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For the City of Fitchburg, WI
MARS-EOR Project # 01052-0004

Lake Barney Stormwater Management Study

Final Report



Cover Image

Lake Barney overflow at Rotary Trail, July 2020 (upper left)

Lake Barney east of Thayer property, July 2020 (upper right)

Standing water on Alpine Dairy property west of Cusick Parkway, July 2020 (bottom)

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1. STUDY BACKGROUND

1.1. Introduction

Lake Barney is a glacial kettle lake located south of CTH M in the rural southeastern corner of the City of Fitchburg (City), as shown in **Appendix A1**. The lake is part of an extended wetland complex including Swan Pond to the west, which does not have a surface water outflow under normal conditions. Since 2018, runoff and high groundwater from abnormally high rainfall have raised water levels in Lake Barney, causing the lake to find a surface water outflow for the first time in at least 70 years, according to review of available aerial imagery (**Figure 1**). The higher lake levels have caused local flooding, loss of agricultural lands, loss of flood storage, and stormwater flooding downstream in the Town and Village of Oregon.

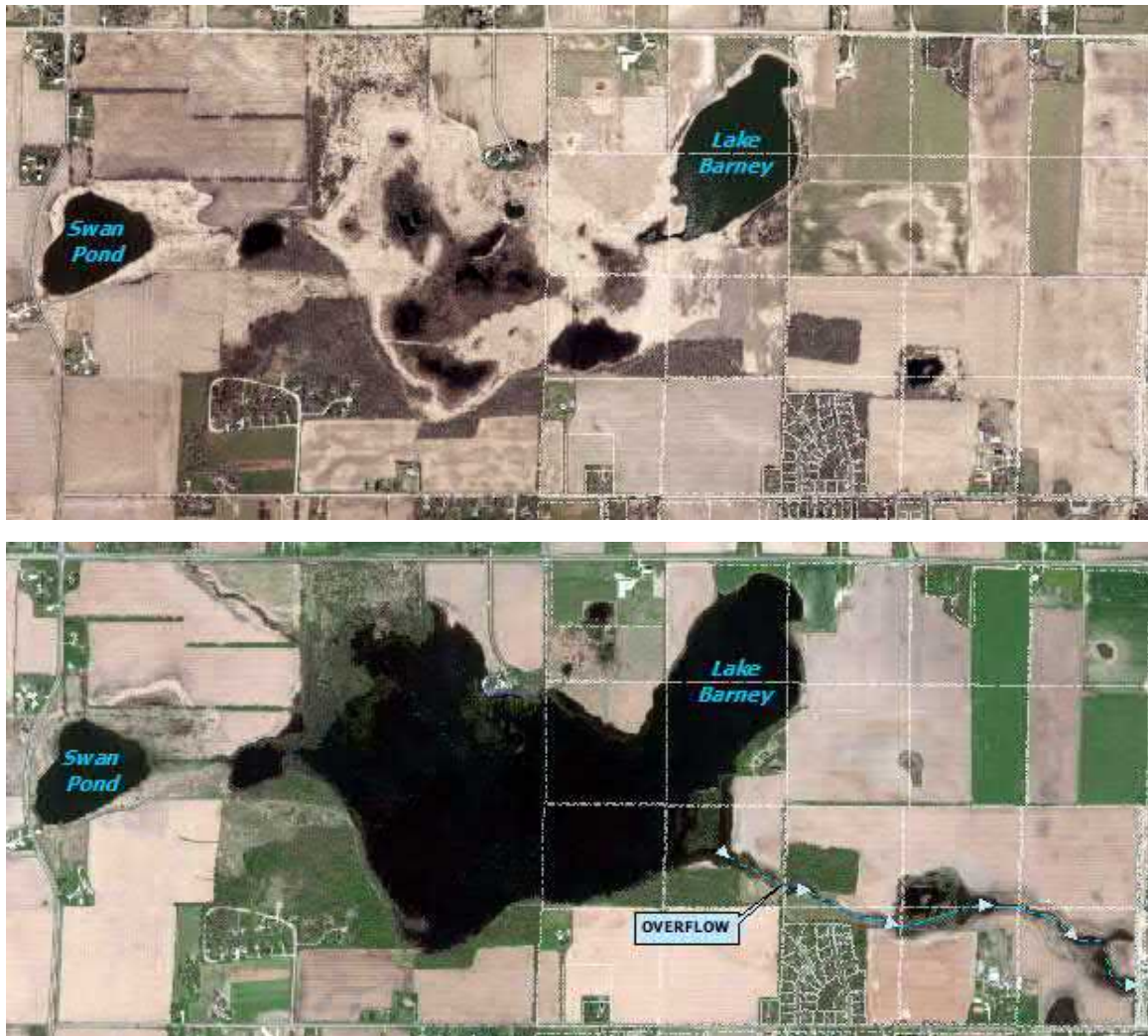


Figure 1. Lake Barney area, Spring 2017 (top image, typical) vs. Spring 2020 (bottom image).

1.2. Study Purpose

The City hired EOR in Spring 2020 to conduct the Lake Barney Stormwater Management Study, which is a collaborative effort between the City and EOR but also includes regular interactions with and contributions from numerous stakeholders including impacted property owners, the Village of Oregon, and regulatory agency personnel. The key study outcomes are:

- Conceptual designs of flooding mitigation alternatives
- Estimations of “time-to-drain” for alternatives including the “do-nothing” option
- Cost-benefit analyses of the mitigation alternatives.

This report describes these outcomes and the steps that led to them, including field data collection, a detailed analysis of past and present lake levels, groundwater and surface water modeling, designing alternatives, the cost-benefit analysis, and conclusions and recommendations.

2. DATA COLLECTION

EOR, the City, and subconsultants created both field- and desktop-based data during the Study. This included installing and monitoring groundwater wells, measuring outflow from Lake Barney, collecting survey information on key hydraulic features, and performing an offsite wetland screening.

2.1. Monitoring wells

Four monitoring wells were installed to monitor groundwater levels near Lake Barney: two to the west of the lake on U.S. Fish and Wildlife Service (USFWS) property, and two to the east of the lake on Department of Corrections (DOC) property. DOC well installation required obtaining an agreement for a temporary easement between the City and DOC, resulting in those wells being installed much later in the study. Well drilling and soil coring was performed by On-Site Environmental Services, Inc. The wells and other field data locations are shown on **Appendix A2** and are described below. Water table measurements collected from the wells are discussed further in **Sections 3 and 4**.

- MW1 (USFWS). Installed on 6/22/20 to a depth of 10 ft. Soil core consisted of alternating sand and clay with occasional small gravel. Depth to water from ground surface was 4.0 ft at the time of installation.
- MW2 (USFWS). Installed on 6/22/20 to a depth of 11 ft. Soil core consisted of pure clay at the surface with alternating gravelly sand and clay at depths. Depth to water from ground surface was 4.2 ft at time of installation.
- MW3 (DOC). Installed on 9/4/20 to a depth of 15 ft. Soil core consisted of silty clay near the surface and sand w/ small gravel below, with decreasing gravel fraction at depth. Depth to water from ground surface was 9.0 ft at time of installation.
- MW4 (DOC). Installed on 9/4/20 to a depth of 15 ft. Soil core consisted of silty clay near the surface and sand w/ small gravel below, with decreasing gravel fraction at depth. Depth to water from ground surface was 11.8 ft at time of installation.

2.2. Flow measurements

We collected overflow discharge measurements on four dates at the locations shown on **Appendix A2**, which supplemented two previous measurements. The purpose of measuring discharge was to estimate flow coming out of Lake Barney during different times while it was overflowing, to help calibrate both the surface water and groundwater modeling. As **Table 1** shows, the highest measured discharge at the Rotary Trail (approximately 8 cfs) occurred in March 2020 during a snowmelt period. The highest summer 2020 flow (4.7 cfs) occurred at the end of June after about 1.7" of rain in the preceding week. Flow had receded in mid-July, and the overflow path was completely dry by mid-August as the lake had dropped below its natural overflow point. We checked the site during later visits through October 2020 and did not observe any additional active overflow from the lake.

Table 1. Discharge measurements.

Date	Flow	Source and Notes
1/28/2020	ICE (Rotary) 3 cfs (Cusick)	Ruekert-Mielke. Flow calculation based on depth at the culvert under Cusick.
3/10/2020	~8 cfs (Rotary) ~7-8 cfs (Cusick)	Ruekert-Mielke. Calculations based on approximate velocity at Rotary Trail and measured depth at the culvert under Cusick. <u>Taken during snow melt event.</u>
6/19/2020	0.2 cfs (Rotary) 0.3 cfs (Cusick)	EOR. Rotary Trail flow calculation based on approximate velocity (too shallow for current meter) and depth measurements. Cusick flow based on measured depth at the culvert and rating curve (from Ruekert-Mielke).
6/30/2020	4.7 cfs (Rotary) 6.8 cfs (Cusick)	EOR. Rotary Trail flow calculation based on USGS protocols using top-setting wading rod and Pygmy current meter. Cusick based on measured depth at culvert. <u>Taken following ~1.7" of rain in 2nd half of June.</u>
7/16/2020	2.5 cfs (Rotary) 3 cfs (Cusick)	EOR. Same methods as 6/30.
8/18/2020	DRY (Rotary) 0 (Cusick)	EOR. Nearest standing water to Rotary was 500' to the west. Much smaller pond near Cusick, and water level was below the culvert invert (no flow). Both sites were dry/not flowing on subsequent visits through <u>October 2020.</u>

2.3. Topographic Survey

The City collected two rounds of topographic data for the project. The first was a survey of key roadway culverts that direct flow towards Lake Barney, which we requested after our preliminary modeling and map review identified likely culvert locations. The second captured monitoring well elevations so we could assign water table elevations and to survey the Rotary Trail overflow geometry and elevation for inclusion in the hydraulic model.

2.4. Offsite Wetland Determination

An “offsite” wetland determination was performed by Heartland Ecological Group, Inc. Trained wetland personnel obtained all available aerial imagery for the site and looked through the record for distinct areas with wet signatures during a variety of dry, normal, and wet years. These areas were compared to mapped hydric soils and mapped wetlands in the Wisconsin and/or National Wetland Inventory and were determined to be a wetland based on persistence of wet signatures and considering the available soil and wetland data. The process determined the presence of likely wetland areas, although some areas were flagged as needing additional field verification for a determination.

Because we did not get permission from Alpine Dairy (at this time) to access their property and review the preliminarily identified wetlands, the wetland determination report (**Appendix B**) is attached as preliminary. As seen on the “Offsite Wetland Identification” figure in the appendix, four of the twelve distinct areas that sometimes showed wet signatures were determined to be identified as wetlands. Three of these four wetlands (W-1, W-2, and W-3) are directly along the current

overflow route and near the likely gravity drainage route for an outlet project. These areas are to be confirmed with an onsite review and/or formal wetland delineation, but for our purposes they provided valuable information about potential routes, wetland impacts, and permitting challenges for alternatives recommended in the study.

2.5. Site Visit Photo Compilation

Selected photos from RFP reconnaissance (winter 2020) and during project field work (summer-fall 2020) are attached as **Appendix D**. These portray the extent of overflow from Lake Barney and ponded water downstream west of Cusick Parkway that were typical from 2018 to mid-summer 2020, and also show the progression from actively overflowing during June and July to completely dry starting in August following a period of dry and hot weather. As shown in the final photos, the overflow dried up sometime in late July 2020, Lake Barney shrunk and the overflow area west of the Rotary Trail was plowed for a return to agriculture, and the standing water on Alpine Dairy property had completely dried up although it was likely wet at times following fall rains.

3. LAKE LEVEL DATA ANALYSIS

EOR reviewed historical and new stage data for Lake Barney to understand the factors that drive high lake levels, evaluate groundwater-surface water interactions, and to quantify the rate of lake level drop that might be expected in the future if no outlet were to be constructed.

Lake level estimates were based on comparison of aerial photographs included in the RFP and available on Dane County's DCI Map with topographic contours, measurements reported by others and new measurements conducted as part of this study. The specific dates that many aerial photographs were taken are not available, so dates were estimated based on conditions observed in the photographs (e.g. leaves on or off trees; crops visible in fields).

Based on Dane County's 2017 LiDAR-based Digital Elevation Model (DEM) and the Lake Barney stage record during 2020, the overflow elevation of Lake Barney is approximately 947.3'. This overflow point is located approximately 500 ft west-northwest of where the overflow route crosses the Rotary Trail (see **Appendix A2**).

3.1. Lake Barney Stage Record

Available information on the level of Lake Barney extends from 1937 to 2020. Lake levels before 2018 were estimated from aerial photographs (**Table 2**), with more recent lake levels measured by stakeholders and by EOR. Lake levels reported by others and surveyed by the City of Fitchburg were compiled into a time series representing best estimate of lake stage in 2020 (**Figure 2**). The full time series of estimated and measured data for 1937 to 2020 is shown on **Figure 3**, and the images are attached as **Appendix C**.

Observations about historical lake stage data include the following:

- From 1937 – 2005, observed levels were between 941 – 943 ft;
- Lake stage was 946 ft in 2010 after very wet conditions in 2008;
- The lake dropped to 941.3 ft in 2017;
- The lake rose again in 2018, with peak in late 2018 of almost 949 ft;
- Lake overflow occurred continuously from fall of 2018 through summer 2020; and
- The lake dropped approximately 1 ft from April – October 2020.

These data indicate that Lake Barney has risen several feet in as little as a few months, but that it has taken several years for the water level to drop back down to comparable levels.

Table 2. Historical Lake Barney stage observations

Estimated Date	Stage (ft)	Source and Notes**
7/1/1937	943	DCI Map aerial photo. Leaves on & crops in fields.
7/1/1955	941.5	RFP aerial photo. Approximate elevation below 942 ft contour. Leaves on & crops in fields.
7/1/1968	941	RFP aerial photo. Approximate elevation below 942 ft contour. Leaves on & crops in fields.
7/1/1974	942.5	DCI Map aerial photo. Leaves on & crops in fields.
7/1/1976	941.7	DCI Map aerial photo. Stage below 942 ft contour & higher than 1955 photo. Leaves on & crops in fields.
7/1/1987	941.5	RFP aerial photo. Approximate elevation below 942 ft contour. Leaves on & crops in fields.
10/1/1995	942	RFP & DCI Map aerial photo. Leaves off & standing corn.
10/1/2000	942	RFP & DCI Map aerial photo. Leaves off.
10/1/2005	943	RFP & DCI Map aerial photo. Leaves off & standing crops.
9/15/2010	946	RFP & DCI Map aerial photo. Leaves off or partially off; standing crops & stubble.
7/4/2013*	944	RFP aerial photo. Green fields, leaves on & macrophytes in lake. Date from NRCS.
10/1/2014	943.5	DCI Map aerial photo. Leaves off & standing corn.
10/11/2015	941.5	DCI Map aerial photo. Date from NRCS.
5/1/2017	941.3	2017 LiDAR + 6" orthoimagery survey. 2017 Fly Dane commenced in April 2017.
9/22/2017	~943	2017 NAIP. Main lake looks 942-943, but pockets of open water and saturated areas appear at higher elevations and lake fringe is unclear due to heavy vegetation.
7/1/2018	947	RFP & DCI Map aerial photo. Leaves on, green fields & macrophytes in lake.
10/1/2018	948.8	Stage from AECOM. No date reported; extreme high lake stages occurred in October 2018.
10/10/2018*	948	Stage estimated from photograph of overflow from RFP before trail was cut to lower lake level.
1/17/2019*	947.5	Stage estimated from photograph of overflow from RFP after trail cut.
5/31/2019*	947	Stage estimated from photograph of overflow from RFP after trail cut.
12/26/2019*	947.7	Stage from R/M drone survey for Village of Oregon.
7/16/2020	947.71	Stage surveyed by City of Fitchburg.
9/2/2020	947.13	Stage surveyed by Moore Surveying for Thayer property.

* Known date reported by others.

** DCI Map = Dane County's web-based mapping application; RFP = City's request for proposals.

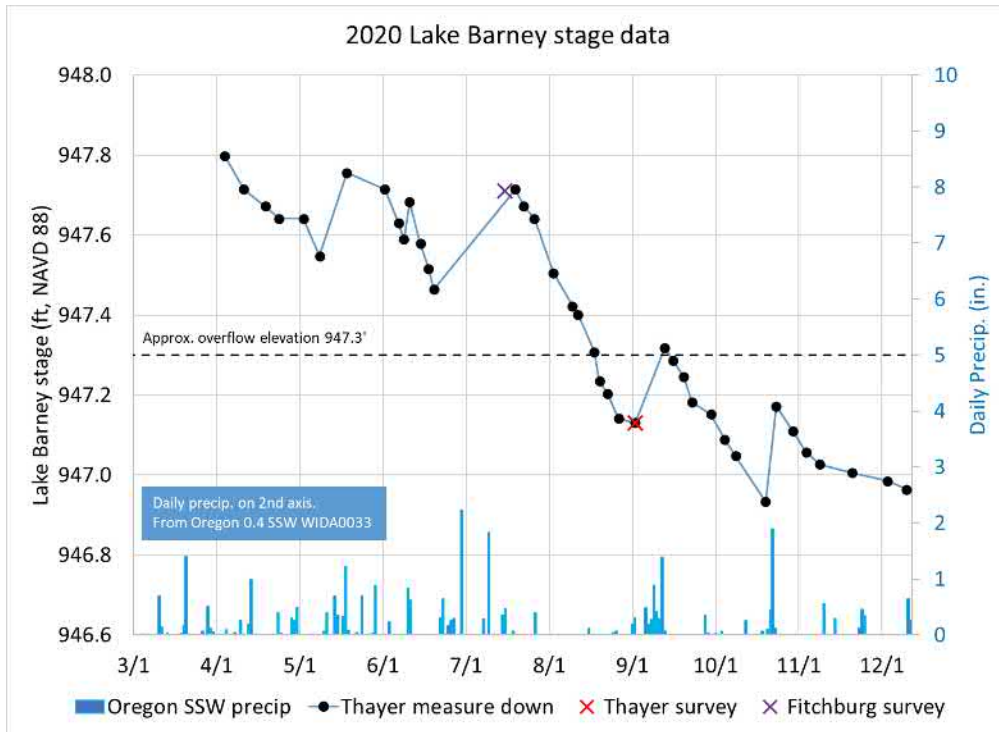


Figure 2. Lake Barney stage measurements, 2020.

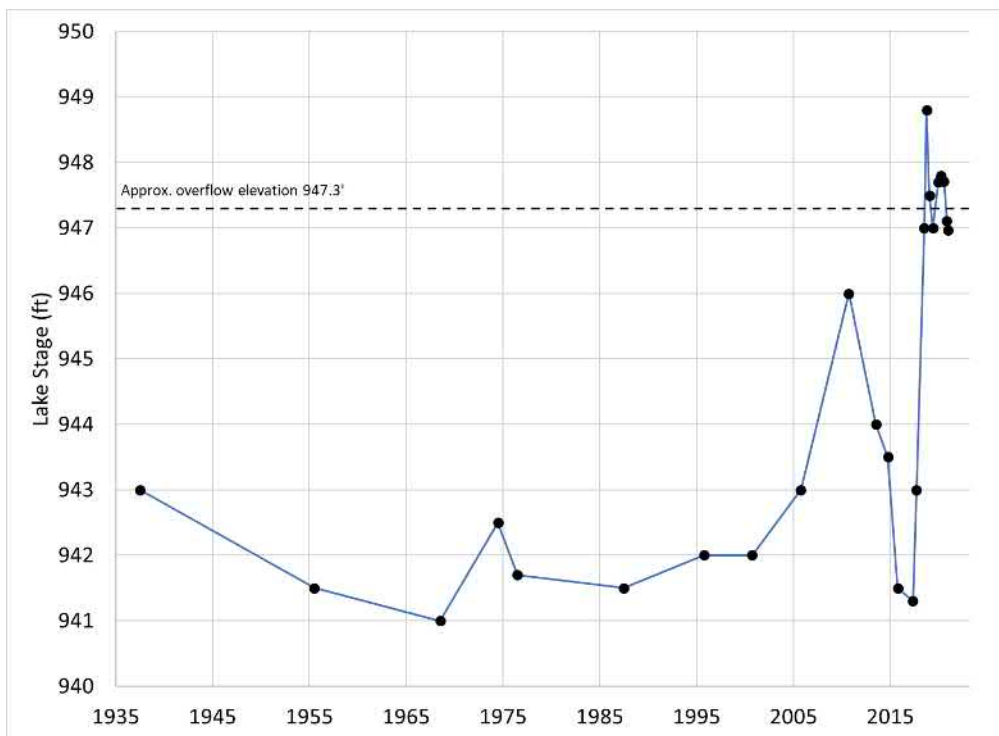


Figure 3. Available lake level data for Lake Barney, 1937-2020.

3.2. Comparison of Lake and Groundwater Elevations

Water table elevations at monitoring well locations (**Appendix A2**) and Lake Barney levels were measured manually in June - September 2020 (**Figure 4**). In June and July, the water table elevation at the USFWS property was higher than the lake stage, indicating groundwater discharge into the lake. After several dry weeks in August, groundwater dropped by approximately 1 ft, and the lake stage was above groundwater in August and September including at the newly drilled DOC wells. This indicates seepage from the lake into the groundwater. It is likely that the lake level fell more slowly than the groundwater due to hydraulic resistance of fine-grained lakebed sediment, indicating some hydraulic disconnection between the lake and groundwater.

The drop of approximately 3.5 - 4 ft from Lake Barney to the easternmost monitoring well on the DOC property (MW4) indicates a much steeper gradient away from the lake in that direction than toward the north and northwest. This reflects the regional flow direction toward the east and the Oregon Branch of Badfish Creek and represents the natural subsurface groundwater drainage route from Lake Barney.

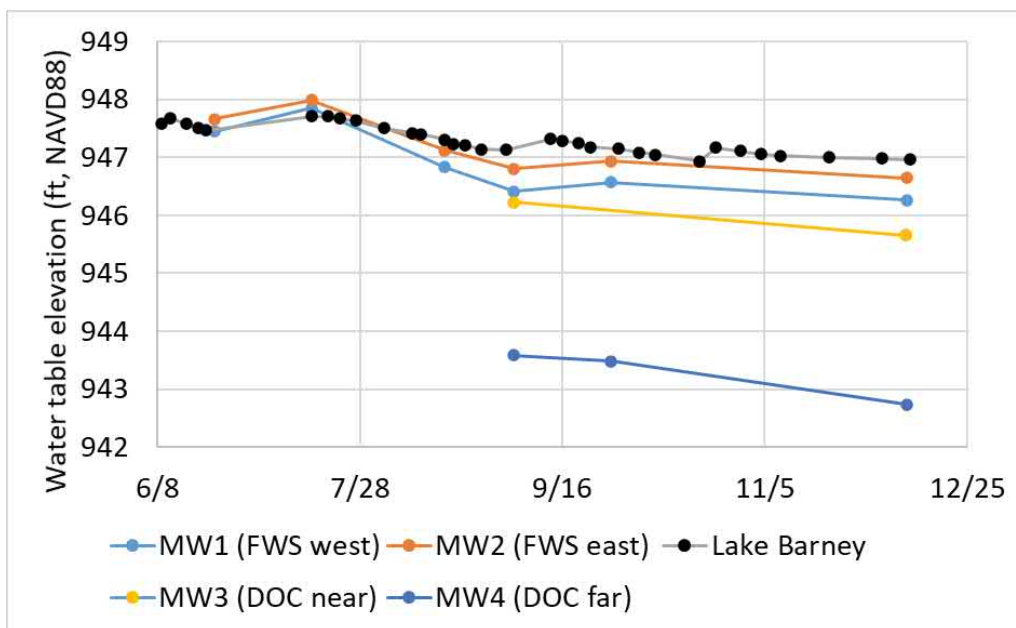


Figure 4. Groundwater elevations in monitoring wells compared to Lake Barney level.

3.3. Lake Level and Precipitation Statistical Analysis

High lake levels in 2010 and in 2018-2020 occurred in response to extremely high annual precipitation across south central Wisconsin for multiple years (**Figure 5**). The high stage of 946 ft in 2010 occurred after more than 44 inches of precipitation fell at the Dane County Airport (Truax Field) during both 2007 and 2008, compared to the long-term weather station average of about 33

inches¹. The even higher lake levels in 2018 – 2020 have occurred during 6 consecutive years with 38 or more inches of precipitation, including 50.6 inches in 2018.

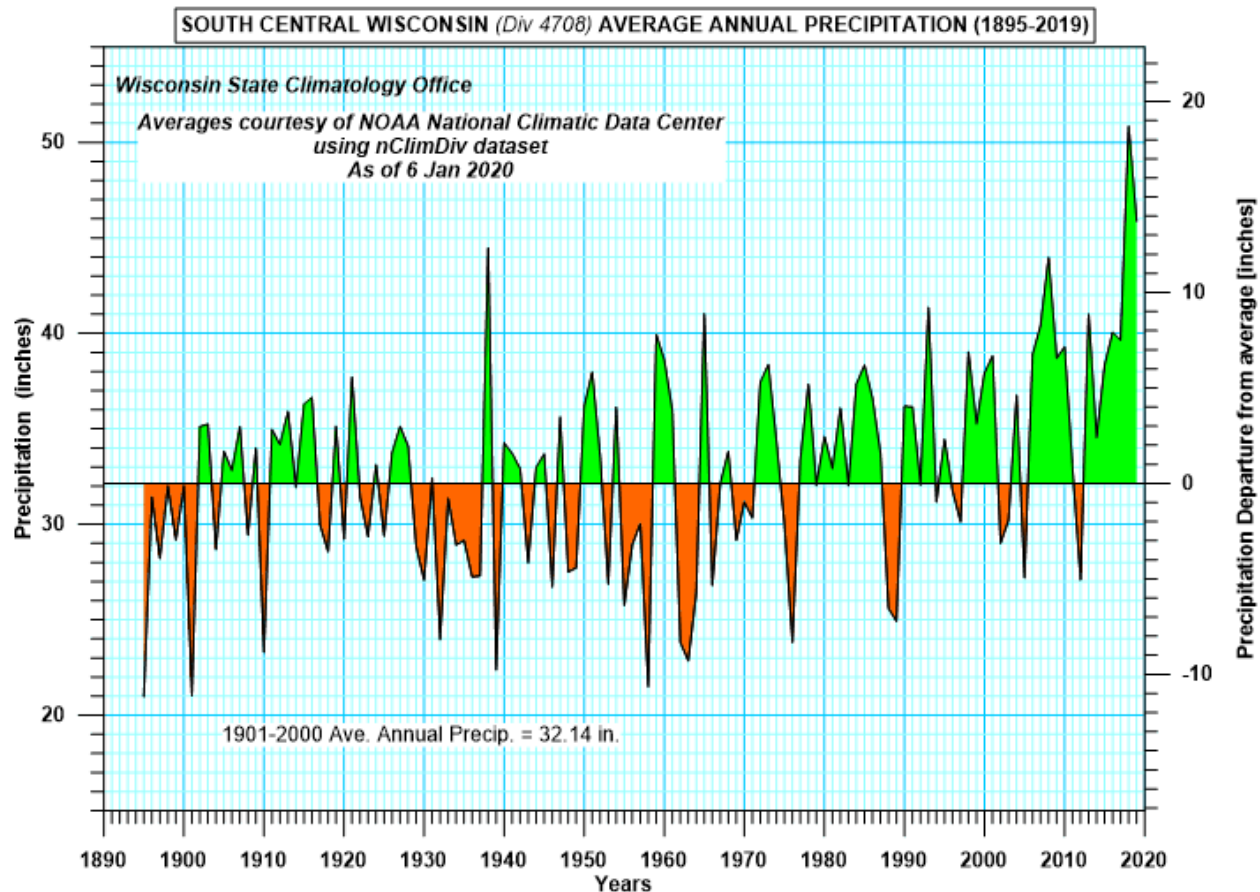


Figure 5. Annual precipitation in south central Wisconsin.

Although it is obvious that high lake levels are driven by higher than average precipitation, additional data analysis was conducted to provide information on the hydrology of Lake Barney and how the lake level might change in the future. This includes the relative contributions of groundwater and surface water to Lake Barney and how long it might take for the lake level to drop in the future if drier weather conditions occur.

¹ Annual Data Summary from Madison Dane County Airport – Truax Field, Station WBAN 14837. Downloaded from <https://mrcc.illinois.edu/CLIMATE/welcome.jsp>. Retrieval date Feb. 5, 2021.

We followed the method of Smail and others², which has found a strong correlation between groundwater fluctuations and rainfall across Wisconsin. Smail found that groundwater levels in many parts of Wisconsin can be predicted by tracking how monthly precipitation deviates from the average precipitation over the past 5 years (or 60 months). Periods of above average precipitation tend to cause increasing groundwater levels, and below-average precipitation periods tend to lead to decreasing groundwater levels.

We applied this approach using monthly precipitation data from Truax Field in Madison (**Figure 6**), the nearest weather station with the longest continuous precipitation record. The cumulative deviation from the mean (CDM) precipitation was calculated for each month by:

1. Calculating the mean precipitation for the previous 60 months;
2. Calculating the deviation of the current month's precipitation from the 60-month mean;
3. Tracking the cumulative deviation from the mean for each month;
4. Calculating the statistical z-score for each month's cumulative deviation from the mean (number of standard deviations above or below the mean).

At Truax Field, cumulative departure from the 5-year mean shows an increasing trend from 1944 – 2020, with many fluctuations with wet and dry cycles. This pattern qualitatively compares well with groundwater trend data for Madison (**Figure 7**).

Lake Barney stage data plotted by its z-score on **Figure 6** show that low lake levels before 1990 generally corresponded with negative cumulative deviations from mean precipitation, and the recent high lake stages correspond with very high deviations above mean precipitation, as expected. However, several low lake stages observed since 2000 have occurred during times with cumulative deviations well above mean precipitation, most notably in 2017. This lack of correlation between the cumulative precipitation deviation and Lake Barney's stage is an indication of complex groundwater hydraulics and the influence of surface water inputs which have different timing than groundwater fluctuations.

² Smail, RA, AH Pruitt, PD Mitchell and JB Colquhoun, 2019. Cumulative deviation from moving mean precipitation as a proxy for groundwater level variation in Wisconsin. *Journal of Hydrology* X 5.

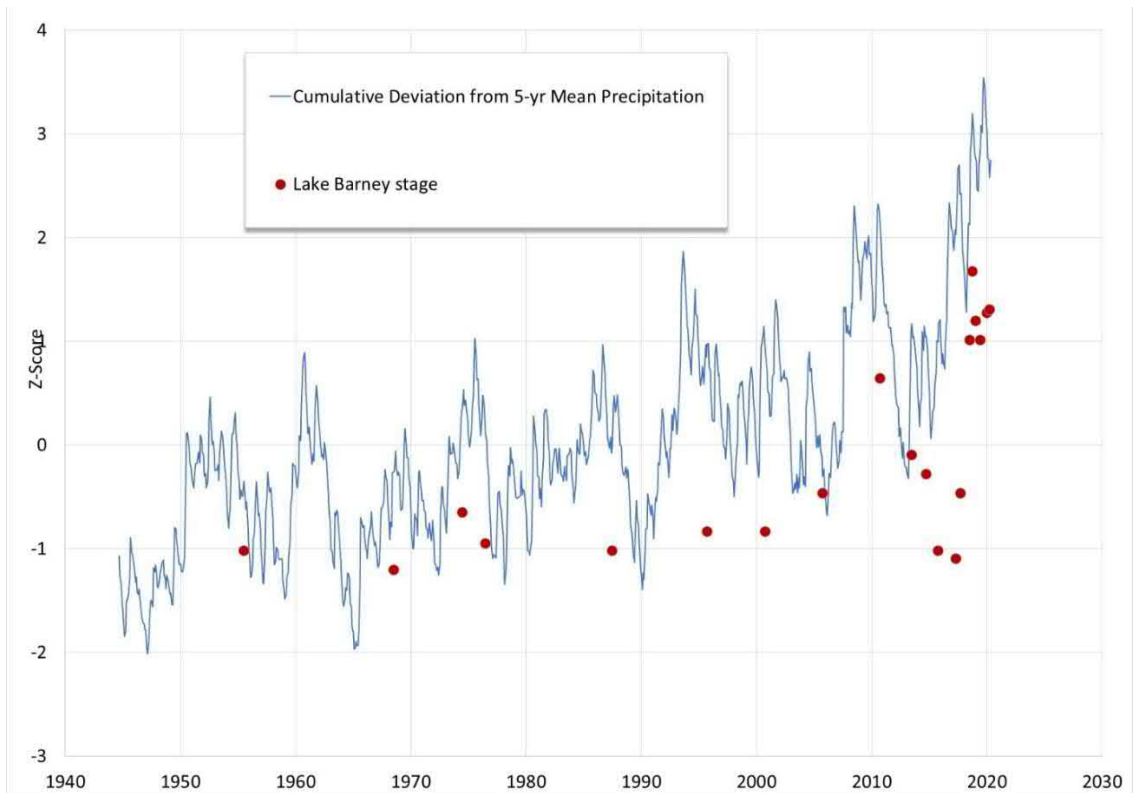


Figure 6. Cumulative departure from 5-year mean precipitation at Truax Field vs. Lake Barney Stage.

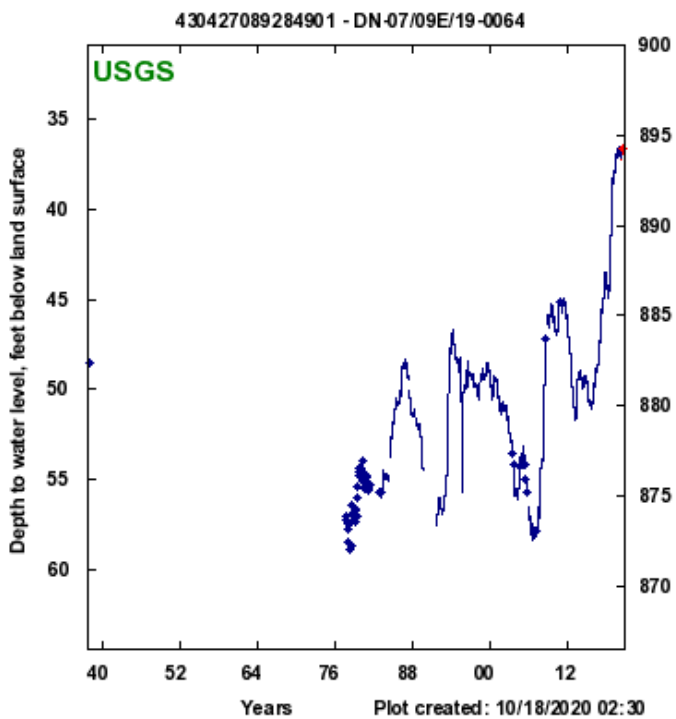


Figure 7. Groundwater level trend in Madison (from USGS)

3.4. Comparison with Other Waterbodies

We compared Lake Barney’s stage with the levels of nearby waterbodies on the same dates for insights into the relative roles of groundwater and surface water in lake level fluctuations. If groundwater is the primary driver of lake level fluctuations, nearby waterbodies would be expected to fluctuate similarly. A greater surface runoff influence on lake stage would be indicated by out-of-sync fluctuations, because of differences in local rainfall, watershed area and other watershed characteristics. Waterbodies reviewed included Lake Harriet, located approximate 2 miles to the southwest, and the pond at the Oakhill Correctional Institute located 0.7 mile to the northeast (see **Table 3**). Over the period of review (2000 – 2018), Lake Harriet ranged from below 944 ft to approximately 949.5 ft, and Oakhill Pond ranged from below 931 ft to approximately 935 ft.

Of the 6 years reviewed, Lake Barney and Lake Harriet were at different parts of their recent stage fluctuation ranges on 3 of those dates. The biggest difference was in 2005, when Lake Barney was at a low stage of 943 ft and Lake Harriet was at a high stage of 948 ft. Both lakes have large surface watersheds with numerous partially closed depressions that affect watershed runoff. The stage of the pond at the Oakhill Correctional Institute has tracked Lake Barney more closely. These observations suggest a mix of surface water and groundwater influence on the stage at Lake Barney.

Table 3. Comparison of historical stages of Lake Barney and nearby waterbodies

Year	Lake Barney	Lake Harriet	Oakhill Pond
2000	942 ft (low)	<944 ft	931 ft
2005	943 ft (low)	948 ft	<931 ft
2010	946 ft (medium)	<944 ft	935 ft
2014	943.5 ft (low)	946 ft	931 – 932 ft
2017	942 ft (low)	944 ft	931 ft
2018	948 ft (high)	949.5 ft	935 ft

Note: highlighted cells indicate other waterbodies at different relative stages than Lake Barney.

3.5. Historical Rate of Lake Level Drop

Data on the rate at which Lake Barney has dropped from previous high stages is informative regarding what might be expected to occur in the future. Data are available for the high lake levels in 2010 and 2018 – 2020 (**Figure 8**).

After the high lake stage observed in 2010, Lake Barney fell 2 feet in 3 years during 2011 – 2013. During that period, annual precipitation at Truax Field in Madison was 34 inches (**Table 4**), slightly above the long-term average of about 33 inches. The lake fell an additional 2.5 feet during 2014 – 2017, even though precipitation was above average (40 inches). In total, Lake Barney dropped 4.5

feet during the 7 years from 2010 – 2017, even though precipitation was above average during that period (37 inches). The average rate of lake level drop during this period was about 0.6 feet per year.

Lake level data for 2020 illustrate that the lake fell at a rate of 1.1 ft/yr from April 4 – October 24. Precipitation in 2020 to-date has been above average, with 32 inches recorded at Truax Field through September. During two shorter periods during 2020 with little to no rain, the lake fell at a faster rate. The lake dropped 0.45 ft over 30 days during July and August (a period with high evapotranspiration), and it dropped by 0.31 ft over 30 days in September and October. While these short-term rates equate to an annual drop of several feet per year, it is unrealistic to expect such high rates to persist throughout a year except in extreme drought conditions.

Based on historical data, Lake Barney might be expected to drop from its current high level at a rate of half a foot to one foot per year, during years when precipitation is closer to the long-term average than it has been recently. At that rate, it would take 2 – 4 years to drop to a stage of 945 ft and 5 - 10 years or more to drop to 942 ft. Obviously, future weather conditions are unknown, and a wet year and/or a large storm could cause Lake Barney to rise again before it drops to these lower stages. Note that the recent lake stage is higher than observed in 2010 and appears unprecedented in the historical data record. It is possible that these prolonged high stages have altered the infiltration capacity of the lakebed, and that future lake water level drop could be slower than what occurred between 2010 - 2017.

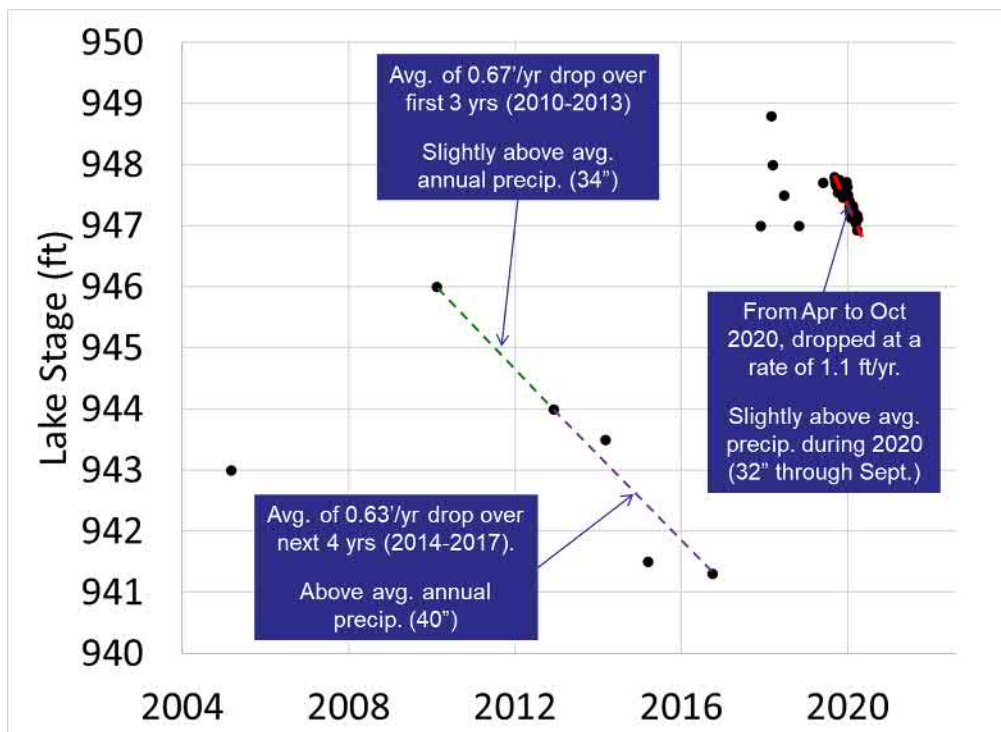


Figure 8. Lake Barney water level recession, 2010-2017 and 2020.

Table 4. Annual precipitation at Truax Field in Madison, 2011 - 2020.

Year	Truax
2011	30.54
2012	26.36
2013	45.38
2014	35.31
2015	39.59
2016	45.56
2017	38.28
2018	50.64
2019	46.39
2020	38.92
Average 2011 - 2013	34.09
Average 2014 - 2017	39.69
Average 2011 - 2017	37.29

4. GROUNDWATER AND SURFACE WATER ANALYSIS

4.1. Groundwater Analysis

The purpose of this groundwater analysis was to quantify the seepage into Lake Barney that an outlet and the downstream drainage system would need to accommodate. The approach used the Dane County Regional Groundwater computer model developed in 2016 by the Wisconsin Geological and Natural History Survey (WGNHS) and the U.S. Geological Survey (USGS)³, which is the best available groundwater model of the area.

Main steps in the analysis included:

1. Refining the model to better represent Lake Barney.
2. Simulating recent high groundwater conditions by increasing groundwater recharge in the model.
3. Calibrating the model to available lake outflow and groundwater level measurements.
4. Simulating construction of an outlet.
5. Quantifying the groundwater discharge through the outlet under the recent high groundwater conditions at different lake stages, for use in the SWMM surface water model.
6. Identifying the area around Lake Barney where groundwater would be lowered due to outlet construction.

4.1.1. Existing Conditions Model Refinement

The existing regional groundwater model covers all of Dane County as was not designed for site-specific analysis. Areas with numerous closed depressions such as Lake Barney are not well represented, because the model does not simulate overflow from the closed depressions which actually occurs. As a result, the model overpredicts water levels at Lake Barney by 5-10 ft (**Figure 9**). After discussion with WGNHS staff who constructed the model, we refined the model around Lake Barney to more accurately represent groundwater-surface water interactions for the purpose of this project.

³ Parsen, Bradbury, Hunt & Feinstein, 2016: <https://wgnhs.wisc.edu/pubs/b110/>



Figure 9. Water table contours from existing regional groundwater model.

Note large errors at Lake Barney prior to refinement of model.

Modifications to the existing conditions model included:

1. Adding Lake Barney as constant head boundary condition cells at elevation 947 ft.
2. Adding the overflow route as stream cells, using the SFR2 package.
3. Refining the hydraulic conductivity of surficial soils around the lake, including removing the low conductivity lake bottom deposits and making those cells the same as the adjacent material (glacial lake sediment in much of Lake Barney basin; outwash sand and gravel at east end of the lake).

With these modifications, the model (**Figure 10**) simulates the water table at realistic elevations around the lake and quantifies flux into the lake and out the overflow route.

The use of constant head cells to simulate Lake Barney is suitable for the purposes of this study but has important limitations. The method is only appropriate if the water level in the aquifer is above the lake; otherwise, the constant head cells would unrealistically raise the water table around the lake because the model would simulate infiltration from the high lake into the aquifer. This was not an issue for the wet conditions modeled in this study, because the water table was always simulated to be higher than the lake.

Constant head cells also do not represent any hydraulic resistance between the aquifer and the lake. The monitoring data demonstrate that there is some resistance between them by the observation of

slightly higher water levels in the lake than the adjacent water table. To test the impact of this simulation, we constructed models representing Lake Barney with river boundary cells. These head-dependent boundary cells simulate lakebed resistance to groundwater flow, calculating flux into the boundary cells dependent on the head difference between the specified lake level and the head in the underlying aquifer. We adjusted the lakebed conductance so that the head difference between the lake and the adjacent water table matched the observed head difference between the monitoring wells on the USFWS property and Lake Barney. Simulations with a lake outlet using these models yielded nearly identical predictions of groundwater seepage rates and water table drop as the constant head models. As with the constant head models, the models using river boundary cells for Lake Barney are only appropriate when the aquifer head is above the lake level; otherwise, the boundary cells will infiltrate unlimited water into the aquifer artificially raising the water table.

Note that neither modeling method can predict the lake level for different recharge conditions, since the level of the lake is specified in both methods. However, these models are useful for quantifying the groundwater flow into the lake under different lake level and recharge conditions.

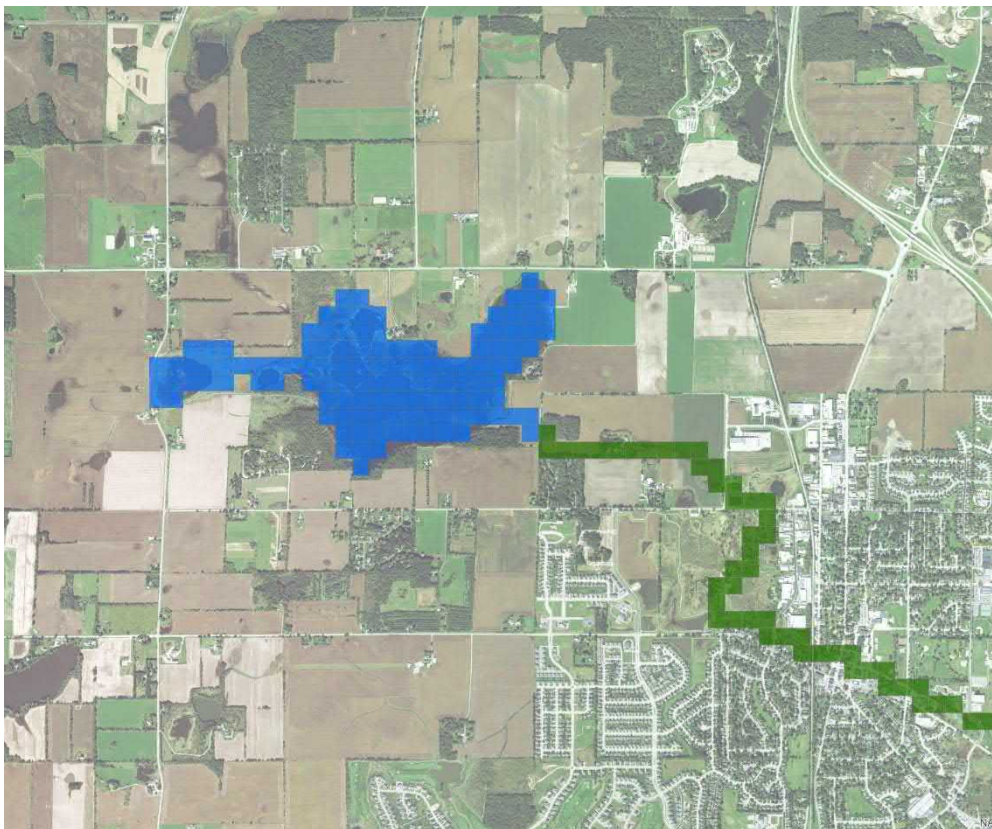


Figure 10. Existing conditions model of Lake Barney and overflow route.

Constant head boundary cells representing Lake Barney at 947 ft shown in blue. Stream cells representing overflow route shown in green.

4.1.2. Existing Conditions Model Calibration

The model was calibrated to field measurements of water table elevations and overflow discharge to provide additional confidence in model predictions. Calibration was performed on recent high lake stage because (1) overflow and groundwater elevation data are available and (2) it is important to quantify how much groundwater would discharge through an outlet under high groundwater conditions. The model was calibrated to 2020 conditions, when the lake was at approximately 947 ft and outflow discharge was 3 – 5 cfs. Note that some of this outflow could be the result of surface runoff draining through the lake.

Recharge

The WGNHS calibrated the steady-state regional model to conditions between 2006 and 2010, when Lake Barney was lower. To simulate the recent high groundwater and lake conditions, recharge was increased uniformly across the model domain (i.e. the county) using a global multiplier. The degree of recharge increase in recent years was estimated by reviewing nearby stream gage records, using streamflow as an indicator of groundwater recharge.

The Yahara River watershed, which contains Lake Barney and covers much of Dane County, was the initial area of analysis for assessing increased streamflow and inferred groundwater recharge. At the USGS stream gage located on the Yahara River at Stoughton the mean annual flow in 2018 was 29% higher than the average flow for 2006 – 2010, and the average flow in 2018 and 2019 was 48% higher. The latter reflects an enormous amount of drainage flowing through the Yahara lakes in late 2018 and 2019 due to runoff and sustained high lake levels related to the record-setting August 2018 storm.

The Sugar River watershed to the west is another nearby watershed that is presumably representative of the same recent weather conditions and increased groundwater recharge that have affected Lake Barney. For the USGS gage on the Sugar River at Verona, the earliest year of available data is 2010. For the Yahara River, the 2010 annual flow was close to the mean for 2006 – 2010. Thus, 2010 is a reasonable year to compare with 2018 and 2019 at the Sugar River site. The mean annual flow on the Sugar River in 2018 was 42% higher than in 2010, and the mean from 2018 and 2019 was 50% higher.

Global recharge multipliers of 1.3 and 1.5 both produced reasonable fluxes through Lake Barney, with less than 1 cfs difference between them. The multiplier of 1.5 resulted in excessive model run times, probably because recharge that high is far greater than the conditions to which the model was calibrated. It should be noted that the model is steady-state and represents conditions that would occur applying the selected recharge for an infinite period, rather than only a year or two. Therefore, the multiplier of 1.3 was chosen for lake outlet evaluation.

Hydraulic Conductivity

The model over-predicted groundwater levels around Lake Barney, with heads above the ground surface in many locations, even after the addition of constant head cells to simulate the lake and

stream cells to simulate the overflow. This suggested the hydraulic conductivity was too low in these areas. We therefore increased the hydraulic conductivity of the glacial till uplands north, south and east of Lake Barney by a factor of two to keep the water table below the ground surface and more closely match water table elevations measured in monitoring wells (**Figure 11**). The new hydraulic conductivity value of 1 ft/d is well within the expected range for local glacial till deposits.

In addition, we removed the till upland adjacent to the eastern shoreline of the lake and replaced it with the higher hydraulic conductivity sand and gravel in surrounding areas of the model. This made the hydraulic conductivity more consistent with the materials observed in soil borings for the monitoring wells on the Department of Corrections property, and it lowered simulated water table elevations to more closely match those measured in monitoring wells MW3 and MW4.

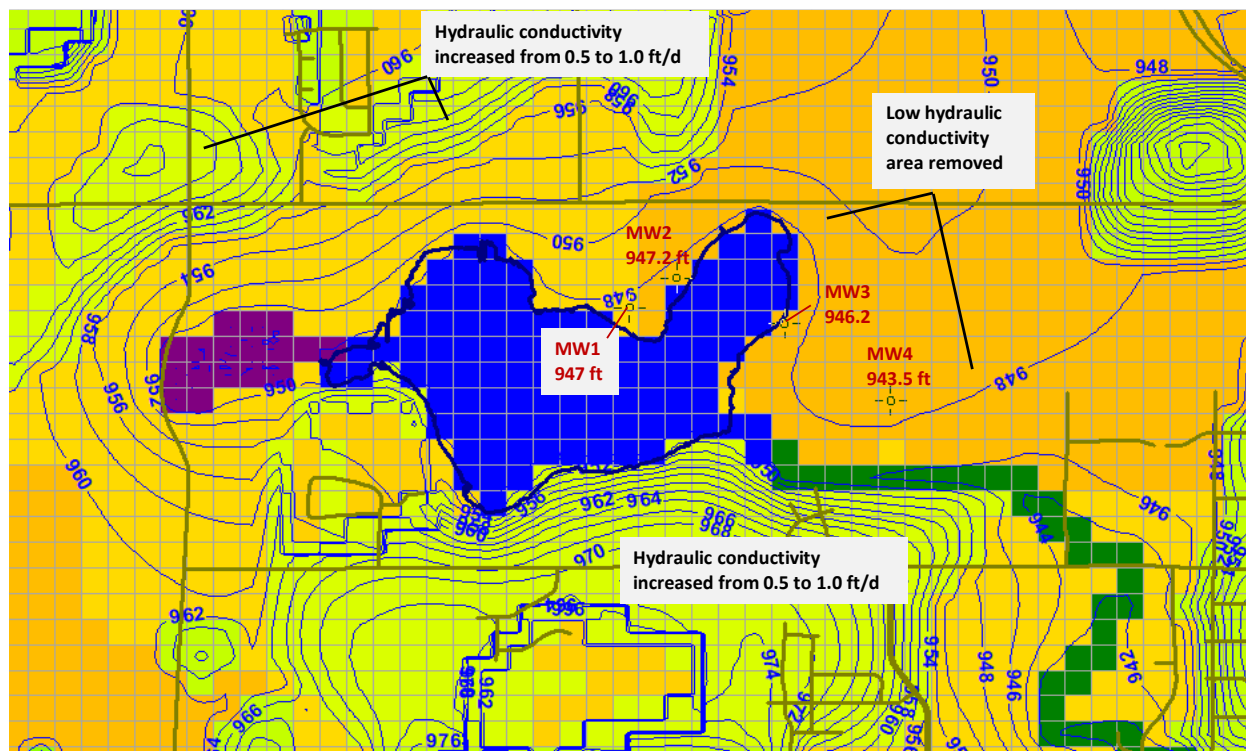


Figure 11. Calibrated existing conditions MODFLOW model and monitoring well data.

Hydraulic conductivity represented by color flood, with orange being highest and light green being lowest.

Calibration Summary

The refined and calibrated model simulates reasonable groundwater levels around and flows out of Lake Barney. Model sensitivity testing with recharge increased by 30% - 50% over the WGNHS's value for 2006 - 2010 predicts about 1.5 - 2 cfs of groundwater discharge. This is lower than measured dry weather outflow, which was typically about 3 cfs in 2020. However, it is likely that

some of the measured outflow is surface runoff that has flowed into Lake Barney and is draining through the overflow, which is not represented in the groundwater model.

4.1.3. Groundwater Seepage with an Outlet

We modified the model to represent Lake Barney with an outlet to quantify groundwater seepage at lower lake stages. Lowering the lake level would increase the gradient from groundwater into the lake, resulting in higher seepage rates. This information was used to construct a rating curve between lake level and groundwater seepage for use in simulating outlets with the surface water model.

The lowered lake levels were simulated with constant head cells, similar to the existing conditions model. Streamflow cells along the overflow route were extended westward to the lake shoreline and lowered to represent the elevation of an outlet channel. The various pools west of Lake Barney were simulated at their overflow elevations, with progressively higher elevations to the west. Simulations were conducted for lake levels of 942 ft, 944 ft and 945 ft.

The greatest groundwater discharge occurs for the lake at 942 ft, due to the higher head difference between the lake and surrounding groundwater heads which are calculated by the 2020 “wet” conditions model. Seepage into the various pools in the Lake Barney basin that would ultimately drain through an outlet was simulated to be 1.9 cfs and 2.9 cfs for recharge multipliers of 1.3 and 1.5, respectively. This represents an increase of approximately 50% above the groundwater discharge at a lake stage of 947 ft.

It appears that an upper estimate of groundwater flux into Lake Barney and through an outlet ranges from 2 cfs at a stage of 947 ft to 3 cfs at a lake stage of 942 ft. This groundwater discharge would be in addition to any surface water stored in the lake that would also drain through an outlet.

4.1.4. Groundwater Drawdown with an Outlet

The effect that lowering the level of Lake Barney with an outlet would have on the surrounding water table during wet conditions was evaluated by comparing model simulations for existing conditions (with the lake at 947 ft) and lowered lake levels (945 ft, 944 ft and 942 ft). Simulated groundwater elevations were imported in GIS to construct water table surfaces for each scenario. The area where an outlet would result in a water table drop of one foot or more was mapped for each outlet scenario. The lower the lake level, the larger the area of water table drop. The area where water table drop is predicted to be one foot or more ranges from approximately 3000 acres for a lake elevation of 942 ft to 1000 acres for a lake elevation of 945 ft (**Figure 12** and **Figure 13**).

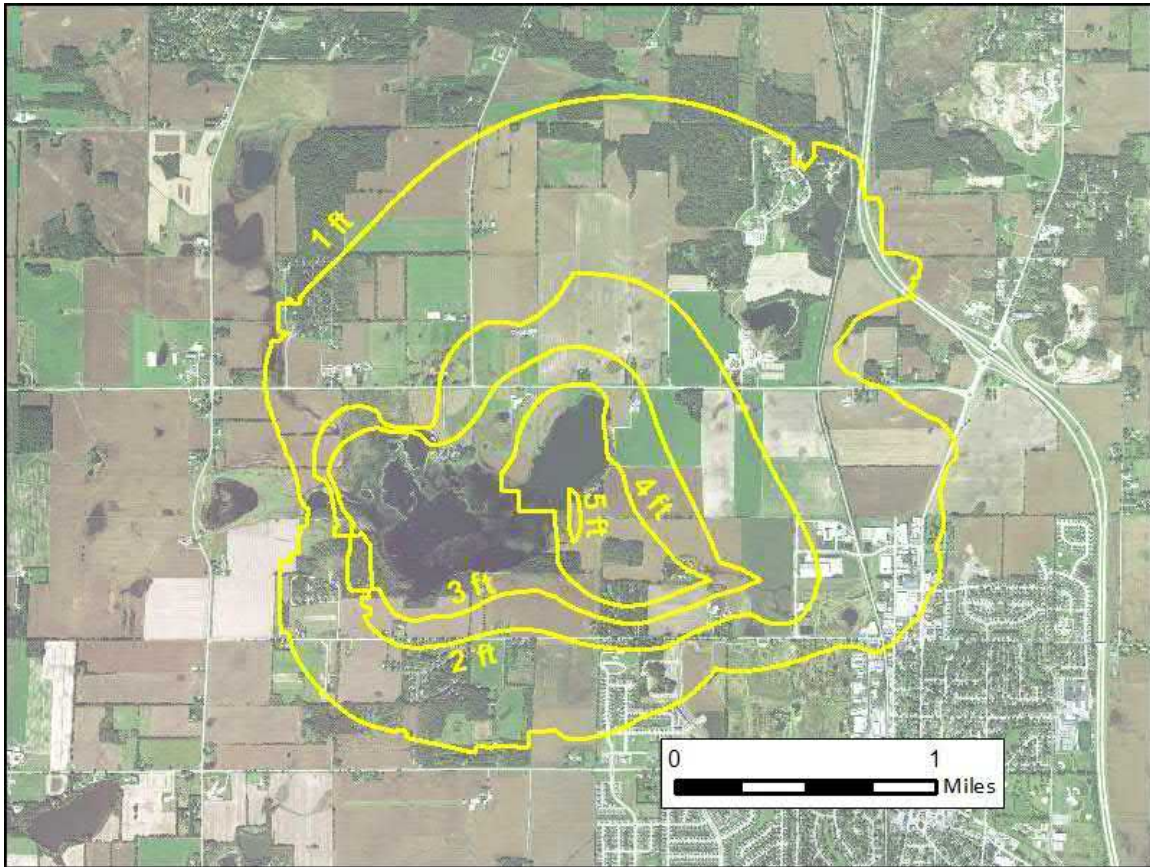


Figure 12. Simulated groundwater drawdown during very wet conditions for an outlet at 942 ft.

While an outlet that controls the elevation of Lake Barney will prevent the local water table from rising substantially during very wet times, during years of normal or dry conditions the outlet would function infrequently, likely only after large storm events. This would be especially true if the selected overflow elevation is higher than 942 ft, as there will likely be years where the lake fluctuates near 942 ft naturally based on the historical record. This would minimize drawdown impacts on surface water bodies, water availability for crops and natural vegetation, private wells, and other groundwater-dependent activities during dry periods.

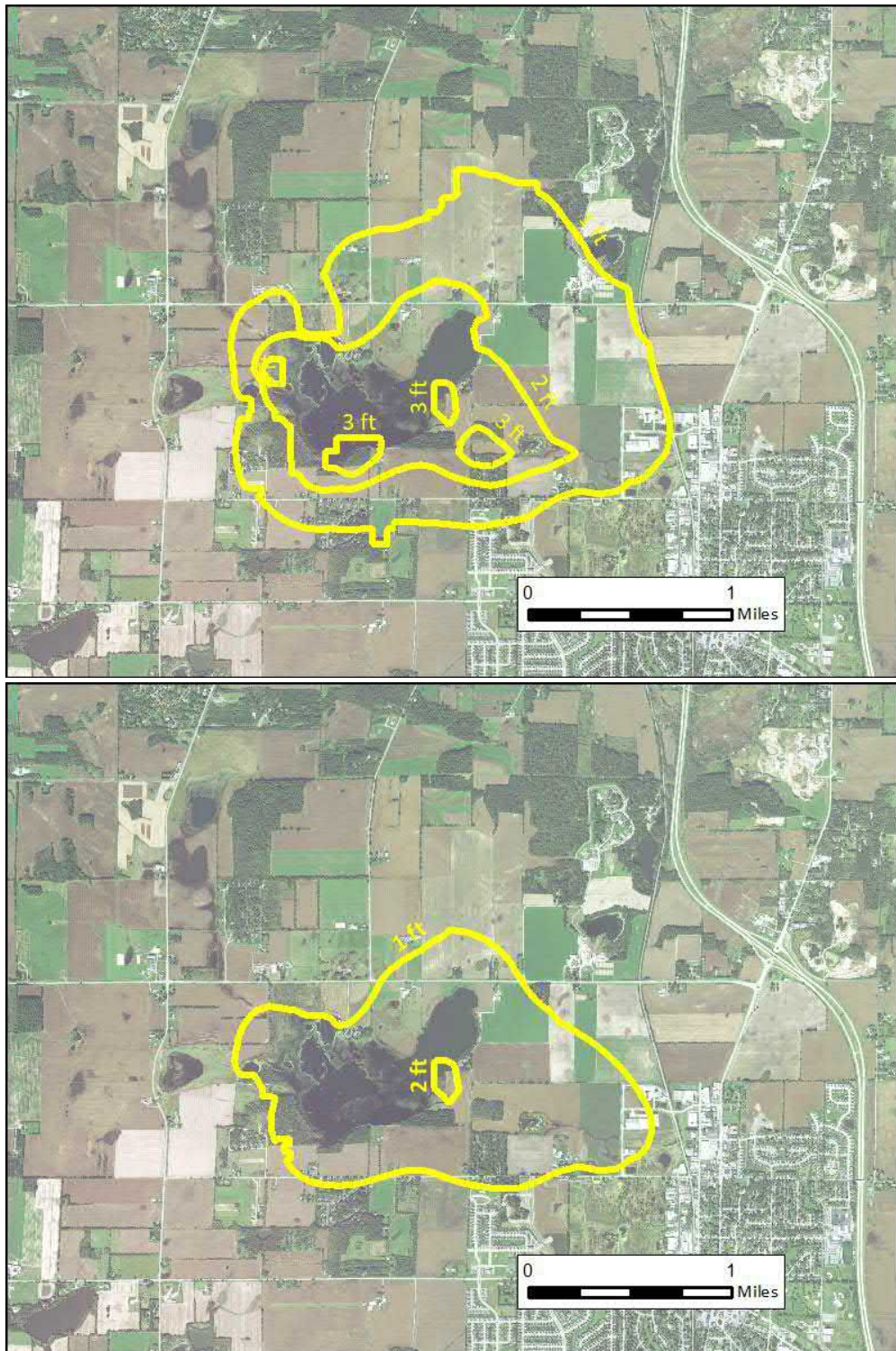


Figure 13. Simulated groundwater drawdown during very wet conditions for an outlet at 944 ft (top) and 945 ft (bottom).

4.2. Surface Water Analysis

This section describes our surface water analysis, which used PCSWMM software to implement the EPA’s Storm Water Management Model (SWMM). We analyzed existing and proposed runoff conditions for the entire watershed upstream of the Village of Oregon, including Lake Barney proper, its overflow path to the east, the unnamed wetlands and Swan Pond to the west, and the many closed depressions in the upper watershed west of Fish Hatchery Rd and north of CTH M. This section focuses on the tools used and key findings, with many additional modeling construction and refinement details included in **Appendix E**.

4.2.1. Model Schematic

The PCSWMM model was built over several iterations, as subcatchment delineation and closed depression analysis revealed important modeling strategies necessary to properly model Lake Barney and its watershed. The final existing conditions model schematic is shown in **Figure 14**, with a larger image included in **Appendix A**. The model consists of 21 storage areas representing large closed depressions or surface water bodies, 54 “irregular” conduits representing runoff flow paths, 9 closed conduits representing road culverts, 38 weirs used to model closed depression overflows or roadway overtopping, and 73 other junctions and minor storage nodes used to route water between other model elements.

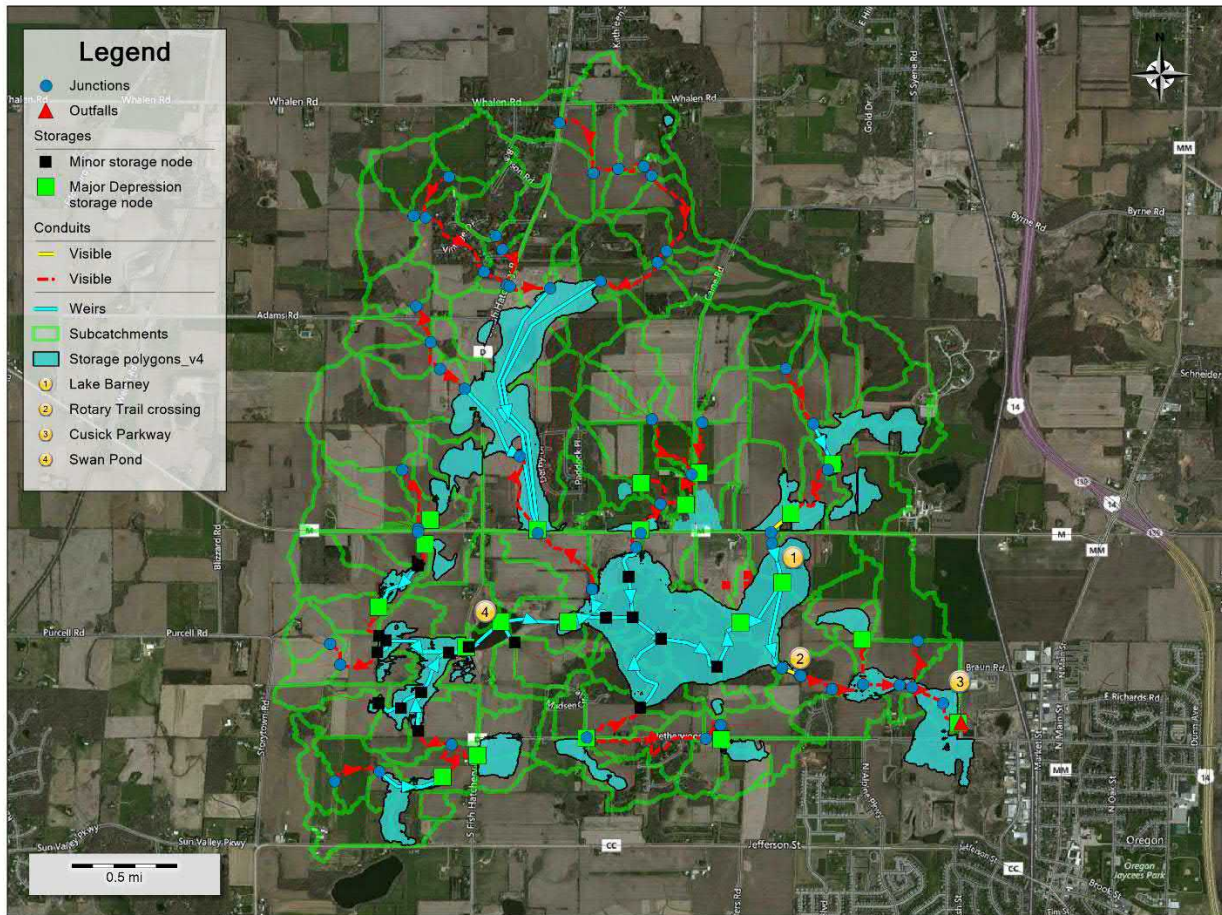


Figure 14. PCSWMM model schematic.

4.2.2. Calibration

Purpose

Hydrologic models are ideally calibrated to observed data to improve model reliability and predictive power. For this study we did not have adequate data to perform any standard calibration procedures, which would require observed flow data at multiple locations in the model, and a longer, more-consistently measured time series of stages in Lake Barney and perhaps other surface water bodies in the watershed. A local, hourly or subhourly rain gage would also be required to perform calibration. Instead, we chose to lightly calibrate our model based on the data available, including:

- The Lake Barney Stage Record (aerial imagery, survey dates, Thayer measurements) as described in **Section 3.1.1**;
- 4 discharge measurements taken at the Rotary Trail overflow in 2019 and 2020;
- Anecdotal reports that Lake Barney had not overflowed prior to recent years and that roadways were not known to have overtopped during heavy storm events during the calibration period.

- Hourly rainfall from Truax Field, adjusted by local precipitation data from the Oregon SSW CoCoRaHS station.

Parameter Selection

The SWMM model contains hundreds of parameters that could potentially be adjusted as part of a calibration effort. These parameters vary widely both in their impacts on the outputs and in their uncertainty – for instance, impervious area is a parameter with a significant impact but minimal uncertainty, while drying time is highly uncertain but has little effect on the model results.

We looked at the following parameters: subcatchment “characteristic width”, subcatchment slope, subcatchment pervious area depression storage, subcatchment maximum and minimum infiltration rate, storage unit evaporation factor, weir length, and weir discharge coefficient.

Calibration Process

The calibration was carried out by running the model in continuous simulation mode from July 1, 2017 to October 1, 2020. This time period was selected because it spanned the time where we had a reasonable starting elevation (based on an aerial image) up through the present where we had much more reliable lake stage data, and also spanned the time including the 4 discharge measurements. We used daily climate data from Truax Field to enable the model’s evaporation, snowmelt, and soil moisture calculations, and modified hourly precipitation from Truax Field as the precipitation input.

The modification of Truax Field hourly rainfall involved comparing daily or multiple-day precipitation totals at Truax Field versus the Oregon 0.4 SSW station and calculating the percent difference for total rainfall over for those individual periods within our calibration dates. We then used that calculated value to adjust the Truax Field data so that the precipitation totals more closely matched the Oregon 0.4 SSW station but retained the hourly temporal pattern of the original data. This method was chosen after we noticed considerable differences between the two stations and understanding that when Lake Barney is actively overflowing it becomes much more important to get the individual precipitation event totals as close as possible to match lake stage and outflow patterns. See **Appendix E** for a more detailed description of the two weather stations used.

Calibration was then carried out to produce a visual fit to historical lake stage data, while also being mindful of having lake outflow being the same general magnitude as the observed dry weather discharge measurements. It should be noted that while SWMM can run a simplified groundwater modeling routine, we did not have the watershed-wide input or calibration data required or a high degree of trust in this methodology for our watershed. Therefore, we expected our dry weather discharges from the lake to be lower than observed since they did not account for groundwater inputs or outputs during the calibration period.

Results

Of the original calibration parameter set, we ultimately only adjusted subcatchment minimum and maximum infiltration rate and the discharge coefficient for the weir representing the lake’s overflow area 500 ft west of the Rotary Trail crossing. Because this overflow area has varying width,

topography, and vegetation and snow / ice cover, we felt that adjusting the discharge coefficient to best match observed lake stage and outflow was appropriate. The comparison of modeled to observed lake stage is shown in **Figure 15**. The fit between both the absolute lake stages and response to storms was better during certain time periods and seasons, and we chose to focus mostly on the period where we had frequent and reliable data (2020) than other times during the calibration period. The period prior to May 2019 lacked any physical measurements to calibrate to, and likely is missing the transient impacts of groundwater outflow during this time when groundwater levels were unknown but likely lower than 2019-2020.

Given the quality of calibration data, we feel this is a reasonably well-calibrated model for this time period and we do not have the quality of calibration data to justify changing default model parameters any further. It is likely that this model is more representative of wet climate conditions, and therefore if it is used for continuous modeling in the future the rainfall runoff may need to be adjusted to reflect drier soils and more available storage on the landscape. Explicitly modeling the groundwater system in the future could further improve the predictive power of the model for continuous simulations but creating a transient groundwater model would be a significant undertaking and would require calibration data at a network of wells over multiple years. These limitations of our model are less likely to impact its use for design storms, as groundwater impacts during a single event are minimal and the rainfall intensities are high enough to overwhelm soil infiltration capacity and minor closed depression storage capacity.

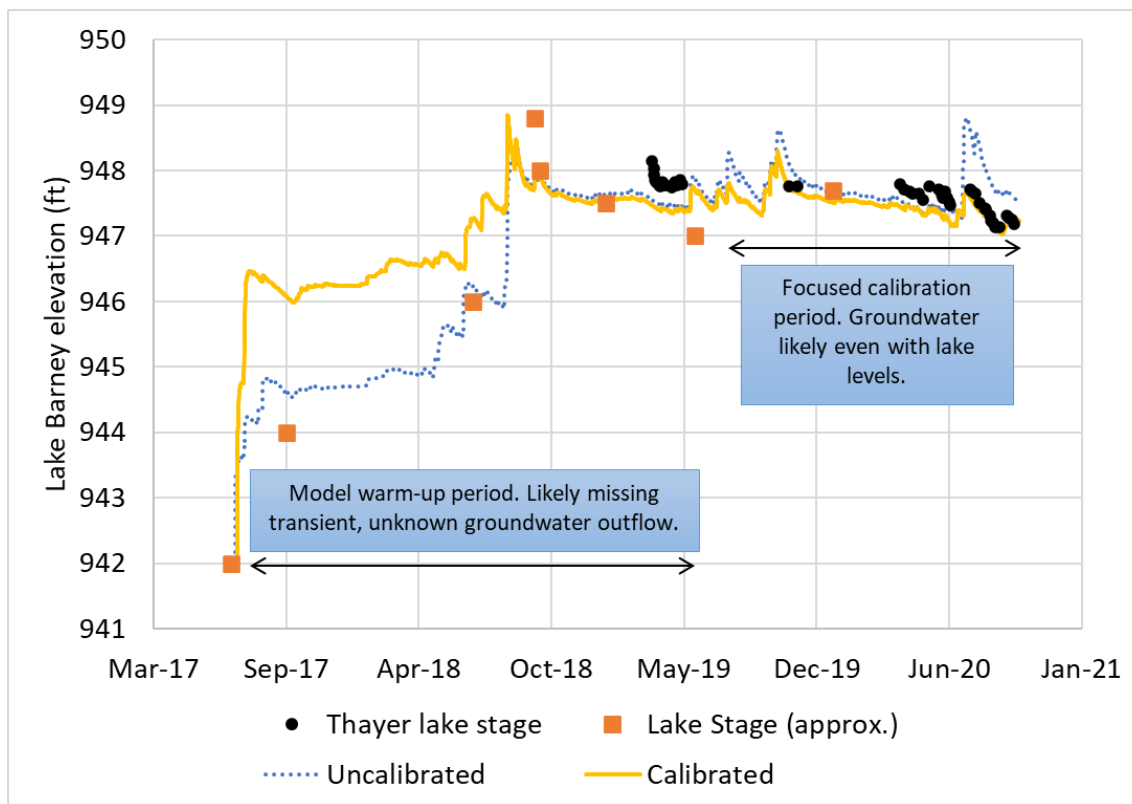


Figure 15. Uncalibrated and calibrated model results compared to Lake Barney stage.

4.3. Existing Condition Design Storm Analysis

Using the prescribed MSE Type 4 distribution, we generated a series of 24-hour design storms based on NOAA Atlas 14 rainfall depths (**Table 5**). The 1- through 100-year recurrence interval depth values were based on the average Dane County Atlas 14 values commonly prescribed for design, while the 500- and 1000-yr values were assessed at Lake Barney using NOAA’s Atlas 14 point-based web tool.

Table 5. 24-Hour design storm rainfall depths.

Recurrence interval (years)	Rainfall depth (inches)
1	2.49
2	2.84
5	3.52
10	4.06
25	5.01
50	5.80
100	6.66
500	8.89
1000	9.97

The key event considered for existing conditions model analysis was the 100-yr storm, since that is a common regulatory event used to assess flood risk. We focused on the impact that different starting lake levels have on overflow from Lake Barney during the 100-yr storm, as we knew that that information would be useful when quantifying flood reduction benefits for any solution and because it would help us better understand the storage and runoff dynamics in the watershed.

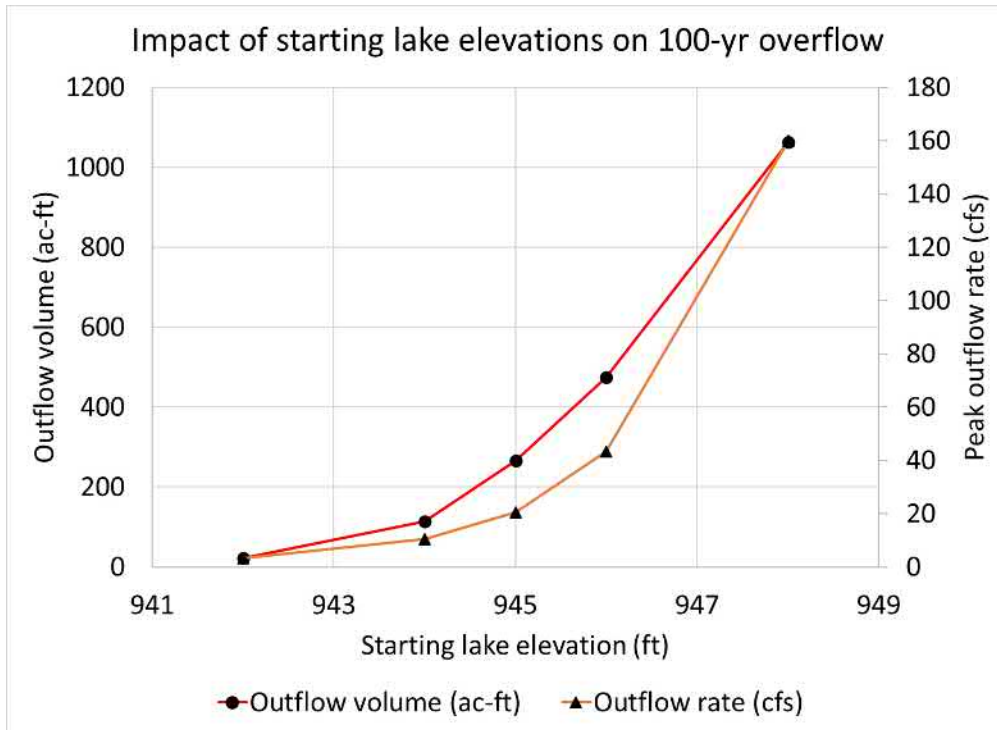


Figure 16. Impact of Lake Barney starting water elevation on 100-yr design storm outflow volume and rate.

As shown in **Figure 16**, the calibrated model predicts that Lake Barney barely overflows during the 100-yr storm when the starting elevation is 942 ft, which is in the range most often seen in the historical aerial photo record. As expected, runoff volume and rate start to increase as the starting stage is increased due to lost storage in the lake. The change in outflow, particularly volume, starts to increase more rapidly between a starting stage of 944 ft and 945 ft. This suggests that there is a tipping point where there is not nearly enough volume of storage between the lake level and the natural overflow (947.3 ft) to handle the design storm runoff, and downstream impacts become more dramatic when the lake starts above 944 ft.

5. PROJECT ALTERNATIVES

5.1. Selection of Alternatives

Based on the design storm analysis in **Section 4.3**, as well as discussions with the City, the Village of Oregon, adjacent landowners, regulators, and other stakeholders, we chose to analyze three different controlled overflow elevations for the project: 942', 944', and 945'. We understood that there would be trade-offs for each, including:

- Impacts to agricultural land use reliability and property valuation;
- Environmental impacts, both positive and negative;
- Flood protection performance;
- Ease of permitting and construction; and
- Project costs.

The remaining sections of this report analyze each alternative in the context of these trade-offs, and ultimately recommend an alternative that provides the best balance for the City in meeting their objectives for the project.

5.2. Outlet and Ditch Configuration

Our preliminary outlet and ditch configurations consist of an outlet structure at the Rotary Trail crossing and a 2-stage ditch that runs from the edge of Lake Barney to Cusick Parkway. These alternatives, shown in **Appendix A - Figure A4**, mainly differ in the overflow elevation (regulated by the control structure) and the length of the ditch between the Rotary Trail and Lake Barney required to reach that elevation along the lake.

5.2.1. Ditch Design

We investigated both a traditional trapezoidal ditch and a 2-stage ditch (**Figure 17** and **Figure 18**). The 2-stage ditch is designed with a low-flow channel to convey baseflow or small runoff events, and a higher bench section that conveys larger events. This design has ecological and water quality advantages as it more closely mimics a natural stream channel than a traditional ditch does and can potentially require less maintenance due to better sediment flushing. It is also considered to be more stable than a trapezoidal design because shallow flow across the bench has less erosive power. We proceeded with a 2-stage ditch design because of these advantages and because we found that it would not require a considerably larger footprint than a traditional ditch. The typical geometry of our proposed 2-stage ditch is shown on **Appendix I – Sheet 4**. The side slopes of the low-flow channel and higher-flow channel are currently designed at 3:1 and 4:1 horizontal:vertical, respectively, in order to minimize the overall ditch footprint. Shallower side slopes might be easier to maintain or more aesthetically pleasing and should be considered during final design if a slightly wider footprint can be accommodated.



Figure 17. Comparison of conventional and 2-stage ditch.



Figure 18. Typical 2-stage ditch during and after construction.

Images in Figures 17 and 18 courtesy of Ohio State University CFAES Extension

Each alternative requires different ditch lengths and starting elevations, which results in different average slopes and depths. These differences are summarized in **Table 6**, including the impact of each alternative on construction earthwork volumes. Alternative 1 requires twice as much earthwork as Alternative 2 and three times as much earthwork as Alternative 3 to construct.

Table 6. Ditch geometry and earthwork for each alternative.

Alternative	Starting elevation (ft)	Ending elevation (ft)	Length (ft)	Ditch depth (ft)	Average slope	Excavation required (cubic yards)
1	942	940	6,520	3-6	0.04%	30,050
2	944	940	6,300	2.5-4	0.08%	16,200
3	945	940	6,275	2-3	0.10%	10,850

5.2.2. Outlet Design

We designed the control structure as a precast 4 ft x 8 ft concrete box with a narrow rectangular weir even with the ditch bottom and a horizontal grate on top of the structure. The weir would limit outflows during small to moderate increases in lake stage, and the horizontal grate would allow much more flow during larger events to prevent the Rotary Trail from overtopping. Both the weir and the grate would route water into the box, which would outflow into a horizontal elliptical pipe discharging on the eastern side of the Rotary Trail. For extreme precipitation events, the rebuilt Rotary Trail would act as an emergency spillway which would require additional armoring at the lowest section of trail. Note that the weir opening and invert, grate elevation, and required Rotary Trail elevation would vary for the three alternatives (**Table 7**).

Table 7. Control structure details for each alternative.

Alternative	Weir invert (ft)	Weir length (ft)	Grate elev. (ft)	Trail elev. (ft)
1	942.0	1	947 ft	947.5 ft
2	944.0	1.6	947.5 ft	948 ft
3	945.0	2	947.75 ft	948 ft

The outlet structure configuration was suggested to meet discharge goals and to provide the fixed outflow elevation. Both the City and the Village of Oregon desire that the outlet structure is completely passive and that it has a fixed outflow elevation, but we believe it would be advantageous to provide some degree of operational flexibility for the future in case watershed conditions or downstream capacities change, which this configuration allows for. The relatively narrow width of the rectangular weir would allow for surface mounted weir plates to be fastened to raise the outlet elevation. This could be done to restrict the downstream flow in case of future capacity issues or to perform maintenance on the channel. Although no manual operation is required for the outlet structure it would be important to perform semi-regular inspections to confirm debris is not blocking the outlet.

The size and shape of the culvert was selected to provide an increased discharge capacity to reduce the probability of overflowing the bike path. A horizontal elliptical pipe was selected to maintain adequate cover without further raising the bike path.

Locating the outlet structure along the bike path requires a relatively long ditch connection to Lake Barney. Although a location closer to the lake may be preferable, the bike path location provides an accessible route, and also shortens the already flat outlet channel. Having the outlet location at the trail would also require less dewatering than an outlet immediately adjacent to the lake, making it easier to construct.

5.3. Design Storm Testing

We tested the alternatives for a range of 24-hour design storms, and results from the 1-, 10-, 100, and 1000-yr storms are shown in **Table 8**. These analyses assume that the lake starts at the overflow elevation for each alternative. While the outlet designs are conceptual and could be refined based on the selected alternative, there are three main takeaways from these results:

- For the smaller (<100-yr) storms, outflow discharge is minimal and the outlets can be configured so that each alternative has a similar magnitude of peak flow rate;
- For the 100-yr storm, all alternatives are below the maximum rate that the Village of Oregon has preliminarily identified as being capable of handling with their proposed storm sewer upgrades at Cusick Parkway (40 cfs); and
- Alternative 1 has a peak discharge of less than half of Alternative 3 for the 1000-yr storm. This suggests that for the largest events there will be clearer differentiation between the alternatives, and there is a clear advantage to maximizing storage (Alt. 1). Note that the peak stage for that event is shown as being slightly higher than for Alternative 2, which is counterintuitive but related both to runoff timing and the weir configuration,

Table 8. Design storm peak lake stage and outflow rate for each alternative.

Starting lake stage (ft)	1-yr design storm (2.49")		10-yr design storm (4.10")		100-yr design storm (6.66")		1000-yr design storm (9.97")	
	Peak stage (ft)	Peak outflow (cfs)	Peak stage (ft)	Peak outflow (cfs)	Peak stage (ft)	Peak outflow (cfs)	Peak stage (ft)	Peak outflow (cfs)
942 (Alt. 1)	943.6	4	945.0	11	947.0	24	949.4	119
944 (Alt. 2)	944.7	1	945.9	8	947.6	22	949.2	249
945 (Alt. 3)	945.6	1	946.6	7	948.1	33	949.5	282

We also looked at how long Lake Barney would take to drain back to its overflow elevation, assuming that relatively dry weather followed a large event (see **Table 9**). As currently configured, the biggest differentiation is for the 1-yr storm, where it takes Alternative 1 much longer to draw back down compared to the other alternatives because the weir opening is smaller. This smaller weir is required to keep large-event peak discharge below the 40 cfs downstream limit because there is a lot more potential head on the weir than for other alternatives since it is 2-3 ft lower. For the rest of the storms there is less differentiation in drawdown between the alternatives, although generally the higher the overflow elevation the less time it takes to draw down to that elevation. There is also an upper limit to how long it would take any alternative to draw down for the largest storms (~ 2 months). This is because for those storms the overflow weir (Rotary Trail) would be activated, so draw down would generally start from the same water level for any storm where the overflow was activated.

Table 9. Draw-down times following design storms for each alternative.

Alternative	Draw-down time following design storm to reach target elevation (days)					
	1-yr	10-yr	25-yr	100-yr	500-yr	1000-yr
1 (942')	24	41	48	57	61	62
2 (944')	12	40	49	60	62	62
3 (945')	6	38	47	56	57	57

During testing we observed trade-offs within alternatives between draw-down time and peak flow. For example, if the Alternative 1 weir length is doubled from 1 ft to 2 ft, the draw-down occurs much faster but the peak discharge for events also increases because the weir can pass more water. Another design trade-off may be maximum lake elevation and peak flow – the larger the control structure openings, the more water can discharge which prevents the lake from getting as high during a storm event. A final design should look at these trade-offs and how they affect both adjacent landowners and downstream riparians.

5.4. Permitting

Based on internal reviews of regulations and discussions with the WDNR and Dane County, we believe that the project may require a significant number of permits and anticipate substantial permitting efforts required to design and construct the project. We anticipate the following categories of permits:

- Dane County Shoreland Zoning.
- WDNR Construction-Time Erosion Control and Dane County Shoreland Erosion Control. Both should be relatively straight-forward, but Dane County may require separate permits for each of the three jurisdictions that the route crosses. Keeping stormwater from entering the ditch before it's completed and handling any dewatering required for excavation near the lake are likely to be key issues.
- WDNR Wetland and Waterway individual permits. These would likely be the wetland permit and several individual waterway permits, one for each activity that triggers a different section of Chapter 30. Based on preliminary conversations, we anticipate needing:
 - Wetland Individual Permit, including required mitigation for temporary and permanent wetland impacts. A formal wetland delineation would be required.
 - If the project is below the Ordinary High Water Mark (OHWM) of Lake Barney, then it would need to meet 30.19 (enlargement and protection of waterways) and 30.18 (withdrawal limits).
 - If the project is above the OHWM, then the waterways program requirements might be minimal if the ditch is mostly dry and does not develop its own OHWM or remain wet for 24 hours or longer following storms.

- If the project is above Lake Barney's OHHM but develops its own OHHM due to persistent flow or slow drying (>24 hours) following flow events, then it would need to meet 30.19 (pond permit) and it could become a navigable waterway which could impact ease of maintenance or future activities on the waterway.
- The WDNR estimated an OHHM of 944-945 ft based on aerial photography we provided but stated that it was difficult to name a precise elevation due to current environmental conditions (flooded lake edge). In general, WDNR stressed the importance of keeping the channel at an elevation that would allow for the historic and normal fluctuation of the lake.
- Any waterway review would include water quality considerations, such as invasive species spread or downstream nutrient impacts.
- United States Army Corps of Engineers (USACE) permits may be required if USACE decides to consider any impacted wetlands as being under their jurisdiction. We can provide conceptual project details to them prior to the final design in order to confirm this, which will help avoid project delays potentially due to USACE review cycles.
- Other WDNR potential permits might be required through the floodplain management and dam safety programs.
 - The dam permit is more likely to be required if the outlet invert is above the ditch invert and the outlet is effectively impounding water, which is not currently the conceptual design. Having the outlet be passive (non-adjustable) will also limit the need for any impoundment-related permitting. The Rotary Trail overflow spillway could be subject to dam safety requirements, but it was not certain whether it would apply based on initial conversations.
 - Floodplain permits, including remapping of regulatory floodplains, might be required depending upon the project's final design and interpretations made by WDNR staff. To ease permitting and potentially expensive FEMA map revisions, it was recommended to us that the project should try to limit the flow changes caused during more frequent (< 100-yr recurrence interval) storm events, as well as to analyze the change caused by the project to the 100-yr, 10-day storm which has been identified as the watershed's "critical duration" event by previous WDNR floodplain models. And, while FEMA remapping may not ultimately be required, WDNR staff noted it would bring zoning and insurance maps more up to date if it were to be remapped.

5.5. Time to Drain (Post-Construction)

We calculated post-construction draw-down times for each alternative. These do not differ greatly from large storm (100-yr) draw-downs calculated in **Section 5.3**, but do incorporate groundwater inflow to Lake Barney because unlike the long-term storm testing we can assume that the water table is still high if the project is constructed within the next couple of years. We based groundwater inflow

on estimates calculated in **Section 4.1.3**, which range from 2 to 3 cfs depending on Lake Barney stage. Since there might also be precipitation during this time period, we used the higher (3 cfs) value to account for groundwater and other inputs during post-construction draw-down. Results are shown in **Table 10** and range from 87 days for Alternative 1 to 49 days for Alternative 3. These times could be lower if the water table draws down before an outlet is built, or higher if wet conditions and high groundwater persist or if there are substantial rains following connection of the outlet.

Table 10. Post-construction draw-down time.

Alternative	Approximate drawdown time to control structure elevation*	Mean flow rate during drawdown	Time for lake levels to fall from control structure elevation to 942 ft**
1 (942')	87 days to reach 942 ft	7.1 cfs	0 years
2 (944')	57 days to reach 944 ft	5.2 cfs	2 – 4 years
3 (945')	49 days to reach 945 ft	4.7 cfs	3 – 6 years
No Outlet	Not Applicable	Not Applicable	5 – 10 years

* - Assumes no major rainfall during draw-down, high starting water table, and starting water elevations ranging from 949' (Swan Pond) to 947.3' (Lake Barney).

** – Assumes relatively normal or below-normal precipitation patterns and groundwater levels over the time span.

6. COST-BENEFIT ANALYSIS

The goal of the cost-benefit analysis was to assess the costs, benefits, and long-term maintenance of the three alternative solutions and recommend the option with the best balance. We considered the benefits in three ways: 1) the maximum annual benefit that having a solution in place would provide to City residents by preventing agricultural losses in a very wet year; 2) the long-term benefit to City residents by preventing devaluation due to persistent high water problems; and 3) other benefits including downstream flood reduction outside of the City and other qualitative benefits within the City. The benefits analysis was conducted knowing that the future conditions of Lake Barney without a constructed outlet are very hard to predict, as high water conditions in the lake can be triggered by a single intense rainfall event (like a 100-yr rainfall), by multiple years of above average precipitation, or a combination of the two. However, given conditions seen in 2008-2010 and 2018 to the present, and considering that climate change modeling generally predicts wetter and more intense precipitation events in the future for our area⁴ we think it's reasonable to anticipate high groundwater and lake levels happening again.

The project costs were more straight-forward to calculate. For each alternative, we considered both the upfront cost of permitting, designing, and constructing the outlet system, as well as the ongoing cost of maintenance.

6.1. Benefits

6.1.1. Maximum Annual Benefit

The rationale for conducting a maximum annual benefit analysis, rather than an average annual benefit, was that it's impossible to predict the frequency of an outlet structure being used to prevent high water levels in the future. During below-average to normal precipitation conditions, the constructed outlet might provide no benefit as the lake may stay below the chosen outlet elevation due to natural water balance processes. But we can estimate the benefit provided by an outlet during very wet years by using our groundwater analysis and looking at where the outlet could prevent the damage observed in recent years, which has been primarily agricultural losses. **The short-term benefit of the chosen outlet could then be anywhere from \$0 in dry years to this maximum benefit in very wet years.**

We calculated this maximum annual benefit for each outlet alternative using the following steps:

⁴ Wisconsin's Changing Climate: Impacts and Adaptation. 2011. Wisconsin Institute on Climate Change Impacts. Nelson Institute for Environmental Studies, University of Wisconsin-Madison and the Wisconsin Department of Natural Resources, Madison, Wisconsin.

- 1) Quantify the acreage of nearby impacted lands during recent very wet years. We did this by consulting with landowners and by looking at recent aerial imagery (2019 and 2020) and comparing area that were unfarmable due to surface water flow or high groundwater to areas that were unfarmable during more typical, drier conditions (2017 aerial image). These new unfarmable areas were considered to be the impacted lands, shown as the orange areas on **Figure 19**.
- 2) For each alternative, superimpose our groundwater drawdown footprint. For this analysis, we considered the drawdown footprint to be where our groundwater analysis predicted 1' or greater of water table lowering due to an outlet during very wet conditions (high groundwater), which are the heavy black lines shown on **Figure 19**. This step reduced the acreage quantified during Step 1 to be areas only within the drawdown footprint, which varied for each alternative. We also checked that the quantified areas were in locations where groundwater was within 10 ft of the surface, such that lowering the water table would actually benefit surface infiltration and increase likelihood of successful farming (i.e. these wet areas weren't "perched" above the groundwater system). These areas were then considered to be the amount of lost productive acreage prevented by each alternative.
- 3) Distinguish between benefited acreage within the City and outside of the City.
- 4) Calculate the agricultural losses prevented for residents of the City. We developed this benefit as a range, recognizing that these losses could be on a spectrum from a sudden crop loss to ongoing losses if it's wet for several years. For the sudden crop loss, we used the average corn yield in Dane County in 2019⁵ (180.9 bushels / acre) and multiplied it by the highest price received for bushel of corn state-wide in 2019⁶ (\$3.98 / bushel), which resulted in a per acre loss of approximately \$700. This situation is considered near the high end of the estimate and assumes that the producer has already sunk considerable costs for the season (seed, planting, etc.) that are to be recouped by the crop sales. For the low end of the estimate, we are assuming that those sunk costs might not apply if there are several wet years in a row and the situation is then more predictable. For this estimate, we initially used an average rental values for non-irrigated cropland in Dane County for 2019 of \$174/acre, then adjusted it to \$200/acre based on landowner input (Appendix F).

This process results in a maximum annual benefit estimate for each alternative. The results of this analysis, including the acreage impacts for each alternative, are shown in **Table 11**. Alternative 1 (942' outlet) has the largest quantifiable maximum annual benefit, as it has a greater impact on

⁵ Wisconsin Ag News – 2019 Corn County Estimates. USDA National Agricultural Statistics Service. https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/County_Estimates/2020/WI-CtyEst-Corn-18-19.pdf. Retrieved 12/23/2020.

⁶ National Agricultural Statistics Service Quick Stats. USDA National Agricultural Statistics Service. <https://quickstats.nass.usda.gov/results/46DD5A0B-38EB-32C0-8516-A3E4A75E2404>. Retrieved 12/23/2020.

lowering the water table during wet periods than the other alternatives. Alternatives 2 and 3 have smaller drawdown footprints and thus smaller maximum annual benefits.

Table 11. Maximum annual agricultural benefit calculations per alternative.

Alternative	>1 ft groundwater drawdown footprint	Total land returned to agricultural production	Land returned to agricultural production – City of Fitchburg only	Maximum annual benefit to City residents*
1 (942')	3,230 ac	70.6 ac	40.0 ac	\$8,000 – \$28,000
2 (944')	1,750 ac	58.6 ac	17.9 ac	\$3,600 – \$12,500
3 (945')	1,080 ac	50.0 ac	10.0 ac	\$2,000 – \$7,000

* Based on the \$200 to \$700 per acre range described on previous page

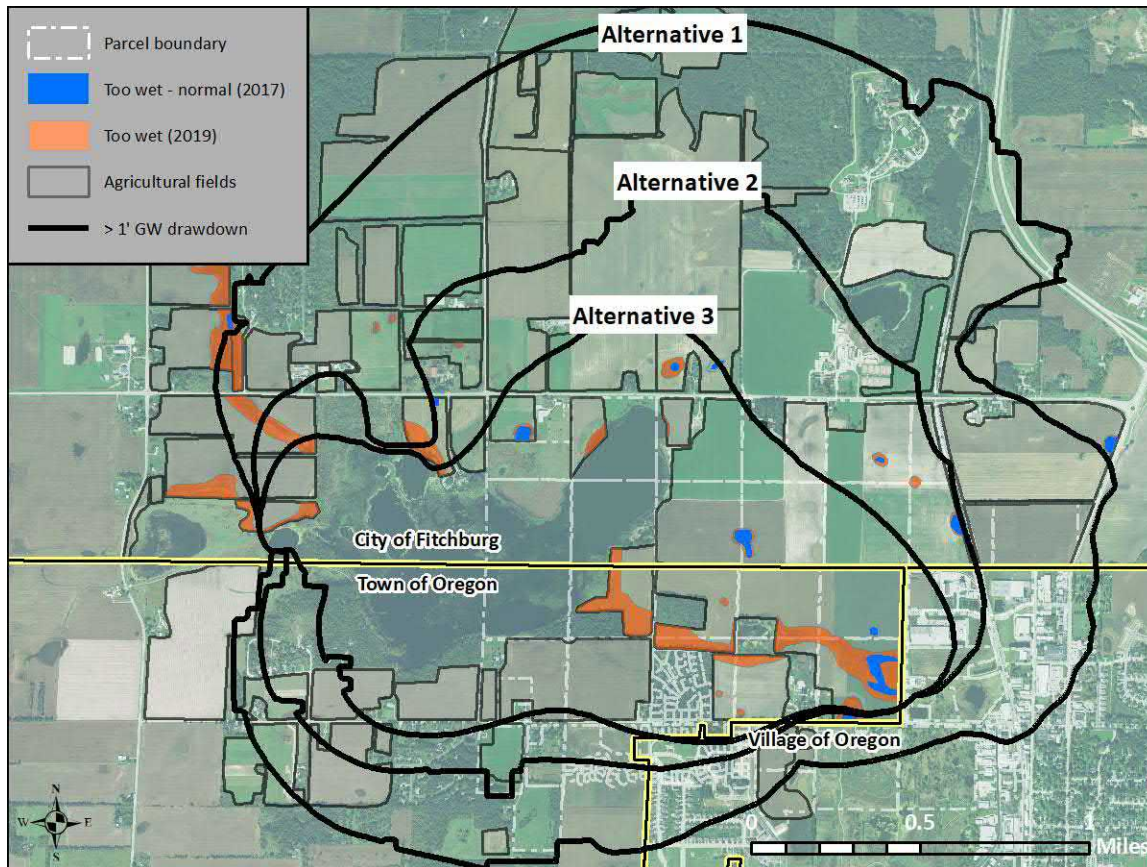


Figure 19. Impacted agricultural areas during high lake stages and 1' groundwater drawdown per alternative.

Our analysis includes only the agricultural areas within the City that we believe will directly benefit from each alternative. But it may be that lowering and providing an outlet for Lake Barney will allow additional water to be drained to the lake during wet conditions, if downstream riparians and regulators approve construction of additional drainage improvement projects. In **Appendix F**, the

Lake Barney Landowners Committee has described agricultural losses in a wider area than just the immediate project, as well as a drainage plan for connecting these other wet areas to Lake Barney if the outlet project is built. In this case, they have identified total production lost both adjacent to the lake and further upstream, which they quantify as \$76,000 of lost production based on rental alone, ignoring profits from cropping. It is our understanding that these projects could be constructed regardless of an outlet structure being built for Lake Barney, but with potential negative consequences for downstream neighbors, so the City may want to consider these types of upstream benefits when weighing the benefits of constructing an outlet on Lake Barney; however, since these upstream projects would not directly benefit from this project, we have not included these upstream benefits in our cost-benefit analysis.

6.1.2. Property Devaluation

The maximum annual benefits analysis addresses short-term impacts of high groundwater but, given the long time-to-drain for Lake Barney under natural conditions and predictions for increased precipitation, we felt it was important to also consider permanent impacts to agricultural and residential properties that might occur if current high groundwater conditions persist in the future. For this assessment we enlisted Craig Hungerford, CRE, ASLA, and his team at Real Estate Dynamics, Inc. We provided them with the same tally of impacted acreages on parcels within the maximum alternative drawdown footprint to be consistent with the maximum annual benefit analysis. They then estimated agricultural and residential devaluation for the three alternatives and the “no outlet” scenario.

We originally asked them to also consider impacts to City and Town tax revenue based on changes to property values, but City staff have clarified that the City and Town would not lose tax revenue as a result of agricultural land in this area becoming unfarmable. The City’s budgetary needs are determined each year, and taxes will be redistributed among property owners to ensure the budgetary needs are met. In fact, agricultural land that is farmed receives a substantial tax break, so if the land is untillable due to wet conditions, it’s possible that owners may pay more taxes as a result (since agricultural land receives a higher tax break than swamp). Regardless, at the end of the day, the City and Town would not lose revenue as tax rates would be adjusted to ensure budgetary needs are met.

The key results from the property devaluation are shown in **Table 12**. Without an outlet, affected parcels within the City that are within our project’s estimated maximum drawdown footprint could experience \$185,500 in agricultural land devaluation and \$114,000 in residential devaluation. Note that for this analysis:

- The “cost-to-cure” for the Thayer property is the cost associated with constructing a permanent berm and installing a permanent pump system. This berm would provide 2 ft of freeboard during the 100-yr design storm for each alternative, including the “no outlet” scenario with Lake Barney starting at recent high stages (948 ft). Because the outlet is

designed to drain slowly, even Alternative 1 would require a modest berm to provide the full 2 ft of freeboard under the current conceptual outlet configuration.

- The DOC properties are summarized separately since they don't pay property taxes or City stormwater utility fees.
- Some land devaluation is still calculated for Alternative 1 because there are some parcels with impacted wet acreage that are only partially within in the maximum drawdown footprint. We kept the parcels whole for the purposes of this analysis.

Table 12. Potential long-term property devaluation impacts by type and municipality (within maximum drawdown footprint).

Potential impacts to City of Fitchburg (doesn't include DOC properties)	Alt. 1 (942 ft)	Alt. 2 (944 ft)	Alt. 3 (945 ft)	No Outlet
Agricultural land devaluation (private property)	\$64,500	\$126,000	\$163,000	\$185,000
Thayer Property cost to cure	\$55,000	\$73,000	\$73,000	\$114,000
Potential impacts to Town of Oregon (doesn't include DOC properties)	Alt. 1 (942 ft)	Alt. 2 (944 ft)	Alt. 3 (945 ft)	No Outlet
Agricultural land devaluation (private property)	\$0	\$2,000	\$4,500	\$153,000
Potential impacts to Department of Corrections	Alt. 1 (942 ft)	Alt. 2 (944 ft)	Alt. 3 (945 ft)	No Outlet
Agricultural land devaluation	\$0	\$0	\$8,000	\$79,000

To more easily compare alternatives to each other and to estimated project costs, we also summarized the devaluations in terms of “potential loss avoidance” – that is, the potential impacts and costs that could be avoided by implementing one of the alternatives, as compared to the no outlet situation. These potential loss avoidances are summarized for each type and municipality in **Table 13**. For example, total devaluation avoided for properties within the City range from approximately \$180,000 for Alternative 1 to \$63,500 for Alternative 3, which can be thought of as the total long-term project benefit due to avoidance of losses that could result due to future high groundwater conditions without an outlet project in place. Note that losses to the Town of Oregon and DOC are relatively consistent across alternatives because most of the currently impacted agricultural lands in those areas would be improved under any of the three alternatives.

Table 13. Potential losses avoided by implementing each project alternative.

Potential City of Fitchburg losses avoided by implementing the Project (doesn't include DOC properties)	Alt. 1 (942 ft)	Alt. 2 (944 ft)	Alt. 3 (945 ft)
Agricultural Land Devaluation (Private Property)	\$121,000	\$59,500	\$22,500
Thayer Property Cost to Cure	\$59,000	\$41,000	\$41,000
<i>Total</i>	<i>\$180,000</i>	<i>\$100,500</i>	<i>\$63,500</i>
Potential Town of Oregon losses avoided by implementing the Project (doesn't include DOC properties)	Alt. 1 (942 ft)	Alt. 2 (944 ft)	Alt. 3 (945 ft)
Agricultural Land Devaluation (Private Property)	\$153,000	\$151,000	\$148,500
<i>Total</i>	<i>\$153,000</i>	<i>\$151,000</i>	<i>\$148,500</i>
Potential Department of Corrections losses avoided by implementing the Project	Alt. 1 (942 ft)	Alt. 2 (944 ft)	Alt. 3 (945 ft)
Agricultural Land Devaluation	\$79,000	\$79,000	\$71,000
<i>Total</i>	<i>\$79,000</i>	<i>\$79,000</i>	<i>\$71,000</i>

6.1.3. Other Considerations

There are other benefits to consider with construction of an outlet. These include quantifiable benefits, such as:

- Downstream flood reduction in the Village of Oregon. Outflow from the lake for the outlet alternatives can be compared to existing conditions to assess peak flow reduction during major events (e.g. the 100-yr design storm). While final reduction will depend on the selected alternative and final design, the range of existing conditions peak flow rates shown in **Figure 16** illustrate that 100-yr peak flows increase greatly when the lake has a starting elevation about 945 ft. The outlet alternatives would primarily benefit downstream flood reduction in very wet years (like recent conditions) by ensuring that flood storage is available.
- Reduced pumping costs for the Village of Oregon. The Village purchased a bypass pump system for \$80,000 to pump water across Netherwood Drive, in response to flooding caused by Lake Barney overflow. If uncontrolled releases from Lake Barney are eliminated, the City could save \$20,000 to \$30,000 in annual operational costs for the pump during very wet years.
- Rotary Trail reconstruction costs. The Village has preliminarily identified a cost of \$367,000 to raise the trail 5 feet from its current elevation of ~947 ft to 952 ft as a means of avoiding future damages and loss of use. With an outlet in place and lake elevations more controlled, the Village would still need to repair the damaged trail and possibly raise the elevation slightly, but it would likely be a much smaller project and much of the \$367,000 cost estimate could be avoided.
- Landowner flood protection cost prevention. For reference, Tom Thayer spent approximately \$120,000 on temporary flood protection measures including the purchase,

operation, and maintenance of inflatable barriers and pumps during the high water of 2018-2020 (**Appendix F**).

They also include benefits that are qualitative, subjective, or exceedingly hard to quantify including:

- Increased landowner peace of mind;
- Reduced nuisance high water (yard flooding and wet ditches);
- Reduced landowner costs to farm and/or access lands that are still farmable but are difficult to access due to wet areas; and
- Reduced negative ecological impacts. Large areas of mature oak trees have died due to persistent high water, particularly near the Thayer property. Additionally, much of the original wetland fringe or sedge habitat has been replaced by open water. USFWS has indicated that they would prefer a return to more typical lake levels to promote stable waterfowl nesting habitat.

6.2. Costs

6.2.1. Design and Construction Costs

Design and construction costs will include the same major elements for each alternative, although the prices vary substantially because of the difference in the depth and length of the ditch for each alternative. These costs include:

- Preliminary through Final Design
- Permitting, including formal wetland delineation
- Outlet structure
- Ditch earthwork
- Restoration
- Erosion Control

We have prepared feasibility-level cost estimates (Class 5, 0 to 2% design completion per ASTM E 2516-06) for each alternative, which are summarized below in **Table 14** and have an estimated accuracy range of -20 to +30%. More detailed cost estimates including quantities and unit costs are included in **Appendix G**. Our estimated costs include a 25% construction contingency and percentage-based professional fees for planning and engineering, permitting and approvals, for bidding and construction services. This project is expected to be relatively straightforward to design with the exception of the outlet and Rotary Trail crossing, but is expected to have higher than normal permitting and approvals fees because of the need for a wetland delineation and numerous DNR Chapter 30 individual permits that would be required. These fees are a constant percentage across alternatives, which is reasonable at this time given that Alternative 1 has a much higher cost but would require more professional fee-related effort due to larger wetland delineation footprint, more

spoils placement planning and management, and more of the assumed ditch construction below Lake Barney’s ordinary high water mark and possibly in wet conditions.

A major assumption for these estimates is that excess excavated material could be placed and worked into surrounding agricultural lands. If haul-off of material is required, the earthwork costs for each project could be ~35% higher than shown in the detailed estimates. If Lake Barney is at current high lake levels during construction, much of the length of ditch between the lake and the Rotary Trail would require dewatering to construct which would add to costs and complexity.

The project costs do not include reconstructing the Rotary Trail where it was temporarily excavated by the Village of Oregon – for now it is assumed that the Village would perform that work, but if this project occurs after they rebuild the trail that could add more project costs.

Table 14. Estimated project costs.

Alternative	Earthwork	All other construction items	Construction contingency	Professional fees	Total Project Cost* (nearest \$5k)
1 (942')	\$538,000	\$163,000	\$175,000	\$98,000	\$975,000
2 (944')	\$326,000	\$148,000	\$118,000	\$66,000	\$660,000
3 (945')	\$243,000	\$141,000	\$96,000	\$54,000	\$535,000

** Does not include wetland mitigation costs or easement costs, as discussed in Section 6.2.2 and 6.2.3, respectively.*

6.2.2. Potential Wetland Mitigation Costs

Wetland mitigation project costs are unknown at this time but may be considerable. Based on the preliminary offsite determination, the ditch route might be able to avoid regulatory wetlands except near the connection to Lake Barney, which would limit wetland mitigation credits required to offset temporary and permanent impacts to wetlands caused by the ditch. But it’s also possible, and has been suggested by WDNR staff, that an onsite wetland delineation would show much more extensive wetlands currently present after the multiple years of wet conditions along the overflow route. For this case the amount of impacts to wetlands and cost of wetland mitigation would increase greatly.

Since the City is unable to access the Alpine Dairy property and perform a full onsite wetland delineation currently, we instead provide a range of potential wetland mitigation costs. At the low end is the scenario where the final mapped wetlands are similar to the preliminary offsite determination, while the high end assumes that the entire ditch route crosses regulatory wetlands. For each alternative, we took the ditch excavation footprint and buffered it by five feet on each side. The costs below (**Table 15**) assume that a wetland credit ratio of 1.7 acres required : 1 acre impacted would be required for wetland impacts adjacent to Lake Barney, as those are likely to be more permanent and higher quality. For the remainder of the route through former agricultural lands, we assumed that the wetlands would be low quality due to their disturbed nature and recent formation and a 1.2:1 ratio would be allowed. The calculation also assumes that this type of wetland credit (wet meadow) is available in the DNR mitigation program’s Rock River Service Area at time of construction. We used the 2020 Credit Fee (\$74,700) for this service area listed on the DNR’s website

but recognize that wetland credits are market-based and subject to change. The results of the analysis show that potential minimum wetland mitigation costs range from \$20,000 to \$60,000, while the maximum costs are all at or above \$550,000 if the whole overflow and proposed ditch route is mapped as wetlands once the formal wetland delineation is conducted.

Table 15. Range of potential wetland mitigation costs.

Alternative	Minimal wetland impacts	Maximum wetland impacts	Assumed Credit ratio and applicable acreage	Potential Mitigation Costs
1 (942')	0.47 acres	8.5 acres	1.7: 1 (0.47 ac), 1.2:1 (8.04 ac)	\$60,000 – \$780,000
2 (944')	0.18 acres	6.9 acres	1.7: 1 (0.18 ac), 1.2:1 (6.67 ac)	\$22,000 – \$620,000
3 (945')	0.15 acres	6.1 acres	1.7: 1 (0.15 ac), 1.2:1 (5.96 ac)	\$20,000 – \$550,000

6.2.3. Easements

A permanent easement would need to be obtained from the Department of Corrections and Alpine Dairy to construct the project. Easement costs are unknown at this time, although it's possible that costs could be considerably less than a standard easement as the project would improve the reliability of agricultural lands surrounding the ditch. The project could also increase these properties' future development value since they would be less susceptible to flooding and the ditch could serve as the "greenway" typically required for local development projects. The size of easement needed from each property owner is shown in **Table 16**.

Table 16. Easement acreage requirements.

Alternative	Easement required – Department of Corrections	Easement required – Alpine Dairy
1 (942')	2.9 acres	5.7 acres
2 (944')	2.1 acres	4.8 acres
3 (945')	1.8 acres	4.3 acres

6.2.4. Long-term Operations and Maintenance

We believe that long-term operations and maintenance (O&M) costs could be relatively low. The ditch and buffer would need periodic mowing estimated at \$500 per year. This cost assumes the City performs two mowings per year using a regular tractor along the edges of the ditch and an arm mower within the ditch. It is possible that an agreement with either the Department of Corrections or Alpine Dairy could be reached to provide in-kind services for occasional mowing, in exchange for the improved drainage in their agricultural areas.

One of the advantages of 2-stage ditches is that they have been shown to require very little channel maintenance due to sedimentation over their lifespans. Because of their self-cleaning nature, and because water flowing from Lake Barney should be relatively clean since the lake will act as a de-facto sediment basin, regular channel maintenance (dredging) may not be needed. But it's also

possible that runoff from adjacent agricultural lands will be silt-rich, and that the proposed ditches will have too low of slopes to effectively transport the sediment. Therefore, based on City experience with other ditches adjacent to agricultural lands we are assuming that dredging of six inches of material along the channel bottom (five ft width) is required every five years, to be performed by the City. The cost of dredging would be relatively low (~\$1,000 per dredging) if spoils can be placed adjacent to the ditch but could be considerably more expensive if they need to be piled, loaded, and trucked off-site. Assuming a \$20/cubic yard haul-off cost, this cost would be approximately \$12,000. There would also be costs for erosion control such as tracking pads and street sweeping at the access location and restoration of any damaged vegetation, which are estimated at \$2,000 per dredging.

As mentioned in **Section 5.2.2**, the outlet structure should be inspected for debris, animal nesting, and other potential blockages at least annually, with more frequent inspections recommended during wet years and/or when the outlet is actively flowing.

With these activities in mind, we think that an annual cost of \$3,500 for O&M is a reasonable, conservative estimate for the City to consider when weighing project costs.

6.3. Cost-Benefit Analysis Summary

While future benefits from an outlet project are difficult to predict, we think that these analyses highlight the range of possible economic benefits from project alternatives which can be compared to estimated project costs. To help the City consider these costs and benefits and select a path forward, a summary of the cost-benefit analysis is shown in **Table 17** with further discussion in **Section 7**.

Table 17. Cost-benefits analysis summary.

Benefits (City of Fitchburg lands only)			
	Alternative 1 (942 ft)	Alternative 2 (944 ft)	Alternative 3 (945 ft)
<p>Maximum annual benefit</p> <p>The maximum potential losses avoided in a single year due to lost agricultural rental income (low number) up to lost crops (high number)</p>	\$8,000 – \$28,800	\$3,600 – \$12,900	\$2,000 – \$7,200
<p>Potential long-term benefit</p> <p>The long-term potential losses avoided including private property devaluation</p>	\$180,000	\$100,500	\$63,500

Costs			
	Alternative 1 (942 ft)	Alternative 2 (944 ft)	Alternative 3 (945 ft)
<p>Estimated project cost</p> <p>Includes design, permitting, and construction</p>	\$975,000	\$660,000	\$535,000
<p>Potential additional wetland mitigation costs</p> <p>Will depend on results of wetland delineation, impacts of selected route, and market wetland credit prices</p>	\$60,000 – \$780,000	\$22,000 – \$620,000	\$20,000 – \$550,000
<p>Easement required</p> <p>Includes DOC and Alpine Dairy properties</p>	8.6 acres	6.9 acres	6.1 acres
<p>Annual O&M</p> <p>Includes mowing ditch banks and bottom twice a year with a tractor and arm mower, annual structure inspection and clean-out, and ditch dredging every 5 years*</p>	\$3,500	\$3,500	\$3,500

* Assumes 1/2 foot of sediment buildup in the ditch every five years due to adjacent agriculture land use and very shallow ditch slopes.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

During this study we have reviewed existing data, created new field and analysis data, modified and created groundwater and surface water models, created and tested alternative solutions, and estimated performance, benefits, and costs of various solutions. Of equal importance, we have had numerous conversations with the City, the Village of Oregon, WDNR and Dane County regulators, and numerous landowners and other stakeholders to identify existing issues and the likely feasibility of various options. Based on this work, we present the following conclusions:

1. Lake Barney has fluctuated over the last century, but recent water levels are unprecedented and will likely persist for many years without an outlet. We estimate it could take 5 – 10 years to drop down to 942 ft under normal climate conditions, or longer if recent above-normal precipitation and groundwater levels continue.
2. High Lake Barney levels are a function of both surface water runoff and the groundwater system. The very wet conditions of the last four years have raised shallow groundwater across Dane County, and the high water table observed adjacent to the lake is currently limiting groundwater drainage from the lake. This condition, combined with increased surface water inflows during recent years including several large rainfall events, has led to extended high levels in the lake. Until groundwater is considerably lower so that more runoff infiltrates in the upper watershed and water drains more effectively directly from the lake, Lake Barney will continue to be susceptible to surface water events “resetting” the lake back to its recent high levels.
3. If the lake was artificially lowered by an outlet during high groundwater conditions like those seen currently, the rate of groundwater release into the lowered lake would be relatively slow (2-3 cfs) and drawdown of surrounding groundwater could take several years. But since groundwater also rises slowly, we believe that a lake that is artificially lowered could prevent groundwater from rising adjacent to the lake and causing damage to agricultural lands and other private property. This lowering and prevention of high groundwater within “drawdown footprints” for our project alternatives forms the basis of our benefit analyses.
4. Under natural (no outlet) conditions, there is a quantifiable benefit to lower lake levels in terms of downstream flood flows during large (100-yr and greater) design storm events. There seems to be a tipping point between a starting lake elevation of 944 ft and 945 ft where the volume of downstream runoff starts to dramatically increase during these larger storms, and a similar tipping point for downstream peak flow rate increases that occurs when the lake is 945 ft or higher.
5. Based on the above analysis, historical lake level review, and discussions with stakeholders, we choose to analyze three alternatives. Each alternative consists of an outlet control structure and a 2-stage ditch connecting Lake Barney to the proposed culvert going under

Cusick Parkway. The alternatives differed mainly in their Lake Barney overflow elevation: 942 ft (Alternative 1), 944 ft (Alternative 2), and 945 ft (Alternative 3).

6. For any alternative, the outlet control structure can be configured such that the peak flow rates acceptable to the Village of Oregon can be met for storms up to the 100-yr design storm. For larger (>100-yr) storms, Alternative 1 demonstrates a clearer flood control benefit than the other alternatives.
7. Artificially lowering the lake with an outlet would also lower the surrounding groundwater during wet periods, such as the present. The extent of the area where groundwater would be lowered by 1 ft or more is predicted by the groundwater model to range from about 1000 acres for a lake outlet at 945 ft to about 3000 acres for a lake outlet at 942 ft.
8. Estimated time to drain the lake to the target elevation with a constructed outlet ranges from 49 days for an elevation of 945 ft to 87 days for an elevation of 942 ft (compared to 5-10 years with no outlet).
9. Of the three proposed solutions there is a considerable amount more earthwork associated with the lowest overflow elevation (Alternative 1 – 942 ft) versus the other options. There is very little (~ 2 ft) total elevation drop between a Lake Barney overflow at 942 ft and the Cusick Parkway culvert (~940 ft), and the ditch for Alternative 1 needs to be dug much deeper than the other alternatives in order to cut through the higher ground between the lake and the downstream end. Since the earthwork costs are estimated to be the largest portion of the construction cost for any alternative, this leads to Alternative 1 being a much more expensive project.
10. The costs for all alternatives were considerably higher than the calculated benefits to the City. But we recognize that the City may place a higher priority on the “Other Considerations” (**Section 6.1.3**) than the Cost-Benefit Analysis does, or that the City may find downstream municipal partners who are willing to consider downstream benefits and provide project support. It’s possible that downstream landowners (not just municipalities) might also be able to provide support including easements, labor, or financial contributions. It seems to be in their interest to keep their agricultural lands workable or to make the property suitable for future development by having a de facto greenway and stormwater conveyance feature installed.
11. The short-term and long-term potential benefits and flood protection benefits are not surprisingly greatest with the lake kept to a lower overflow (Alternative 1), but this alternative is also much more expensive than the other options and may be difficult to permit as it will be likely meet resistance from permitting agencies for limiting natural wetland and lake fluctuations.
12. Alternative 2 has more modest economic benefits but is projected to have 35% lower design and construction costs than Alternative 1. This alternative is also projected to keep the 100-yr design storm lake level to 947.6 ft, which would be a full foot lower than the nearest structures (Thayer outbuildings at 948.8 ft). Alternative 2 would also allow for a wider range

of natural lake level and wetland fluctuations, from the historical low estimated at 941.3 ft up to 944 ft, with short periods above 944 ft following runoff events. Alternative 2 appears to strike the best balance between project cost, benefit, effectiveness, and ability to be approved by permitting agencies.

13. Alternative 3 is estimated to have 45% lower design and construction costs than Alternative 1 but provides the fewest economic and flood prevention benefits. It also does not provide the minimum recommended 1 foot of freeboard for the Thayer outbuildings for the projected 100-yr design storm. Besides cost, the advantages to Alternative 3 include anticipated easier permitting (likely above the ordinary high water mark of Lake Barney and provides the most natural fluctuation), slightly steeper ditch slope, and likely less wetland disturbance and mitigation.
14. The amount of wetland disturbance and required mitigation is unknown but may add significant project costs. We have estimated the potential range of costs based on our assumption that the area near Lake Barney is likely to be delineated wetland, while the area along the potential ditch route may or may not be delineated wetland depending on near-term conditions, precipitation, and how soon the land is returned to active agriculture.

7.2. Recommendations

Based on our findings, we recommend the following:

- The City review this report and its conclusions, particularly the cost-benefit analysis including likely project costs, calculated benefits, and other non-quantified project benefits to the City and landowners.
- Stay informed on the status of the downstream work proposed by the Village of Oregon. Though not discussed in this report, the Village's proposed drainage upgrades are essential for a Lake Barney outlet project to proceed. Without those upgrades, an outlet would cause significant downstream problems on property and infrastructure in the Village. Their upgrades have been delayed pending approval to increase drainage capacity through Lerner Park, which is not guaranteed to ultimately be approved.
- Once it appears the downstream improvements will proceed, the City should make a go/no-go decision on the project, and if the decision is to proceed, begin contacts and negotiations with downstream landowners (DOC and Alpine Dairy) for project partnership, financial contribution, easements and wetland delineation access.
- Then, the City should commence final design including a formal wetland delineation. We recommend **Alternative 2** should form the basis of this final design, although we recognize that final details of the outlet structure and ditch may change due to project goals and/or permitting constraints. We have attached a conceptual-level plan set (**Appendix H**) which

shows Alternative 2's route, footprint, ditch slope, outlet configuration, and downstream connection.

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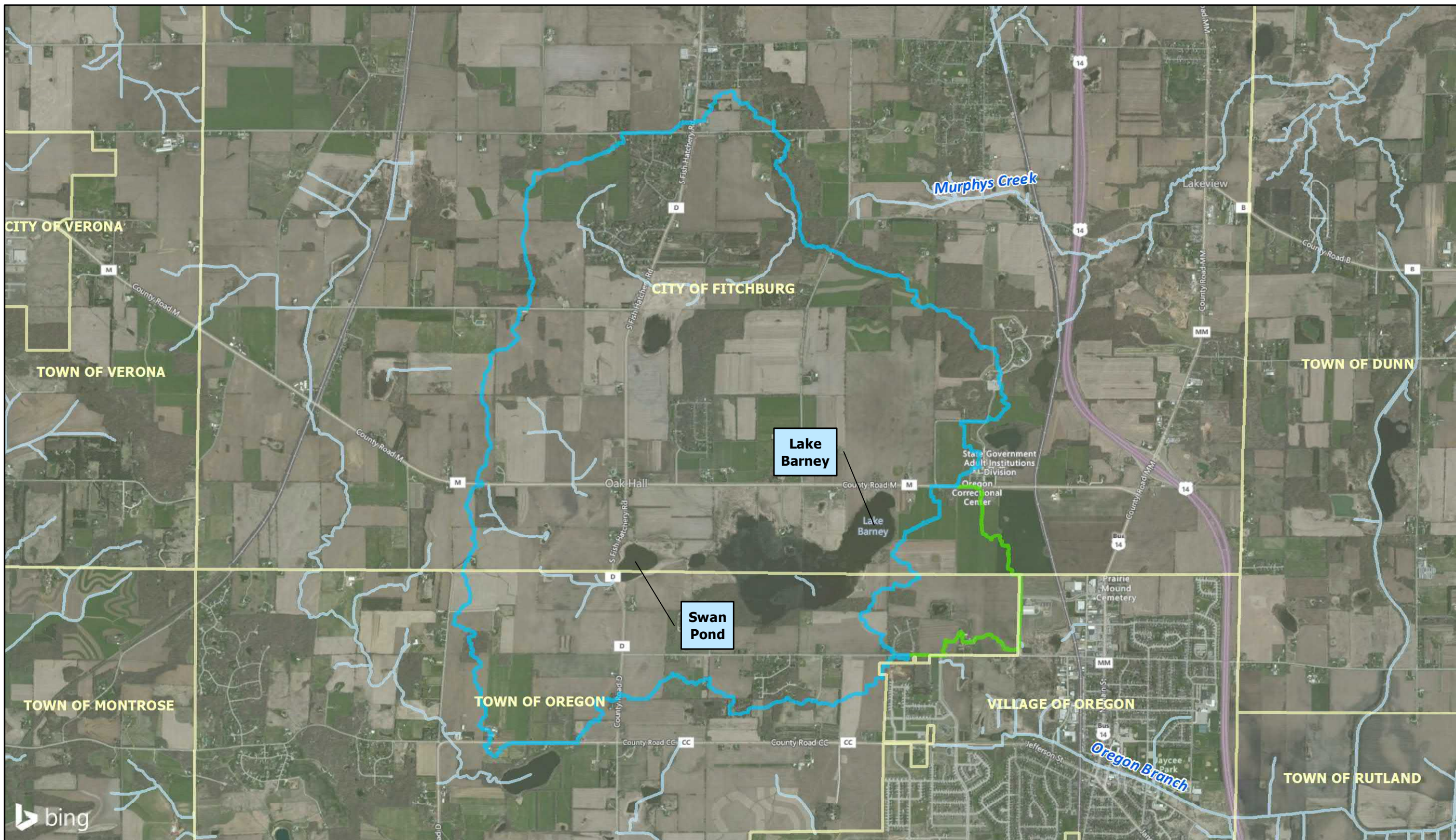
APPENDIX A. MAP FIGURES

Figure A1 - Project area.

Figure A2 - Field data collection.

Figure A3 - PCSWMM model schematic.

Figure A4 - Project alternatives.



- Municipal Boundary
- Lake Barney Watershed
- Downstream Watershed to Cucisk Pkwy
- Dane Co. Hydrography

Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community © 2020 Microsoft Corporation © 2020 Maxar © CNES (2020)

Parcel data from WI State Cartographer's Office.
Main Map Projection: Dane County CS (ft) - NAD 1983 (HARN).
Locator map not to scale.

DRAWN BY: NGH
CHECKED BY: SJG

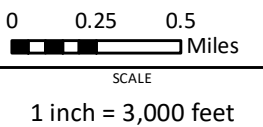
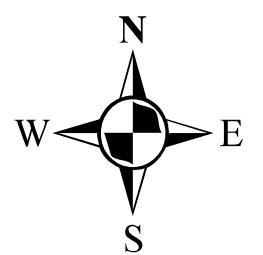
MARS-EOR
water-ecology-community

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119 South Main Street | Cottage Grove, WI 53527
(608) 839-4422 | www.eorinc.com

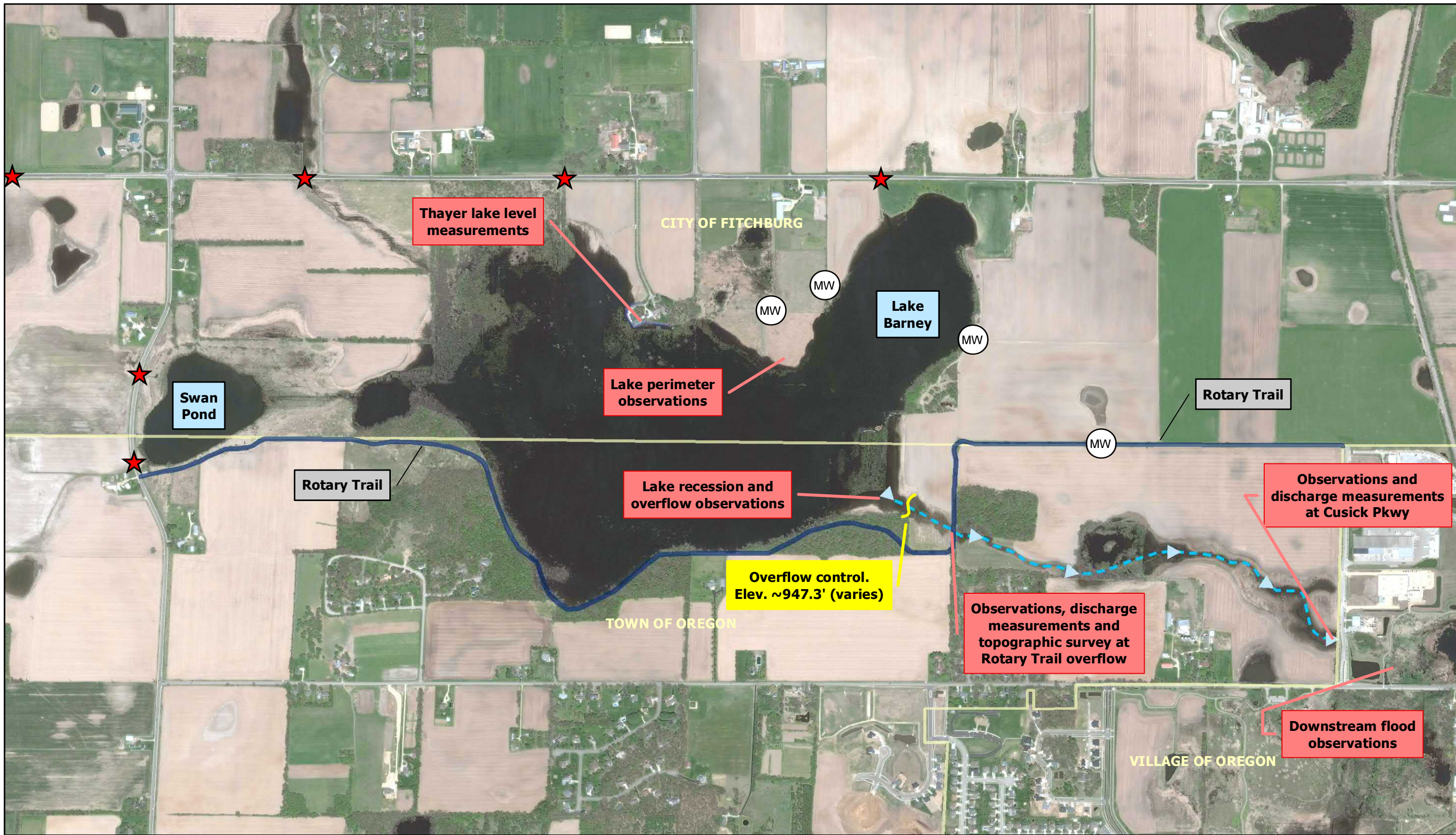
PROJECT AREA
Lake Barney Stormwater & Flood Mitigation Study
City of Fitchburg
Dane County, WI





Client: City of Fitchburg



PROJECT NO. 01052-0004
DATE 11/15/2020

FIGURE NO.
A1



-  Municipal Boundary
-  Monitoring well and soil boring
-  Culvert surveyed by City of Fitchburg
-  Overflow route

Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Image data from USFWS, May 2020.

Main Map Projection: Dane County CS (ft) - NAD 1983 (HARN).

Locator map not to scale.

DRAWN BY
NGH

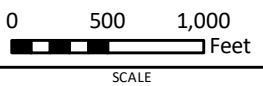
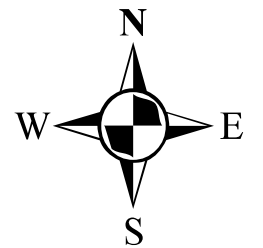
CHECKED BY
SJG



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FIELD DATA COLLECTION
Lake Barney Stormwater & Flood Mitigation Study
City of Fitchburg
Dane County, WI

Client: City of Fitchburg



SCALE
1 inch = 1,000 feet

PROJECT NO.
01052-0004

DATE
11/21/2020

FIGURE NO.
A2

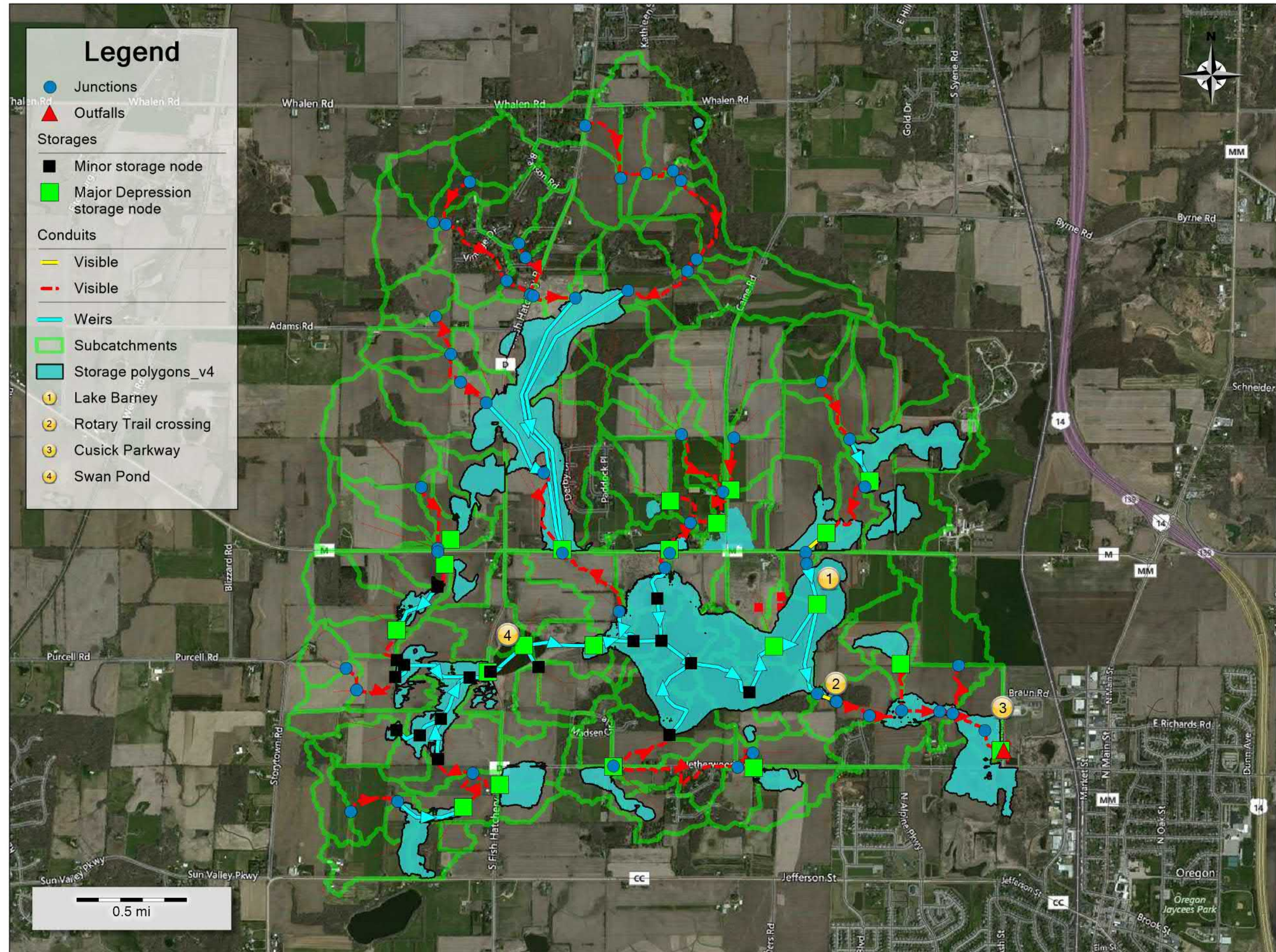
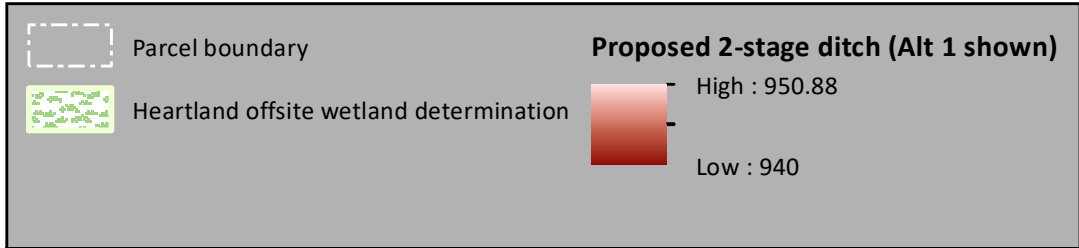
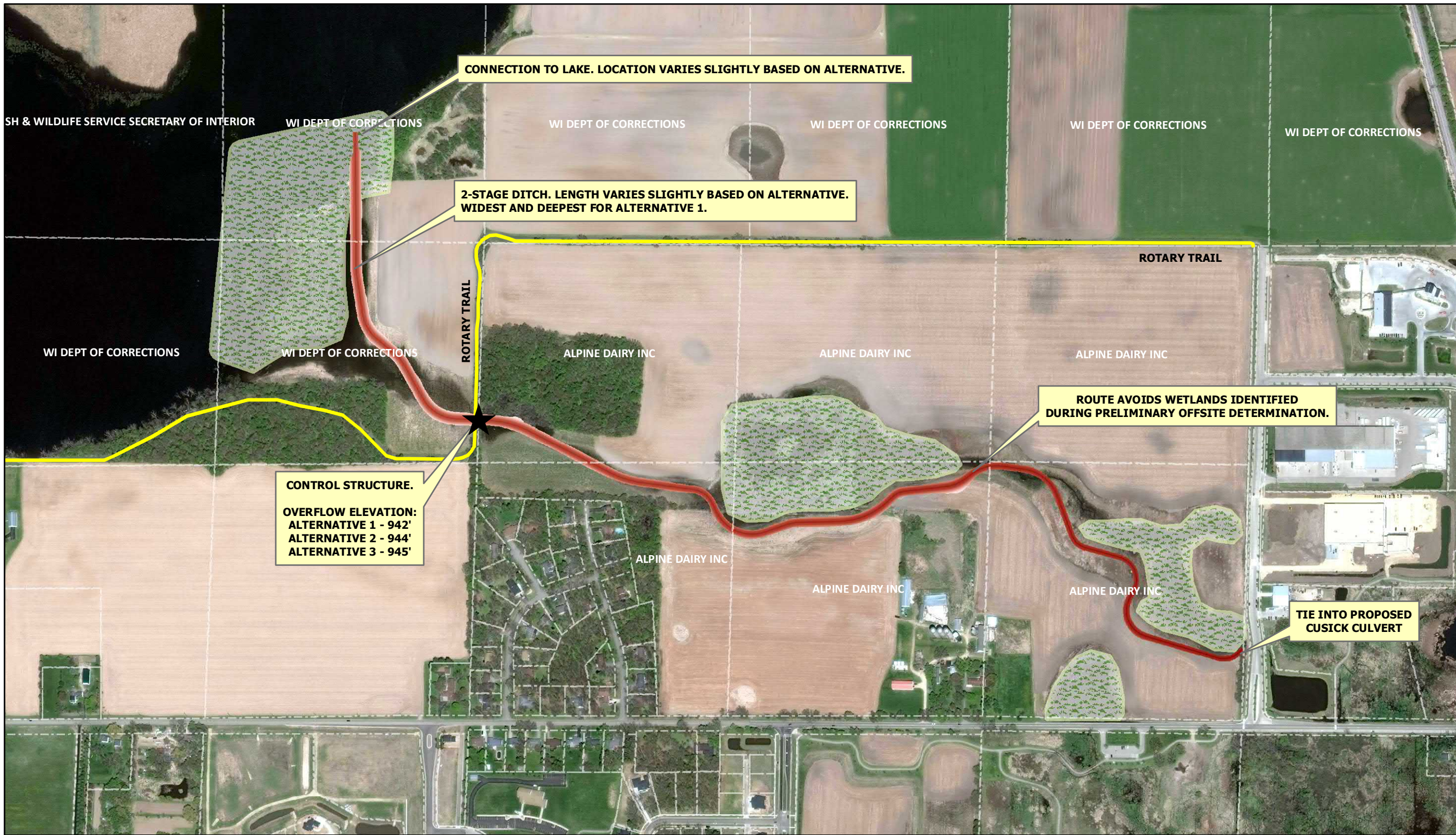


Figure A3. PCSWMM Model Schematic.



DRAWN BY
NGH

CHECKED BY
SJG



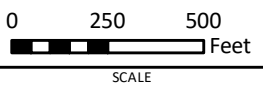
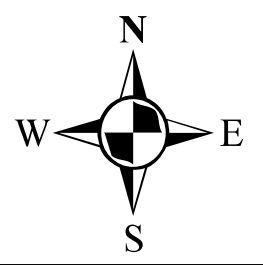
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PROJECT ALTERNATIVES

Lake Barney Stormwater & Flood Mitigation Study
City of Fitchburg
Dane County, WI

Client: City of Fitchburg



SCALE
1 inch = 500 feet

PROJECT NO.
01052-0004

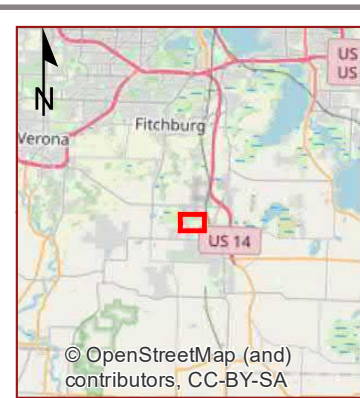
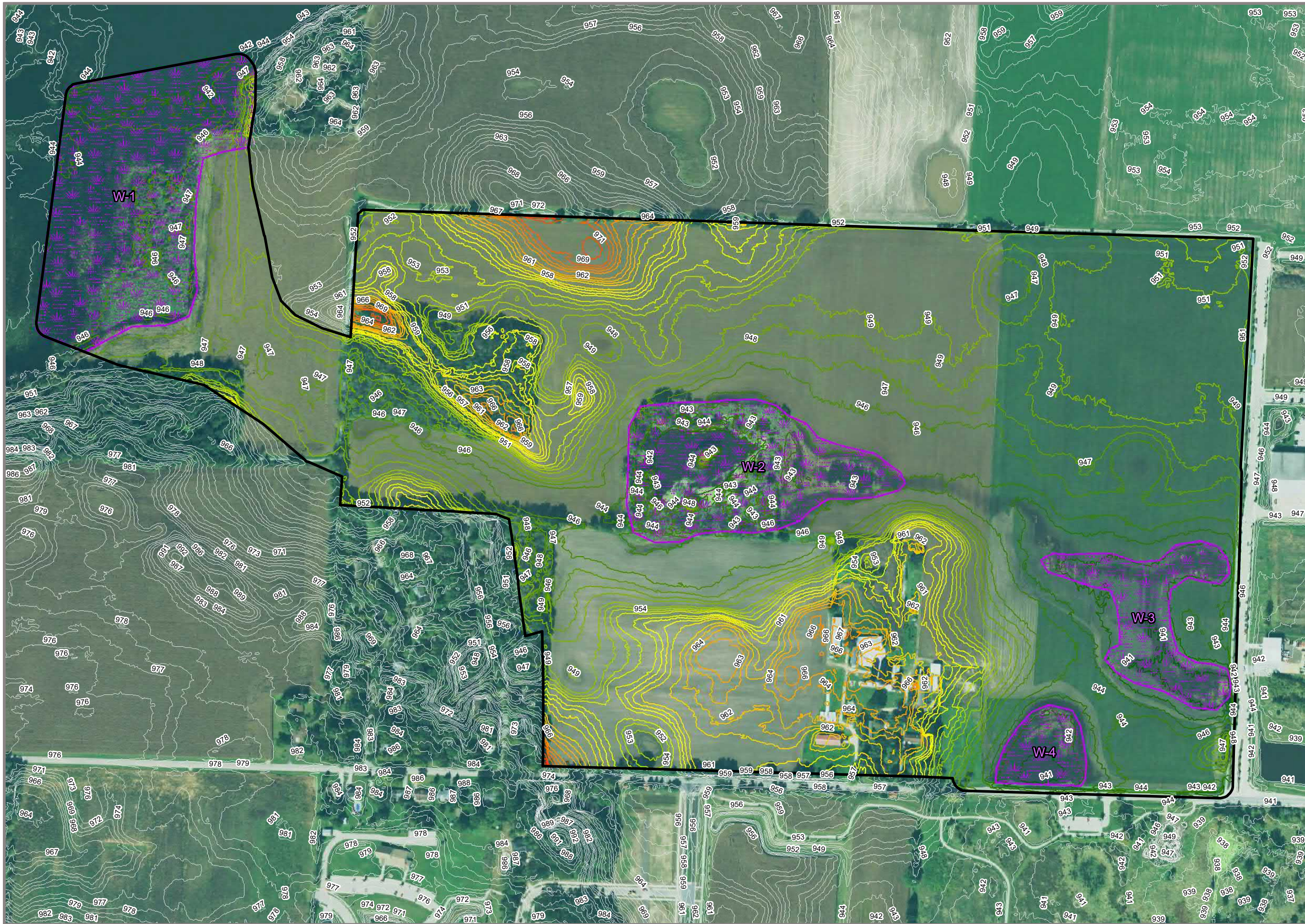
DATE
12/5/2020

FIGURE NO.
A4

Parcel data from WI State Cartographer's Office.
Aerial image from US FWS (May 2020).

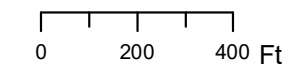
Main Map Projection: Dane County CS (ft) - NAD 1983 (HARN).
Locator map not to scale.

**APPENDIX B. PRELIMINARY OFF-SITE WETLAND DETERMINATION (HEARTLAND
ECOLOGICAL GROUP, INC.)**



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- Study Area (226.44 ac)
- Identified Wetlands (38.87 ac)



Heartland
 ECOLOGICAL GROUP INC

Offsite Wetland Identification
 Lake Barney
 #20200313
 T6N, R9E, S34 & 35
 T5N, R9E, S02 & 03
 C Fitchburg / T Oregon, Dane Co

2018 NAIP
 Data: USDA 5/27/2020

Wetland Determination from Aerial Imagery - Recording Form*

Project Name: Lake Barney
Investigator: Scott Fuchs

Date: 5/26/2020 County: Dane
Legal Description (T, R, S): T6N R9E Sec. 34 & 35

Use the decision matrix below to create Table A2

Hydric Soils Present? ¹	Identified on NWI or WWI? ²	Percent with Wet Signatures from TABLE A1	Field Verification Required? ³	Wetland?
Yes	Yes	>50%	No	Yes
Yes	Yes	30-50%	No	Yes
Yes	Yes	<30%	Yes	Yes, if other hydrology indicators are present
Yes	No	>50%	No	Yes
Yes	No	30-50%	Yes	Yes, if other hydrology indicators are present
Yes	No	<30%	No	No
No	Yes	>50%	No	Yes
No	Yes	30-50%	No	Yes
No	Yes	<30%	No	No
No	No	>50%	Yes	Yes, if other hydrology indicators are present
No	No	30-50%	Yes	Yes, if other hydrology indicators are present
No	No	<30%	No	No

¹The presence of hydric soils can be determined from the "Hydric Rating by Map Unit Feature" under "Land Classifications" from the Web Soil Survey. "Not Hydric" is the only category considered to not have hydric soils. Field sampling for the presence/absence of hydric soil indicators can be used in lieu of the hydric rating if appropriately documented by providing completed field data sheets.

² At minimum, the most updated NWI data available for the area must be reviewed for this step. Any and all other local or regional wetland maps that are publically available should be reviewed.

³ Area should be reviewed in the field for the presence/absence of wetland hydrology indicators per the applicable 87 Manual Regional Supplement, including the D2

TABLE A2

Area	Hydric Soils Present? ¹	Identified on NWI or WWI?	Percent with Wet Signatures from TABLE A1	Other Hydrology Indicators Present? ¹	Wetland?
1	Yes	Yes	64%		Yes
2	Yes	No	36%		No
3	Yes	No	27%		No
4	Yes	No	27%		No
5	No	No	18%		No
6	Yes	No	36%		No
7	Yes	No	36%		No
8	Yes	No	18%		No
9	Yes	Yes	73%		Yes
10	Yes	No	27%		No
11	Yes	No	55%		Yes
12	Yes	No	55%		Yes

¹ Answer "N/A" if field verification is not required and was not conducted.

* Source: [http://www.bwsr.state.mn.us/wetlands/delineation/Guidance for Offsite Hydrology and Wetland Determinations.pdf](http://www.bwsr.state.mn.us/wetlands/delineation/Guidance%20for%20Offsite%20Hydrology%20and%20Wetland%20Determinations.pdf)



June Aerial Imagery

Off-Site Aerial Imagery Analysis

Date	Monthly Rainfall in Inches ¹						Weighted Sum	Relative Wetness
	March	Weighted Precip	April	Weighted Precip	May	Weighted Precip		
6/23/05	1.73	2	1.92	2	3.71	6	10	Normal
30% chance less than**	1.27		3.05		2.99			
30 Year Average**	2.31		4.18		4.34			
30% chance more than**	2.82		4.92		5.17			

UW Arboretum Weather Station

30-Year Precipitation Data (1990-2018) from NOAA Website

https://efotg.sc.egov.usda.gov/efotg_locator.aspx

PRELIMINARY

July Aerial Imagery

Off-Site Aerial Imagery Analysis

Date	Monthly Rainfall in Inches ¹						Weighted Sum	Relative Wetness
	April	Weighted Precip	May	Weighted Precip	June	Weighted Precip		
Jul-93	6.15	3	4.31	4	7.49	9	16	Wet
Jul-94	1.72	1	2.97	2	5.80	6	9	Dry
Jul-97	1.81	1	3.85	4	5.93	6	11	Normal
Jul-98	5.25	3	4.78	4	8.12	9	16	Wet
Jul-99	7.85	3	4.29	4	4.67	6	13	Normal
Jul-00	3.75	2	7.16	6	9.61	9	17	Wet
Jul-01	3.35	2	4.63	4	5.86	6	12	Normal
Jul-02	4.27	2	2.91	2	5.18	6	10	Normal
Jul-03	2.77	1	6.97	6	3.61	6	13	Normal
Jul-04	1.91	1	11.13	6	4.26	6	13	Normal
Jul-06	6.34	3	5.04	4	2.16	3	10	Normal
Jul-08	7.64	3	2.54	2	9.56	9	14	Normal
Jul-10	4.52	2	4.19	4	8.64	9	15	Wet
Jul-13	6.55	3	7.09	6	11.73	9	18	Wet
30% chance less than**	3.05		2.99		3.32			
30 Year Average**	4.18		4.34		5.61			
30% chance more than**	4.92		5.17		6.81			

UW Arboretum Weather Station

30-Year Precipitation Data (1990-2018) from NOAA Website

https://efotg.sc.egov.usda.gov/efotg_locator.aspx

PRELIMINARY

September Aerial Imagery

Off-Site Aerial Imagery Analysis

Date	Monthly Rainfall in Inches ¹						Weighted Sum	Relative Wetness
	June	Weighted Precip	July	Weighted Precip	August	Weighted Precip		
Sep-95	1.43	1	4.41	4	3.40	6	11	Normal
Sep-17	7.92	3	10.49	6	2.70	3	12	Normal
30% chance less than**	3.32		3.18		2.79			
30 Year Average**	5.61		4.63		4.30			
30% chance more than**	6.81		5.51		5.17			

UW Arboretum Weather Station

30-Year Precipitation Data (1990-2018) from NOAA Website

https://efotg.sc.egov.usda.gov/efotg_locator.aspx

PRELIMINARY

October Aerial Imagery

Off-Site Aerial Imagery Analysis

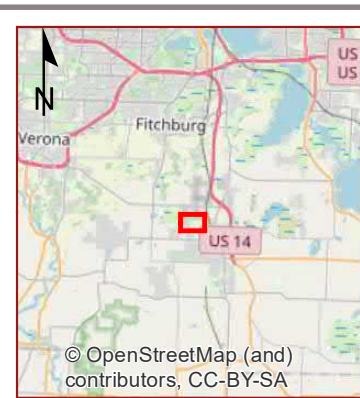
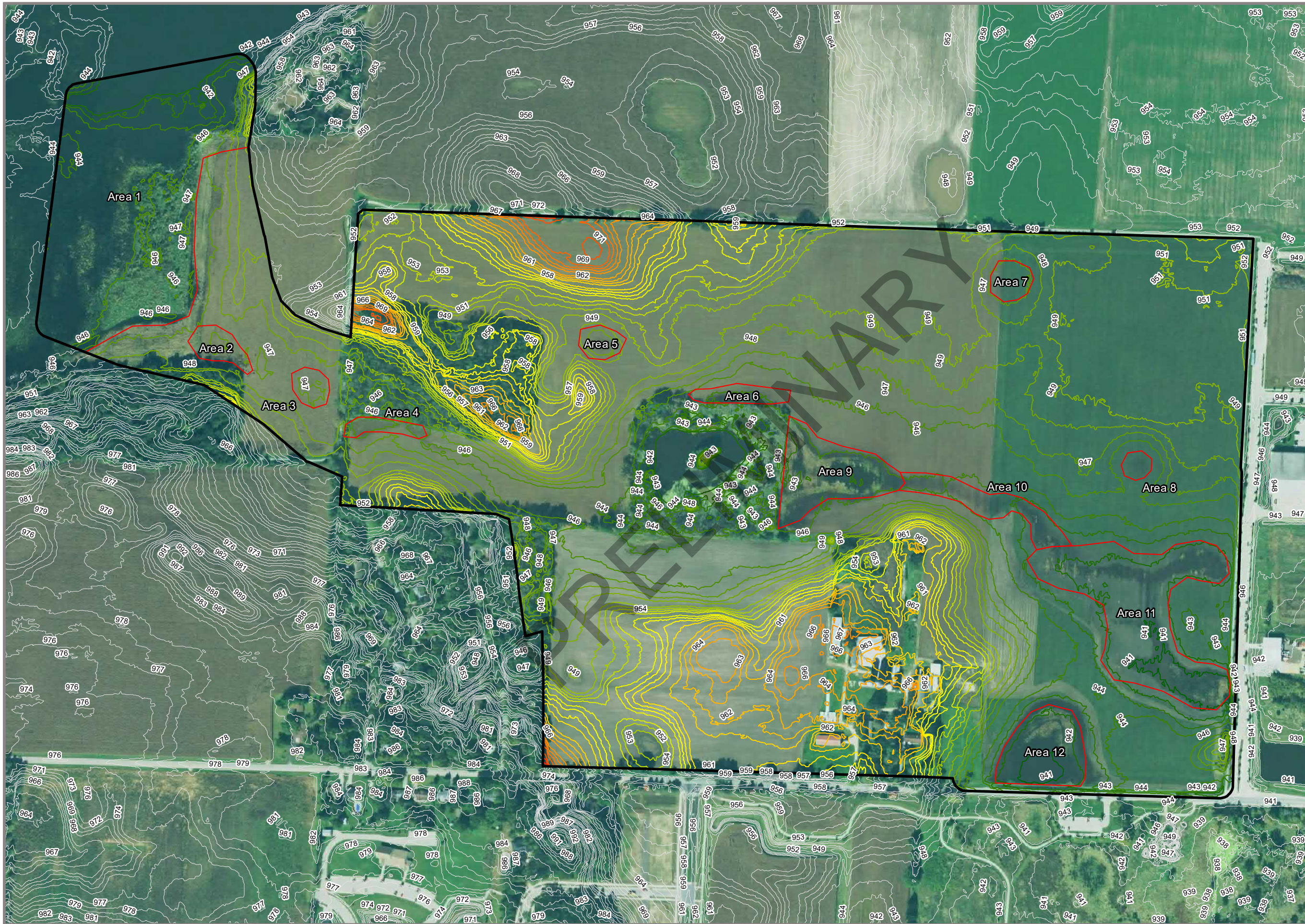
Date	Monthly Rainfall in Inches ¹						Weighted Sum	Relative Wetness
	July	Weighted Precip	August	Weighted Precip	September	Weighted Precip		
Oct-96	4.38	2	1.49	2	1.43	3	7	Dry
Oct-15	4.68	2	4.30	4	6.11	9	15	Wet
Oct-18	3.73	2	11.38	6	7.76	9	17	Wet
30% chance less than**	3.18		2.79		2.28			
30 Year Average**	4.63		4.30		3.55			
30% chance more than**	5.51		5.17		4.28			

UW Arboretum Weather Station

30-Year Precipitation Data (1990-2018) from NOAA Website

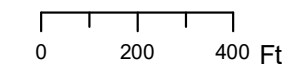
<http://agacis.rcc-acis.org/>

PRELIMINARY



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- Study Area (226.44 ac)
- Offsite Analysis Areas



Heartland
 ECOLOGICAL GROUP INC

**Offsite Analysis
 Reference Areas**

Lake Barney
 #20200313
 T6N, R9E, S34 & 35
 T5N, R9E, S02 & 03
 C Fitchburg / T Oregon, Dane Co

2018 NAIP
 Data: USDA 5/26/2020

1993 July Wet



1994 July Dry



1995 September Normal



1996 October Dry



1997 July Normal



1998 July Wet



1999 July Normal



2000 July Wet



2001 July Normal

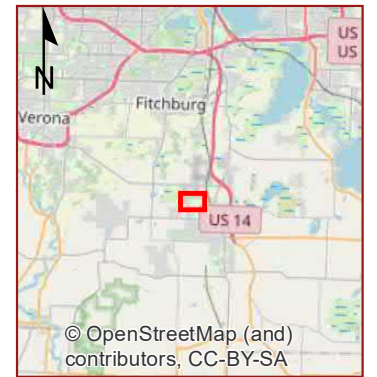


2002 July Normal



2003 July Normal





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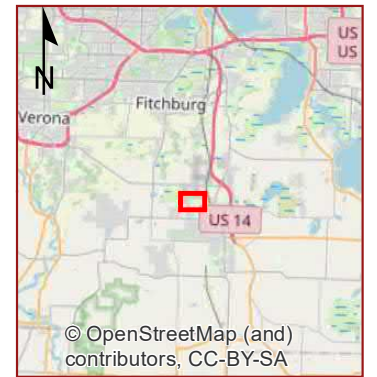
Study Area (226.44 ac)

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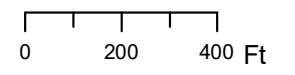
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ECOLOGICAL GROUP INC

Appendix: 2004-07-28
NAIP Aerial Imagery
Lake Barney
#20200313
T6N, R9E, S34 & 35
T5N, R9E, S02 & 03
C Fitchburg / T Oregon, Dane Co

2004 NAIP
Data: USDA 5/26/2020

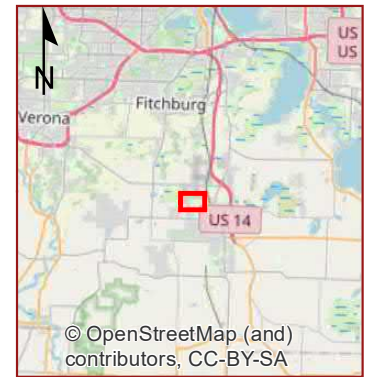


Study Area (226.44 ac)



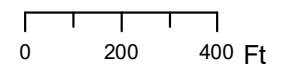
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Appendix: 2005-06-23
NAIP Aerial Imagery
Lake Barney
#20200313
T6N, R9E, S34 & 35
T5N, R9E, S02 & 03
C Fitchburg / T Oregon, Dane Co
2005 NAIP
Data: USDA 5/26/2020



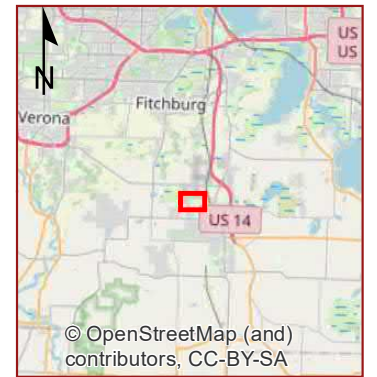
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Study Area (226.44 ac)



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Appendix: 2006-07-15
NAIP Aerial Imagery
Lake Barney
#20200313
T6N, R9E, S34 & 35
T5N, R9E, S02 & 03
C Fitchburg / T Oregon, Dane Co
2006 NAIP
Data: USDA 5/26/2020



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Study Area (226.44 ac)

0 200 400 Ft

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Appendix: 2008-07-09
NAIP Aerial Imagery
Lake Barney
#20200313
T6N, R9E, S34 & 35
T5N, R9E, S02 & 03
C Fitchburg / T Oregon, Dane Co

2008 NAIP
Data: USDA 5/26/2020



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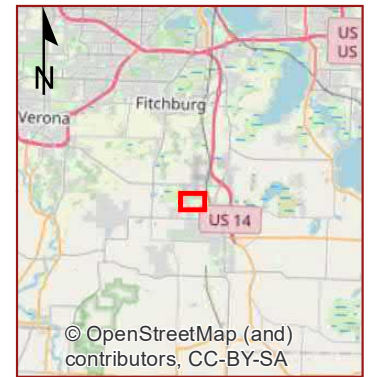
Study Area (226.44 ac)

0 200 400 Ft

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Appendix: 2010-07-02
NAIP Aerial Imagery
Lake Barney
#20200313
T6N, R9E, S34 & 35
T5N, R9E, S02 & 03
C Fitchburg / T Oregon, Dane Co

2010 NAIP
Data: USDA 5/26/2020



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Study Area (226.44 ac)

0 200 400 Ft

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Appendix: 2013-07-04
NAIP Aerial Imagery
Lake Barney
#20200313
T6N, R9E, S34 & 35
T5N, R9E, S02 & 03
C Fitchburg / T Oregon, Dane Co

2013 NAIP
Data: USDA 5/26/2020



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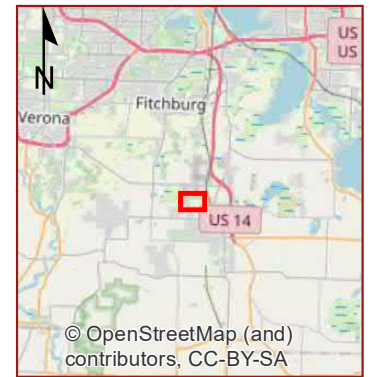
Study Area (226.44 ac)

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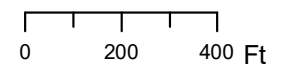
**Appendix: 2015-10-11
NAIP Aerial Imagery**
Lake Barney
#20200313
T6N, R9E, S34 & 35
T5N, R9E, S02 & 03
C Fitchburg / T Oregon, Dane Co

2015 NAIP
Data: USDA 5/26/2020



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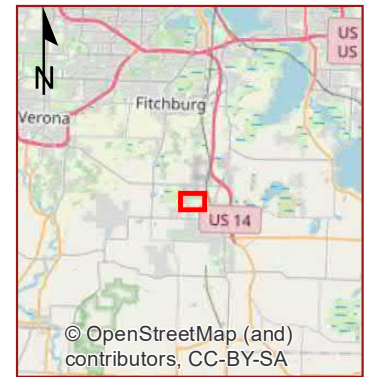
Study Area (226.44 ac)



Heartland
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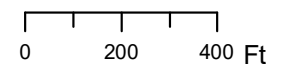
Appendix: 2017-09-22
NAIP Aerial Imagery
Lake Barney
#20200313
T6N, R9E, S34 & 35
T5N, R9E, S02 & 03
C Fitchburg / T Oregon, Dane Co

2017 NAIP
Data: USDA
5/26/2020



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Study Area (226.44 ac)



Heartland
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Appendix: 2018-10-04
NAIP Aerial Imagery
Lake Barney
#20200313
T6N, R9E, S34 & 35
T5N, R9E, S02 & 03
C Fitchburg / T Oregon, Dane Co

2018 NAIP
Data: USDA 5/26/2020

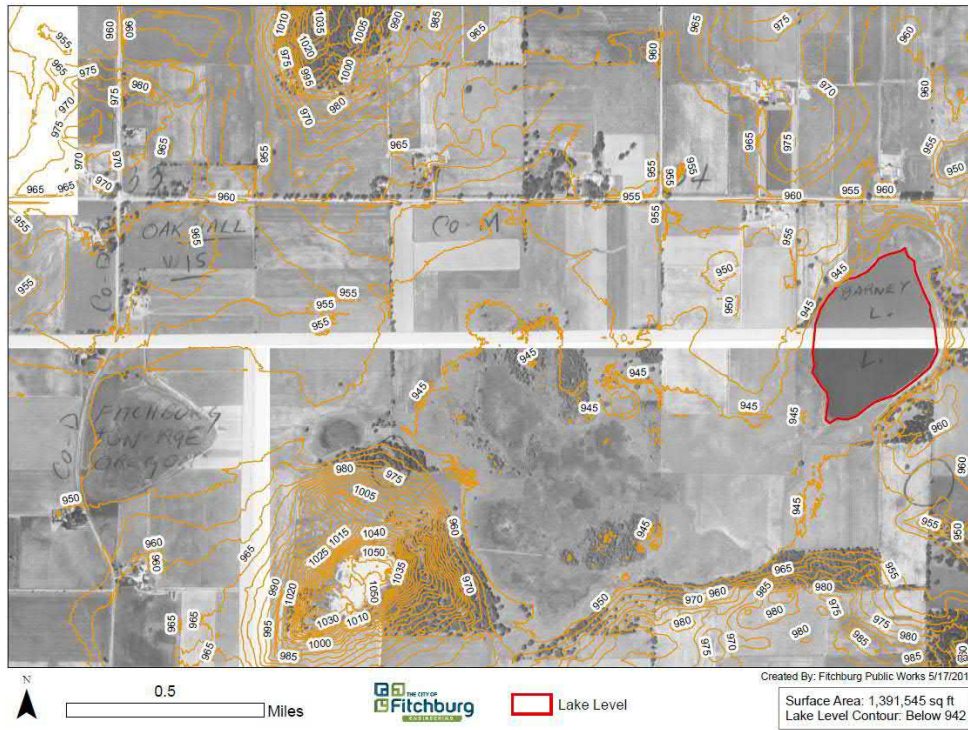
APPENDIX C. AERIAL IMAGERY

APPENDIX C – LAKE BARNEY AERIAL IMAGERY

Compiled available imagery shown below. Original source data is assumed to be USDA / NRCS except as noted. Lake stage estimate by comparing Dane County 2017 LiDAR contours to footprint of lake.



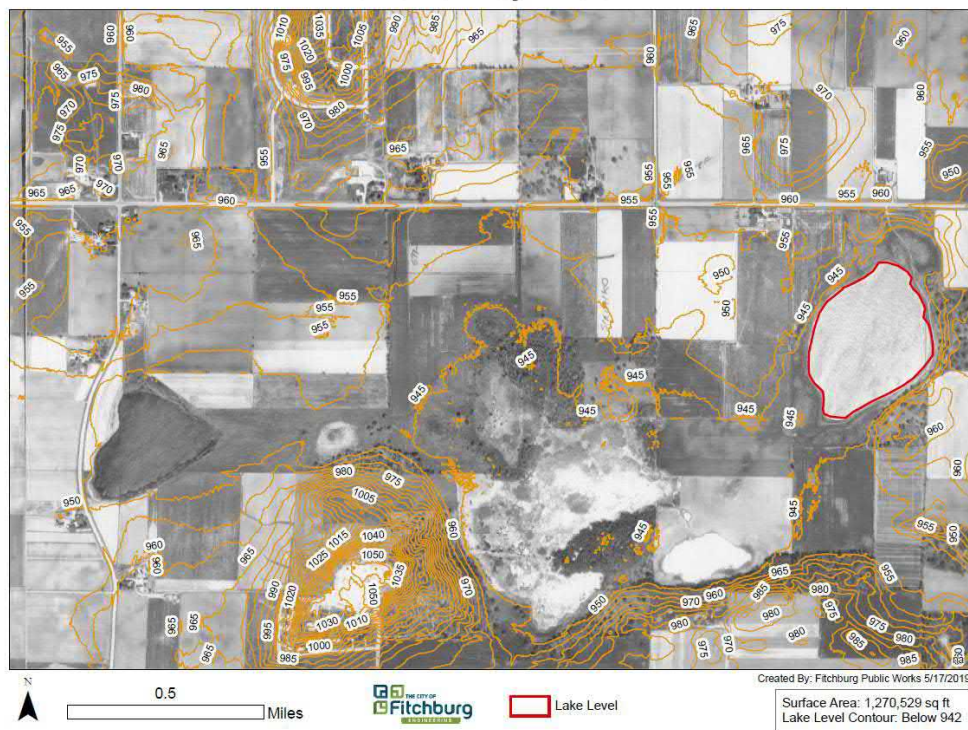
Lake Barney - 1955



1955 AERIAL IMAGE PROVIDED BY CITY OF FITCHBURG.

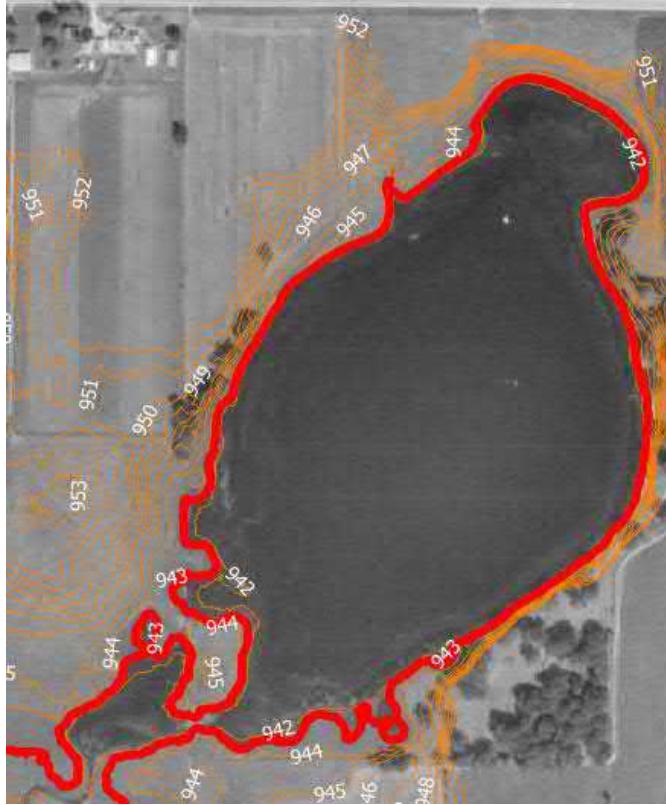
APPROXIMATE LAKE STAGE: 941.5 FT

Lake Barney - 1968



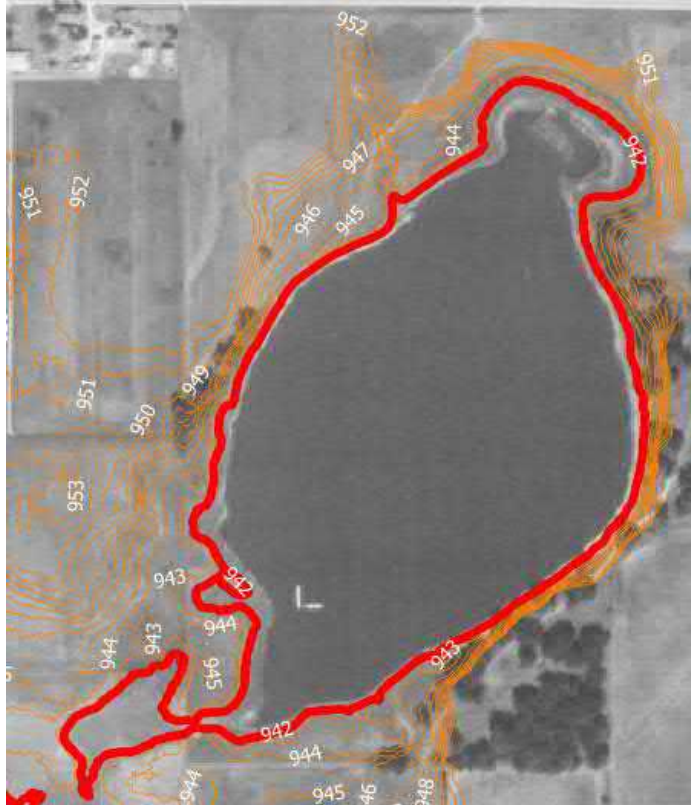
1968 AERIAL IMAGE PROVIDED BY CITY OF FITCHBURG.

APPROXIMATE LAKE STAGE: 941 FT



1974 AERIAL IMAGE
FROM DCI MAP.

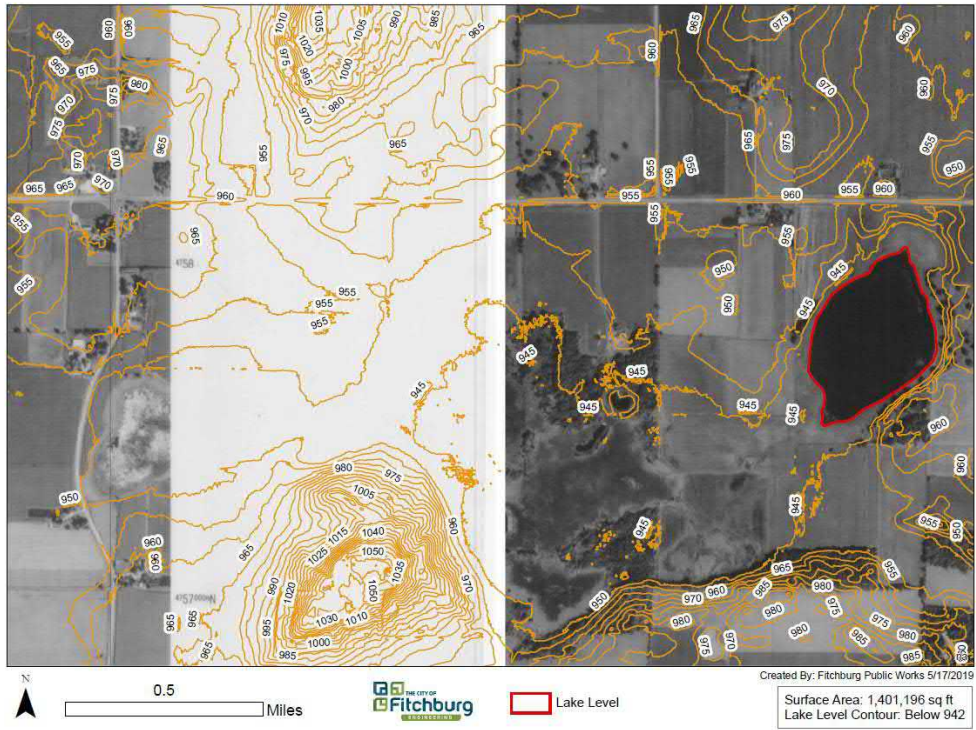
**APPROXIMATE LAKE
STAGE: 942.5 FT**



1976 AERIAL IMAGE
FROM DCI MAP.

**APPROXIMATE LAKE
STAGE: 941.7 FT**

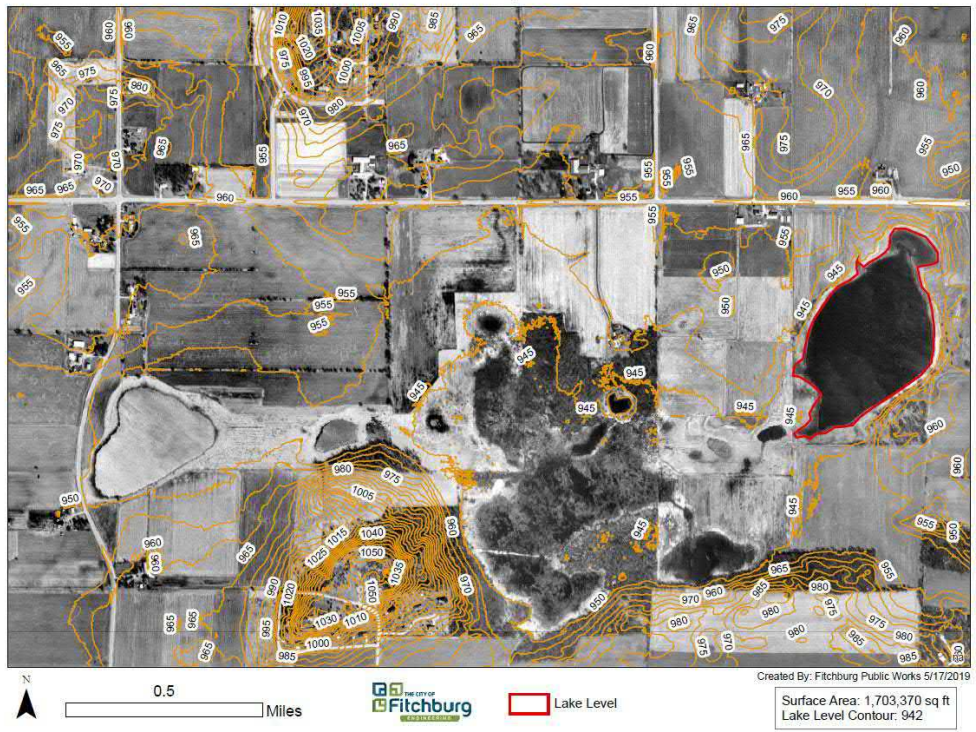
Lake Barney - 1987



1987 AERIAL IMAGE PROVIDED BY CITY OF FITCHBURG.

APPROXIMATE LAKE STAGE: 941.5 FT

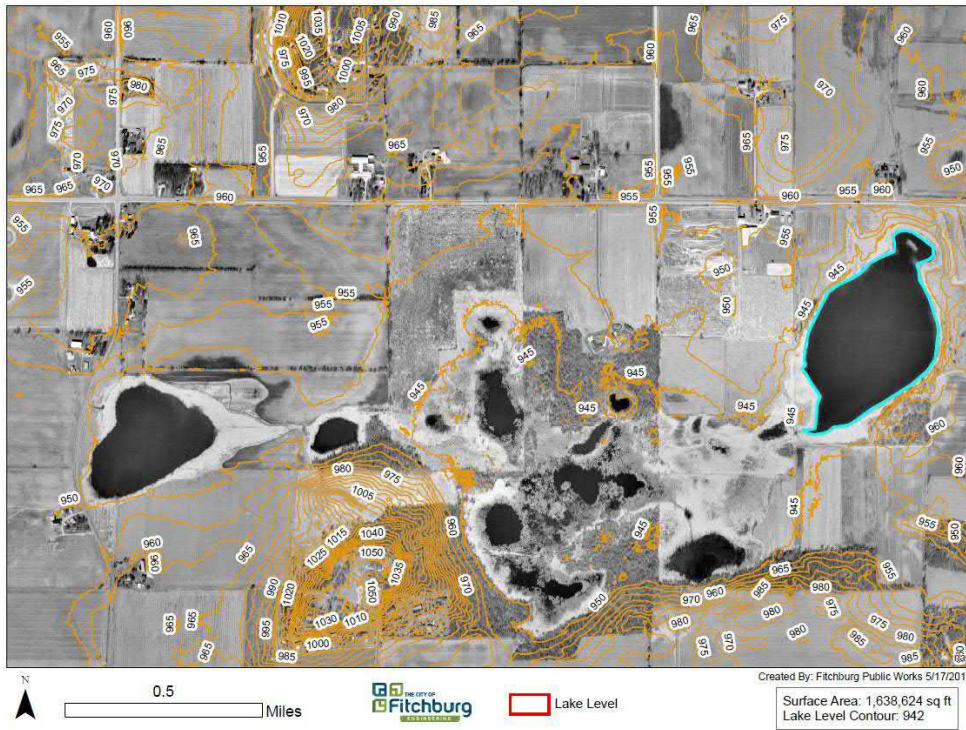
Lake Barney - 1995



1995 AERIAL IMAGE PROVIDED BY CITY OF FITCHBURG.

APPROXIMATE LAKE STAGE: 942 FT

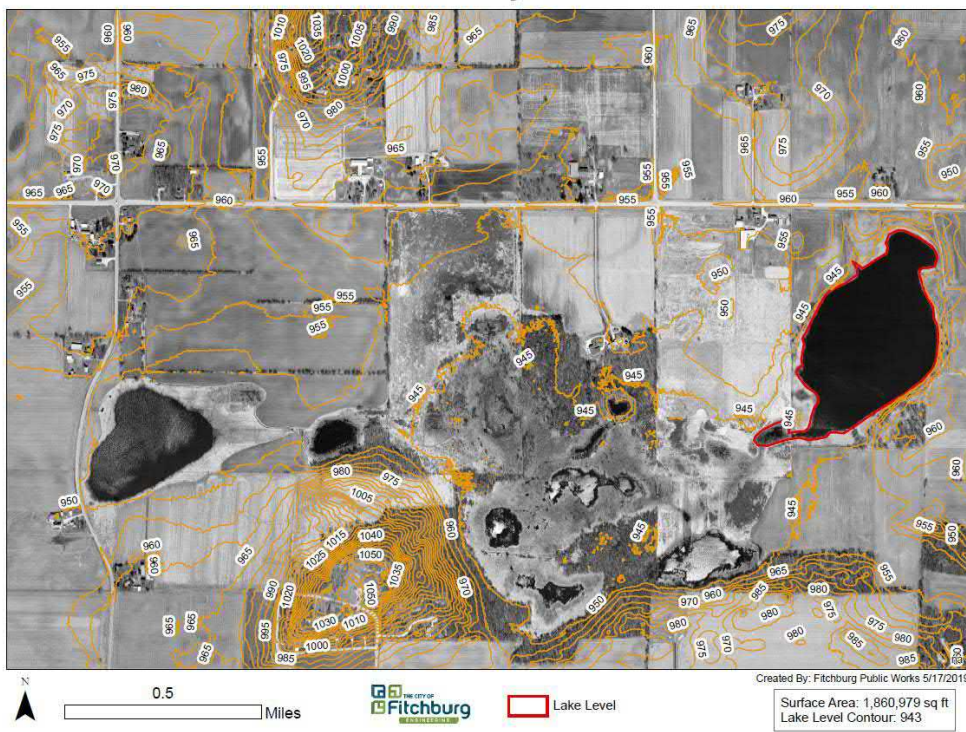
Lake Barney - 2000



2000 AERIAL IMAGE PROVIDED BY CITY OF FITCHBURG.

APPROXIMATE LAKE STAGE: 942 FT

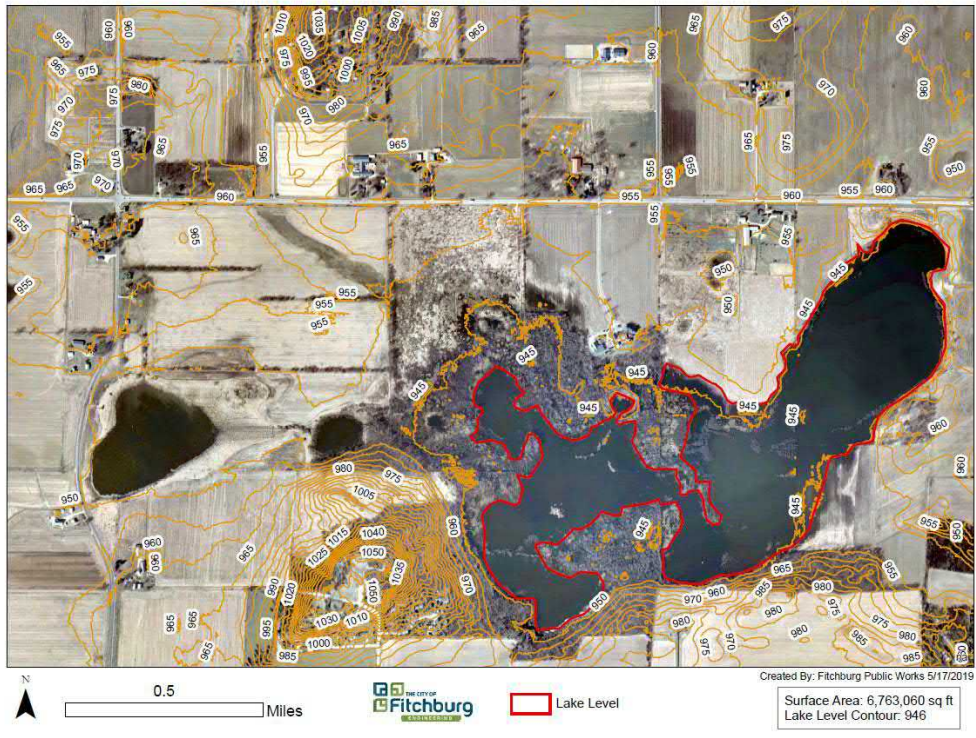
Lake Barney - 2005



2005 AERIAL IMAGE PROVIDED BY CITY OF FITCHBURG.

APPROXIMATE LAKE STAGE: 943 FT

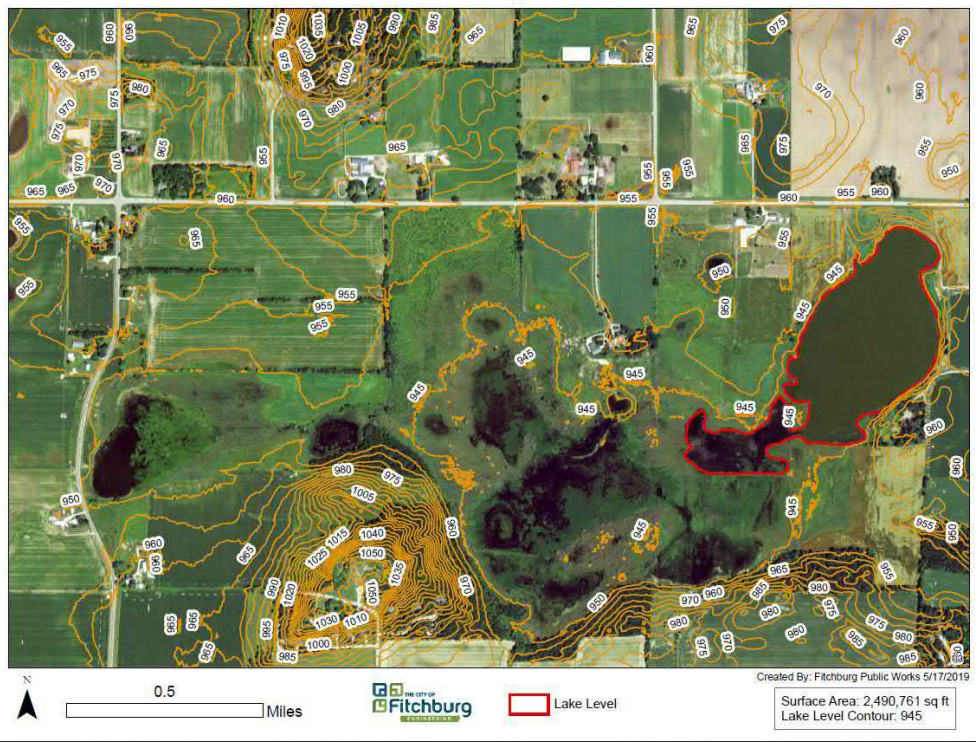
Lake Barney - 2010



2010 AERIAL IMAGE PROVIDED BY CITY OF FITCHBURG.

APPROXIMATE LAKE STAGE: 946 FT

Lake Barney - 2013



2013 AERIAL IMAGE PROVIDED BY CITY OF FITCHBURG.

APPROXIMATE LAKE STAGE: 944 FT



2014 AERIAL IMAGE
FROM DCI MAP.

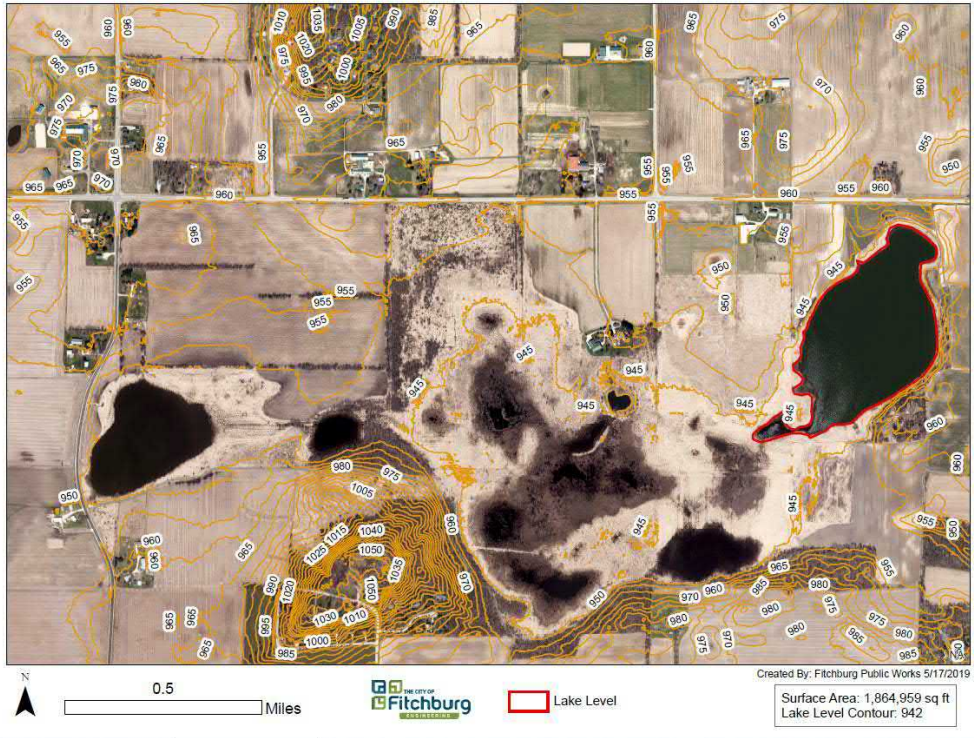
APPROXIMATE LAKE
STAGE: 943.5 FT



2015 AERIAL IMAGE
FROM DCI MAP.

APPROXIMATE LAKE
STAGE: 941.5 FT

Lake Barney - 2017



SPRING 2017 AERIAL
IMAGE PROVIDED BY
CITY OF FITCHBURG.

**APPROXIMATE LAKE
STAGE: 942 FT**



FALL 2017 AERIAL
IMAGE FROM USDA
NAIP.

**APPROXIMATE LAKE
STAGE: 943 FT**

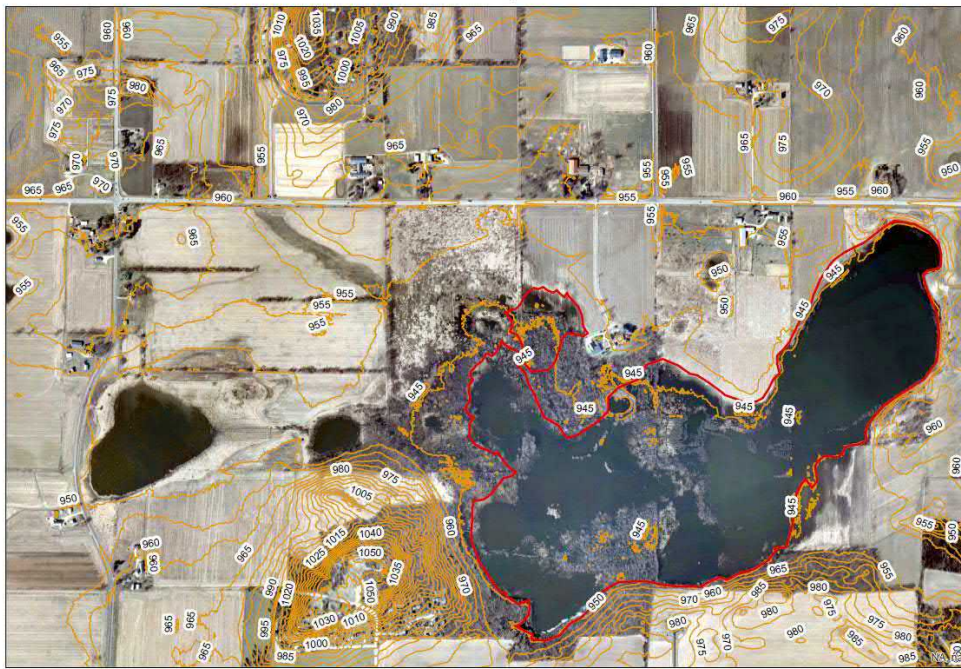


SUMMER 2018

AERIAL IMAGE FROM DCI MAP.

APPROXIMATE LAKE STAGE: 947 FT

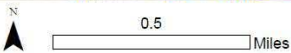
Lake Barney - 2018



FALL 2018

AERIAL IMAGE PROVIDED BY CITY OF FITCHBURG.

APPROXIMATE LAKE STAGE: 947 FT



 THE CITY OF Fitchburg

 Lake Level

Created By: Fitchburg Public Works 5/17/2019

Surface Area: 8,979,819 sq ft
Lake Level Contour: 947



2020 AERIAL IMAGE
FROM DCI MAP.

**APPROXIMATE LAKE
STAGE: 947-948 FT**

APPENDIX D. FIELD PHOTOGRAPHS

APPENDIX D – FIELD PHOTOGRAPHS

Winter images taken by Ryan Moe, summer-fall taken by Nick Hayden during project site visits.



ROTARY TRAIL
CROSSING WITH
TEMPORARY BRIDGE.

1/31/2020



LOOKING WEST AT
ALPINE DAIRY
PROPERTY, FROM
CUSICK PARKWAY

1/31/2020



LOOKING WEST
FROM CUSICK
PARKWAY CULVERT

1/31/2020



ACTIVE FLOW
THROUGH CULVERT
AT CUSICK PARKWAY

1/31/2020



FLOW AT ROTARY
TRAIL CROSSING, ~0.2
CFS

6/19/2020



LOOKING WEST
FROM ROTARY TRAIL

6/19/2020



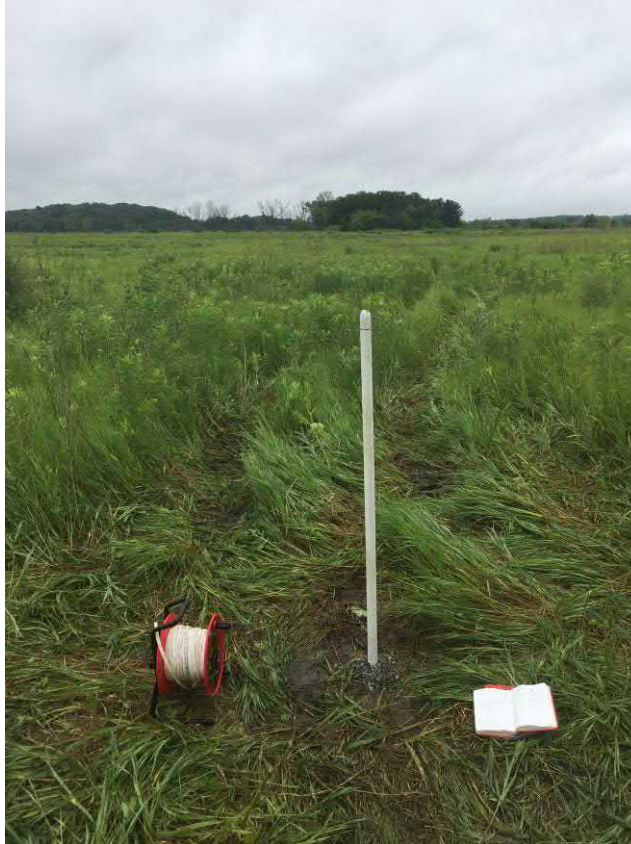
LOOKING WEST AT
ALPINE DAIRY
PROPERTY FROM
CUSICK PARKWAY

6/19/2020



LOOKING EAST AT
CULVERT
UNDERNEATH
CUSICK PARKWAY,
~0.3 CFS

6/21/2020



MONITORING WELL
1 INSTALL, US FWS
PROPERTY

6/22/2020



MONITORING WELL
2 INSTALL, US FWS
PROPERTY

6/22/2020



FLOW AT ROTARY
TRAIL CROSSING, 4.7
CFS

6/30/2020



LOOKING WEST
TOWARDS ALPINE
DAIRY PROPERTY
FROM CUSICK
PARKWAY.

FLOW THROUGH
CULVERT 6.8 CFS.

6/30/2020



FLOW AT ROTARY
TRAIL CROSSING, 2.5
CFS

7/16/2020



LOOKING WEST
TOWARDS ALPINE
DAIRY PROPERTY
FROM CUSICK
PARKWAY.

7/16/2020



LOOKING AT
CULVERT
UNDERNEATH
CUSICK PARKWAY,
FLOW THROUGH
CULVERT ~3 CFS

7/16/2020



ROTARY TRAIL
CROSSING, DRY WITH
NO SURFACE WATER
NEARBY.

8/18/2020



CUSICK PARKWAY
CULVERT PERCHED
ABOVE STANDING
WATER (NO FLOW).

8/18/2020



LOOKING WEST
TOWARDS ALPINE
DAIRY PROPERTY
FROM CUSICK
PARKWAY. WET
AREA SHRUNKEN
AND SHALLOW.

8/18/2020



DRIED UP OVERFLOW
PATHWAY, ~500'
WEST OF ROTARY
TRAIL CROSSING

8/18/2020



RETREATING EDGE
OF LAKE BARNEY,
~500' WEST OF
ROTARY TRAIL
CROSSING

8/18/2020



RETREATING EDGE
OF LAKE BARNEY,
NEAR US FWS
MONITORING WELLS
AND EAST OF
THAYER PROPERTY

8/18/2020



MONITORING WELL
#3 INSTALL, DOC
PROPERTY

9/4/2020



MONITORING WELL
#4 INSTALL, DOC
PROPERTY. FLUSH
MOUNT ALONG SIDE
ROTARY TRAIL.

9/4/2020



ROTARY TRAIL
CROSSING, DRY WITH
NO SURFACE WATER
NEARBY.

9/4/2020



LOOKING WEST
FROM ROTARY TRAIL
CROSSING, FORMER
OVERFLOW HAS BEEN
PLOWED.

9/4/2020



RETREATING EDGE
OF LAKE BARNEY,
~500' WEST OF
ROTARY TRAIL
CROSSING

8/18/2020



RETREATING EDGE
OF LAKE BARNEY,
NEAR US FWS
MONITORING WELLS
AND EAST OF
THAYER PROPERTY

9/4/2020



LOOKING WEST
TOWARDS ALPINE
DAIRY PROPERTY
FROM CUSICK
PARKWAY. NO
STANDING WATER
VISIBLE FROM TRAIL.

9/4/2020



CUSICK PARKWAY
CULVERT, DRY

9/4/2020

APPENDIX E. PCSWMM MODELING DETAILS

The techniques used to construct, parameterize, and refine the SWMM model are described below. For a full description of the SWMM conceptual model, see the SWMM reference manuals for hydrology (U.S. EPA, 2016) and hydraulics (U.S. EPA, 2017).

SWMM Model Background

Hydrology

Rainfall

SWMM allows for both event-based and continuous modeling. PCSWMM can rapidly generate design storms, such as NOAA's MSE (for the midwestern and southeastern United States) Type 4 rainfall distribution, which is standard practice for design storm modeling in Dane County. It can also accept both external rainfall files and internally processed NEXRAD data for continuous modeling. We used design-storm modeling for model construction, then loosely calibrated the model using local rainfall and other climate measurements from local weather stations. The final alternative analyses included both design-storm modeling for assessing large storm events and continuous modeling to assess drawdown times for existing conditions and proposed alternatives.

Infiltration

SWMM has three main infiltration methods to choose from: Horton, Green-Ampt, and Curve Number. We preferred both Horton and Green-Ampt as they are more physically based and more capable of modeling antecedent moisture than Curve Number, and we ultimately selected Horton to be consistent with our own experience modeling Pheasant Branch Creek in the City of Middleton and the City of Madison's numerous ongoing modeling efforts. SWMM allows the user to implement a "Modified Horton" approach, which "uses the cumulative infiltration in excess of the minimum rate as its state variable (instead of time along the Horton curve), providing a more accurate infiltration estimate when low rainfall intensities occur" (U.S. EPA, 2016). Horton's equation requires minimum and maximum infiltration rates, a decay coefficient that describes how fast infiltration rate decreases over time, and drying time to recover the infiltration rate.

Surface Runoff

Surface runoff from subcatchments is governed by SWMM's non-linear reservoir model. Depth of water in the "reservoir" is a water balance of run-on, precipitation, evaporation, and infiltration, and once that depth exceeds depression storage runoff occurs. Infiltration and depression storage are calculated separately for pervious and impervious areas, and runoff from impervious areas can be routed to pervious areas to simulate disconnected impervious areas. The rate of runoff depends upon manning's n for overland flow, subcatchment slope, and subcatchment width. The subcatchment width parameter was originally developed as a physical measurement in urban settings, but in

undeveloped watersheds the physical basis of the parameter is less clear, and it becomes more of a calibration parameter.

Calibration

PCSWMM features the Sensitivity-based Radio Tuning Calibration (SRTC) tool which can be used in calibration and sensitivity analysis. Prior to using the SRTC, the user assigns uncertainty ranges to selected parameters, and then the SRTC runs and compares multiple realizations of the model with adjusted parameter values. The SRTC provides parameter sensitivity reports, allows the user to perform a visual calibration through parameter adjustment, and calculates calibration statistics (Integral square error, Nash-Sutcliffe efficiency, etc.). The tool then performs a validation run of the model with the adjusted parameters. While we did not sufficient flow or lake stage elevations to perform a detailed calibration, we did use the SRTC to loosely-calibrate our model to the observed stages at Lake Barney and the few flow measurements taken at the Rotary Trail overflow.

Hydraulics

Model Extent and Detail

Most of the model hydraulic elements were generated using available LiDAR elevation data and assigned roughness values based on aerial imagery, consistent with FEMA “Base-Level Analysis” Options B and C for hydraulic elements that are not included in formal floodplain mapping (FEMA, 2019a). We did use more detailed topographic information where necessary or available, including a survey of key roadway culverts and of the Rotary Trail overflow performed by the City of Fitchburg, and plan sets provided by the Village of Oregon and Ruckert-Mielke.

Hydraulic Model Elements

The key visual components of our SWMM hydraulic model are:

- Nodes (junctions, storage units, and model outfall);
- Conduits (“closed” conduits with culvert inlet control codes and “irregular” type conduits for open channels);
- Orifices (certain outlet structure elements); and
- Weirs (outlet structures and roadway overflows)

The geometry of irregular conduits is stored as non-visual “transects” in the SWMM model text file. In PCSWMM, these can be entered manually or automated by creating visual transects and sampling a digital elevation model (DEM). We typically relied on LiDAR DEM for these transects except where survey data were collected for this project (Rotary Trail overflow).

Routing Method

SWMM’s hydraulic model has routing options ranging from steady flow (least complex), to kinematic wave, to dynamic wave (most complex). We chose dynamic wave routing, which solves the St. Venant flow equations for gradually varied, unsteady flow. Based on our experience, we chose the “dampen inertial terms” option which dampens the inertial terms of the St. Venant equation when the Froude

number approaches 1 and ignores them completely when the Froude number exceeds 1 (supercritical flow). This results in a more stable model with far fewer oscillations at detailed model elements such as culverts and weirs.

Routing Settings

In addition to the routing method, SWMM results can be sensitive to other routing settings. We typically used the default settings except when we found that adjusting settings decreased model instability or continuity errors. The key settings were as follows:

- Routing time step = 1 sec for design storms, 60 sec for continuous modeling
- Wet weather runoff time step = 5 min
- Normal flow criterion = Slope and Froude Number
- Inertial terms = Dampen
- Surcharge method = Extran
- Variable time steps on, with minimum time step = 0.1 sec

Boundary condition

The hydraulic model ends downstream at the stormwater pond on the northeast side of the Cusick Parkway – W Netherwood Rd intersection. The boundary condition for the existing model was assigned a “normal” boundary type once waters flows through the existing 15” pipe under Cusick Parkway, since we have an exact pond stage to use as a condition for various events or model the stormwater pond and its watershed area west of Cusick Parkway. For the proposed models, we added a second “free” boundary type at the end of the proposed bypass culvert that routes flow around the stormwater pond during very large flows.

Model Construction

Source Data

GIS

Geographic Information System (GIS) datasets were obtained for use in creating the model. Key datasets and their sources are grouped by geographic coverage below:

- State of WI
 - Statewide Parcel data ver. 5 [State Cartographer’s Office]
 - Municipal boundaries [WiDNR]
 - WISCLAND land cover [WiDNR]
 - HUC-12 watersheds [WiDNR]
- Dane County
 - Hydrography [Dane Co. Land Information Office (LIO)]
 - 2017 LiDAR DEM and contours [Dane Co. LIO]
 - Building footprints [Dane Co. LIO]

- 2020 SSURGO soils [National Resources Conservation Service (NRCS)]
- City of Fitchburg
 - Storm sewer pipes [City of Fitchburg OpenData GIS App]
 - Culverts [City of Fitchburg OpenData GIS App]
- Aerial Imagery
 - Drone flights [Ruekert-Mielke]

Drawings / CAD

- Ruekert-Mielke provided CAD files showing existing and proposed improvements for the Cusick Parkway, including existing and proposed culverts at the downstream end of our model.

Other Hydrology/Hydraulic parameters

- City of Madison initial parameters and modeling guidance document for South Fork of Pheasant Branch Creek (especially Horton infiltration parameters)

Rainfall and streamflow

Streamflow, lake stage, and rainfall data were used to perform model calibration and to define storms for floodplain mapping. Data sources included:

- Flow measurements at the Rotary Trail overflow taken by Ruekert-Mielke
- Lake Barney stage data from Tom Thayer and interpreted from aerial imagery review (see **Section 3**)
- National Oceanic and Atmospheric Agency (NOAA)
 - Dane County Regional Airport – Truax Field (Station WBAN: 14837). Record includes continuous subhourly (20-minute) precipitation data and has a long period of record (1948 – present). However, this gage is located ~14 miles north-northwest of Lake Barney, which meant that it may not always reflect actual precipitation in the watershed, especially during locally-heavy thunderstorm events.
 - Oregon 0.4 SSW (Station CoCoRaHS: WIDA0003). Record includes daily precipitation totals at a site very close to the watershed. Daily precipitation totals were used to compare hourly and adjust as described in the Calibration section.
 - Atlas 14 data were used for design storm events. We used the Dane County averages for those storms (100-yr recurrence interval and smaller) as published by the NRCS, and used NOAA’s point-based Atlas 14 web tool to get rainfall depths for the 500- and 1000-yr events.

Parameterization of Hydrology Elements

Subcatchments

Discretization

Subcatchment delineation was performed using PCSWMM's Watershed Delineation Tool (WDT) to perform hydro-conditioning and burn stream lines into the 2017 DEM to create subcatchments. After a few iterations we settled on a target subcatchment size of 40 acres, which seemed to capture the footprint of most of the important closed depressions within a single subcatchment without creating an overly detailed and discretized model.

Parametrization

Methods to derive key subcatchment parameters are described below:

Characteristic Width

Characteristic width is the width of the representative kinematic wave plane, and is also described as the subcatchment's area divided by an approximation of the longest flow path (U.S. EPA, 2016). Higher widths typically result in higher runoff volume and higher and faster peak flows, and the parameter is frequently seen as a calibration, rather than physical, parameter (Open SWMM, 2019). Characteristic width values and theory differ between urban and non-urban settings, but in our case our entire watershed was almost entirely non-urban land cover so we used the following technique:

- In non-urban subcatchments delineated using the WDT, the characteristic width was automatically calculated by the Guo and Urbonas method (Guo & Urbonas, 2009). This method incorporates both flow path analysis and skewness of the subcatchment.

Subcatchment slope

We used PCSWMM's Set DEM Slope tool on Dane County's LiDAR DEM, resampled to 500 ft (500 - check) to remove the effects of microtopography on the results.

Imperviousness

Dane County's building footprints and road centerlines layers were the basis for our impervious cover layer. We started with the building footprints, then buffered the road layer based on observed road width and added it to the buildings. We then digitized key additional areas within the watershed using 2017 leaf-off aerial imagery, although the need for this was limited due to the rural nature of the area.

SWMM has options to route some of the impervious runoff to pervious areas as a means of representing disconnected impervious areas. We used the Sutherland Equations (Sutherland) to calculate the percentage of impervious runoff routed to pervious areas (disconnected impervious). There are five different equations used depending on drainage characteristics of the subcatchment (presence of storm sewer, ditches, infiltration areas, etc.); the equation used for each area was determined based on a GIS-based visual assessment. We did not use the heavily-urban categories of these equations since they did not apply to this watershed.

Manning's n and Depression Storage

SWMM requires separate manning's n and depression storage (initial abstraction) values for pervious and impervious areas. These were calculated by linking the WISCLAND land use layer to an internal look-up table that EOR has built during the development of other SWMM projects. The initial linking was done in ArcGIS, and then PCSWMM's Area Weighting tool was used to assign average values for each subcatchment.

Horton Infiltration

We followed the guidance we have adapted for other projects for best-available data for Horton soil parameters. We used SSURGO Hydrologic Soil Groups to set maximum and minimum infiltration rates and drying days, and subcatchment average values were calculated using the Area Weight tool.

Rain gages

SWMM applies precipitation to subcatchments using rain gage objects. PCSWMM features a Design Storm Creator that we used to create a 24-hour, MSE Type 4 design storm rain gage for model construction and testing. We also imported various precipitation time series for use in continuous modeling of existing conditions. Once the existing model was built, we created design storm rain gages for testing runoff and lake stage changes for existing and proposed conditions.

Hydraulic layers

The base hydraulic model started by using the Dane County hydrography centerlines (where present in this closed watershed) and the 2017 LiDAR DEM to automatically delineate subcatchments and a network of conduits and nodes including closed depressions. As we received survey and other data, we added geometric and parameter details to hydraulic elements until the model was complete. The key parameterization steps for each element are described below.

Junctions

Junctions were used to connect various conduit types and were typically automatically placed at subcatchment outfalls for irregular conduits or at transitions between different types of conduits. These junctions were assigned invert elevations based on the LiDAR, which were then applied to the upstream or downstream end of conduits. The depth of the junctions was set high enough to allow the conduits to fill up, and ponded area was added to the junctions where it was realistic (e.g. where there was a junction that represented a low area or storm sewer inlet). Having a nominal junction ponded area helps the dynamic wave routine solver, but this was kept to a minimum to not represent storage that does not exist.

Irregular Conduits

Irregular conduits were the dominant conduit type used and represent flow in natural open channels or other flowpaths across the landscape which carry water during certain runoff events but don't have a defined channel. Our typical workflow was to use PCSWMM's Transect Creator tool to sample

the 2017 DEM along a conduit, then creating a representative cross-section for that section of irregular by automatically merging those transects. An exception to this was the Rotary Trail overflow, which was based on survey data from the City combined with the DEM data further away from the overflow.

Manning's n values for the conduits were estimated by assuming a relatively low roughness, as most of the flowpaths go across agricultural fields that often lack significant ground cover.

Closed Conduits

Closed conduits were used to represent the existing and proposed culverts. Dimensions for these were based on survey and plan sets for existing pipes. Culvert codes (defining culvert inlet geometry) were assigned based on culvert geometry and end section characteristics so that the solver can check for and correct for inlet control conditions. Culvert codes, inlet loss coefficients, and Manning's n roughness values were based on published values in Chapter 24 of the User's Guide to SWMM 5 (James, Rossman, & James, 2010).

Roadway Overflows

The flow area not included in the by culverts at road crossings was modeled using either irregular conduits or roadway weirs. Irregular conduits were used where the dominant flow path was water flowing across natural ground adjacent to and lower than the roadway. These conduits typically had higher roughness than the channel conduits and had a loss coefficient to account for expansion and contraction as water flowed over the road (typically a loss coefficient totaling 0.8). Roadway weirs were used where adjacent ground was not lower than the roadway immediately over the culvert. Weir width and length were based on roadway dimensions, and a weir coefficient of 2.6 was typically used. For both irregular conduit and roadway weir high chord areas, elevations were DEM-based.

Storage Units (surface water bodies and closed depressions)

Storage elements were used to model persistent water bodies (Swam Pond and the Lake Barney wetland complex) and natural depressional areas. The stage-storage relationships from the surface water bodies were developed from the 2017 LiDAR DEM and represent only the area above the long-term water level since the 2017 data were captured in a relatively normal year for surface water bodies in this area. Natural depressional areas were identified with PCSWMM's "Storage Creator" tool, which identifies areas based on user definition of minimum depth and area. Identifying these areas was extremely important for this model since so much of the watershed is typically "closed" meaning it does not produce surface water runoff except during normal precipitation conditions. The tool creates both a stage-storage relationship and an overflow elevation for each closed depression, so that this storage units had to fill to a certain depth with runoff before overflowing downstream.

Weirs (storage areas)

The trade-off of representing closed depressions as large storage areas was that we chose not to model any flowpaths through these storage areas, so that we were not double-counting available storage in the model. Instead, we used weirs to route flow entering a closed depression to the storage unit that represented the storage, and then a second weir to allow water to flow out of the closed

depression at its natural overflow elevation. In some areas, in particular the Lake Barney wetland complex, we had to add many “intermediate weirs” in between the 4 large storage units that represent Swan Pond and Lake Barney, so that runoff from subcatchments was routed to a realistic junction location but then quickly routed to one of the 4 large storage areas without having flow double-counted in channels within the wetland.

SWMM References

- FEMA. (2019a, February). *Guidance Document 52: General Hydraulics Considerations*. Retrieved from <https://www.fema.gov/media-library/assets/documents/34953>:
https://www.fema.gov/media-library-data/1556727028010-090889650cfe5ad6845c3f2f39863053/General_Hydrologic_Considerations_Guidance_Feb_2019.pdf
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- U.S. EPA. (2016, January). Storm Water Management Model Reference Manual Volume I - Hydrology (Revised). Cincinnati, Ohio, U.S.A.
- U.S. EPA. (2017, May). Storm Water Management Model Reference Manual Volume II - Hydraulics (Revised). Cincinnati, Ohio, U.S.A.

**APPENDIX F. LAKE BARNEY FLOODING COST MEMORANDUM (PROVIDED BY
LANDOWNERS)**

Hickory Knoll Farm

5438 Highway M
Fitchburg WI 53575



Lake Barney Flooding Cost

1. Crop or land rents losses per annum

Some owners actively farm while others rent their land out. We have used the rental rate, not the actual income rates, which are higher. For example, in 2018 we lost \$44,000 of vegetables on only three acres. Hay harvested at a rate of 120 bales per acre is equal to \$600 per acres, less production costs netting \$440 per acre. Tus the summary below is the lowest reasonable estimate if all the land were rented, ignoring actual profits from cropping.

For Thayer and others, some years have been a complete loss on larger acreage, but we have used the 2020 planting season figures with Thayer showing partial crops on his land, where the seeding failed on wet soils.

Note that after three years of losses, crop insurance is no longer available.

<u>FARMER</u>	<u>ACREAGE</u>	<u>RATE</u>	<u>PRODUCTION LOSS</u>
Darin Schultz	3	200	\$600
Don Dunn	4	200	\$800
Emilie Harris	8	200	\$1,600
Patrick Barry	12	200	\$2,400
Tom Thayer	20	200	\$4,000
Philip Peterson	25	200	\$5,000
John Brown	40	200	\$8,000
Steve Anderson	42	200	\$8,400
Keller	70	200	\$14,000
Bill Thorhorst	80	200	\$16,000
Hickory Knoll/Frostwood	96	200	\$19,200
TOTAL PER YEAR			\$76,000

2. Repair cost for buildings and fields

- 2.1 Jerry Schmilyer: basement foundation repairs, replace water heater and furnace, add sump pump
- 2.2 John Brown: Move electrical, furnace and other utilities, infill basement to 36 inch crawl space
- 2.3 Thomas Thayer: Cost of water barrier, (\$45,310) sandbagging (\$3,200), pumps, hose, electrical (\$3,418) installation and maintenance of barrier by others (\$49,300). Thayer family labor not included.
- 2.4 Thomas Thayer: cost of breach March 13 & 14, 2019 when water levels rose quickly and overwhelmed defenses. Rental of diesel pumps (\$1,015) four gas power pumps (\$660.00), hired labor to pump out buildings, raise sandbag barrier (\$10,200
- 2.5 Thomas Thayer: damage to buildings net of insurance payments received. Lower level of house, carpet, furniture, drywall etc (\$26,705) Due to wetness, this area has not been restored. Basement water collection system (\$5,750) Revised drain lines increased to 6 inch pipes, larger pumps to reach 16,200 GPH (\$16,276)
- 2.6 Hickory Knoll Farm: dig 1900 lineal feet of drainage ditches, install pumpable pond, dikes along Caine Road (12,500)

- 2.7 Hickory Knoll Farm: install breaker and gravel roads to get horses to pasture, access north part of farm, culverts at intersection of drainage ditches (\$9,700)
 - 2.8 Hickory Knoll Farm: replant former vegetable fields after drainage installed (\$1,400)
 - 2.9 Hickory Knoll Farm: haul in 70 triaxle loads of top soil, grades and plant(\$5,400). Family labor utilized for work not included
 - 2.10 Hickory Knoll Farm: remove 21 dead walnuts, 8 large oaks, 8 smaller trees (estimated \$12,000)
- Work is underway

Jerry Schmilyer	repairs ot residence	\$ 10,200
John Brown	repairs to residence	21,000
Thomas Thayer	water barriers and maintenance	101,228
Thomas Thayer	March 2019 breach of barriers	11,875
Thomas Thayer	damage to house, buildings and additional pumps	16,276
Hickory Knoll Farm	drainage, roads, culverts	22,200
Hickory Knoll Farm:	soil, grading and planting	6,800
Hickory Knoll Farm:	tree removal	12,000

TOTAL PAID OR COMMITTED TO DATE **\$201,679**

3 Drainage planned

The following drainage costs are based upon a preliminary survey of the Fitchburg land owners with flooded land and were provided by Martinson Excavating of Oregon, Wisconsin. The McKenzie Farm has discussed drainage, but to date there is no plan or cost included here. The total length of drainage without McKenzie: 6561 feet. The culvert under M and culvert under D will need to be inspected and measured and invert determined Frostwood may require north to south tile in areas to be determined and no cost is presented here.

Drain profile:

Depth:	mean of 30 inches
Side slope	4 to 1
Width at bottom	6 feet
Total width	11 feet
Grass	pasture mix with annual rye, mowable

Culverts

Anderson:	one 24" concrete 20 feet long with wings
Frostwood	one or two, one 24" concrete 20 feet long with wings
Barry	one 24" concrete 20 feet long with wings

Costs

Anderson	1467 feet	\$4,401 ditch	\$3,084.40 culvert	\$ 7,485.40
Barry	1334 feet	\$4,002 ditch	\$3,084.40 culvert	\$ 7,086.40
Frostwood north	1540 feet			
Frostwood west	2020 feet			
Fish Hatch Ditch	200 feet	\$11,280	\$,6168.80 culverts	\$17,448.80
McKenzie	TBD			

TOTAL ESTIMATE FOR AREA DRAINAGE: **\$ 32,020.60**

4. Temporary Lake Barney drainage and control structure

We have planned to have a wetland delineation done by Heartland Ecological Group (\$4,900) so that permits may be obtained to install a two foot deep drainageway and control structure as a temporary improvement in drainage, until the Village and City design and can install a permanent drainage system.

The land crossed would be in the Town of Oregon on lands belonging to the Department of Corrections and Alpine Dairy. The Department of Corrections and Alpine Dairy have both lost tillable land the last three years and the depth of water on the southeastern portion of the Alpine lands is that which has closed Netherwood drive multiple time in the last few years. This loss of income from farming has not be included in this report, but as we land owners in Fitchburg may have to pay some or all of the temporary drainage cost, we are including that item.

Depending on permitting, a best case cost estimate for approximately eighteen hundred feet of ditch, with an Agri-Drain type control structure, is \$33,831.60 with seeding of disturbed areas by the owners.

COST FOR TEMPORARY DRAINAGE **\$43,631.60**

5. Bike trail

The village of Oregon has investigated purchasing land or easements to move the portions of the bike trail that is under water. The southern portion of the trail has not been useable the last three summers. Our understanding is that there is a lack of willing landowners and that moving the trail may not be possible. We believe Oregon had roughly estimated significant cost to acquire land and move the trail. We have not included those costs in this estimate.

6. Summary

Crop or land rents cost for 2018-2020	\$ 228,000	2021 not included
Repair costs for buildings and fields	201,679	
Filed drainage costs	32,021	
Temporary drainage and control structure	43,632	
Cost of moving bike path	0	not included
SUM OF COST:	\$505,332	

The costs included in this letter are the direct dollar costs that have been and may be borne by Fitchburg landowners and does not include other costs. We have lost pre-settlement trees that have died due to oxygen starvation caused by high water. The Thayer loss of perhaps a hundred trees and the cost to remove them is not included in the costs. Hickory Knoll/Frostwood Farm used to offer multiple annual equine and charity events at the Farm. None of those have been possible the last three years and a loss of economic impact of \$330,000 for Fitchburg is estimated, based upon our annual filing with the Chamber of Commerce.

We have lost valuable nesting habitat in what was the Lake Barney pond and marsh system. US Fish and Wildlife would like to see the area restored to bring back the crane, goose, duck and small bird resources. What is now open water was a complex mix of ponds, marshes, tall grasses and forest that sustained many winged and four footed species. The decrease in quality of life, stress and sorrow at the loss of land and habitat is profound.

John Freiburger
For the Fitchburg Lake Barney Landowners Committee

APPENDIX G. CONCEPTUAL PROJECT COST ESTIMATES

Conceptual Cost Estimate
City of Fitchburg - Lake Barney Outlet
Alternative 1 (942')

Item	WisDOT Reference #	Unit	Quantity	Unit Cost	Total
Excavation Common	205.0100	CY	30,070.00	10.00	\$ 300,700.00
Topsoil Strip, Stockpile, and Place	-	CY	23,760.00	10.00	\$ 237,600.00
Culvert Pipe Reinforced Concrete Horizontal Elliptical Class HE-III 24x38-Inch	522.23	LF	60.00	150.00	\$ 9,000.00
Apron Endwalls for Culvert Pipe Reinforced Concrete Horizontal Elliptical 24x38-Inch	522.26	EACH	1.00	1,400.00	\$ 1,400.00
Precast Outlet Structure w/ Weir Plate, Top Grate and Trash Rack	-	EACH	1.00	25,000.00	\$ 25,000.00
Riprap Heavy	606.0300	CY	30.00	75.00	\$ 2,250.00
Mobilization	619.1000	EACH	1.00	20,000.00	\$ 20,000.00
Silt Fence	628.1504	LF	12,000.00	2.30	\$ 27,600.00
Erosion Mat Urban Class I Type A	628.2006	SY	42,000.00	1.60	\$ 67,200.00
Tracking Pads	628.7560	EACH	1.00	1,600.00	\$ 1,600.00
Seeding Mixture No. 40	630.0140	LB	750.00	12.00	\$ 9,000.00
Geotextile Type HR	645.0120	SY	50.00	5.00	\$ 250.00
Construction Totals				Refined Total	\$ 701,600.00

CONSTRUCTION CONTINGENCY	25%	\$	175,400.00
PLANNING AND ENGINEERING	6%	\$	42,096.00
PERMITTING AND APPROVALS	5%	\$	35,080.00
BIDDING AND CONSTRUCTION ADMIN	3%	\$	21,048.00
PROFESSIONAL FEES TOTAL		\$	98,224.00
TOTAL PROJECT COST		\$	975,224.00
ESTIMATED ACCURACY RANGE***		-20%	\$ 780,179.20
		30%	\$ 1,267,791.20

Conceptual Cost Estimate
City of Fitchburg - Lake Barney Outlet
Alternative 2 (944')

Item	WisDOT Reference #	Unit	Quantity	Unit Cost	Total
Excavation Common	205.0100	CY	16,190.00	10.00	\$ 161,900.00
Topsoil Strip, Stockpile, and Place	-	CY	16,450.00	10.00	\$ 164,500.00
Culvert Pipe Reinforced Concrete Horizontal Elliptical Class HE-III 24x38-Inch	522.23	LF	60.00	150.00	\$ 9,000.00
Apron Endwalls for Culvert Pipe Reinforced Concrete Horizontal Elliptical 24x38-Inch	522.26	EACH	1.00	1,400.00	\$ 1,400.00
Precast Outlet Structure w/ Weir Plate, Top Grate and Trash Rack	-	EACH	1.00	25,000.00	\$ 25,000.00
Riprap Heavy	606.0300	CY	30.00	75.00	\$ 2,250.00
Mobilization	619.1000	EACH	1.00	20,000.00	\$ 20,000.00
Silt Fence	628.1504	LF	12,000.00	2.30	\$ 27,600.00
Erosion Mat Urban Class I Type A	628.2006	SY	33,200.00	1.60	\$ 53,120.00
Tracking Pads	628.7560	EACH	1.00	1,600.00	\$ 1,600.00
Seeding Mixture No. 40	630.0140	LB	600.00	12.00	\$ 7,200.00
Geotextile Type HR	645.0120	SY	50.00	5.00	\$ 250.00
Construction Totals				Refined Total	\$ 473,820.00

CONSTRUCTION CONTINGENCY	25%	\$	118,455.00
PLANNING AND ENGINEERING	6%	\$	28,429.20
PERMITTING AND APPROVALS	5%	\$	23,691.00
BIDDING AND CONSTRUCTION ADMIN	3%	\$	14,214.60
PROFESSIONAL FEES TOTAL		\$	66,334.80
TOTAL PROJECT COST		\$	658,609.80
ESTIMATED ACCURACY RANGE***		-20%	\$ 526,887.84
		30%	\$ 856,192.74

Conceptual Cost Estimate
City of Fitchburg - Lake Barney Outlet
Alternative 3 (945')

Item	WisDOT Reference #	Unit	Quantity	Unit Cost	Total
Excavation Common	205.0100	CY	10,850.00	10.00	\$ 108,500.00
Topsoil Strip, Stockpile, and Place	-	CY	13,480.00	10.00	\$ 134,800.00
Culvert Pipe Reinforced Concrete Horizontal Elliptical Class HE-III 24x38-Inch	522.23	LF	60.00	150.00	\$ 9,000.00
Apron Endwalls for Culvert Pipe Reinforced Concrete Horizontal Elliptical 24x38-Inch	522.26	EACH	1.00	1,400.00	\$ 1,400.00
Precast Outlet Structure w/ Weir Plate, Top Grate and Trash Rack	-	EACH	1.00	25,000.00	\$ 25,000.00
Riprap Heavy	606.0300	CY	30.00	75.00	\$ 2,250.00
Mobilization	619.1000	EACH	1.00	20,000.00	\$ 20,000.00
Silt Fence	628.1504	LF	12,000.00	2.30	\$ 27,600.00
Erosion Mat Urban Class I Type A	628.2006	SY	29,600.00	1.60	\$ 47,360.00
Tracking Pads	628.7560	EACH	1.00	1,600.00	\$ 1,600.00
Seeding Mixture No. 40	630.0140	LB	535.00	12.00	\$ 6,420.00
Geotextile Type HR	645.0120	SY	50.00	5.00	\$ 250.00
Construction Totals				Refined Total	\$ 384,180.00

CONSTRUCTION CONTINGENCY	25%	\$	96,045.00
PLANNING AND ENGINEERING	6%	\$	23,050.80
PERMITTING AND APPROVALS	5%	\$	19,209.00
BIDDING AND CONSTRUCTION ADMIN	3%	\$	11,525.40
PROFESSIONAL FEES TOTAL		\$	53,785.20
TOTAL PROJECT COST		\$	534,010.20
ESTIMATED ACCURACY RANGE***		-20%	\$ 427,208.16
		30%	\$ 694,213.26

APPENDIX H. CONCEPTUAL PLAN SET – ALTERNATIVE 2

LAKE BARNEY STORMWATER STUDY

CONCEPTUAL PLAN SET - ALTERNATIVE 2

PLAN OF PROPOSED IMPROVEMENT

CITY OF FITCHBURG
DANE COUNTY, WI

4 DECEMBER 2020

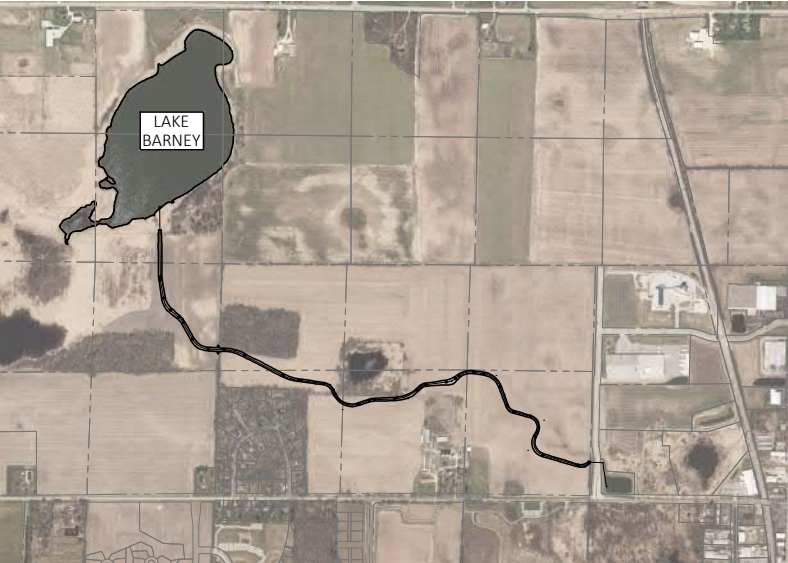
TO OBTAIN LOCATIONS OF PARTICIPANT UNDERGROUND FACILITIES BEFORE YOU DIG IN WISCONSIN



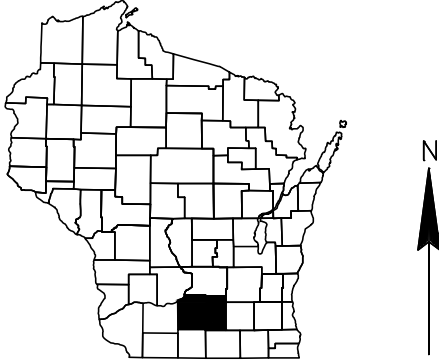
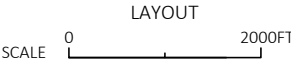
CALL DIGGERS HOTLINE
811 TOLL FREE

WISCONSIN STATE STATUTE 182.0175(1974) REQUIRES MINIMUM THREE (3) WORK DAYS NOTICE BEFORE YOU EXCAVATE

"THE INFORMATION SHOWN ON THIS DRAWING CONCERNING TYPE AND LOCATION OF UNDERGROUND UTILITIES IS NOT GUARANTEED TO BE ACCURATE OR ALL INCLUSIVE. THE CONTRACTOR IS RESPONSIBLE FOR MAKING HIS OWN DETERMINATIONS AS TO THE TYPE AND LOCATION OF UNDERGROUND UTILITIES AS MAY BE NECESSARY TO AVOID DAMAGE THERETO. IF ADDITIONAL UTILITIES ARE KNOWN TO EXIST IN THE PROPERTY, THE OWNER WILL PROVIDE EXISTING PLANS OF OTHER UTILITIES SERVING THE SITE AND THE BUILDING THAT OTHERWISE CANNOT BE LOCATED BY A VISUAL INSPECTION OF THE PROPERTY OR OF WHICH THE SURVEYOR WOULD HAVE NO KNOWLEDGE".



PROJECT LOCATION



ORDER OF SHEETS

Sheet No.	DESCRIPTION
1	TITLE SHEET
2-3	INDEX SHEETS
4	TYPICAL SECTION
5	OUTLET DETAIL
6-17	PLAN & PROFILES

PROJECT ID: 01052-0004
REVISION DATE: XXXX/2020

CONVENTIONAL SYMBOLS

PLAN		PROFILE	
REPLACE PAVEMENT		GRADE LINE	
PROPERTY LINE		ORIGINAL GROUND	
LOT LINE		SPECIAL DITCH	
EASEMENT		GRADE ELEVATION	
EXISTING RIGHT OF WAY		CULVERT (Profile View)	
PROPOSED OR NEW R/W LINE		UTILITIES	
SLOPE INTERCEPT		ELECTRIC	
REFERENCE LINE		FIBER OPTIC	
EXISTING CULVERT		GAS	
PROPOSED CULVERT (Box or Pipe)		SANITARY SEWER	
COMBUSTIBLE FLUIDS		STORM SEWER	
MARSH AREA		TELEPHONE	
WOODED OR SHRUB AREA		WATER	
		UTILITY PEDESTAL	
		POWER POLE	
		LIGHT POLE, 18', TYPE G	
		LIGHT POLE, 30', TYPE D	
		TELEPHONE POLE	

PLANS PREPARED BY:
MARS-EOR
water-ecology-community
EMMONS & OLIVIER RESOURCES, INC.
119 SOUTH MAIN STREET, COTTAGE GROVE, WI 53527
(608)839-4422
Ryan Moe, Civil Engineer

NO.	DATE	DESCRIPTION
3		
4		
5		



PROJECT: LAKE BARNEY - CONCEPTUAL PLAN

CLIENT: CITY OF FITCHBURG

PLAN AND PROFILE INDEX 1



SHEET 2

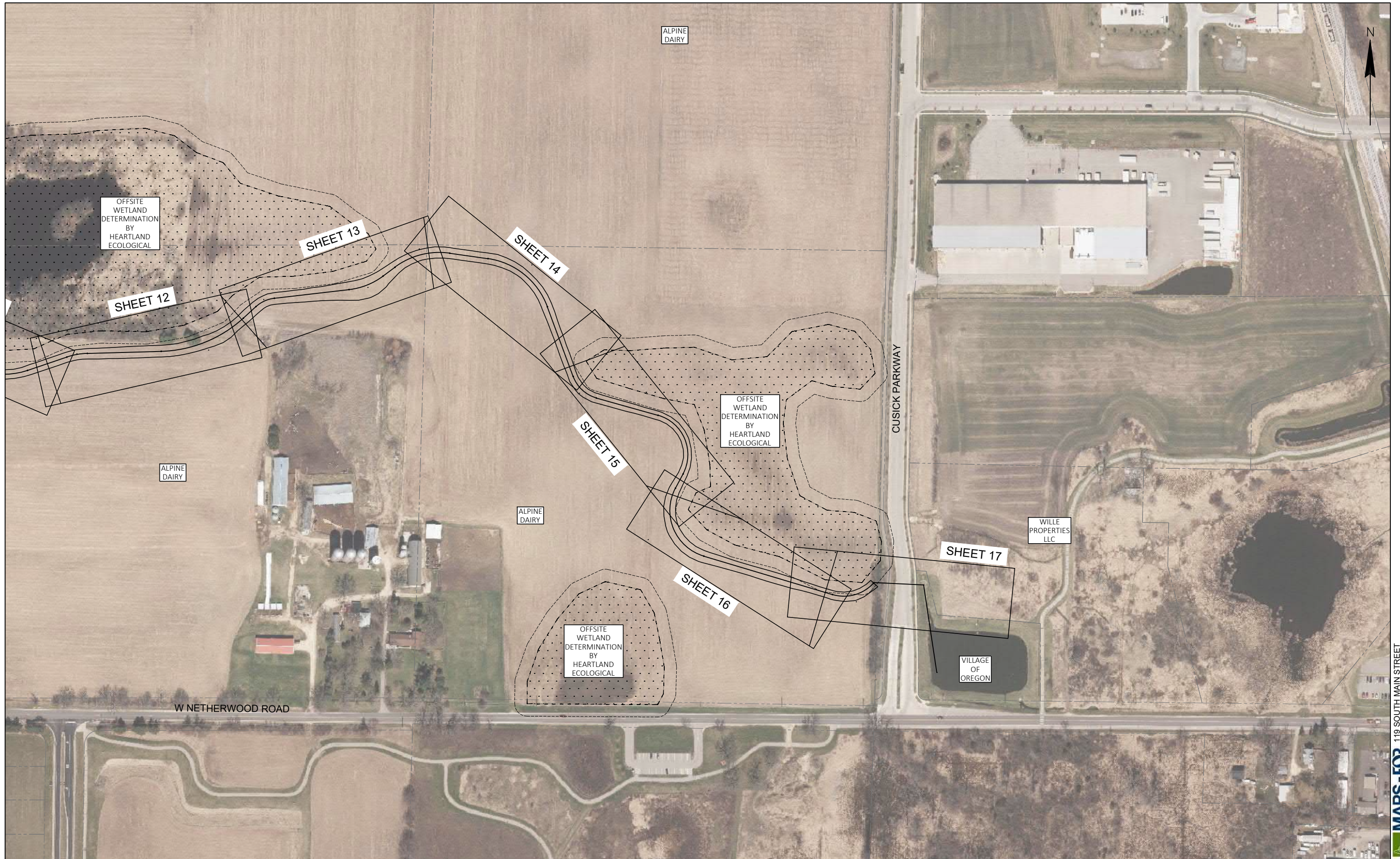
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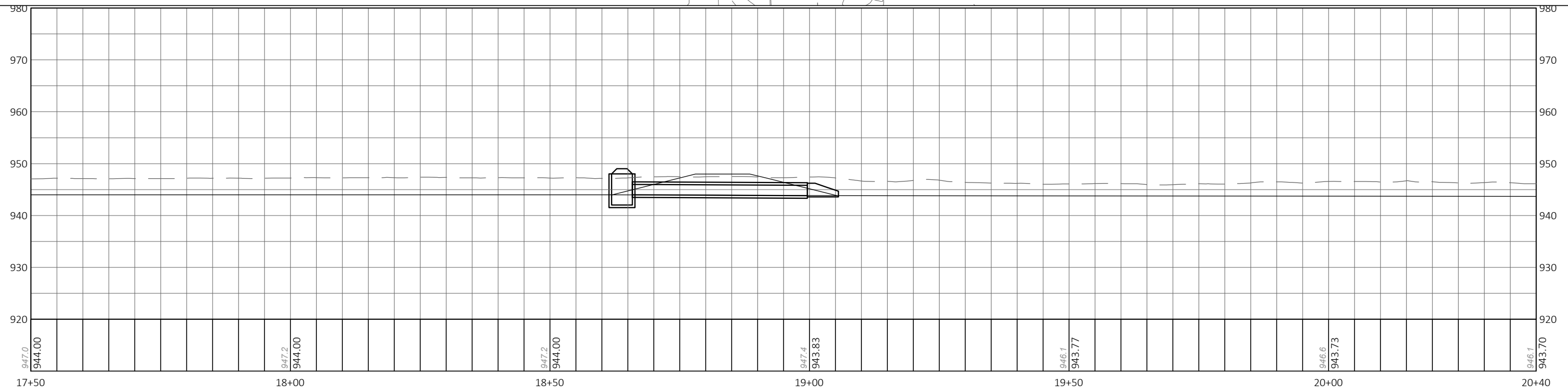
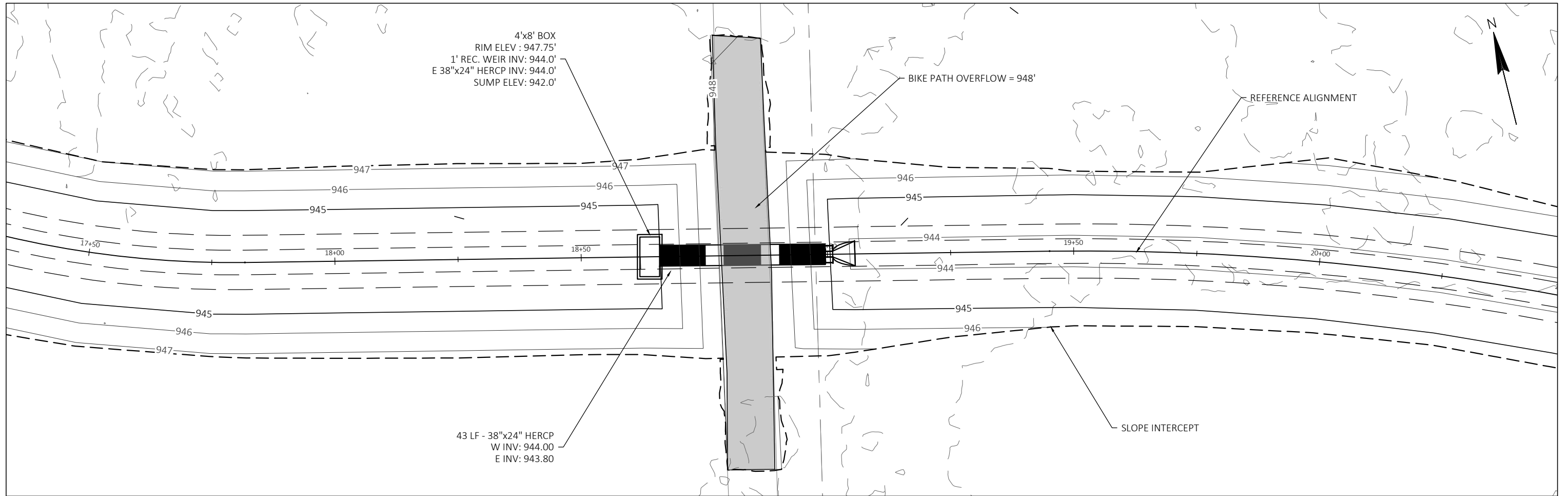
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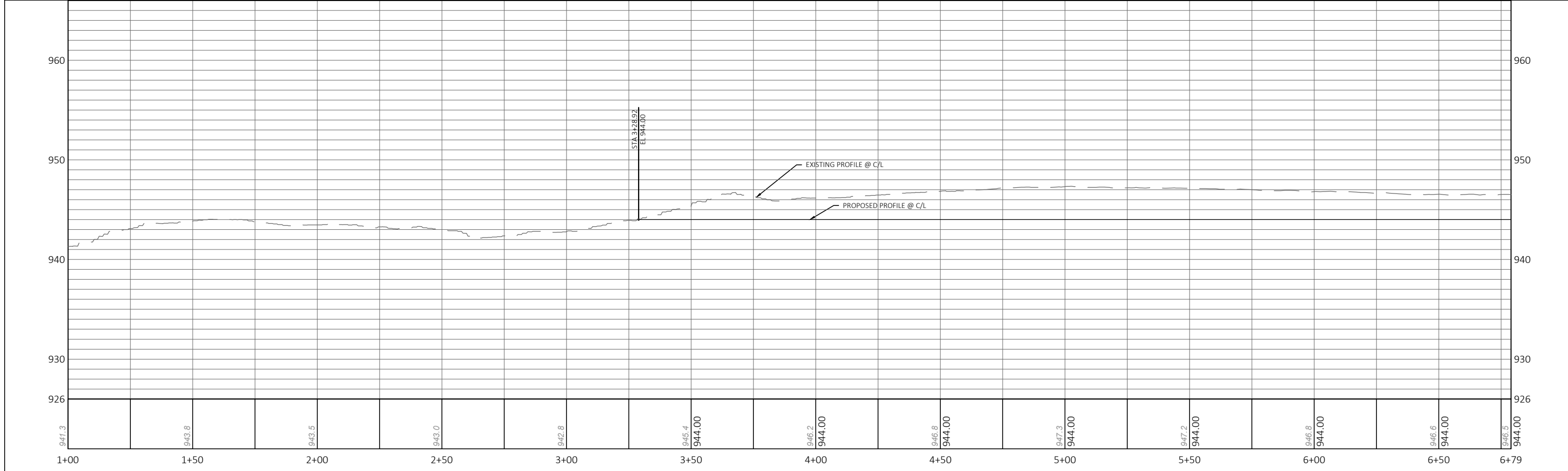
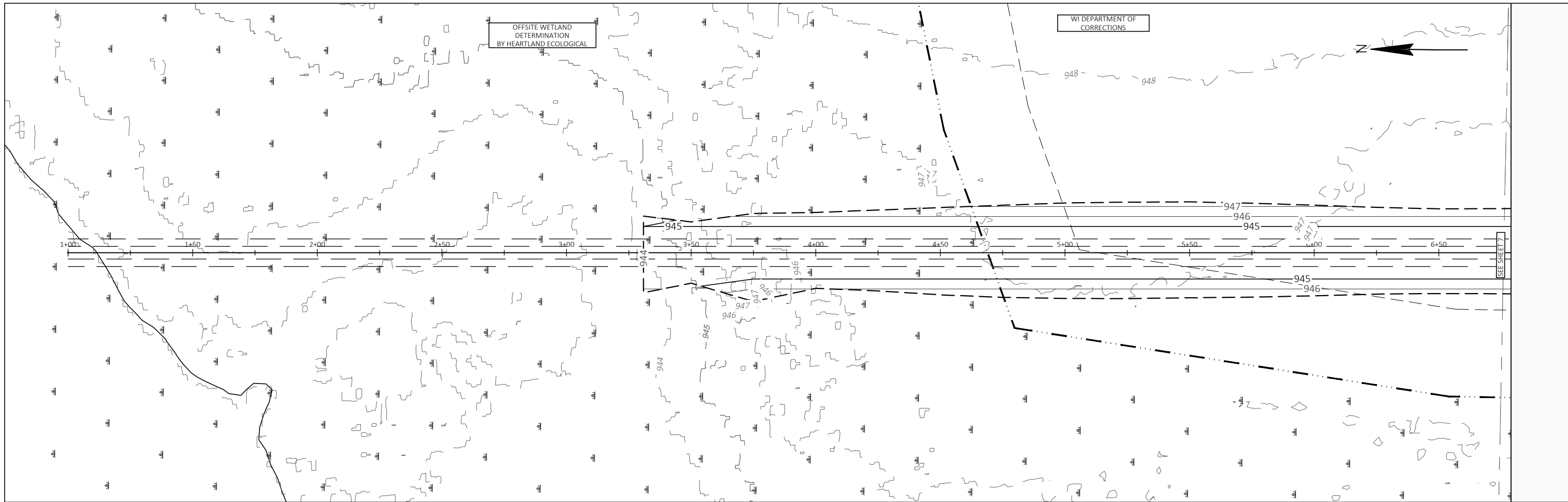
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PLOT NAME :

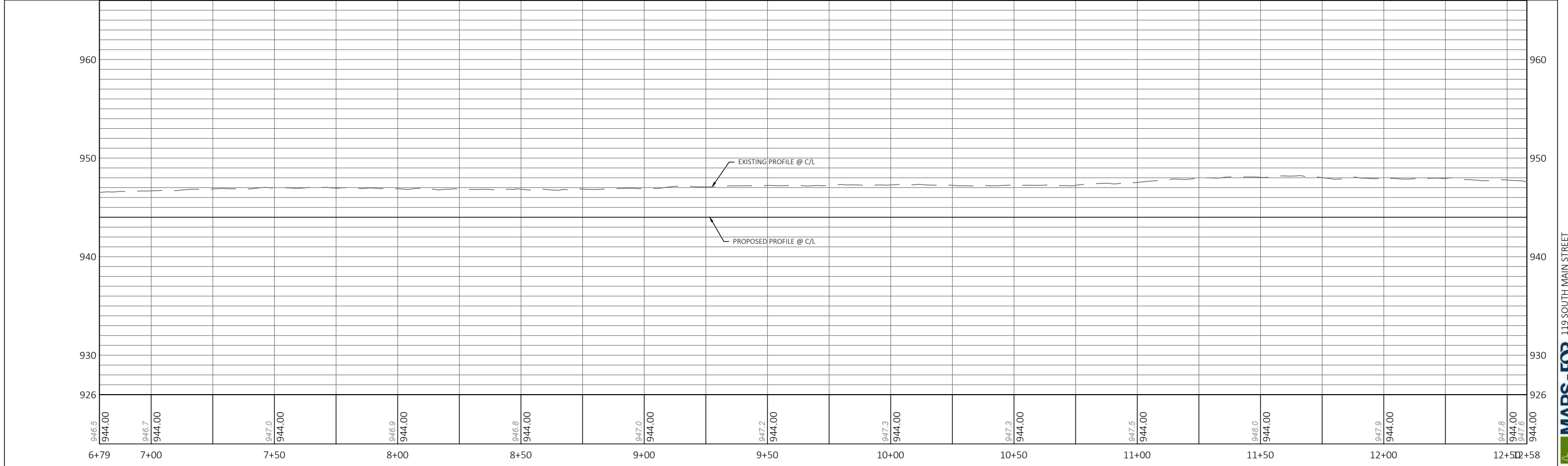
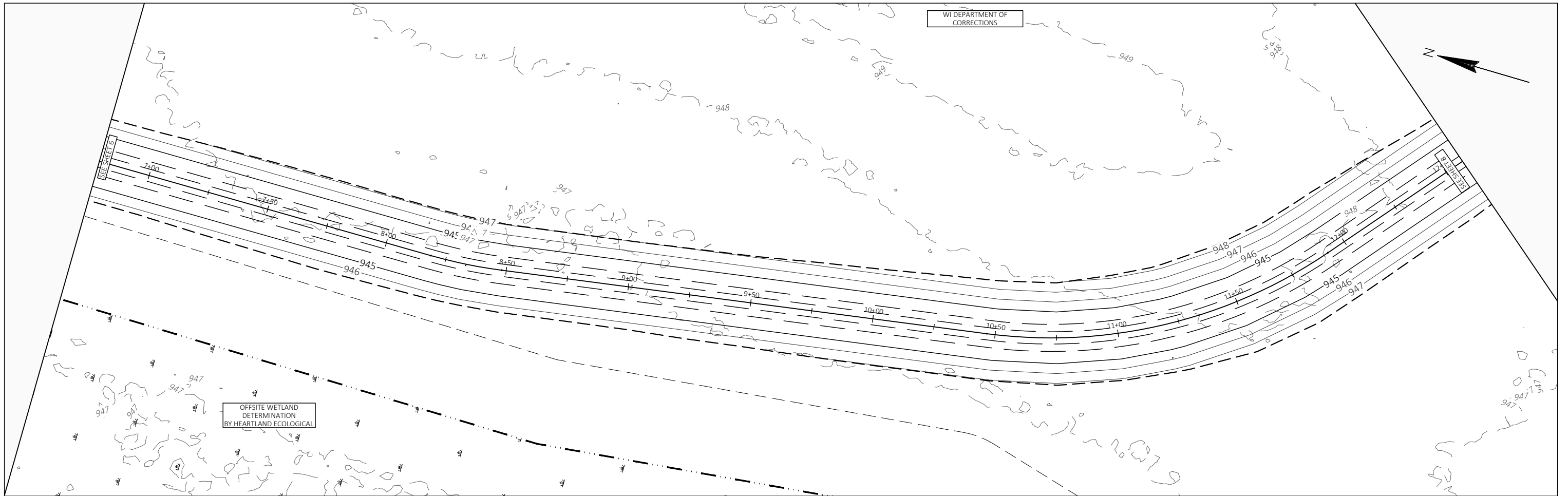
MARS-EOR
 water-ecology-community
 119 SOUTH MAIN STREET
 COTTAGE GROVE, WI 53527 (608) 839.4422



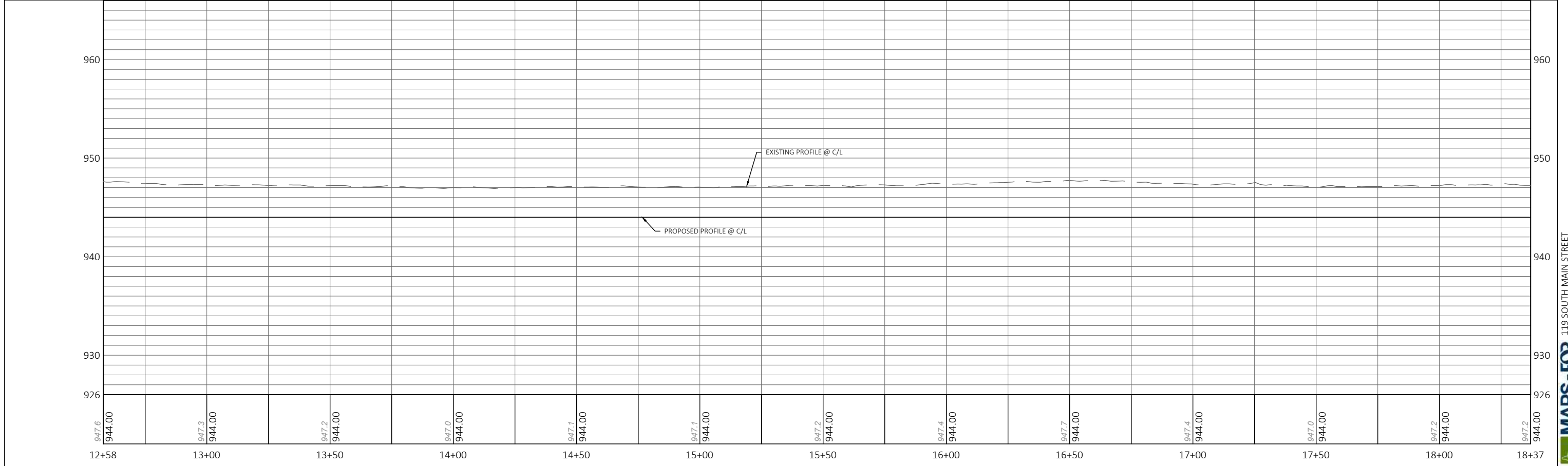




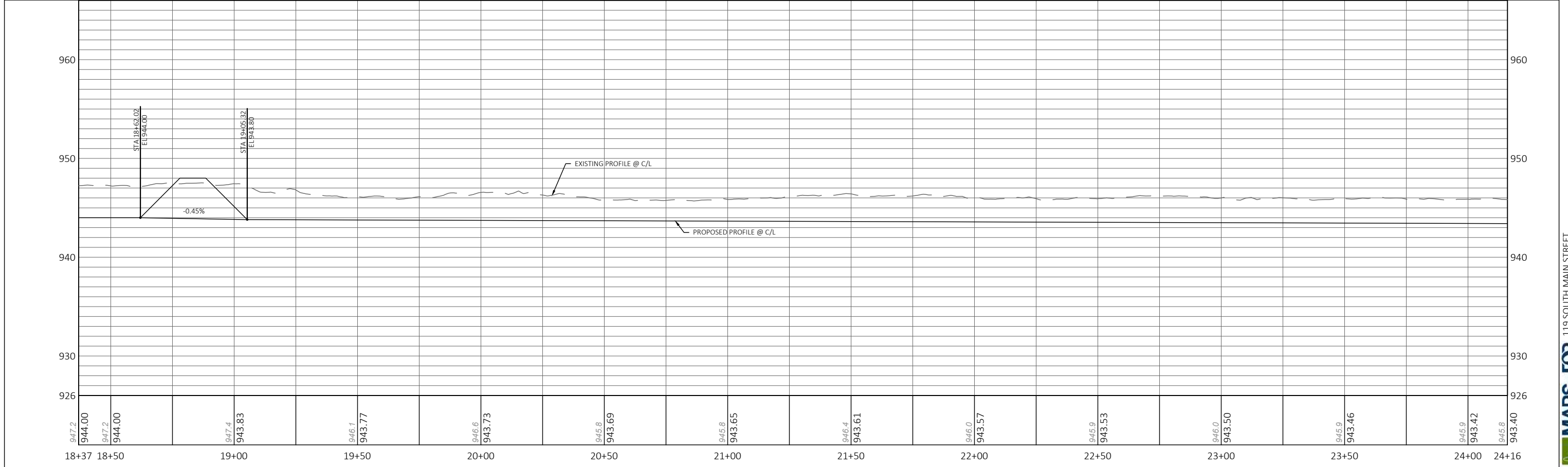
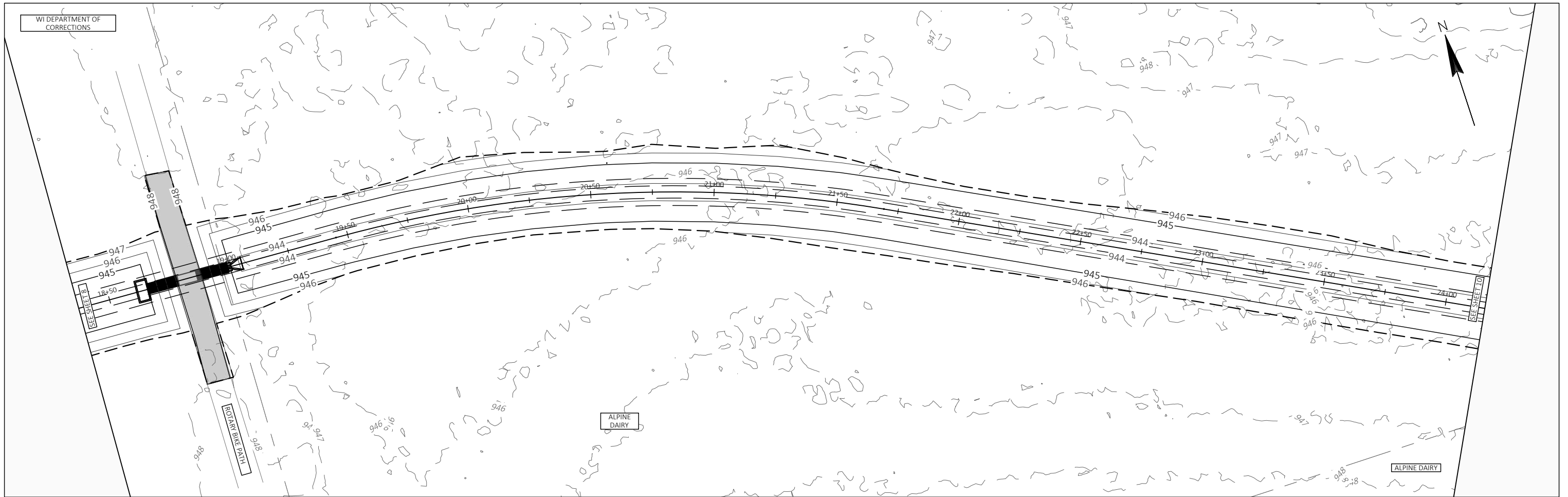
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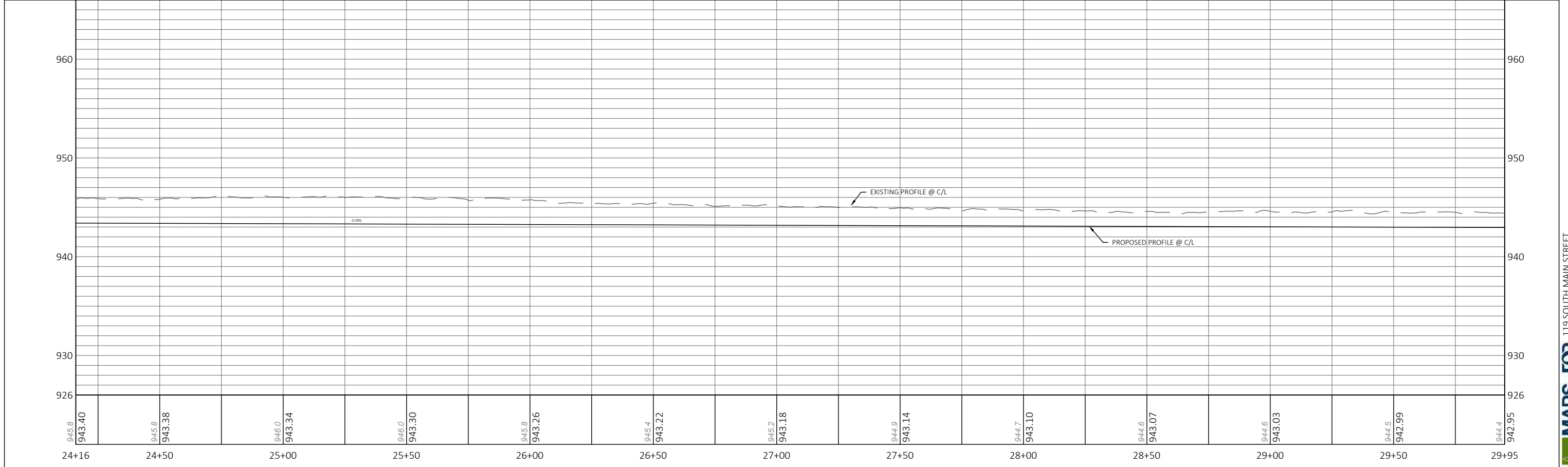
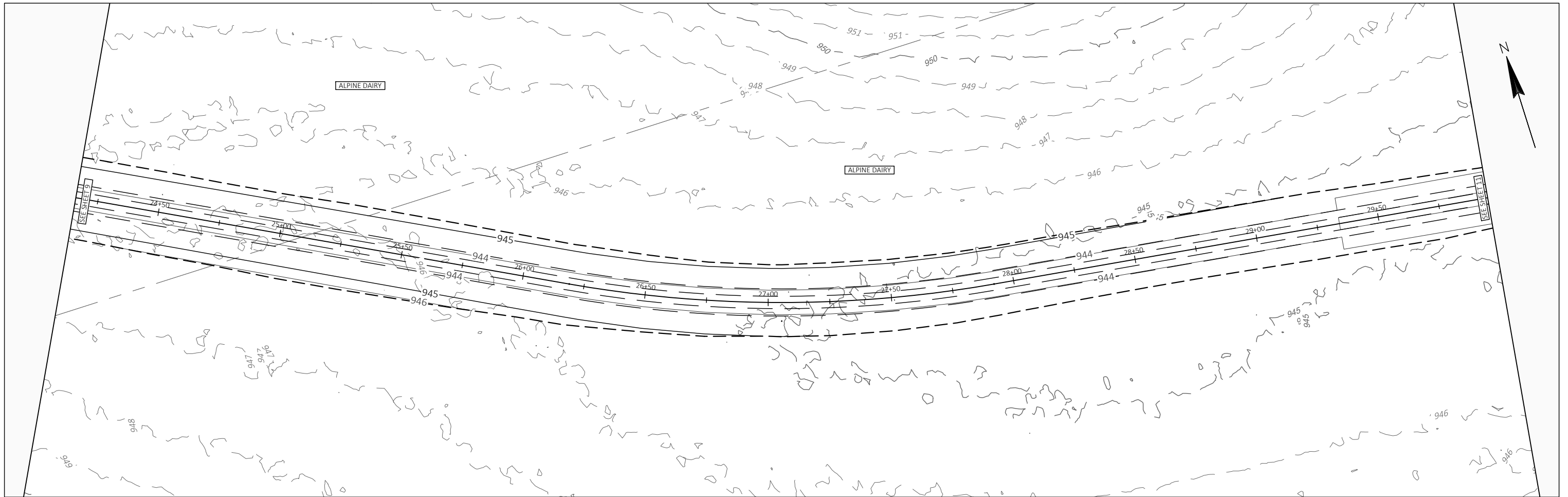


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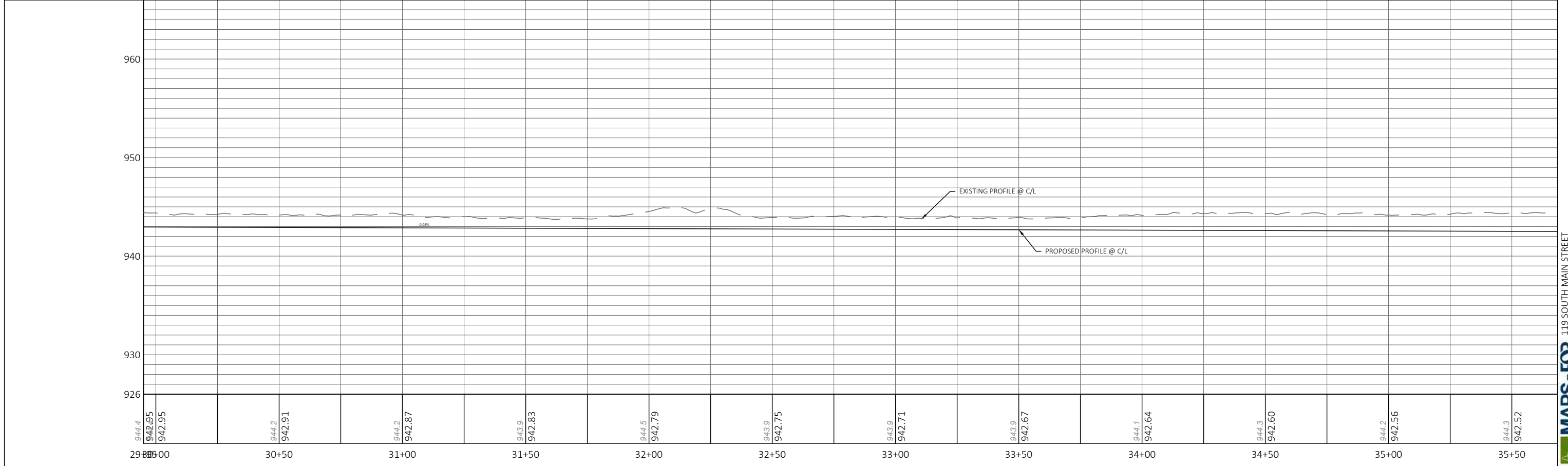
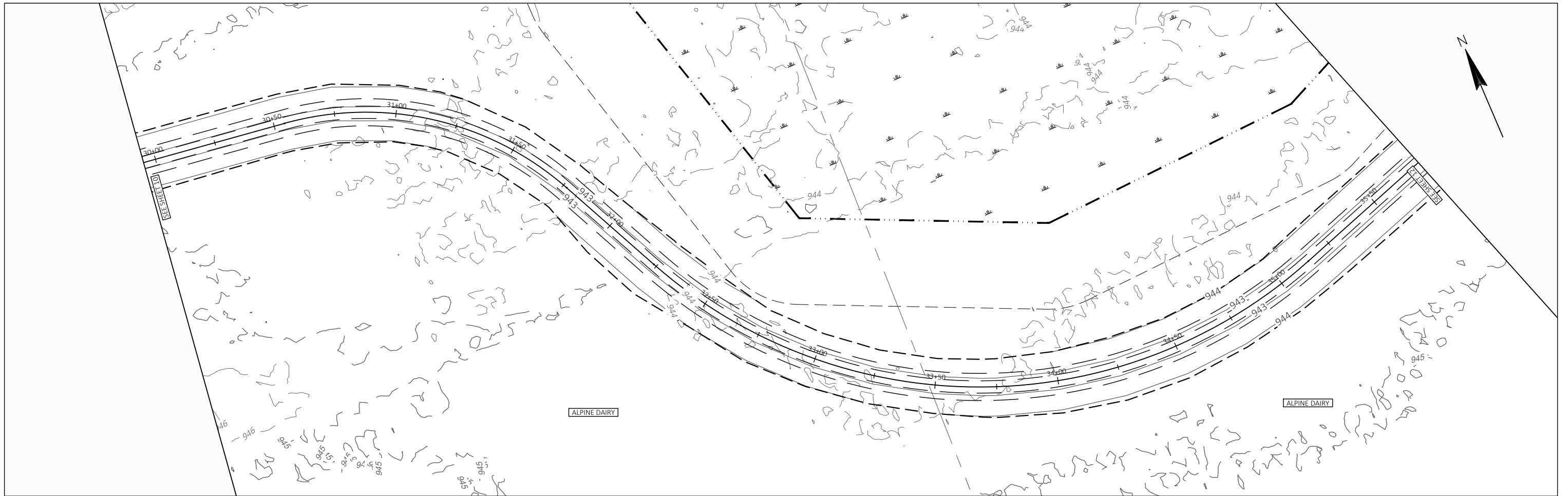
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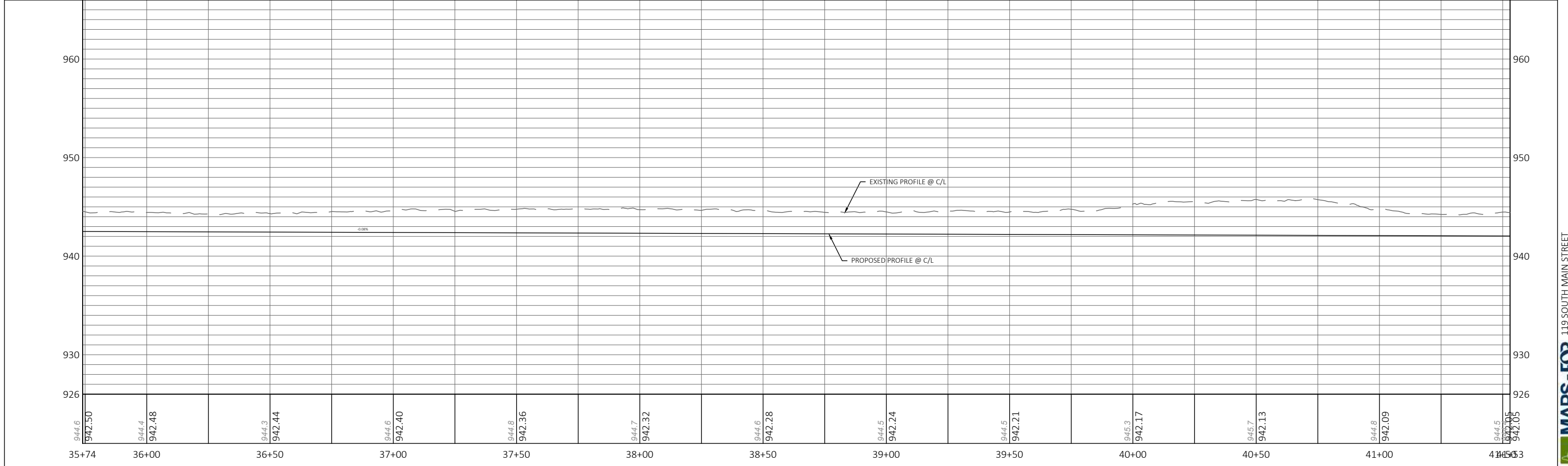


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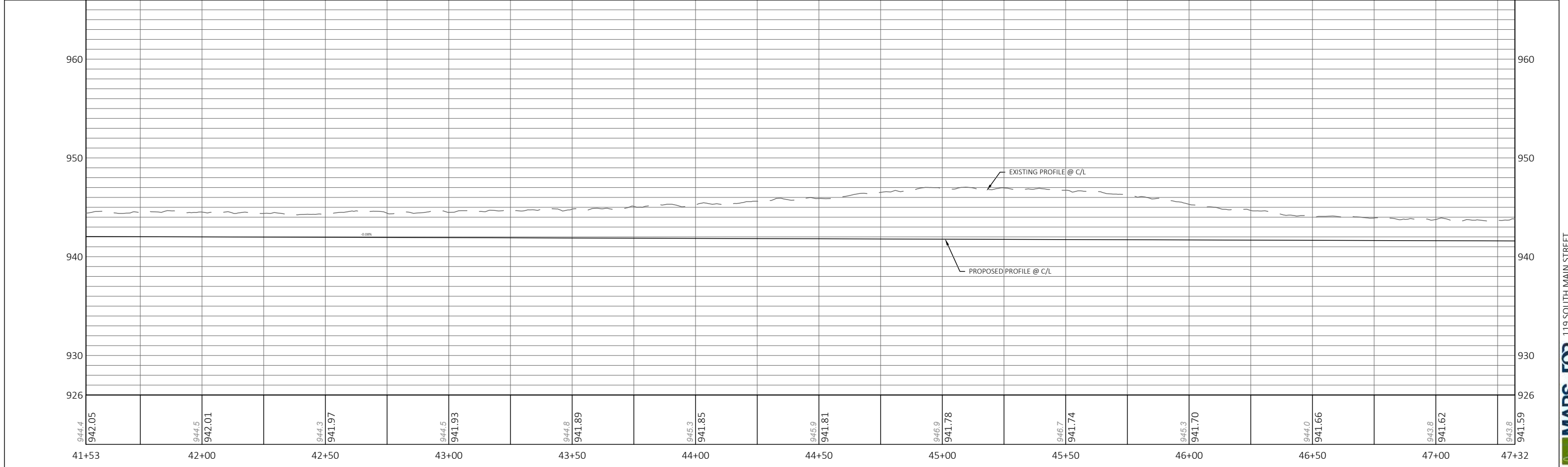
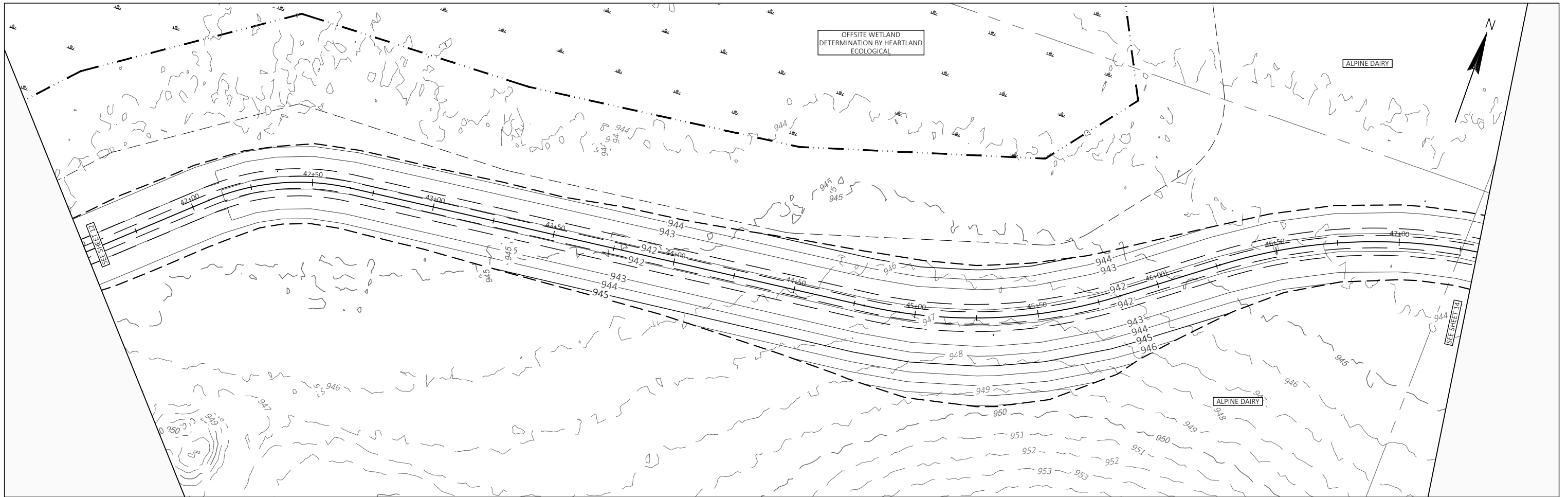


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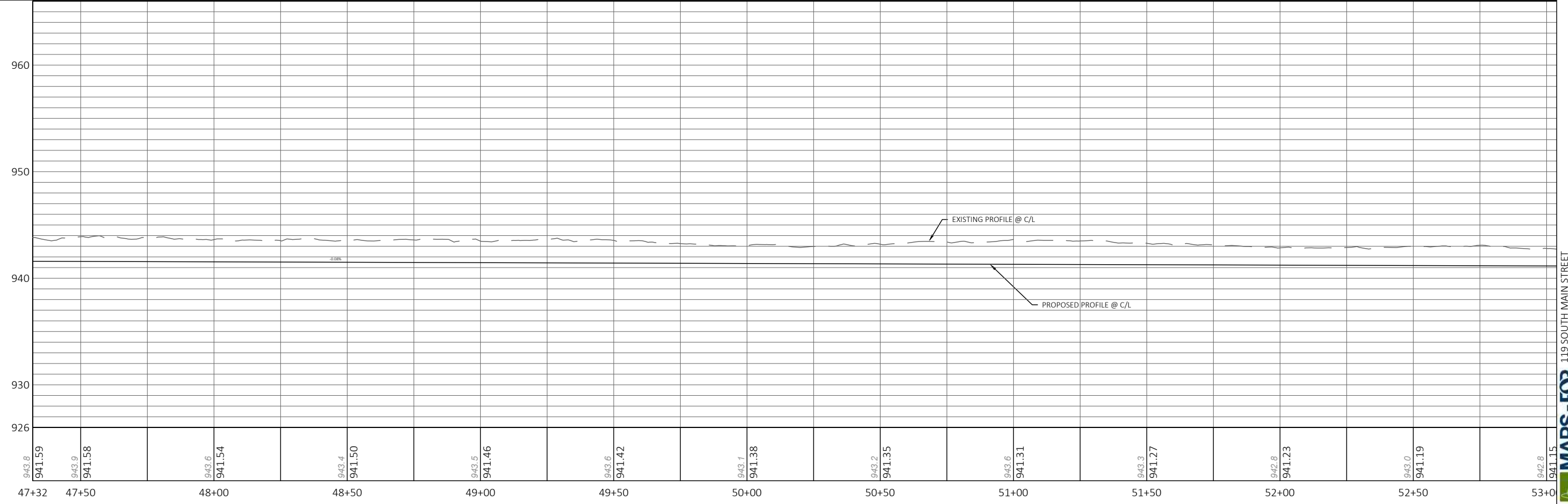
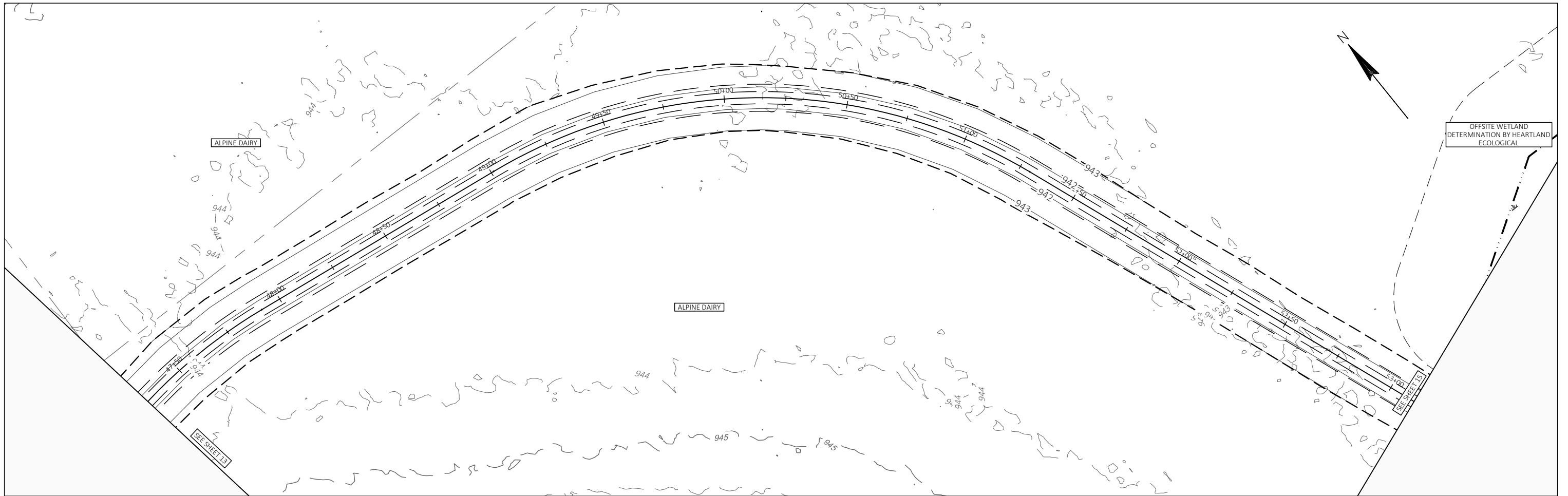
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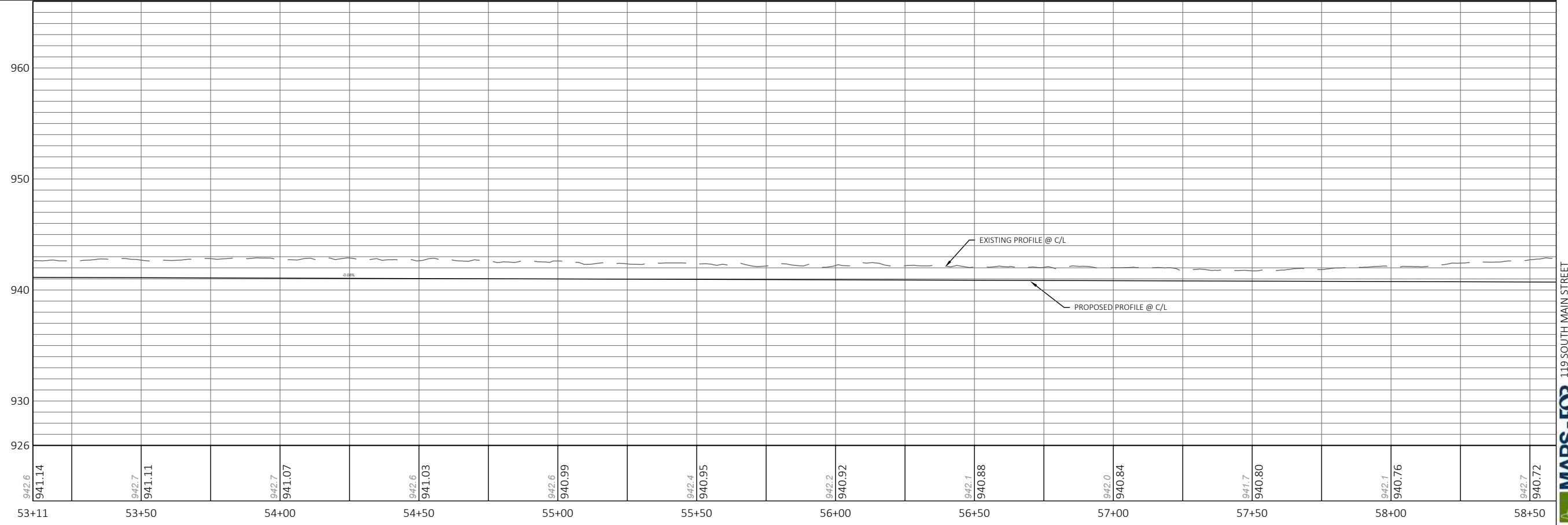
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MARS-EOI
water-ecology-community
119 SOUTH MAIN STREET
COTTAGE GROVE, WI 53527 (608) 839.4422



PROJECT: LAKE BARNEY - CONCEPTUAL PLAN CLIENT: CITY OF FITCHBURG PHASE: CONCEPTUAL PLAN PLAN AND PROFILE: 53+11.00 to 58+90.00 SHEET 15

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