# STRASBURG SLOUGH INVESTIGATION

Emmons County, North Dakota

SWC Project #558
January 2020

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# STRASBURG SLOUGH INVESTIGATION

Strasburg, North Dakota, Emmons County

*SWC Project #558*
*North Dakota State Water Commission*
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**Prepared for:**
Emmons County Water Resource District

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# 1. Purpose

The purpose of this report is to document the findings of an investigation that evaluated flood risk reduction alternatives for Strasburg, ND due to flood issues caused by the adjacent Strasburg Slough. The alternatives documented in this report were created as part of a Section 22 Planning Assistance to States Study, in accordance with an agreement between the U.S. Army Corps of Engineers (Omaha District) and the Emmons County Water Resource District (District), and pursuant to an investigation agreement between the District and the North Dakota State Water Commission (SWC). The purpose of the study is to investigate flood risk management alternatives for areas of concern in Emmons County, ND.

### *1.1 Site Location*

Strasburg Slough is located on the eastern edge of the City of Strasburg in Emmons County, ND (**Figure 1**). Strasburg Slough is a water body in a complex series of non-contributing water bodies surrounding the City of Strasburg. This series of water bodies ultimately outlets to Baumgartner Lake, which eventually flows into Beaver Creek.


**Figure 1.** Strasburg Slough, site location

### *1.2 Background*

The first known flooding issue that arouse from Strasburg Slough was during the spring of 2009. At that time, the city experienced flooding from a rapid snowmelt and contacted the SWC for assistance. The SWC provided pumping equipment, and the water levels within the slough were drawn down to a point where it was no longer an immediate threat. The water from Strasburg Slough was pumped to a slough to the northwest (**Figure 2**).

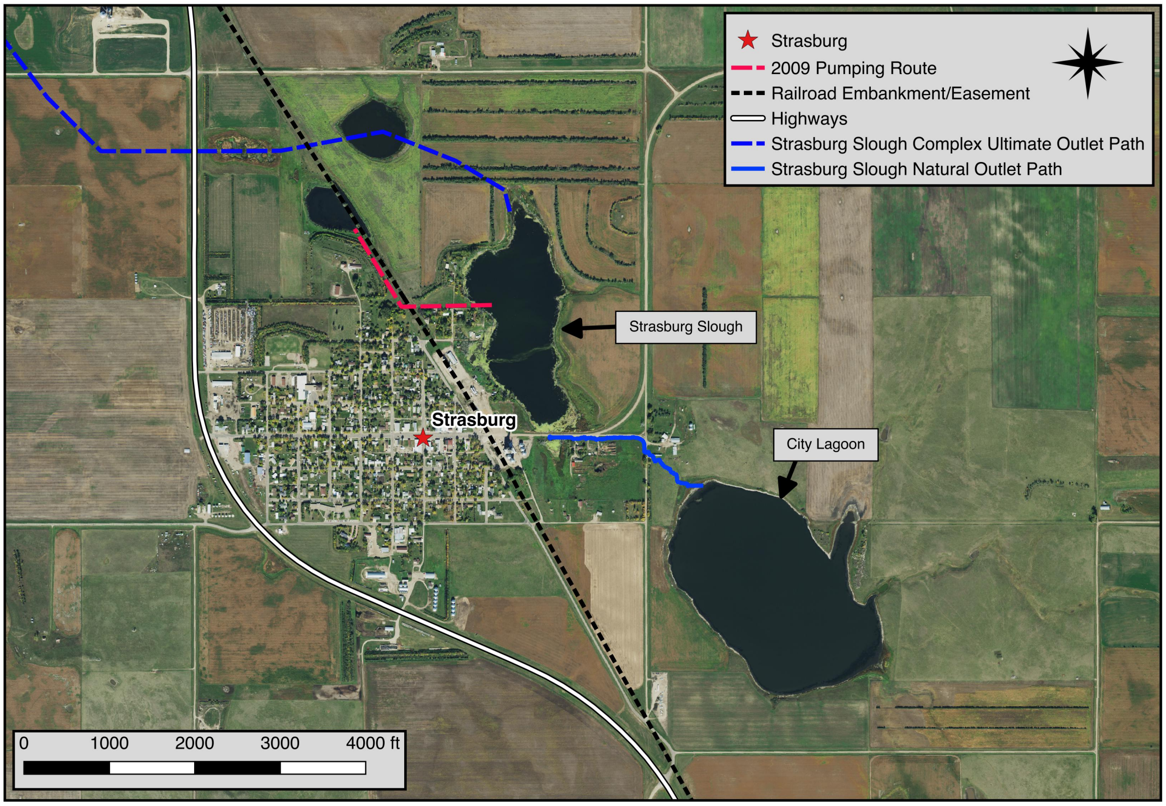


**Figure 2.** Strasburg Slough, 2009 pumping route (aerial photograph - 2017)

The slough rose again in 2014, which lead the SWC to conduct a preliminary findings analysis to find a potential outlet. The 2014 SWC memorandum (**Appendix A**) detailed two issues other than the inundation of homes that further complicate this already challenging project. The first issue is a potential ground water connection between Strasburg Slough and the water bodies to the northwest, and the second is that Strasburg Slough's natural outlet is to the city's sanitary lagoon.

The potential ground water connection is an issue because it creates unique challenges for evacuating the water from Strasburg Slough. It is believed that Strasburg Slough is connected to the northwest water bodies based on our evaluation of the geologic data and 2014 water surface survey. The geologic maps described in the 2014 memorandum indicate material conducive to a groundwater connection and the 2014 water surface survey resulted in nearly identical water surfaces for each slough. This groundwater connection requires that the water evacuated, via an outlet, be delivered outside of the groundwater system, which means it needs to end up in Baumgartner Lake or another location outside of this potential connection. The open channel outlet to Baumgartner Lake analyzed in the 2014 preliminary analysis, while appropriate, was found to be costly and could have political implications due to the drained water ultimately flowing through Beaver Creek at Linton, ND.

Strasburg Slough's initial outlet being the city's sanitary lagoon further complicates the issue because it could have implications on potential alternatives. The 2014 SWC memorandum suggested that a long-term buyout of affected residents was a valid solution to the flooding problem, but acknowledged that Strasburg Slough merging with the city's lagoon could have health and human safety concerns for the city.

In 2019, the slough rose to its highest elevation on record. Temporary emergency pumping was employed to evacuate water to Baumgartner Lake along the route identified in **Figure 3**. The temporary emergency pumping was deemed successful and cost the community approximately $58,000 to employ.

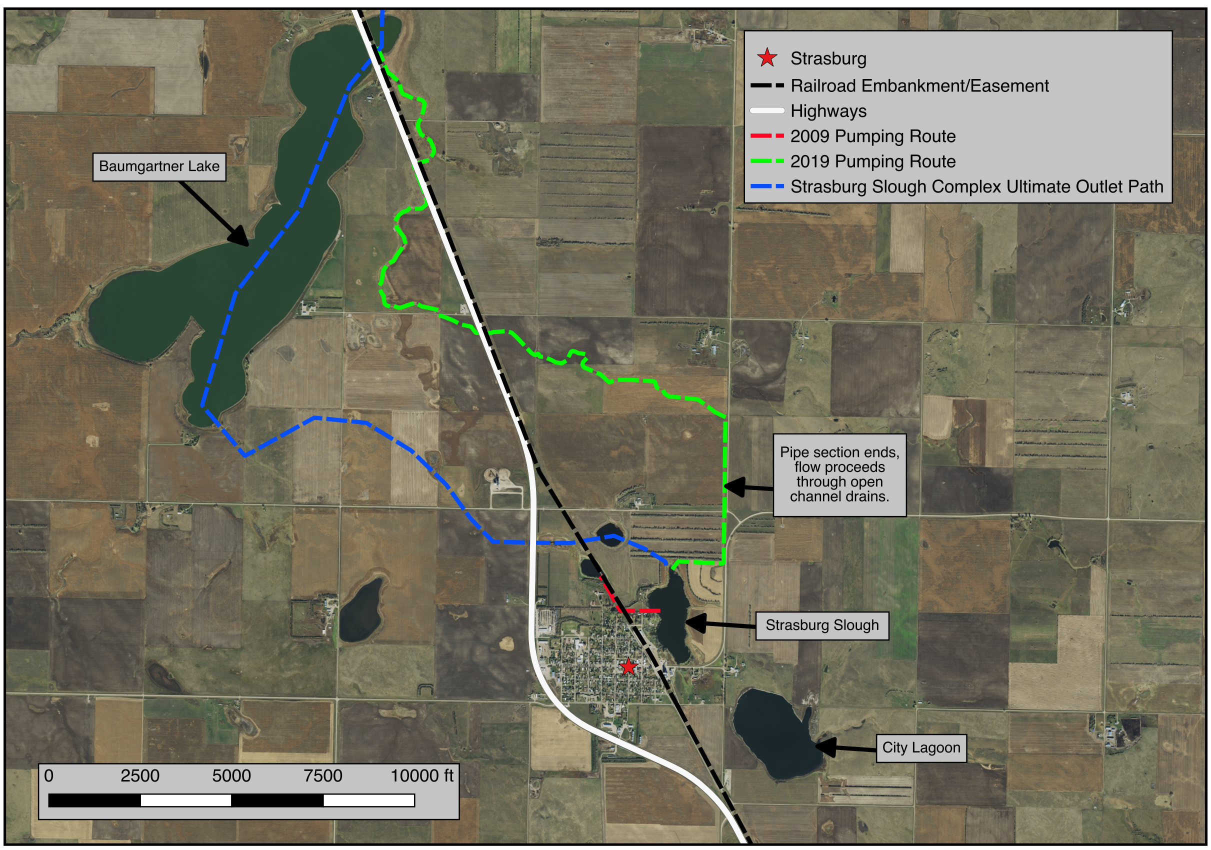


**Figure 3.** 2019 Pumping Route

### *1.3 Benefits of Re-evaluation of Strasburg Slough*

Conducting the current analysis for Strasburg Slough improves the findings delivered in the 2014 memorandum. The inclusion of Light Detection and Ranging (LiDAR) data, which was unavailable during the 2014 study, helps to better define the elevation at which Strasburg Slough overflows into the city's lagoon and provides a better platform to examine open channel outlet alignments. These are important elements because further definition of Strasburg Slough's spilling point helps conceptualize what events could cause this action to occur. The increased precision of elevation data from the LiDAR also provides greater confidence in the alternative analysis, with potential of lowering the cost of alternatives to the point of feasibility.

The inclusion of hydrologic modeling via U.S. Army Corps of Engineer's Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), while not as robust or complex as other methods, defines the basin boundaries and provides the District with even more detail on the types of events and conditions that could cause Strasburg Slough to flow into the city's sanitary lagoon.

The reopening of the study also allowed opportunity to work with other entities to determine the types of impacts that could occur from Strasburg Slough and the city's sanitary lagoon merging into one water body.

## 2. Strasburg Topography

Strasburg Slough, being located within a complex series of non-contributing sloughs, requires detailed information on the region's topography. The 2014 SWC memorandum utilized a coarse digital elevation model (DEM) to determine the spill elevation and storage capacity of Strasburg Slough. This coarse DEM provided some confidence on the elevation Strasburg Slough would flow into the city's sanitary lagoon, which was the best available data at the time the analysis was conducted. The current analysis of Strasburg Slough includes newly collected LiDAR and survey data to determine culvert locations in the region.

### *2.1 Topographic Data*

Survey data collected consisted of culvert data (**Figure 4**) in order to determine potential flow paths for the drainage complex. The data collected were based on the North American Vertical Datum of 1988 (NAVD88), GEOID03, with the horizontal coordinate system being the North Dakota State Plane System (NDSPCS), South Zone, units in international feet, based on the NAD83 (1986). A text file of the completed survey is provided electronically with this report (**Appendix C**).

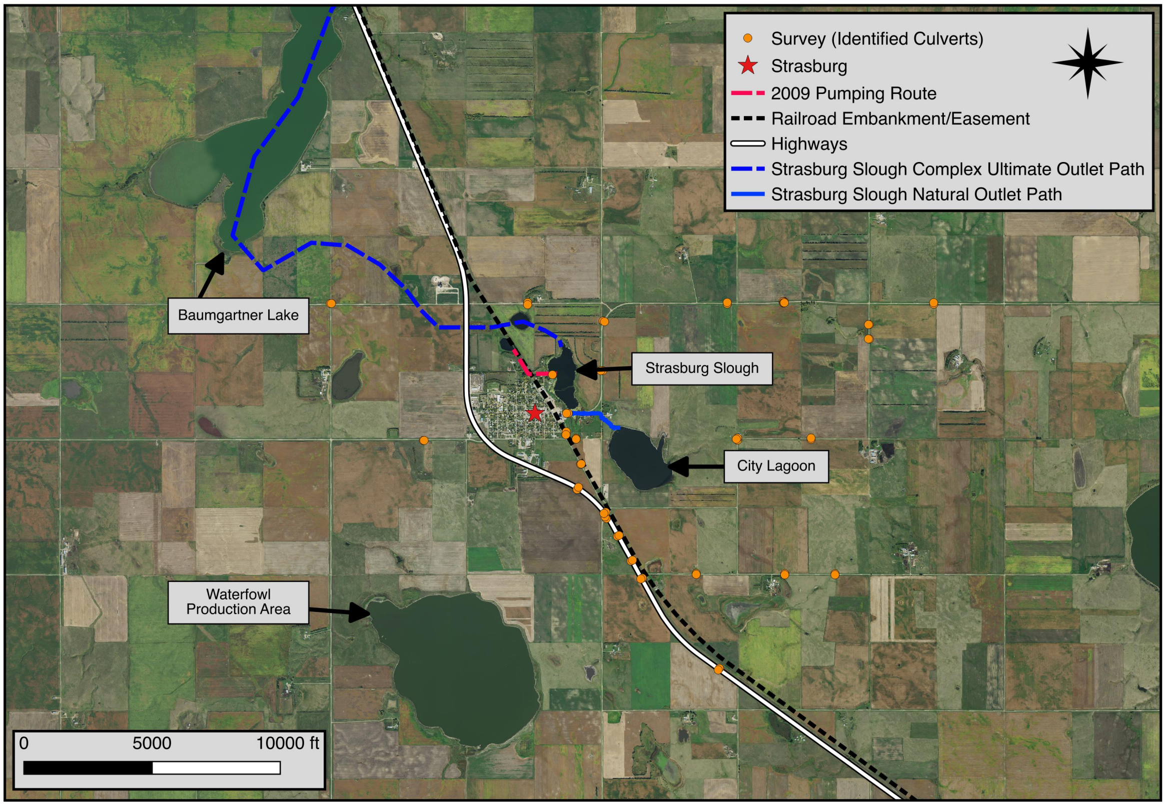


**Figure 4.** Culvert survey conducted for Strasburg Slough analysis

The LiDAR data utilized for this study consisted of a bare earth 1-meter DEM. The LiDAR was flown in the fall of 2015. The LiDAR elevations in the model are based on the NAVD88, GEOID03, with the horizontal coordinate system being the NDSPCS, South Zone, units in international feet, based on the NAD83 (1986). Individual LiDAR tiles were obtained from the SWC's LiDAR web service and merged using Quantum GIS. The DEM used for this study is included electronically with this report (**Appendix B**). The LiDAR was converted to different horizontal and vertical units in order to use tools required to complete the study. **Figure 5** illustrates a section of the LiDAR utilized for this study.

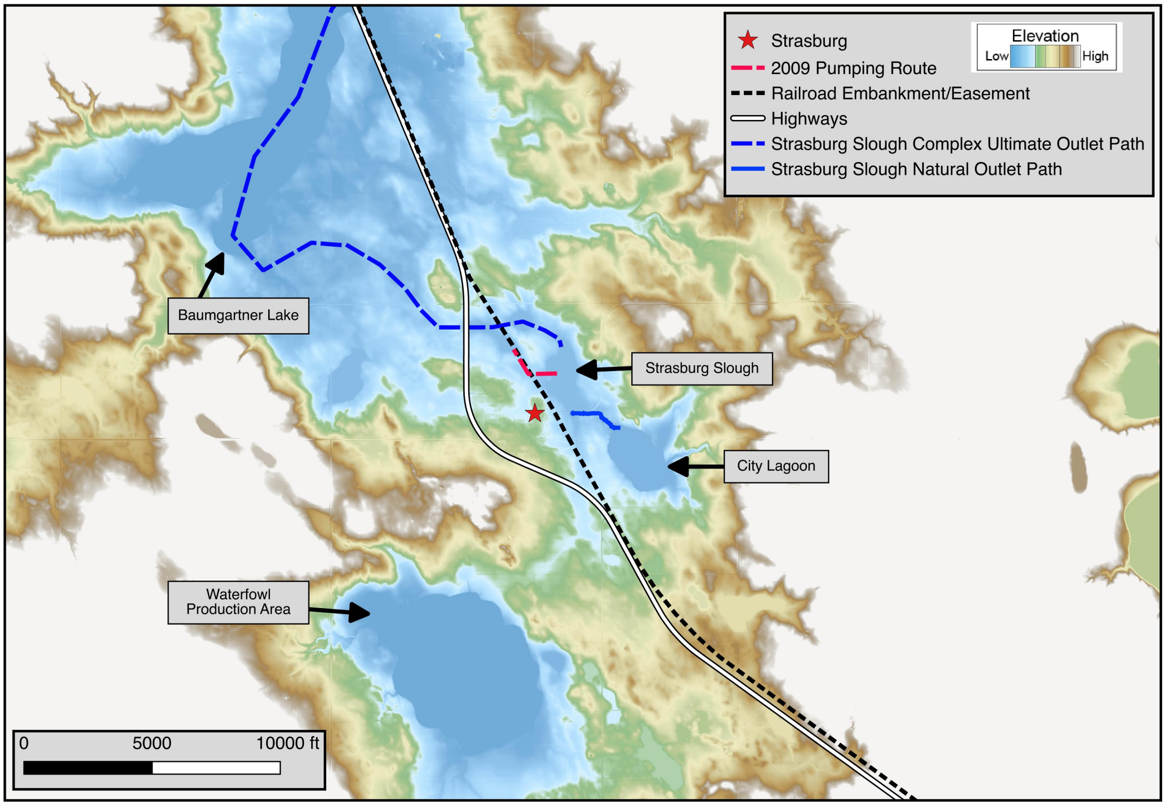


**Figure 5.** LiDAR utilized for the Strasburg Slough analysis

### *2.2 Strasburg Slough Drainage Complex Delineation*

The drainage basins for the Strasburg Slough complex were delineated using the culvert survey and LiDAR, coupled with a series of processing scripts within a Geographic Information System (GIS). The culvert survey data was used to burn pathways through the roads in the LiDAR in order to develop continuous streamlines throughout the LiDAR and accurately depict the drainage basins. A stream line processing script, which examines the contributing area to a low point and traces stream lines throughout the LiDAR, was utilized to identify flow paths within the drainage complex. Drainage basins were then determined by identifying locations above a particular point in the stream. A drainage basin processing script was then used to determine the drainage area above the identified location. **Figure 6** illustrates the drainage basins delineated within the Strasburg Slough drainage complex before ultimately leaving Strasburg Slough to flow into Baumgartner Lake.

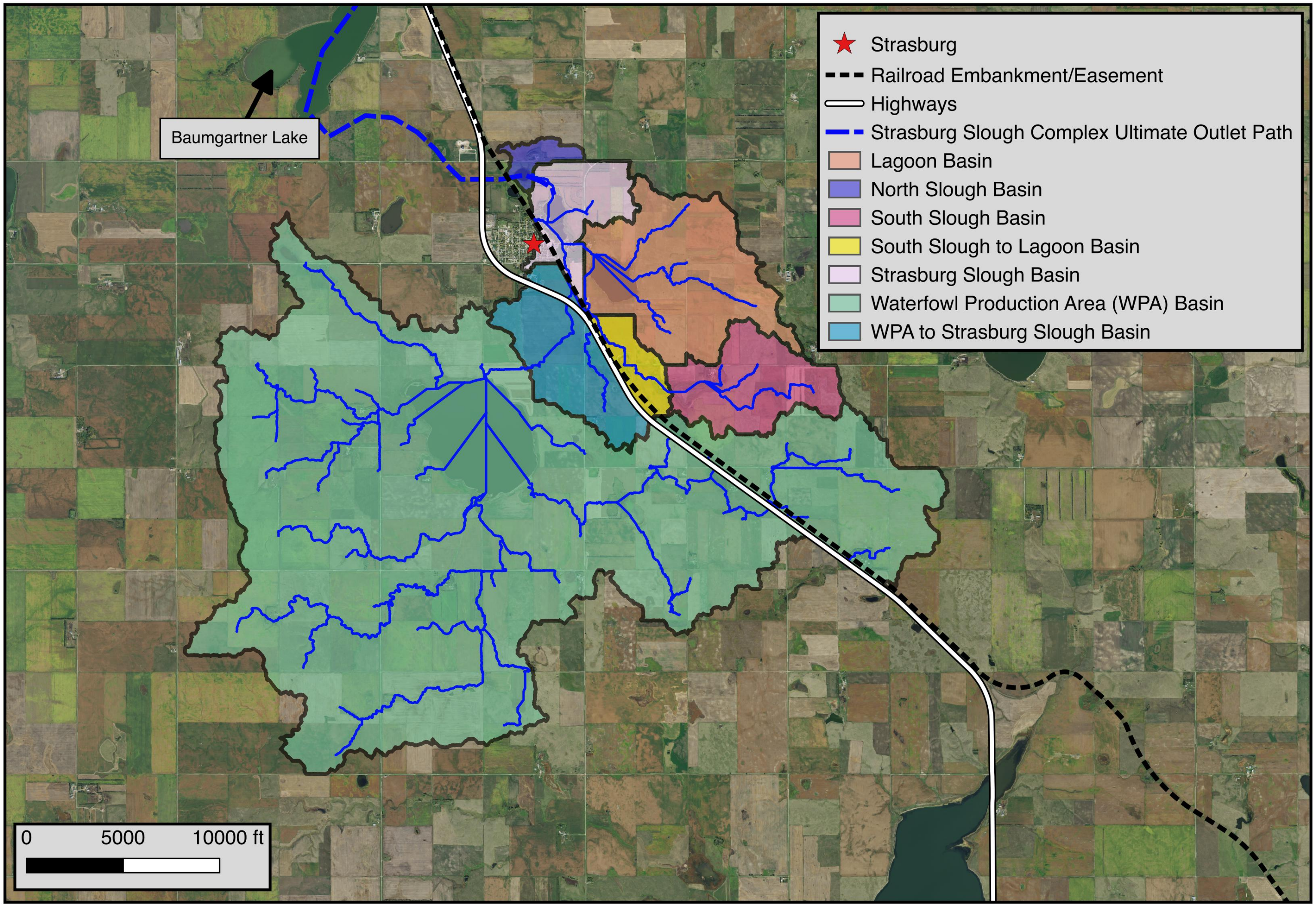


**Figure 6.** Strasburg Slough drainage basins

### *2.3 Strasburg Slough Non-Contributing Waterbodies*

In order to properly capture the effects of rainfall on the Strasburg Slough drainage complex, elevation-capacity curves were developed for major water bodies in the system. Elevation-capacity curves were developed for North Slough, South Slough, the WPA slough, city lagoon, and Strasburg Slough using the LiDAR and a post processing script. The elevation-capacity curves for Strasburg Slough and the city lagoon are illustrated in **Figures 7** and **8**, respectively. The elevation-capacity curves for North Slough, South Slough, and the WPA slough are provided in **Appendix D**, along with the city lagoon and Strasburg Slough curves. **Figure 7** provides the original curve utilized in the 2014 SWC memorandum, including its spill elevation, and the updated curve with the inclusion of the LiDAR utilized for this study. It is important to note that the volumes from the 2014 SWC memorandum were much larger than what is provided in **Figure 7**. The change in volume was due to an error in the original study, which was the improper definition of the horizontal datum during the original processing of the elevation-capacity curve. The original DEM was projected to the correct horizontal datum to fix this error and the results of reanalyzing the elevation-capacity curve is what is provided in **Figure 7**. The 2014 SWC memorandum also stated the spill elevation was 1797.3 feet (NAVD88), which should have been stated as a range between 1796.8 feet to 1797.3 feet (NAVD88). The updated spill elevation from this analysis is 1798.1 feet (NAVD88), which is the lowest possible spill elevation based on the updated curve that includes LiDAR.

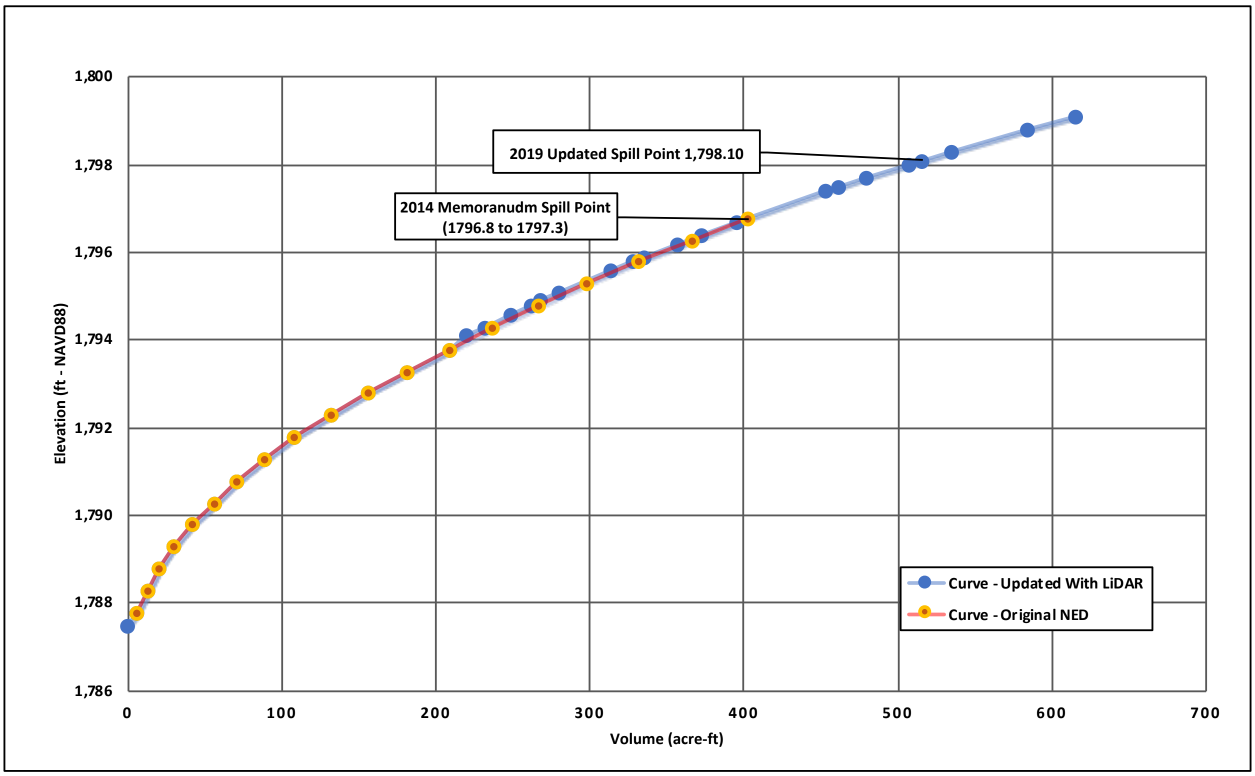


**Figure 7.** Strasburg Slough elevation-capacity curve

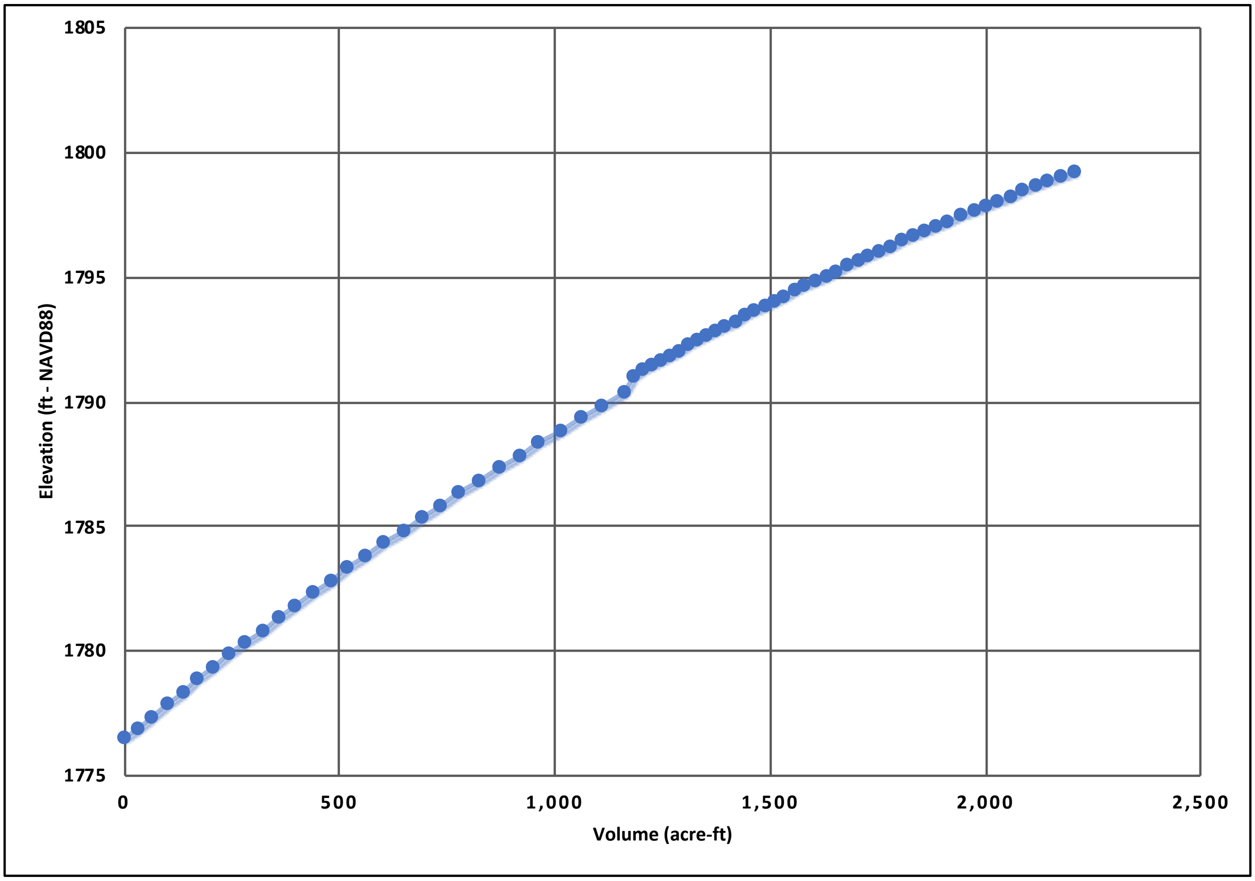


**Figure 8.** City lagoon elevation-capacity curve

The processing script that created the elevation-capacity curves for each water body also produced inundation bounds at specific elevations. **Figure 9** illustrates the inundation bounds for Strasburg Slough at its highest water surface elevation (1798.1 feet NAVD88) prior to the slough spilling into the city's lagoon. Water surface elevations near the slough's maximum capacity results in the inundation of eleven primary structures. Eight structures appear to be homes and three structures appear to be commercial buildings, with the majority of the structures located on the west side of the slough.

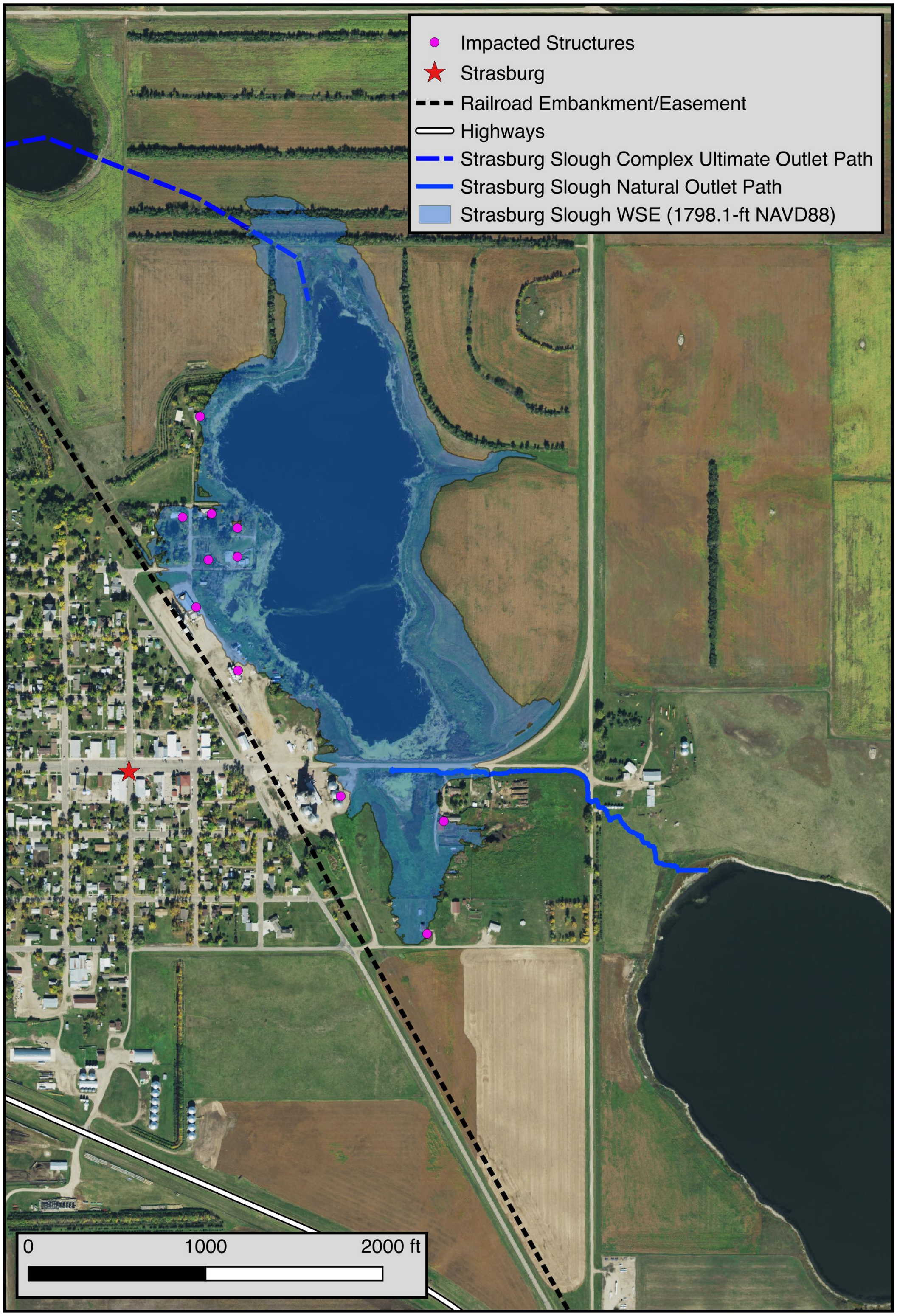


**Figure 9.** Strasburg Slough inundation boundary

## 3. Strasburg Area Geology

The geologic review conducted in the 2014 SWC memorandum looked into the potential groundwater connection of Strasburg Slough to the sloughs in the northwest and the city's lagoon. The initial review looked at the Emmons County Geologic Surface Map, a portion of which is displayed in **Figure 10**, which displays the surficial geologic layers between the region's water bodies. The 2014 SWC memorandum suggests that the slough and its outlet lie in a fluvial plain, part of an ancient glacial streambed that consists of sandy/gravely soil. The 2014 SWC memorandum also states the following:

> "Boring logs in the area show a sand and gravel layer directly beneath the topsoil, further suggesting a strong hydraulic connection. The sand and gravel layer from the boring logs appear to be between 8 to 50 feet deep in some areas along the fluvial plain."

If a strong groundwater connection exists as described in the 2014 SWC memorandum, the 2009 pumping, illustrated in **Figure 2**, probably only provided temporary relief to the flooding occurring at that time.

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

The runoff characteristics in SSURGO are organized into 5 categories including high, medium, negligible, low, and very low runoff. **Figure 11** illustrates the runoff characteristics of the Strasburg Slough drainage complex. The illustration shows that the runoff classification in the Strasburg Slough Basin is very low near the slough and medium in the higher elevations located to the east of the slough. Generally, the runoff classification for the entire Strasburg Slough drainage complex is medium to low, with no high runoff classified soils within the complex.

The hydrologic soil group classification from SSURGO was also examined within the Strasburg Slough drainage complex. The hydrologic soil groups are based on estimates of runoff potential (like the runoff classification), but provide more information on the description of each classification. In the United States, four groups are assigned and three dual classes exist within each group. The groups and definitions are defined as follows:

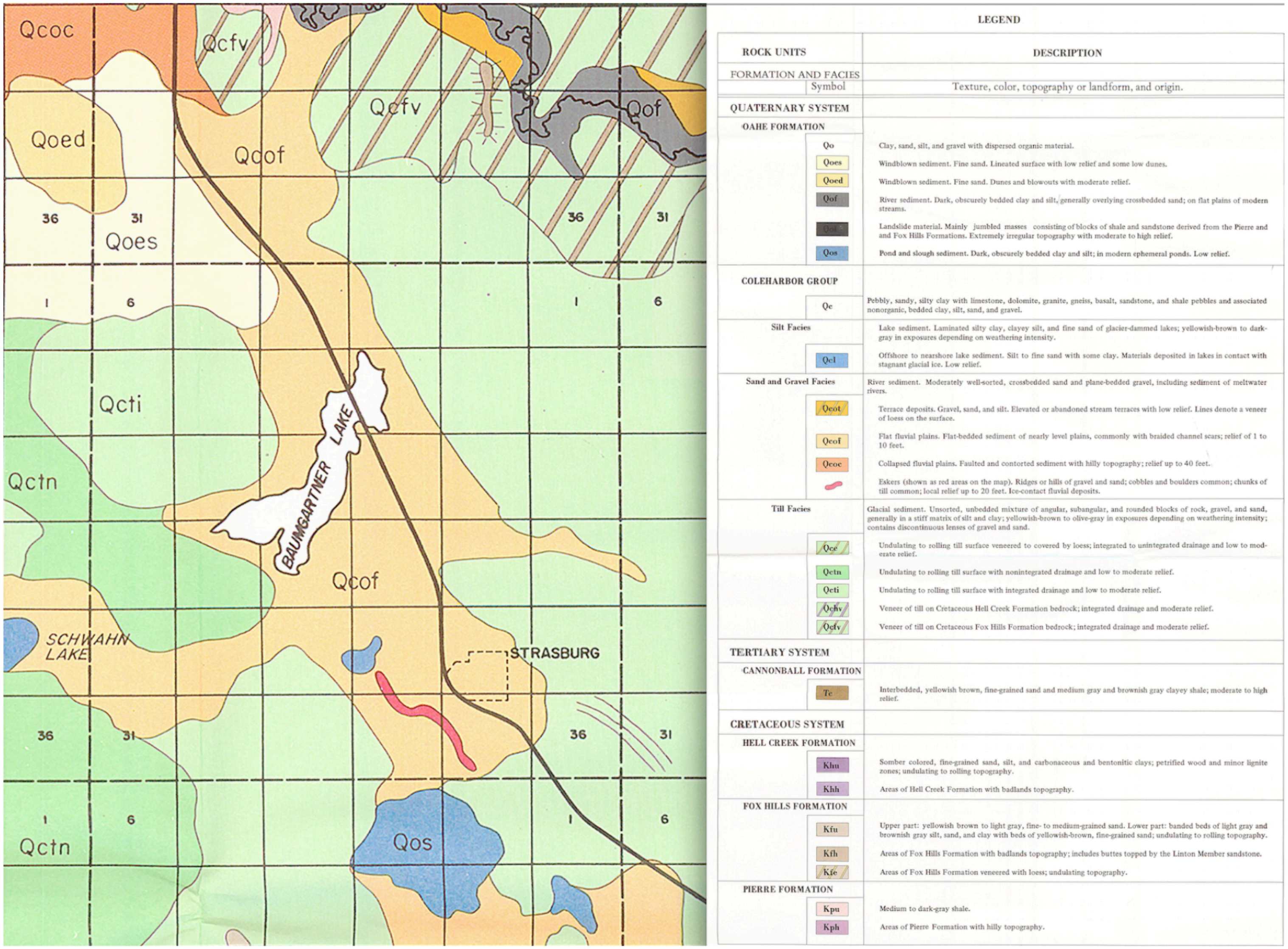


**Figure 10.** USGS geologic surface map (Bluemle, 1979)

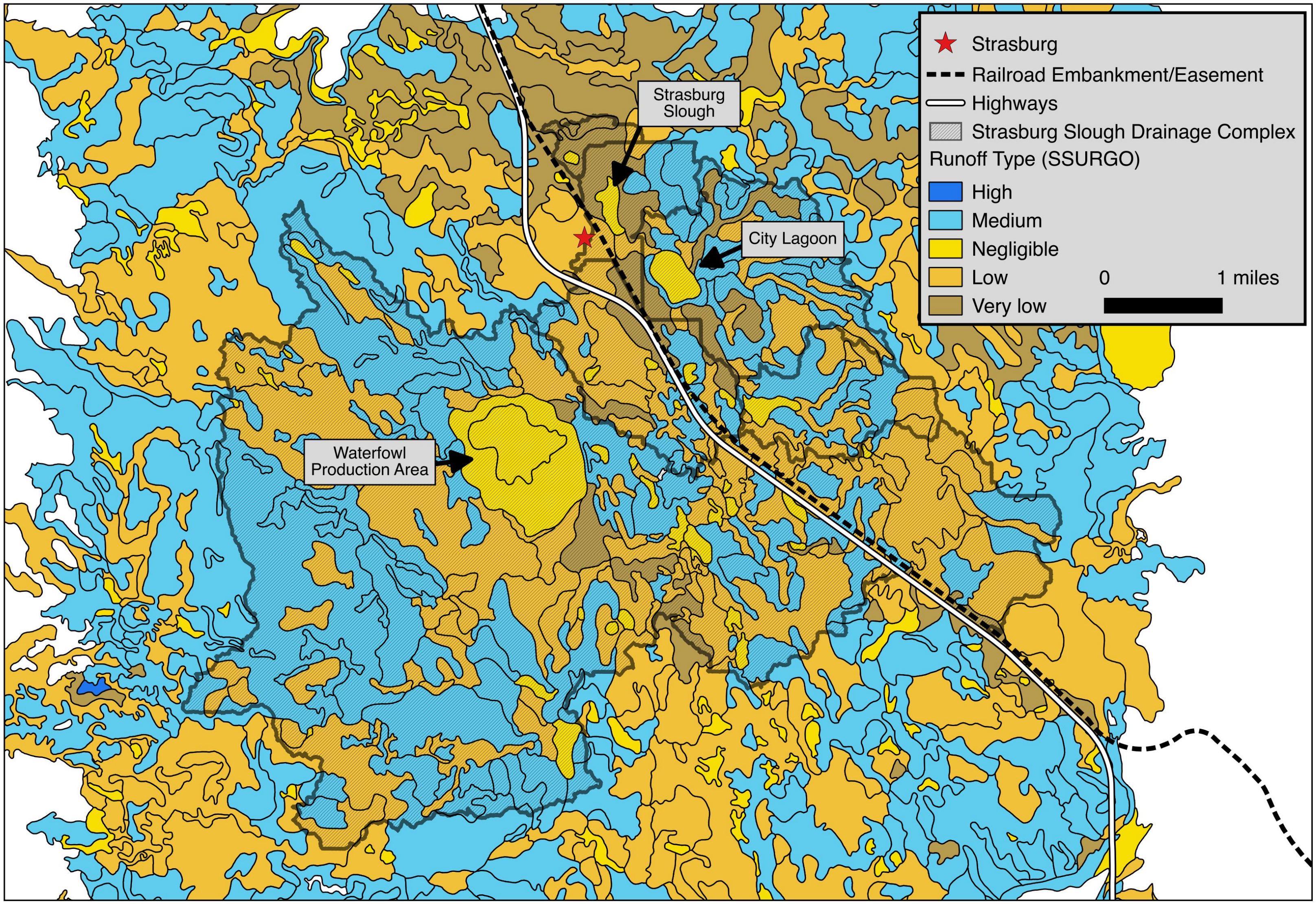


**Figure 11.** Runoff classifications for the Strasburg Slough drainage complex based on SSURGO

*Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have high rate of water transmission.*

*Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.*

*Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.*

*Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high-water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.*

*If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes* (web soil survey).

**Figure 12** illustrates the hydrologic soil groups in the Strasburg Slough drainage complex. As illustrated in **Figure 12**, the hydrologic soil groups surrounding Strasburg Slough indicate it is extremely well drained (Group A) and provides further documentation of a strong potential for groundwater connection between Strasburg Slough and the sloughs to the northwest.

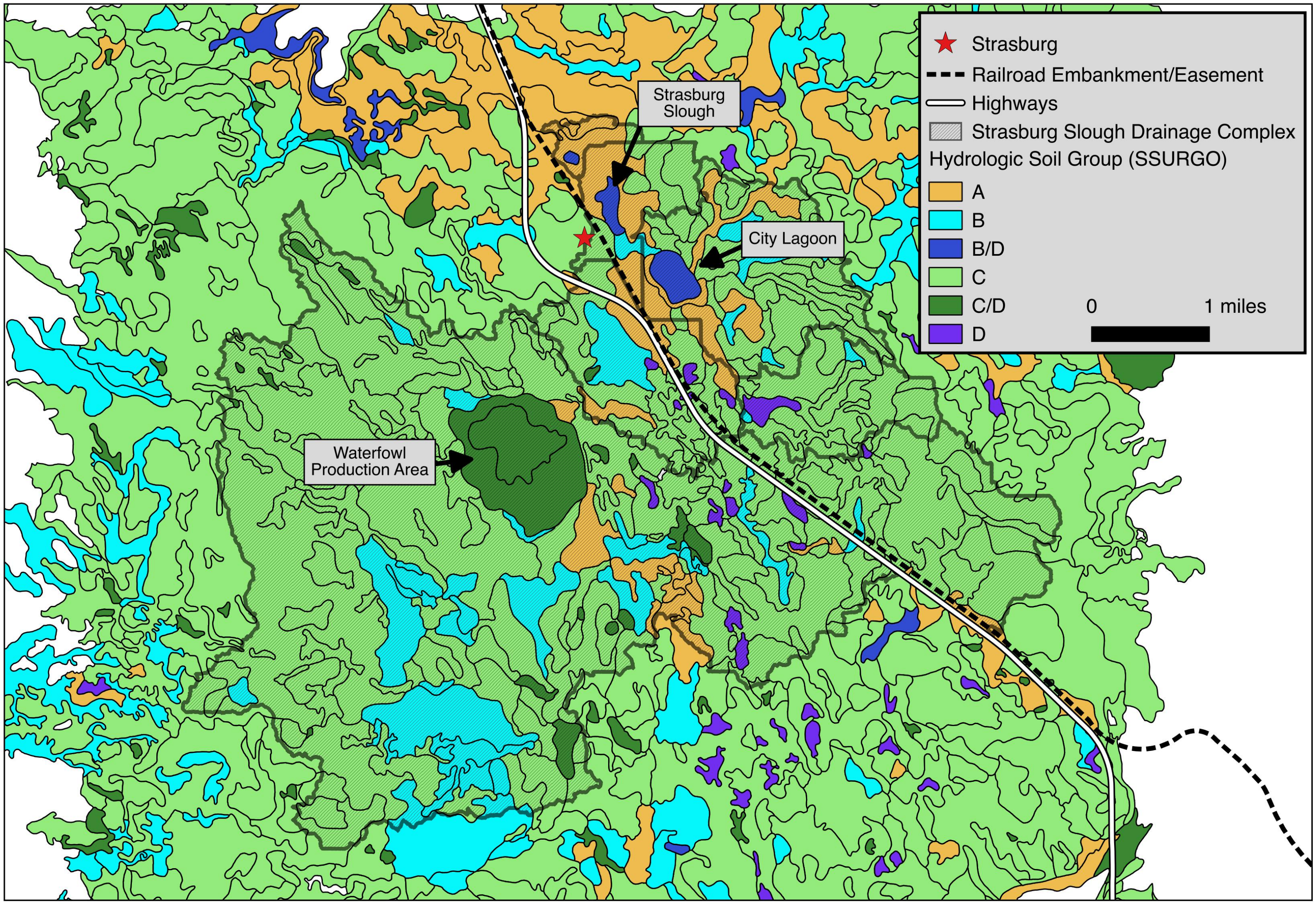


**Figure 12.** Hydrologic soil groups for the Strasburg Slough drainage complex based on SSURGO

# 4. Strasburg Hydrology

In order to understand the potential for Strasburg Slough to overflow into the city's sanitary lagoon, a hydrologic model of the Strasburg Slough drainage complex is required. A detailed hydrologic model can convert rainfall and snowmelt into runoff, and route the runoff downstream to the waterbodies within the drainage complex. This proceeds with the filling and spilling of water bodies into each other, as well as evaporation of those water bodies. Several options exist to create a hydrologic model including short-term or event-based models and long-term models, such as stochastic, water balance, and soil moisture accounting models. Due to the lack of observed data on the water bodies within the drainage complex, it was deemed acceptable to produce a soil moisture accounting model of the drainage complex. The soil moisture accounting model was calibrated to the existing observed data on Strasburg Slough and short-term frequency events underlined what scenarios would be undesirable for the community.

### *4.1 Observed Data*

After the finalization of the 2014 SWC memorandum, the SWC decided it would be beneficial to monitor Strasburg Slough. A gage was installed in the spring of 2015 to measure the water surface elevation of the slough. The gage was placed in the slough each spring and removed each fall from 2015 through 2018. This, along with a water surface elevation of Strasburg Slough captured on July 22, 2014, provided information on the slough's sensitivity to precipitation events and evaporation, details which are necessary for calibration of a hydrologic model. **Figure 13** illustrates the water surface elevations recorded by the gage and the survey point from 2014. The period of record utilized in this study is from 2014 to 2018 and does not include the events that took place in 2019. Exclusion of the 2019 event would not impact the viability of alternatives identified as part of this study, but likely warrant the need to implement an alternative.

As illustrated in **Figure 13**, the water surface elevations of Strasburg Slough are in a decreasing trend with the peak being in the summer of 2015, 1794.6 feet (NAVD88), and the lowest elevation occurring in September of 2018, 1791.6 feet (NAVD88). During the period of record utilized in this analysis there are only three significant rises in the slough's water surface elevation that are recorded from rainfall events, which occurred in 2015, 2016, and 2018. It is also important to note that the slope of decrease in the water surface elevation appears to be similar in 2015, 2017, and 2018, as evaporation is an important feature to consider when modeling closed-basin systems.

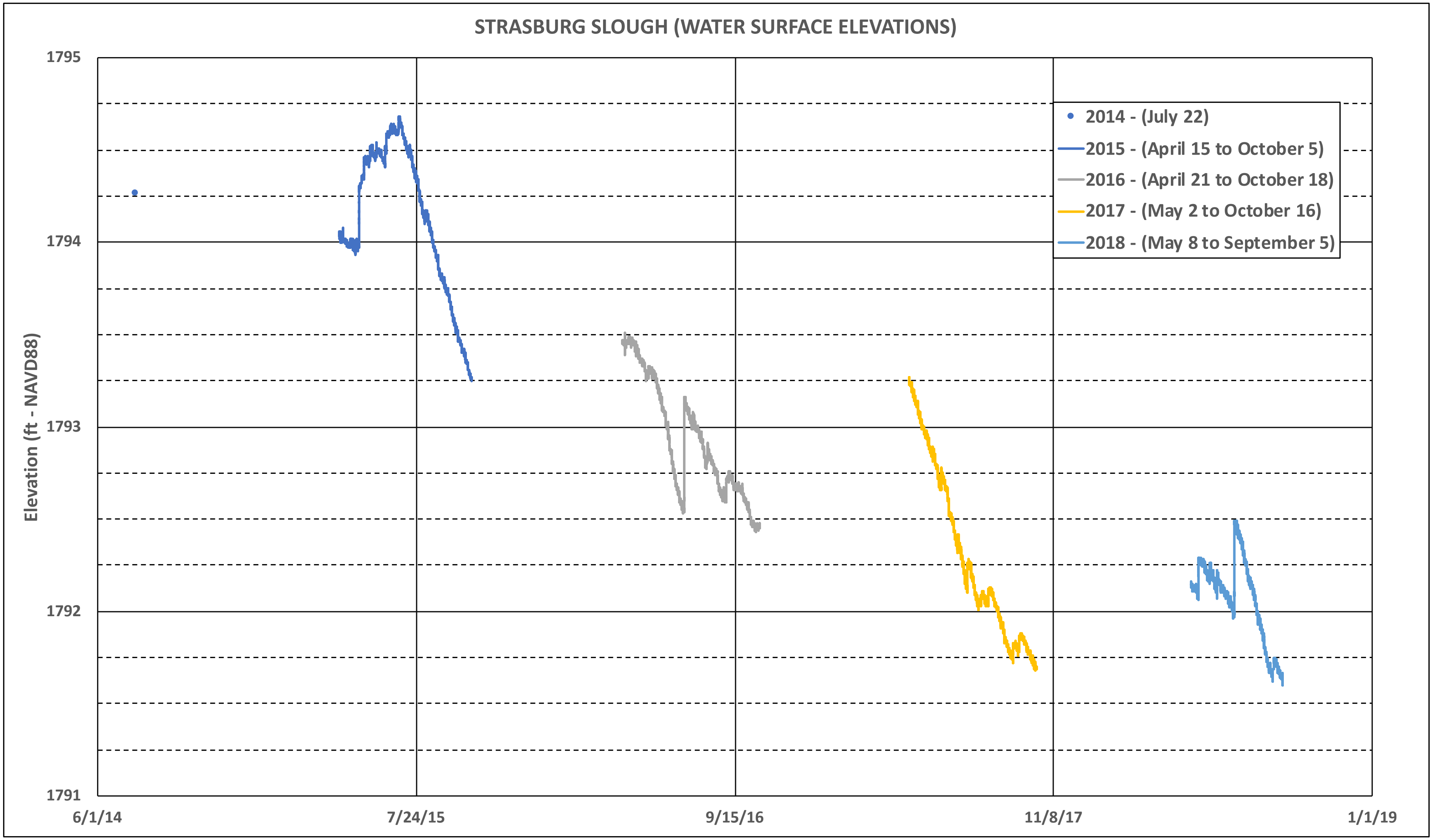


**Figure 13.** Strasburg Slough recorded water surface elevations

### *4.2 Precipitation Data*

Precipitation data for the period of record was collected from the Parameter Elevation Regression on Independent Slopes Model (PRISM) precipitation dataset (PRISM Climate Group, 2019). **Figure 14** provides the PRISM dataset utilized for the study.

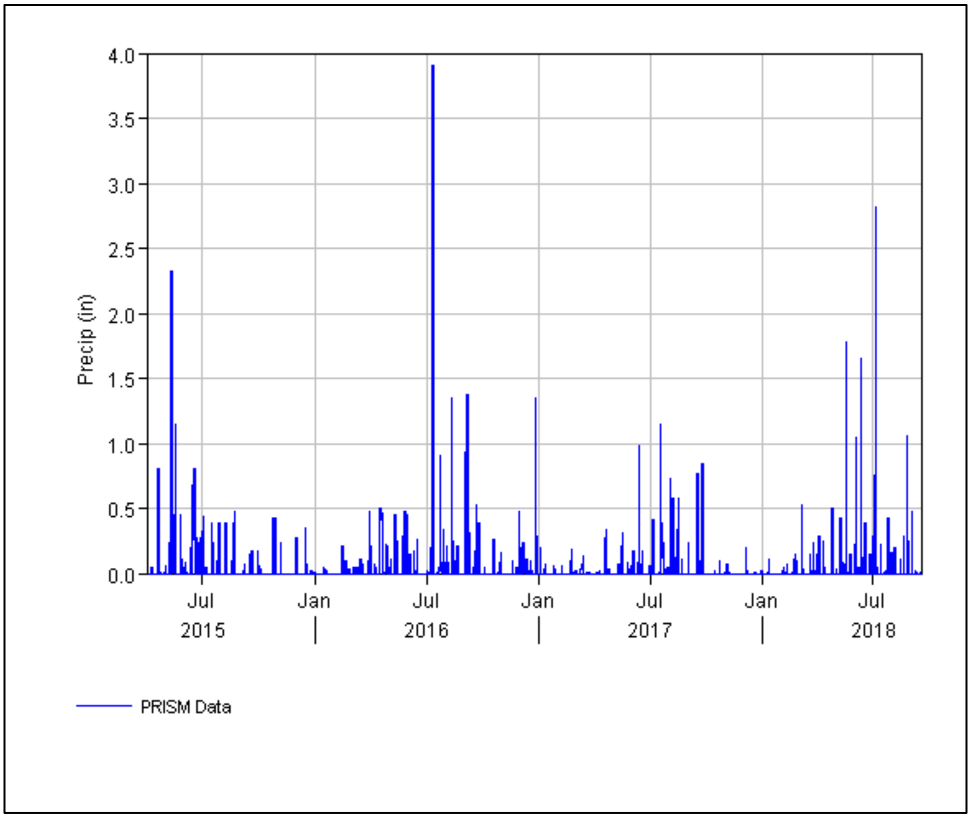


**Figure 14.** PRISM dataset utilized for the Strasburg Slough study

Precipitation frequency events were also obtained to compute frequency events for the study. The National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 precipitation frequency estimates were utilized to determine the probabilistic rainfall depths for the Strasburg Slough drainage complex. **Table 1** provides the Atlas 14 probabilistic rainfall depths utilized for the study.

**Table 1.** Atlas 14 precipitation frequency events

| Duration | Precipitation Frequency Events (Return Interval in Years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 5 | 10 | 25 | 50 | 100 | 200 | 500 | 1000 |
| | (in) | (in) | (in) | (in) | (in) | (in) | (in) | (in) | (in) | (in) |
| 5-min: | 0.278 | 0.341 | 0.449 | 0.543 | 0.681 | 0.792 | 0.909 | 1.03 | 1.2 | 1.34 |
| 10-min: | 0.408 | 0.5 | 0.657 | 0.796 | 0.997 | 1.16 | 1.33 | 1.51 | 1.76 | 1.96 |
| 15-min: | 0.497 | 0.609 | 0.802 | 0.97 | 1.22 | 1.42 | 1.62 | 1.84 | 2.15 | 2.39 |
| 30-min: | 0.681 | 0.834 | 1.1 | 1.33 | 1.66 | 1.93 | 2.21 | 2.51 | 2.92 | 3.25 |
| 60-min: | 0.861 | 1.04 | 1.36 | 1.64 | 2.06 | 2.4 | 2.76 | 3.15 | 3.68 | 4.11 |
| 2-hr: | 1.04 | 1.25 | 1.63 | 1.96 | 2.46 | 2.87 | 3.31 | 3.78 | 4.44 | 4.97 |
| 3-hr: | 1.15 | 1.37 | 1.76 | 2.12 | 2.66 | 3.11 | 3.59 | 4.11 | 4.85 | 5.45 |
| 6-hr: | 1.34 | 1.58 | 2.03 | 2.43 | 3.04 | 3.55 | 4.09 | 4.68 | 5.52 | 6.19 |
| 12-hr: | 1.54 | 1.83 | 2.34 | 2.8 | 3.47 | 4.02 | 4.61 | 5.23 | 6.11 | 6.81 |
| 24-hr: | 1.77 | 2.1 | 2.66 | 3.15 | 3.87 | 4.45 | 5.06 | 5.71 | 6.61 | 7.32 |
| 2-day: | 2.03 | 2.36 | 2.94 | 3.45 | 4.19 | 4.79 | 5.42 | 6.09 | 7.02 | 7.76 |
| 3-day: | 2.21 | 2.56 | 3.16 | 3.68 | 4.43 | 5.04 | 5.68 | 6.35 | 7.28 | 8.01 |
| 4-day: | 2.37 | 2.73 | 3.35 | 3.88 | 4.65 | 5.27 | 5.91 | 6.57 | 7.49 | 8.22 |
| 7-day: | 2.79 | 3.19 | 3.86 | 4.42 | 5.23 | 5.86 | 6.51 | 7.18 | 8.1 | 8.81 |

### *4.3 Conceptual Layout for the Strasburg Slough Drainage Complex*

HEC-HMS was the modeling system selected to analyze the Strasburg Slough drainage complex. HEC-HMS has several built-in options for selecting infiltration, transform, and routing methods. Most notably for this study, HEC-HMS was selected as the study's modeling platform because it is the most widely used platform with the capability to use soil moisture accounting as its infiltration method. The selection of HEC-HMS also allowed for the development of the conceptual layout for the hydrologic analysis, since the capabilities of the platform dictate how the model needs to be setup.

The hydrologic model includes 12 subbasins to capture the effects of rainfall on the Strasburg Slough drainage complex (**Figure 15**). Seven of the subbasins represent the physical ground within the drainage complex, including the Strasburg Slough, Lagoon, Waterfowl Production Area (WPA), South Slough, North Slough, WPA to Strasburg Slough, and South Slough to Lagoon basins. Five of the subbasins represent the physical water bodies, which are simulated as "reservoirs" in HEC-HMS.

The hydrologic model was setup to include five reservoirs (**Figure 15**), including the WPA, Strasburg Slough, city's sanitary lagoon, North Slough, and South Slough. Reservoirs in HEC-HMS allow the entry of elevation-capacity curves, monthly evaporation data, and discharge functions. The reservoirs do not capture the direct rainfall on the water body and require a subbasin with parameters set to mirror the effects of rain falling on the water body.

The hydrologic model includes five routing reaches for moving water through the system from one reservoir to another (**Figure 15**).

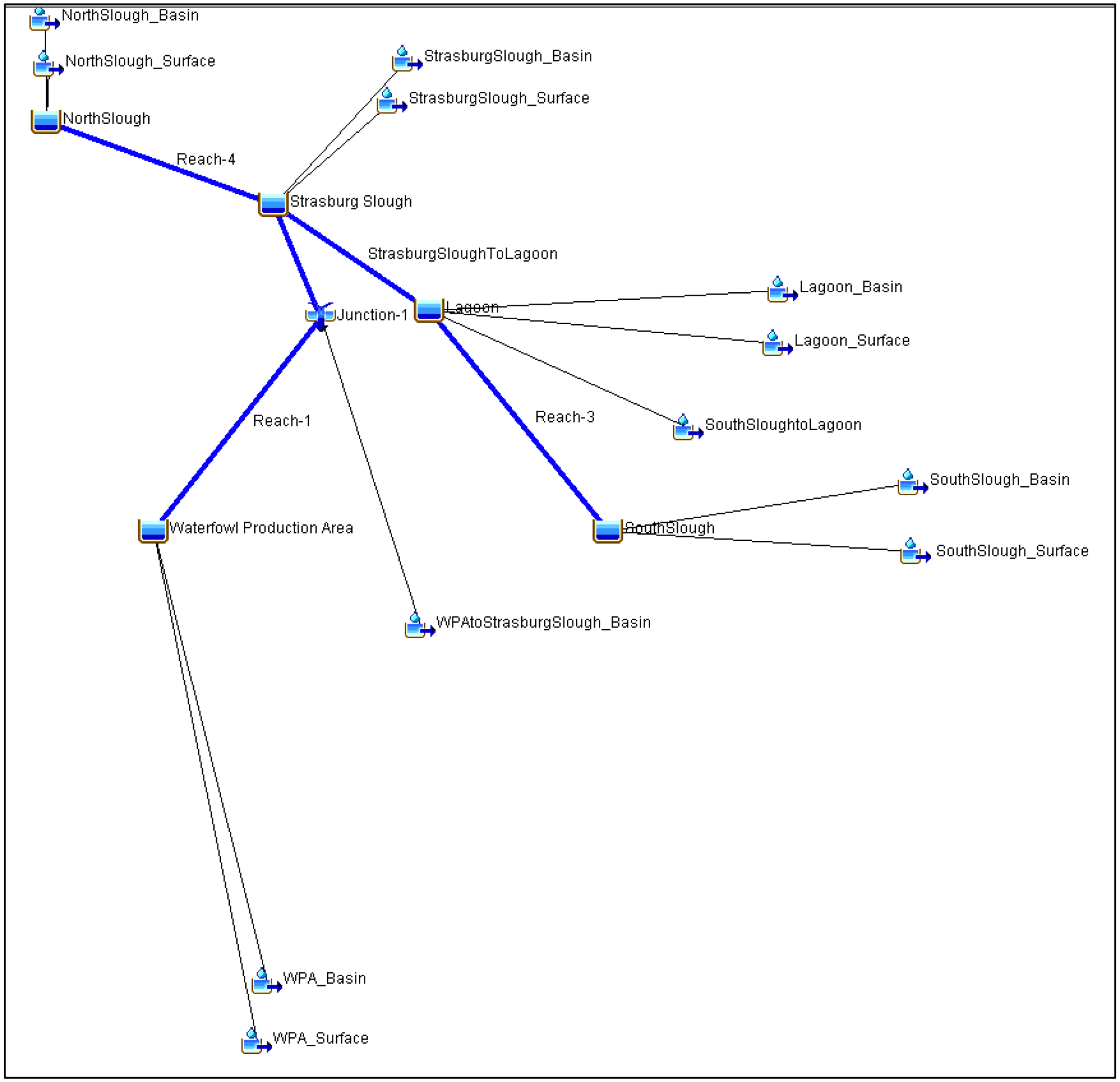


**Figure 15.** Screenshot of the hydrologic model's conceptual layout

### *4.4 Strasburg Slough Drainage Complex's Basin Parameters*

The Strasburg Slough drainage complex has several sets of parameters for each basin. These parameter sets correspond to particular infiltration, transform, and baseflow methods.

Infiltration methods are the mathematical models that translate precipitation depth into the runoff depth that will eventually move downstream. The infiltration method selected for the Strasburg Slough drainage complex is the soil moisture accounting method. This method is important when modeling changes in water surface elevations for a reservoir due to the methods ability to track the soil moisture throughout the modeled simulation. Other infiltration methods in HEC-HMS do not track the changes to soil moisture and do not allow drying of the soils between precipitation events. **Table 2** provides the calibrated soil moisture accounting parameters for each subbasin of the Strasburg Slough drainage complex. The basin parameters were estimated from the SSURGO soils data and calibrated during the modeling process.

Transform methods are mathematical models that move the runoff from the basin to the basin's outlet. The transform methodology selected for the Strasburg Slough drainage complex is the Clark Transform method. This methodology is commonly used and was deemed suitable for this study. The Clark Transform method requires two parameters, time of concentration and a storage coefficient. These are estimated by examining the length of the longest flow path for the basin and estimating the velocity, using land use data. The transform methodology for the Strasburg Slough drainage complex wasn't as important in calibration as the infiltration methodology. This is due to the calibration of the model to the Strasburg Slough gage being more sensitive to the total runoff volume flowing into the slough than to the timing of the peak flow entering the slough. **Table 3** provides the transform method parameters for each subbasin in the Strasburg Slough drainage complex.

No baseflow methodology was utilized for the Strasburg Slough drainage complex. The complex is composed of a series of sloughs and wetlands, which typically have low to no baseflow. For this reason, baseflow was not used in the model.

**Table 2.** Strasburg Slough drainage complex soil moisture accounting parameters

| Subbasin | Subbasin Area | Soil | Groundwater 1 | Maximum Infiltration | Impervious | Soil Storage | Tension Storage | Soil Percolation | Groundwater 1 Storage | Groundwater 1 Percolation | Groundwater 1 Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (square miles) | % | % | (in/hr) | % | (in) | (in) | (in/hr) | (in) | (in/hr) | (hr) |
| WPA Basin | 17.79 | 0.5 | 30 | 0.299 | 0.49 | 20.64 | 14.544 | 1.66 | 5 | 0 | 120 |
| WPA (Surface) | 1 | 100 | 0 | 0.01 | 100 | 0 | 0 | 0.1 | 0 | 0 | 120 |
| WPA to Strasburg Slough Basin | 1.29 | 0.5 | 30 | 0.3185 | 1.45 | 20.64 | 14.544 | 1.354 | 5 | 0 | 120 |
| Strasburg Slough Basin | 0.823 | 0.5 | 30 | 0.2665 | 5.23 | 20.64 | 14.544 | 2.52 | 5 | 0 | 120 |
| North Slough Basin | 0.122 | 0.5 | 30 | 0.286 | 1.04 | 20.64 | 14.544 | 5.87 | 5 | 0 | 120 |
| North Slough (Surface) | 0.078 | 100 | 0 | 0.286 | 100 | 0 | 0 | 0.1 | 0 | 0 | 120 |
| Strasburg Slough (Surface) | 0.076 | 100 | 0 | 0.01 | 100 | 0 | 0 | 0.1 | 0 | 0 | 120 |
| Lagoon Basin | 2.15 | 0.5 | 30 | 0.273 | 0.46 | 20.64 | 14.544 | 2.279 | 5 | 0 | 120 |
| South Slough to Lagoon Basin | 1.195 | 0.5 | 30 | 0.2535 | 1.36 | 20.64 | 14.544 | 1.86 | 5 | 0 | 120 |
| South Slough Basin | 1.109 | 0.5 | 30 | 0.286 | 0.52 | 20.64 | 14.544 | 1.82 | 5 | 0 | 120 |
| South Slough (Surface) | 0.086 | 100 | 0 | 0.01 | 100 | 0 | 0 | 0.1 | 0 | 0 | 120 |
| Lagoon (Surface) | 0.153 | 100 | 0 | 0.01 | 100 | 0 | 0 | 0.1 | 0 | 0 | 120 |

**Table 3.** Transform parameters for each subbasin of the Strasburg Slough drainage complex

| Subbasin | Time of Concentration (hr) | Storage Coefficient (hr) |
|---|---|---|
| WPA Basin | 2.05 | 4.10 |
| WPA (Surface) | 0.10 | 0.10 |
| WPA to Strasburg Slough Basin | 0.73 | 2.00 |
| Strasburg Slough Basin | 2.00 | 4.00 |
| North Slough Basin | 0.50 | 1.00 |
| North Slough (Surface) | 0.10 | 0.10 |
| Strasburg Slough (Surface) | 0.10 | 0.10 |
| Lagoon Basin | 0.90 | 1.80 |
| South Slough to Lagoon Basin | 0.75 | 1.50 |
| South Slough Basin | 0.75 | 1.50 |
| South Slough (Surface) | 0.10 | 0.10 |
| Lagoon (Surface) | 0.10 | 0.10 |

### *4.5 Strasburg Slough Drainage Complex's Reservoir Setup*

The Strasburg Slough drainage complex HEC-HMS model (**Appendix E**) was setup to include five reservoirs, which represent North Slough, South Slough, Strasburg Slough, the city's lagoon, and the WPA. The hydrologic model requires reservoirs to have elevation-capacity curves, elevation-discharge curves, initial water surface elevations for each simulation, and monthly evaporation rates for each simulation.

The elevation-capacity curves discussed in the topography section of this report were utilized for each reservoir in the hydrologic model. This information allowed the hydrologic model to simulate the increase in water surface elevation of the reservoir due to a corresponding runoff amount.

Elevation-discharge curves were made using a combination of the elevation-capacity curve inundation bounds and a flow estimation tool developed for Quantum GIS. The flow estimation tool solves Manning's equation for a user defined cross section and channel slope. These estimates were completed and entered into the hydrologic model for the elevation-discharge curve for each reservoir and are included in **Appendix D**.

The initial water surface elevation was set at the start of each simulation. This was set to the beginning elevation recorded at the gage for each year. The calibration was then conducted by fitting the modeled output to the gage observations by adjusting the monthly evaporation rates.

### *4.6 Strasburg Slough Drainage Complex's Hydrologic Model Calibration and Verification*

The model was calibrated to the gage record of 2015, 2016, and 2017. The calibrated parameters were then verified with the 2018 gage record. The only parameters changed in calibration were the initial water surface elevation for Strasburg Slough and the evaporation rates for each reservoir in the system. It is important to note that during the period of record, none of the reservoirs contributed flow to Strasburg Slough and Strasburg Slough has not overtopped to contribute to the city's sanitary lagoon. This is important because the system could only be calibrated to the short period of record at the Strasburg Slough gage. The limited understanding of water surfaces at the other reservoirs makes calibration of them difficult, but ultimately would not change the alternatives developed as part of this investigation. **Figures 16** through **19** provide the water surface elevations from the model compared to the gage and **Table 4** provides the monthly evaporation rate used for each simulation.

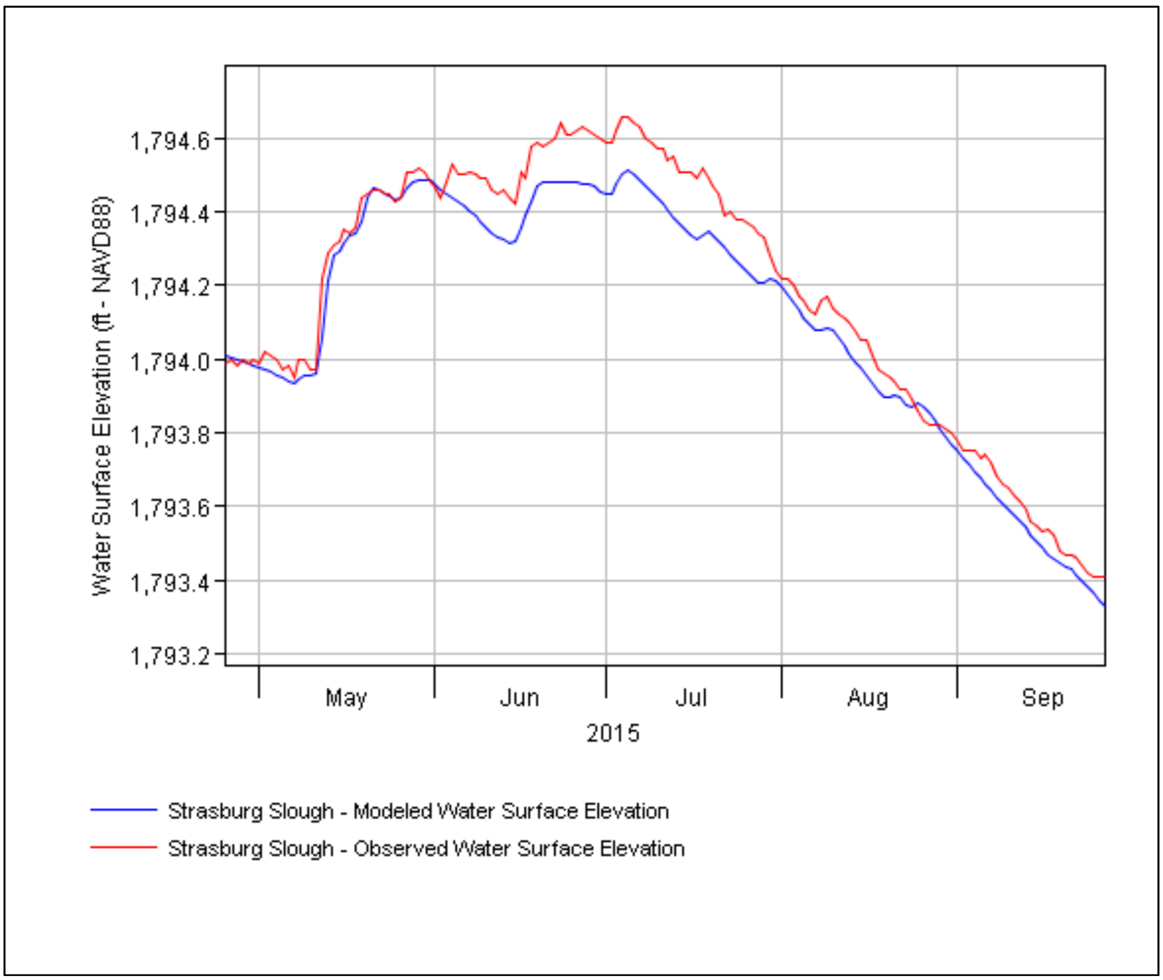


**Figure 16.** 2015 Strasburg Slough water surface comparison

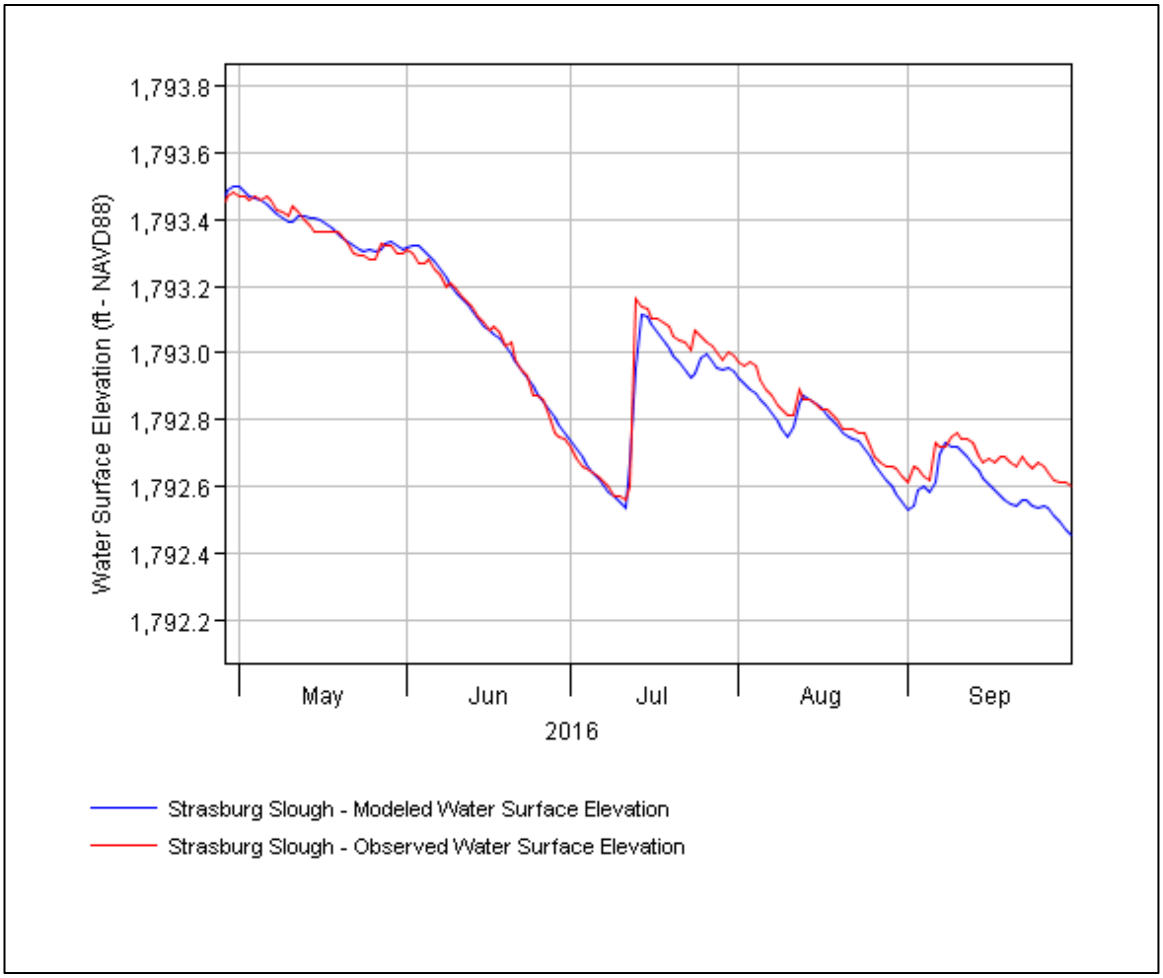


**Figure 17.** 2016 Strasburg Slough water surface comparison

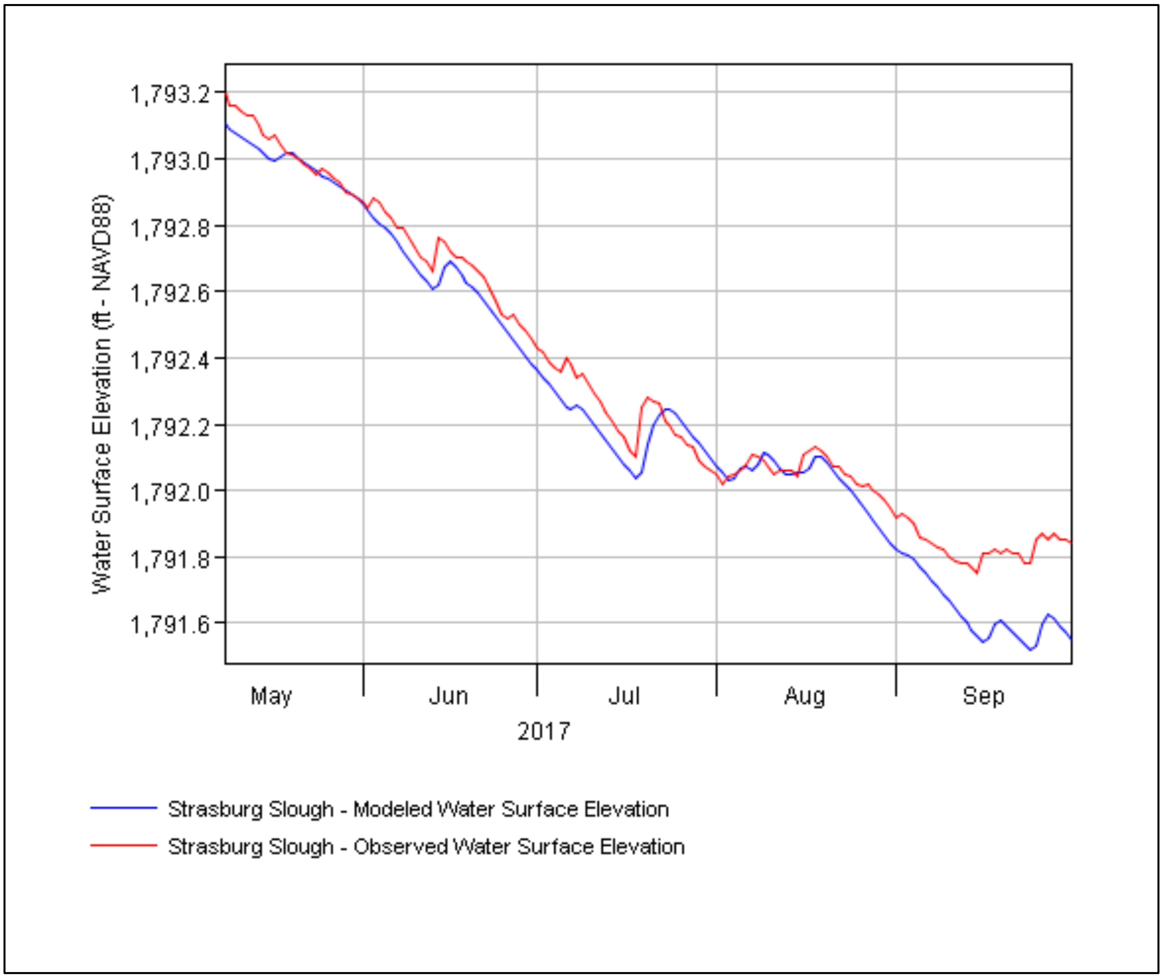


**Figure 18.** 2017 Strasburg Slough water surface comparison

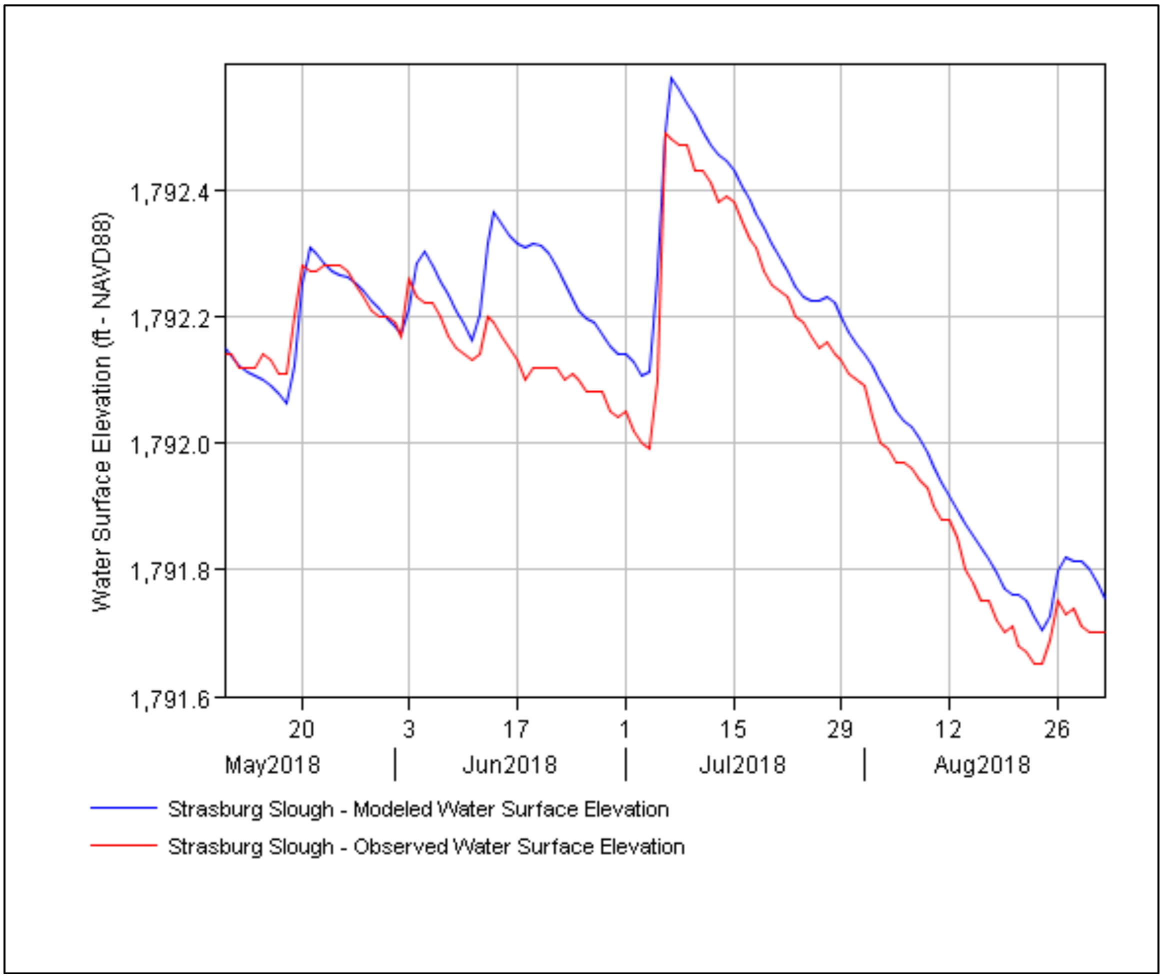


**Figure 19.** 2018 Strasburg Slough water surface comparison

**Table 4.** Evaporation rates used for the Strasburg Slough Drainage Complex Reservoirs

| Month | Evaporation (In) | | | |
|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 |
| January | 0 | 0 | 0 | 0 |
| February | 0 | 0 | 0 | 0 |
| March | 0 | 0 | 0 | 0 |
| April | 1.9 | 1.9 | 1.9 | 1.9 |
| May | 3 | 5 | 5 | 5 |
| June | 5.5 | 8.5 | 8.5 | 8.5 |
| July | 6.6 | 8.6 | 8.6 | 8.6 |
| August | 7.6 | 8.6 | 8.6 | 8.6 |
| September | 6.4 | 7.4 | 7.4 | 7.4 |
| October | 3.6 | 3.6 | 3.6 | 3.6 |
| November | 1.4 | 1.4 | 1.4 | 1.4 |
| December | 0 | 0 | 0 | 0 |

A significant effort was undertaken to try and minimize the amount of variance in the evaporation rates for each calibration event. Each event could be modeled slightly closer to the observed water surface elevations with more alteration of the evaporation rates, but it was deemed to be more efficient to attempt to keep the rates the same for multiple events. The only event that required different evaporation rates was 2015.

### *4.7 Strasburg Slough Drainage Complex's Modeled Frequency Events*

Frequency events were developed for the hydrologic model using the frequency event meteorological model in HEC-HMS and NOAA's Atlas-14 precipitation data. For the purpose of categorizing impacts in the study, 25-, 50-, 100-, and 500-year frequency events were examined against the maximum water surface elevation that occurred in the period of record utilized for this study. This occurred in July of 2015 with an elevation of 1794.66 feet (NAVD88)**. Figure 20** illustrates the water surface elevations for Strasburg Slough for each of the frequency events, with an initial water surface elevation of 1794.66 feet (NAVD88). **Figure 21** illustrates the water surface elevations for the city's sanitary lagoon for each of the frequency events, with an initial water surface elevation of 1789.00 feet (NAVD88). Based on the frequency events, simulated with these initial conditions, Strasburg Slough overflows into the city's sanitary lagoon during 50-, 100-, and 500-year events and equalizes with Strasburg Slough during the 500-year event.

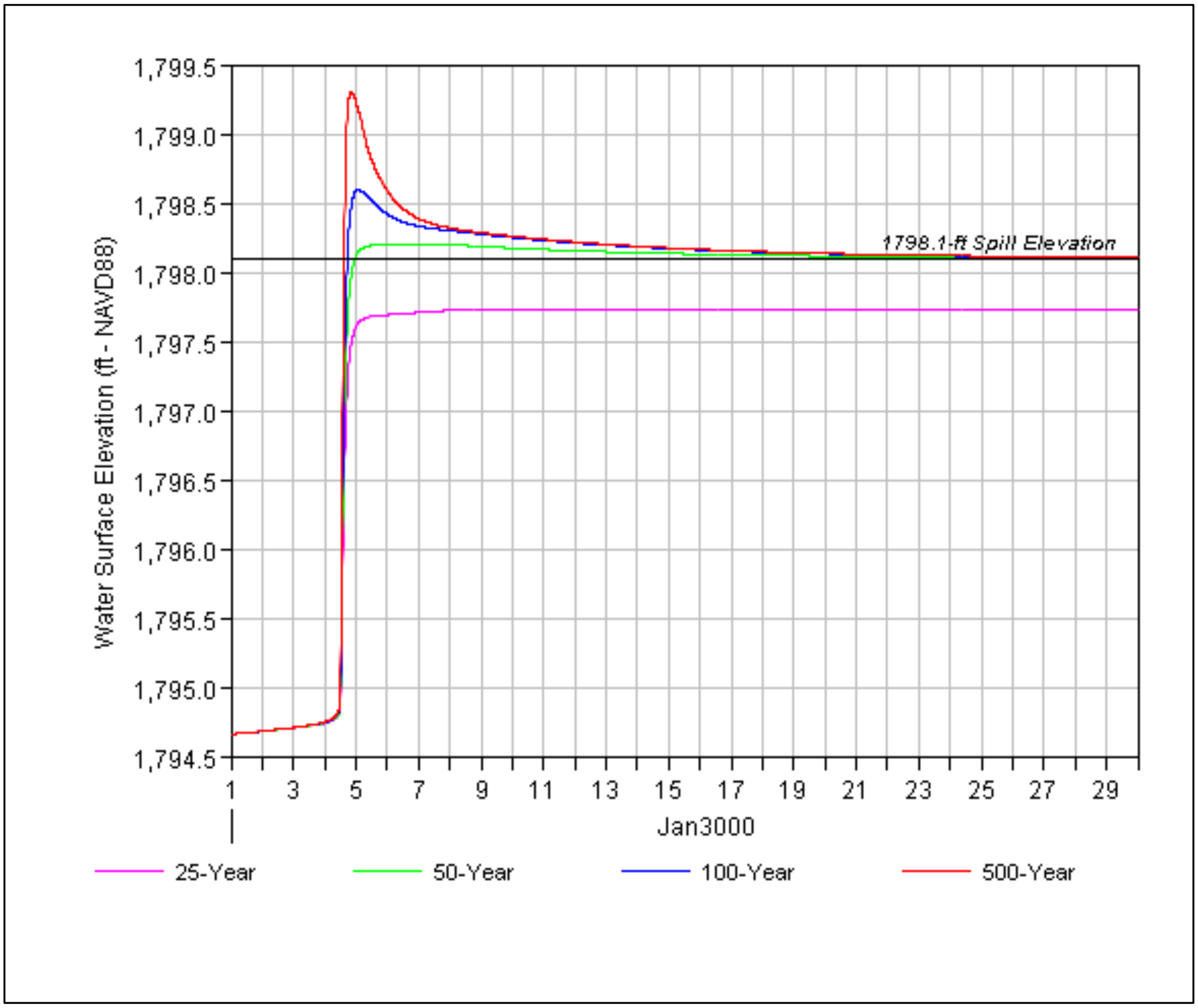


**Figure 20.** Strasburg Slough frequency events

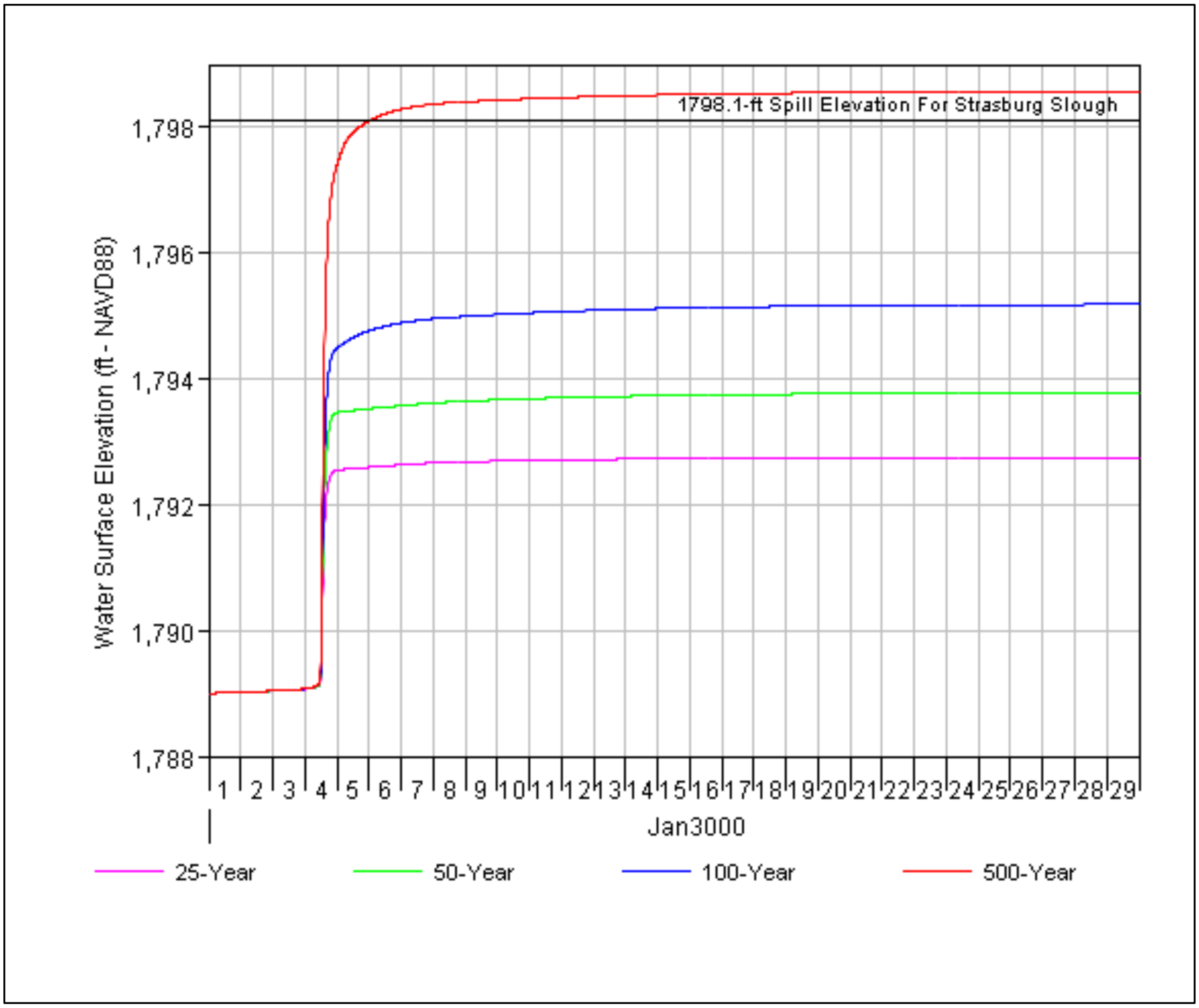


**Figure 21.** Lagoon frequency events

# 5. Impacts of Strasburg Slough Flooding

The impacts analysis for Strasburg Slough flooding considered two separate sources of damage. The first being the flood impacts to primary structures and the second being the health impacts that could occur from raw wastewater leaving the city's lagoon caused by Strasburg Slough flooding. As briefly described earlier in the report and illustrated in **Figure 9**, eleven structures fall within the inundation bounds of Strasburg Slough before it spills into the city's sanitary lagoon. Of these nine structures, eight are residential homes, one is a set of grain silos near the city's elevator, one is a set of fuel tanks near the city's elevator, and one is a large shop. Small garages and sheds were excluded from the inundated structure estimate due to the difficulty in estimating the value of each structure from tax assessed data and wide variation in potential values for each structure. Based on elevation-inundation boundaries outputted from GIS processing, it appears that impacts to structures begin to occur at approximately elevation 1794 feet (NAVD 88).

Based on 2017 tax assessed values from the Emmons County Tax Assessors' office, the total value of structures that exist on the parcels these eleven structures occupy is nearly $614,000. These values may be lower than fair market value, but provide some guidance on the total value of structural impacts that could occur in the event that the water surface between Strasburg Slough and the city's sanitary lagoon equalize.

The SWC contacted the North Dakota Department of Environmental Quality (DEQ) to determine the potential health impacts that could occur from Strasburg Slough coming into contact with wastewater from the city's sanitary lagoon. Three potential scenarios (listed below) were provided to DEQ to define the level of impacts that could occur.

1. The health implications of Strasburg Slough flowing into the city's sanitary lagoon.
2. The health implications of Strasburg Slough equalizing with the lagoon.
3. The health implications of Strasburg Slough and the lagoon overflowing into Baumgartner Lake, which ultimately flows to Beaver Creek.

DEQ responded to scenario 1 by describing the process for necessary treatment of domestic wastewater and the implications of mixing. DEQ stated "A city lagoon system must have a minimum of three lagoon cells to provide the required secondary treatment of domestic wastewater. The city's sanitary lagoon consists of only one lagoon cell and does not provide proper treatment of domestic water." This means that none of the effluent entering the lagoon is treated to current standards. DEQ also described that the risk of exposure to pathogens could occur from Strasburg Slough mixing with the city's sanitary lagoon. Consequences from exposure to pathogens can include diseases that result in fever-like symptoms or exposure to Helminths, parasitic worms, that can result in illness and malnutrition.

The potential health impacts from scenario 1 were expanded on for scenario 2 and 3 due to the wastewater being more accessible to the public by entering public areas. Strasburg Slough equalizing with the city's sanitary lagoon also violates DEQ's North Dakota Pollutant Discharge Elimination System Wastewater Discharge Permit. A permittee may be subject to the proceedings found in North Dakota Century Code section 61-28-08.

# 6. Strasburg Slough Alternatives

Development of structural alternatives for prevention of flooding for the City of Strasburg is an extremely arduous task. Non-contributing water bodies fill until they spill and finding cost effective solutions for removing that water and relieving impacts is extremely difficult. Typically, options for reducing flood impacts from non-contributing water bodies falls into two categories: buying out the impacted structures or finding a way to evacuate floodwaters (i.e. open channel outlets or pumping). As discussed in the previous section, flooding from Strasburg Slough also has another element that involves health implications and permit violations that would be realized from Strasburg Slough overflowing into the city's sanitary lagoon. This adds another element to flood risk reduction that must be taken into account, which is the prevention of wastewater escaping the city's sanitary lagoon. For the purpose of this study, the following four different categories of alternatives were analyzed:

1. Do nothing
2. Structural buyouts and construction of a new sanitary lagoon
3. Open channel outlets from Strasburg Slough for relieving flooding above 1794.0 feet (NAVD88)
4. Pumping water out of Strasburg Slough for relieving flooding above 1792.0 feet (NAVD88)

### *6.1 Do Nothing Alternative*

As the name of the alternative implies, the do nothing alternative is essentially letting nature take its course and allowing Strasburg Slough to continue to fill and potentially spill without any permanent flood risk reduction measures or structure buyouts in place. This alternative does nothing to mitigate the current risks documented in this report.

Based on the 2016 Emmons County Tax Assessor's data, approximately $614,000 in assessed structures could be inundated at an elevation of 1798.1 feet (NAVD88), which is the elevation Strasburg Slough overflows to, and eventually equalizes with, the city's sanitary lagoon. The total structure value after inflation, which is 4.62% from 2016 to 2018, is $642,000. The structures would likely not be totally destroyed, but inundation of the structures would likely be long-term due to the flooded water having no means of evacuation with the exception of evaporation and infiltration. The equalizing of Strasburg Slough and the city's sanitary lagoon would also likely have health implications for the public and would potentially violate the city's North Dakota Pollutant Discharge Elimination System Wastewater Discharge Permit.

Temporary counter measures such as emergency pumping could be utilized, as previously done in 2009 and 2019, to evacuate the flood waters and reduce risk. It is recommended that if this alternative is selected, emergency pumping efforts follow the route utilized in 2019. It is also recommended for the county to obtain a drainage permit from the Office of the State Engineer (OSE), so that the county can remove water from the slough without having to file for a temporary emergency drainage permit. In most cases, the District would have to wait weeks to obtain a temporary emergency drainage permit and by applying for a drainage permit, the District would be able to evacuate water from the slough as needed.

### *6.2 Structural Acquisitions and Construction of a New Lagoon System*

Prevention of the impacts described in section 5 of this report, which are reducing the flooding of structures and prevention of uncontrolled releases of wastewater, are the primary focus of this analysis. Structural acquisition of the structures identified in **Figure 9** and the construction of a new sanitary lagoon in a location that is not prone to flooding would alleviate each of the primary flood risks for the community. Acquisitions are not typically deemed desirable for a community, but in the case of non-contributing waterbodies, they are typically the most feasible option due to the high cost of constructing outlet works to remove water from the watershed. For this reason, structural acquisitions and construction of a new lagoon system was examined and used as a standard of comparison to determine the feasibility of other alternatives evaluated as part of this study. If other alternatives are more expensive, than structural acquisitions and construction of a new lagoon is recommended for the District to consider.

In order to determine the approximate value of the structures identified in **Figure 9**, Emmons County's parcel data and 2016 tax assessment was used to determine the approximate value of the structures at risk. The total property value for the parcels with structures was utilized for the cost analysis. In total, three commercial structures and eight residential structures with an assessed value of $614,516 and property value of $1,956,896 were identified for acquisition. Adjusting for inflation, 4.62 percent, and inclusion of 20 percent contingency to offset the unknowns associated with this estimate, the approximate cost of acquisition of these eleven properties is nearly $2,456,766.

Cost estimation of sanitary lagoons is not typically determined by the SWC. Typically, an engineering firm that specializes in water/wastewater treatment is hired. Currently, the City of Strasburg has hired Ulteig Engineering to design a new sanitary lagoon system for the City. The cost estimate for this lagoon is approximately $3.89 million.

Based on the two estimates, structural acquisitions and new sanitary lagoon system, the total cost of this alternative is approximately $6.3 million.

### *6.3 Open Channel Alternatives*

In order to prevent outflow from Strasburg Slough into the city's sanitary lagoon and prevent flooding of the identified structures, open channel outlets were examined as an alternative. The first identified structure begins to take on water at elevation 1794.0 feet (NAVD88). Several landowners have expressed interest in maintaining the slough for aesthetic and recreation purposes, so this alternative examined the size and route of an open channel outlet to maintain Strasburg Slough's elevation at 1794.0-feet (NAVD88). **Figure 22** illustrates the six open channel outlet alignments that were examined to determine their feasibility.

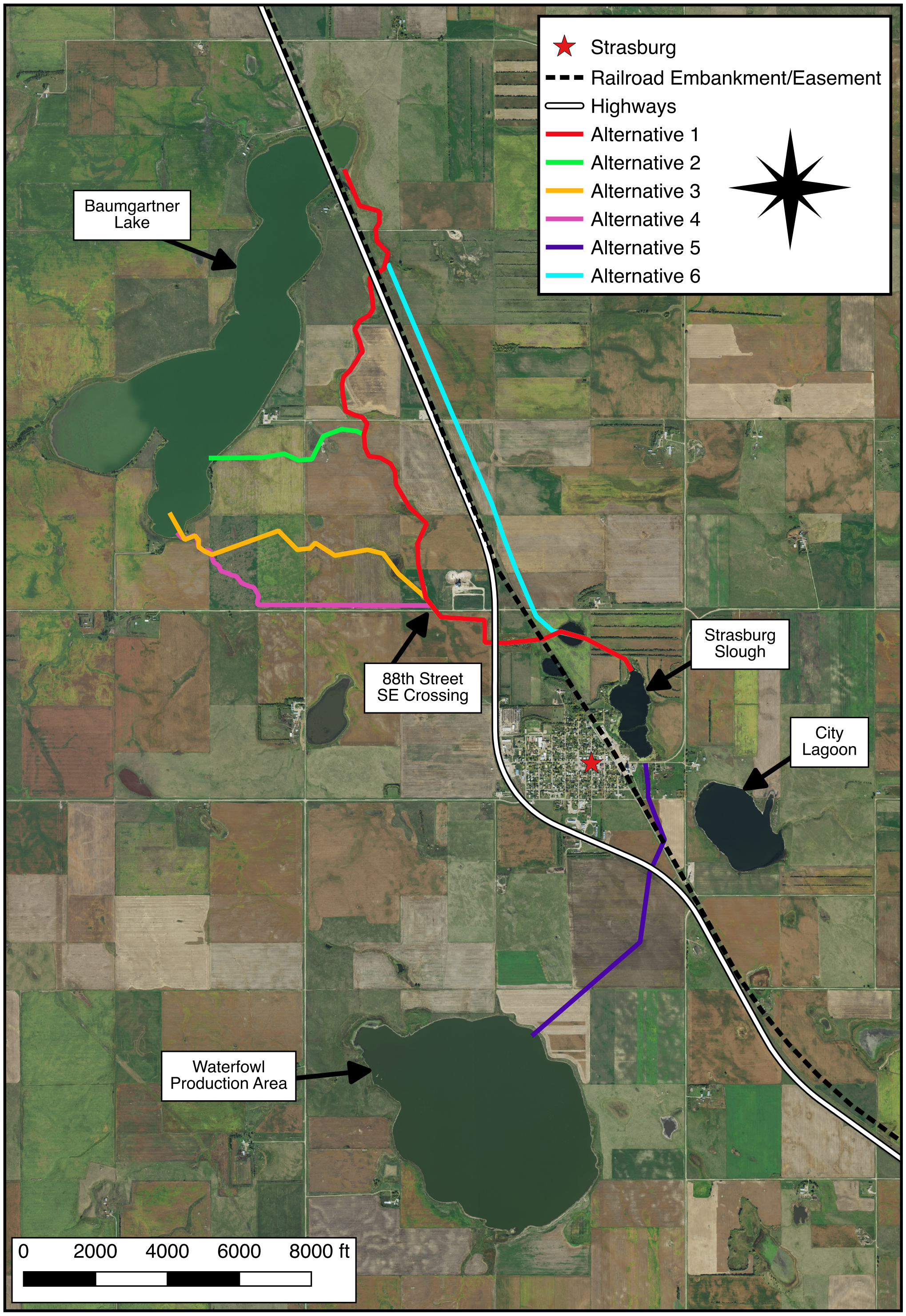


**Figure 22.** Open channel outlet alignments examined

Five of the alignments evacuate the flood waters from Strasburg Slough to Baumgartner Lake, four of which follow the same path until the alignment proceeds north of 88$^{th}$

Street Southeast. One alignment proceeds southwest, evacuating flood waters into the WPA. **Table 5** provides a summary of each alignment path illustrated in **Figure 22**.

**Table 5.** Alternative Alignments Summary Table

| Alternative Alignments | | | | | | |
|---|---|---|---|---|---|---|
| **Alignments** | **Total Length (ft)** | **Bottom Width (ft)** | **Side Slopes (H:V)** | **Number of Road Crossings** | **Slope Change Required (yes/no)** | **Total Cut Volume (cu. yds)** |
| **Alternative 1** | 21,400 | 10 | 3:1 | 5 | No | 122,443 |
| **Alternative 2** | 17,150 | 10 | 3:1 | 3 | No | 116,808 |
| **Alternative 3** | 15,860 | 10 | 3:1 | 3 | No | 114,439 |
| **Alternative 4** | 14,850 | 10 | 3:1 | 3 | No | 159,900 |
| **Alternative 5** | 9,030 | 10 | 3:1 | 3 | No | 406,509 |
| **Alternative 6** | 13,700 | 10 | 3:1 | 3 | No | 313,958 |

Each of the six alignments were screened using a 10-ft bottom width and 3:1 side slopes to determine the most optimum path based on cut volume and the number of road crossings required. Both are indicators at which route would be most cost effective to build. Each of the alignments would create an open channel until the water would naturally flow through ravines to its outlet. The most optimum route was then examined in the hydrologic model to determine the necessary size of channel to keep Strasburg Slough below elevation 1794.0 feet (NAVD88). Alignment 3 is the most optimum alignment based on the amount of cut required, but the alignment doesn't follow a path that is desirable to surrounding landowners. Alignment 4 was then developed to mimic Alignment 3 but follow roads along the route to be more beneficial to the surrounding landowners. For this reason, Alternative 4 was selected for further analysis.

Alternative 4 was examined in the hydrologic model to determine what size outlet would be required to protect the homes near Strasburg from flooding. A 100-year 7-day rainfall was selected as the benchmark for protection against flooding, with an initial water surface elevation of 1792.0 feet (NAVD 88). The goal in sizing the open channel outlet was to prevent the water surface of Strasburg Slough from exceeding 1794.0 feet (NAVD88) during the benchmark event. This would create an alternative that could successfully protect the residents of Strasburg, while maintaining the slough at a manageable elevation. Completely draining the slough was also considered, but this option was screened out due to the cost of cut volume required to completely drain the slough. **Figure 23** illustrates the results of the benchmark event for Alternative 4 with a bottom width of 10-, 50-, and 100-feet. Each outlet width examined in the hydrologic model exceeds the threshold water surface elevation of 1794.0 feet (NAVD88), which means certain structures would flood with the largest bottom width, 100-feet, in place.

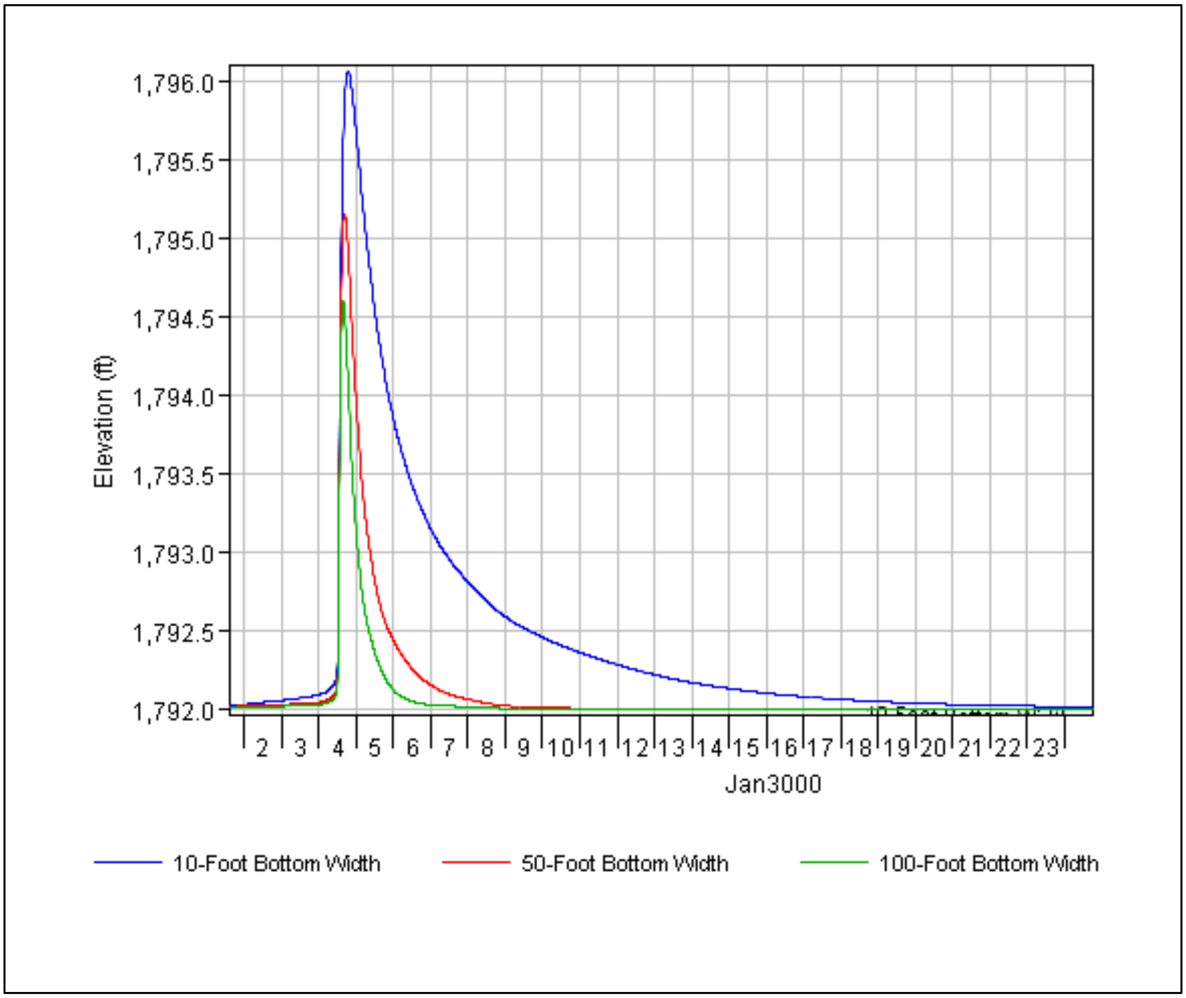


**Figure 23.** Alternative 4, open channel outlet

A cost estimate was prepared for Alternative 4 with a 10-foot and 100-foot bottom width. The estimate excludes the costs required to purchase an easement or buy the land required to build the alignment and the cost of constructing road crossings. “RSmeans Heavy Construction Cost Data for 2014” was used to prepare the cost of construction and was adjusted for inflation. The cost of Alternative 4 with a 10-foot bottom width channel would cost approximately $1.75 million, while a 100-foot bottom width channel would cost approximately $5.28 million. Each estimate includes 20-percent contingency. It is important to note that the 10-foot bottom width channel does not prevent flooding from occurring in Strasburg, but slowly evacuates the water, which would reduce long-term impacts. Neither of these channels includes the cost of road crossings and land acquisition, which would most likely exceed the cost of the acquisition and new lagoon construction.

The 100-foot bottom width channel exceeds the cost of structural acquisition and lagoon replacement, but provides permanent flood protection for up to the 100-year event for most structures. The 10-foot bottom width provides a route for water to be evacuated from the slough, but does not prevent flooding when the slough is already high and a large inflow event occurs. A more detailed breakdown of the cost estimate and the geometry of each alternative alignment is provided in **Appendix D** of this report.

### *6.4 Pumping Alternatives*

Pumping alternatives were evaluated as a means to evacuate water from Strasburg Slough to an outlet location that would not be hydraulically connected to it (i.e. through groundwater connection). Early on in the analysis it became clear that a pumping option could only be developed to slowly drain the slough over time and not to prevent large storms from flooding the surrounding structures if the slough's water surface elevation was above 1792.0 feet (NAVD88). This limitation is due to the large inflow volumes that occur during these storms, requiring a pump so large that it's cost would exceed the feasibility level laid out in this report.

In order to reduce Strasburg's flood risk and minimize the cost, a centrifugal pump with a rate of 4 cfs or 1798 gpm was analyzed, which is similar to the size pump used in 2019. Strasburg Slough's volume typically ranges between 200 acre-feet to 450 acre-feet. At 450 acre-feet the analyzed rate would drain the slough roughly 8 acre-ft/day, requiring 56 days to drain the slough without additional inflow. Based on the head loss that would occur throughout the system and cost associated with a pump/pipe, a 12-inch centrifugal pump and HDPE pipe were analyzed.

Out of the alternative routes analyzed in the open channel outlet alternative section of this report, alternative route 5 would be the most cost-effective route to pump water out of Strasburg Slough. It was assumed that 12-inch HDPE would be placed for the entirety of the 9,030-foot alignment at a depth of 10-feet. Assuming a 50-foot easement, the alignment would require acquisition of approximately 10 acres of land. Two homes exist along the WPA, which is the outlet of the alternative route, and could be affected by pumping. However, it is unlikely due to the homes being approximately 18-feet higher than the WPA's water surface elevation.

Based on alternative route 5's total head loss with a 12-inch HDPE pipe and a cost per kilowatt of $0.12, it would cost approximately $6,000 to drain the slough entirely with no additional inflows or approximately $20,000 to operate the pump from May 1$^{st}$ to November 1$^{st}$, which is a typical pumping season in North Dakota. This would be an ongoing cost that could persist whenever the slough needs to be drawn down to prevent impacts.

In order to develop a cost estimate for pumping alternatives, "RSmeans Heavy Construction Cost Data for 2014" was used to prepare the cost of construction of the trenched pipe route and EPA guidance was used to prepare an estimate of the lift station. The EPA's "Collection Systems Technology Fact Sheet" provided an approximate cost for lift stations based on their daily flow. Interpolation was used to size the lift station for this alternative and the total cost was adjusted for inflation. The estimated total cost of the lift station was determined to be approximately $546,000. The total cost estimation for the 12-inch HDPE, trenching and placing the pipe, and reseeding the alignment amounted to $595,000. The total cost for this alternative amounts to approximately $1.41 million with 20-percent contingency and does not include the cost of purchasing an easement for the trenched pipeline. The next most cost-effective pumping alignment using this methodology would be alternative route 6. Alternative route 6 would cost nearly $1.80 million with 20-percent contingency. Detailed estimates for these alternatives and other alignments are provided in **Appendix D**. The pumping route utilized in 2019 was not examined with this methodology because of its longer path to its ultimate outlet. However, outlet paths like the 2019 route could be utilized without being piped the entire route if easements are obtained.

Although this alternative appears to be more cost effective than structural acquisition and construction of a new lagoon, this alternative requires continual operations and maintenance costs and does not prevent large storms from producing flood impacts. If the water surface elevation of the slough is not low enough when a large storm hits the basin, it could impact the structures and property identified in this report. Consideration should also be given to the lifecycle of centrifugal pumps and ongoing replacement costs associated with running a lift station for the purposes of flood protection.

# 7. Conclusion

Although the several permanent pumping options and smaller open channel outlet alternatives met the feasibility levels outlined in this report, each of these alternatives are still expensive. If the county viewed the temporary pumping conducted in 2019 to be effective, a drainage permit could be obtained by the Office of the State Engineer (OSE). After obtaining a permit, the pumps and pipes could be rented or purchased to continue water removal when necessary without the capital costs of a more permanent system. It's expected that costs would be similar to the operations in 2019 (which totaled $58,000) and based on the past record, this type of operation could have been conducted in 2009, 2014, and 2019 (approximately every 5 years).  Even with the permanent pump option, the seasonal operation of the pump could result in nearly $20,000 in power costs or approximately a third of the 2019 costs. Inclusion of other operation and maintenance costs would likely increase the gap between permanent pump infrastructure and temporary pumping as conducted in 2019.

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