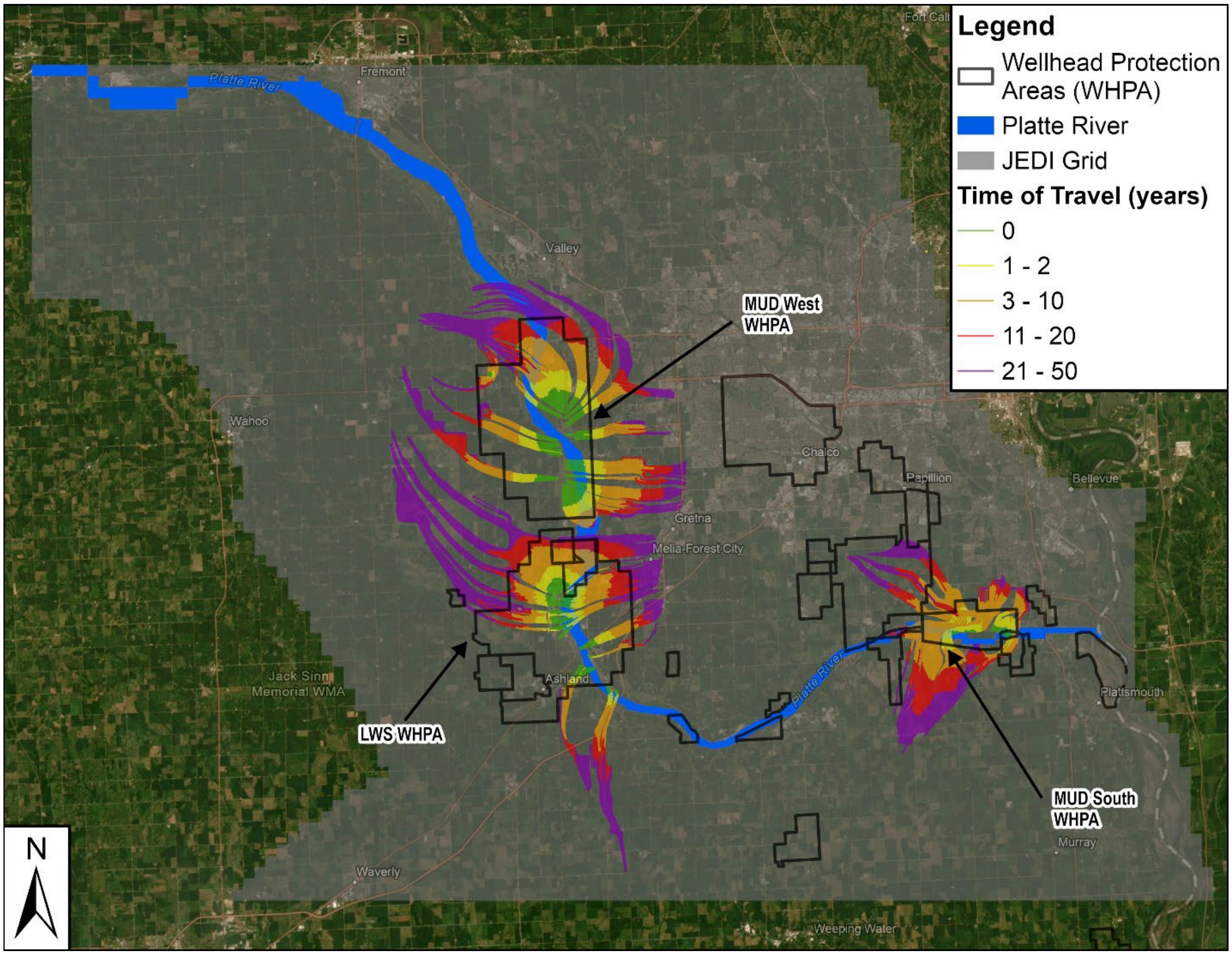

Figure 41: Results from Dry Event - Particles Placed around Municipal Well Cells

As more pumping is applied to the model, each well pulls from a larger radius of surrounding aquifer; therefore, particles have the potential to travel farther. This result can be seen by comparing **Figure 36** to **Figure 40**. **Figures 40 and 41** show that in the high pumping scenario, the wells pull from a larger radius of aquifer; therefore, a larger radius of particles is formed. As shown in **Figures 38 and 39**, the normal conditions fall between the two extremes depicted in these figures.

4.2 Lake Scenarios

A steady-state model was created for each potential lake location (Elkhorn River lake near Nickerson, Salt Creek lake between Greenwood and Ashland, Platte River small lake upstream of Louisville, and Platte River large lake downstream of Louisville) to evaluate impacts to water level elevations. The calibrated steady-state model served as the baseline model. For each potential lake location, all cells within the lake boundaries were assigned as constant head cells.

For the excavated lakes, the constant head value was set to the mean between the maximum and minimum head within the lake boundary at the end of the steady-state baseline model. For the dammed lakes, the constant head value was assigned as the minimum head within the lake boundary plus the difference between the river invert and normal pool elevation. It is important to note that the constant head elevation in the groundwater models does not necessarily match the permanent pool elevation of the potential lakes.

The drawdown for each cell was determined by subtracting the baseline water level elevation from the scenario water level elevation on a cell-by-cell basis. Each potential lake was evaluated individually. As shown in **Figures 44 – 46**, water table levels decrease at the upstream end of each excavated lake and increase downstream. For the dammed lakes, as illustrated in **Figures 42 and 43**, water levels increase in the vicinity of the reservoirs, with the largest increases occurring downstream.

Each lake has a distinct area of influence, beyond which water levels remain constant between the baseline and scenario model runs. Specific details for each lake are provided in Table 8.

Additionally, the Elkhorn River lake falls outside the JEDI model domain, so the regional LPMT model was used to simulate a potential lake at this location. However, the LPMT model has a much coarser resolution (larger cell sizes) than the JEDI model, resulting in less-detailed simulations for the lake at this location. The JEDI model, with its finer resolution, offers more precise insights that the LPMT model cannot provide.

Table 8: Lake Scenario Details

Potential Lake Location	Modeled Surface Area (acres)	Constant Head Elevation (feet)	Maximum Decrease in Water Level Elevation (feet)	Maximum Increase in Water Level Elevation (feet)
Elkhorn River near Nickerson	4,120	1,201.00	N/A	29.4
Salt Creek between Greenwood and Ashland	4,110	1,120.10	N/A	41.8
(Small) Platte River Upstream of Louisville	908	1,023.65	-6.8	6.8
(Large) Platte River Downstream of Louisville	2,097	1,007.60	-8.4	8.4

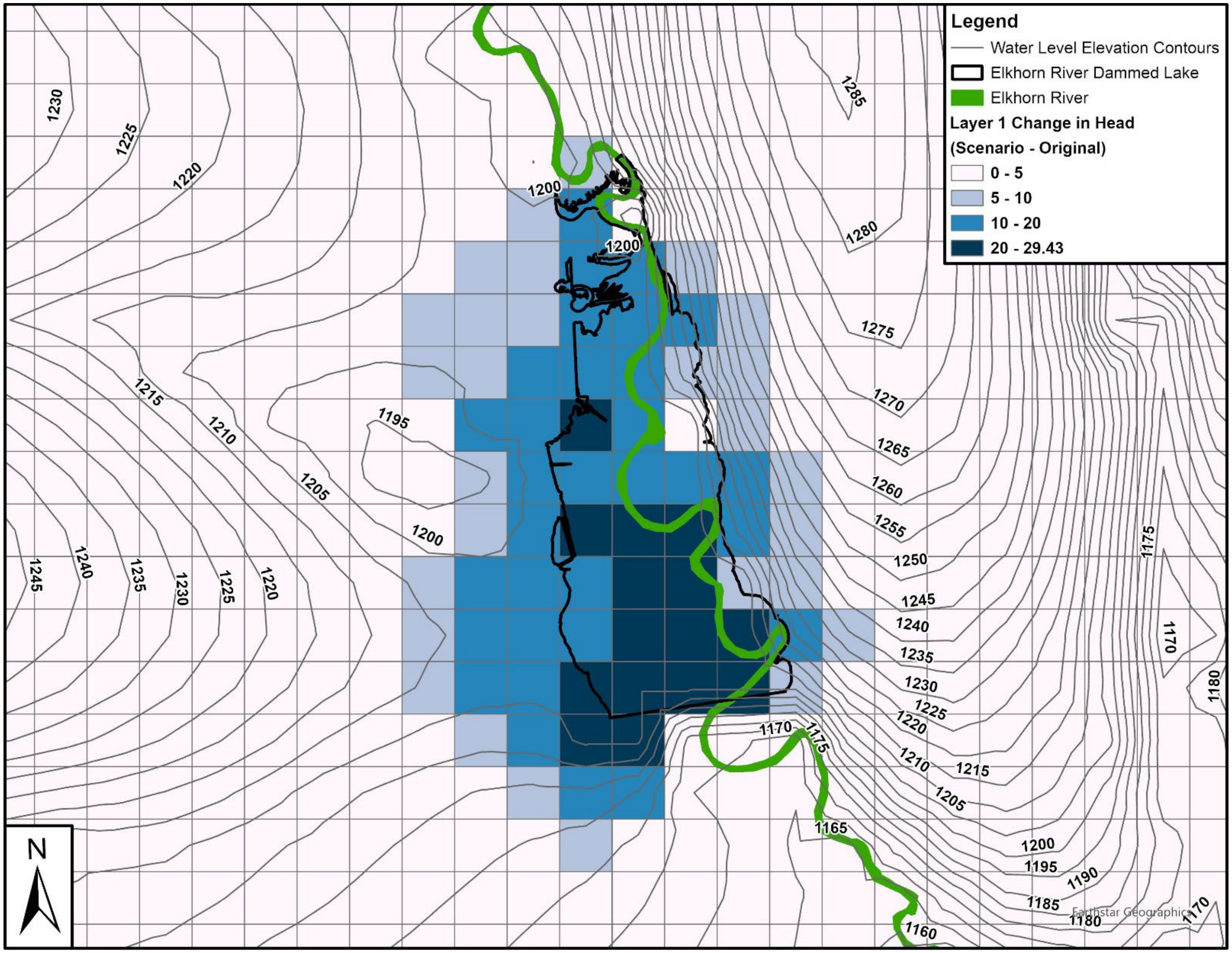

Figure 42: Changes in Head at Elkhorn River Lake Location

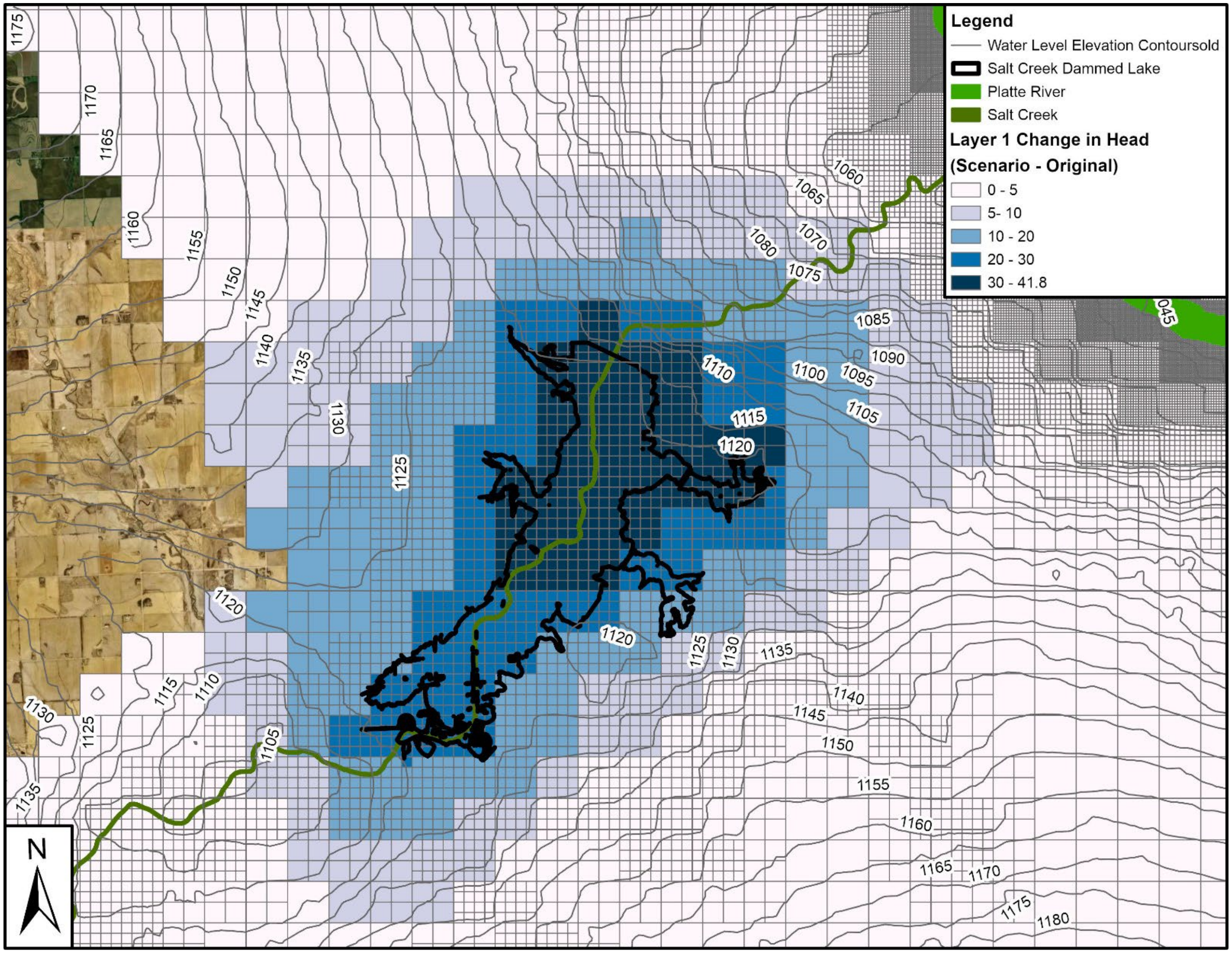

Figure 43: Changes in Head at Salt Creek Lake Location

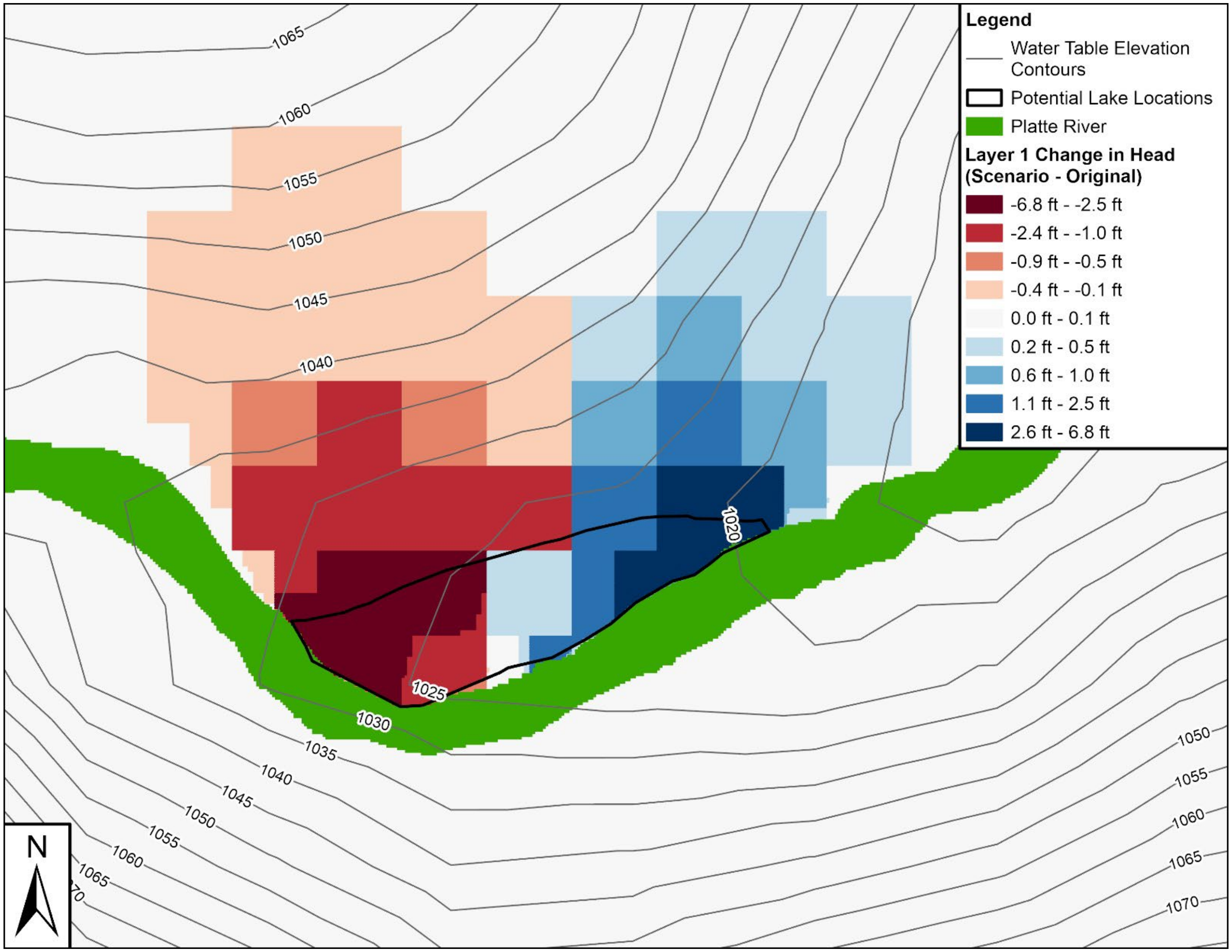

Figure 44: Changes in Head at Upstream of Louisville Lake Location

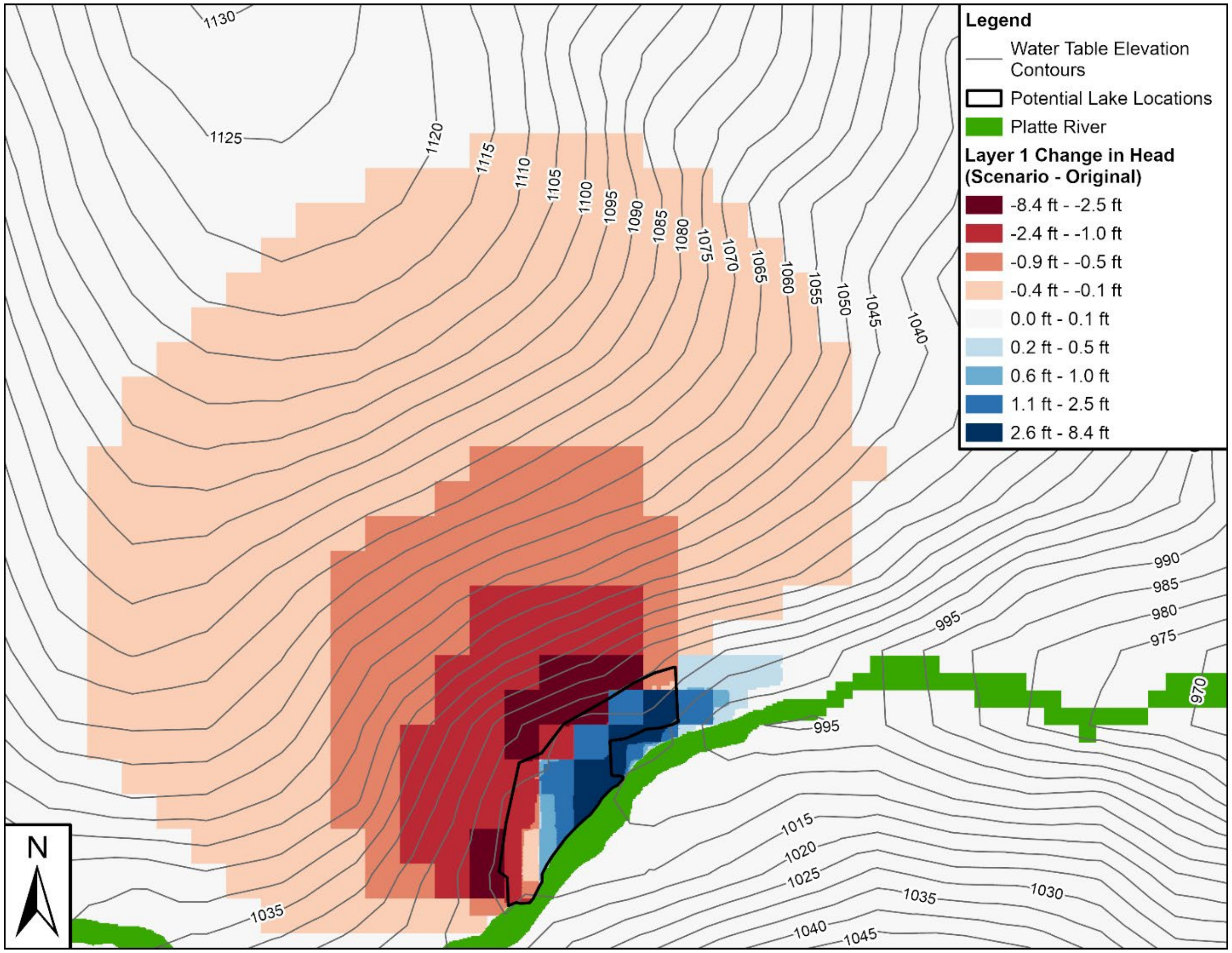

Figure 45: Changes in Head at Downstream of Louisville Lake Location

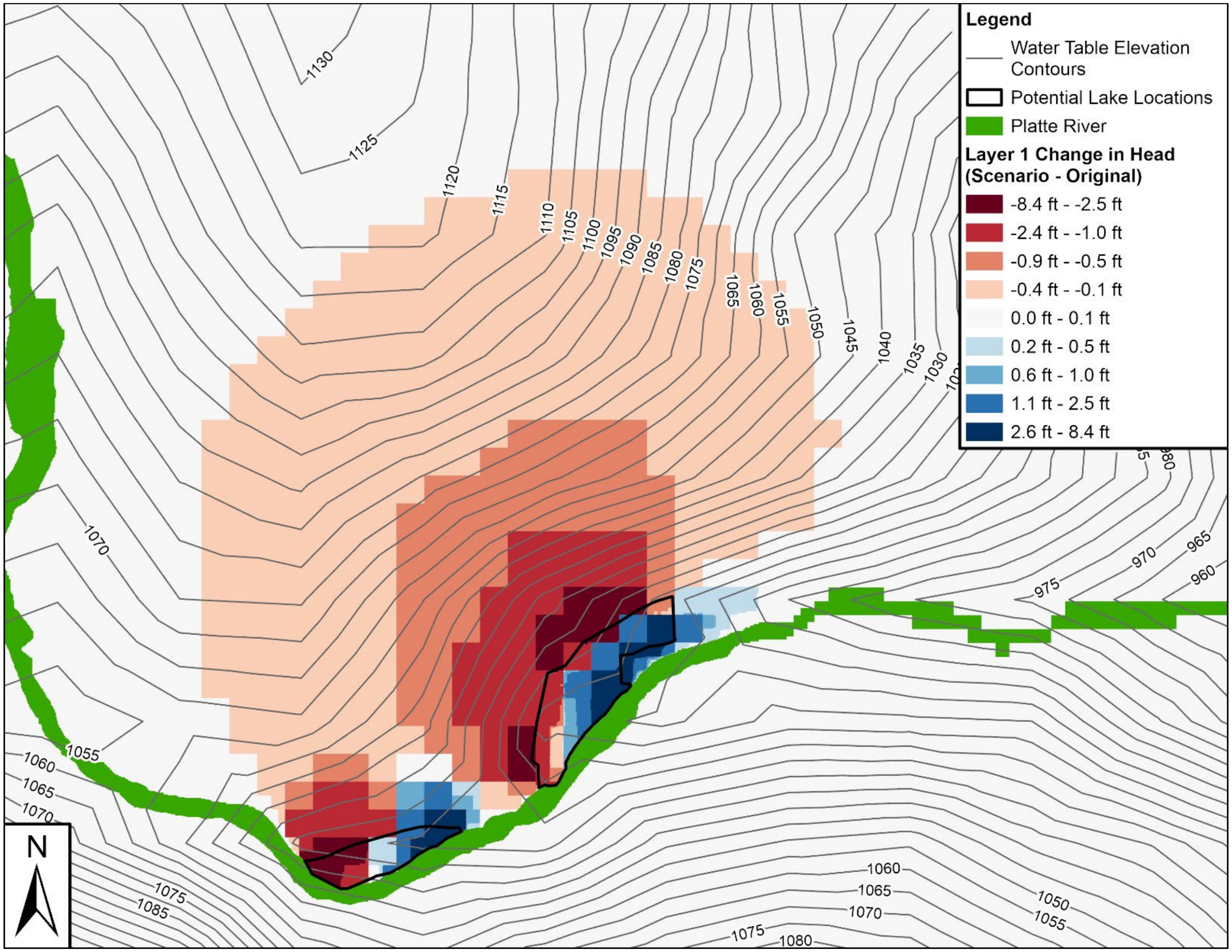

Figure 46: Changes in Head at Both Platte River Lake Locations

4.3 Forward Particle Tracking Scenario

With the potential for water quality impacts to MUD's Platte South wellfield from either or both of the Platte River lakes (upstream and downstream of Louisville), a forward particle tracking scenario was also completed to demonstrate time of travel from the lakes to the Platte River. This scenario assumed normal climate and pumping conditions as described in Section 4.1, and particles were placed in each model cell in each layer, within the lake boundaries. As shown in Figure 47, times of travel from these lakes to the Platte River are as little as 1-2 years.

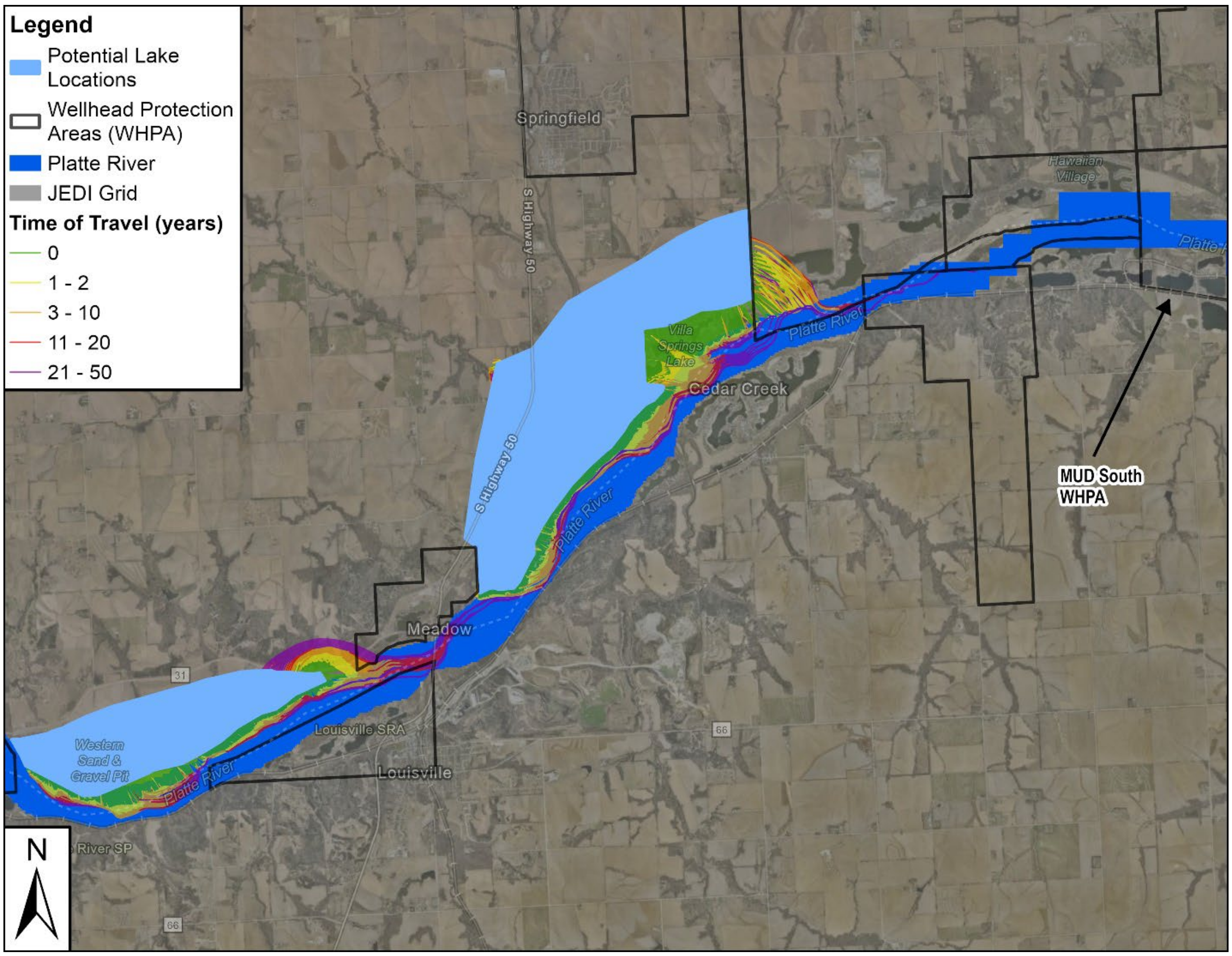

Figure 47: Forward Particle Tracking - Particles Placed in Platte River Lakes

5. CONCLUSIONS

Reverse particle tracking scenarios were completed using wet, dry, and normal climatic conditions, which were built to isolate the effects of Platte River flow and municipal wellfield pumping rates on contaminant time of travel, i.e., the amount of time as determined by modeling for a single particle of a contaminant to move from one location to another. Particles traveled the farthest (largest radius of influence) when the Platte River was at a low-flow stage and pumping rates were high, and conversely had the smallest radius of influence when the Platte River was at a high-flow stage and pumping rates were low. When the Platte River flow stage and pumping rates were set to normal conditions (mean values), the radius of influence predictably landed between these two extremes. The reverse particle tracking scenarios both allowed for a more complete understanding of how groundwater and surface water interact in and near the lower Platte River and the importance of ensuring that any possible lake locations to be considered did not intersect with wellhead protection areas (WHPAs) or existing infrastructure. WHPAs are delineated to aid public water systems both in understanding where their source water comes from and potential sources of contamination, and to provide a basis from which to consider and implement protections against contamination of public water supplies.

Following identification of viable potential lake locations with feedback from the client advisory group consisting of LWS, MUD, and the Nebraska Department of Natural Resources (NeDNR), four total lakes – dammed lakes on the Elkhorn River and Salt Creek, and large and small excavated lakes along the Platte River – were modeled. It is noted that the small lake along the Platte River was originally not included in analyses, but was added upon request of the Nebraska Department of Economic Development once results of the original scenarios were presented. In all scenarios, generally, water table levels decreased at the upstream boundary and increased at the downstream boundary of each lake. Additionally, forward particle tracking scenarios were completed for the two lake locations along the Platte River. These scenarios demonstrated that contaminants in either of these two lakes would have short times of travel – on the order of five years or fewer – to the Platte River and, from there, to the MUD Platte South wellfield. It is noted that presence of either lake configuration along the Platte River (either the large lake alone or the large and small lake combined) would present a significantly different hydrologic regime than is present currently in the vicinity of these municipal wellfields and, thus, contaminants not yet encountered at these wellfields could become a concern.

Using the JEDI model, water level scenarios showed that for the Salt Creek lake location, an increase in groundwater level of approximately 41.8 feet could be expected on the downstream end of the lake. For the Elkhorn River lake location, this increase was 29.4 feet. For the Platte River lakes, this increase was 8.4 feet with an equal upstream decrease for the large lake, and the increase was 6.8 feet downstream with an equal decrease upstream for the small lake.

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LB 1023 (JEDI) IMPACT EVALUATION FOR CITY OF LINCOLN WATER SYSTEM AND METROPOLITAN UTILITIES DISTRICT: GROUNDWATER MODELING SUMMARY REPORT

Lincoln and Omaha, Nebraska – 2024

October 2024

City Project No. 702309
Olsson Project No. 021-01559
B&V Project No. 413017

APPENDIX B: SURFACE WATER FLOOD MODELING REPORT

LB 1023 (JEDI) IMPACT EVALUATION FOR CITY OF LINCOLN WATER SYSTEM AND METROPOLITAN UTILITIES DISTRICT: SURFACE WATER FLOOD MODELING REPORT

CITY PROJECT NO. 702309
OLSSON PROJECT NO. 021-01559
B&V PROJECT NO. 413017

PREPARED FOR

LINCOLN
Transportation and Utilities

METROPOLITAN
UTILITIES DISTRICT

CITY OF LINCOLN WATER SYSTEM
METROPOLITAN UTILITIES DISTRICT
18 OCTOBER 2024

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Project Name: LB 1023 (JEDI) Impact Evaluation for City of Lincoln Water System and Metropolitan Utilities District
Project Address/Location: Cass, Dodge, Douglas, Sarpy, and Saunders Counties

ACRONYMS AND ABBREVIATIONS

cfs .... Cubic Feet per Second
CLOMR.. Conditional Letter of Map Revision
DEM.. Digital Elevation Model
FEMA... Federal Emergency Management Agency
FT .... Feet
HEC-RAS.. Hydrologic Engineering Center River Analysis System
JEDI... Jobs and Economic Development Initiative
Lidar.. Light Detection and Ranging
LWS... Lincoln Water System
MI .... Mile
MUD .... Metropolitan Utilities District
NAVD88... North American Vertical Datum of 1988
NE .... Nebraska
NDED .... Nebraska Department of Economic Development
NeDNR .... Nebraska Department of Natural Resources
RC .... Rating Curve
STAR WARS . Statewide Tourism and Recreational Water Access and Resources Sustainability
USGS .... United States Geological Survey
WSE .... Water Surface Elevation

TABLE OF CONTENTS

Executive Summary **S-1**

1. Background **1**

2. Hydrologic Concerns **4**

2.1 Flood Frequency Analysis **4**

2.2 Model Geometry **7**

2.3 Model Boundary Conditions **8**

2.4 Model Calibration **10**

3. Evaluation of Lake Alternatives **13**

3.1 Platte River Large Excavated Lake **13**

3.2 Platte River Small Excavated Lake **15**

3.3 Salt Creek Dammed Lake Example **17**

3.4 Elkhorn River Dammed Lake Example **18**

4. Conclusions **20**

LIST OF FIGURES

Figure 1: Lake Locations Considered 3

Figure 2: Location of Stream Gages used in Flood Frequency Analysis 6

Figure 3: HEC-RAS Model Geometry, Digital Elevation Model, Bridges and Break Lines 8

Figure 4: HEC-RAS Model Boundaries 9

Figure 5: Rating Curves Developed for Five USGS Gage Locations 11

Figure 6: Platte River Large Excavated Lake (red areas correspond to WHPAs) 14

Figure 7: Platte River Small Excavated Lake (red areas correspond to WHPAs) 16

Figure 8: Salt Creek Dammed Lake (red areas correspond to WHPAs) 18

Figure 9: Elkhorn River Dammed Lake (red areas correspond to WHPAs) 19

LIST OF TABLES

Table 1: Flood Frequency Analysis Results for Platte River Stream Gages 5
Table 2: Flood Frequency Analysis Results for Salt Creek and Elkhorn River Tributary Gages 5
Table 3: Model Calibration Results 12
Table 4: Model Results – Platte River 15
Table 5: Model Results – Platte River 17

EXECUTIVE SUMMARY

In 2021 and 2022, the Nebraska legislature enacted LB406 and LB1023, respectively, which first established the Statewide Tourism and Recreational Water Access and Resources Sustainability (STAR WARS) special committee, and then the Lake Development Act which was codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (*Neb. Rev. Stat.* §61-401 to 61-404). In these pieces of legislation, the unicameral recognized the importance – in the wake of historic flooding in 2019 and the COVID-19 pandemic – for both flood control and major recreational opportunities in the state to attract and retain an increasingly remote workforce. The STAR WARS committee envisioned, in the lower Platte River corridor, a lake that would rival Iowa's Lake Okoboji as a tourist destination and hub for public-private partnerships to develop lakeside communities, a community town center, and a major resort. As outlined in the STAR WARS committee's report, a lake location northeast of the city of Ashland, Nebraska was contemplated and this informed the committee's recommendation that further analysis be conducted to inform viable locations for a lake of at least 3,600 acres, located in or near Sarpy County, and adjacent to – but not impounding – the Platte River.

Recognizing the potential for impacts to public water system wellfields, the legislature also appropriated funds to be administered through the Nebraska Department of Natural Resources (NeDNR) for further study on possible lake sites. The City of Lincoln Water System (LWS) already had its Water 2.0 project – investigating possibilities for additional source(s) of drinking water – underway with Black & Veatch and Olsson, and recognized that these consultants have the necessary expertise regarding the water system as well as expertise in the types of technical analysis needed for potential lake sites. Thus, LWS amended its Water 2.0 contract to include this study and entered into a memorandum of understanding with Omaha's Metropolitan Utilities District (MUD) to allow for MUD's wellfields and concerns to also be considered.

A surface water model was developed for this study and consists of a model of the Platte River including the Elkhorn River and Salt Creek tributaries. The surface water model geometry is foundationally a digital elevation model (DEM) constructed from available topographic and bathymetric data from the United States Geological Survey (USGS), the Eastern Nebraska Lidar Download Application, and the Headwaters Corporation. The DEM extends along the Platte River from North Bend to the confluence with the Missouri River and includes a portion of the Missouri River, Elkhorn River, and Salt Creek.

The surface water model was used to evaluate potential impacts of excavating a lake or two lakes in the floodplain of the Platte River, or damming the Elkhorn River or Salt Creek. The impacts of the Platte River excavated lakes were evaluated for flow conditions associated with the 2, 10, 50, 100, 500-year floods, and during the 2019 flood event. For the example dammed lakes located along the Elkhorn River and Salt Creek, the analysis was limited to evaluating conditions during the 100-year and the 2019 flood event. While a dammed lake was not necessarily envisioned by the legislature in LB1023, NeDNR requested that these areas also be considered in this study, as examples of sites chosen to examine initial feasibility, with the possibility that similar sites could be considered in the future.

The Platte River large excavated lake is limited in spatial extent to roughly 2,100 acres because the area is confined by two wellhead protection areas (WHPA), the Platte River itself, and bluffs. The lake would likely need a berm – acting as a levee – constructed around it to prevent the entry of floodwaters. It is also notable that several small tributaries exist to the northwest of this lake, and flow from these would either have to be allowed to enter the lake or be routed around it. The berm would be approximately 10 feet high. The lake boundary was defined by attempting to limit increases in water surface elevation (WSE) during the 100-year flood event to no more than 1.0 foot, as required by Federal Emergency Management Agency (FEMA) regulations; however, final modeling results indicated the maximum increase in WSE during the 100-year flood event may be slightly above this threshold. This may require a reduction in the lake footprint. Alternatively, a letter of map revision (LOMR) or conditional letter of map revision (CLOMR) from FEMA could be sought, to update the regulatory flood map(s) and/or provide federal regulatory comment on whether changes in hydrology resulting from the lake's construction would be acceptable under the National Flood Insurance Program standards.

After reviewing the findings of the Platte River large excavated lake evaluation, the Nebraska Department of Economic Development (NDED) asked whether a smaller Platte River lake could be built in conjunction with the larger Platte River lake. As requested, a two excavated lakes option was also analyzed along the Platte River. This option consisted of both the Platte River large excavated lake (approximately 2,100 acres) and the Platte River small excavated lake (approximately 900 acres). Combined, the two excavated lakes would have a total surface area of approximately 3,000 acres which is closer to the targeted size in the legislation. The inclusion of the Platte River small excavated lake produced similar results to the large excavated lake and would need to address the same elements and considerations.

Both the Salt Creek and Elkhorn River example dammed lakes, as analyzed, are approximately 4,100 acres in size. The conceptual Salt Creek dammed lake had a dam height of approximately 50 feet and a dam length of approximately 5,500 feet. For the Elkhorn River dammed lake, the conceptual dam height was approximately 36 feet with a dam length of 9,000 feet. Modeling results indicated that downstream reductions in WSE for the Salt Creek and Elkhorn River lakes would be relatively small; less than 0.1 foot and less than 0.01 foot, respectively. From these lake footprints, then, additional groundwater modeling scenarios were carried out to evaluate the impacts of each lake on water table elevations. Modeling showed that each lake would locally produce both declines and rises in water tables, with the magnitude of these changes being roughly ± 7 to 10 feet.

Results from this surface water flood modeling analysis indicated that implementation of these lakes is possible. However, further studies will be required to assess the feasibility of these lakes. From a surface water flood modeling perspective and accounting for impacts to the regulatory floodplain, further modeling will be needed to refine the footprint of the Platte River large excavated lake and Platte River small excavated lake. Refinement of hydraulic modeling will also be needed for the Salt Creek dammed lake and Elkhorn River dammed lake. It is recommended to conduct a conceptual design of the dam embankment and spillway to refine potential hydrologic and hydraulic impacts. It is also recommended to conduct an alternative analysis that includes cost, benefits, impacts to the floodplain, and a comprehensive determination of environmental and dam safety regulatory requirements.

No fatal flaws were identified based on the surface water flood modeling for Platte River large excavated lake, Platte River small excavated lake, Elkhorn River dammed lake, and Salt Creek dammed lake in relation to LWS' wellfield and MUD's wellfields at Platte West and Platte South. However, challenges and potential adverse impacts were identified for each lake requiring additional, more-detailed analyses to identify whether the potential impacts can be mitigated. For example, remediation may be required to lower the increase in flood elevation caused by a berm. Therefore, it is recommended that full feasibility studies of the lakes be performed.

1. BACKGROUND

In 2021 and 2022, the Nebraska legislature enacted LB406 and LB1023, respectively, which first established the Statewide Tourism and Recreational Water Access and Resources Sustainability (STAR WARS) special committee, and then the Lake Development Act which was codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (*Neb. Rev. Stat.* §61-401 to 61-404). In these pieces of legislation, the unicameral recognized the importance – in the wake of historic flooding in 2019 and the COVID-19 pandemic – for both flood control and major recreational opportunities in the state to attract and retain an increasingly remote workforce. The STAR WARS committee envisioned, in the lower Platte River corridor, a lake that would rival Iowa's Lake Okoboji as a tourist destination and hub for public-private partnerships to develop lakeside communities, a community town center, and a major resort. As outlined in the STAR WARS committee's report, a lake location northeast of the city of Ashland, Nebraska was contemplated and this informed the committee's recommendation that further analysis be conducted to inform viable locations for a lake of at least 3,600 acres, located in or near Sarpy County, and adjacent to – but not impounding – the Platte River.

Hydraulic modeling of the Platte River, Elkhorn River, and Salt Creek was conducted to evaluate potential impacts of constructing an excavated lake along the Platte River or a dammed lake along the Elkhorn River or Salt Creek. The Hydrologic Engineering Center River Analysis System (HEC-RAS), version 6.4.1 was used in this analysis. The locations and type of lakes were determined based on groundwater modeling documented in the Groundwater Modeling Summary Report, wellhead protection areas (WHPA), surface water modeling documented in this report, and monthly progress meetings and workshops that were held between Lincoln Water System (LWS), MUD, Nebraska Department of Natural Resources (NeDNR), Olsson, and Black & Veatch. LWS, MUD, and NeNDR provided direction and feedback on assumptions and decisions throughout this study.

The following two types of lakes were considered for this study. Figure 1 shows the location of these potential lakes:

- The first type consists of excavating natural ground along the floodplain until bedrock is reached. This first type is possible along the Platte River because groundwater is relatively shallow and excavation to bedrock results in exposing the groundwater. The excavated lakes around the Platte River are near Louisville, Nebraska, which are the Platte River large excavated lake, downstream of Louisville, and the Platte River small excavated lake, upstream of Louisville. After reviewing the findings of the Platte River large excavated lake evaluation, the Nebraska Department of Economic Development (NDED) asked whether a smaller Platte River lake could be built in conjunction with the larger Platte River lake. As requested, a two excavated lakes option was also analyzed along the Platte River. Combined, the two excavated lakes would have a total surface area of approximately 3,000 acres which is closer to the targeted size in the legislation.

- The second type is a traditional dammed lake, that is, a dam is constructed across the floodplain to impound water. For the example dammed type lakes examined, the potential lakes are the Elkhorn River dammed lake, near Nickerson, and the Salt Creek dammed lake, between Greenwood and Ashland. While a dammed lake was not necessarily envisioned by the legislature in LB1023, the NeDNR requested that these areas also be considered in this study, as examples of sites chosen to examine initial feasibility, with the possibility that similar sites could be considered in the future.

This report summarizes the analysis conducted to evaluate potential impacts of the potential lakes. The analysis focused on evaluating potential changes in flood water surface elevations along the Platte River and the two tributaries (Elkhorn River and Salt Creek). The surface water modeling results also informed the water balance modeling and geomorphic analysis conducted under for this study. Relevant results associated with the water balance modeling and the geomorphic analysis are summarized in the Water Balance Modeling Report and Geomorphic Analysis Report, respectively.

The impacts of the Platte River excavated lakes were evaluated for flow conditions associated with the 2, 10, 50, 100, 500-year floods and during the 2019 flood event. For the example dammed lakes located along the Elkhorn River and Salt Creek, the analysis was limited to evaluating conditions during the 100-year and the 2019 flood event.

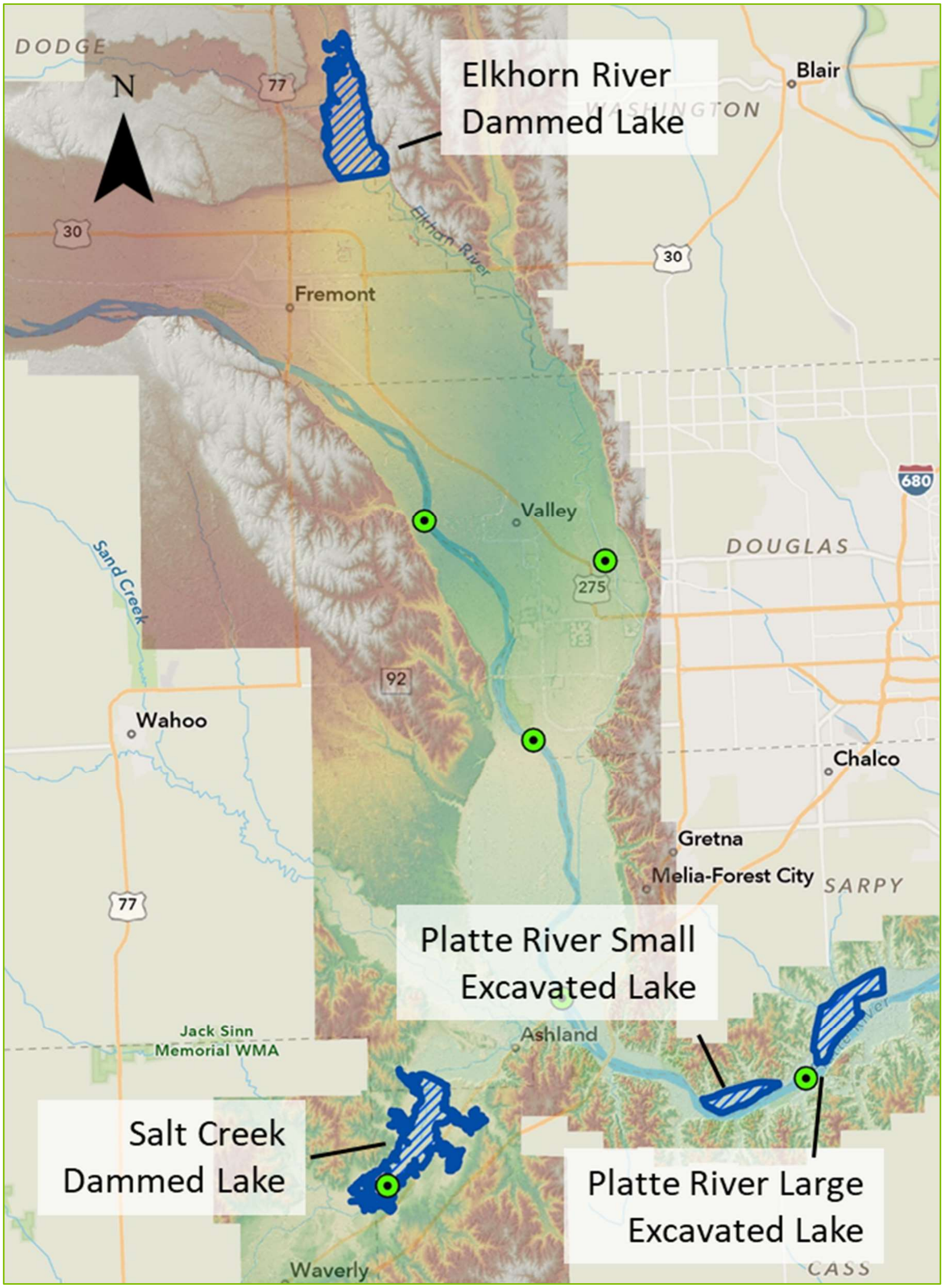

Figure 1: Lake Locations Considered

2. HYDROLOGIC CONCERNS

2.1 Flood Frequency Analysis

Flood frequency analysis was conducted using peak streamflow data available for four USGS stream gages located along the Platte River and one gage on the Salt Creek and two gages on the two main tributaries to the Elkhorn River. The gages used in the analysis are listed below. Table 1 and Table 2 list the estimated peak flows associated with the 2, 10, 50, 100, 500-year events for all gages analyzed. Figure 2 shows the location of the stream gages used in the analysis. The figure includes the location of the Venice gage that was used for calibration but did not have enough years of record to conduct flood frequency analysis. Note that most gages had over 50 years of record except the Leshara gage; the years of record are noted in Tables 1 and 2. Note that the estimated 500-year peak flow at the Leshara gage is larger than the peak flow at the Ashland gage, which is located downstream of Leshara; this discrepancy could be due to attenuation as water moves through the floodplain from the Leshara gage to the Ashland gage without major additions of flow, or an issue with determining the flood frequency from a relatively small period of record compared to the other gages.

- USGS 06796000 Platte River at North Bend, Nebraska
- USGS 06796500 Platte River near Leshara, Nebraska
- USGS 06801000 Platte River near Ashland, Nebraska
- USGS 06805500 Platte River at Louisville, Nebraska
- USGS 06803555 Salt Creek at Greenwood, Nebraska
- USGS 06799385 Elkhorn River at West Point, Nebraska
- USGS 06799500 Logan Creek near Uehling, Nebraska

Table 1: Flood Frequency Analysis Results for Platte River Stream Gages

Return Period (year)	Peak Flows – Platte River Stream Gages (cfs)			
	North Bend (years of record = 74)	Leshara (years of record = 28)	Ashland (years of record = 59)	Louisville (years of record = 70)
2	25,100	22,200	37,700	45,400
10	58,600	53,000	81,200	103,000
50	106,100	106,900	135,000	173,500
100	132,800	141,800	162,800	209,600
500	214,900	266,900	241,300	309,700

Table 2: Flood Frequency Analysis Results for Salt Creek and Elkhorn River Tributary Gages

Return Period	Peak Flows – Salt Creek and Elkhorn River Tributary Gages (cfs)		
	Salt Creek (years of record = 71)	Elkhorn River at West Point (years of record = 63)	Logan Creek (years of record = 83)
2	14,200	10,200	6,100
10	35,100	29,100	14,000
50	49,400	55,800	20,500
100	54,000	70,300	22,900
500	62,300	112,900	28,000

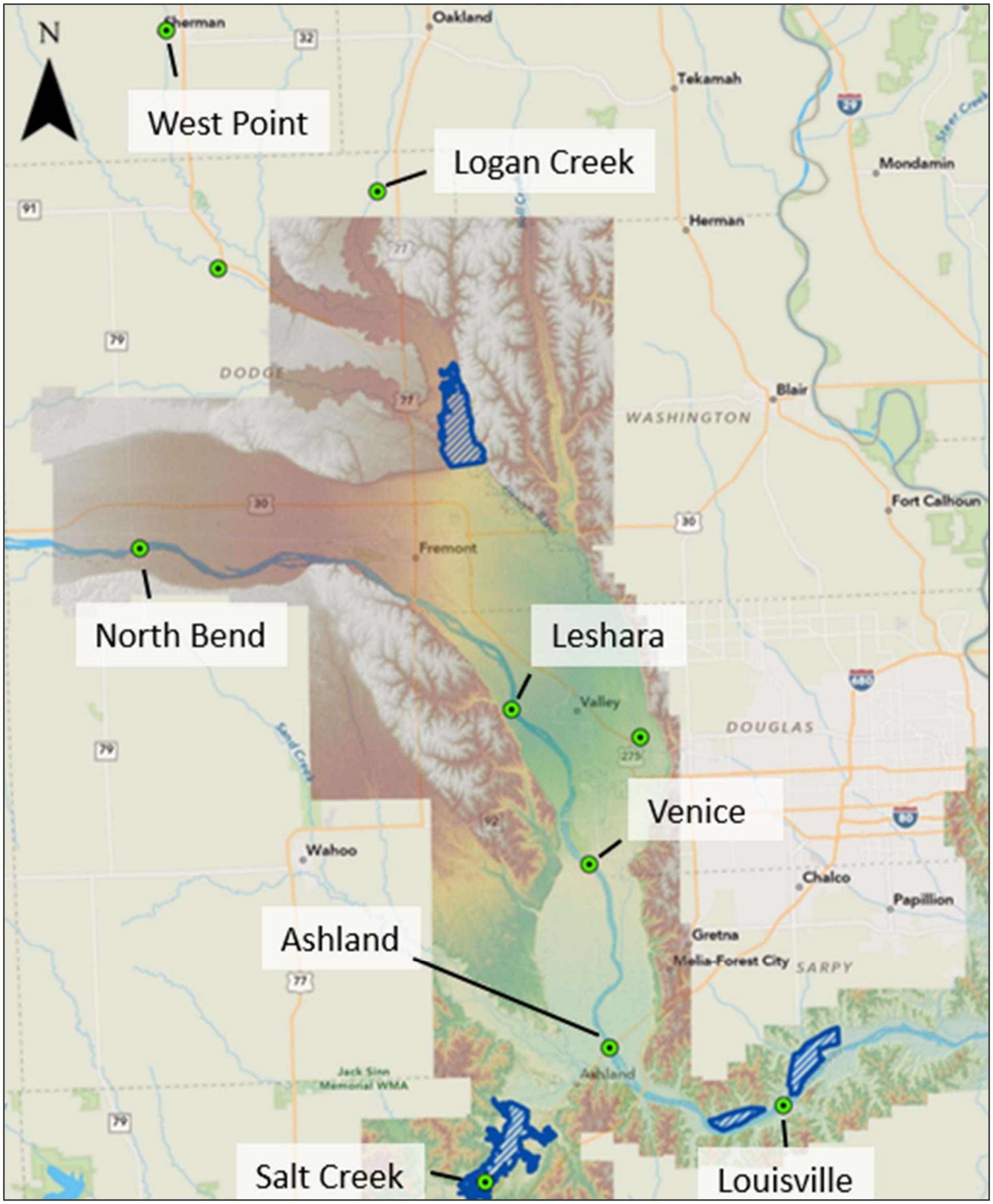

Figure 2: **Location of Stream Gages used in Flood Frequency Analysis**

2.2 Model Geometry

A digital elevation model (DEM) constitutes the foundation of the model geometry. The DEM was constructed using a combination of available topographic and bathymetric data.

Light detection and ranging (lidar) data available from the USGS, the National Map geospatial database, and from the Eastern Nebraska Lidar Download Application were used. The latter included lidar data available for Douglas, Lancaster, and Sarpy Counties. Topobathymetric lidar data collected in Summer 2022 by Headwaters Corporation was also used. The most recent lidar data was mosaicked and combined with the topobathymetric lidar data to produce a comprehensive terrain model. The resolution of the lidar data used varies between 1.5x1.5 to 3x3 feet. The final DEM was resampled to a resolution of 10x10 feet. Figure 3 shows the DEM developed. The DEM extends along the Platte River from North Bend to the confluence with the Missouri River and includes a portion of the Missouri River, and the Elkhorn River and Salt Creek tributaries. Elevations in the DEM are referenced to the North American Vertical Datum of 1988 (NAVD88). Consistently, all elevations listed in the report are referenced to NAVD88.

The model geometry includes 11 bridges and several break lines that represent levees and road embankments. Bridges and break lines used in the model are depicted on Figure 3. The break lines are needed in the HEC-RAS 2D model to demarcate levee and road embankments that pose a potential barrier to flow. Bridge geometry was obtained from the current Federal Emergency Management Agency (FEMA) effective hydraulic model. The effective model is an HEC-2 model. The dimensions of three of the bridges were adjusted based on as-built drawings provided by the State of Nebraska and confirmed by inspecting aerial photography.

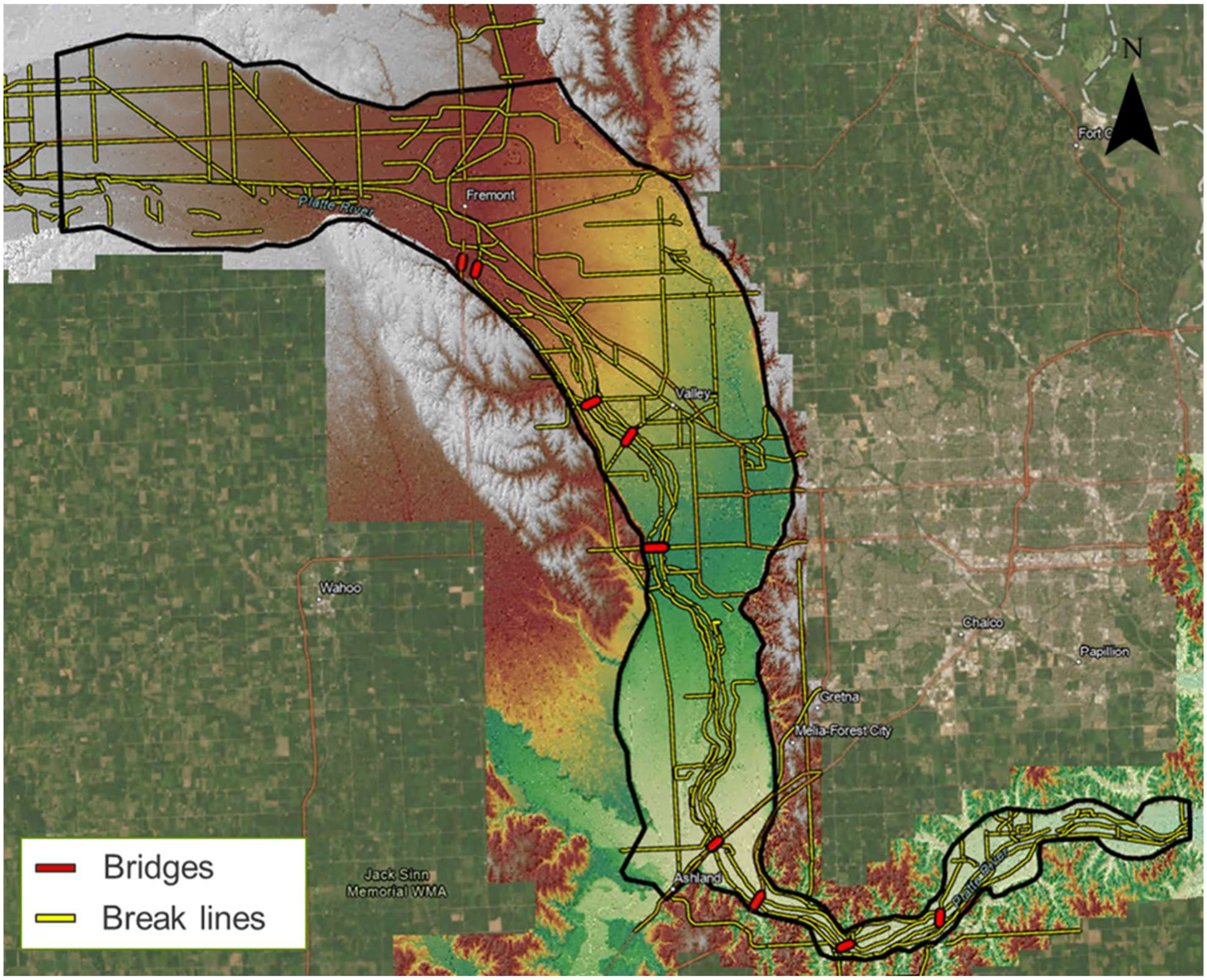

Figure 3: HEC-RAS Model Geometry, Digital Elevation Model, Bridges and Break Lines

2.3 Model Boundary Conditions

Figure 4 shows the boundaries of the HEC-RAS 2D model. Two types of boundary conditions are defined in the model. Boundaries at the upstream end of the Platte River, the Elkhorn River, Logan Creek, and Salt Creek are defined as flow boundaries. Flow is added to the model at these locations in the form of a hydrograph. Note that in most instances the flow boundary is defined as a constant flow hydrograph. The exception is for the evaluation of the 2019 event for the potential lakes and the 100-year event for the dammed lakes The downstream boundary is located approximately 3 miles upstream of Highway 75. The downstream boundary is defined in the model using a rating curve (RC) (flow versus water surface elevation curve). The RC was defined based on calibration.

Figure 4 shows the location of nine sections, Platte 1 through Platte 7, Elkhorn 1 and Salt Creek 1, where model results will be reported to evaluate changes to the water surface elevation (WSE) for the different flow conditions modeled.

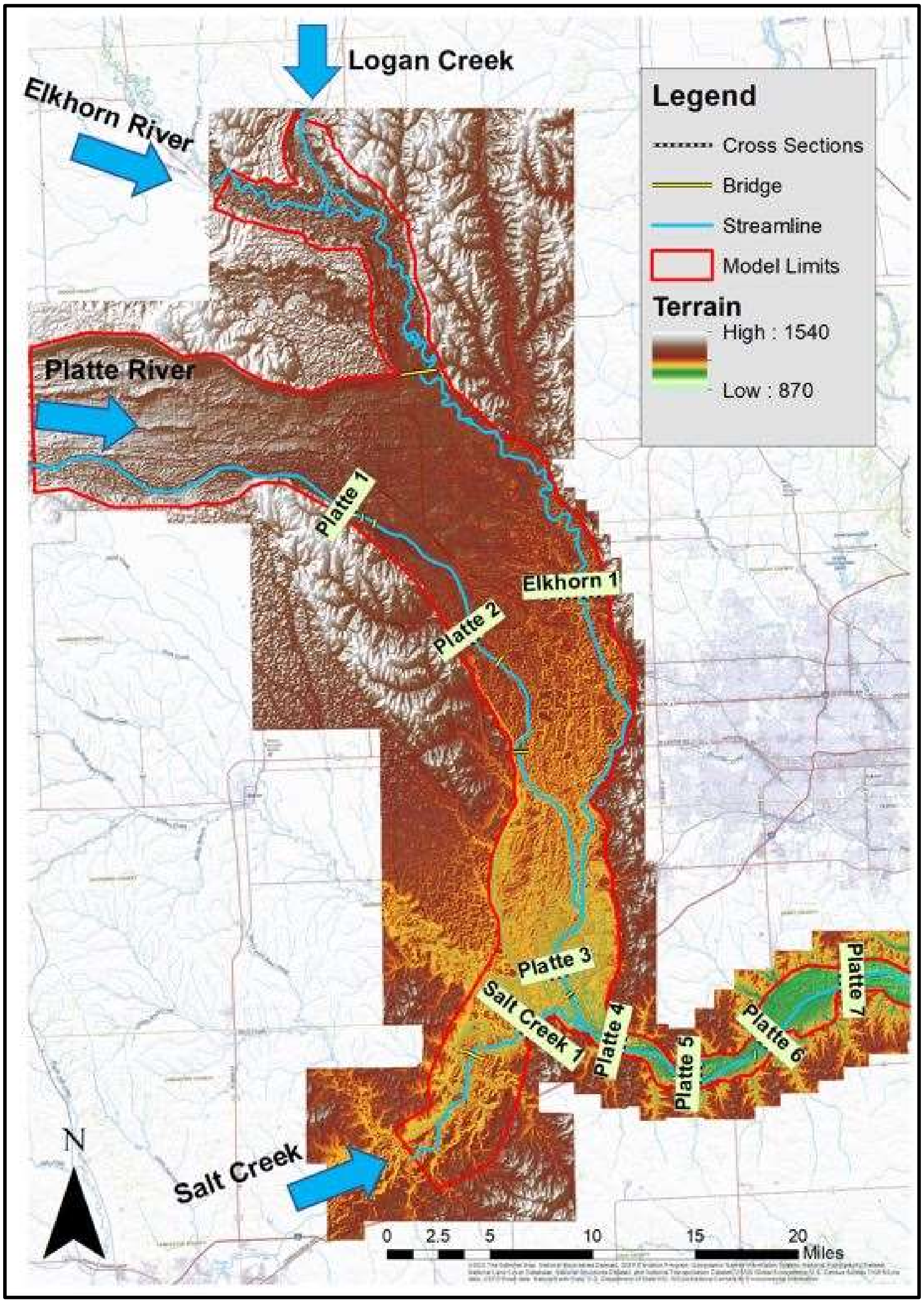

Figure 4: HEC-RAS Model Boundaries

2.4 Model Calibration

USGS streamflow data was used to calibrate the model. Specifically, streamflow and corresponding water levels measurements by the USGS at five stream gage locations were used to develop RCs at those five locations. Figure 5 shows the rating curves developed for the location of the five USGS gages. These RCs allow the anticipated water levels to be determined at a given flow rate in the Platte River at those five locations. The five gages used for calibration are the following below.

- USGS 06796000 Platte River at North Bend, Nebraska
- USGS 06796500 Platte River near Leshara, Nebraska
- USGS 06796550 Platte River near Venice, Nebraska
- USGS 06801000 Platte River near Ashland, Nebraska
- USGS 06805500 Platte River at Louisville, Nebraska

Calibration was conducted using three selected flow rates, 25,000, 160,000, and 200,000 cfs. These flow rates span the range of flows from the 2-year to the 100-year peak flows for the gages considered. Note that the 2-year peak flow at the North Bend gage is 25,100 cfs and the 100-year peak flow at the Louisville gage is 209,600 cfs. An intermediate large flood event of 160,000 cfs was used to have a third point of comparison, this flow rate approximately corresponds to the 100-year peak flow at the Ashland gage, which is 162,800 cfs.

These flow rates were entered in the model as a constant flow hydrograph at the Platte River upstream boundary. Results from the model were compared to the WSEs calculated from the abovementioned RCs. Note that the RCs are based on depths measured above the gage datum, as reported by the USGS. The depth was added to the gage datum to obtain the corresponding WSE. Calibration consisted of changing the Manning's "n" roughness values in the main channel of the Platte River. Table 3 shows the results of the calibration and lists the gage location with stationing in miles from the confluence with the Missouri River, the model Manning's roughness values, the WSEs from the discharge RCs, WSEs from model results, and the corresponding difference at the target river flows. The differences in WSE are mostly within +/- 1 foot and below +/- 2 feet; the results of the calibration were considered acceptable and within the error of the measured data.

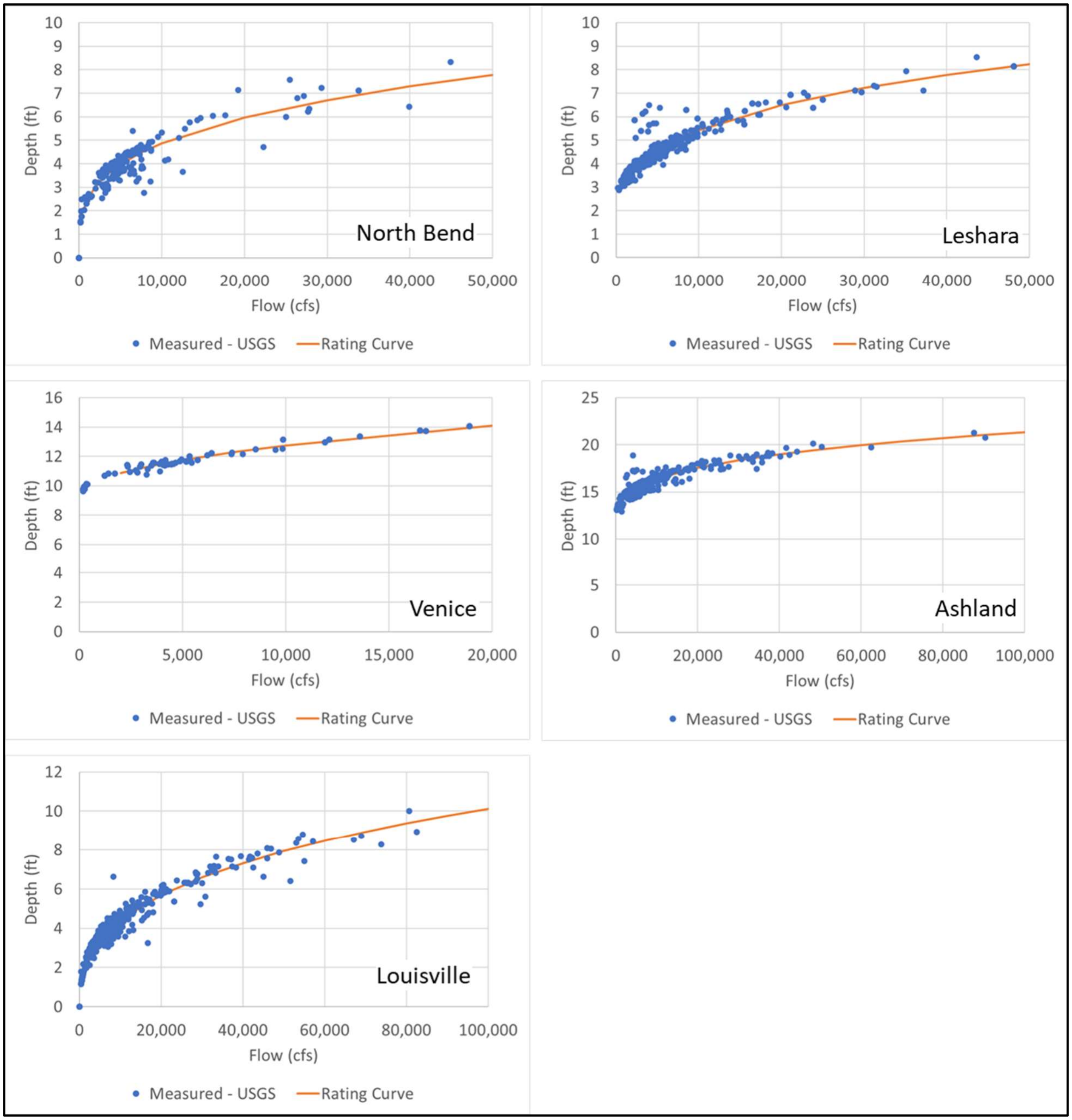

Figure 5: Rating Curves Developed for Five USGS Gage Locations

Table 3: Model Calibration Results

Location	Station (mi)	Manning's Roughness	25,000 cfs			160,000 cfs			200,000 cfs		
			WSE RC (ft)	WSE Model (ft)	Diff. (ft)	WSE RC (ft)	WSE Model (ft)	Diff. (ft)	WSE RC (ft)	WSE Model (ft)	Diff. (ft)
Louisville	16.38	0.017	1013.53	1012.80	-0.73	1019.22	1019.91	0.69	1020.14	1021.30	1.16
Ashland	27.74	0.025	1058.26	1057.80	-0.46	1063.07	1063.33	0.26	1063.82	1064.14	0.32
Venice	38.75	0.050	1104.50	1105.56	1.06	1110.22	1109.31	-0.91	1110.98	1109.47	-1.51
Leshara	48.88	0.020	1151.35	1150.49	-0.86	1155.00	1155.16	0.16	1155.38	1155.39	0.01
North Bend	72.89	0.027	1269.25	1269.08	-0.17	1273.71	1274.39	0.68	1274.41	1275.13	0.72

3. EVALUATION OF LAKE ALTERNATIVES

3.1 Platte River Large Excavated Lake

The layout and general location of the Platte River large excavated lake is shown on Figure 6. The lake extent is limited to 2,100 acres because the area is confined by two WHPAs (northeast and southwest, respectively), the Platte River (southeast), and bluffs (northwest).

It is likely that a berm would need to be constructed around the lake to prevent floodwaters from entering the lake. Effectively, this berm will act as a levee.

Several small tributaries exist towards the northwest. Flow from these tributaries would have to be allowed to enter the lake or routed around the lake. It is anticipated that the crest of the berm will be set at approximately elevation 1,027 feet assuming approximately 2 feet of freeboard above the 500-year level. The berm elevation may be lowered gradually from the upstream side to the downstream end of the lake.

The lake boundary was defined trying to limit increases in WSE during the 100-year flood event to no more than 1.0 foot as required by FEMA floodplain regulatory requirements. Final model results indicate that the maximum increase in WSE during the 100-year flood may be slightly above the target threshold. Based on these results, a reduction in the lake footprint may be needed. Alternatively, a conditional letter of map revision (CLOMR) request from FEMA may be required to implement the lake as currently defined.

Model results are summarized in Table 4 for Platte 5 and Platte 6 sections indicated on Figure 4. The table only shows results for sections were differences in elevation greater than 0.00 foot are observed in the model for at least one event (for example, Platte 5 section had a value greater than 0.00 foot for only the 500 year event). Significant changes in WSE elevation were observed only at the Platte 6 location.

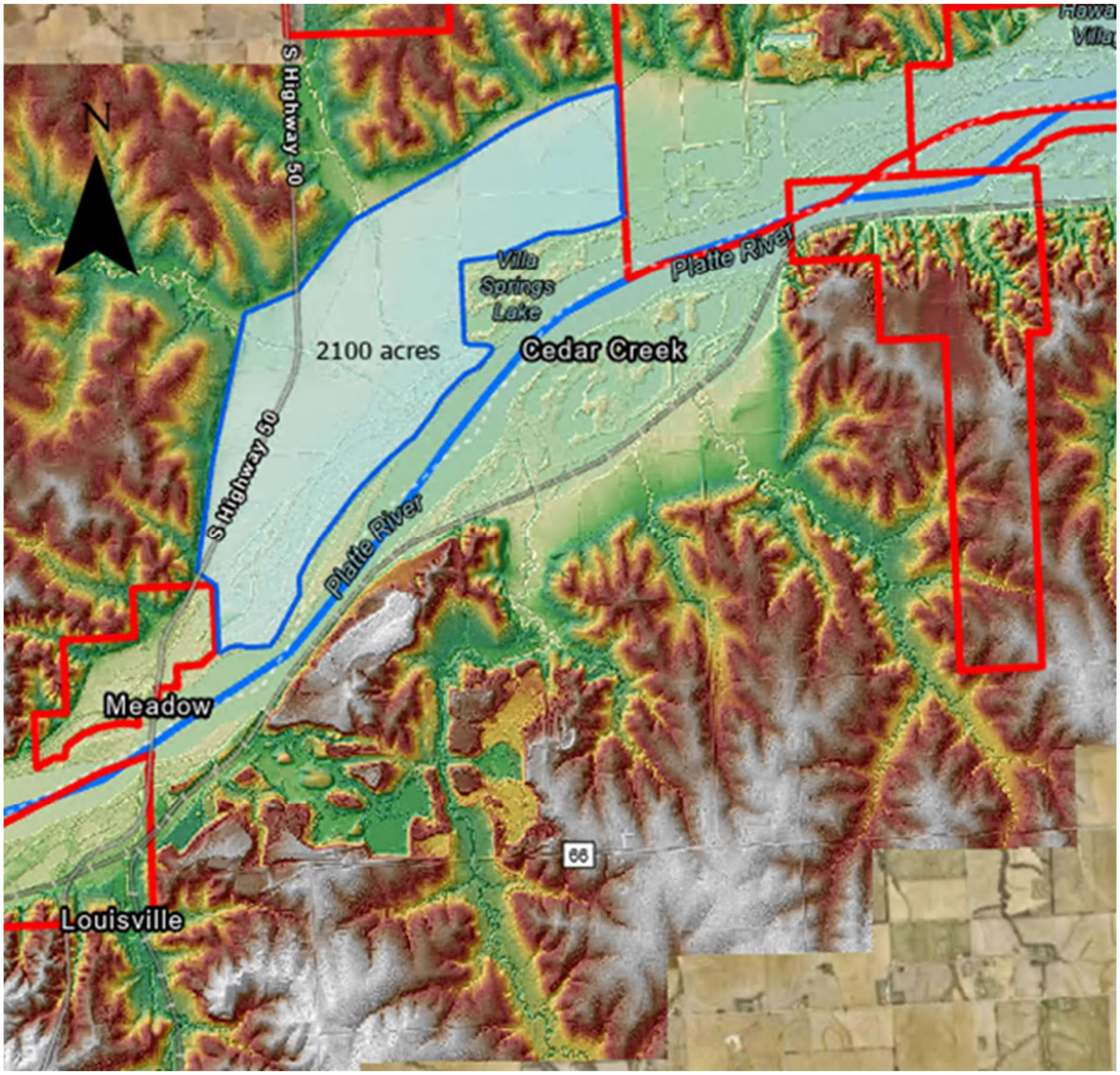

Figure 6: **Platte River Large Excavated Lake (red areas correspond to WHPAs)**

Table 4: Model Results – Platte River

Location	Event	Existing WSE	Proposed WSE	WSE Change
Platte 5 Section (Upstream of Platte River large excavated lake)	2019 Event	1035.40	1035.40	0.00
	2 yr	1030.33	1030.33	0.00
	10 yr	1031.06	1031.06	0.00
	50 yr	1033.73	1033.73	0.00
	100 yr	1034.67	1034.67	0.00
	500 yr	1037.49	1037.52	0.03
Platte 6 Section (Platte River large excavated lake)	2019 Event	1019.80	1021.17	1.37
	2 yr	1014.49	1014.52	0.03
	10 yr	1015.27	1015.82	0.55
	50 yr	1017.97	1018.85	0.88
	100 yr	1019.05	1020.16	1.11
	500 yr	1023.94	1024.52	0.58

3.2 Platte River Small Excavated Lake

The layout and general location of the Platte River small excavated lake is shown on Figure 7. The lake extent is limited to 900 acres because the area is confined by one WHPA (west), the Platte River (southeast), and bluffs (north). It is assumed that this Platte River small excavated lake will be implemented in combination with the Platte River large excavated lake.

It is likely that a berm would need to be constructed around the lake to prevent floodwaters from entering the lake. Effectively, this berm will act as a levee.

Several small tributaries exist towards the north. Flow from these tributaries would have to be allowed to enter the lake or routed around the lake. It is anticipated that the crest of the berm will be set at approximately elevation 1,041 feet assuming approximately 2 feet of freeboard above the 500-year level. The berm elevation may be lowered gradually from the upstream side to the downstream end of the lake.

The lake boundary was defined trying to limit increases in WSE during the 100-year flood event to no more than 1.0 foot as required by FEMA floodplain regulatory requirements. Final model results indicate that the maximum increase in WSE during the 100-year flood may be almost 1 foot above the target threshold. Based on these results, a reduction in the lake footprint may be needed. Alternatively, a CLOMR request from FEMA may be required to implement the lake as currently defined.

Model results are summarized in Table 5 for Platte 4, Platte 5, and Platte 6 sections indicated on Figure 4. The table only shows results for sections were differences in elevation greater than

0.00 foot are observed in the model for at least one event. Significant changes in WSE elevation were observed only at the Platte 4, Platte 5, and Platte 6 sections.

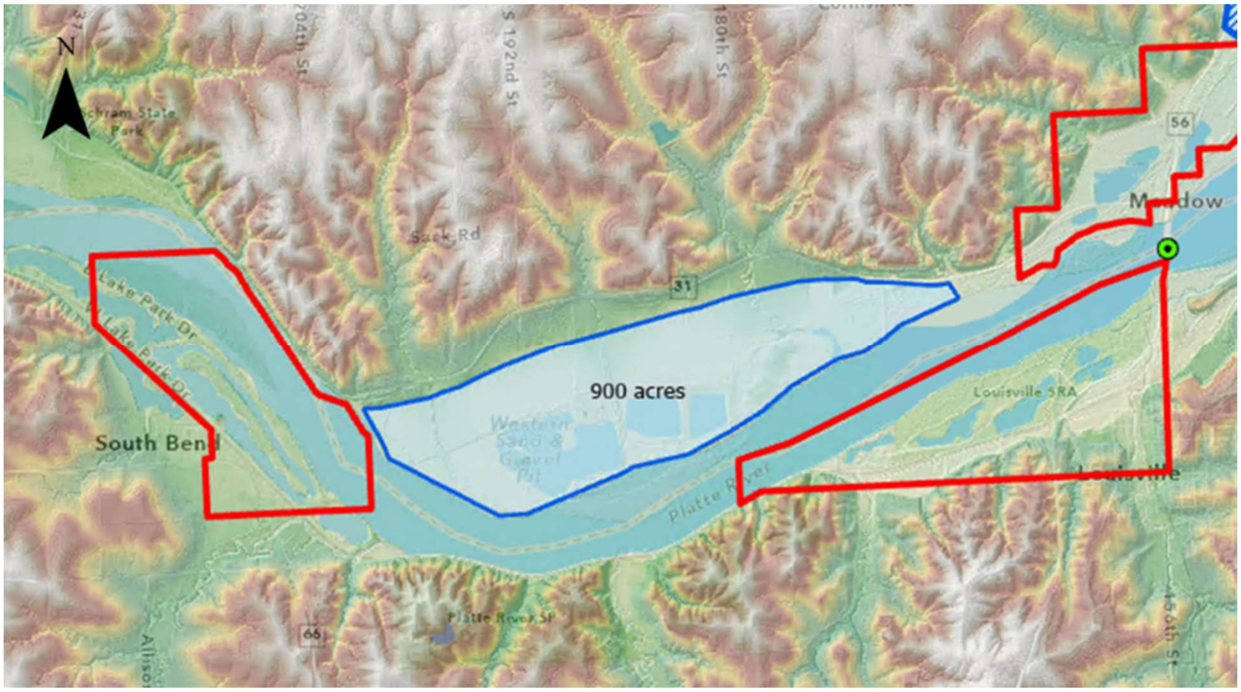

Figure 7: Platte River Small Excavated Lake (red areas correspond to WHPAs)

Table 5: Model Results – Platte River

Location	Event	Existing WSE	Proposed WSE	WSE Change
Platte 4 Section (Upstream of Platte River small excavated lake)	2019 Event	1051.56	1051.56	0.06
	2 yr	1045.98	1045.98	0.00
	10 yr	1046.76	1046.76	0.00
	50 yr	1049.55	1049.57	0.02
	100 yr	1050.68	1050.70	0.03
	500 yr	1053.96	1054.14	0.18
Platte 5 Section (Platte River small excavated lake)	2019 Event	1035.40	1038.59	0.50
	2 yr	1030.33	1030.33	0.00
	10 yr	1030.85	1030.92	0.08
	50 yr	1033.45	1033.79	0.35
	100 yr	1034.67	1034.99	0.51
	500 yr	1037.49	1038.61	1.12
Platte 6 Section (Platte River large excavated lake)	2019 Event	1019.80	1021.18	1.82
	2 yr	1014.49	1014.50	0.01
	10 yr	1014.83	1015.82	0.99
	50 yr	1016.96	1018.85	1.89
	100 yr	1019.05	1020.16	1.89
	500 yr	1023.94	1024.53	0.59

3.3 Salt Creek Dammed Lake Example

The layout and general location of the example Salt Creek dammed lake is shown on Figure 8. The lake normal pool area will be approximately 4,110 acres.

This concept assumes a normal pool at elevation 1,097 feet and a total dam height of approximately 50 feet. The dam length is approximately 5,500 feet. This concept will likely require a spillway length of approximately 4,200 feet.

The embankment height was determined based on the elevation needed to obtain approximately a 4,000 acres water surface at normal pool with the elevation rounded to the nearest foot. Note that to obtain approximately the target acreage, this lake may encroach into the Greenwood WHPA.

This lake will retain natural flows from Salt Creek; therefore, a reduction in water levels is anticipated downstream of the lake. Modeling results indicated that maximum reductions in WSE, as measured at the Salt Creek 1 section indicated on Figure 4, are approximately 0.3 foot and 1.3 feet for the 100-year and the 2019 flood, respectively. In addition, the modeling results also indicated that reduction in WSE is small along the Platte River with maximum reductions of less than 0.1 foot.

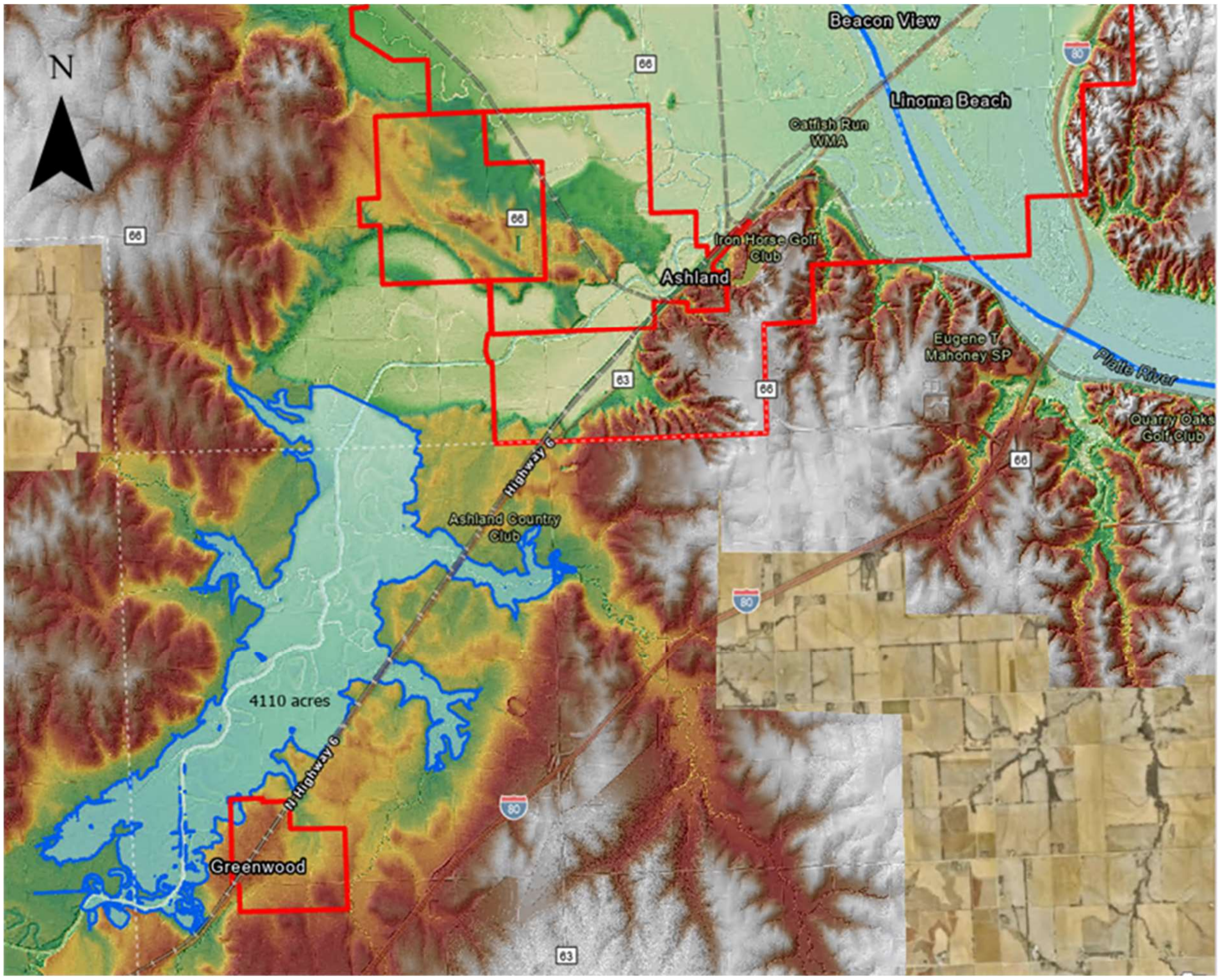

Figure 8: Salt Creek Dammed Lake (red areas correspond to WHPAs)

3.4 Elkhorn River Dammed Lake Example

The layout and general location of the example Elkhorn River dammed lake is show on Figure 9. The lake normal pool area will be approximately 4,120 acres.

This concept assumes a normal pool at elevation 1,196 feet and a total dam height of approximately 36 feet. The dam length is approximately 9,000 feet. This concept will likely require a spillway length of approximately 6,500 feet.

The embankment height was determined based on the elevation needed to obtain approximately 4,000 acres water surface at normal pool with the elevation rounded to the nearest foot.

This lake will retain natural flows from Elkhorn River; therefore, a reduction in water levels is anticipated downstream of the lake. Modeling results indicated that maximum reductions in WSE, as measured at the Elkhorn 1 section indicated on Figure 4, are approximately 0.6 foot for both the 100-year and the 2019 flood. In addition, modeling results also indicated that reduction in WSE is small along the Platte River with maximum reduction of less than 0.01 foot.

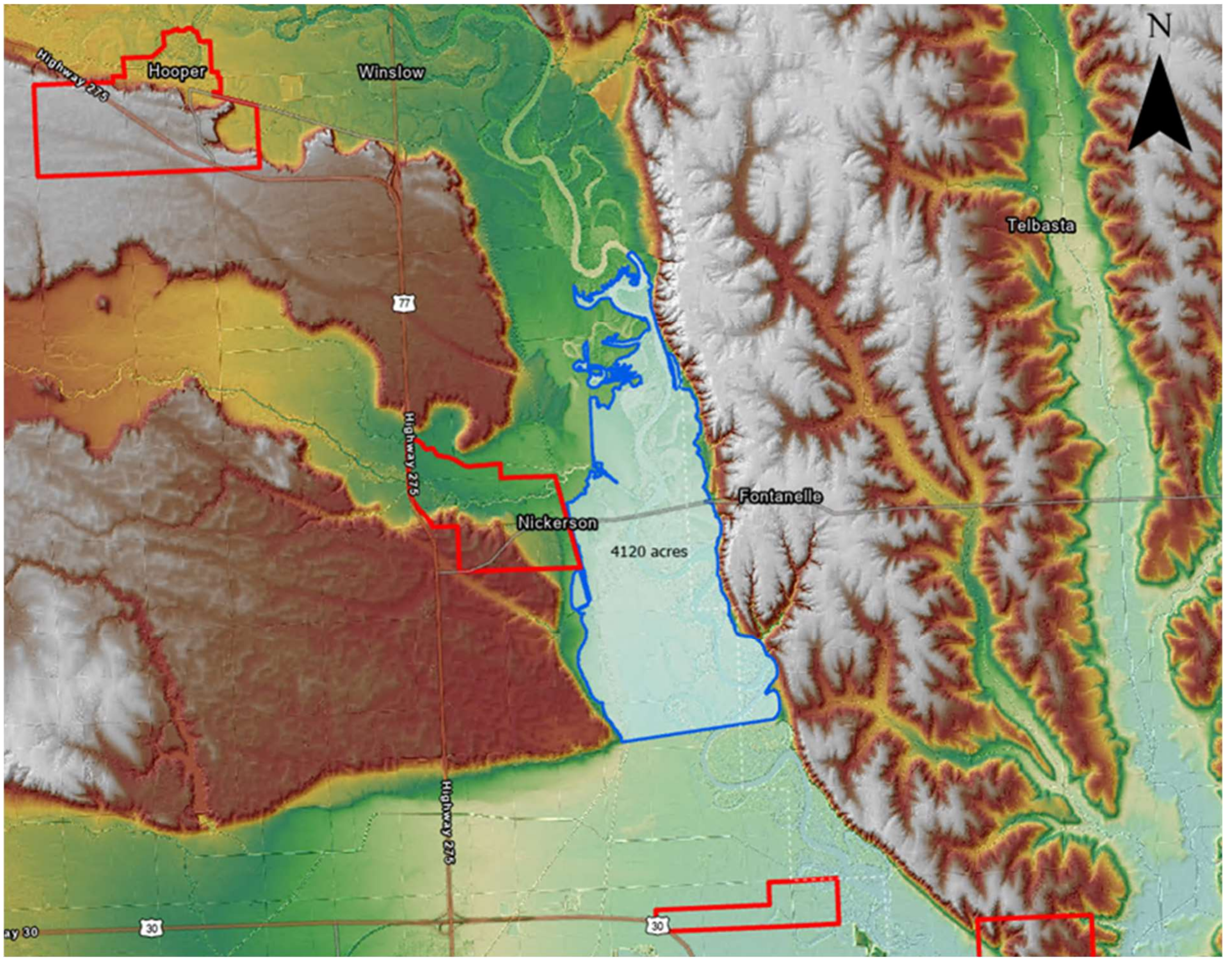

Figure 9: Elkhorn River Dammed Lake (red areas correspond to WHPAs)

4. CONCLUSIONS

Hydraulic modeling of the Platte River, Elkhorn River, and Salt Creek was conducted to evaluate potential impacts of constructing an excavated lake along the Platte River or a dammed lake along the Elkhorn River or Salt Creek.

The limits of the Platte River large excavated lake were defined trying to limit increases in WSE during the 100-year flood event to no more than 1.0 foot as required by FEMA floodplain regulatory requirements. Final model results indicated that the maximum increase in WSE during the 100-year flood may be slightly above the target threshold. These results indicate a reduction in the lake footprint may be needed. Alternatively, a CLOMR request from FEMA may be required to implement the lake as currently defined.

A second smaller Platte River excavated lake, the Platte River small excavated lake, was also considered. The Platte River small excavated lake would have an extent of approximately 900 acres and would be located approximately 1.5 miles upstream from the Platte River large excavated lake. Combined, these two excavated lakes would have a total surface area of approximately 3,000 acres which is closer to the targeted size in the legislation. Results indicated that adding the second lake may result in further increases in WSE above the target threshold of 1.0 foot. The impact of the Platte River small excavated lake is anticipated to be similar to the Platte River large excavated lake and would have to comply with similar environmental and FEMA floodplain regulatory requirements.

The example Salt Creek dammed lake and the example Elkhorn River dammed lake will retain natural flows from the Salt Creek and the Elkhorn River; therefore, a reduction in flood water levels is anticipated downstream of the lakes. Model results indicated that some reduction in flood levels will occur immediately downstream from the lakes but marginal reductions of less than 0.1 foot are anticipated in the Platte River floodplains due to either one of these lakes. The dammed lakes will result in an increase in WSEs at the lake. A CLOMR request from FEMA will be required for the dammed lakes.

Results from this analysis indicated that implementation of these lakes is possible. However, further studies will be required to assess the feasibility of these lakes. From a surface water flood modeling perspective and accounting for impacts to the regulatory floodplain, further modeling will be needed to refine the footprint of the Platte River large excavated lake and Platte River small excavated lake. Refinement of hydraulic modeling will also be needed for the example Salt Creek dammed lake and example Elkhorn River dammed lake. It is recommended to conduct a conceptual design of the dam embankment and spillway to refine potential hydrologic and hydraulic impacts. It is also recommended to conduct an alternative analysis that includes cost, benefits, impacts to the floodplain, and a comprehensive determination of environmental and dam safety regulatory requirements.

No fatal flaws were identified based on the surface water flood modeling for Platte River large excavated lake, Platte River small excavated lake, Elkhorn River dammed lake, and Salt Creek dammed lake in relation to LWS' wellfield and MUD's wellfields at Platte West and Platte South. However, challenges and potential adverse impacts were identified for each lake requiring additional, more-detailed analyses to identify whether the potential impacts can be mitigated. For example, remediation may be required to lower increased flood elevation caused by a berm. Therefore, it is recommended that full feasibility studies of the lakes be performed.

APPENDIX C: WATER BALANCE MODELING REPORT

LB 1023 (JEDI) IMPACT EVALUATION FOR CITY OF LINCOLN WATER SYSTEM AND METROPOLITAN UTILITIES DISTRICT: WATER BALANCE MODELING REPORT

CITY PROJECT NO. 702309
OLSSON PROJECT NO. 021-01559
BLACK & VEATCH PROJECT NO. 413017

PREPARED FOR

LINCOLN
Transportation and Utilities

METROPOLITAN UTILITIES DISTRICT

CITY OF LINCOLN WATER SYSTEM
METROPOLITAN UTILITIES DISTRICT
18 OCTOBER 2024

PROFESSIONAL CIVIL ENGINEER
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TEL: 913.458.2000
www.bv.com

Project Name: LB 1023 (JEDI) Impact Evaluation for City of Lincoln Water System and Metropolitan Utilities District
Project Address/Location: Cass, Dodge, Douglas, Sarpy, and Saunders Counties

ACRONYMS AND ABBREVIATIONS

ac-ft	Acre-Feet
cfs	Cubic Feet per Second
FAO	Food and Agriculture Organization
ft	Feet
ft^2	Square Feet
ft^3	Cubic Feet
ft/yr	Feet per year
HPRCC	High Plains Regional Climate Center
in./d	Inches per Day
in./yr	Inches per Year
JEDI	Jobs and Economic Development Initiative
LWS	Lincoln Water System
mi^2	Square Mile
mm/yr	Millimeter per year
NE	Nebraska
NDED	Nebraska Department of Economic Development
NeDNR	Nebraska Department of Natural Resources
rad	Radians
sq mi	Square Mile
STAR WARS	Statewide Tourism and Recreational Water Access and Resources Sustainability
USGS	United States Geological Survey
WY	Water Year

TABLE OF CONTENTS

Executive Summary **S-1**

1. Background **1**

2. Data **2**

2.1 Elevation **2**

2.2 Flow **11**

2.3 Evapotranspiration **24**

2.4 Land Use **30**

2.5 Irrigated Lands **32**

3. Modeling Approach **32**

4. Results **34**

4.1 Platte River Large Excavated Lake **34**

4.2 Platte River Large Excavated Lake and Platte River Small Excavated Lake **34**

4.3 Elkhorn River Dammed Lake Example **34**

4.3.1 Repeated WY2006 Flows 34

4.3.2 WY2001-2003 Flows 35

4.3.3 1994-2023 Flows 35

4.4 Salt Creek Dammed Lake Example **42**

4.4.1 Repeated WY2006 Flows 42

4.4.2 WY2001-2003 Flows 42

4.4.3 1994-2023 Flows 42

5. Conclusions **49**

6. References **52**

LIST OF FIGURES

Figure 1: Potential Lake Alternatives ... 3
Figure 2: Example Illustration of Mass Balance Components for a Water Balance Analysis ... 4
Figure 3: Elevation Data within the Elkhorn River Dammed Lake ... 5
Figure 4: Elevation Data within the Salt Creek Dammed Lake ... 6
Figure 5: Relationship between Volume and Elevation for the Elkhorn River Dammed Lake ... 7
Figure 6: Relationship between Volume and Area for the Elkhorn River Dammed Lake ... 8
Figure 7: Relationship between Volume and Elevation for the Salt Creek Dammed Lake ... 9
Figure 8: Relationship between Volume and Area for the Salt Creek Dammed Lake ... 10
Figure 9: Delineated Watershed for the USGS Gages and Drainage Area to the Elkhorn River Dammed Lake ... 12
Figure 10: Delineated Watersheds for the USGS Gages and Drainage Area to the Salt Creek Dammed Lake ... 13
Figure 11: Measured Daily Flow at USGS 06800500 Elkhorn River at Waterloo ... 14
Figure 12: Measured Daily Flow at USGS 06803555 Salt Creek at Greenwood ... 15
Figure 13: Scaled Daily Flows for Potential Elkhorn River Dammed Lake ... 16
Figure 14: Scaled Daily Flows for Dammed Salt Creek Lake ... 17
Figure 15: Scaled Annual Volume for Elkhorn River Dammed Lake ... 18
Figure 16: Scaled Annual Volume for Salt Creek Lake Dammed Lake ... 19
Figure 17: Annual Volume WY1994-2023 for the Elkhorn River Dammed Lake Inflows ... 22
Figure 18: Annual Volume WY1970-2023 for the Salt Creek Dammed Lake Inflows ... 23
Figure 19: Measured Evapotranspiration at Station Memphis 5N for Alfalfa ... 25
Figure 20: Open Water Evaporation as Calculated from the Alfalfa Evapotranspiration at Station Memphis 5N ... 26
Figure 21: Daily Open Water Evaporation Calculated with the Hargreaves and Samani Approach ... 28
Figure 22: Inflow and Outflow for the Elkhorn River Dammed Lake during the Repeated WY2006 Conditions ... 36
Figure 23: Water Surface Elevation for the Elkhorn River Dammed Lake during the Repeated WY2006 Conditions ... 37
Figure 24: Inflow and Outflow for the Elkhorn River Dammed Lake during the WY2001-2003 Conditions ... 38

Figure 25: Water Surface Elevation with Inflow and Outflow for the Elkhorn River Dammed Lake for WY2001-2003 39
Figure 26: Inflow and Outflow for the Elkhorn River Dammed Lake during the WY1994-2023 Conditions 40
Figure 27: Water Surface Elevation for the Elkhorn River Dammed Lake during the WY1994-2023 Conditions 41
Figure 28: Inflow and Outflow for the Salt Creek Dammed Lake during the Repeated WY2006 Conditions 43
Figure 29: Water Surface Elevation for the Salt Creek Dammed Lake during the Repeated WY2006 Conditions 44
Figure 30: Inflow and Outflow for the Salt Creek Dammed Lake during the WY2001-2003 Conditions 45
Figure 31: Water Surface Elevation for the Salt Creek Dammed Lake during the Repeated WY2001-2003 Conditions 46
Figure 32: Inflow and Outflow for the Salt Creek Dammed Lake during the WY1994-2023 Conditions 47
Figure 33: Water Surface Elevation for the Salt Creek Dammed Lake during the Repeated WY1994-2023 Conditions 48
Figure 34: Comparison of the Salt Creek Dammed Lake and Elkhorn River Dammed Lake Volume and Depth....51

LIST OF TABLES

Table 1: Drainage Area for the Two Gages on Elkhorn River and Salt Creek 11
Table 2: Drainage Area for the Potential Dammed Lakes 11
Table 3: Annual Volume (Water Year) Ranking for Scaled Elkhorn River and Salt Creek Flows 20
Table 4: Crop Reference Evaporation Coefficients 24
Table 5: Atmospheric Water Loss (in./yr) Calculated via the Penman and Hargreaves Approaches 29
Table 6: USDA CropScape Land Use (2023) Area (acres) within the Potential Lake Boundaries 30
Table 7: Atmospheric Water Loss (in/yr) within each Potential Lake Boundary for the 2023 Land Use and Open Water 31
Table 8: Estimated Irrigated Land (2005) Area (acres) in the Boundaries of the Potential Lakes 32
Table 9: Comparison of Flows from the Elkhorn River and Salt Creek to the Platte River With and Without the Dammed Lakes 50

EXECUTIVE SUMMARY

In 2021 and 2022, the Nebraska legislature enacted LB406 and LB1023, respectively, which first established the Statewide Tourism and Recreational Water Access and Resources Sustainability (STAR WARS) special committee, and then the Lake Development Act which was codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (*Neb. Rev. Stat.* §61-401 to 61-404). In these pieces of legislation, the unicameral recognized the importance – in the wake of historic flooding in 2019 and the COVID-19 pandemic – for both flood control and major recreational opportunities in the state to attract and retain an increasingly remote workforce. The STAR WARS committee envisioned, in the lower Platte River corridor, a lake that would rival Iowa's Lake Okoboji as a tourist destination and hub for public-private partnerships to develop lakeside communities, a community town center, and a major resort. As outlined in the STAR WARS committee's report, a lake location northeast of the city of Ashland, Nebraska was contemplated and this informed the committee's recommendation that further analysis be conducted to inform viable locations for a lake of at least 3,600 acres, located in or near Sarpy County, and adjacent to – but not impounding – the Platte River.

Recognizing the potential for impacts to public water system wellfields, the legislature also appropriated funds to be administered through the Nebraska Department of Natural Resources (NeDNR) for further study on possible lake sites. The City of Lincoln Water System (LWS) already had its Water 2.0 project – investigating possibilities for additional source(s) of drinking water – underway with Black & Veatch and Olsson, and recognized that these consultants have the necessary expertise regarding the water system as well as expertise in the types of technical analysis needed for potential lake sites. Thus, LWS amended its Water 2.0 contract to include this study and entered into a memorandum of understanding with Omaha's Metropolitan Utilities District (MUD) to allow for MUD's wellfields and concerns to also be considered.

A water balance analysis was conducted to estimate evaporation from the potential excavated flood plain lakes and dammed lakes, and the impacts of the lakes on changes in evapotranspiration within their footprints and evaporation from the river under low-flow conditions. The lake was assumed to be for recreational purposes.

The water balance for the Platte River large excavated lake, downstream of Louisville, showed a reduced loss of water to the atmosphere from groundwater, as the evapotranspiration conditions in the area currently (i.e., crops) are greater than would be the evaporative loss from an open water body. In other words, the Platte River large excavated lake would marginally increase the amount of groundwater retained in the local aquifer as compared to present conditions. Additionally, over half of the land within the footprint of the lakes as modeled and analyzed is assumed to be irrigated; so, conversion of these acres to permanent pool from irrigated row crops would reduce groundwater demand in the area.

After reviewing the findings of the Platte River large excavated lake evaluation, the Nebraska Department of Economic Development (NDED) asked whether a smaller Platte River lake could be built in conjunction with the larger Platte River lake. As requested, a two excavated lakes option was also analyzed along the Platte River. This option consisted of both the Platte River large excavated lake (approximately 2,100 acres) and the Platte River small excavated lake (approximately 900 acres). Combined, the two excavated lakes would have a total surface area of approximately 3,000 acres which is closer to the targeted size in the legislation. The inclusion of the Platte River small excavated lake produced similar results to the large excavated lake and would need to address similar elements and considerations.

While a dammed lake was not necessarily envisioned by the legislature in LB1023, NeDNR requested that these areas also be considered in this study, as examples of sites chosen to examine initial feasibility, with the possibility that similar sites could be considered in the future. For the two example dammed lake locations examined, the Salt Creek dammed lake (between Greenwood and Ashland) would drain a much smaller land area compared to the Elkhorn River dammed lake (near Nickerson) and would thus be more influenced by low-flow conditions. As such, the relative impact of evaporative and groundwater losses would be less significant for the Elkhorn River dammed lake. Results indicated that under the driest modeled years, the Salt Creek dammed lake would result in passing approximately 92.5% of the upstream volume while Elkhorn River dammed lake would pass approximately 98.1% of the volume. Note that daily flows would be highly controlled by lake operation rules and requirements to maintain minimum environmental instream flows. The minimum flow estimates controlled the downstream flows and the impacts on hydrology, geomorphology, biology, water quality, temperature and connectivity will need to be further evaluated under full feasibility studies.

This water balance provided an initial assessment of the viability of the potential lake locations along the Platte River, Elkhorn River and Salt Creek. The operation of the recreational lake was not defined in this analysis. Because the lake is for recreational purposes, releases have not been assumed to be made for augmenting flows in the Platte River. A more detailed analysis of the water balance needs to be conducted before these lake locations can be fully evaluated, including lake operation and augmenting of downstream flow requirements. A more detailed hydrologic study with the lake inflows routed through the lakes and downstream via the spillway or low flow diversions should be conducted. The analysis was very sensitive to the low flow instream flow requirements and, thus, a detailed analysis of those instream flow requirements needs to be conducted. In addition, additional analysis and modeling will be required to determine the appropriate minimum flows, including any potential impacts on the wellfields or existing instream flow rights. The groundwater interactions should be more explicitly included, especially the Platte River large excavated lake and Platte River small excavated lake which are heavily reliant on groundwater interactions.

No fatal flaws were identified based on the water balance modeling for Platte River large excavated lake, Platte River small excavated lake, Elkhorn River dammed lake, and Salt Creek dammed lake in relation to LWS' wellfield and MUD's wellfields at Platte West and Platte South. For the excavated lakes, no advisory impacts were identified. If a dammed lake is pursued, further evaluation of releases needs to be conducted to minimize downstream impact. Therefore, it is recommended that full feasibility studies of the lakes be performed.

1. BACKGROUND

In 2021 and 2022, the Nebraska legislature enacted LB406 and LB1023, respectively, which first established the Statewide Tourism and Recreational Water Access and Resources Sustainability (STAR WARS) special committee, and then the Lake Development Act which was codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (*Neb. Rev. Stat.* §61-401 to 61-404). In these pieces of legislation, the unicameral recognized the importance – in the wake of historic flooding in 2019 and the COVID-19 pandemic – for both flood control and major recreational opportunities in the state to attract and retain an increasingly remote workforce. The STAR WARS committee envisioned, in the lower Platte River corridor, a lake that would rival Iowa's Lake Okoboji as a tourist destination and hub for public-private partnerships to develop lakeside communities, a community town center, and a major resort. As outlined in the STAR WARS committee's report, a lake location northeast of the city of Ashland, Nebraska was contemplated and this informed the committee's recommendation that further analysis be conducted to inform viable locations for a lake of at least 3,600 acres, located in or near Sarpy County, and adjacent to – but not impounding – the Platte River.

The purpose of the hydrologic water balance was to estimate the impact of the lakes off the Platte River, Elkhorn River and Salt Creek locations (refer to Figure 1) on changes in evapotranspiration, evaporation from the lake, and river flow under low flow conditions. Figure 2 provides an illustration of the mass balance for this water balance analysis. The approach outlined below compiles relevant available data to characterize the environmental conditions (flow, evapotranspiration, etc.), develops a conceptual model of the water budget of each lake, and then evaluates the water levels and flows. The purpose of the analysis was to estimate evaporation from the potential lakes, and the impacts of the lakes on changes in evapotranspiration within their footprints and evaporation from the river under low-flow conditions.

The following two types of lakes were considered for this study. Figure 1 shows the location of these potential lakes.

- The first type consists of excavating natural ground along the floodplain until bedrock is reached. This first type is possible along the Platte River because groundwater is relatively shallow and excavation to bedrock results in exposing the groundwater. The excavated lakes around the Platte River are near Louisville, Nebraska, which are the Platte River large excavated lake, downstream of Louisville, and the Platte River small excavated lake, upstream of Louisville. After reviewing the findings of the Platte River large excavated lake evaluation, the Nebraska Department of Economic Development (NDED) asked whether a smaller Platte River lake could be built in conjunction with the larger Platte River lake. As requested, a two excavated lakes option was also analyzed along the Platte River. Combined, the two excavated lakes would have a total surface area of approximately 3,000 acres which is closer to the targeted size in the legislation.

- The second type is a traditional dammed lake; that is, a dam is constructed across the floodplain to impound water. For the example dammed type lakes examined, the potential lakes are the Elkhorn River dammed lake, near Nickerson, and the Salt Creek dammed lake, between Greenwood and Ashland. While a dammed lake was not necessarily envisioned by the legislature in LB1023, the Nebraska Department of Natural Resources (NeDNR) requested that these areas also be considered in this study, as examples of sites chosen to examine initial feasibility, with the possibility that similar sites could be considered in the future.

2. DATA

2.1 Elevation

Elevation data for the Elkhorn River dammed lake, near Nickerson, and Salt Creek dammed lake, between Greenwood and Ashland, were obtained from the United States Geological Survey (USGS) National Map Viewer (USGS, 2024a). High resolution elevation data at a 1-meter resolution was downloaded to obtain within the lake boundaries (refer to Figure 3 and Figure 4).

A python script was developed to relate lake volume with elevation and area. The python script sliced the elevation raster at 1-foot intervals and calculated the volume below that elevation and the surface area at that elevation. Figure 5 through Figure 8 show the relationships between volume, area, and elevation for the two dammed lakes. Note that if additional excavation is performed, those relationships will change and additional storage will be available in each dammed lake.

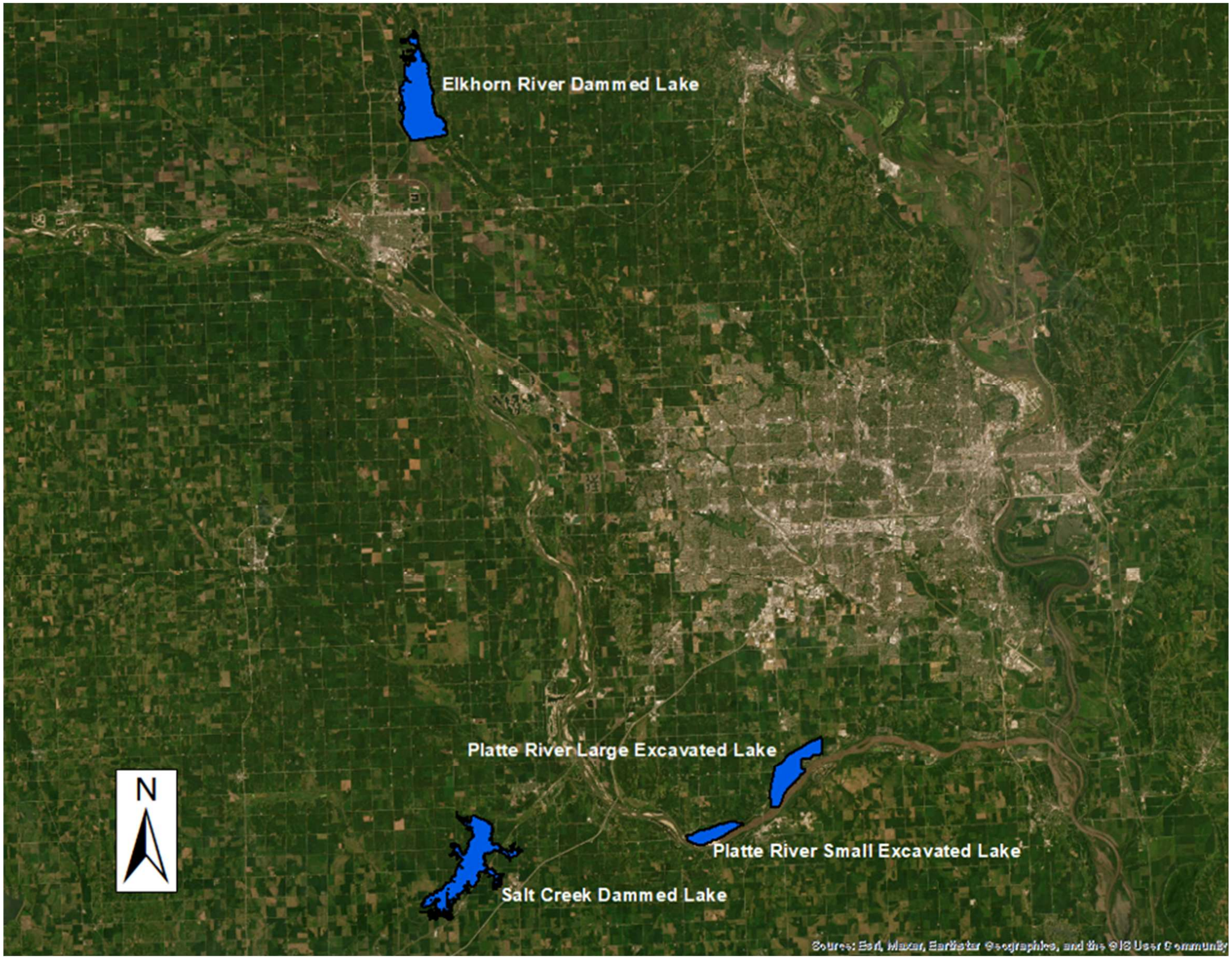

Figure 1: Potential Lake Alternatives

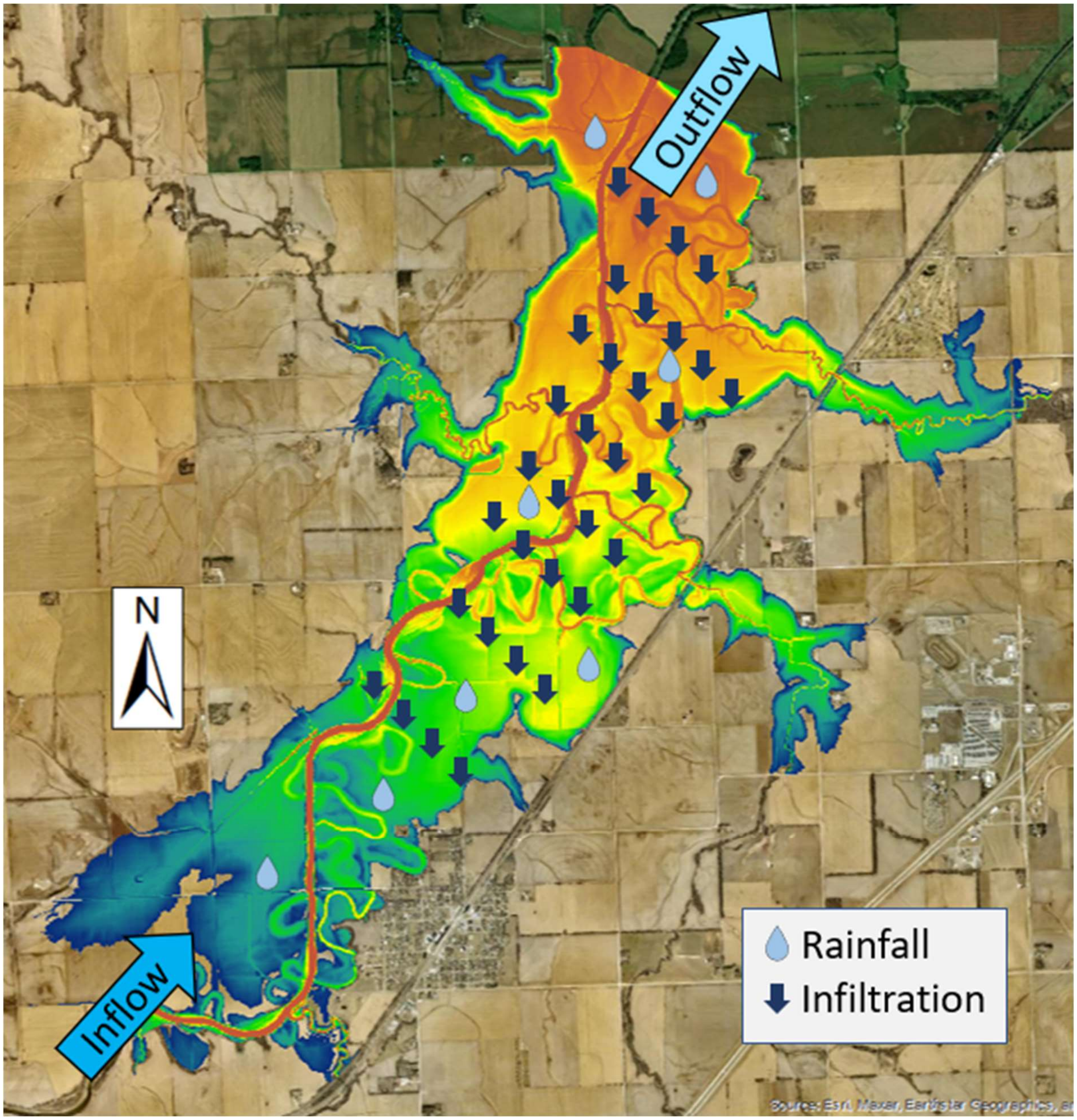

Figure 2: Example Illustration of Mass Balance Components for a Water Balance Analysis

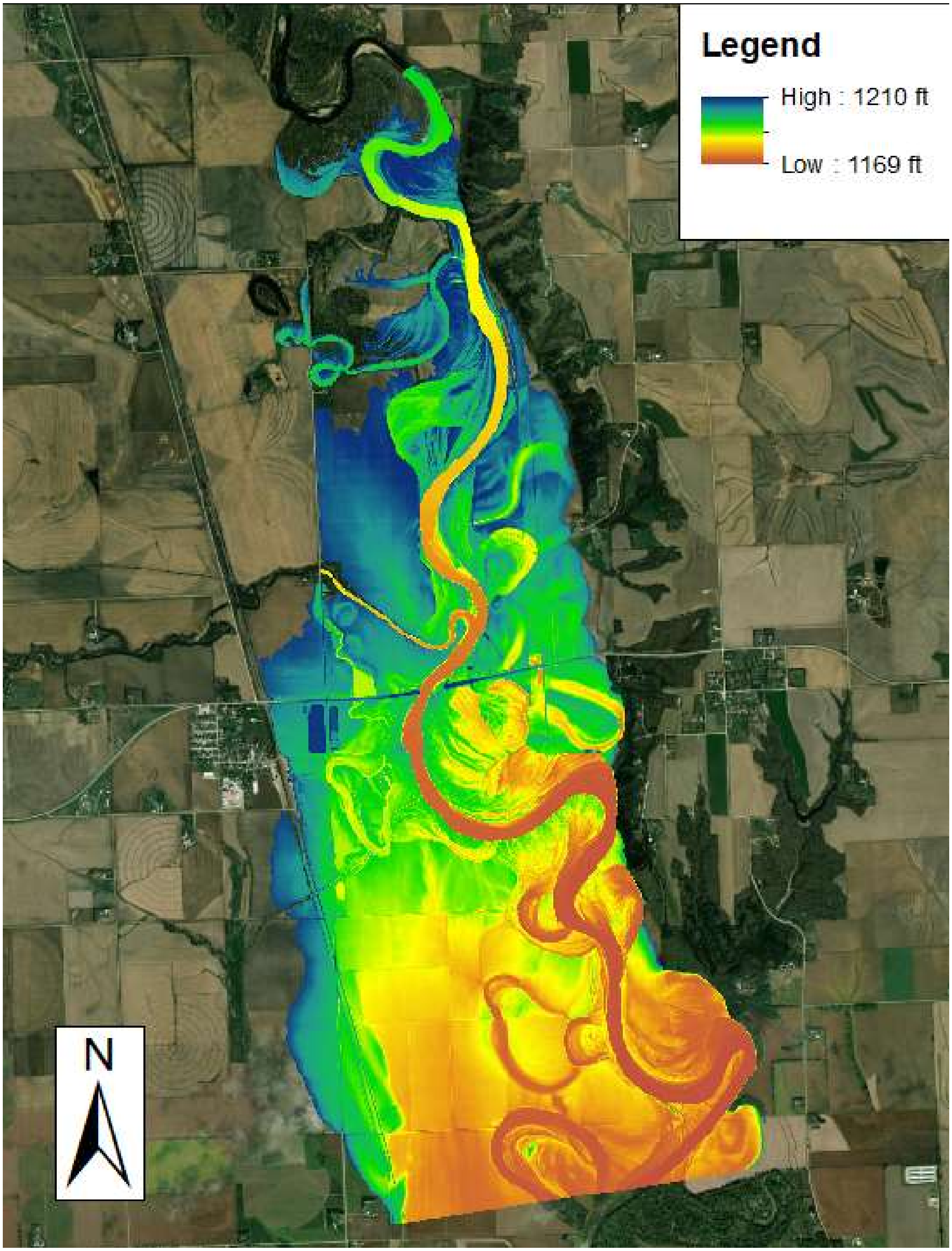

Figure 3: Elevation Data within the Elkhorn River Dammed Lake

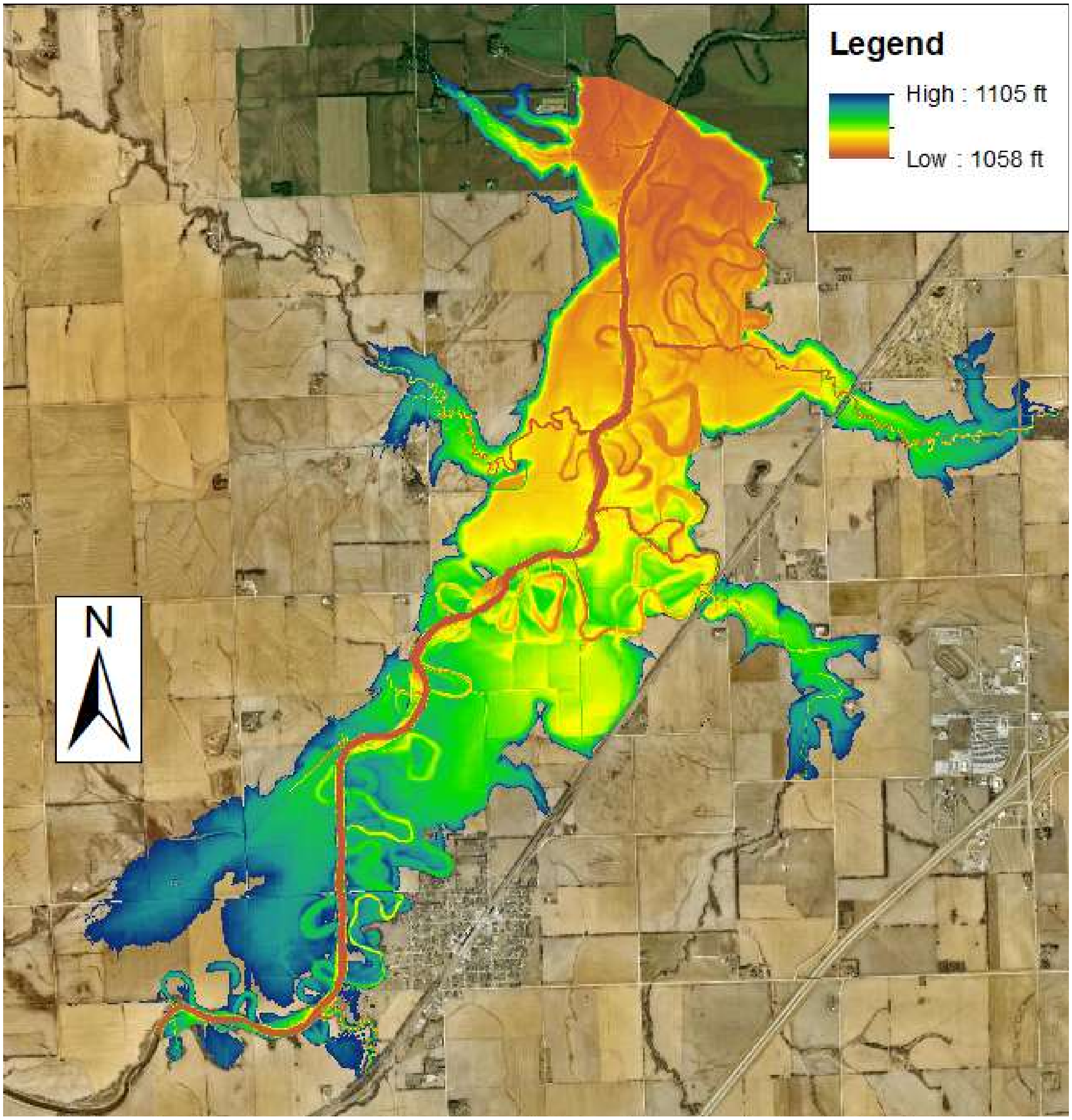

Figure 4: Elevation Data within the Salt Creek Dammed Lake

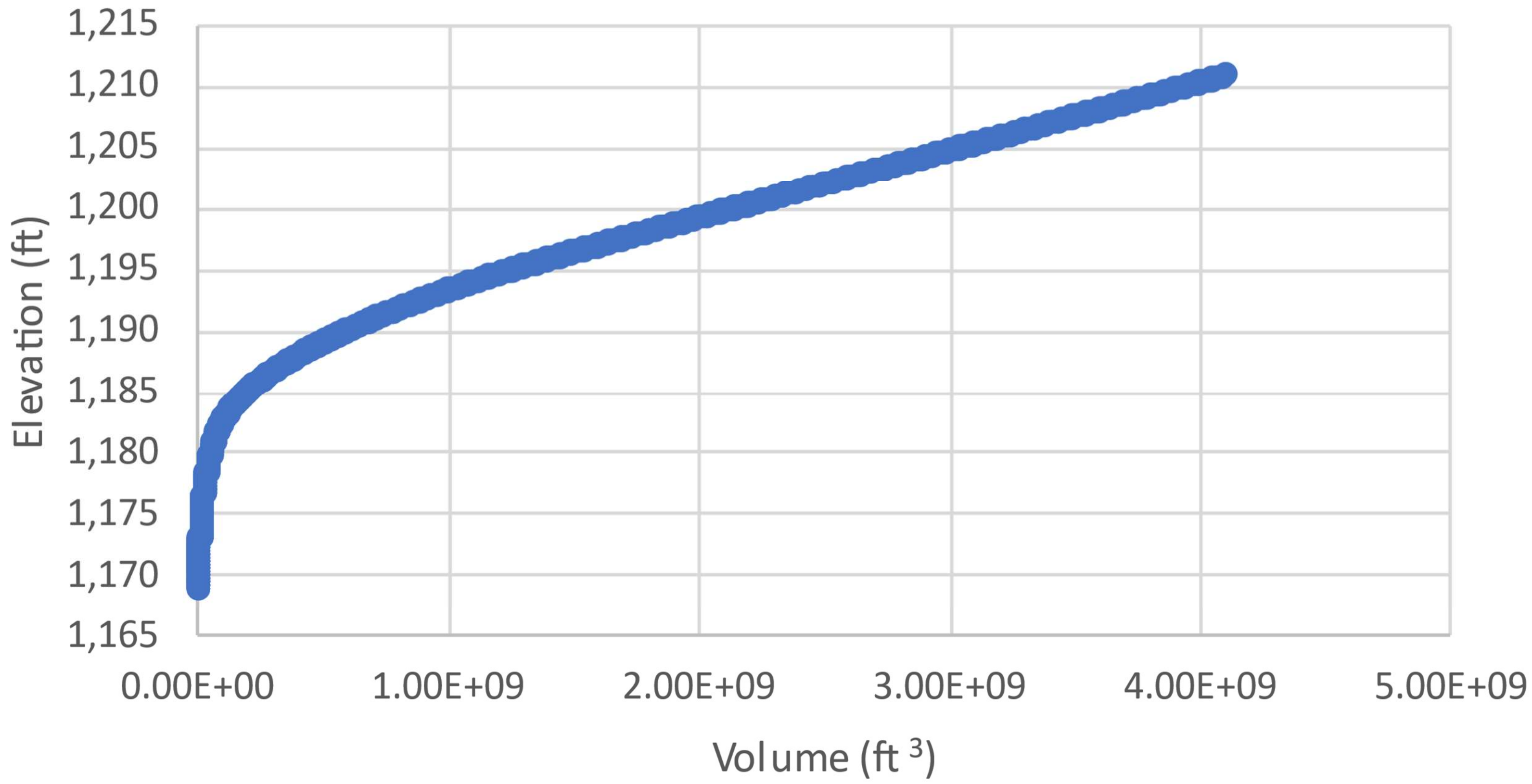

Figure 5: **Relationship between Volume and Elevation for the Elkhorn River Dammed Lake**

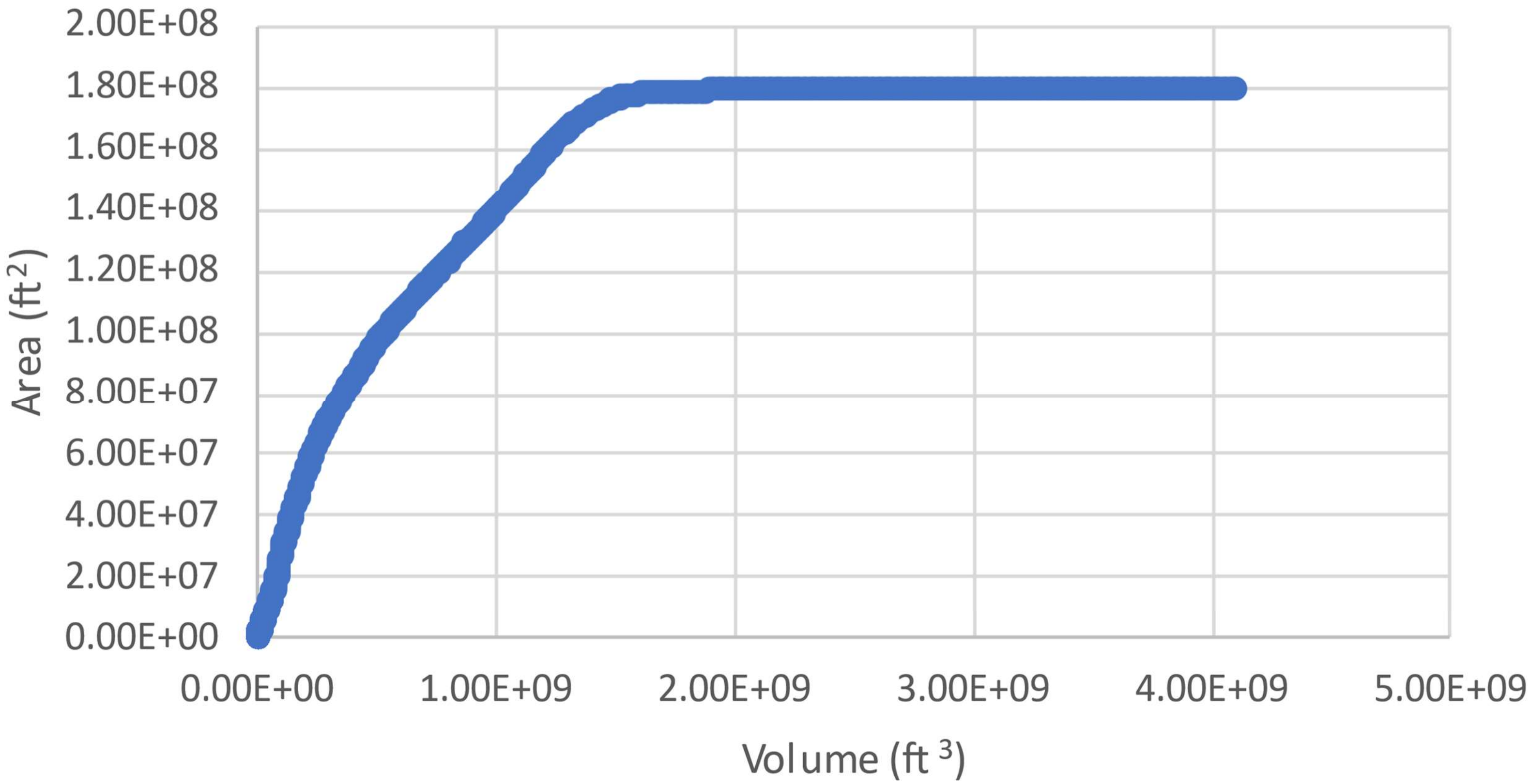

Figure 6: **Relationship between Volume and Area for the Elkhorn River Dammed Lake**

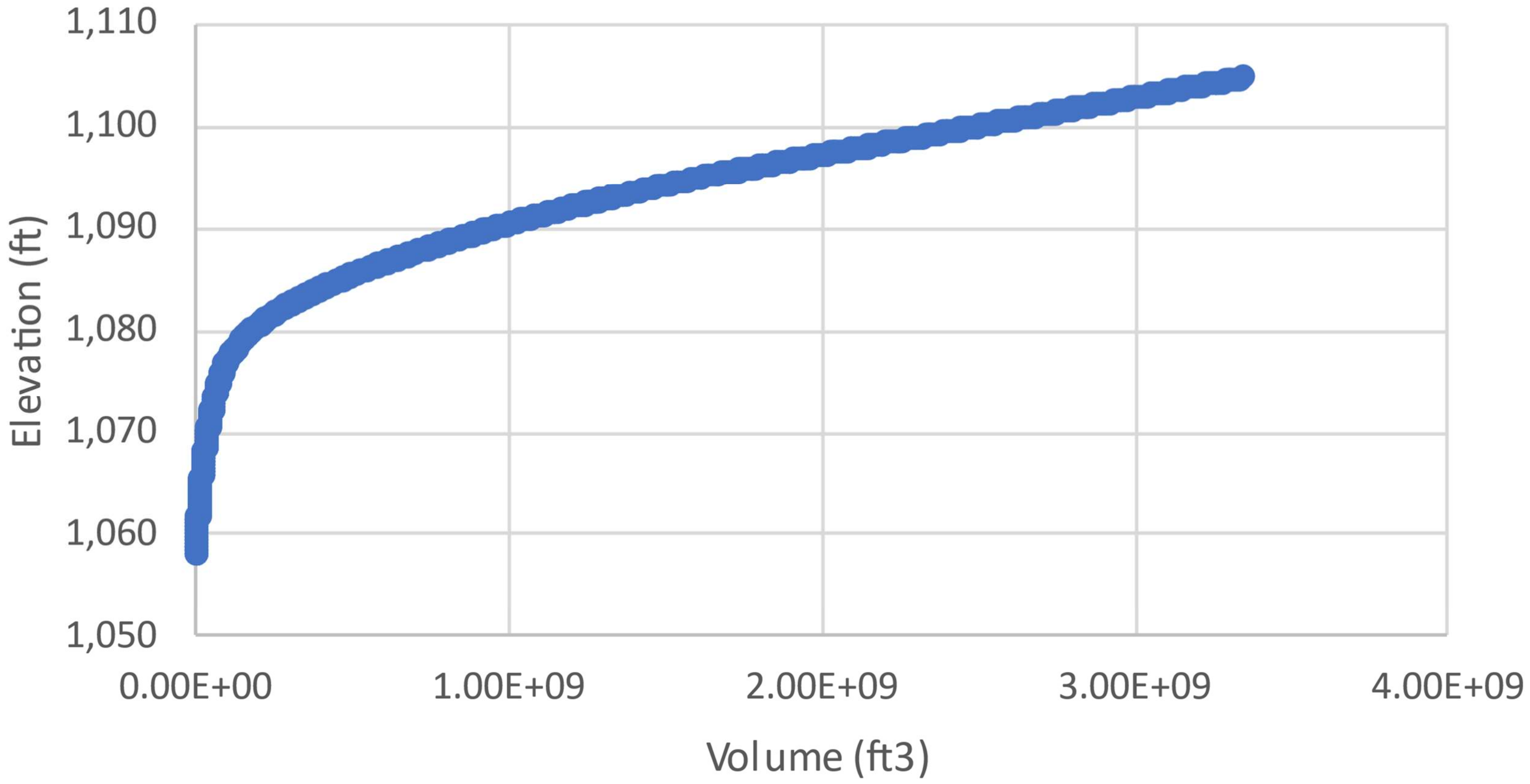

Figure 7: Relationship between Volume and Elevation for the Salt Creek Dammed Lake

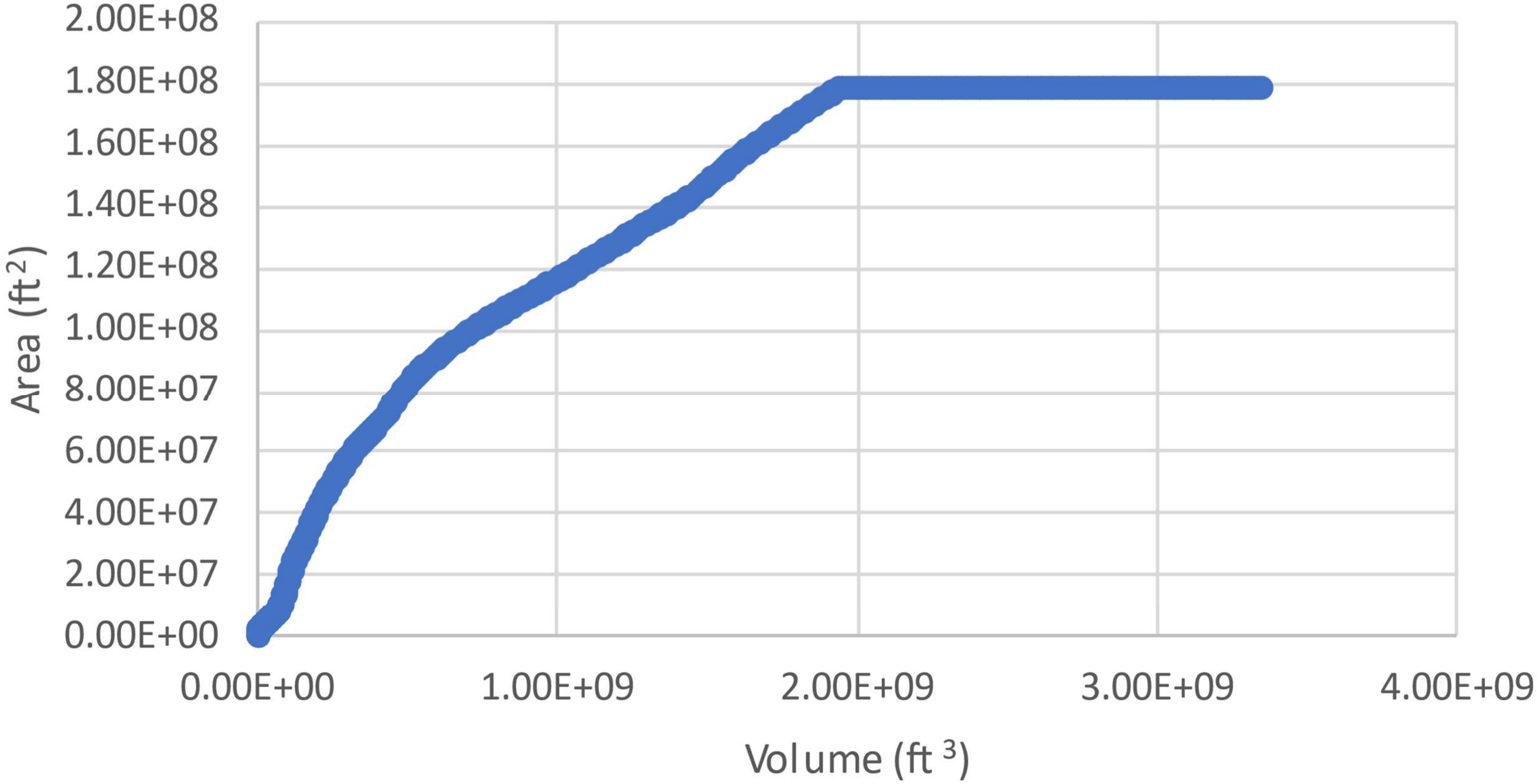

Figure 8: Relationship between Volume and Area for the Salt Creek Dammed Lake

2.2 Flow

Flow data for the Elkhorn River and Salt Creek were downloaded from the USGS National Water Information System. The two gages were: USGS 06800500 Elkhorn River at Waterloo and USGS 06803555 Salt Creek at Greenwood (USGS, 2024b). The delineated drainage area for each gage is presented on Figure 9 and Figure 10 for the Elkhorn River dammed lake and the Salt Creek dammed lake, respectively. Approximately 15 percent of the drainage area at the Elkhorn River gage at Waterloo was non-contributing to the downstream flows (i.e., water was intercepted by low areas, lakes, etc.), refer to Table 1. Measured flow data at each gage are shown on Figure 11 and Figure 12 for the Elkhorn River and Salt Creek, respectively.

Table 1: Drainage Area for the Two Gages on Elkhorn River and Salt Creek

	Drainage Area (sq mi)	Contributing Area (sq mi)
Elkhorn River	6,900	5,870
Salt Creek	1,050	1,050

The potential dammed lakes on the two streams are not located at the gages, so adjustments to the flow records were made to improve estimates of total inflow based on the drainage area for each lake. The drainage areas of the two lakes were determined using the watershed delineation tool in the Model My Watershed (Model My Watershed, 2024) utility, refer to Figure 9 and Figure 10. The delineated drainage areas for the Elkhorn River dammed lake and Salt Creek dammed lake were 6,355 and 1,119 mi^2, respectively (refer to Table 2). The Elkhorn River drainage area was adjusted from 6,355 to 5,406 mi^2 based on the ratio of total area and contributing area as noted by the USGS at the monitoring location.

Table 2: Drainage Area for the Potential Dammed Lakes

	Drainage Area (mi^2)	Contributing Area (mi^2)	Flow Scaling Ratio
Elkhorn River Dammed Lake	6,355	5,406	0.92
Salt Creek Dammed Lake	1,119	1,119	1.07

Flows into the Elkhorn River dammed lake and the Salt Creek dammed lake were scaled (refer to Table 2) according to their contributing areas and contributing areas for the respective USGS gages (refer to Figure 13 and Figure 14). Figure 15 and Figure 16 show the total annual (water year--WY) volume of water supplied by each surface water unit. A Mann-Kendall test was performed on the annual volumes to examine the data set for a significant change in the annual time series. Both data sets exhibited a significant change in 1970; thus, data before 1970 was not included in the remainder of the volumetric analysis.

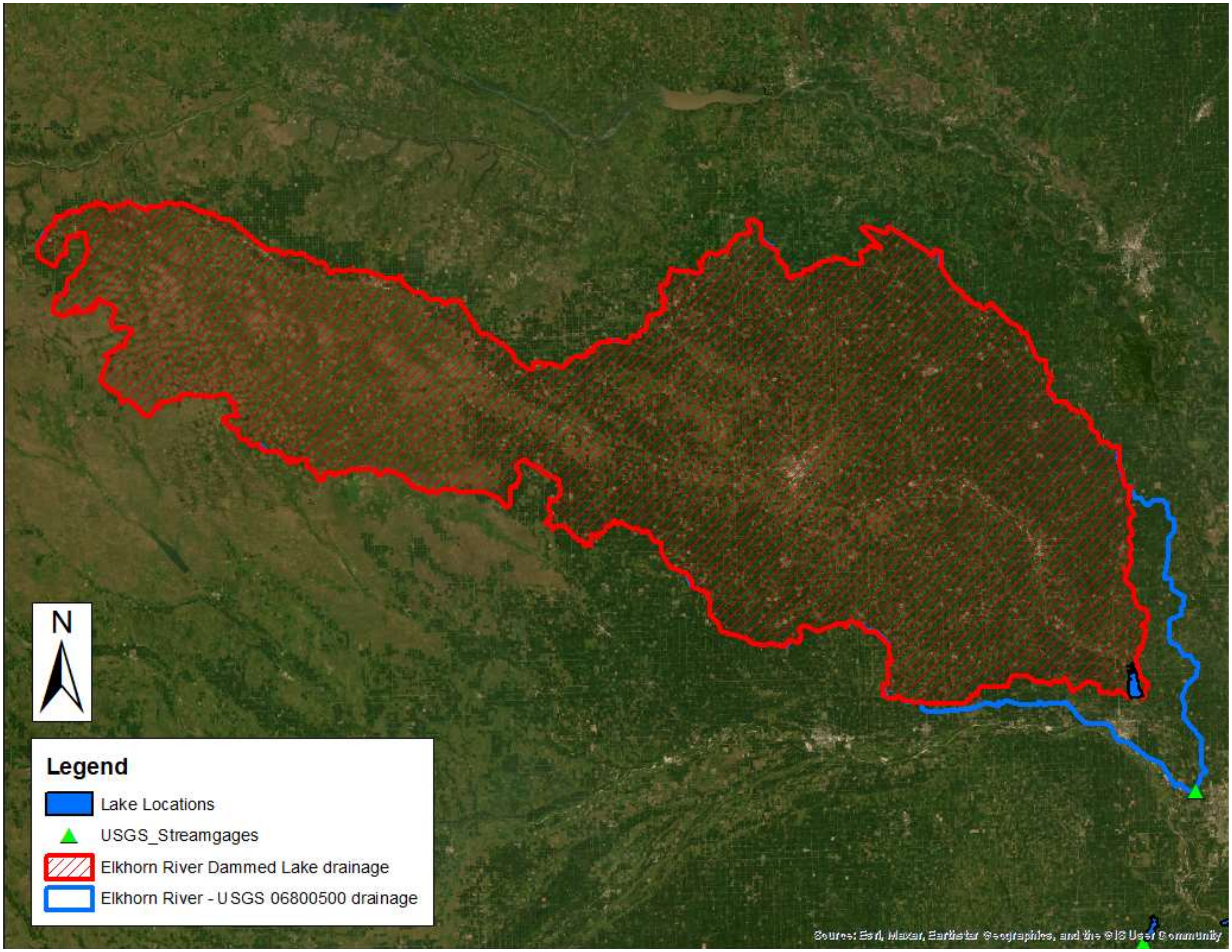

Figure 9: **Delineated Watershed for the USGS Gages and Drainage Area to the Elkhorn River Dammed Lake**

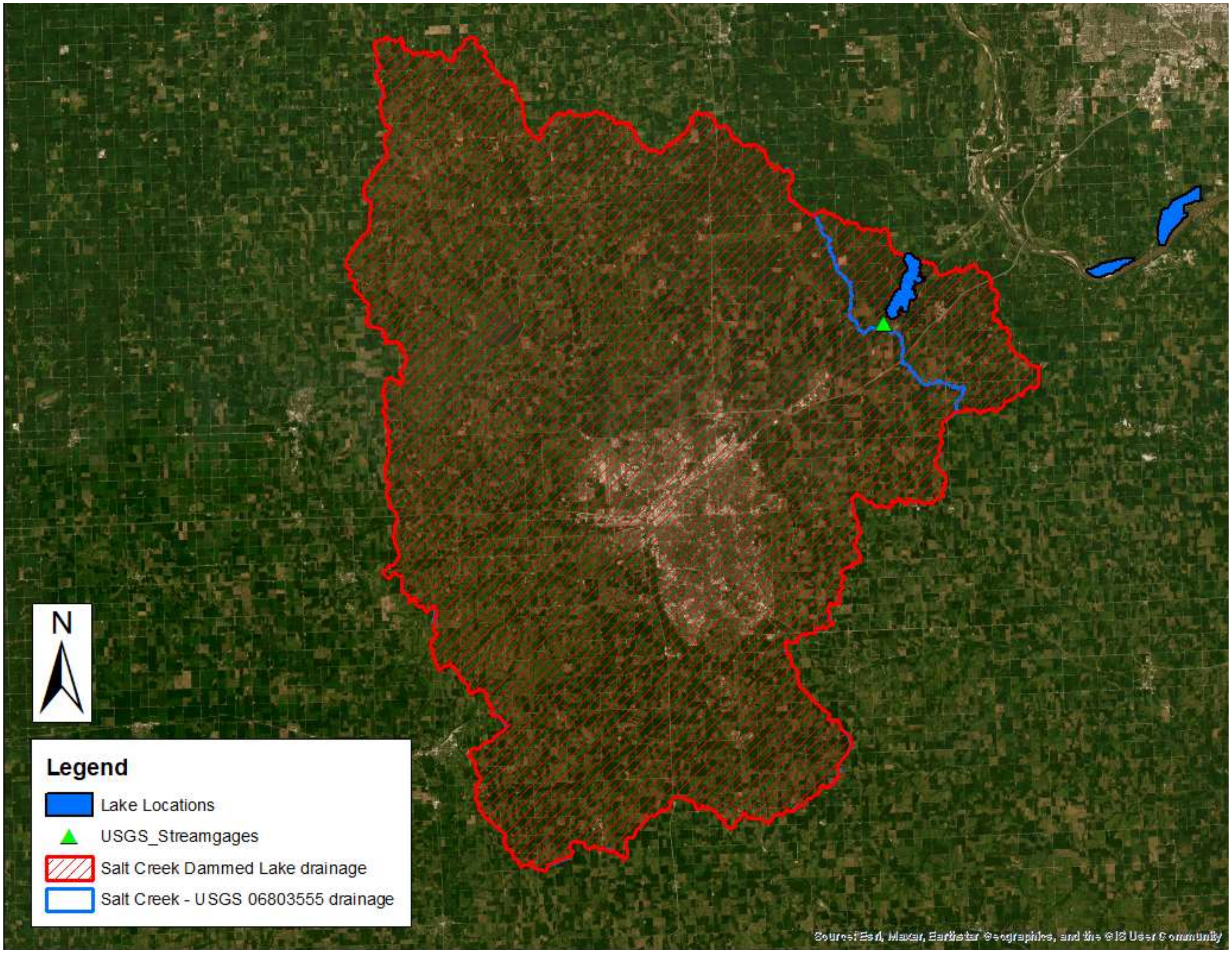

Figure 10: Delineated Watersheds for the USGS Gages and Drainage Area to the Salt Creek Dammed Lake

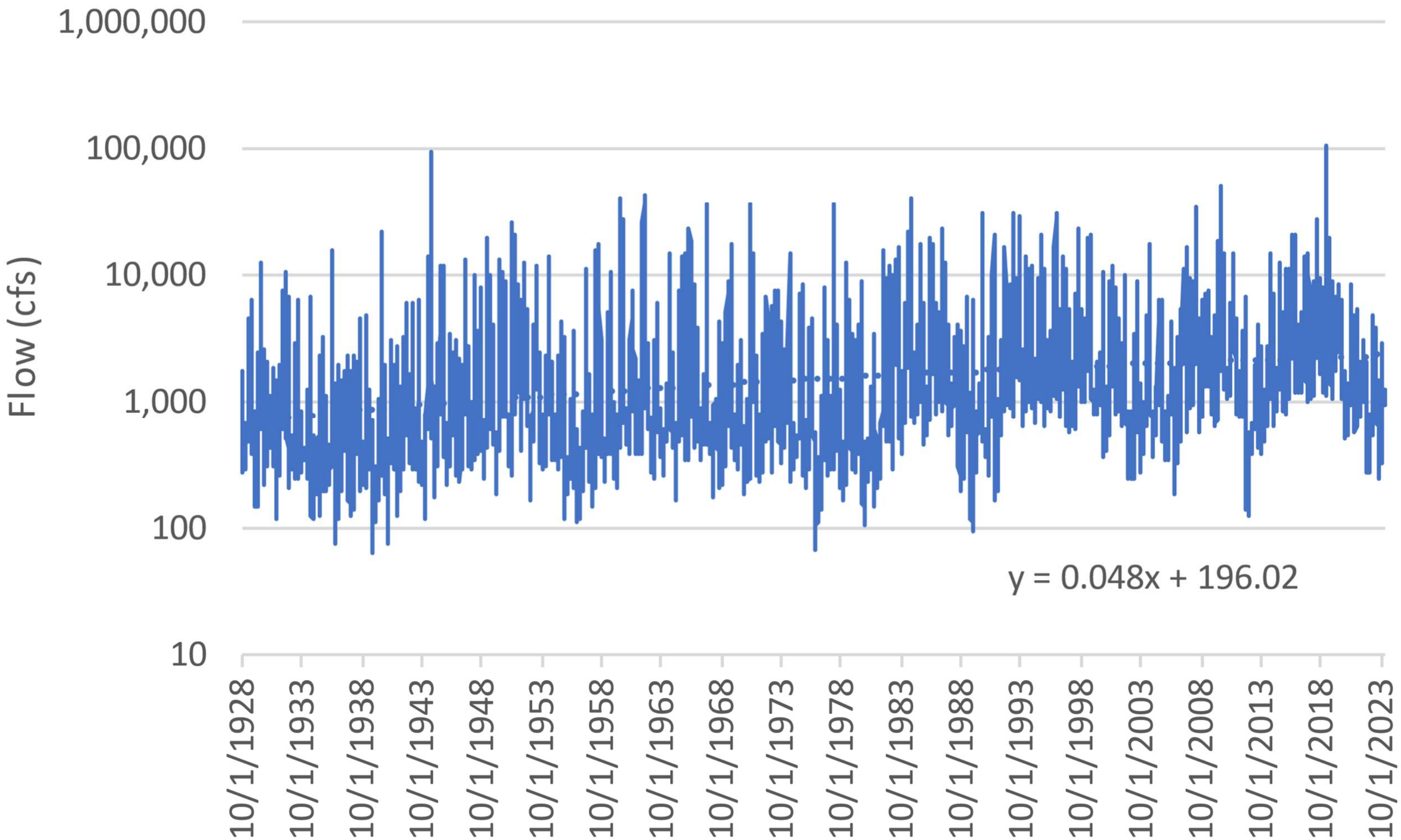

Figure 11: Measured Daily Flow at USGS 06800500 Elkhorn River at Waterloo

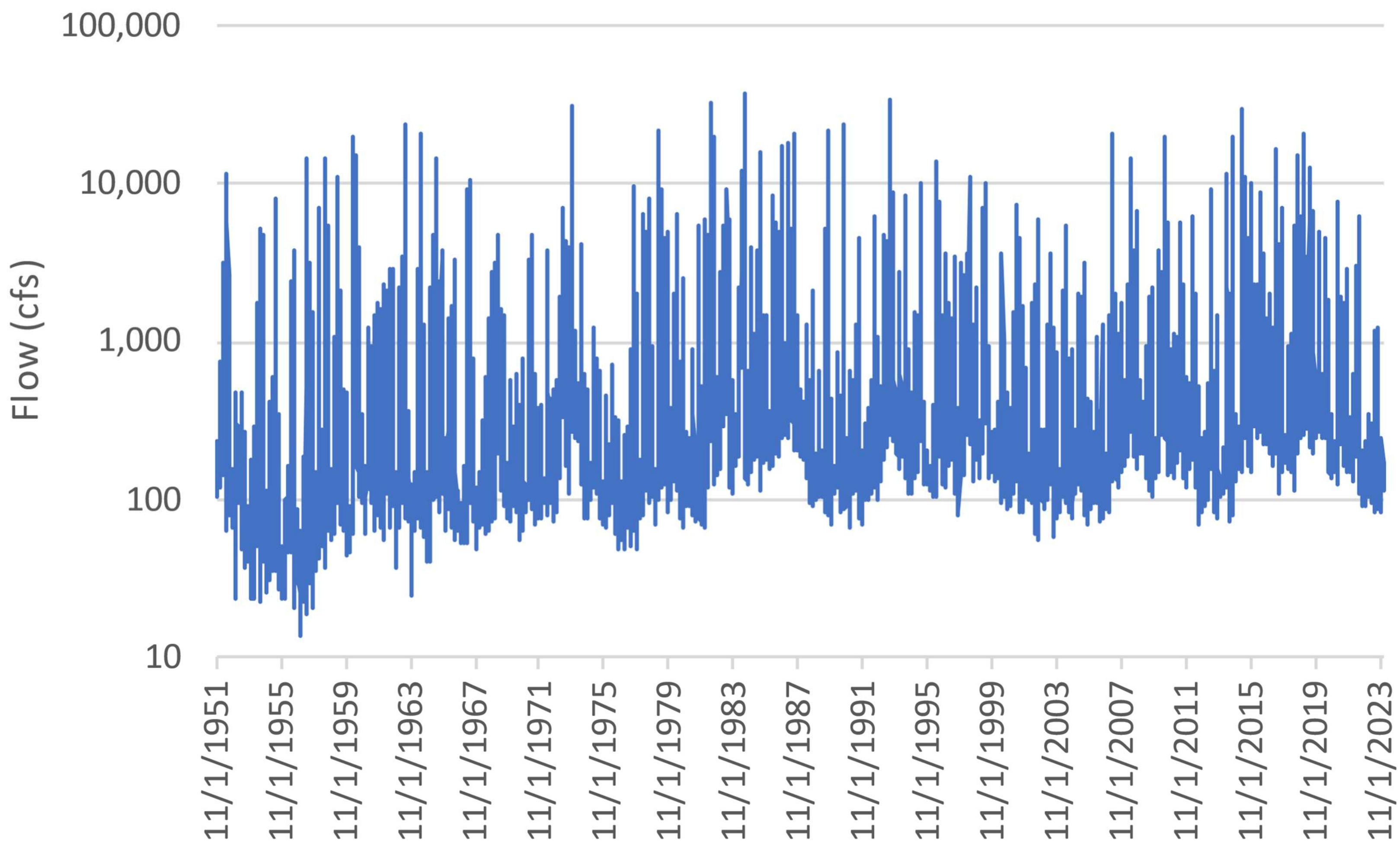

Figure 12: Measured Daily Flow at USGS 06803555 Salt Creek at Greenwood

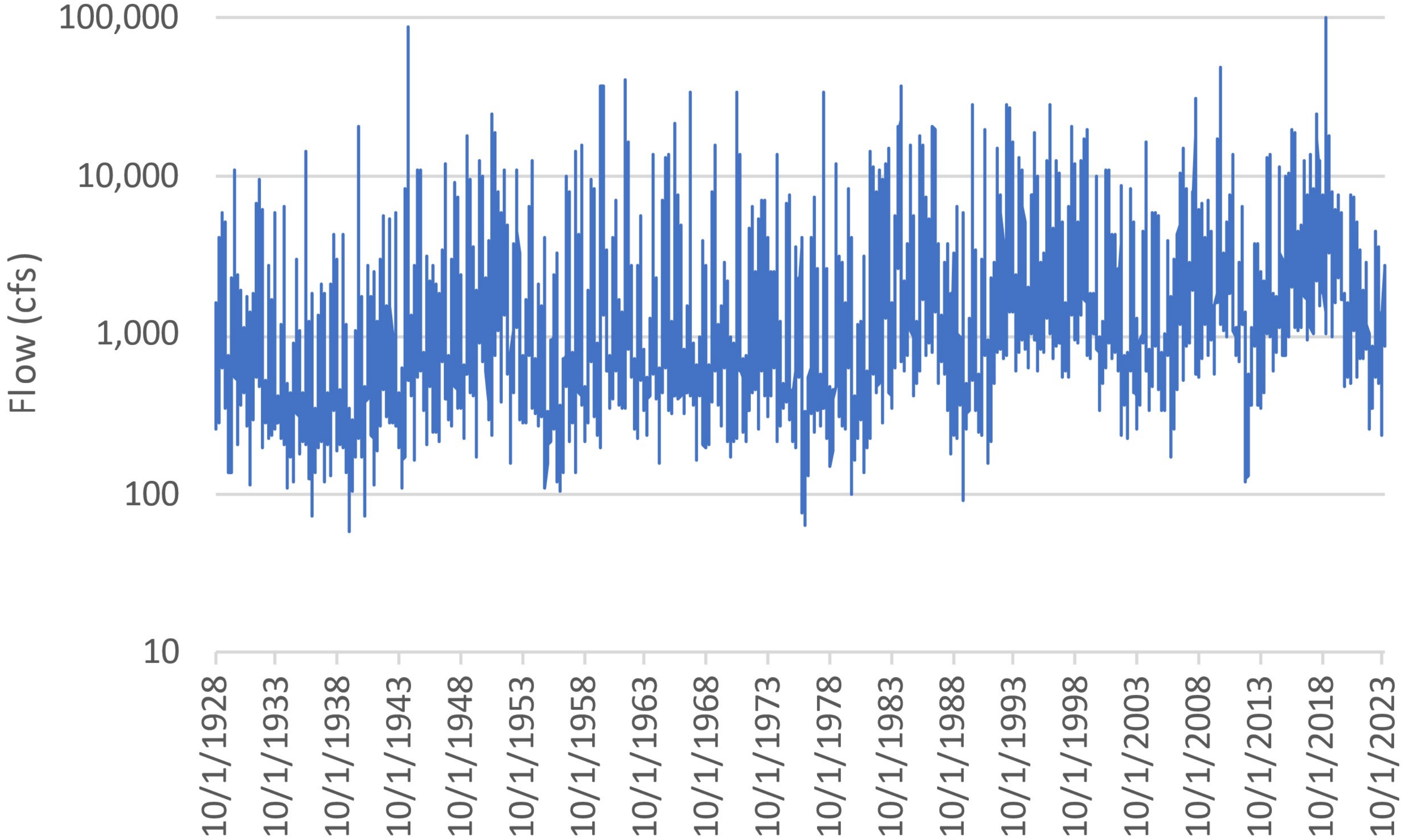

Figure 13: **Scaled Daily Flows for Potential Elkhorn River Dammed Lake**

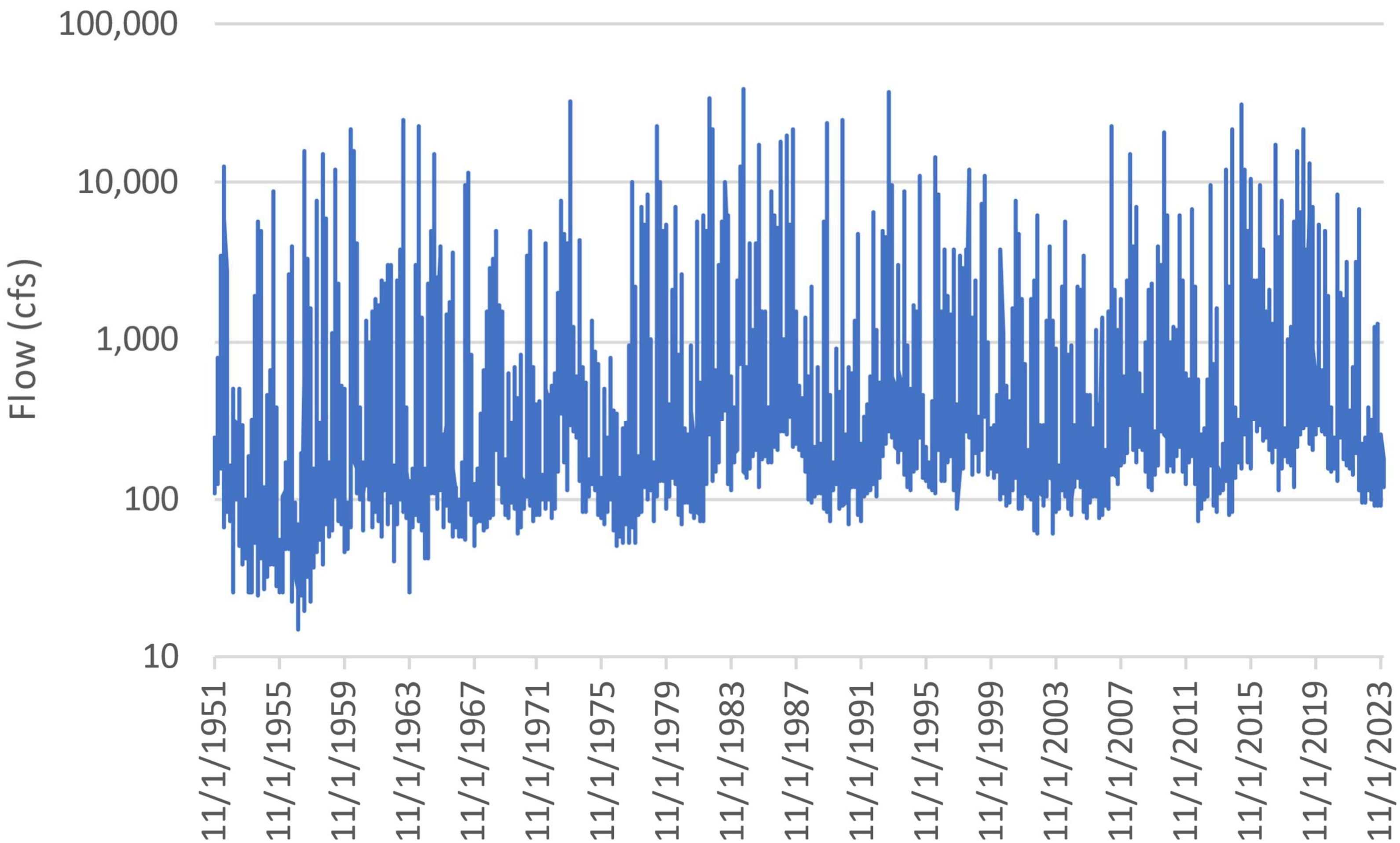

Figure 14: Scaled Daily Flows for Dammed Salt Creek Lake

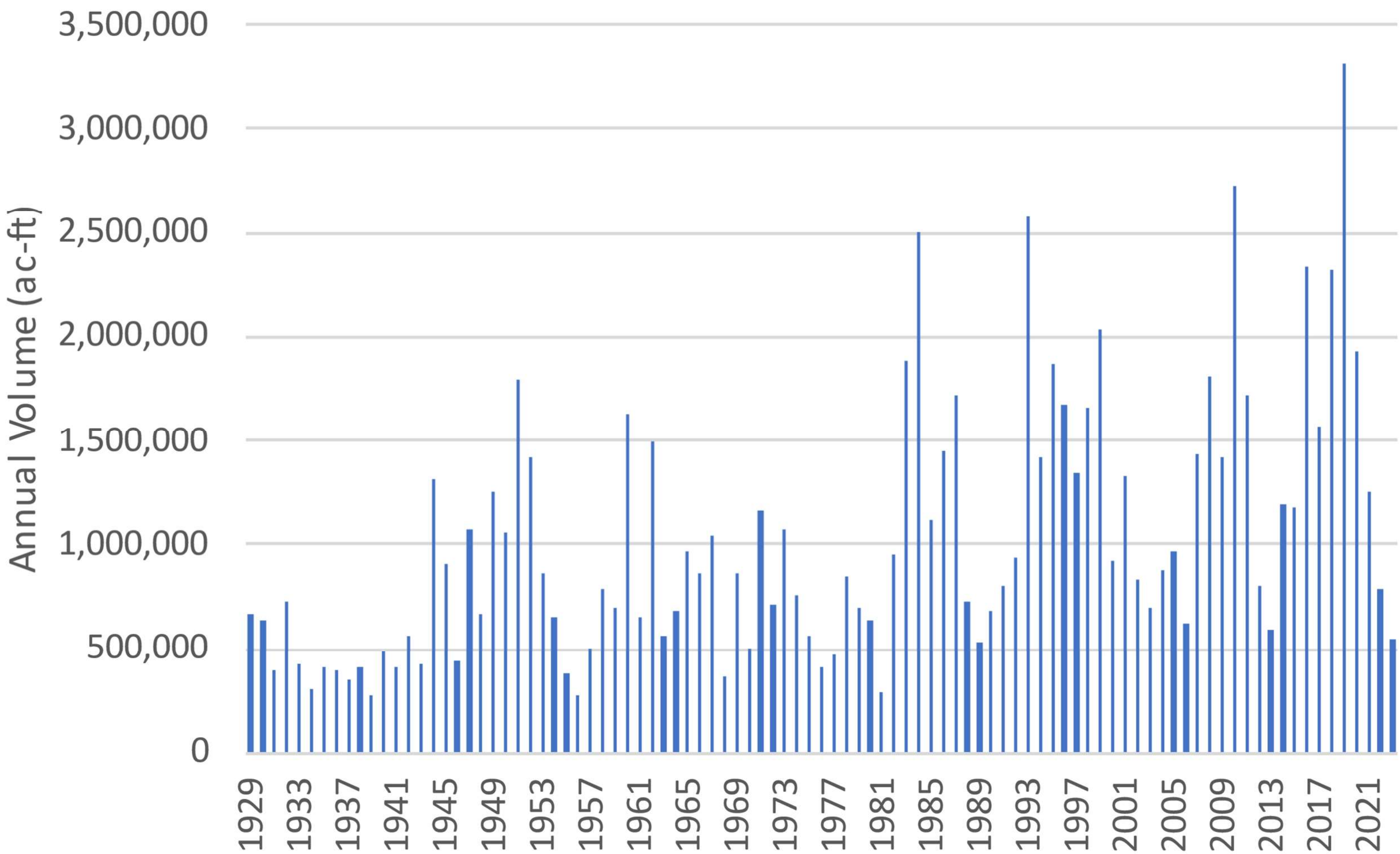

Figure 15: Scaled Annual Volume for Elkhorn River Dammed Lake

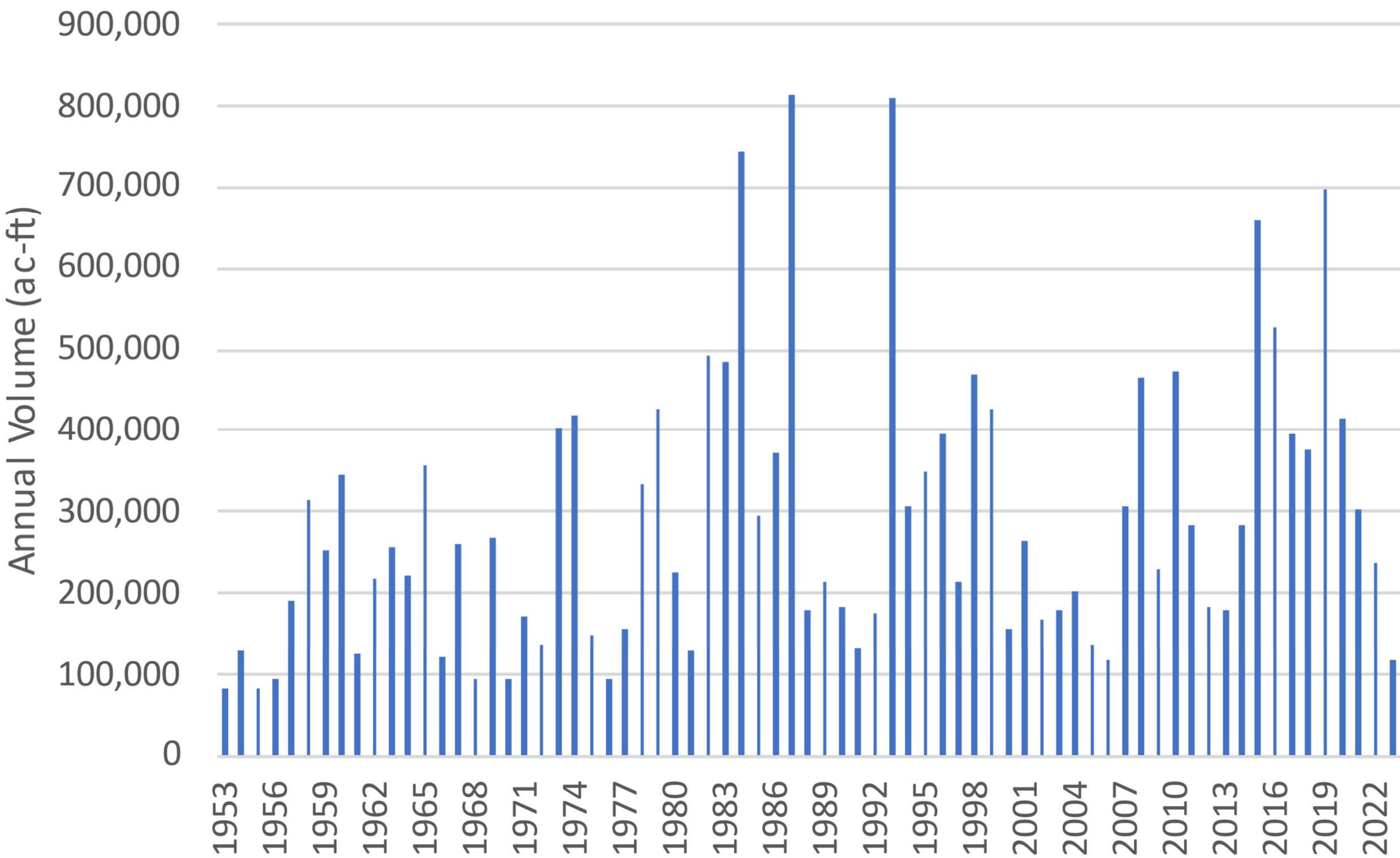

Figure 16: **Scaled Annual Volume for Salt Creek Lake Dammed Lake**

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One of the goals of the water balance analysis was to determine the response of the potential lakes to low flow conditions. Low flows can be determined by looking at the annual volume or by constructing synthetic daily flows based on observed flows. Table 3 shows the ranking of the total annual volume for the scaled Elkhorn River and Salt Creek inflows.

Table 3: Annual Volume (Water Year) Ranking for Scaled Elkhorn River and Salt Creek Flows

Year	Elkhorn River	Salt Creek		Year	Elkhorn River	Salt Creek
1970	6%	2%		1997	62%	40%
1971	53%	23%		1998	74%	83%
1972	25%	13%		1999	89%	79%
1973	49%	72%		2000	42%	19%
1974	28%	75%		2001	60%	47%
1975	11%	15%		2002	36%	21%
1976	2%	0%		2003	23%	26%
1977	4%	17%		2004	40%	36%
1978	38%	60%		2005	47%	11%
1979	21%	77%		2006	15%	6%
1980	17%	42%		2007	68%	58%
1981	0%	8%		2008	81%	81%
1982	45%	89%		2009	64%	43%
1983	85%	87%		2010	98%	85%
1984	94%	96%		2011	77%	49%
1985	51%	53%		2012	32%	32%
1986	70%	64%		2013	13%	30%
1987	79%	100%		2014	57%	51%
1988	26%	28%		2015	55%	92%
1989	8%	38%		2016	92%	91%
1990	19%	34%		2017	72%	70%
1991	34%	9%		2018	91%	66%
1992	43%	25%		2019	100%	94%
1993	96%	98%		2020	87%	74%
1994	66%	57%		2021	58%	55%
1995	83%	62%		2022	30%	45%
1996	75%	68%		2023	9%	4%

Since 1970, there is a significant trend (p-value = 0.0054) in the annual runoff volume in Elkhorn River with the Mann-Kendall test identifying significant changes in 1994 and 2007 (refer to Figure 17 and Figure 18). Thus, more recent flows should be used to determine an appropriate year for analysis for the water balance. Flows since 1994 were chosen for that analysis with the 2023 flows used for the low flows in the water balance analysis. The 2006 annual volume for Elkhorn River was the 15th percentile in the WY1970-2023 record and the 7th percentile in the WY1994–2023 period. There was not a significant trend (p-value = 0.39) in flows for Salt Creek (refer to Figure 17 and Figure 18). However, the Mann-Kendall test detected changes in volumes in 1983 and 1998. The flows in 2006 were used for the low flow water balance analysis, which was the 6th percentile for between WY1970-2023 and the 4th percentile from WY1998-2023.

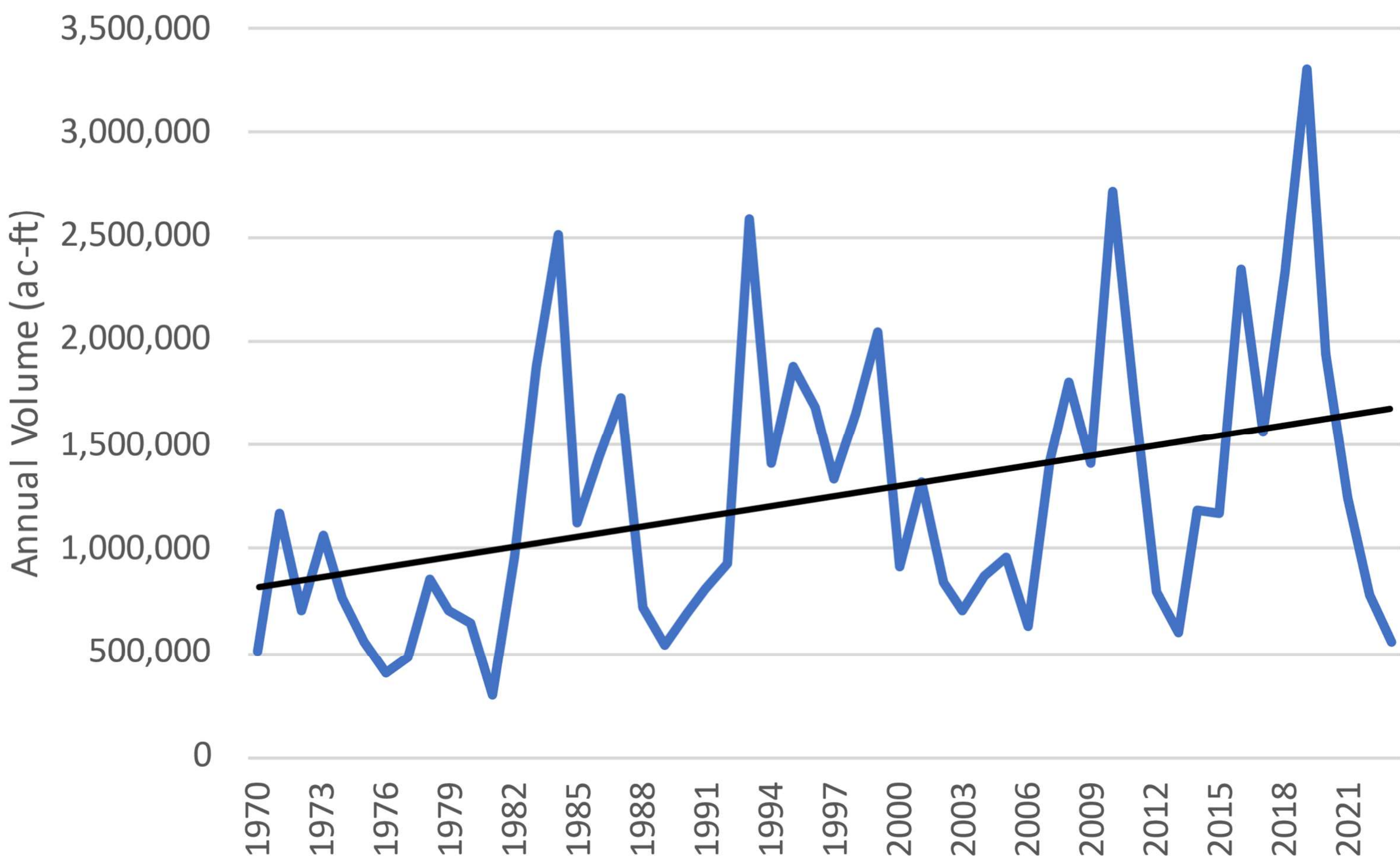

Figure 17: Annual Volume WY1994-2023 for the Elkhorn River Dammed Lake Inflows

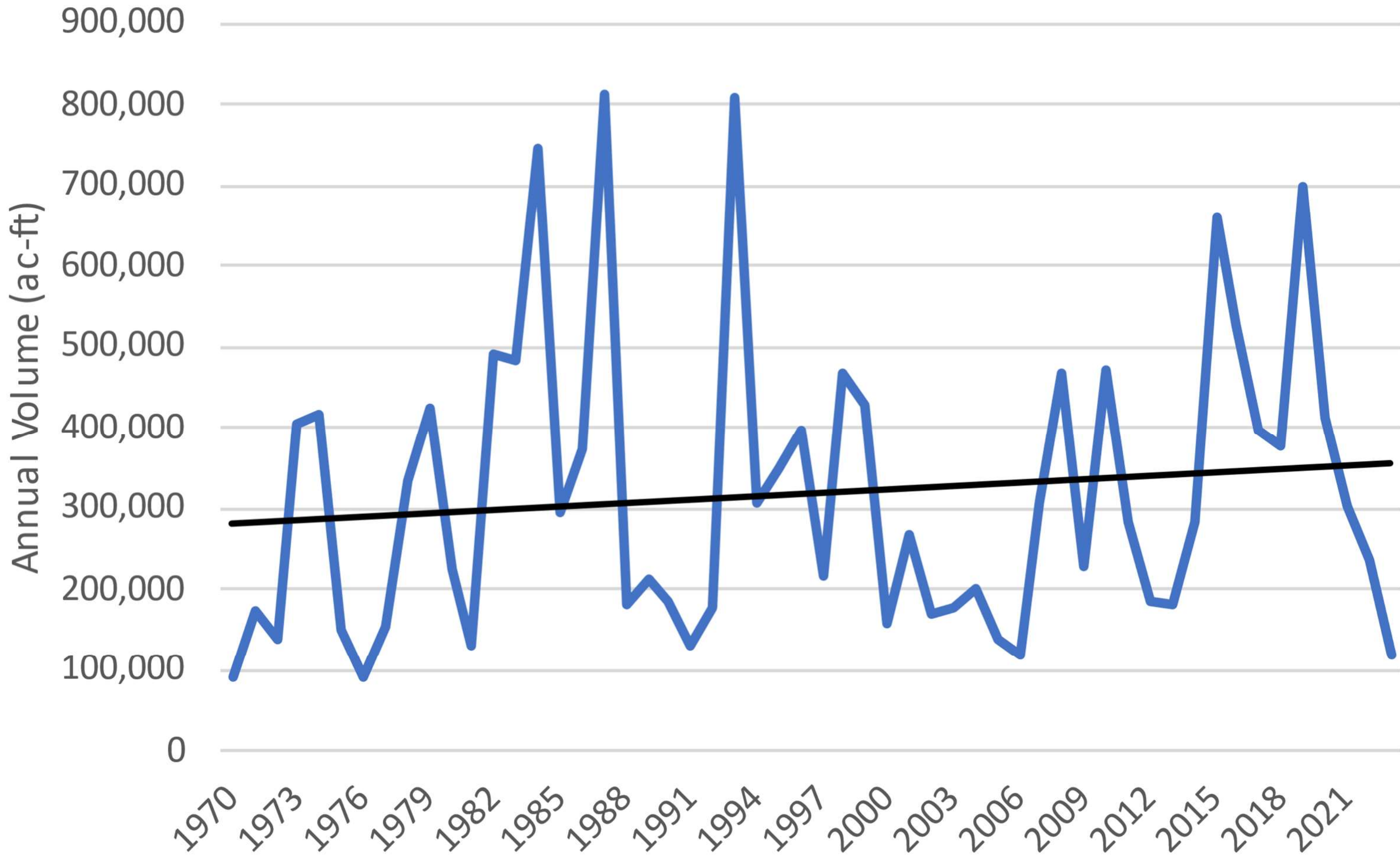

Figure 18: Annual Volume WY1970-2023 for the Salt Creek Dammed Lake Inflows

2.3 Evapotranspiration

Nebraska has an extensive network of monitoring stations that quantify evapotranspiration. The Automated Weather Data Network (High Plains Regional Climate Center [HPRCC], 2024) Station Memphis 5E is near the potential lakes and was used to characterize the atmospheric water loss. The available daily Penman Monteith Evapotranspiration from 1994 through 2023 was used to characterize observed atmospheric water loss with alfalfa as the reference crop, refer to Figure 19. Evapotranspiration was adjusted to determine the evaporation from open water (refer to Figure 20) using an appropriate crop coefficient from the Food and Agriculture Organization (FAO) irrigation and drainage paper 56 (Allen et al., 1998). Refer to Table 4 for crop reference evaporation coefficients.

Table 4: Crop Reference Evaporation Coefficients

	LU Coefficient
Corn	1.20
Sorghum	1.20
Soybeans	1.15
Winter wheat	1.15
Oats	1.15
Alfalfa	1.20
Other hay non-alfalfa	1.15
Sod grass seed	0.95
Switchgrass	1.15
Shrubland	1.00
Barren	1.00
Peaches	0.90
Open water	0.65
Developed open space	0.85
Developed low intensity	0.85
Developed medium intensity	0.85
Developed high intensity	0.85
Deciduous forest	1.10
Evergreen forest	1.00
Mixed forest	1.01
Grassland pasture	0.95
Woody wetlands	1.10
Herbaceous wetlands	1.10

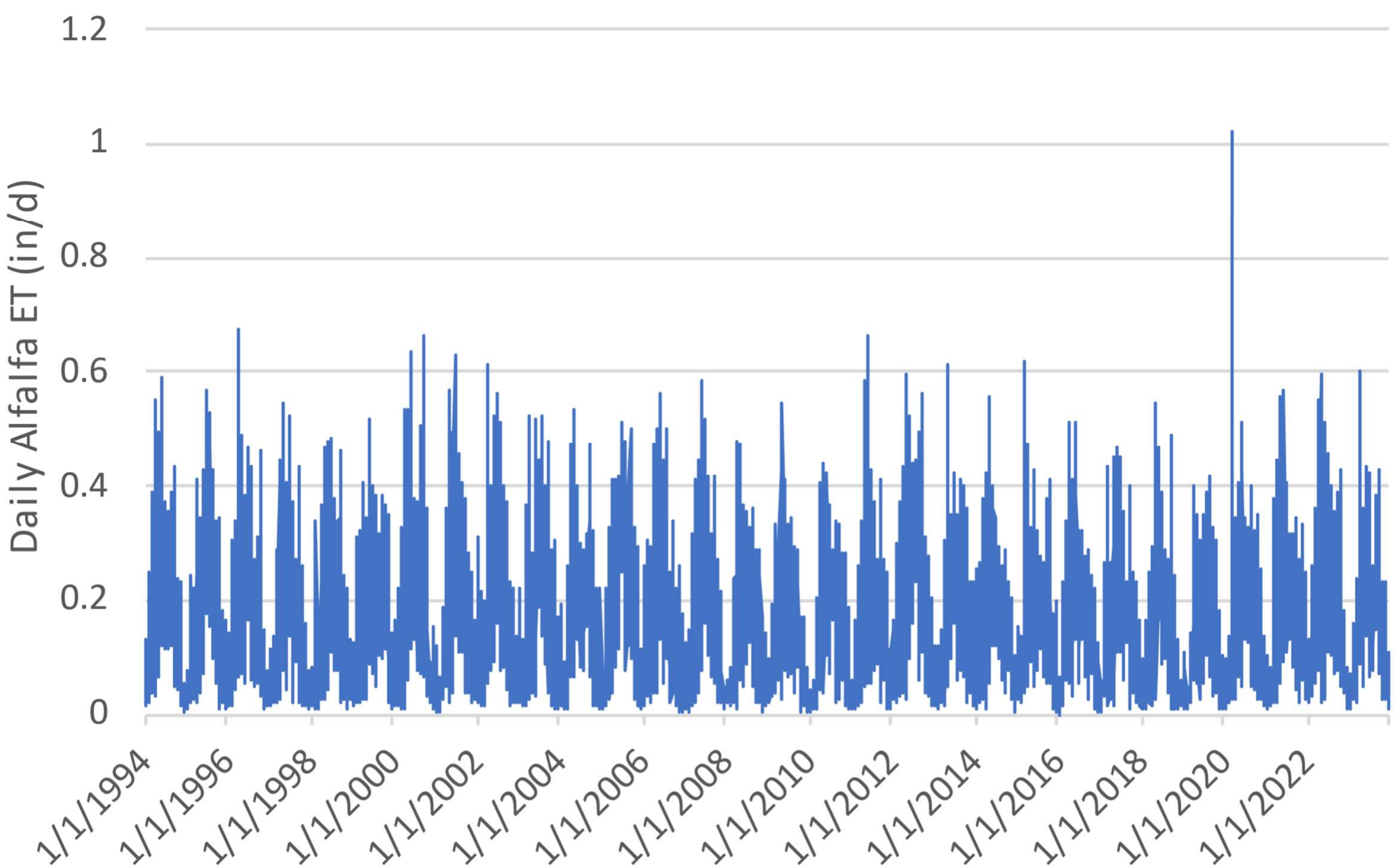

Figure 19: Measured Evapotranspiration at Station Memphis 5N for Alfalfa

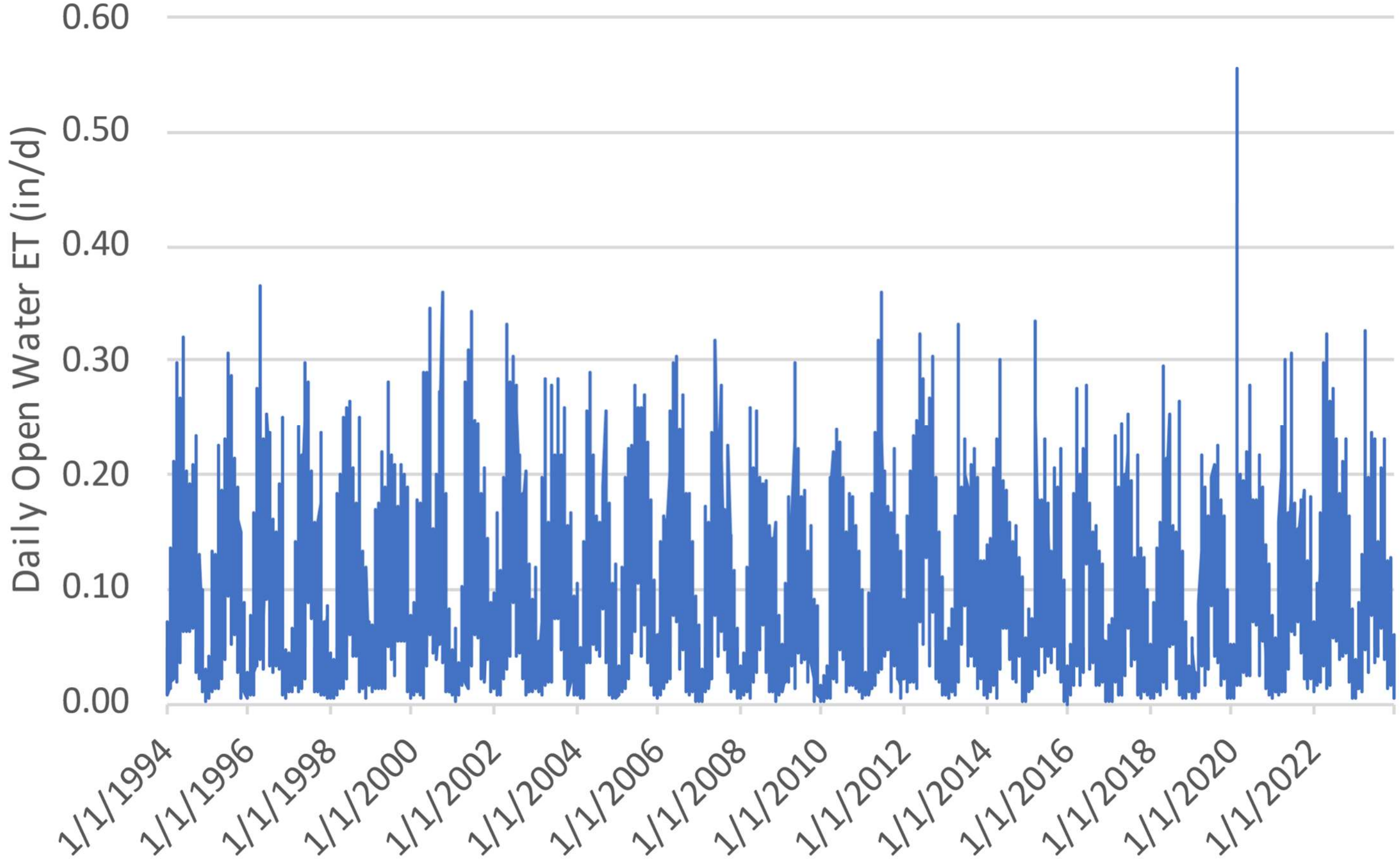

Figure 20: Open Water Evaporation as Calculated from the Alfalfa Evapotranspiration at Station Memphis 5N

Evaporation is a key component of the lake water balance. Ensuring that the evaporative calculations from the conversion from alfalfa to open water is accurate will provide confidence in those losses. A second method was used for the evaporation estimates following an approach outlined by Hargreaves and Samani (1982), which is used when there is a paucity of weather data and is generally not as accurate as Penman-Monteith calculations. The Hargreaves and Samani approach uses daily minimum and maximum temperatures to calculate evaporation (refer to Figure 21) via the following equations and estimated slightly higher evaporative losses, refer to Table 5:

$$ET_o = 0.0023 R_a \left(\frac{T_{max} + T_{min}}{2} + 17.8\right)\sqrt{T_{max} + T_{min}}$$

$$R_a = \frac{1440}{\pi} G_s d_r [\omega_s \sin(\varphi)\sin(\delta) + \sin(\omega_s)\cos(\varphi)\cos(\delta)]$$

$$d_r = 1 + 0.033 cos\left(\frac{2\pi}{365} J\right)$$

$$\delta = 0.409 sin\left(\frac{2\pi}{365} J - 1.39\right)$$

$$\omega_s = arccos[-\tan(\varphi)\tan(\delta)]$$

Where:

ET_o	reference evaporation and transpiration
T_{min}	minimum temperature (°C)
T_{max}	maximum temperature (°C)
R_a	daily extraterrestrial radiation
G_s	solar constant (0.082 MJ/m2/d)
d_r	inverse relative distance from the Earth to the sun
δ	solar declination angle (rad [radians])
ω_s	sunset hour angle (rad)
φ	well geographical latitude (rad)
J	number of day in calendar year (from 1 to 365 or 366)

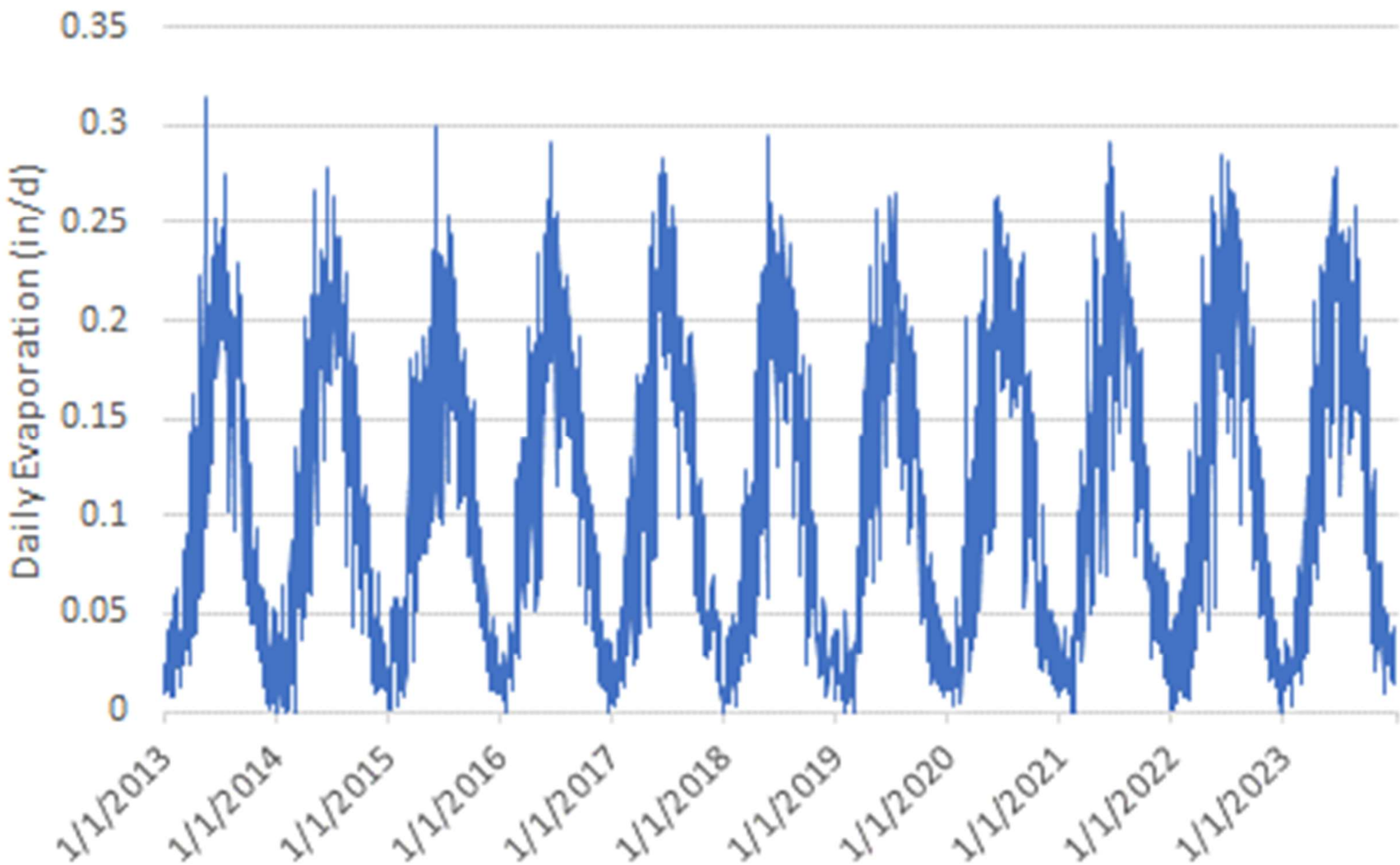

Figure 21: Daily Open Water Evaporation Calculated with the Hargreaves and Samani Approach

Table 5: Atmospheric Water Loss (in./yr) Calculated via the Penman and Hargreaves Approaches

	Penman	Hargreaves
1994	35.88	40.43
1995	32.82	39.34
1996	31.56	37.54
1997	32.14	40.22
1998	29.79	39.64
1999	32.52	40.16
2000	35.75	42.41
2001	34.49	41.07
2002	36.49	42.67
2003	33.58	41.50
2004	31.89	40.18
2005	36.25	42.63
2006	35.27	42.20
2007	31.69	41.03
2008	29.22	39.24
2009	28.28	38.95
2010	30.10	40.16
2011	31.36	39.28
2012	41.09	47.05
2013	30.78	39.38
2014	30.90	39.75
2015	31.34	39.36
2016	31.81	40.79
2017	31.20	41.17
2018	26.79	38.99
2019	27.32	37.94
2020	32.58	41.23
2021	32.50	41.25
2022	36.38	42.82
2023	33.09	42.48
Average	32.50	40.70

2.4 Land Use

United States Department of Agriculture (USDA) CropScape data (CropScape, 2024) was used to obtain information on land use within each potential lake. CropScape data is derived yearly and can vary depending on the crops planted. The 2023 data was used as the baseline year for land use analysis and evapotranspiration loss under current land coverage, refer to Table 6.

Table 6: USDA CropScape Land Use (2023) Area (acres) within the Potential Lake Boundaries

	Elkhorn River Dammed Lake	Salt Creek Dammed Lake	Platte River Large Excavated Lake	Platte River Small Excavated Lake
Corn	1,154	1,805	924	262
Sorghum	0	0	0	0
Soybeans	1,141	1,312	502	155
Winter wheat	0	2	0	0
Oats	0	0	0	0
Alfalfa	16	21	7	2
Other hay non-alfalfa	18	40	9	5
Sod grass seed	2	12	1	1
Switchgrass	0	0	0	0
Shrubland	0	1	0	0
Barren	9	3	8	77
Peaches	0	0	0	0
Open water	314	150	29	128
Developed open space	79	68	40	7
Developed low intensity	36	23	45	3
Developed medium intensity	12	6	10	2
Developed high intensity	3	1	2	0
Deciduous forest	526	325	138	92
Evergreen forest	0	0	0	2
Mixed forest	0	1	0	0
Grassland pasture	174	183	115	59
Woody wetlands	562	127	238	91
Herbaceous wetlands	80	33	28	11
Total	**4,126**	**4,112**	**2,097**	**898**

Combining the CropScape land use (Table 7), the evapotranspiration crop coefficients (refer to Table 4), and 1994-2023 evapotranspiration provided the total annual atmospheric evapotranspirative water loss for the land use current conditions within each footprint.

Table 7: Atmospheric Water Loss (in/yr) within each Potential Lake Boundary for the 2023 Land Use and Open Water

	Elkhorn Rive Dammed Laker	Salt Creek Dammed Lake	Platte River Large Excavated Lake	Platte River Small Excavated Lake	Open Water
1994	62.07	64.00	65.01	64.62	35.88
1995	56.78	58.54	59.46	59.11	32.82
1996	54.59	56.28	57.18	56.83	31.56
1997	55.59	57.31	58.22	57.87	32.14
1998	51.53	53.13	53.97	53.64	29.79
1999	56.26	58.00	58.92	58.57	32.52
2000	61.84	63.76	64.77	64.38	35.75
2001	59.66	61.51	62.49	62.11	34.49
2002	63.13	65.08	66.11	65.72	36.49
2003	58.08	59.88	60.83	60.47	33.58
2004	55.17	56.88	57.78	57.43	31.89
2005	62.71	64.65	65.67	65.28	36.25
2006	61.01	62.90	63.89	63.51	35.27
2007	54.81	56.51	57.41	57.06	31.69
2008	50.55	52.12	52.94	52.62	29.22
2009	48.91	50.43	51.23	50.92	28.28
2010	52.07	53.68	54.53	54.20	30.10
2011	54.25	55.93	56.82	56.48	31.36
2012	71.08	73.28	74.44	73.99	41.09
2013	53.24	54.89	55.76	55.43	30.78
2014	53.45	55.10	55.97	55.64	30.90
2015	54.22	55.90	56.78	56.44	31.34
2016	55.03	56.73	57.63	57.28	31.81
2017	53.98	55.65	56.53	56.19	31.20
2018	46.34	47.78	48.54	48.25	26.79
2019	47.26	48.73	49.50	49.20	27.32
2020	56.36	58.11	59.03	58.68	32.58
2021	56.21	57.96	58.87	58.52	32.50
2022	62.92	64.87	65.90	65.51	36.38
2023	57.24	59.01	59.95	59.59	33.09
Average	**56.21**	**57.95**	**58.87**	**58.52**	**32.50**

2.5 Irrigated Lands

The NeDNR maintains information on irrigated lands (NeDNR, 2024a; NeDNR, 2024b) within the potential lakes' boundaries. Although this information is from 2005, it provides an estimate of likely irrigated areas in each area (refer to Table 8).

Table 8: Estimated Irrigated Land (2005) Area (acres) in the Boundaries of the Potential Lakes

	Elkhorn River Dammed Lake	Salt Creek Dammed Lake	Platte River Large Excavated Lake	Platte River Small Excavated Lake
Center Pivot	293	162	648	0
Other Irrigation	697	594	355	217
Total	990	756	1,003	217
Percent Irrigated	24%	18%	48%	24%

3. MODELING APPROACH

A water balance analysis is an accounting of water that enters and exits a lake. In this simplified assessment, the water source is the upstream surface water flows. In addition, this analysis for outflows did not consider this lake as a water supply and also assumed a minimum flow during drought conditions for releases to support biological integrity. Some of the significant assumptions in the water balance include the following:

- The lake was assumed to be for recreational purposes. The operation of the lake was not defined in this analysis. Because the lake is for recreational purposes, releases have not been assumed to be made for augmenting flows in the Platte River. Additional analysis and modeling will need to be completed to address the lake operation and augmenting of downstream flow requirements.
- Groundwater interactions for both lakes were considered a loss of approximated at 0.38 ft/yr (115 mm/yr) according to groundwater recharge rates observed by Billesbach and Arkebauer (2012).
- Evaporation and outflow were also considered to be losses from each lake.
- Evaporation was assumed to be the median daily evaporative rates from the Loess curve calculations.
- Flow out of the lake was controlled by the proposed dam spillway elevations (1,196 feet for Elkhorn River dammed lake and 1,097 feet for Salt Creek dammed lake) and assumed that outflow over the spillway maintained flow at that elevation.

- Daily lake elevations were calculated as the average of the volume with the sum of the daily inflows and outflows and the elevation after water spilled downstream.
- Lake water balance was calculated for two low inflow conditions:
  - Water year flows (WY2006) repeated three times to allow the lake to achieve a dynamic steady state.
  - 3-year volume flow period (WY2001-2003).
  - Evapotranspiration record (WY1994-2023).
- A minimum flow will likely be required from the potential lakes once constructed, which is designated in this report as the low flow rule. As an approximation of that requirement, the monthly 10th percentile flows were assigned to each lake when water levels were less than the proposed spillway.
  - Minimum instream flows requirements are evaluated to minimize the impacts on hydrology, geomorphology, biology, water quality, temperature and connectivity from changes to natural hydrology.
  - The monthly assigned 10th percentile flows for the minimum flow did not take into account the potential needs of the LWS and MUD wellfields or existing instream flow rights.
  - Additional analysis and modeling will be required to determine the appropriate minimum flows, including any potential impacts on the wellfields or existing instream flow rights.
- Water elevation for outflow calculations at each daily calculation step was the average of the starting and ending elevations (once all losses are subtracted from the starting volume).

As the lake's outflows for the water balance analysis are further defined, then the water balance analysis will need to be updated accordingly during the feasibility phase.

4. RESULTS

4.1 Platte River Large Excavated Lake

The Platte River large excavated lake, downstream of Louisville, was not explicitly evaluated in this analysis. The lake location has a high groundwater table and it is anticipated that an equilibrium will develop between the groundwater and water in the lake. The average annual atmospheric water loss for the Platte River large excavated lake would decrease from 58.9 in./year to 32.5 in./year (refer to Table 7), reducing the demand on the groundwater supplies because of the large portion of the existing land use being crops which has a higher evapotranspiration compared to an open water body. In addition, 48 percent of the land within the boundary of the Platte River large excavated lake was irrigated in 2005 and is likely still irrigated, which would also contribute to less demand on groundwater and raise in groundwater for this area.

4.2 Platte River Large Excavated Lake and Platte River Small Excavated Lake

The Platte River large excavated lake, downstream of Louisville, and Platte River small excavated lake, upstream of Louisville, were not explicitly evaluated in this analysis. The lake locations have a high groundwater table and it is anticipated that an equilibrium will develop between groundwater and water in the lake. The average combined annual atmospheric water loss for the lakes would decrease from 57.3 in./year to 32.5 in./year (refer to Table 7), reducing the demand on the groundwater supplies because of the large portion of the existing land use being crops which has a higher evapotranspiration compared to an open water body. In addition, 41 percent of the land within the boundary of the lakes were irrigated in 2005 and is likely still irrigated, which would also contribute to less demand on groundwater and raise groundwater in that area.

4.3 Elkhorn River Dammed Lake Example

The outflows and lake elevations in the example Elkhorn River dammed lake were evaluated under three conditions: repeated WY2006 flows (15th percentile flows), WY2001-2003 (low 3-year total volume between WY1994 and 2023), and 30-year evaluation 1994-2023.

4.3.1 Repeated WY2006 Flows

Repeating the WY2006 flows would represent three consecutive years of very low flow. The evaluation showed that the Elkhorn River dammed lake would be able to maintain the 10th percentile flows throughout the year and pass some of the larger spring flows (refer to Figure 22). The outflows from the Elkhorn River dammed lake during summer would be controlled by low flow rules but a reasonable hydrograph would be mimicked. The lake levels would also drop during late summer when only the full minimum flows were passed, refer to Figure 23.

4.3.2 WY2001-2003 Flows

The WY2001-2003 flows represented the lowest 3-year total volume between WY1994 and 2023. That evaluation indicated that the outflow hydrograph would closely approximate the inflow hydrograph with minimum flow rules being imposed to maintain downstream aquatic health infrequently (3 percent of the simulation) (refer to Figure 24). The lake levels remained near that spillway elevation throughout the simulation, refer to Figure 25.

4.3.3 1994-2023 Flows

The 30-year simulation showed that flows from the Elkhorn River dammed lake would generally follow the pattern of the inflows, refer to Figure 26. One period at the end of the 2012 summer is where the lake level would significantly drop (refer to Figure 27). However, the passed flows were greater than the observed Elkhorn River inflows during that period (refer to Figure 26), which would provide some buffer for extreme conditions for aquatic health. Throughout that simulation, low flow rules were imposed only 3 percent of the time.

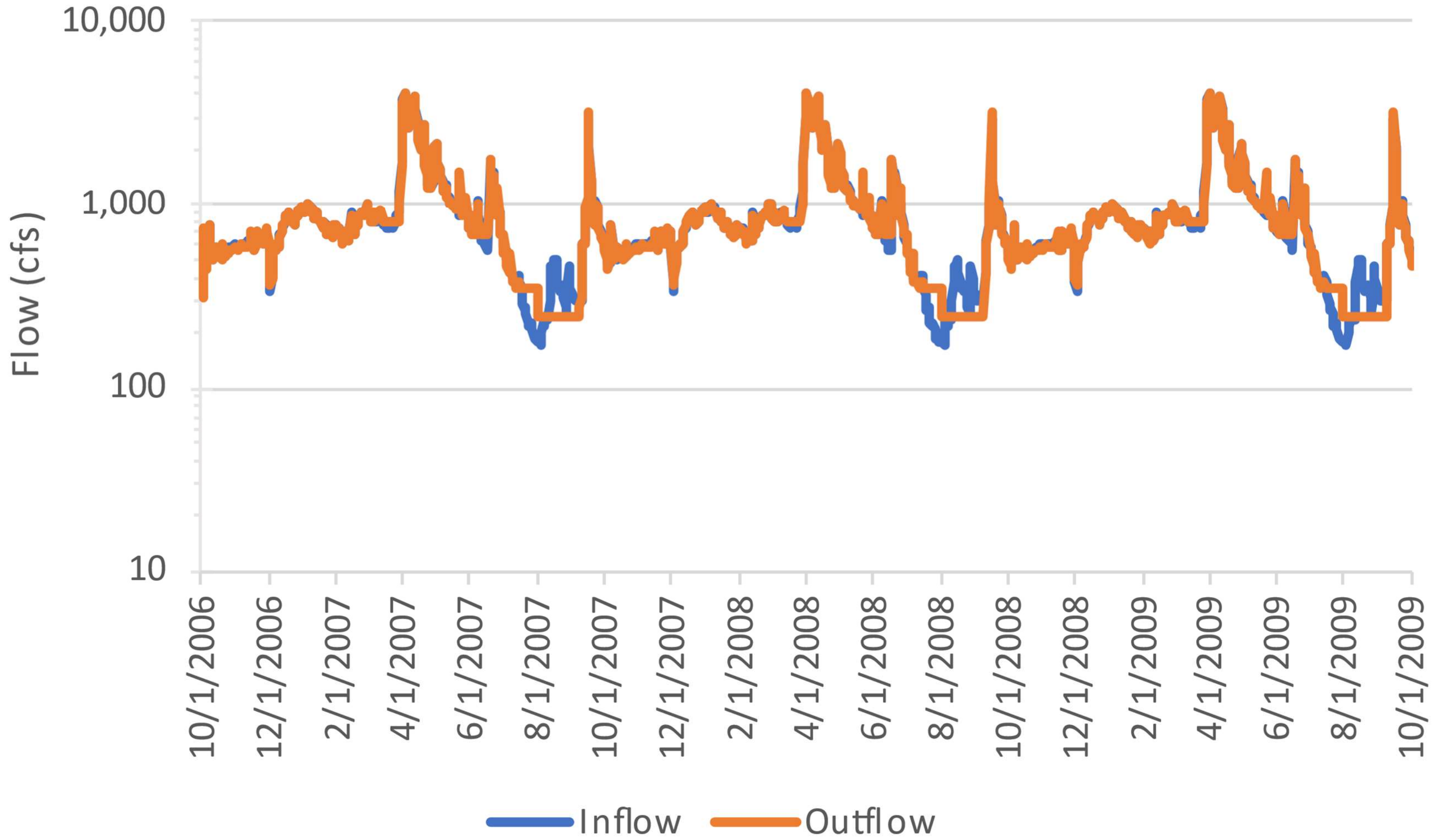

Figure 22: **Inflow and Outflow for the Elkhorn River Dammed Lake during the Repeated WY2006 Conditions**

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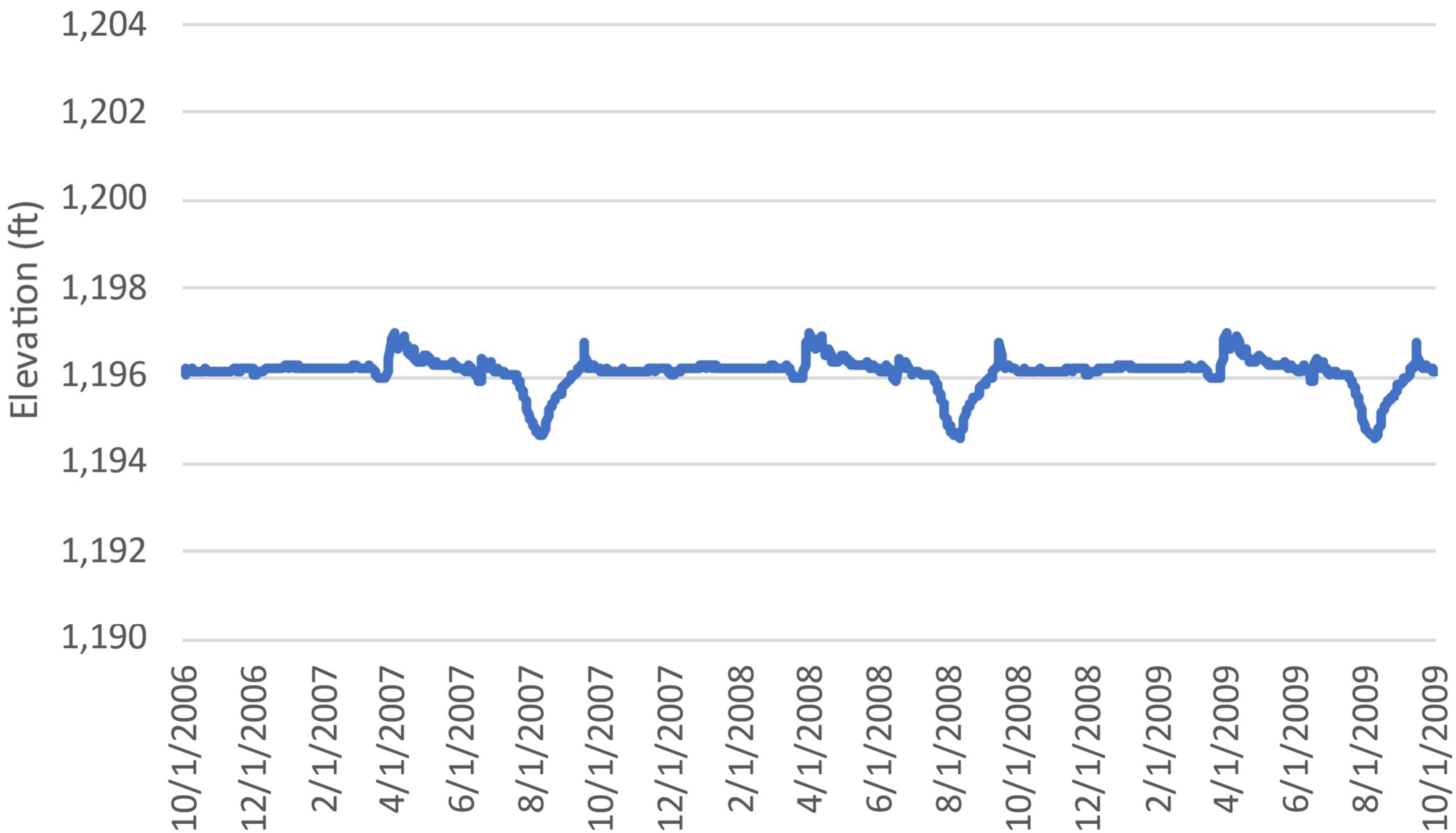

Figure 23: Water Surface Elevation for the Elkhorn River Dammed Lake during the Repeated WY2006 Conditions (Note that 1,169 is the lowest elevation in the potential lake)

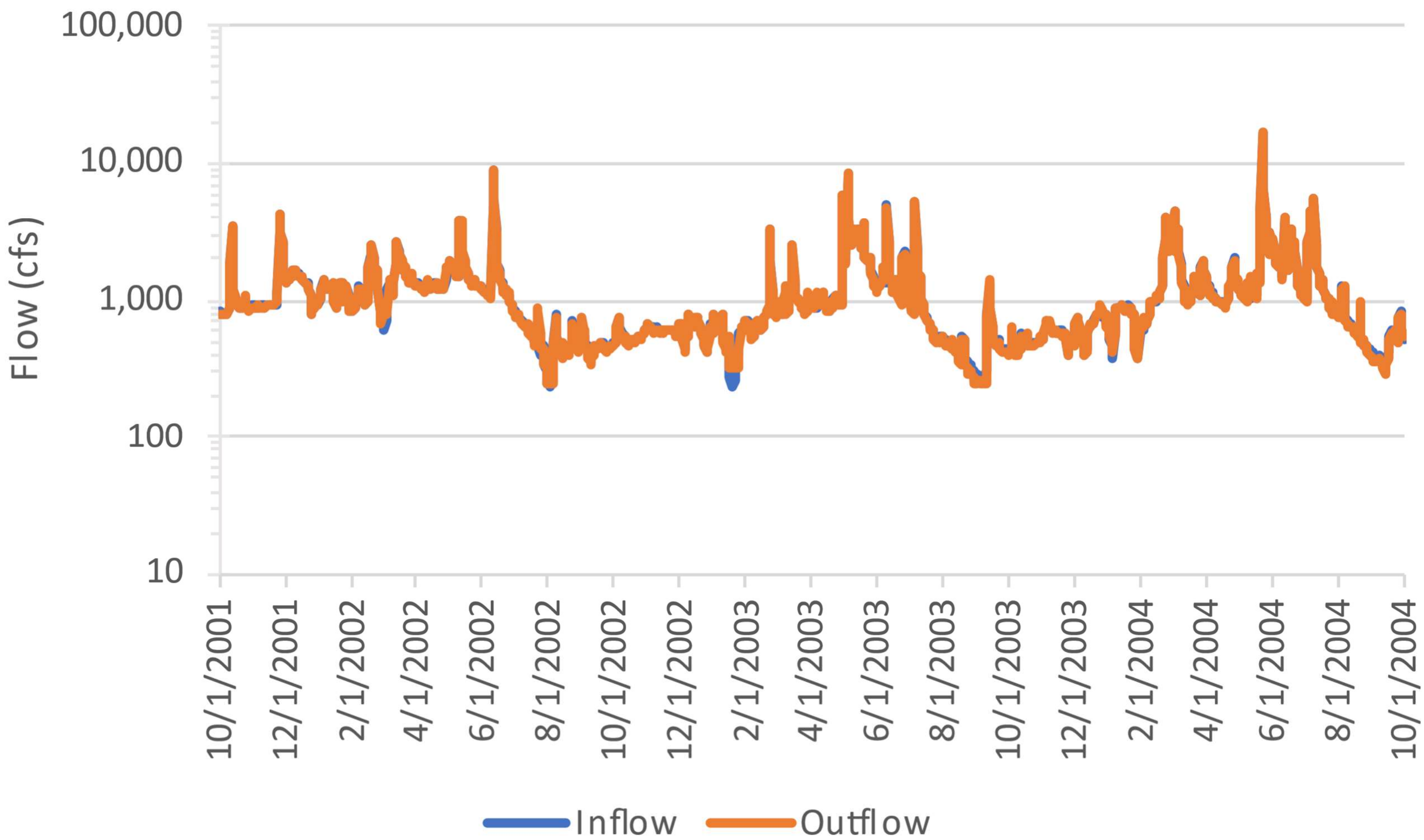

Figure 24: **Inflow and Outflow for the Elkhorn River Dammed Lake during the WY2001-2003 Conditions**

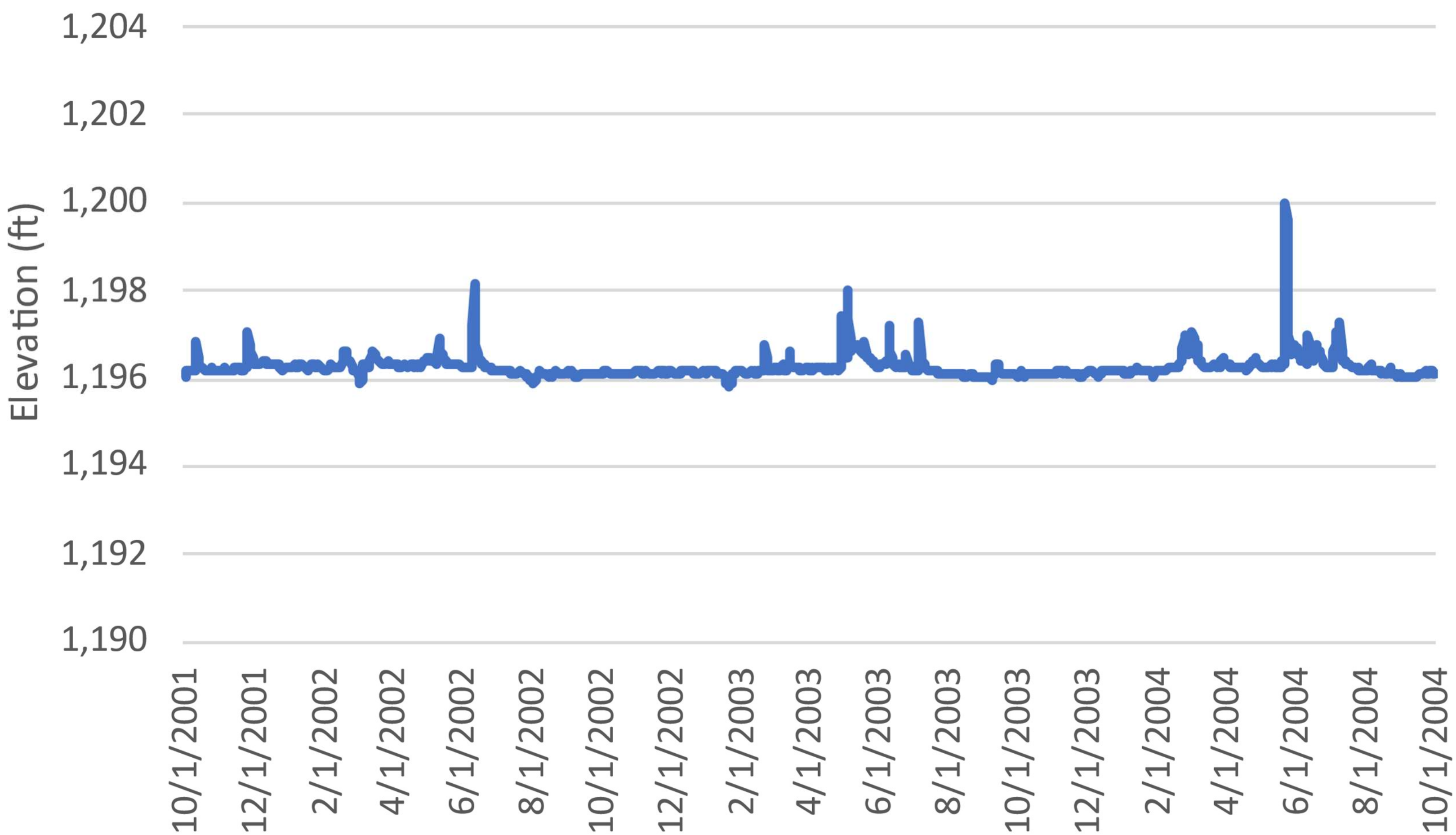

Figure 25: Water Surface Elevation with Inflow and Outflow for the Elkhorn River Dammed Lake for WY2001-2003 (Note that 1,169 is the lowest elevation in the potential lake)

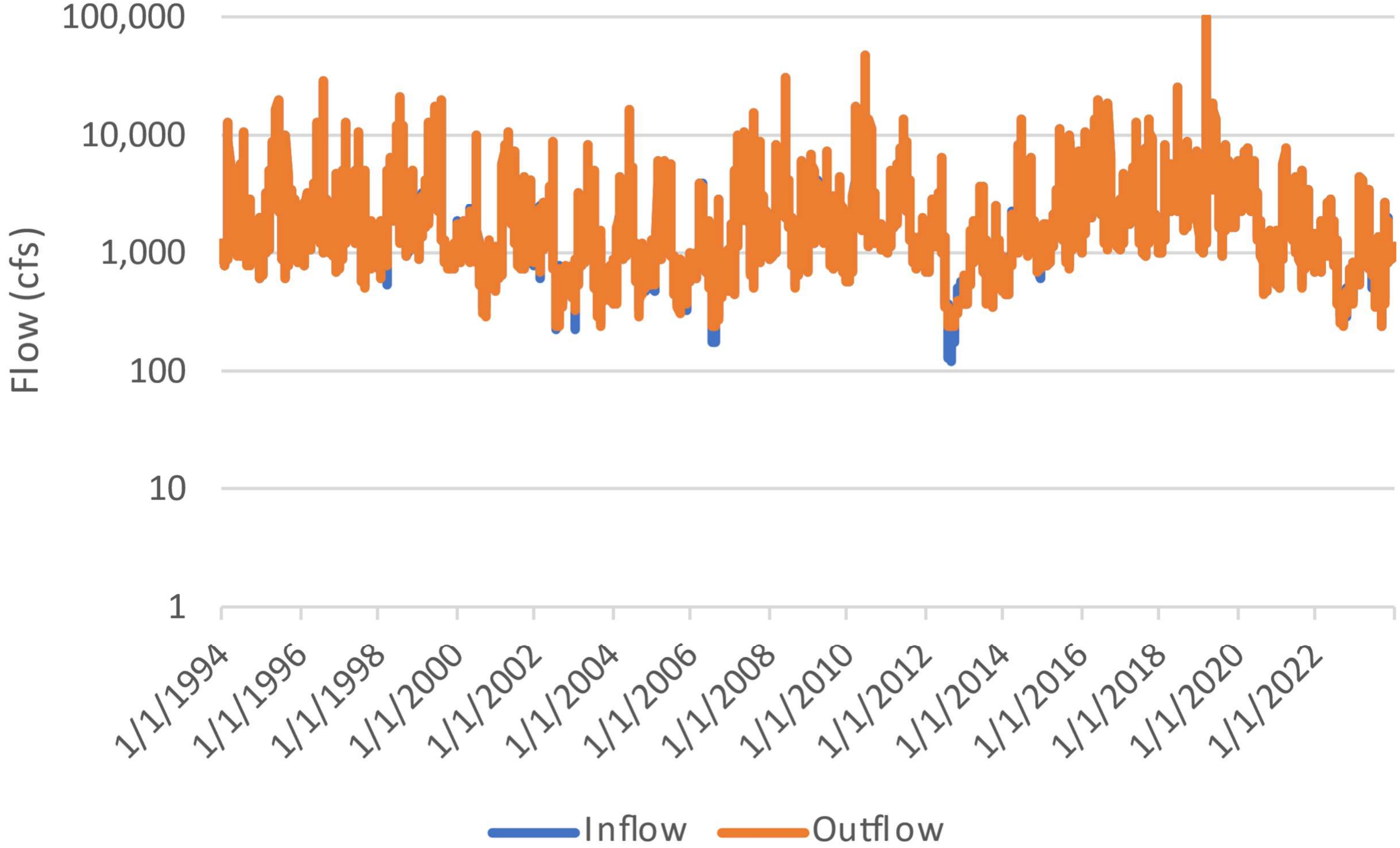

Figure 26: Inflow and Outflow for the Elkhorn River Dammed Lake during the WY1994-2023 Conditions

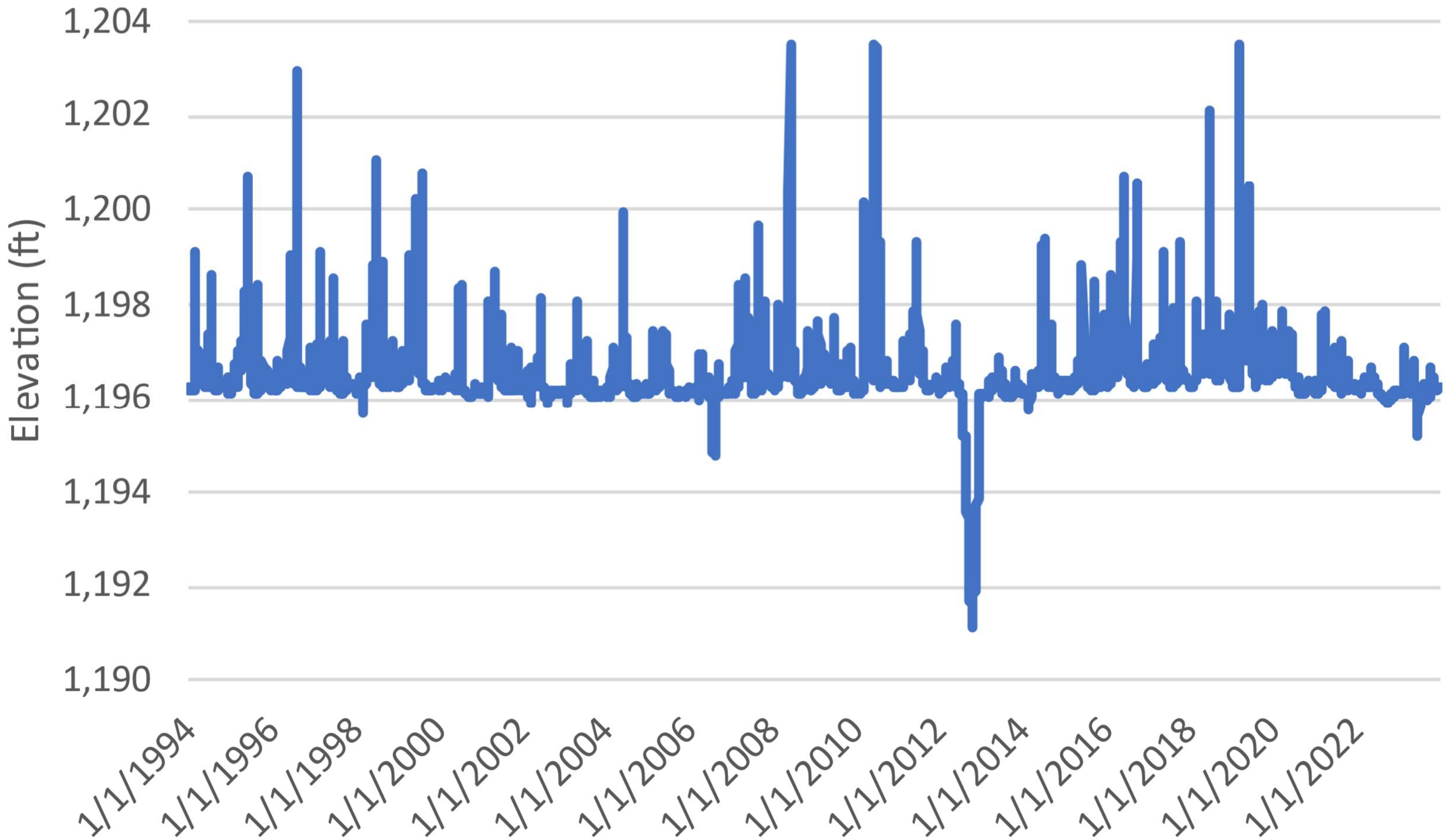

Figure 27: Water Surface Elevation for the Elkhorn River Dammed Lake during the WY1994-2023 Conditions (Note that 1,169 is the lowest elevation in the potential lake)

4.4 Salt Creek Dammed Lake Example

The outflows and lake elevations in the example Salt Creek dammed lake were evaluated under three conditions: repeated WY2006 flows, WY2001-2003, and 30-year evaluation 1994-2023.

4.4.1 Repeated WY2006 Flows

The Salt Creek dammed lake muted the inflow peaks of WY2006 because the water level in the lake dropped from its initial level at the spillway elevation (1,097 ft). Flows throughout the evaluation were controlled by the low flow rules (refer to Figure 28) and showed little variation. The water elevations frequently dropped below the spillway crest (refer to Figure 29) and the low flow rules were imposed 61 percent of the time.

4.4.2 WY2001-2003 Flows

The WY2001-2003 Salt Creek dammed lake evaluation showed more variation in flow than the repeated WY2006 run but flows were still mitigated from the inflow peaks because of the low flow rules (refer to Figure 30). Lake level did not drop as much as in the WY2006 evaluations but was frequently below the spillway crest at 1,097 feet, refer to Figure 31, where low flow rules were imposed 31 percent of the time.

4.4.3 1994-2023 Flows

The 30-year simulation showed that flows from the Salt Creek dammed lake would frequently be controlled by the low flows imposed on the lake management (refer to Figure 32). The lake would also have extended periods where water would not flow over the spillway, refer to Figure 33. Due to the smaller watershed size of the Salt Creek watershed, the Salt Creek dammed lake water levels during extended periods of low inflows are more sensitive than the Elkhorn River dammed lake due to the assumed low flow rules (low flow rules were imposed 15 percent of the total simulation time). Additionally, a more detailed analysis will be needed to determine the downstream flow requirements during those periods to fully characterize the potential water surface elevations.

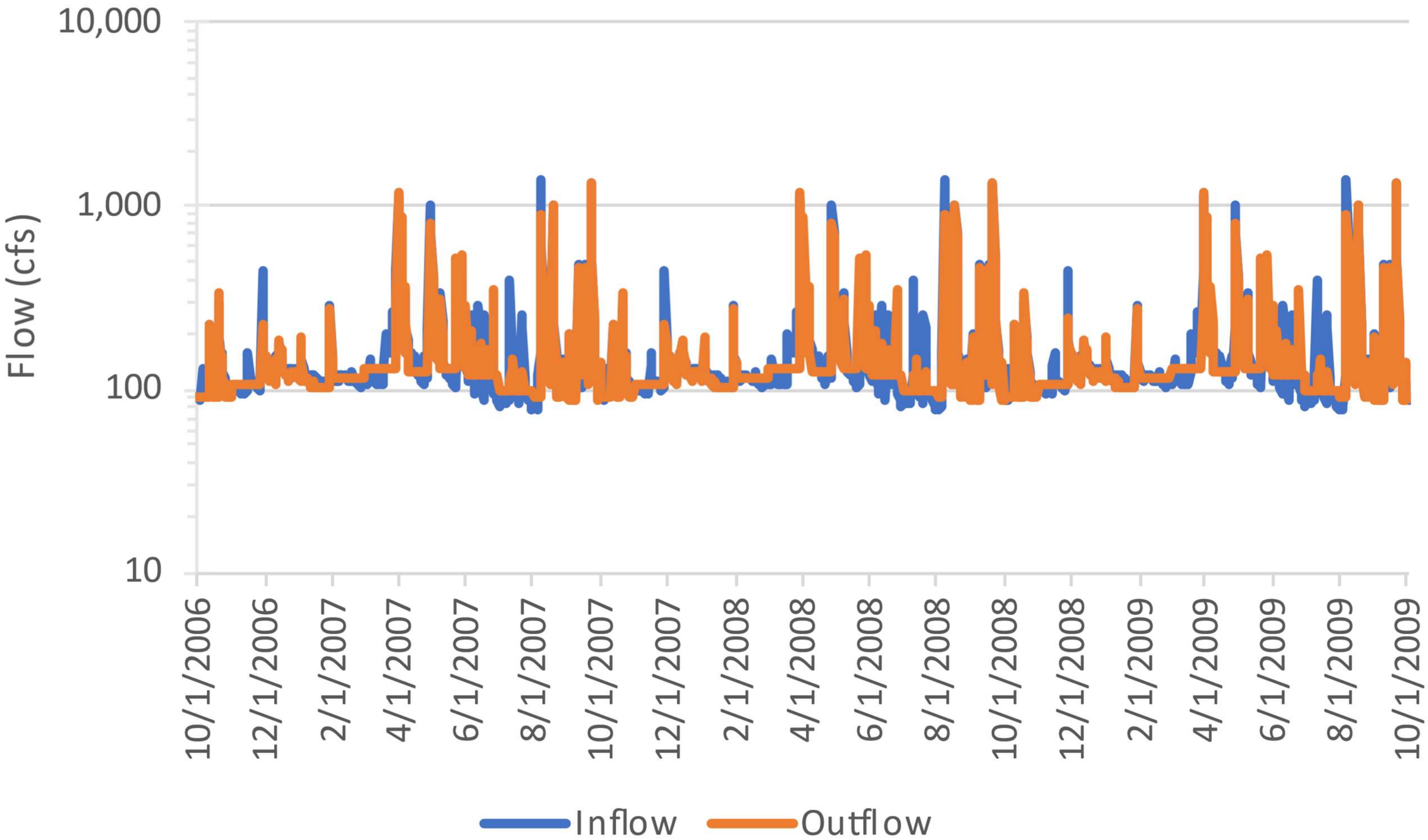

Figure 28: Inflow and Outflow for the Salt Creek Dammed Lake during the Repeated WY2006 Conditions

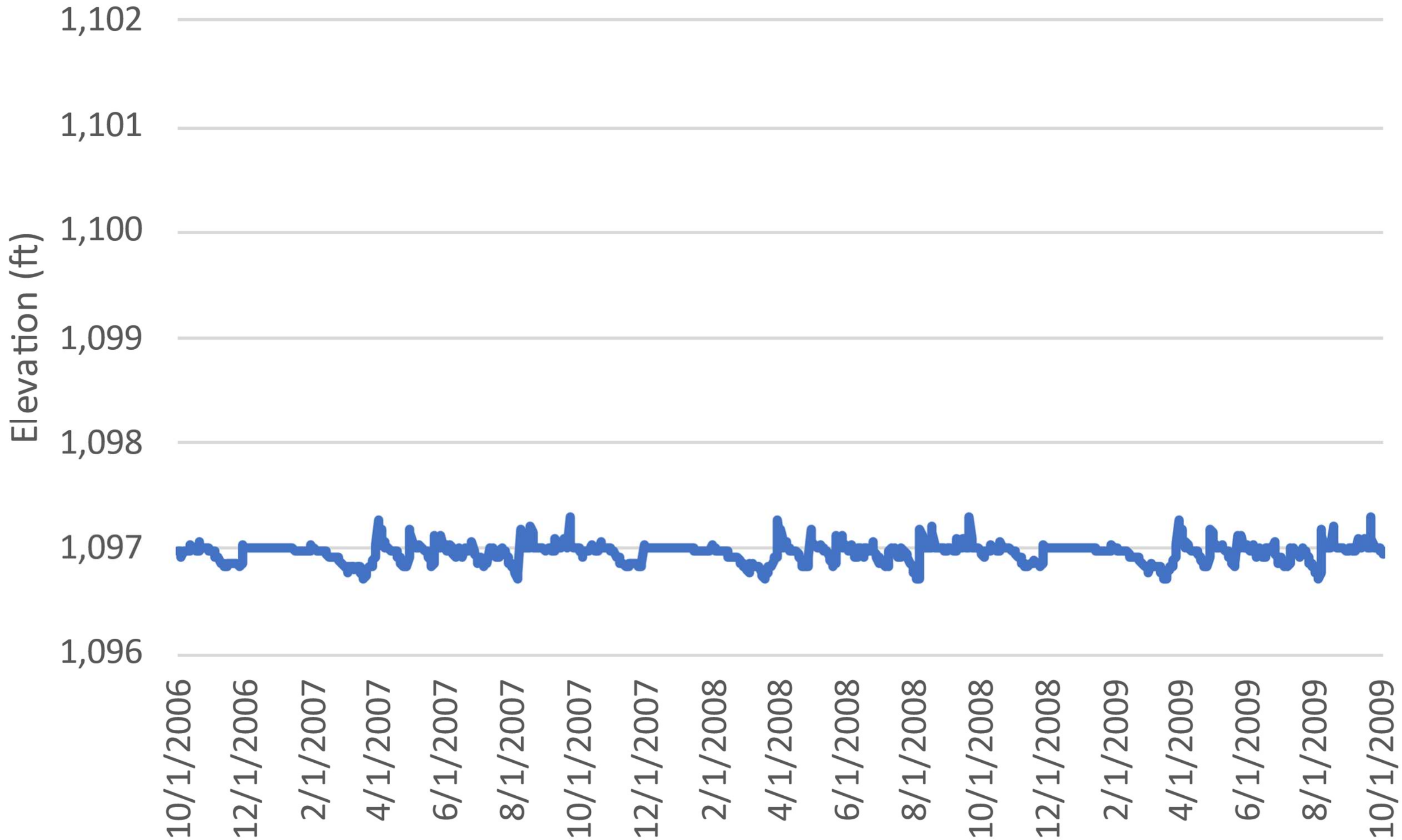

Figure 29: **Water Surface Elevation for the Salt Creek Dammed Lake during the Repeated WY2006 Conditions (Note that 1,058 is the lowest elevation in the potential lake)**

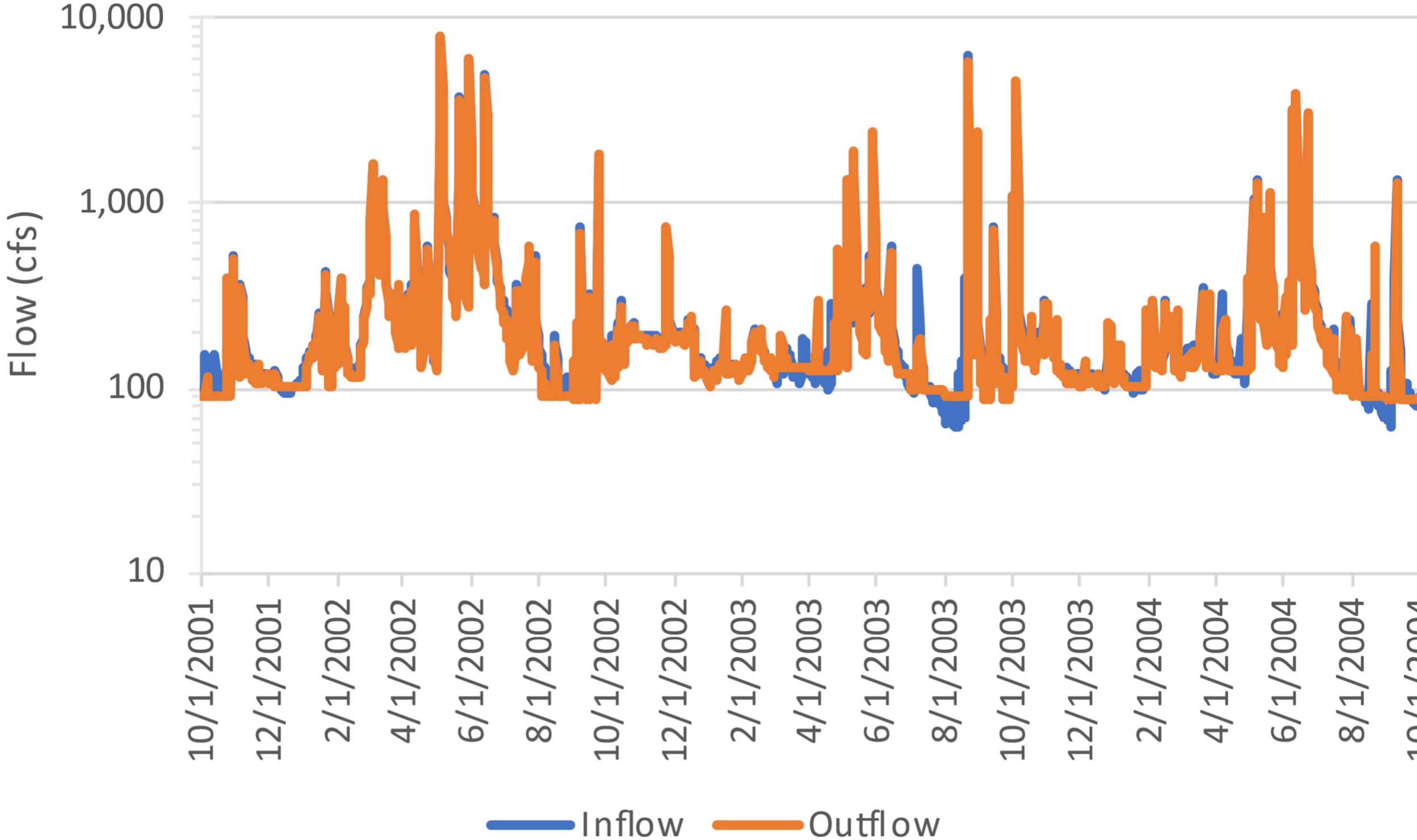

Figure 30: **Inflow and Outflow for the Salt Creek Dammed Lake during the WY2001-2003 Conditions**

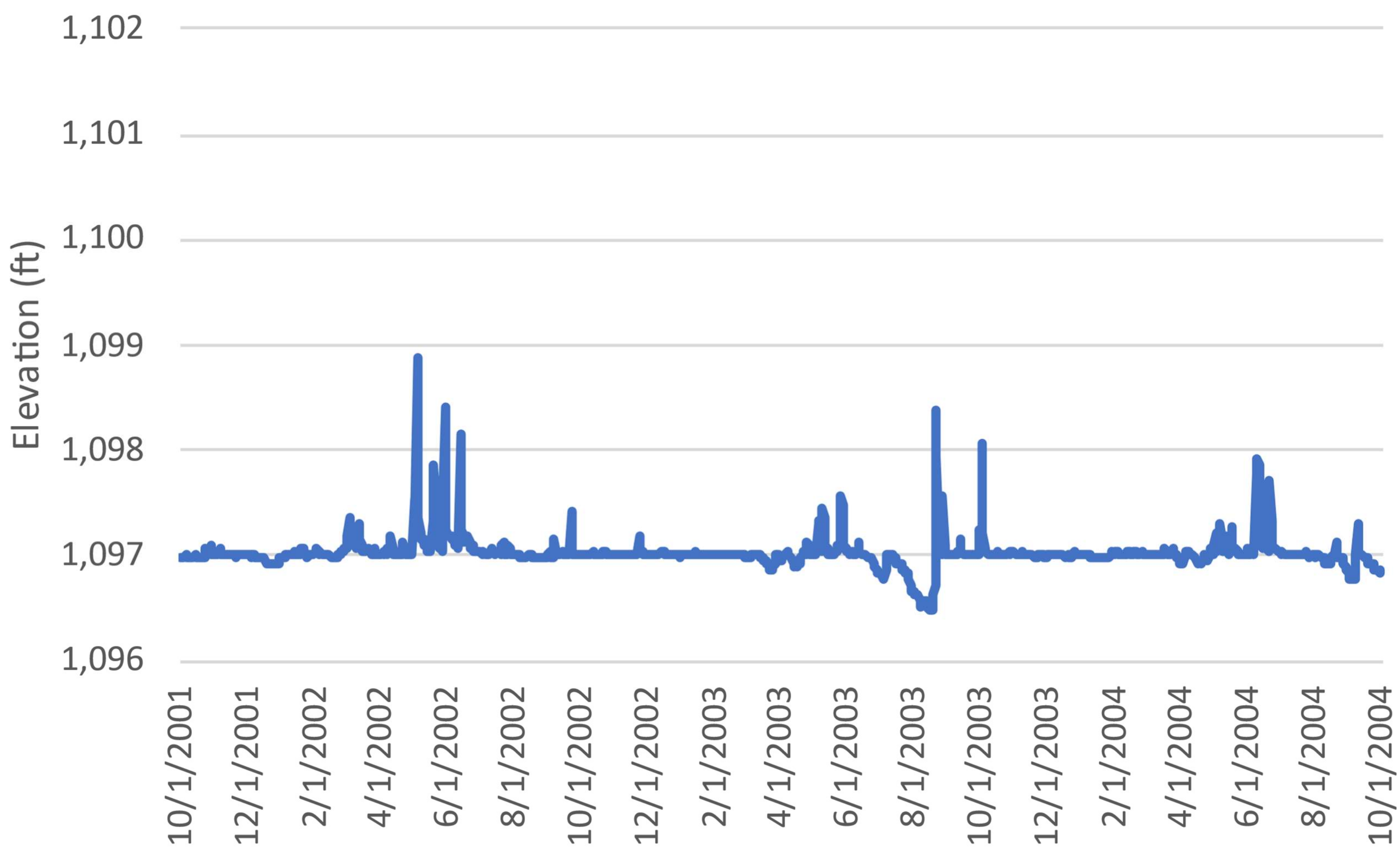

Figure 31: Water Surface Elevation for the Salt Creek Dammed Lake during the Repeated WY2001-2003 Conditions (Note that 1,058 is the lowest elevation in the potential lake)

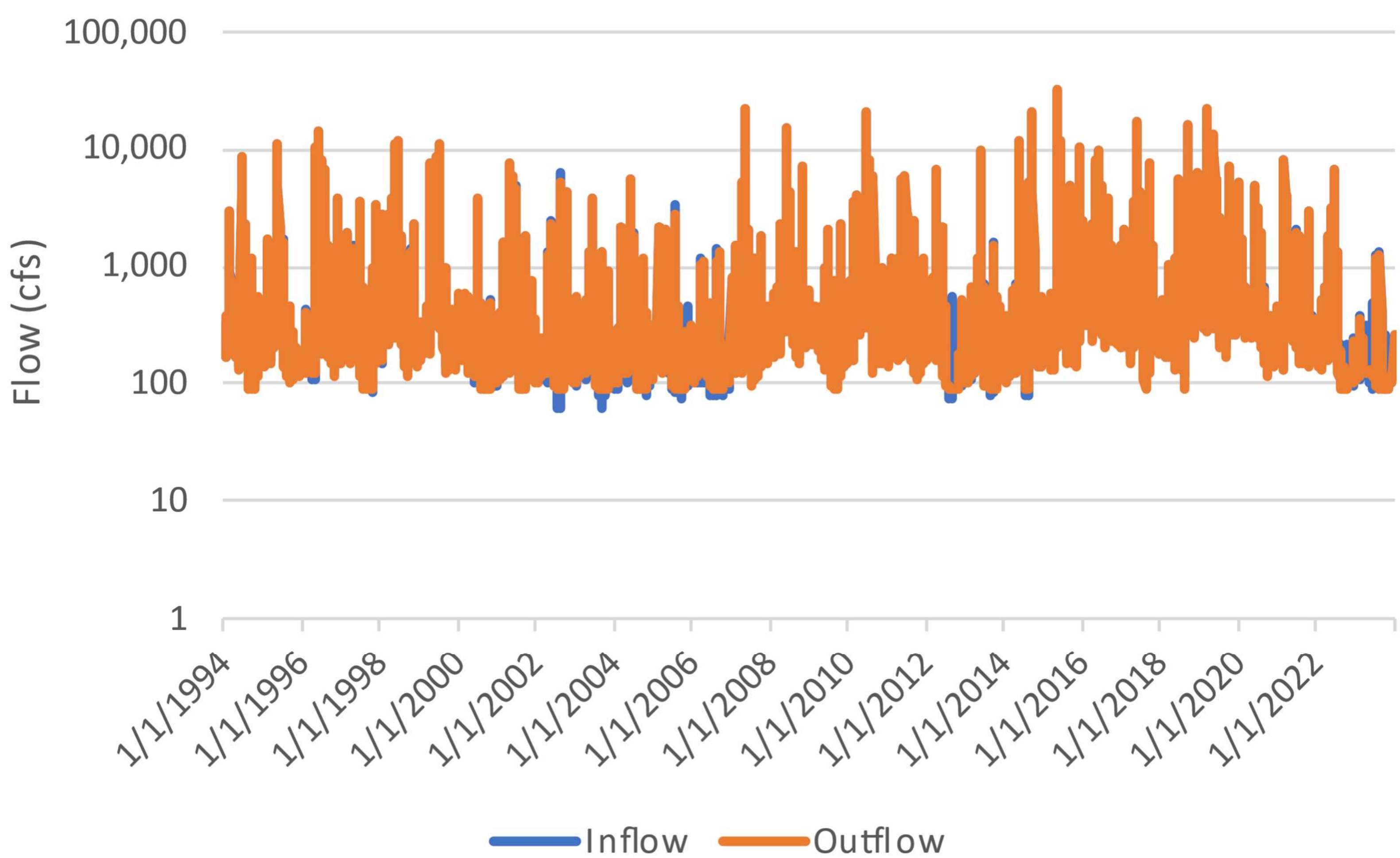

Figure 32: Inflow and Outflow for the Salt Creek Dammed Lake during the WY1994-2023 Conditions

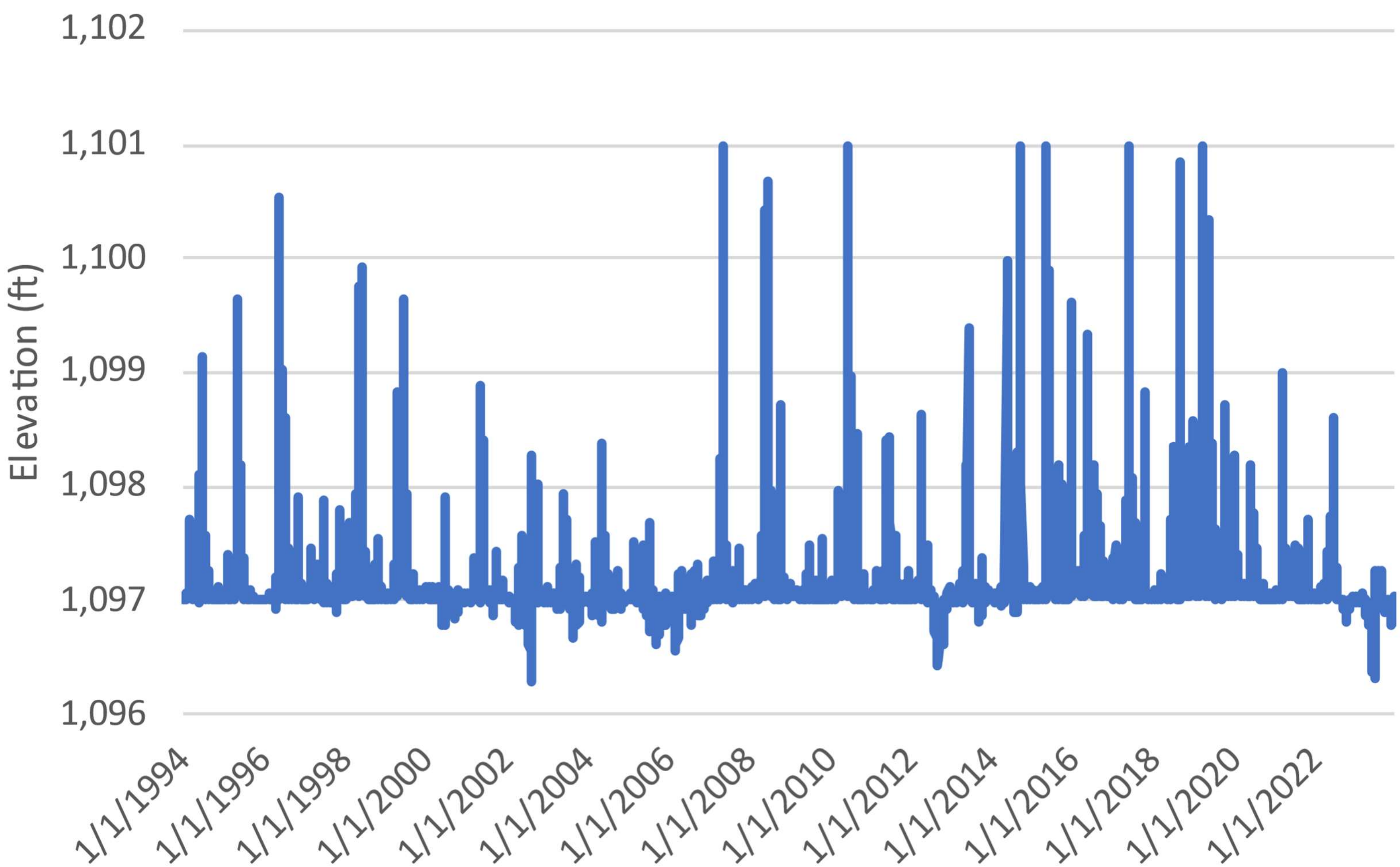

Figure 33: Water Surface Elevation for the Salt Creek Dammed Lake during the Repeated WY1994-2023 Conditions (Note that 1,058 is the lowest elevation in the potential lake)

5. CONCLUSIONS

The example Elkhorn River dammed lake and the example Salt Creek dammed lake are similar in storage volume with the Elkhorn River dammed lake being slightly larger with increasing depth (refer to Figure 34). Under average modeled conditions, the Elkhorn River dammed lake will pass 99.7 percent of the upstream volume to the Platte River while the Salt Creek dammed lake will pass 99.0 percent (Table 9). The year with the greatest reduction in passed flow for the Elkhorn River dammed lake (2022) passed 98.1 percent of the upstream volume to the Platte River while 2023 showed the greatest reduction in passed flows for the Salt Creek dammed lake (92.5 percent) (Table 9).

The average annual flow in the Elkhorn River is almost four times greater than in the Salt Creek because of a larger watershed. This difference allows the Elkhorn River dammed lake to deal with dry periods by having a base flow of more three times greater than in the Salt Creek dammed lake. Flows in the Salt Creek dammed lake are muted and heavily controlled by the low flow rules and as such, the relative impact of the evaporative and groundwater losses are much more significant (refer to Table 9). The minimum flow estimates controlled the downstream flows and the impacts on hydrology, geomorphology, biology, water quality, temperature and connectivity will need to be further evaluated under full feasibility studies.

This water balance provided an initial assessment of the viability of the potential lake locations along the Platte River, Elkhorn River, and Salt Creek. The operation of the recreational lake was not defined in this analysis. Because the lake is for recreational purposes, releases have not been assumed to be made for augmenting flows in the Platte River. A more detailed analysis of the water balance needs to be conducted before these lake locations can be fully evaluated, including lake operation and augmenting of downstream flow requirements. A more detailed hydrologic study with the lake inflows routed through the lakes and downstream via the spillway or low flow diversions should be conducted. The analysis was very sensitive to the low flow instream flow requirements and, thus, a detailed analysis of those instream flow requirements needs to be conducted. In addition, additional analysis and modeling will be required to determine the appropriate minimum flows, including any potential impacts on the wellfields or existing instream flow rights. The groundwater interactions should be more explicitly included, especially the Platte River large excavated lake and Platte River small excavated lake which are heavily reliant on groundwater interactions.

No fatal flaws were identified based on the water balance modeling for Platte River large excavated lake, Platte River small excavated lake, Elkhorn River dammed lake, and Salt Creek dammed lake in relation to LWS' wellfield and MUD's wellfields at Platte West and Platte South. For the excavated lakes, no advisory impacts were identified. If a dammed lake is pursued, further evaluation of releases needs to be conducted to minimize downstream impact. Therefore, it is recommended that full feasibility studies of the lakes be performed.

Table 9: Comparison of Flows from the Elkhorn River and Salt Creek to the Platte River With and Without the Dammed Lakes

	Elkhorn River Dammed Lake				Salt Creek Dammed Lake		
	Total Flow	Lake Flow	Percent to Platte River		Total Flow	Lake Flow	Percent to Platte River
1994	1,445,078	1,440,140	99.7%		392,602	387,503	98.7%
1995	2,136,472	2,132,416	99.8%		510,816	506,628	99.2%
1996	1,711,775	1,709,656	99.9%		620,920	618,732	99.6%
1997	1,443,394	1,440,492	99.8%		314,496	311,503	99.0%
1998	1,955,024	1,956,112	100.1%		723,876	724,999	100.2%
1999	2,054,434	2,049,351	99.8%		574,532	569,285	99.1%
2000	925,890	921,490	99.5%		209,270	204,750	97.8%
2001	1,545,886	1,541,344	99.7%		407,798	403,114	98.9%
2002	785,796	779,601	99.2%		254,781	248,446	97.5%
2003	762,046	758,797	99.6%		243,202	239,854	98.6%
2004	976,786	972,603	99.6%		293,430	289,120	98.5%
2005	1,038,099	1,037,113	99.9%		199,248	198,251	99.5%
2006	674,059	674,043	100.0%		172,510	172,490	100.0%
2007	1,894,171	1,892,146	99.9%		501,497	499,407	99.6%
2008	1,856,820	1,857,263	100.0%		735,524	735,981	100.1%
2009	1,509,521	1,508,340	99.9%		272,477	271,259	99.6%
2010	2,889,854	2,886,071	99.9%		690,336	686,430	99.4%
2011	1,822,304	1,819,761	99.9%		415,524	412,898	99.4%
2012	733,309	732,749	99.9%		249,966	249,033	99.6%
2013	737,982	740,489	100.3%		280,460	283,057	100.9%
2014	1,346,981	1,349,501	100.2%		516,070	518,672	100.5%
2015	1,411,862	1,408,386	99.8%		972,461	968,871	99.6%
2016	2,486,400	2,489,830	100.1%		718,279	721,821	100.5%
2017	1,938,288	1,937,112	99.9%		615,560	614,345	99.8%
2018	2,566,413	2,564,758	99.9%		624,048	622,339	99.7%
2019	3,529,944	3,530,248	100.0%		1,020,136	1,020,450	100.0%
2020	1,762,344	1,755,940	99.6%		470,503	463,891	98.6%
2021	1,423,547	1,415,497	99.4%		481,330	473,018	98.3%
2022	695,974	682,436	98.1%		302,148	288,178	95.4%
2023	693,398	680,974	98.2%		170,583	157,834	92.5%

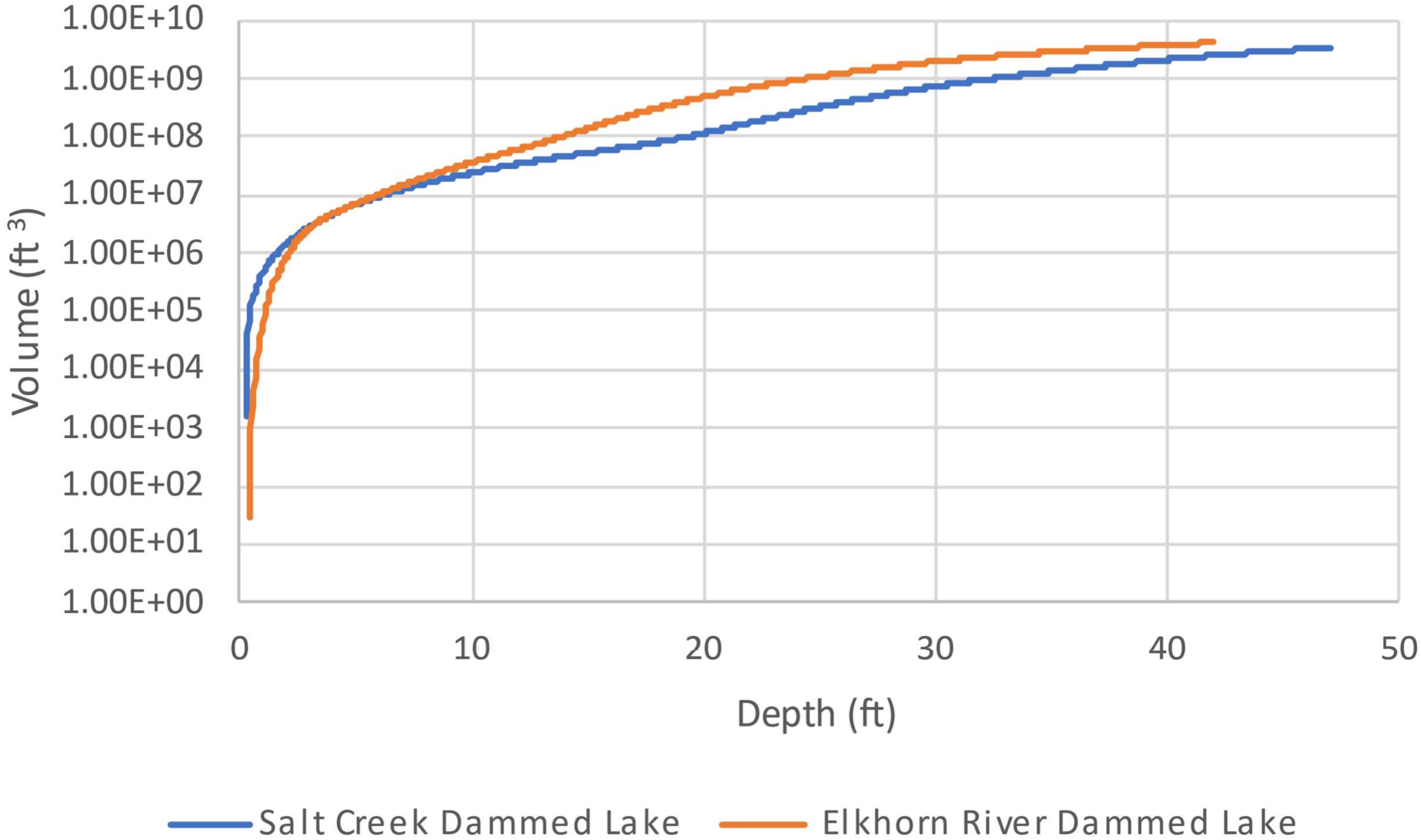

Figure 34: Comparison of the Salt Creek Dammed Lake and Elkhorn River Dammed Lake Volume and Depth

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APPENDIX D: DESKTOP GEOTECHNICAL ANALYSIS SUMMARY REPORT

LB 1023 (JEDI) IMPACT EVALUATION FOR CITY OF LINCOLN WATER SYSTEM AND METROPOLITAN UTILITIES DISTRICT: DESKTOP GEOTECHNICAL ANALYSIS SUMMARY REPORT

CITY PROJECT NO. 702309
OLSSON PROJECT NO. 021-01559
BLACK & VEATCH PROJECT NO. 413017

PREPARED FOR

LINCOLN
Transportation and Utilities

METROPOLITAN
UTILITIES DISTRICT

CITY OF LINCOLN WATER SYSTEM
METROPOLITAN UTILITIES DISTRICT
18 OCTOBER 2024

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TEL: 913.458.2000
www.bv.com

Project Name: LB 1023 (JEDI) Impact Evaluation for City of Lincoln Water System and Metropolitan Utilities District
Project Address/Location: Cass, Dodge, Douglas, Sarpy, and Saunders Counties

ACRONYMS AND ABBREVIATIONS

cfd/lf .... cubic feet per day per linear foot
cm/sec........ centimeters per second
CSD .... Conservation and Survey Division
JEDI .... Jobs and Economic Development Initiative
LWS .... City of Lincoln Water System
MUD........ Metropolitan Utilities District
NeDNR........ Nebraska Department of Natural Resources
NRCS........ Natural Resources Conservation Service
STAR WARS.. Statewide Tourism and Recreational Water Access and Resources Sustainability
UNL........ University of Nebraska-Lincoln
USCS........ Unified Soil Classification System
USDA .... United States Department of Agriculture
WSS........ Web Soil Survey

TABLE OF CONTENTS

Executive Summary 1

1. Introduction 1

2. Surface and Subsurface Conditions 3

- **2.1 Elkhorn River Dammed Lake** 3
- **2.2 Salt Creek Dammed Lake** 5
- **2.3 Platte River Large Excavated Lake** 7

3. Preliminary Geotechnical Seepage Analysis 11

4. Conclusions 13

5. Closure and Limitations 14

LIST OF FIGURES

Figure 1: Lake Locations Considered in This Analysis 2

Figure 2: UNL School of Natural Resources CSD Test Hole Locations Near the Potential Elkhorn River Dammed Lake 4

Figure 3: Groundwater Wells Registered with NeDNR Near the potential Elkhorn River Dammed Lake 5

Figure 4: UNL School of Natural Resources CSD Test Hole Locations Near the Potential Salt Creek Dammed Lake 6

Figure 5: Groundwater Wells Registered with NeDNR Near the Potential Salt Creek Dammed Lake 7

Figure 6: UNL School of Natural Resources CSD Test Hole Locations Near the Potential Platte River Large Excavated Lake 9

Figure 7: Groundwater Wells Registered with NeDNR Near the Potential Platte River Large Excavated Lake 10

LIST OF TABLES

Table 1: Estimated Soil Permeabilities for Preliminary Geotechnical Seepage Analysis 11

Table 2: Project Site Parameters for Preliminary Geotechnical Seepage Analysis 11

Table 3: Estimated Seepage Rates of Preliminary Geotechnical Seepage Analysis 12

ATTACHMENTS

Attachment A United States Department of Agriculture Natural Resources Conservation Service Web Soil Surveys

EXECUTIVE SUMMARY

In 2021 and 2022, the Nebraska legislature enacted LB406 and LB1023, respectively, which first established the Statewide Tourism and Recreational Water Access and Resources Sustainability (STAR WARS) special committee, and then the Lake Development Act which was codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (Neb. Rev. Stat. §61-401 to 61-404). In these pieces of legislation, the unicameral recognized the importance – in the wake of historic flooding in 2019 and the COVID-19 pandemic – for both flood control and major recreational opportunities in the state to attract and retain an increasingly remote workforce. The STAR WARS committee envisioned, in the lower Platte River corridor, a lake that would rival Iowa's Lake Okoboji as a tourist destination and hub for public-private partnerships to develop lakeside communities, a community town center, and a major resort. As outlined in the STAR WARS committee's report, a lake location northeast of the City of Ashland, Nebraska was contemplated and this informed the committee's recommendation that further analysis be conducted to inform viable locations for a lake of at least 3,600 acres, located in or near Sarpy County, and adjacent to – but not impounding – the Platte River.

Recognizing the potential for impacts to public water system wellfields, the legislature also appropriated funds to be administered through the Nebraska Department of Natural Resources (NeDNR) for further study on possible lake sites. The City of Lincoln Water System (LWS) already had its Water 2.0 project – investigating possibilities for additional source(s) of drinking water – underway with Black & Veatch and Olsson, and recognized that these consultants have the necessary expertise regarding the water system as well as expertise in the types of technical analysis needed for potential lake sites. Thus, LWS amended its Water 2.0 contract to include this study and entered into a memorandum of understanding with Omaha's Metropolitan Utilities District (MUD) to allow for MUD's wellfields and concerns to also be considered.

As part of the work under the amended Water 2.0 contract, Olsson was tasked to conduct desktop geotechnical analysis on potential lake sites identified through other analyses within the overall study, the purpose of which is to determine locations where a lake as envisioned in legislation should not be constructed because of impacts to existing infrastructure and/or municipal wellfields, especially those operated by LWS and Omaha's MUD.

This desktop geotechnical analysis involved research of available data and information on each possible lake site, including: (1) identification of general soil formations and engineering parameters; (2) review of groundwater and soil information obtained from test hole logs; (3) review of soil information obtained from registered groundwater wells; and (4) review of readily available geotechnical exploration and engineering reports and/or soil test boring logs completed nearby. It is noted that full site-specific geotechnical exploration and laboratory testing would need to be performed for any of these sites to properly determine geotechnical suitability, and the analysis described herein is performed as an initial screening. Three possible lake sites were examined: (1) a dammed lake on the Elkhorn River near Nickerson, Nebraska; (2) a dammed lake on Salt Creek between Greenwood and Ashland, Nebraska; and (3) an excavated lake on the Platte River downstream of Louisville, Nebraska.

For the dammed lake on the Elkhorn River, on-site soils generally comprise four different complexes that vary from well/excessively drained to very poorly drained. Permeability rates in the upper five feet of soil could generally be between 3.9×10^{-2} to 2.1×10^{-5} centimeters per second (cm/sec). On-site soils could include clay with varying silt or sand content overlying fine to coarse grained sands, with the possibility intermittent layers of fine to coarse grained gravels as well. Estimated seepage rates through the embankment and foundation of the embankment are calculated as less than 0.1 to 2.0 cubic feet per day per linear foot (cfd/lf), and less than 0.1 to 100 cfd/lf, respectively. Foundation seepage rates are expected to be highly variable, based on the likelihood of encountering intermittent layers of sands and gravels within the clay soil alluvial stratigraphy.

For the dammed lake on Salt Creek, on-site soils generally include two different complexes that are also described with variable drainage, but the permeability rates in the upper five feet of soil are expected to be within a smaller range than for the dammed lake on the Elkhorn River, at 9.2×10^{-4} to 2.5×10^{-5} cm/sec. On-site soils could comprise clays with varying silt and sand content or fine to coarse grained sands with varying silt and clay content; it is also possible that intermittent layers of clay soils could be encountered within the sand. In general, seepage through the lakebed would not be expected to be as significant or variable as through the dammed lake on the Elkhorn River. Additionally, limestone bedrock is generally encountered at depths ranging from approximately 40 to 116 feet below the surface, and Dakota sandstone or shale may be encountered at greater depths. Estimated seepage rates through the embankment and foundation of the embankment are calculated as less than 0.1 to 4.0 cfd/lf, and less than 0.1 to 300 cfd/lf, respectively. It is anticipated that seepage rates may be variable, as with the dammed lake on the Elkhorn River, and also that limestone bedrock below a depth of about 40 feet could be encountered which could indicates existence or potential development of karst conditions.

For the large excavated lake on the Platte River, soils largely comprise two complexes, both of which are described as at least well drained (one is described as excessively drained). Permeability rates could generally be between 3.9×10^{-2} and 1.4×10^{-4} cm/sec. Soils on the site could comprise clay with varying silt or sand content, and intermittent layers of fine to coarse grained sands and/or gravels could also be encountered. Sands and gravels may also be encountered with exposed sands more likely along the Platte River and near historic gravel pit areas. Layers of shale, sandstone, and ironstone were encountered in test holes in the area at depths as shallow as 125 feet and as deep as 205 feet below ground surface in the vicinity of this site. Estimated seepage rates through the embankment and foundation of the embankment are calculated as less than 0.1 to 0.3 cfd/lf, and less than 0.1 to 20 cfd/lf, respectively. Seepage rates may be high, based on the likelihood of encountering shallow sands and gravels associated with the Platte River and nearby quarries. Like the dammed lake on Salt Creek, the potential for existence or development of karst conditions exists at this location due to the variable depth of limestone bedrock.

1. INTRODUCTION

This report summarizes the results of a desktop geotechnical study for the construction of a lake at three potential project sites as shown in **Figure 1.** More specific project site location descriptions are as follows:

- **Elkhorn River Dammed Lake:** Dodge and Washington Counties: near Nebraska 91 from County Road R Boulevard to County Road L near Nickerson, Nebraska.
- **Salt Creek Dammed Lake:** Cass and Saunders Counties: north-northwest of U.S. 6 from 205th Street to County Road 7 between Greenwood, Nebraska and Ashland, Nebraska.
- **Platte River Large Excavated Lake:** Sarpy County: near Nebraska 50 from Riha Road to South 120th Street and north of the Platte River downstream of Louisville, Nebraska. For this analysis, only the Platte River Large Excavated Lake was investigated. It is our understanding that most of the Platte River Small Excavated Lake comprises sand and gravel quarries.

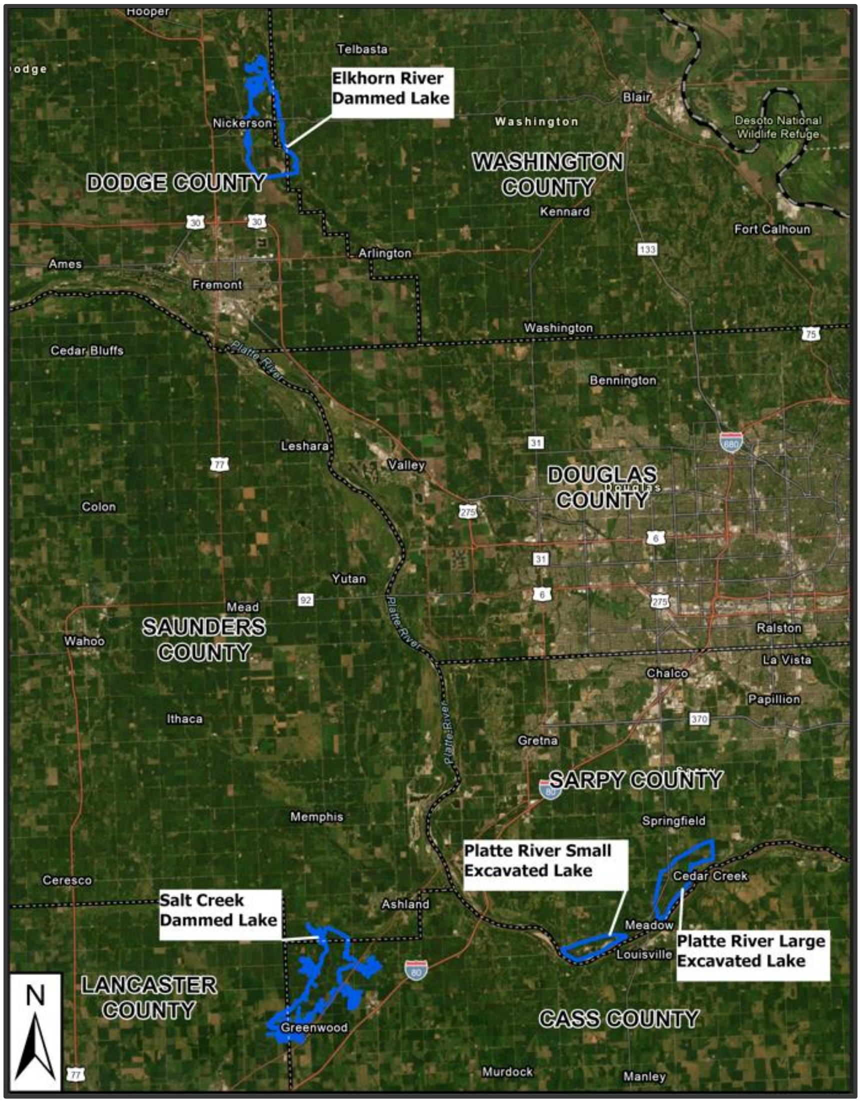

Figure 1: Lake Locations Considered in This Analysis

Our geotechnical and historical research of the parcels included the following:

- Review of United States Department of Agriculture (USDA) – Natural Resource Conservation Service (NRCS) Web Soil Survey (WSS) to identify general soil formations and engineering parameters across the potential lake sites;
- Review of groundwater and soil information obtained from test holes performed by the University of Nebraska-Lincoln (UNL) School of Natural Resources published on the Conservation and Survey Division (CSD) Ground Water and Geology Data Portal;
- Review of soil information obtained from active groundwater wells registered with the Nebraska Department of Natural Resources (NeDNR); and
- Review of readily available geotechnical exploration/engineering reports and/or soil test boring logs completed near the potential lake sites.

2. SURFACE AND SUBSURFACE CONDITIONS

While expected site conditions – based on desktop review – are discussed below, a final site-specific geotechnical exploration and appropriate laboratory testing must be performed to determine actual subsurface conditions at any selected site. In addition, the on-site soils should be visually classified and described in accordance with the Unified Soil Classification System (USCS).

In general, soil complexes comprising predominantly clay soils will have lower permeability rates versus those comprising predominantly sands. If soils comprise a combination of clays and sands, permeability rates could be highly variable.

2.1 Elkhorn River Dammed Lake

Based on soil information obtained from the NRCS WSS, the on-site soils generally appear to predominantly comprise the following soil complexes: Inavale-Cass-Barney, Zook-Wann-Leshara, Luton-Gibbon, and Zook-Wabash-Kennebec. The Inavale-Cass-Barney complex generally consists of deep, well drained to excessively drained soils formed in alluvium and sandy alluvium. The Zook-Wann-Leshara complex generally consists of very deep, very poorly drained to somewhat poorly drained soils formed in alluvium, calcareous alluvium, and loamy alluvium. The Luton-Gibbon complex generally consists of very deep, very poorly drained to somewhat poorly drained soils formed in calcareous alluvium and clayey alluvium. The Zook-Wabash-Kennebec complex generally consists of very deep, very poorly drained to moderately well drained soils formed in alluvium and silty alluvium.

In addition, the NRCS WSS indicates permeability rates in the upper five feet of the referenced soil complexes in the vicinity of the Elkhorn River dammed lake could generally be between 3.9 x 10^{-2} cm/sec and 2.1 x 10^{-5} cm/sec.

The on-site soils could comprise clay with varying silt or sand content overlying fine to coarse grained sands. Intermittent layers of fine to coarse grained gravels may also be encountered. A map indicating relevant soil associations in the project area are shown on the NRCS WSS presented in **Attachment A**.

There is information for eight test holes published on the UNL School of Natural Resources CSD Ground Water and Geology Data Portal that are located east and west of the potential dammed lake on the Elkhorn River. Based on review of the referenced test holes, groundwater was encountered at depths ranging from 2.4 to 75 feet circa 1940 to 2023. Shale was also encountered at depths ranging from approximately 156 to 209 feet below the ground surface in test holes 70-A-42, 71-A-42, 72-A-42, and 75-A-42. The approximate locations of the referenced test holes are presented in **Figure 2**.

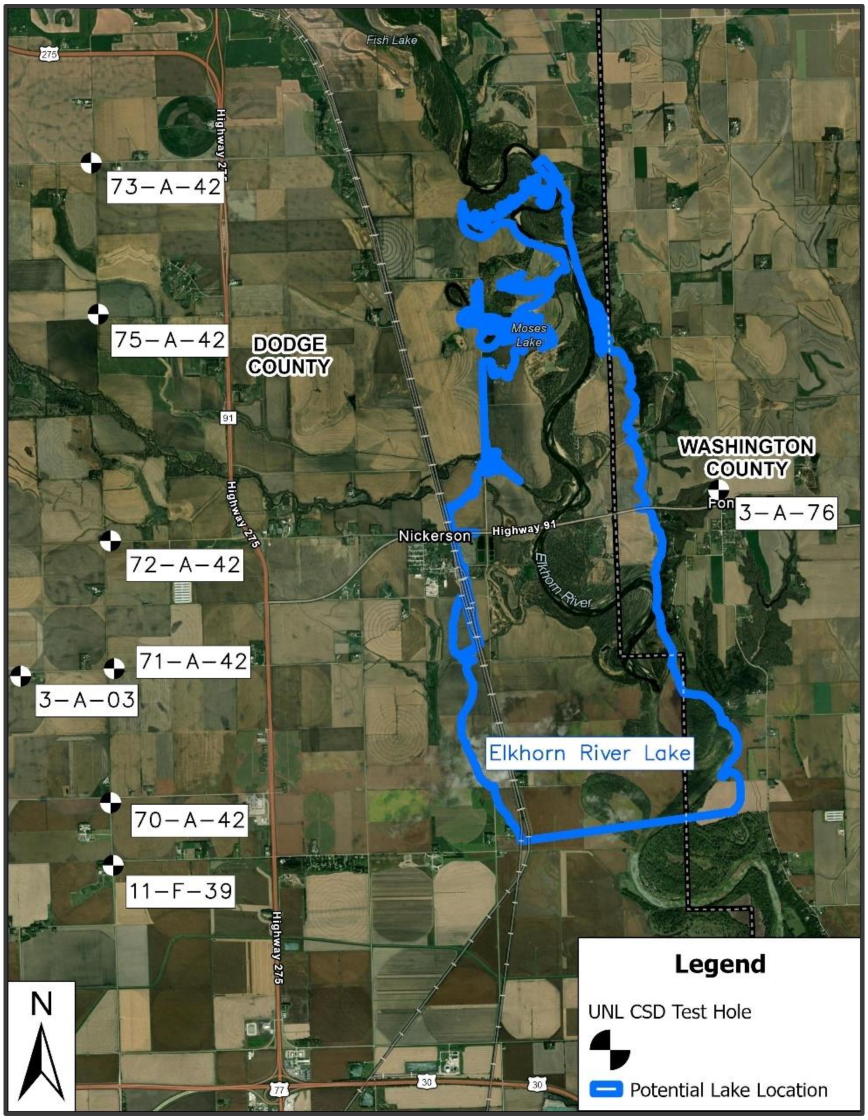

Figure 2: UNL School of Natural Resources CSD Test Hole Locations Near the Potential Elkhorn River Dammed Lake

Near the potential dammed lake on the Elkhorn River, there are numerous active and decommissioned groundwater wells registered with NeDNR as shown below in **Figure 3**. A purple, blue, green, yellow, or orange circle indicates and active groundwater well, while a letter 'x' indicates a decommissioned well. The soil and bedrock (shale) subsurface conditions described in the referenced groundwater wells are generally similar in composition to the soils discovered in the UNL School of Natural Resources CSD test holes.

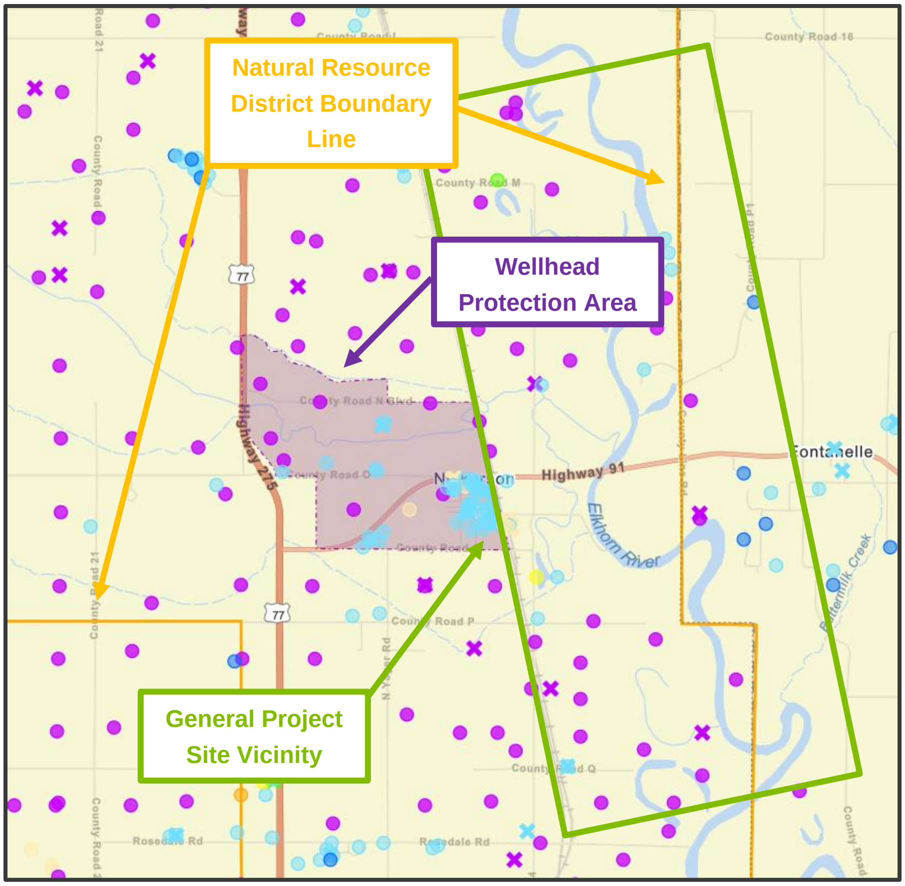

Figure 3: Groundwater Wells Registered with NeDNR Near the potential Elkhorn River Dammed Lake

2.2 Salt Creek Dammed Lake

Based on soil information obtained from the NRCS WSS, the on-site soils generally appear to predominantly comprise the following soil complexes: Zook-Wabash-Kennebec and Sharpsburg-Fillmore. The Zook-Wabash-Kennebec complex generally consists of very deep, very poorly drained to moderately well drained soils formed in alluvium and silty alluvium. The Sharpsburg-Fillmore complex generally consists of very deep, somewhat poorly drained to moderately well drained soils formed in loess.

In addition, the NRCS WSS indicates permeability rates in the upper five feet of the referenced soil complexes in the vicinity of the potential dammed lake on Salt Creek could generally be between 9.2 x 10^{-4} cm/sec and 2.5 x 10^{-5} cm/sec.

The on-site soils could comprise clays with varying silt and sand content or fine to coarse grained sands with varying silt and clay content. Intermittent layers of clay soils may also be encountered within sands. A map indicating relevant soil associations in the project area are shown on the NRCS WSS presented in **Attachment A**.

There is information for six test holes on the UNL School of Natural Resources CSD Ground Water and Geology Data Portal that are located in the vicinity of the potential dammed lake on Salt Creek. Based on review of the referenced test holes, groundwater was encountered at depths ranging from 0.5 to 43 feet circa 2008 to 2023. Limestone was also encountered at depths ranging from approximately 40 to 116 feet below the ground surface in test holes 1-SC-08, 3-SC-08, 4-SC-08, 5-SC-08, and 6-SC-08. The approximate locations of the referenced test holes are presented in **Figure 4**.

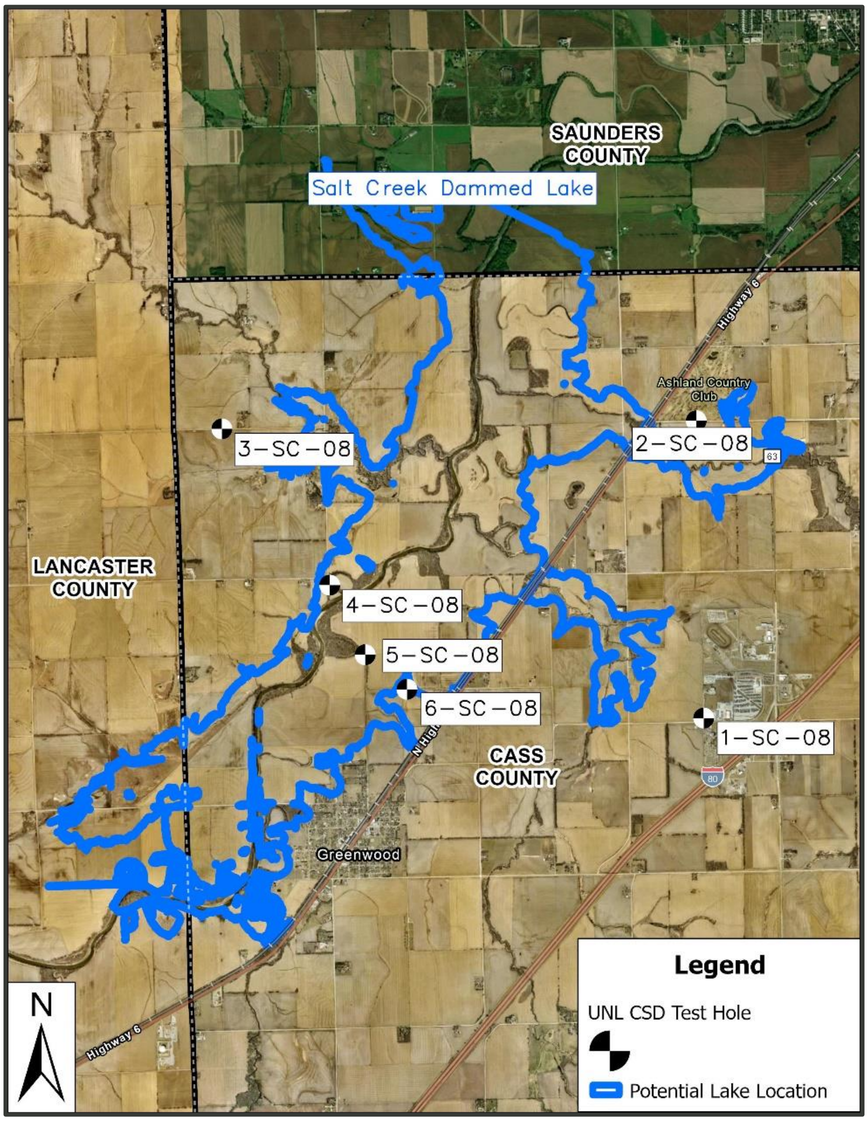

Figure 4: UNL School of Natural Resources CSD Test Hole Locations Near the Potential Salt Creek Dammed Lake

Near the potential dammed lake on Salt Creek, there are numerous active and decommissioned groundwater wells registered with NeDNR as shown below in **Figure 5**. As described previously, a purple, blue, green, yellow, or orange circle indicates an active groundwater well, while a letter ‘x’ indicates a decommissioned groundwater well. The soil and bedrock (limestone) subsurface conditions described in the referenced groundwater wells are generally similar in composition to the soils and bedrock discovered in the UNL School of Natural Resources CSD test holes. However, Dakota sandstone or shale may be encountered at greater depths (50 feet or more).

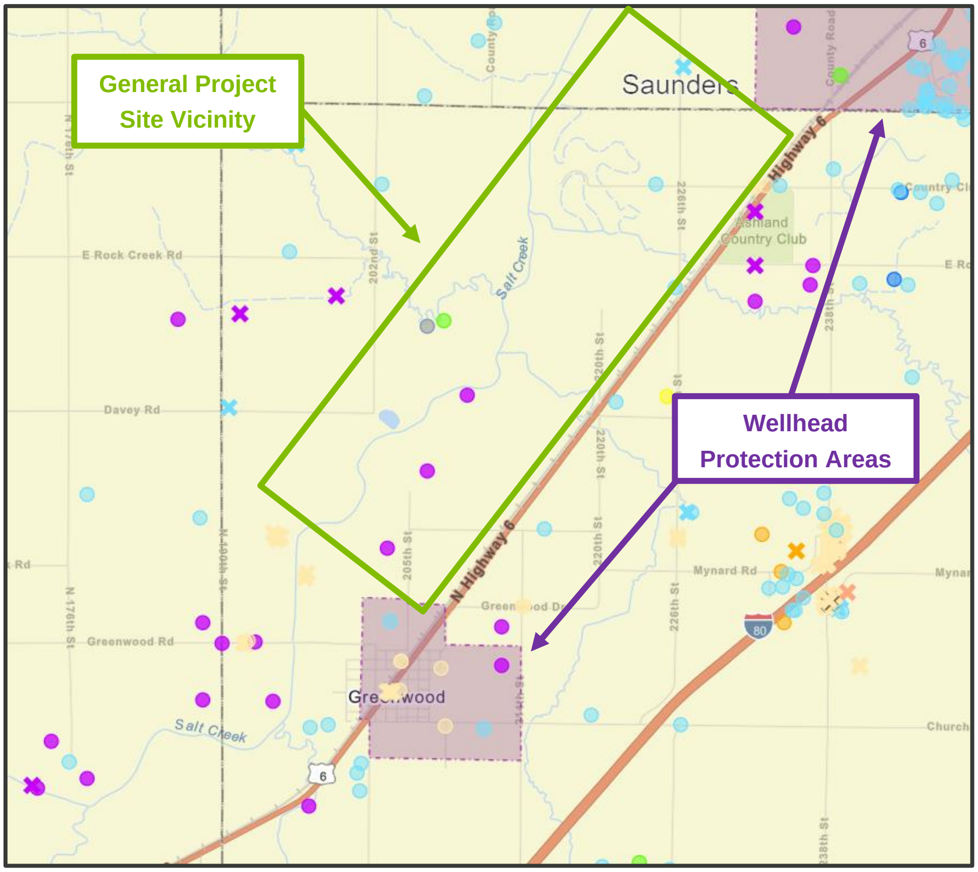

Figure 5: Groundwater Wells Registered with NeDNR Near the Potential Salt Creek Dammed Lake

2.3 Platte River Large Excavated Lake

Based on soil information obtained from the NRCS WSS, the on-site soils generally appear to predominantly comprise the following soil complexes: Ponca-Marshall and Inavale-Cass-Barney. The Ponca-Marshall complex generally consists of very deep, well drained soils that formed in loess. The Inavale-Cass-Barney complex generally consists of deep, well drained to excessively drained soils formed in alluvium and sandy alluvium. Previous sand and gravel pits were also noted at various locations along the Platte River.

In addition, the NRCS WSS indicates permeability rates in the upper five feet of the referenced soil complexes in the vicinity of the potential large excavated lake on the Platte River could generally be between 3.9 x 10^{-2} cm/sec and 1.4 x 10^{-4} cm/sec.

The on-site soils could comprise clay with varying silt or sand content. Intermittent layers of fine to coarse grained sands and/or gravels may also be encountered. Sands and gravels may also be encountered, with exposed sands more likely along the Platte River and near the historic gravel pit areas. A map indicating revelation soil associations in the area are shown on the NRCS WSS presented in **Attachment A**.

There is information for four test holes published on the UNL School of Natural Resources CSD Ground Water and Geology Data Portal that are located in the vicinity of the potential large excavated lake on the Platte River. Based on review of the referenced test holes, groundwater was encountered at depths ranging from 5 to 52 feet circa 1962 to 2023. Shale was also encountered at a depth of approximately 205 feet below the ground surface in test hole 26-80. Intermittent layers of sandstone, ironstone, and shale were encountered at a depth of approximately 125 feet below the ground surface in test hole 1-A-62. Lastly, intermittent layers of shale and limestone were encountered at a depth of approximately 91 feet below the ground surface in test hole 1-80. The approximate locations of the referenced test holes are presented below in **Figure 6**.

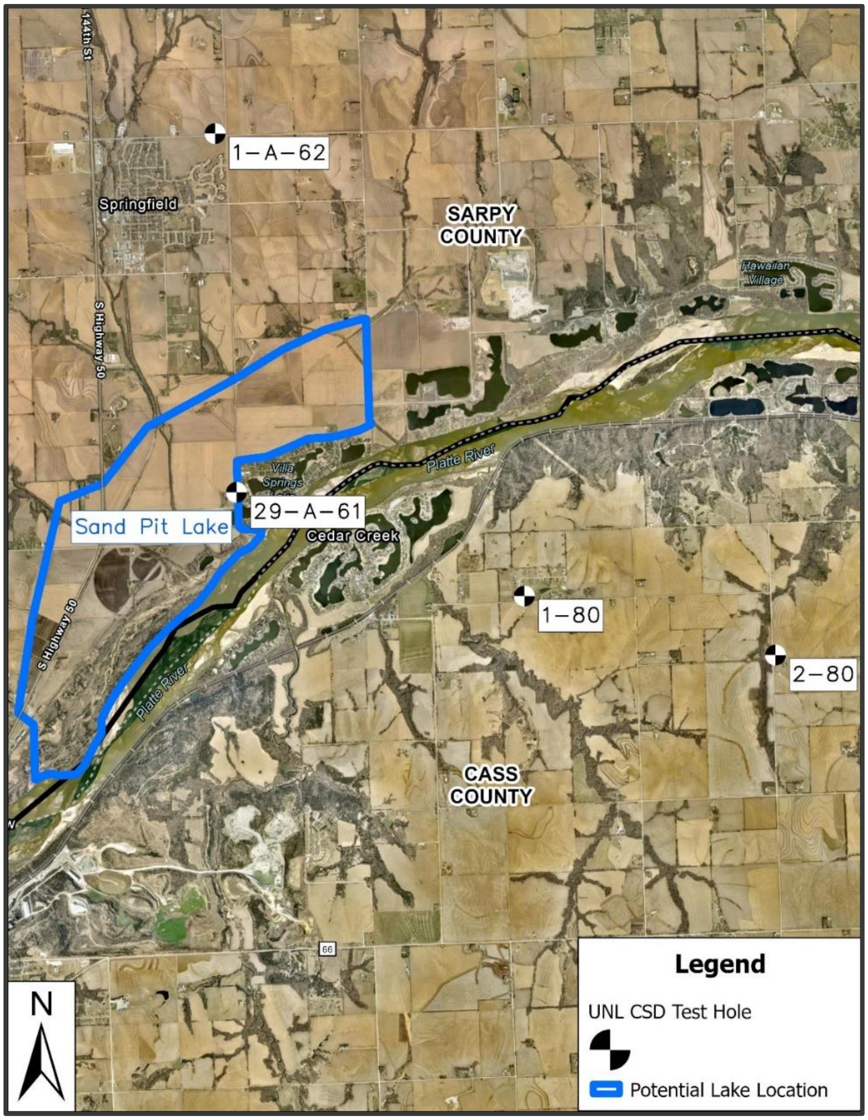

Figure 6: UNL School of Natural Resources CSD Test Hole Locations Near the Potential Platte River Large Excavated Lake

Near the potential Platte River Large Excavated Lake, there are numerous active and decommissioned groundwater wells registered with NeDNR as shown below in Error! Reference source not found.. The soil and bedrock (shale, sandstone, ironstone, and limestone) subsurface conditions described in the referenced groundwater wells are generally similar in composition to the soils and bedrock discovered in the UNL School of Natural Resources CSD test holes.

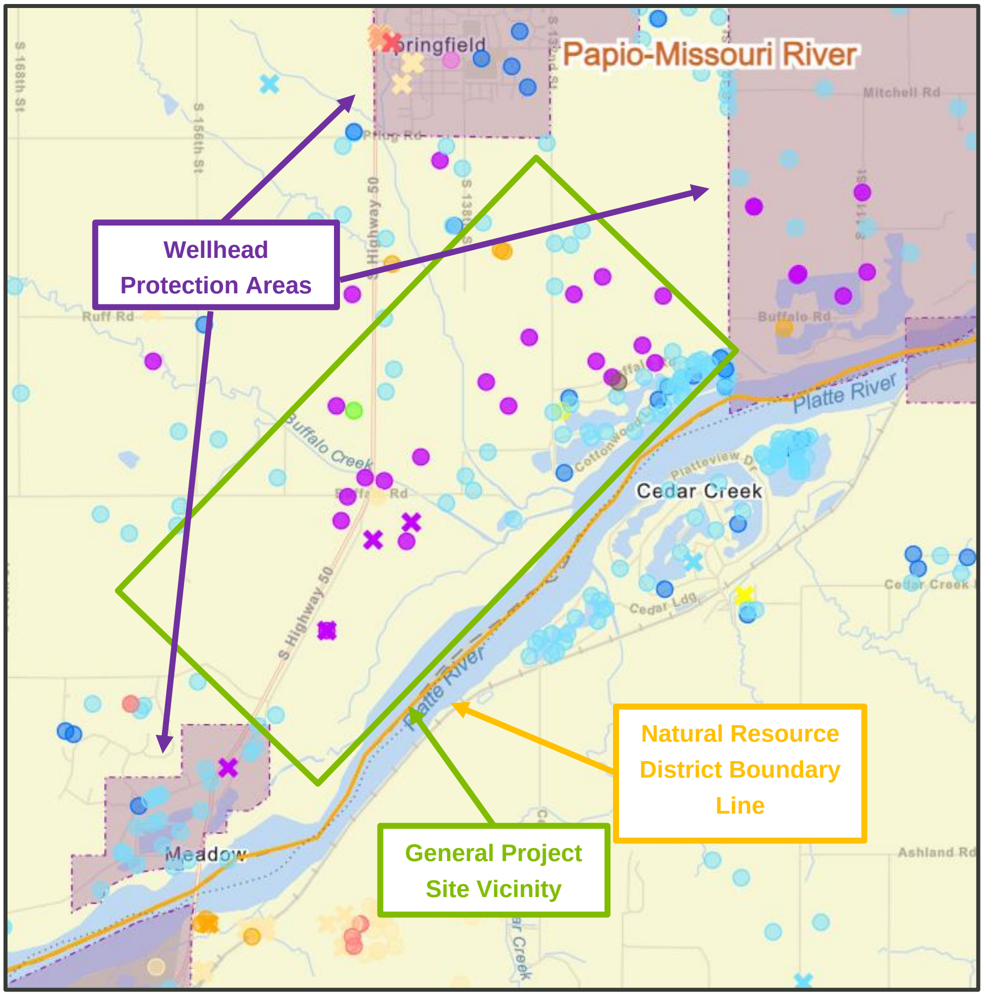

Figure 7: Groundwater Wells Registered with NeDNR Near the Potential Platte River Large Excavated Lake

3. PRELIMINARY GEOTECHNICAL SEEPAGE ANALYSIS

For the preliminary geotechnical seepage analysis at each potential site, we obtained the design parameters used to describe the physical behavior of the soils from available published information, our geotechnical engineering judgement, and local experience. The goal of this process is a hypothetical and conservative site characterization of seepage through embankments and underlying soil foundations based on the provided preliminary information.

The ranges of permeability rate were estimated conservatively by our engineering judgement through our local experience in the Nebraska region. **Table 1** displays estimated vertical and horizontal permeability rates used in our preliminary geotechnical seepage analysis. Please note that soil permeability can drastically vary based on numerous factors and, as such, actual soil permeabilities at each site could be outside of the listed ranges.

Table 1: Estimated Soil Permeabilities for Preliminary Geotechnical Seepage Analysis

Formation	Vertical Permeability (cm/s)	Horizontal Permeability (cm/s)
Embankment Soils	1.0E-05 to 1.0E-07	1.0E-04 to 1.0E-06
Foundation Soils	1.0E-03 to 1.0E-07	1.0E-02 to 1.0E-06

In addition, based on information provided by the Olsson/Black & Veatch project team, the following parameters for each site were used in our preliminary geotechnical seepage analysis.

Table 2: Project Site Parameters for Preliminary Geotechnical Seepage Analysis

Project Site	Surface Area (acres)	Embankment Length (feet)	Maximum Embankment Height (feet)	Normal Pool Elevation (feet)	Top of Embankment Elevation (feet)
Elkhorn River Dammed Lake	4,123.37	9,000	36	1,196	1,206
Salt Creek Dammed Lake	4,113.00	5,500	50	1,097	1,107
Platte River Large Excavated Lake	2,097.39	52,462	32*	1,005	1,027

**Estimate based on an assumed low ground surface elevation of 995*

To complete our analysis, we assumed that the proposed embankments would comprise idealized trapezoidal cross-sections with crest widths of 20 feet, upstream/downstream slopes of 3(H):1(V), and embankment toe drains located within the downstream portion of the embankments. Our analysis evaluated seepage at the maximum embankment section. The results of our preliminary geotechnical seepage analysis are presented in **Table 3**.

Table 3: Estimated Seepage Rates of Preliminary Geotechnical Seepage Analysis

Project Site	Maximum Embankment Height (feet)	Normal Pool Elevation (feet)	Estimated Seepage Rates Through Embankment (cfd/lf)	Estimated Seepage Rates Through Foundation (cfd/lf)
Elkhorn River Dammed Lake	36	1,196	<0.1 to 2.0	<0.1 to 200
Salt Creek Dammed Lake	50	1,097	<0.1 to 4.0	<0.1 to 300
Platte River Large Excavated Lake	32*	1,005	<0.1 to 0.3	<0.1 to 20

The results show that seepage through an embankment and the underlying foundation soils of the embankment depend on the soil permeability and water gradient between the normal pool elevations and the downstream toe elevations. As shown above, change in conditions such as gradient (displayed through the maximum embankment height) and permeability can play a significant role in seepage through a dam.

We reiterate that full analysis involving a soils investigation that includes sampling and laboratory testing must be completed for any selected site in order to properly assess seepage.

4. CONCLUSIONS

Considering the potential surface and subsurface conditions as well as potential seepage rates, we anticipate there to be general concerns at each possible site. Here, we provide a preliminary overview of general concerns at each project site as they relate to the feasibility of construction.

Near the dammed lake on the Elkhorn River, shallow groundwater could be a potential concern during earthwork operations and excavations. If shallow groundwater is encountered during earthwork operations and excavations, dewatering operations would need to be considered. In addition, we anticipate foundation seepage rates to be highly variable based on the likelihood of encountering intermittent layers of sands and gravels within the clay soil stratigraphy of the alluvium. If seepage rates are higher than desired, remediation of foundation soils may be required.

Near the dammed lake on Salt Creek, shallow groundwater could also be a potential concern during earthwork operations and excavations. Again, if it is encountered, dewatering operations would need to be considered. We also, again, anticipate seepage rates may be variable based on the likelihood of encountering intermittent layers of sands and gravels within the clay soil stratigraphy. Bedrock (limestone) below a depth of approximately 40 feet could be encountered, which could cause concern for karst conditions to be present or develop based on the potential of shallow groundwater. Evaluation of such conditions should be considered if this project site is selected.

Lastly, near the large excavated lake on the Platte River, shallow groundwater could again be a concern during earthwork operations and excavations. We anticipate seepage rates may be high based on the likelihood of encountering shallow sands and gravels associated with the Platte River and nearby quarries. If seepage rates are higher than desired, remediation of the foundation soils may be required. While bedrock (shale or limestone) may be encountered deeper at this project, we anticipate the depth to bedrock may be variable based on the vicinity of the existing and operating quarry. Paired with shallow groundwater, karst conditions could be present or develop in the underlying limestone. Evaluation of such conditions should be considered if this project site is selected.

We note, again, that this information should be considered preliminary in nature as site-specific geotechnical explorations will be required to document site-specific subsurface and groundwater conditions prior to future development, earthwork, and construction. In essence, the information included in this report provides estimates of possible seepage results.

5. CLOSURE AND LIMITATIONS

The information presented in this report has been gathered, reviewed, and interpreted by an Olsson Professional Geotechnical Engineer. However, this information should be considered preliminary in nature as site-specific geotechnical explorations will be required to document site-specific subsurface and groundwater conditions prior to future development, earthwork, and construction.

Furthermore, the above information is intended only to provide an estimate of possible seepage results. Final seepage results must be based on final site-specific geotechnical explorations and final project characteristics such as surface area, dam dimensions, final pool elevation, thickness of clay layer, etc.

We appreciate the opportunity to provide our services for this project. Should you have any questions regarding the information provided, please do not hesitate to contact us at your convenience.

Respectfully submitted,
Olsson, Inc.
Nebraska Certificate of Authority No. CA-0638

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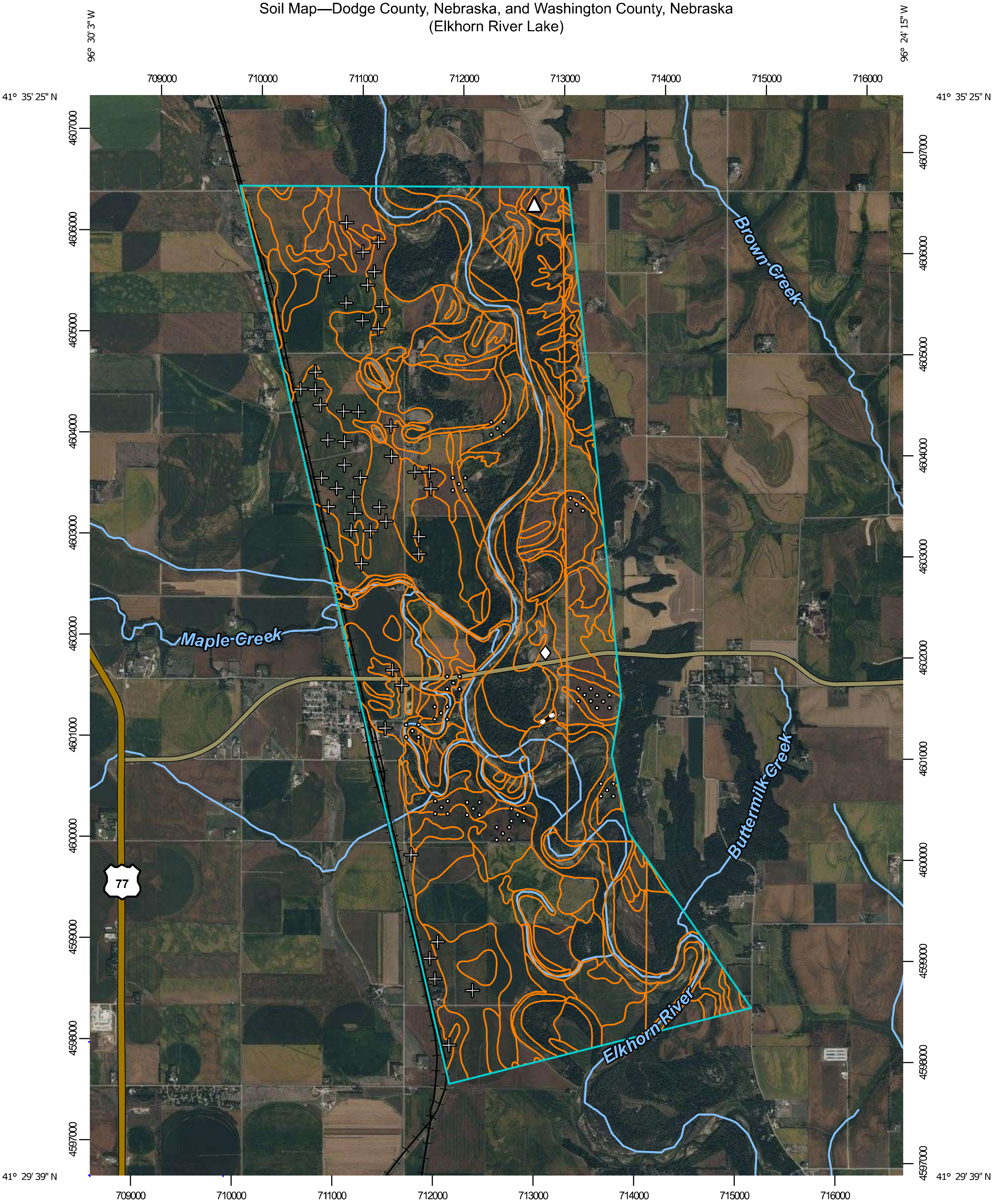
ATTACHMENT A

United States Department of Agriculture Natural Resources Conservation Service Web Soil Surveys

Soil Map—Dodge County, Nebraska, and Washington County, Nebraska
(Elkhorn River Lake)



Map Scale: 1:52,000 if printed on A portrait (8.5" x 11") sheet.

Meters: 0 500 1000 2000 3000

Feet: 0 2500 5000 10000 15000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at scales ranging from 1:12,000 to 1:20,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Dodge County, Nebraska
Survey Area Data: Version 25, Sep 6, 2023

Soil Survey Area: Washington County, Nebraska
Survey Area Data: Version 22, Sep 7, 2023

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Data not available.

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

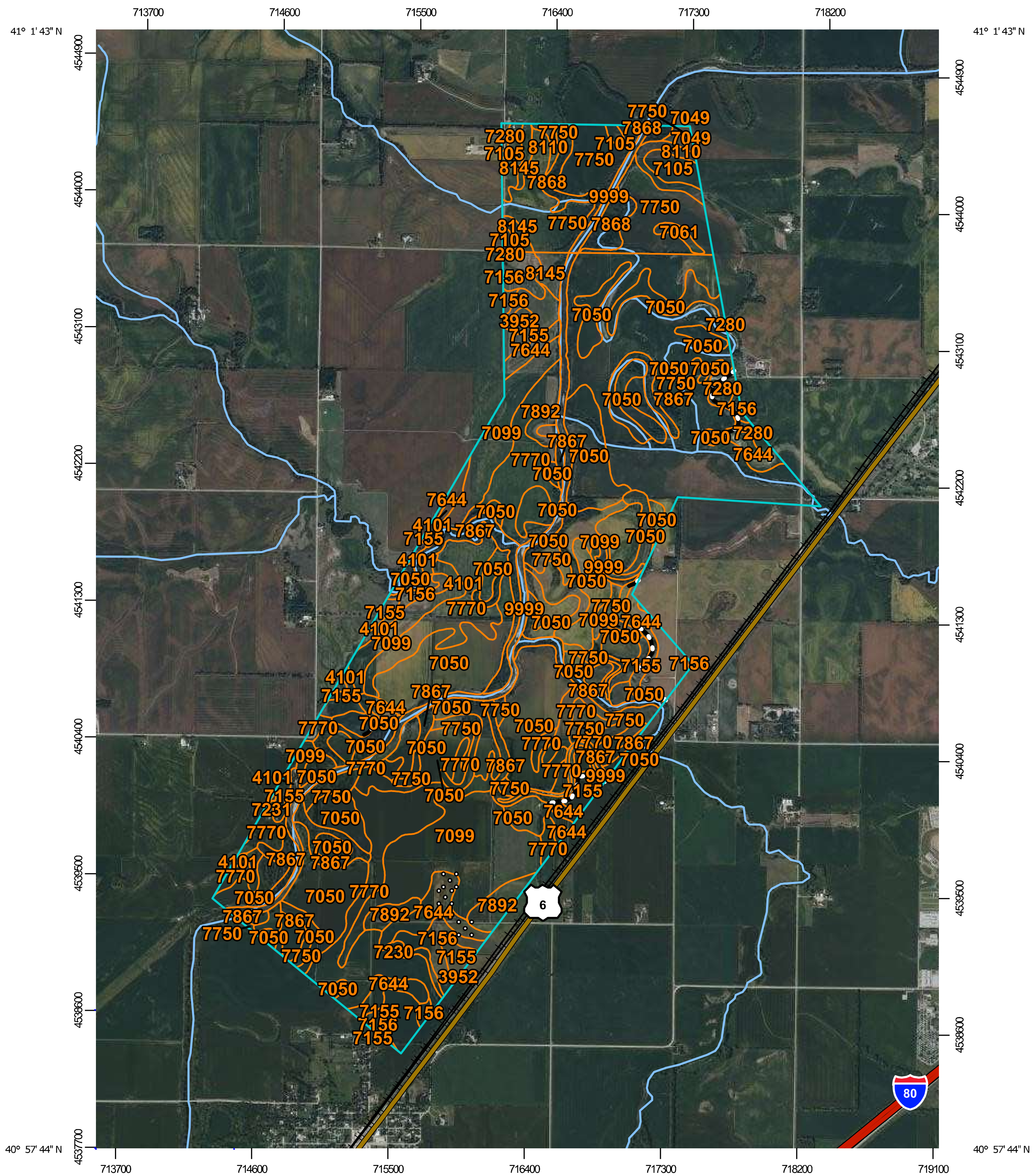
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
2110	Inavale loamy fine sand, 0 to 3 percent slopes, occasionally flooded	120.4	2.0%
2288	Wann loam, 0 to 2 percent slopes, occasionally flooded	254.1	4.3%
3521	Cass fine sandy loam, 0 to 2 percent slopes, occasionally flooded	71.7	1.2%
3529	Gibbon loam, 0 to 2 percent slopes, occasionally flooded	632.7	10.6%
3537	Gibbon silty clay loam, occasionally flooded	279.0	4.7%
3710	Cass fine sandy loam, 0 to 2 percent slopes, rarely flooded	42.3	0.7%
6324	Coleridge silty clay loam, 0 to 2 percent slopes, occasionally flooded	12.4	0.2%
6327	Fontanelle silty clay loam, frequently flooded	16.5	0.3%
6380	Saltine-Gibbon complex, occasionally flooded	38.5	0.6%
6385	Shell silt loam, occasionally flooded	35.8	0.6%
6526	Janude loam, rarely flooded	84.4	1.4%
6528	Janude loam, clayey substratum, rarely flooded	150.8	2.5%
6545	Moody silty clay loam, terrace, 0 to 2 percent slopes	329.0	5.5%
6603	Alcester silty clay loam, 2 to 6 percent slopes	51.0	0.9%
6681	Crofton silt loam, 17 to 30 percent slopes, eroded	10.9	0.2%
6738	Thurman-Moody complex, 11 to 30 percent slopes, eroded	0.3	0.0%
6750	Nora silt loam, 11 to 17 percent slopes, eroded	9.8	0.2%
6768	Nora silty clay loam, 6 to 11 percent slopes, eroded	18.8	0.3%
6774	Nora-Crofton complex, 11 to 17 percent slopes, eroded	38.4	0.6%
6860	Crofton silt loam, 8 to 17 percent slopes, eroded	22.2	0.4%
7050	Kennebec silt loam, occasionally flooded	120.7	2.0%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
7055	Kennebec and Colo soils, channeled, frequently flooded	15.2	0.3%
7099	Zook silty clay loam, 0 to 2 percent slopes, occasionally flooded	104.8	1.8%
7612	Steinauer clay loam, 11 to 30 percent slopes, eroded	96.9	1.6%
7787	Luton silty clay, occasionally flooded	687.4	11.5%
7891	Zook silt loam, overwash, 0 to 2 percent slopes, occasionally flooded	185.8	3.1%
7902	Monona silt loam, terrace, 2 to 6 percent slopes	9.3	0.2%
8418	Boel loam 0 to 2 percent slopes, occasionally flooded	86.6	1.5%
8433	Cass fine sandy loam, clayey substratum, rarely flooded	4.7	0.1%
8435	Cass loam, rarely flooded	246.5	4.1%
8436	Cass loam, occasionally flooded	24.9	0.4%
8475	Gibbon variant soils, frequently flooded	143.0	2.4%
8563	Platte loam, occasionally flooded	196.6	3.3%
8574	Platte-Inavale complex, channeled, occasionally flooded	532.9	8.9%
8580	Wann fine sandy loam, occasionally flooded	42.7	0.7%
9903	Fluvaquents, sandy, frequently flooded	96.9	1.6%
9970	Aquolls	31.9	0.5%
9986	Miscellaneous water, sewage lagoon	4.7	0.1%
9999	Water	331.5	5.6%
Subtotals for Soil Survey Area		**5,181.9**	**87.0%**
Totals for Area of Interest		**5,958.4**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
3521	Cass fine sandy loam, 0 to 2 percent slopes, occasionally flooded	117.5	2.0%
6327	Fontanelle silty clay loam, frequently flooded	26.6	0.4%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
6385	Shell silt loam, occasionally flooded	100.0	1.7%
6603	Alcester silty clay loam, 2 to 6 percent slopes	30.8	0.5%
6628	Belfore silty clay loam, 0 to 2 percent slopes	3.7	0.1%
6681	Crofton silt loam, 17 to 30 percent slopes, eroded	45.4	0.8%
6756	Nora silt loam, 6 to 11 percent slopes, eroded	13.4	0.2%
6774	Nora-Crofton complex, 11 to 17 percent slopes, eroded	54.7	0.9%
6811	Moody silty clay loam, 2 to 6 percent slopes	42.0	0.7%
6860	Crofton silt loam, 8 to 17 percent slopes, eroded	0.9	0.0%
7099	Zook silty clay loam, 0 to 2 percent slopes, occasionally flooded	21.8	0.4%
7266	Burchard-Steinauer clay loams, 11 to 17 percent slopes, eroded	1.6	0.0%
8436	Cass loam, occasionally flooded	77.5	1.3%
8563	Platte loam, occasionally flooded	174.5	2.9%
9999	Water	65.8	1.1%
Subtotals for Soil Survey Area		**776.3**	**13.0%**
Totals for Area of Interest		**5,958.4**	**100.0%**

Soil Map—Cass County, Nebraska, and Saunders County, Nebraska
(Salt Creek Lake)



Map Scale: 1:35,900 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 500, 1000, 2000, 3000

Feet: 0, 1500, 3000, 6000, 9000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at scales ranging from 1:12,000 to 1:20,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Cass County, Nebraska
Survey Area Data: Version 23, Sep 6, 2023

Soil Survey Area: Saunders County, Nebraska
Survey Area Data: Version 21, Sep 6, 2023

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jun 1, 2021—Sep 13, 2022

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

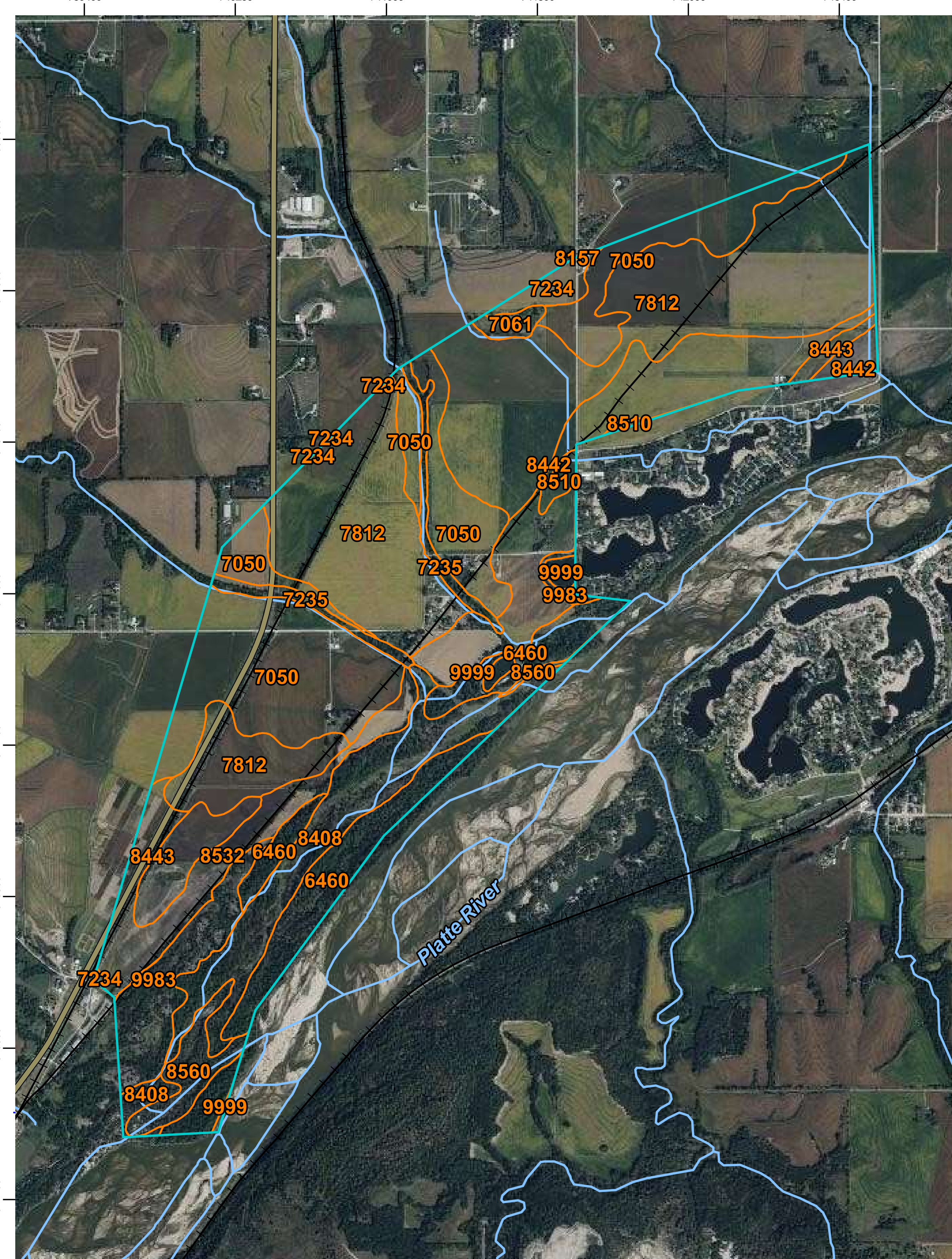
Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
3952	Fillmore silt loam, frequently ponded	5.1	0.2%
4101	Littlesalt silty clay loam, 1 to 6 percent slopes	19.5	0.8%
7050	Kennebec silt loam, occasionally flooded	637.0	25.6%
7099	Zook silty clay loam, occasionally flooded	256.2	10.3%
7155	Aksarben silty clay loam, terrace, 0 to 1 percent slopes	96.5	3.9%
7156	Aksarben silty clay loam, terrace, 1 to 3 percent slopes	41.7	1.7%
7230	Judson silt loam, 0 to 2 percent slopes	5.7	0.2%
7231	Judson silt loam, 2 to 6 percent slopes	0.8	0.0%
7280	Tomek silt loam, 0 to 2 percent slopes	13.8	0.6%
7644	Yutan silty clay loam, 6 to 11 percent slopes, eroded	96.9	3.9%
7750	Nodaway silt loam, occasionally flooded	455.2	18.3%
7770	Colo silty clay loam, occasionally flooded	301.1	12.1%
7867	Nodaway silt loam, channeled, frequently flooded	159.1	6.4%
7892	Zook silty clay, occasionally flooded	33.6	1.3%
8145	Pohocco-Pahuk complex, 6 to 11 percent slopes, eroded	15.6	0.6%
9999	Water	76.8	3.1%
Subtotals for Soil Survey Area		**2,214.7**	**88.9%**
Totals for Area of Interest		**2,490.3**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
7049	Kenridge silty clay loam, occasionally flooded	0.1	0.0%
7061	Muscotah silty clay loam, occasionally flooded	10.2	0.4%
7105	Yutan silty clay loam, terrace, 2 to 6 percent slopes, eroded	19.2	0.8%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
7280	Tomek silt loam, 0 to 2 percent slopes	2.7	0.1%
7750	Nodaway silt loam, occasionally flooded	156.5	6.3%
7868	Nodaway silt loam, channeled, occasionally flooded	36.6	1.5%
8110	Olmitz loam, 2 to 6 percent slopes	9.2	0.4%
8145	Pohocco-Pahuk complex, 6 to 11 percent slopes, eroded	31.0	1.2%
9999	Water	10.0	0.4%
Subtotals for Soil Survey Area		**275.5**	**11.1%**
Totals for Area of Interest		**2,490.3**	**100.0%**

Soil Map—Sarpy County, Nebraska
(Sand Pit Lake)



Map Scale: 1:32,200 if printed on A portrait (8.5" x 11") sheet.

N

0 450 900 1800 2700 Meters

0 1500 3000 6000 9000 Feet

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

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- Soil Map Unit Lines
- Soil Map Unit Points

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- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
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- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:12,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Sarpy County, Nebraska
Survey Area Data: Version 17, Sep 6, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Data not available.

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
6460	Inglewood-Novina complex, occasionally flooded	150.2	8.1%
7050	Kennebec silt loam, occasionally flooded	365.6	19.8%
7061	Muscotah silty clay loam, occasionally flooded	10.6	0.6%
7234	Judson silty clay loam, 2 to 6 percent slopes	19.8	1.1%
7235	Judson-Nodaway channeled-Contrary complex, 0 to 12 percent slopes	32.6	1.8%
7812	Smithland-Kenridge silty clay loams, occasionally flooded	629.3	34.1%
8157	Contrary-Monona-Ida complex, 6 to 17 percent slopes	0.0	0.0%
8408	Alda-Platte complex, occasionally flooded	154.6	8.4%
8442	Cass-Novina complex, occasionally flooded	194.6	10.5%
8443	Cass-Wann fine sandy loams, occasionally flooded	49.9	2.7%
8510	Lex-Platte complex, occasionally flooded	9.8	0.5%
8532	Novina-Gibbon complex, occasionally flooded	103.8	5.6%
8560	Platte and Alda soils, frequently flooded	37.4	2.0%
9983	Pits, sand and gravel	78.8	4.3%
9999	Water	10.8	0.6%
Totals for Area of Interest		**1,848.0**	**100.0%**

LB 1023 (JEDI) IMPACT EVALUATION FOR
CITY OF LINCOLN WATER SYSTEM AND METROPOLITAN UTILITIES DISTRICT:
DESKTOP GEOTECHNICAL ANALYSIS SUMMARY REPORT

Lincoln and Omaha, Nebraska – 2024

October 2024

City Project No. 702309
Olsson Project No. 021-01559
B&V Project No. 413017

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APPENDIX E: GEOMORPHIC ANALYSIS REPORT

LB 1023 (JEDI) IMPACT EVALUATION FOR CITY OF LINCOLN WATER SYSTEM AND METROPOLITAN UTILITIES DISTRICT: GEOMORPHIC ANALYSIS REPORT

CITY PROJECT NO. 702309
OLSSON PROJECT NO. 021-01559
B&V PROJECT NO. 413017

PREPARED FOR

LINCOLN
Transportation and Utilities

METROPOLITAN
UTILITIES DISTRICT

CITY OF LINCOLN WATER SYSTEM
METROPOLITAN UTILITIES DISTRICT
18 OCTOBER 2024

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ACRONYMS AND ABBREVIATIONS

cfs .... Cubic Feet per Second
FEMA.. Federal Emergency Management Agency
ft .... Feet
JEDI .... Jobs and Economic Development Initiative
LID ....Low Impact Development
LTU .... Lincoln Transporation and Utilities
LWS .... Lincoln Water System
NE .... Nebraska
NDED ....Nebraska Department of Economic Development
NeDNR ....Nebraska Department of Natural Resources
STAR WARS . Statewide Tourism and Recreational Water Access and Resources Sustainability
USGS ....United States Geological Survey
W/D.. Stream width to depth radio

TABLE OF CONTENTS

Executive Summary S-1
1. Background 1
2. Platte River Large Excavated Lake 5
   2.1 Hydrologic Concerns 5
   2.2 Geomorphic Concerns 9
   2.3 Water Quality and Ecological Concerns 18
3. Platte River Small Excavated Lake 19
   3.1 Hydrologic Concerns 19
   3.2 Geomorphic Concerns 22
   3.3 Water Quality Concerns 22
4. Dammed Tributary Lakes 23
   4.1 Salt Creek Dammed Lake Example 24
   4.2 Elkhorn Dammed River Lake Example 24
5. Conclusions 25
6. References 28

LIST OF FIGURES

Figure 1: Potential Lake Alternatives, USGS Gages, and the Lower Platte River Valley Confinement 4
Figure 2: Existing Ground Surface along Center Line of Platte River Large Excavated Lake 6
Figure 3: Channel and Floodplain Velocities 10
Figure 4: Sediment Deposition on Floodplain 11
Figure 5: Multi-Thread Channel Footprint Over Time for Platte River Large Excavated Lake 13
Figure 6: Example of Platte River Shoreline Armoring and Downstream Scour 17
Figure 7: Algal Bloom in Platte River Floodplain Dredge and Fill Lake 18
Figure 8: Existing Ground Surface along Center Line of Platte River Small Excavated Lake 20
Figure 9: Platte River Large Excavated Lake and Platte River Small Excavated Lake Locations in the Platte River Valley 23

LIST OF TABLES

Table 1: Approximate Platte River Large Excavated Lake Areas in FEMA Hazard Zones 7
Table 2: Approximate Platte River Small Excavated Lake Areas in FEMA Hazard Zones 21
Table 3: Comparison of Flows in Salt Creek and Platte River at Louisville 24
Table 4: Comparison of Flows in Elkhorn River and Platte River at Louisville 25

EXECUTIVE SUMMARY

In 2021 and 2022, the Nebraska legislature enacted LB406 and LB1023, respectively, which first established the Statewide Tourism and Recreational Water Access and Resources Sustainability (STAR WARS) special committee, and then the Lake Development Act which was codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (*Neb. Rev. Stat.* §61-401 to 61-404). In these pieces of legislation, the unicameral recognized the importance – in the wake of historic flooding in 2019 and the COVID-19 pandemic – for both flood control and major recreational opportunities in the state to attract and retain an increasingly remote workforce. The STAR WARS committee envisioned, in the lower Platte River corridor, a lake that would rival Iowa's Lake Okoboji as a tourist destination and hub for public-private partnerships to develop lakeside communities, a community town center, and a major resort. As outlined in the STAR WARS committee's report, a lake location northeast of the city of Ashland, Nebraska was contemplated and this informed the committee's recommendation that further analysis be conducted to inform viable locations for a lake of at least 3,600 acres, located in or near Sarpy County, and adjacent to – but not impounding – the Platte River.

Recognizing the potential for impacts to public water system wellfields, the legislature also appropriated funds to be administered through the Nebraska Department of Natural Resources (NeDNR) for further study on possible lake sites. The City of Lincoln Water System (LWS) already had its Water 2.0 project – investigating possibilities for additional source(s) of drinking water – underway with Black & Veatch and Olsson, and recognized that these consultants have the necessary expertise regarding the water system as well as expertise in the types of technical analysis needed for potential lake sites. Thus, LWS amended its Water 2.0 contract to include this study and entered into a memorandum of understanding with Omaha's Metropolitan Utilities District (MUD) to allow for MUD's wellfields and concerns to also be considered.

A geomorphic analysis was conducted for each of the potential lake locations, excavated floodplain lakes, or dammed lakes. The purpose of this assessment is to consider the nature and magnitude of such changes in flood and erosion hazards in response to the scope and scale of different lake positions.

The Platte River large excavated lake would require a berm isolating it from river floods to prevent the lake from eroding and capturing the normal river flow and filling with river sediment. The berm would displace natural floodplain surfaces where sediment normally is deposited and force that sediment downstream where it could have substantial unintended consequences and accumulations in areas that could acerbate downstream flooding. The narrowing of the floodplain would also accelerate flow during floods by constricting the floodplain, and the extra energy would increase erosion in the vicinity of the berm and beyond.

Tributaries would be intercepted by the Platte River large excavated lake, lowering their confluence elevation with the Platte River floodplain. Without intervention, this lowering could lead to head cutting on those tributaries, leading to substantial bank failures and property loss well upstream of the lake boundary.

After reviewing the findings of the Platte River large excavated lake evaluation, the Nebraska Department of Economic Development (NDED) asked whether a smaller Platte River lake could be built in conjunction with the larger Platte River lake. Combined, the two excavated lakes would have a total surface area of approximately 3,000 acres which is closer to the targeted size in the legislation. The inclusion of the Platte River small excavated lake produced similar results to the large excavated lake and would need to address similar elements and considerations.

While a dammed lake was not necessarily envisioned by the legislature in LB1023, NeDNR requested that these areas also be considered in this study, as examples of sites chosen to examine initial feasibility, with the possibility that similar sites could be considered in the future. The two example dammed lakes examined would produce different effects. The Elkhorn River dammed lake would trap a significant volume of sediment, preventing its normal delivery to the Platte River. This would require dredging upstream of the dam to maintain lake volume. Without intervention, the trapping of this sediment would facilitate riverbed and bank erosion downstream of the dam and would likely increase localized erosion on portions of the Platte River and Elkhorn River, especially near their confluence. The Salt Creek dammed lake would have less effect on the Platte River's stability because it normally delivers a less consequential sediment load to the Platte River. However, the dammed lake would increase erosivity of Salt Creek itself where it runs through an infrastructure-dense area of Ashland. While various structural and other strategies could mitigate most of the erosion impacts, building and maintenance of any structures are costly. Further, such structures can displace energy and create their own downstream impacts.

This study has provided a screening level analysis of the most likely effects of different lake positions and types on river stability. To gain a sufficient understanding of the specific areas where assets, habitats, and infrastructure are most likely to be affected by geomorphic adjustments, perhaps the first line of a future feasibility and alternatives investigation should be to set up and run a rigorous and defensible hydrodynamic and sediment transport model at sufficient calibration, scale, and granularity to predict more precisely and accurately where erosion and sedimentation will be displaced and reside over time. Such delineations will facilitate an improved understanding of the specific magnitude and locations of adverse outcomes. This will better inform a carefully targeted suite of countermeasure types and positions, and the model can be used to assess the outcomes of different river mechanics and erosion control deployments as well as integration of any necessary habitat and flood mitigation requirements. All such activities will be expensive and optimizing their deployment will likely be a critical component of updating any benefit-cost analysis or assessment of return on economic stimulus from lake establishment. Such delineations are also necessary to appropriately identify the most-affected stakeholders in public outreach campaigns and negotiations.

Each of the lake positions contemplated would likely create a variety of complex upstream and/or downstream property instabilities and risk management scenarios to a greater extent or in different positions from which they currently occur, especially at the locations in closest proximity to the lakes. Fluvial geomorphic modeling, including detailed numerical modeling of sediment transport and erosive forces will be necessary to determine the specific locations of impacts and the magnitude of those impacts on flood risks, habitat loss, and asset erosion.

Although lake locations have selected without fatal physical or engineering flaws related to public water supply, the full feasibility of alternatives will rest on their permittability in accordance with federal regulations related to wetlands, endangered species, water quality, property losses due to hazardous erosion and shoaling, and flood hazards among other issues. Almost all of these factors are likely to be affected by alterations to the Platte River's geomorphic conditions, and on the Elkhorn River and Salt Creek if they are dammed. Further, the modeling tool will become an important driver for identifying permitting issues and to explore and discuss potential mitigative measures with regulatory agencies with greater specificity. During modeling explorations, it might become apparent that reducing lake sizes or other adjustments to lake alignments may avoid or minimize direct and secondary impacts to regulated features and functions. These adjustments should be carefully documented to demonstrate that avoidance and minimization were included in the feasibility and alternatives assessment.

These suggestions for next steps are from the perspective of fluvial geomorphologists and river engineers based on experience predicting and coping with the suite of issues identified in this report on other rivers. They are not intended to provide a comprehensive scope of feasibility and alternative analysis activities. In addition, note that a model should be one part of a weight-of-evidence approach to assess specific requirements and outcomes, and as with most human interventions in river corridors a long-term adaptive maintenance and retrofit strategy is likely to be required.

In summary, no fatal flaws were identified based on the geomorphic analysis for Platte River large excavated lake, Platte River small excavated lake, Elkhorn River dammed lake, and Salt Creek dammed lake in relation to LWS' wellfield and MUD's wellfields at Platte West and Platte South. As noted above, further evaluations will be important in determining remediation for downstream impacts to minimize changes in sediment transport. Therefore, it is recommended that full feasibility studies of the lakes be performed.

1. BACKGROUND

In 2021 and 2022, the Nebraska legislature enacted LB406 and LB1023, respectively, which first established the Statewide Tourism and Recreational Water Access and Resources Sustainability (STAR WARS) special committee, and then the Lake Development Act which was codified in statute as the Jobs and Economic Development Initiative (JEDI) Act (*Neb. Rev. Stat.* §61-401 to 61-404). In these pieces of legislation, the unicameral recognized the importance – in the wake of historic flooding in 2019 and the COVID-19 pandemic – for both flood control and major recreational opportunities in the state to attract and retain an increasingly remote workforce. The STAR WARS committee envisioned, in the lower Platte River corridor, a lake that would rival Iowa's Lake Okoboji as a tourist destination and hub for public-private partnerships to develop lakeside communities, a community town center, and a major resort. As outlined in the STAR WARS committee's report, a lake location northeast of the city of Ashland, Nebraska was contemplated and this informed the committee's recommendation that further analysis be conducted to inform viable locations for a lake of at least 3,600 acres, located in or near Sarpy County, and adjacent to – but not impounding – the Platte River.

This Geomorphic Analysis report describes perspectives in applied fluvial geomorphology which is the primary scientific discipline used to understand river corridor stability, pattern, and dimension. These factors are predominantly under alluvial control on the Platte River and its local tributaries in our study area. The pattern and dimension of alluvial rivers achieve a state of dynamic equilibrium that results from adjustments the system makes to balance its input of water flow and sediment load. If either of these variables change in a reach of the river, it will make a sometimes complex yet predicable series of changes to the path, depth, and width of the river channel and its floodplain. These changes can vary tremendously based on the position and magnitude of the altered inputs versus the resistance thresholds of the system, so the response is typically non-linear and threshold dependent. Natural stream systems have an intrinsic resilience and resistance to change. Up to a certain threshold, changes to flow or sediment can be absorbed by the system, preventing noticeable impacts. If the changes are great enough to overwhelm the system's capacity, notable impacts can occur slowly and incrementally or rapidly and catastrophically. Either way, changes to the distribution of sedimentation and erosion zones along the river can have profound effects on flood hazards, property loss due to erosion, and the associated threats to common infrastructure along and across rivers (such as bridge crossings, roads, docks, marinas, farmland, housing, industrial facilities, mines, levees, rail lines, and subsurface utilities, etc.). Further, such alterations can disrupt fish and wildlife habitat and fish passage by changing the basic conditions under which these fauna have adapted to thrive.

Other common controls in geomorphology include geologic (e.g., bedrock outcrops and some legacy effects from prehistoric climates) and biological (the effects of vegetation and some animals). These are not the dominant considerations for the Platte River's stability, but they do play a secondary role. For this reason, the focus of this investigation was to screen the different lake establishment approaches and positions for their most likely potentially severe disruptions to alluvial processes and resultant geomorphology.

The following two types of lakes were considered for this study. Figure **1** shows the location of these potential lakes, United States Geological Survey (USGS) gages, and the lower Platte River valley confinement:

- The first type consists of excavating natural ground along the floodplain until bedrock is reached. This first type is possible along the Platte River because groundwater is relatively shallow and excavation to bedrock results in exposing the groundwater. The excavated lakes around the Platte River are near Louisville, Nebraska, which are the Platte River large excavated lake, downstream of Louisville, and the Platte River small excavated lake, upstream of Louisville. After reviewing the findings of the Platte River large excavated lake evaluation, the Nebraska Department of Economic Development (NDED) asked whether a smaller Platte River lake could be built in conjunction with the larger Platte River lake. As requested, a two excavated lakes option was also analyzed along the Platte River. Combined, the two excavated lakes would have a total surface area of approximately 3,000 acres which is closer to the targeted size in the legislation.
- The second type is a traditional dammed lake, that is, a dam is constructed across the floodplain to impound water. For the example dammed type lakes examined, the potential lakes are the Elkhorn River dammed lake, near Nickerson, and the Salt Creek dammed lake, between Greenwood and Ashland. While a dammed lake was not necessarily envisioned by the legislature in LB1023, the Nebraska Department of Natural Resources (NeDNR) requested that these areas also be considered in this study, as examples of sites chosen to examine initial feasibility, with the possibility that similar sites could be considered in the future.

The planning level geomorphic analyses in this report are based on the assumption that a large lake or lakes would be excavated into the Platte River floodplain, but would not impound the river, creating a primarily groundwater-fed lake for recreation. Groundwater modeling conducted by Olsson and surface water modeling conducted by Black & Veatch indicated that in order to protect existing wellfields, municipal groundwater supply, and existing infrastructure, the floodplain lake(s) would need to be located on the more confined stretch of the Platte River on the northern floodplain near Louisville (refer to Figure 1). Two excavated Platte River floodplain lake scenarios were considered: first, creation of a singular large excavated lake downstream of Louisville, then creation of an additional smaller excavated lake upstream of Louisville. The primary focus of the scope was to assess impacts to the Platte River and potential threats to the excavated lakes in the Platte River floodplain. In addition, a supplementary assessment was also explored briefly for impacts to the Platte River from additional options involving lake creation by damming the Elkhorn River or Salt Creek tributaries.

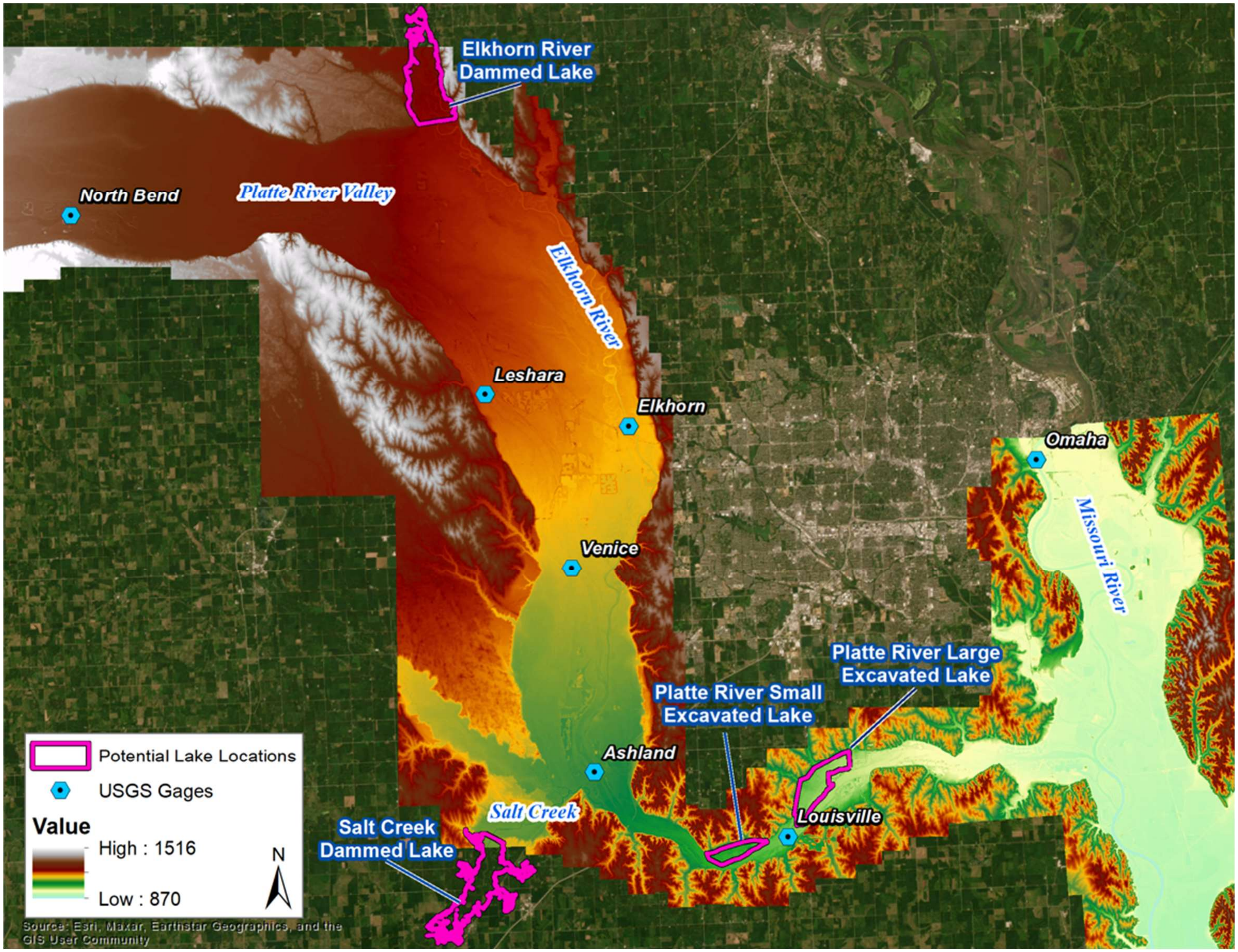

Figure 1: Potential Lake Alternatives, USGS Gages, and the Lower Platte River Valley Confinement

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2. PLATTE RIVER LARGE EXCAVATED LAKE

2.1 Hydrologic Concerns

The Platte River large excavated lake, downstream of Louisville, is approximately 2,100 acres, 4.2 miles long, and ranges from 2,500 to 6,500 feet wide in the Platte River floodplain. Figure 2 shows the profile of the existing ground surface along the center line of the potential lake that experiences approximately 10 feet of drop in elevation from one end to the other. If the potential lake is to be primarily groundwater-fed, excavated into the floodplain, the surface level of the lake will be approximately equal to the river stage throughout the year. Because such a large elevation change occurs across the long length of the lake, maintaining a level pool without building an embankment would result in approximately 10 to 15 feet (vertically) of dry, sloped shoreline along the upstream, higher edges of the lake, decreasing the overall available wet footprint of the lake. If the desire is to have the entire potential area full of water for most of the year, maintaining a level pool would require some kind of embankment on the lower, downstream end. An embankment resulting in “stored” water to maintain water levels in the lake would also affect the Federal Emergency Management Agency (FEMA) floodplain and likely increase the flood depths in areas adjacent to the lake. Because any development associated with the excavated lake would be built in FEMA floodway or Flood Hazard Zone A, embankments that bring finished floor elevations above the base flood elevation would be needed either way. Any infrastructure in the excavated lake vicinity will be in a high Flood hazard area, requiring more extensive permitting and insurance.

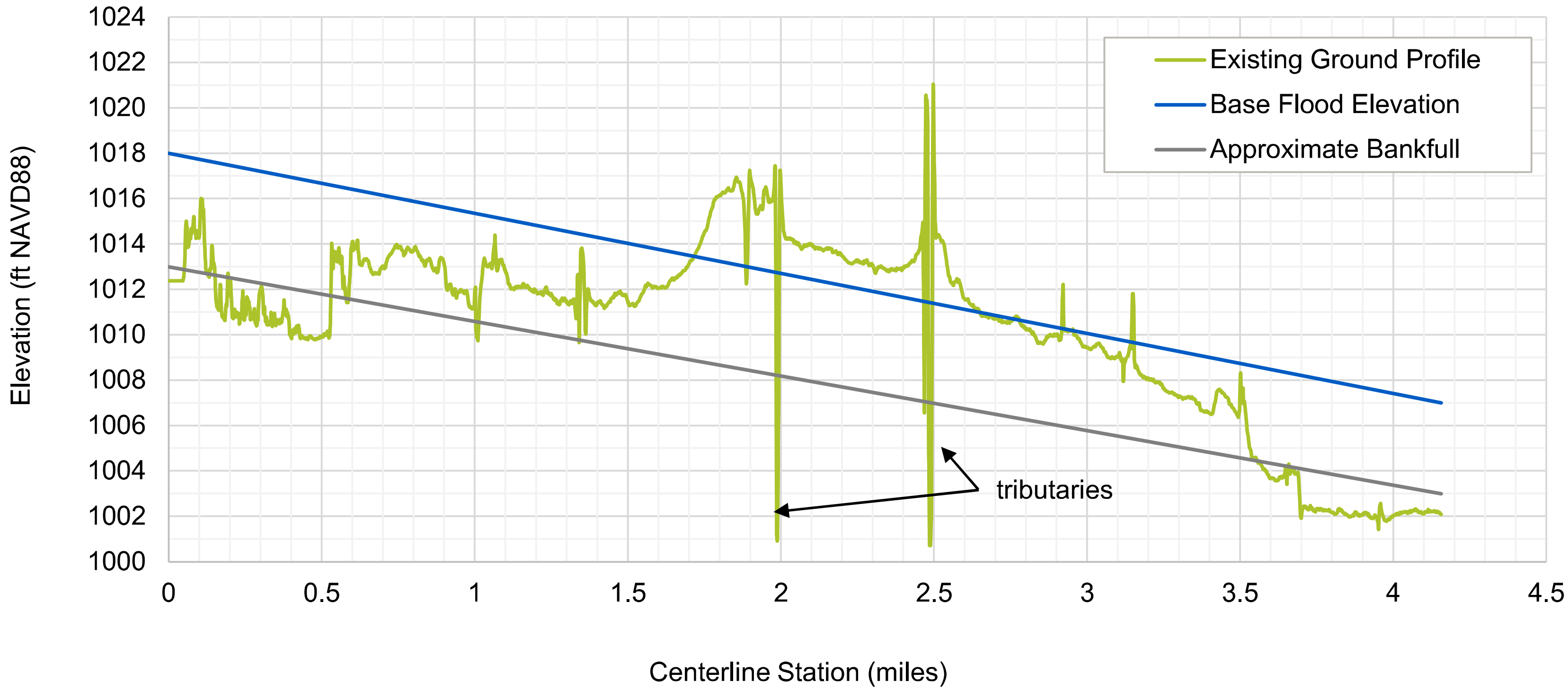

Figure 2: **Existing Ground Surface along Center Line of Platte River Large Excavated Lake**

Approximately 19 percent of the Platte River large excavated lake is classified as FEMA regulatory floodway, which is effectively the stream channel required to pass 1 foot of rise (FEMA, 2020). An additional 46 percent of the potential lake area is within FEMA flood Hazard Zone AE, a high-risk flood zone at the base flood elevation. While there is certainly local precedent for dredge and fill construction of lakes and homes within these designated flood zones, it is generally not advised to build permanent or residential structures within the floodway. While a large excavated lake in the floodplain would not necessarily decrease flood storage volume, loss of vegetative abstraction and groundwater infiltration and the addition of water control structures could potentially cause localized flood risks to surrounding proposed infrastructure. Refer to Table 1 for the approximate areas of the potential Platte River large excavated lake area in the FEMA Hazard Zones.

Table 1: Approximate Platte River Large Excavated Lake Areas in FEMA Hazard Zones

FEMA Hazard Zone	Acres Within Platte River Large Excavated Lake Area	Percent of Total Platte River Large Excavated Lake Area
AE-FLOODWAY	399	19%
AE	967	46%
AH	259	12%
AO	111	5%
X	361	17%
Total	**2097**	**100%**

Surface water modeling results for the 100-year storm show flood levels overtop the riverbanks by 5 feet, with 5 to 10 feet of flood depth within the FEMA floodway and 1 to 5 feet of flood depth in FEMA Zone AE. Model results for the 2-year storm show flood levels overtop the riverbanks by 1.5 feet, with 1 to 6 feet of flood depth within the FEMA floodway and 1 to 2 feet of flood depth in FEMA Zone AE. These results are geomorphically significant because when a river frequently stages up higher than adjacent lake levels during a flood rise or even during common flow conditions, the lake embankments are vulnerable to massive erosion leading to an avulsion. An avulsion is a shift in the position of a river within its floodplain. In this case, an unprotected lake boundary would lead to such an avulsion resulting in the lake subsequently capturing the river and all of its normal flow and associated sediment yield. This rather inevitable outcome would require substantial routine dredging to preclude the river sediments from filling the lake and naturally reclaiming it as a shallow river channel and floodplain. The Platte River carries a large sediment load, and this approach would be untenable.

Therefore, the lake must be isolated from overbank flow and its margins protected from all forms of erosion that could promote an avulsion. An obvious approach is to fully rim the lake with an earthen berm between it and the river. Such a structure will necessarily be designed for a particular level of service (e.g., 100-year event, 200-year event, or other). When that level of service is exceeded, the structure will fail, and a retrofit of the lake and its isolation system will be required.

Further, overtopping of the lake embankment is not the only erosion mechanism that could induce avulsion. Another potential path is groundwater sapping. This occurs when concentrated groundwater flow moves sand or gravel through an embankment when the river stages up higher than the lake for a sustained period. The deep open water of the lake simply allows this process to unnaturally occur by creating an artificial void in what once was a fully filled floodplain. Sapping countermeasures include groundwater curtains, slurry walls, and wick drains among other approaches. These are expensive measures to implement in upland landscapes and are significantly more difficult to install in deeply excavated river corridors. Sapping (also called 'piping' by geotechnical engineers) can also occur through berms and levees, but berm design and construction is comparatively straightforward to integrate sapping countermeasures than it is deeper into a riparian aquifer cut.

A stream's native vegetated floodplain serves many purposes including attenuating flood flows, dampening erosive velocities and shear forces, and settling alluvial sediment deposits. The removal of the native floodplain with a bermed lake will render proposed embankments and structures more vulnerable to damage from routine overbank flows.

In the potential location, the Platte River large excavated lake footprint envelops the confluences of two tributaries (Buffalo Creek and Springfield Creek) with the Platte River. These tributaries drain an approximate combined area of 30 square miles. While the flows from these tributaries may appear negligible in comparison to the flow of the Platte River, they would contribute non-negligible flow to the potential lake and would require the lake to have inflow control structures and outfall structures for flood management. These tributaries make a strictly groundwater-fed lake infeasible. Managing lake levels by controlling flow from the tributaries will likely result in periods of impoundment, which could have negative impacts on water quality, habitat, fish passage, and flooding that propagate upstream.

2.2 Geomorphic Concerns

The Lower Platte River valley is generally wide and flat. In the upstream reaches between North Bend and Ashland, the stream valley is 3 to 8 miles wide, and the confinement ratio (the ratio of valley width to bankfull channel width) ranges from 20:1 to 50:1. As the Platte River approaches the Missouri River, the valley becomes more geologically confined, with confinement ratio ranges from 2:1 to 9:1 (refer to Figure 1). The more confined segment of the river valley has steeper longitudinal grades with more energy to carve and maintain a distinct channel, and overbank flows and floods are being dissipated by much smaller floodplain areas.

Within the more confined valley section, localized areas occur where the valley (and associated confinement ratio) suddenly expands and contracts. The areas of contraction experience higher velocities and tend to be deeper, while the expansion areas where the flow can dissipate over a larger area experience lower velocity, allowing sediment to deposit (refer to Figure 4). These expansion areas tend to be shallower and wider with high stream width to depth (W/D) ratios. Figure 3 shows the maximum velocities in the channel and floodplain during the 100-year storm (modeled in HEC-RAS software). The higher velocities correspond to more constrained channel cross sections, while the following sections with wider channels and floodplain access experience lower velocities. The areas with lower velocities correspond to areas of substantial sand deposition, bar development, and channel aggradation (shallowing due to sediment accumulation).

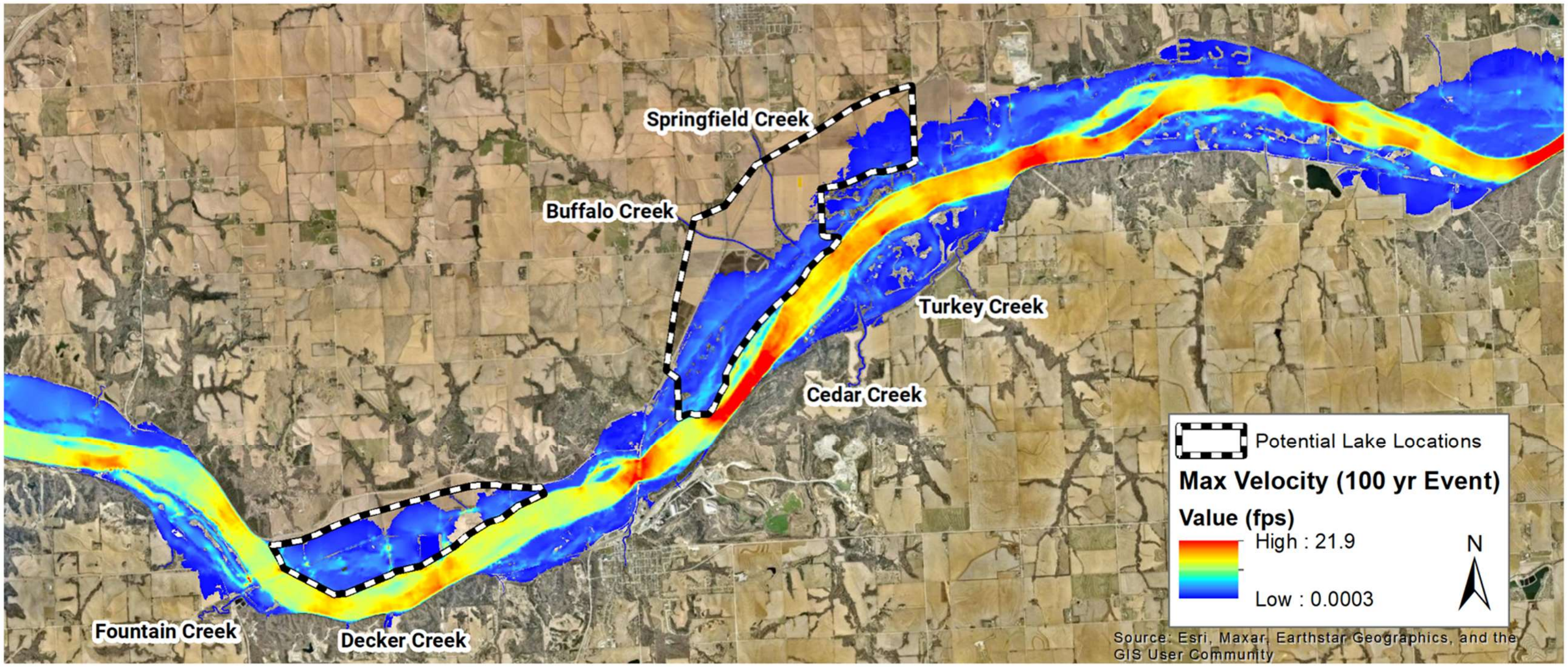

Figure 3: Channel and Floodplain Velocities

Contractions with sudden expansion (often seen at bridge sections) can also create backwater effects, or temporary embayments that deposit substantial sediment in the channel and higher up on the floodplain (evidenced by the fresh sand deposits visible on Figure 4). Backwater effects can also induce eddies that cause localized scour around bridge supports or embankments. The Platte River actively deposits sediment on its floodplain in the potential lake location. If proposed lake embankments are high enough to act as levees and prevent river overflow into the lake, this sediment will need to deposit elsewhere and could cause problematic sand bar development downstream, leading to localized flooding, lateral migration, navigation hazards, and property loss from excessive bank erosion.

2024 Airbus imagery obtained through Google Earth.

Figure 4: Sediment Deposition on Floodplain

Wide, shallow channels with W/D ratios over 40 have multiple threads (i.e., braided stream). These types of channels are constantly changing and have excessive bedload which leads to the braiding nature of the channel. These types of river systems are very active laterally and meander across wide floodplains. The excess sediment and lack of efficient sediment transport result in constant lateral migration and associated bank erosion. It is harder for the stream to entrain the sediments along the stream bed than to scour the sediment associated with the sandy banks, so the channels scour laterally and exasperates the system's ability to transport sediment. The result is a multiple thread, constantly changing river system consisting of center bars and active bank erosion. It is important to recognize that this dynamic condition normally occurs within a well-defined and contained part of the floodplain referred to as the meander belt. Meander belt width is the wiggle room the stream requires as it laterally meanders across its floodplain over time. This alluvially active feature achieves an equilibrum dimension and position within the valley over time that localized changes in sediment yield or river velcoties can disprupt. Such dispruptions can lead to property loss and asset damage along the historic margins of the meander belt.

Figure 5 shows the footprint of the Platte River over a stretch with sudden expansions and contractions and multi-threaded channels from 1955 to 2016 (according to historic aerial imagery). Over time, some of the parallel channel threads fill with sediment, transferring flow to the other threads that themsleves later breach and re-carve a channel within the abandoned channel foodprint. This area is one example of the highly variable and constantly changing nature of multiple thread channels with very high W/D ratios and excess bed loads. To maximize lake footrprint it intersects the highly active meanderbelt and a large alluvial floodplain terrace above it (refer to Figure 5). The meanderbelt could be avoided with a smaller lake, which may be a prudent call in risk reduction, but even so the overall disruption to the floodplain surface will remain.

The Platte River large excavated lake is also currently at the outside bend of the river, which is vulnerable to erosive forces. The erosive forces of the outer bank of the bend pose a scour threat to structures or embankments between the river and the potential lake (southeast lake boundary). When the river reaches flood stages, flow moves through the entire stream valley, which includes the floodplain. Thus, the loss of energy dissipation from the floodplain acerbates the normal high stress on the bend, requiring robust channel stabilization measures to protect the bank foundation under and along the lake berm from catastrophic erosion.

The potential lake location is also in an area where four sizeable tributaries meet and discharge to the Platte River, creating a local sandy delta. Buffalo Creek and Springfield Creek enter from the north of the Platte River, and Cedar Creek and Turkey Creek enter from the south. The tributaries, each transporting their own sediment loads, have steeper grades and higher velocities than the river. When they meet the wide, flat Platte River, the sediments settle out, leading to shoaling and shallowing of the stream channel and a widened floodplain. The tributary delta exacerbates the potential for increased sediment deposition, which increases W/D ratio and associated lateral migration.

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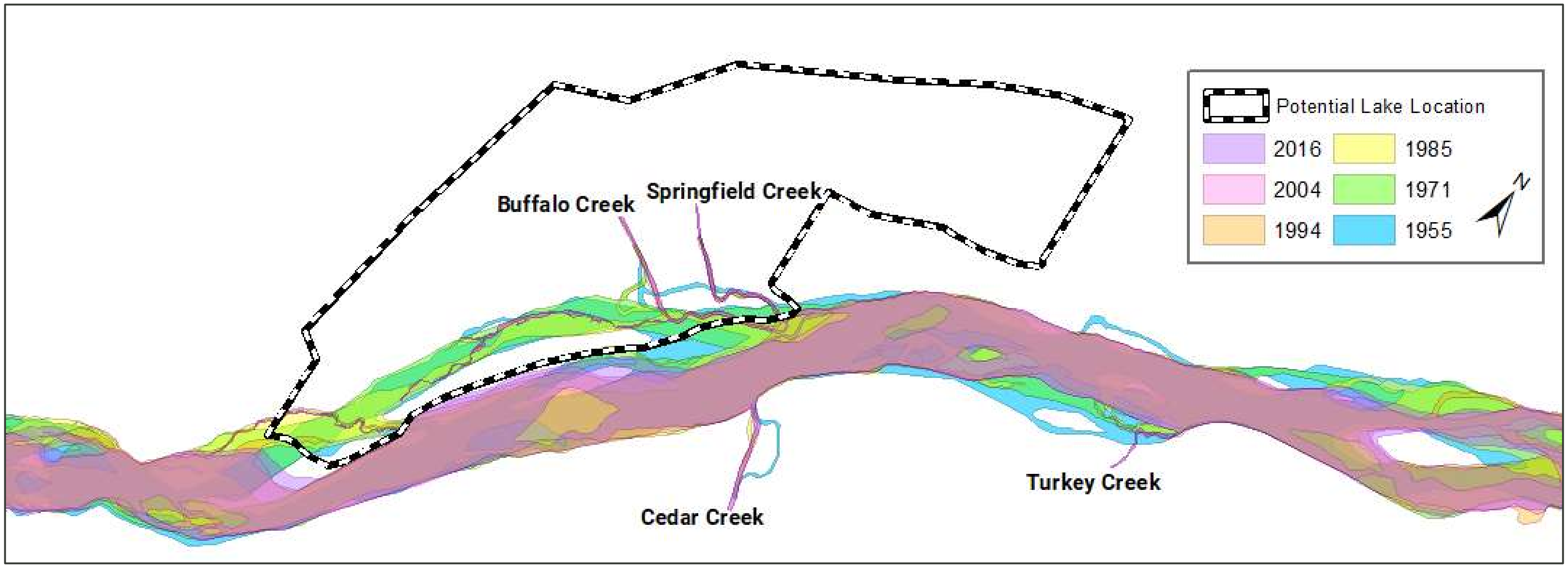

Figure 5: Multi-Thread Channel Footprint Over Time for Platte River Large Excavated Lake

The potential Platte River large excavated lake area directly intercepts the confluences of the two northern tributaries with the Platte River, lowering the baselevel of the floodplain where they currently cross it. Consequently, the outflows from these creeks will likely need to be stabilized with control structures to manage sediments and control erosion. If such countermeasures are not taken, the potential lake and tributaries will require substantial maintenance to address unstable conditions.

This occurs because the existing plan for the lake is to dig below existing ground level for a primarily groundwater-fed lake. Lowering the base level where the tributaries discharge creates a higher energy gradient that may not support the equilibrium of sediment transport required for a stable stream. These areas of sudden and drastic elevation change cause the tributary to dissect their channels more deeply where they currently cross the Platte River's valley hillslope. As this process unfolds a series of small cascades called knickpoints migrate upstream over time. As the stream seeks to achieve a stable and more gradual valley slope, the knickpoints will migrate upstream (known as headcutting) and destabilize valley side slopes as the bed erosion attempts to flatten the valley's longitudinal slope. The loss of longitudinal grade control thus causes significant gravity failures along the tributary side slopes that can lead to property loss and jeopardize infrastructure on or above the creek valley. Maintaining a stable stream grade at these outfalls is imperative to prevent loss of grade control and extreme bank failures that propagate upstream. Grade control structures are relatively straightforward to design, construct, and maintain. However, absent such countermeasures, once grade control is lost and especially after bank and slope failures have progressed containment of the process is very expensive.

Currently, an excessive sediment load does not appear to be coming from the tributaries, but the tributaries and their contributing drainage networks are relatively natural, and even where channelized, have forested buffers in addition to drainage areas with extremely low impervious cover. If widespread urban or suburban development is to follow the recreational lake construction, these watersheds will become more impervious, leading to flashier hydrology, increased flood levels and velocities, which leads to excess scour, possible loss of grade control, and increased sediment load. This phenomenon is often referred to as "urban stream syndrome" and can cause a host of hydrologic, geomorphic, and ecological impacts upstream and downstream of the urbanization (Walsh et al., 2005; Booth et al., 2016). Low impact development (LID) approaches to stormwater management can preclude such outcomes, if they are required and implemented and maintained at sufficient scope and scale.

Additionally, two tributaries discharge to the Platte River on the banks opposite from the potential lake location. If these tributaries experience similar urbanization and increased erosivity due to urban stream syndrome, they will likely erode their own channel and valley slopes and cause increased shoaling at their respective confluences, which can cause localized shallowing of the Platte River. The river meander belt may widen to accommodate the same flow in a shallower channel (lateral migration). Infrastructure along the riverbanks (including existing roads, homes, rail lines, and residential lake embankments along with proposed adjacent infrastructure) will be vulnerable to bank failures and property loss. Again, LID approaches in the tributary watersheds could serve as a countermeasure against such outcomes. This is rarely accomplished voluntarily by developers and will require explicit planning, zoning, and development criteria to achieve.

From a geomorphic perspective, erosion, bank failures, and associated channel over-widening are the primary threats to riverbanks and potential proposed infrastructure, followed by sapping and avulsions. A traditional method to guard against erosive stream forces is to harden the banks with riprap, revetments, or other hard structures, and this approach has been used along the Platte River banks, especially along historic rail lines. Hard armoring is often an expensive and temporary solution. Riprap and other hard armoring solutions resist, but do not dissipate erosive energy. These structures can still be eroded by large storm events and can be undermined by consistent scour at the toe of the structure and by flow overtopping and piping or scouring from behind the structure. These structures are costly to build and often require frequent inspections and regular repairs.

Additionally, hard armoring select sections of riverbanks or shorelines can lead to a “domino effect” of passing the erosion downstream. Because the armored banks do not dissipate energy, but often reflect or magnify it, the unarmored banks downstream that previously did not have erosion issues will start to be scoured after construction of the armoring structures (Kiss et al., 2019). This often leads to those downstream banks being armored, passing the erosion downstream, and so on, until most of the banks require hard armoring. Rivers meander and adjust within a floodplain over time, similar to a rope on a frictionless surface that is shaken. The meanders are in constant motion and adjust across the surface. When one section of rope is “hardened” and not able to adjust, an effect is transferred up and down the rest of the rope. This phenomenon is already apparent along various stretches of the banks of the Platte River, as seen on Figure 6. If the Platte River large excavated lake is to be constructed, it will be important to retain or rebuild natural floodplain buffers that effectively dissipate erosive forces without transferring them downstream. If the potential lake was to cause substantial erosion of banks and shorelines downstream, the parties responsible for the potential lake development could be sued for damages (Wu et al., 2014; Koran, 2022).

Erosion is not the only displacement of concern. So is amplified and altered positions of sedimentation. Displaced sediment and increased sediment yields require space to deposit and until such space is intersected, the higher sediment load will decrease flow efficiency during floods which can increase flood levels. Further, even when it finds a depositional position, such sediment often accumulates at bridge crossings and other places where it then creates obstruction and raises water levels during subsequent floods. Sediment shoals also can displace fluvial forces to channel margins that cause even more bank erosion than normal, creating a vicious cascade of excessive erosion, sedimentation, and flood effects that propagate downstream of the source of original impact. For these reasons, a suite of flow redirective structures such as bendway weirs and groins alter river mechanics in ways to promote better sediment transport continuity through sediment-induced flood-sensitive river sections. Carefully considered bridge and approach channel retrofits or complete rebuilds may be required to assure sediment transport continuity through road and rail crossings in ways that do not overshoot the mark and cause excessive structural scour at those sites.

2024 Airbus imagery obtained through Google Earth.

Figure 6: Example of Platte River Shoreline Armoring and Downstream Scour

2.3 Water Quality and Ecological Concerns

Vegetated floodplains provide nutrient load removal through physical settling and filtration, nutrient uptake in plants, and microbial processing. Riparian wetlands can treat 15 to 40 percent of influent total nitrogen and total phosphorus load and 20 to 30 percent of influent total suspended solids loads (Law et al., 2020). The destruction of native wetlands and vegetated floodplains, in addition to the disconnection of existing tributaries, removes essential biogeochemical and ecological processes that improve water quality within the Platte River.

In many nutrient-rich waters, consistent flow, shade, temperature, and color (a product of wetlands contributing tannins) are important factors that help control algal blooms and eutrophication. These conditions where flowing water is impounded, exposed to increased light and heat, or removed from a source of color can tip the scales, creating algal bloom issues where none previously existed.

Nutrient loading from native geological, legacy agricultural, and urban fertilizer and wastewater can potentially overwhelm groundwater fed systems and lead to increased algal accumulation through eutrophication. Costly to diagnose and manage, eutrophication can cause increased sedimentation, fish kills, and limited recreation. This phenomenon has been observed in smaller dredge and fill lake neighborhoods in the Platte River floodplain, as seen on Figure 7. Additional concerns include initial water quality fluctuations after construction, sediment management, and microclimate influences on lake water quality.

Google Earth Street View. Springfield, Nebraska.

Figure 7: Algal Bloom in Platte River Floodplain Dredge and Fill Lake

Wetland and natural channel habitat alterations to alluvial systems typically are impacted by geomorphic change and the various countermeasures mentioned that will likely be necessary to address the adverse of effects of such changes on flood risks and erosion of infrastructure and assets. Some of those natural system impacts are subject to intense regulatory control, especially if wetlands will be destroyed or functionally diminished; fisheries adversely affected; recreation eliminated; navigation reduced; or threatened or endangered species are likely to be adversely affected. Most such impacts must first be demonstrated to be unavoidable and in the public interest. If that test is met, then impacts must be minimized. Once the agency accepts that minimization is sufficient, then compensatory mitigation for the unavoidable habitat losses will be required. It is not a given that regulatory agencies will accept the essential nature and public benefits of the impacts, or even if that hurdle is passed that acceptable mitigation options are available. Permitting procedures at the anticipated scope and scale of the potential lakes will require public notice and public meetings, and offer points of entry for public comment and challenge.

3. PLATTE RIVER SMALL EXCAVATED LAKE

3.1 Hydrologic Concerns

The Platte River small excavated lake, upstream of Louisville, is approximately 900 acres in area, 2.7 miles long, and 3,500 feet wide in the Platte River floodplain area. Figure 8 shows the profile of the existing ground surface along the center line of the potential lake that experiences approximately 12 feet of drop in elevation from one end to the other. As described in Section 2.1, the large elevation change would require an embankment around the downstream end of the lake. Similar to the Platte River large excavated lake, developments surrounding the Platte River small excavated lake would be built in FEMA high hazard zones and require finished floor elevations to be raised above the base flood elevations.

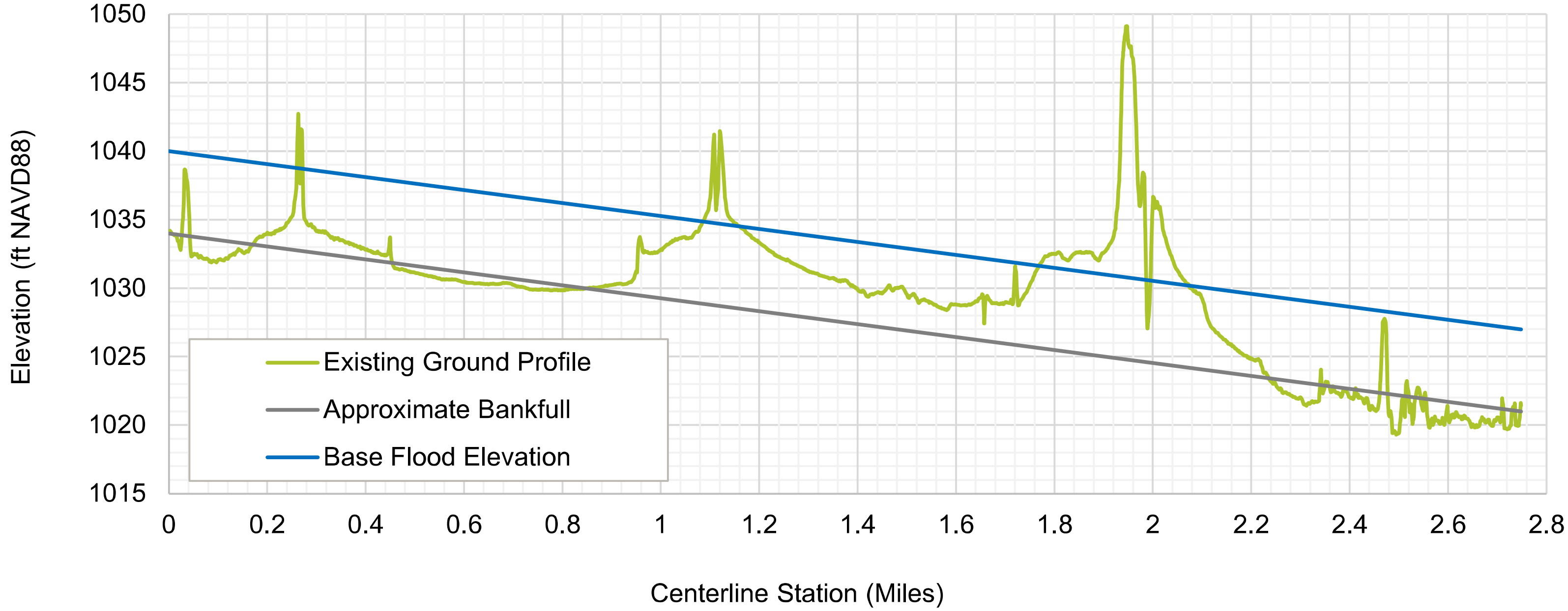

Figure 8: Existing Ground Surface along Center Line of Platte River Small Excavated Lake

Approximately 12 percent of the Platte River small excavated lake's 900 acres is classified as FEMA regulatory floodway, and 70 percent is classified as Flood Hazard Zone AE (refer to Table 2). The same concerns listed for the large excavated lake are valid for the small excavated lake.

Table 2: Approximate Platte River Small Excavated Lake Areas in FEMA Hazard Zones

FEMA Hazard Zone	Acres Within Platte River Small Excavated Lake Area	Percent of Total Platte River Small Excavated Lake Area
AE-FLOODWAY	103	12%
AE	625	70%
AH	0	0%
AO	0	0%
X	169	19%
Total	**898**	**100%**

Surface water modeling results for the 100-year storm show flood levels overtop the riverbanks adjacent to the Platte River small excavated lake by 5 feet, with 5 to 8 feet of flood depth within the FEMA floodway and 1 to 7 feet of flood depth in FEMA Zone AE. Model results for the 2-year storm show flood levels overtop the riverbanks by 1 to 3 feet, with 1 to 4 feet of flood depth within the FEMA floodway and 1 to 2 feet of flood depth in FEMA Zone AE. Nearly all of the potential lake area is flooded during the 100-year event. As described in Section 2.1, river flood stages higher than lake levels can lead to avulsions, groundwater sapping, and the need for routine lake dredging.

The Platte River small excavated lake envelops the confluences of three unnamed tributaries with the Platte River. These tributaries drain an approximate combined area of 5 square miles. These tributaries will likely require control structures for lake level management and potentially create impoundments and cause associated negative impacts on water quality, habitat, fish passage, and flooding. However, they are much smaller than the tributaries enveloped by the Platte River large excavated lake, and are potentially intermittent, so impacts from the Platte River small excavated lake will likely be less severe than impacts from the Platte River large excavated lake.

3.2 Geomorphic Concerns

Similar to the Platte River large excavated lake, the Platte River small excavated lake upstream is also located in an area where the river valley expands, several tributaries discharge to the Platte River, and the stream channel is wide and flat with multiple threads and a history of channel migration. Figure 9 shows the locations of the Platte River large excavated lake, Platte River small excavated lake, and the tributaries in the Platte River Valley. Thus, both potential lakes share the geomorphic concerns of erosion induced by lateral migration, potential loss of grade control in tributaries, displacement of erosive forces and sediment deposition causing bank erosion or problematic shoaling, and potential sapping or avulsions.

There are key notable differences in the geomorphic attributes of the Platte River small excavated lake location. The Platte River small excavated lake is on an inner bend of the Platte River. While outer bends experience higher erosive forces, inner bends experience more sediment deposition. Additionally, this reach only has a floodplain on its northern side and the main channel of the river borders a bluff along its southern margin. Consequently, floods and their associated entrained sediments only have the option to access the northern floodplain, where the lake will be located. If a berm is constructed around the smaller lake to prevent overbank flows from entering the lake, this reach of the Platte River will have effectively no energy dissipating floodplain. Velocities and flood depths will increase to accommodate the full flood volume in the smaller available channel, which will likely lead to localized flooding, scour of the stream bed and adjacent banks and infrastructure, and subsequent deposition of excess sediments downstream that could exacerbate existing scour and flooding issues. The existing southern embankment along the river margin currently supports a rail line that could be vulnerable to bank collapse induced by the elimination of the floodplain.

3.3 Water Quality Concerns

Creation of the Platte River small excavated lake will have similar water quality and ecological impacts as those associated with the Platte River large excavated lake downstream (described in Section 2.3). Decreased floodplain functions, less groundwater infiltration, impoundment of flowing water, and increased exposure to light and heat can all contribute to eutrophication of the potential lake and declining water quality in the upstream tributaries and the Platte River downstream. Control structures can cause barriers to fish passage, and changes in flow or sediment dynamics can impact in-stream habitat.

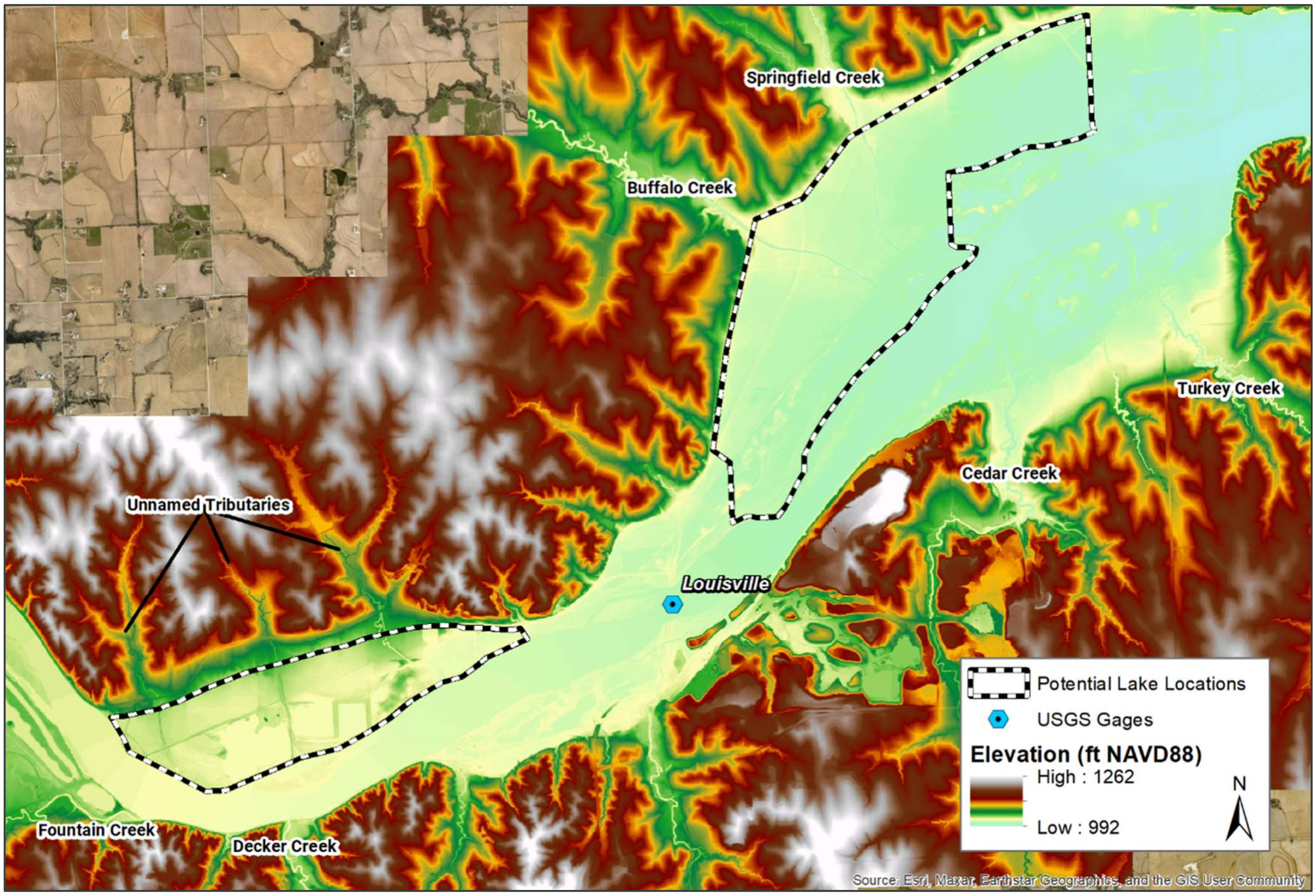

Figure 9: Platte River Large Excavated Lake and Platte River Small Excavated Lake Locations in the Platte River Valley

4. DAMMED TRIBUTARY LAKES

Stability of natural streams depends on maintaining sediment, water, and energy in equilibrium. If the sediment scoured from the channel during flow rise is replaced by sediment deposited during flow recession, the stream remains stable. If either the scouring forces or the deposition deviate from equilibrium over a sustained period of years, the stream becomes unstable. Tributaries contribute both water and sediment to the Platte River, helping to maintain the Platte River's sediment equilibrium. If tributaries were to be dammed to create a lake, sediment would settle out behind the dam, preventing the sediment load to downstream tributary reaches and to the Platte River. If the streams retain substantial energy for scour, but the scour is not equally replaced by deposition, the disequilibrium can cause streambed downcutting (degradation) and subsequent bank collapse until the river carves out enough local bank erosion to re-achieve sediment balance. As this process unfolds it chronically and sometimes catastrophically threatens existing infrastructure and riparian habitat. Sometimes dams can be designed to pass some of the sediment load downstream, but the ability to do this and continuously maintain stable or useful lake levels behind the dam is not always an achievable solution.

This screening-level assessment assumed that a tributary's percent of sediment contribution to the Platte River is roughly equal to that tributary's percent of flow contribution to the Platte River. The percent of flow contribution of each tributary to the Platte River was estimated using projected flows for 10-year, 50-year, and 100-year events. The event flows were estimated using Log Pearson analysis of maximum daily flows at the USGS gages nearest to the potential lakes (06805500 Platte River at Louisville, Nebraska, 6805000 Salt Creek near Ashland, Nebraska, and 06800500 Elkhorn River at Waterloo, Nebraska). It should be noted that this assessment did not evaluate impacts to Salt Creek geomorphology, hydrology, or habitat as a result of damming the creek for lake creation in depth, as the scope was focused on impacts to the Platte River. A bit more attention to the Elkhorn River was deemed warranted as it does have greater potential influence on Platte River geomorphology.

4.1 Salt Creek Dammed Lake Example

According to comparison of the 10-year, 50-year, and 100-year storm flows, the Salt Creek tributary contributes less than 1 percent of flows and sediments to the Platte River (measured at the Louisville USGS gage), as shown in Table 3. When setting environmental flows to ensure development and water use do not cause adverse impacts on the health and function of waterways and their ecosystems, the general rule is to avoid changing hydraulic, hydrologic, or environmental variables by more than 10 percent to prevent harm and by 20 percent to prevent adverse effects (Richter et al. 2012).

Table 3: Comparison of Flows in Salt Creek and Platte River at Louisville

Return Interval	Platte River Flow at Louisville (cfs)	Salt Creek Flow (cfs)	Salt Creek Flow as % of Platte River Flow
10-year	89,088	21	0.02
50-year	171,254	24	0.01
100-year	220,176	25	0.01

These assumptions indicate that damming the Salt Creek to create a lake would likely have minimal impacts on the overall sediment, flow, and habitat in the Platte River reaches downstream. However, damming this system could adversely affect creek bend stability and bridge scour where the creek flows through Ashland downstream of the dam along Salt Creek itself.

4.2 Elkhorn Dammed River Lake Example

According to comparison of the 10-year, 50-year, and 100-year storm flows, the Elkhorn River tributary contributes approximately 40 percent of flows and sediments to the Platte River at the

Louisville gage during such events (refer to Table 4). Because the change in flow and sediment exceeds the preventive threshold of 20 percent, damming the Elkhorn River to create a large recreational lake would likely lead to adverse downstream impacts to Platte River hydrology, geomorphology, and habitat. As discussed in Section 4.0, impoundment of Salt Creek or the Elkhorn River would likely lead to water quality issues within the tributaries, within the reservoir lakes, and downstream in the Platte River.

Table 4: Comparison of Flows in Elkhorn River and Platte River at Louisville

Return Interval	Platte River Flow at Louisville (cfs)	Elkhorn River Flow (cfs)	Elkhorn River Flow as % of Platte River Flow
10-year	89,088	38,452	43
50-year	171,254	73,377	43
100-year	220,176	92,917	42

Cross valley dams can act as substantial barriers to fish passage and can destroy access to upstream spawning grounds of migratory aquatic species. These artificial geomorphic barriers can be severely damaging to select fisheries and, in some cases, adversely affect threatened and endangered or commercially valuable species. Disruptions to the continuity of commercial navigation and river recreation can also occur. In some cases, fish ladders and locks can be established to overcome passage discontinuities at significant implementation, maintenance, and operational expense. Notably, the endangered species pallid sturgeon forage on the Elkhorn River after floods and in the lower Platte River more routinely. The lower Platte River is a potential spawning area although spawning has not been conclusively demonstrated there.

5. CONCLUSIONS

From a geomorphic perspective, the primary risks involved in creating a lake in the Platte River floodplain include bank erosion, loss of grade control leading to bank collapse, sapping and avulsion of embankments, sediment accumulation in the lake, and degraded water quality within the potential Lake, the Platte River, and in tributaries upstream of the lake. The location of the Platte River large excavated lake is in a rapid expansion of the valley and along an outer bend are particularly vulnerable to scour. For the Platte River small excavated lake, it is located on an inner bend of the Platte River, which will experience more sediment deposition. An excavated lake that eliminates existing floodplain buffer and subsumes tributary confluences can lead to localized flooding and water quality issues. Changing the sediment dynamics of the tributaries and Platte River with embankments and impoundments could lead to future dredging needs and bank failures associated with lateral migration. Countermeasures against erosion, sedimentation, and related flood risks and property losses are available and create their own impacts to be addressed. Direct and secondary impacts to floodplain and river habitat will require compensatory mitigation.

While a Salt Creek dammed lake would not have a significant impact on flows or sediments to the Platte River, it would likely have hydrologic, ecological, and water quality impacts upstream of the dam, near Ashland, and within the remaining downstream segment of Salt Creek. Because the Elkhorn River is a more significant contributor of flows and sediments to the Platte River, an Elkhorn River dammed lake would have significant impacts on flow and sediments in the Platte River, creating downstream erosion and bank failure vulnerabilities. The dam would also likely cause ecological and water quality impacts upstream of the dam and on the downstream segment of the Elkhorn River. The flow would be released through the dam; however, sediment trapping would occur at the dam and would cause sedimentation deficiency after the dam along the Elkhorn River and Platte River.

While these potential lakes could be possible to construct, construction would be extremely costly, and associated infrastructure would need repetitive and costly repairs and maintenance. All associated development and infrastructure built within the high hazard floodplain would require extensive permitting and flood insurance. Additionally, the potential lake could contribute to excess erosion of downstream properties, cause localized flooding issues, and impact off-site habitat and water quality. Permitting of the lake(s) and appurtenant mitigative and fluvial geomorphic risk management activities and structures will be challenging and require extensive public outreach.

Although lake locations have selected without fatal physical or engineering flaws related to public water supply, the full feasibility of alternatives will rest on their permittability in accordance with federal regulations related to wetlands, endangered species, water quality, property losses due to hazardous erosion and shoaling, and flood hazards among other issues. Almost all of these factors are likely to be affected by alterations to the Platte River’s geomorphic conditions, and on the Elkhorn River and Salt Creek if they are dammed.

This study has provided a screening level analysis of the most likely effects of different lake positions and types on river stability. To gain a sufficient understanding of the specific areas where assets, habitats, and infrastructure are most likely to be affected by geomorphic adjustments perhaps the first line of a future feasibility and alternatives investigation should be to setup and run a rigorous and defensible hydrodynamic and sediment transport model at sufficient calibration, scale, and granularity to predict more precisely and accurately where erosion and sedimentation will be displaced and reside over time. Such delineations will facilitate an improved understanding of the specific magnitude and locations of adverse outcomes. This will better inform a carefully targeted suite of countermeasure types and positions, and the model can be used to assess the outcomes of different river mechanics and erosion control deployments as well as integration of any necessary habitat and flood mitigation requirements. All such activities will be expensive and optimizing their deployment will likely be a critical component of updating any benefit-cost analysis or assessment of return on economic stimulus from lake establishment. Such delineations are also necessary to appropriately identify the most-affected stakeholders in public outreach campaigns and negotiations.

Further, the modeling tool will become an important driver for identifying permitting issues and to explore and discuss potential mitigative measures with regulatory agencies with greater specificity. During modeling explorations, it might become apparent that reducing lake sizes or other adjustments to lake alignments may avoid or minimize direct and secondary impacts to regulated features and functions. These adjustments should be carefully documented to demonstrate that avoidance and minimization were included in the feasibility and alternatives assessment.

These suggestions for next steps are from the perspective of fluvial geomorphologists and river engineers based on experience predicting and coping with the suite of issues identified in this report on other rivers. They are not intended to provide a comprehensive scope of feasibility and alternative analysis activities. In addition, note that a model should be one part of a weight-of-evidence approach to assess specific requirements and outcomes, and as with most human interventions in river corridors a long-term adaptive maintenance and retrofit strategy is likely to be required.

No fatal flaws were identified based on the geomorphic analysis for the Platte River large excavated lake, Platte River small excavated lake, Elkhorn River dammed lake, and Salt Creek dammed lake in relation to LWS' wellfield and MUD's wellfields at Platte West and Platte South. As noted above, further evaluations will be important in determining remediation for downstream impacts to minimize changes in sediment transport. Therefore, it is recommended that full feasibility studies of the lakes be performed.

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LB1023 (JEDI) IMPACT EVALUATION FOR CITY OF LINCOLN WATER SYSTEM AND METROPOLITAN UTILITIES DISTRICT: ANALYSIS SUMMARY AND FINAL REPORT

Lincoln and Omaha, Nebraska – 2024

October 2024

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I, Mallory Morton, am the Coordinating Professional on the LB 1023 (JEDI) Impact Evaluation for the City of Lincoln Water System and Metropolitan Utilities District project.

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