Stormwater Management Study

Lake DeNeveu
Fond du Lac County, Wisconsin

Prepared For

FOND DU LAC COUNTY, WISCONSIN

AUGUST 18, 2017

McM. No. F0983-9-17-00160.02

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I. INTRODUCTION

Fond du Lac County retained McMahon Associates, Inc. (McMAHON) to evaluate stormwater runoff and identify implementation strategies to mitigate flooding concerns along the northeast shore of Lake DeNeveu. Lake DeNeveu is an 80 acre lake located along USH 45 in the Town of Empire. The lake shoreline is developed with residential homes and cottages, except the south portion which is wetlands and woodlands. Exhibit 1 depicts recent flooding of private property at the northeast corner of the lake, just downstream of the northern most USH 45 culvert.

Exhibit 1 – Flooding Downstream of USH 45 Culvert

Source: www.lakedeneveu.com

During 2018, the Wisconsin Department of Transportation (WisDOT) plans to resurface USH 45 between the City of Fond du Lac and Village of Eden, which includes the portion of USH 45 located east of Lake DeNeveu. The proposed resurfacing project does not widen the pavement or realign the highway, except at the intersection of CTH H and USH 45, which is being realigned in order to improve public safety and function. As part of the project, the WisDOT plans to replace culvert crossings along USH 45, which is a rural highway.

On behalf of the Town of Empire, the East Central Wisconsin Regional Planning Commission (ECWRPC) prepared a report to assist with assessing the causes and potential strategies for flooding improvements along the northeast shore of Lake DeNeveu. The report summarizes the issues and identifies some potential flood mitigation strategies to consider for the watershed. ECWRPC did not evaluate the flooding concerns, water quality concerns, or potential flood mitigation strategies. The ECWRPC report is titled "Lake DeNeveu Drainage Study and Action Plan" and is dated July 2015.

The purpose of this stormwater management study is to evaluate the feasibility and effectiveness of strategies identified in the ECWRPC report, including other strategies not identified in the ECWRPC report. The ECWRPC report identifies three (3) strategies: infrastructure and mitigation, watershed restoration, and policy / planning practices. Fond du Lac County desires that McMAHON's scope of recommendations be limited to flood and runoff mitigation at the northeast side of the lake. When evaluating the strategies, the County wants McMAHON to consider the ability to permit and receive approval for the projects.

To assist with the study, Fond du Lac County assembled a stakeholder group to assist with information gathering, observations, perspectives, expertise, and public input. The stakeholder group includes representatives from Fond du Lac County, Town of Empire, Wisconsin

Department of Natural Resources (DNR), WisDOT, Lake DeNeveu Association, and McMAHON. The stakeholder group includes the following individuals:

- Allen Buechel, County Executive – Fond du Lac County
- Erin Gerred, Director of Administration – Fond du Lac County
- Paul Tollard, County Conservationist – Fond du Lac County LWCD
- Fred Christ, Board Member – Lake DeNeveu Association
- Mary Toriello, Board Member – Lake DeNeveu Association
- Bryan Learst, Project Manager – WisDOT
- David Bolha, Water Resources Management Specialist – DNR
- Heidi Bunk, Water Resources Management Specialist – DNR
- Jared Seidl, Water Regulations and Zoning Specialist – DNR
- Jay Schiefelbein, Env. Analysis and Review Specialist – DNR
- Rob McLennan, NR Basin Supervisor – DNR
- Joe Hoechst, Project Engineer – McMAHON
- Nick Vande Hey, Project Manager – McMAHON

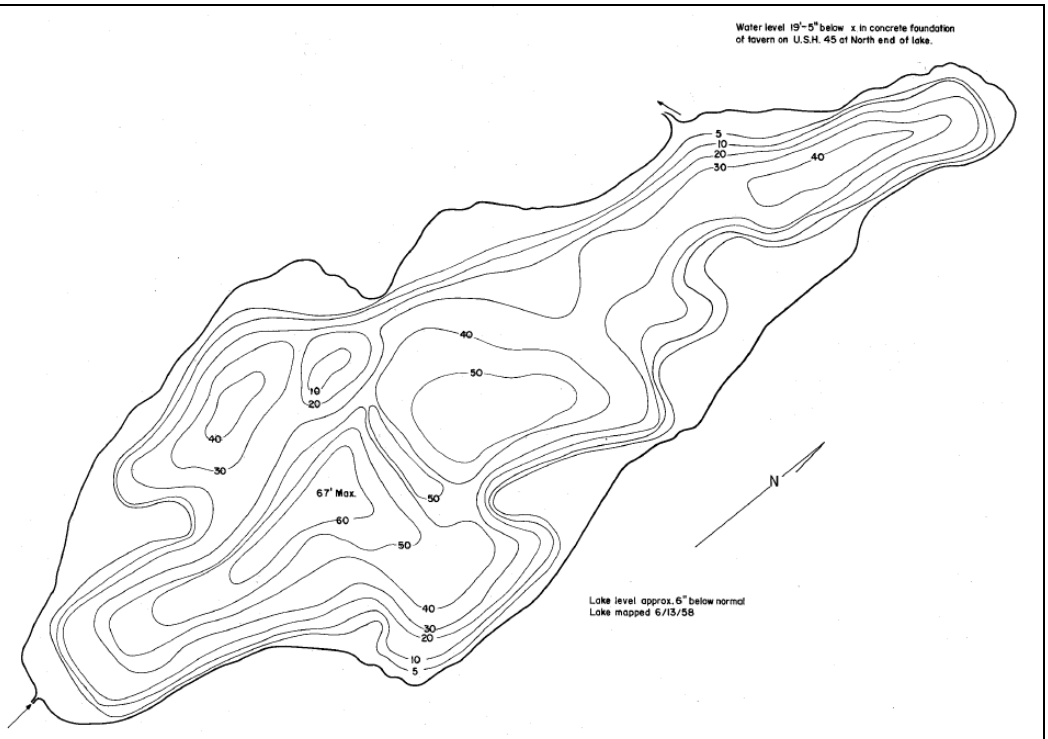
II. STUDY AREA

Figure 1 depicts the study area and watershed draining into Lake DeNeveu. The study area contains 649.6 acres or 1.02 square miles of property.

A. Lake DeNeveu

The DNR identifies Lake DeNeveu as a seepage lake. While a seepage lake typically does not have an outlet, Lake DeNeveu is drained by an unnamed tributary to DeNeveu Creek, which is located on the west side of the lake. As shown in Exhibit 2, the lake has a maximum depth of 67 feet.

Exhibit 2 – Lake DeNeveu Bathymetric Map



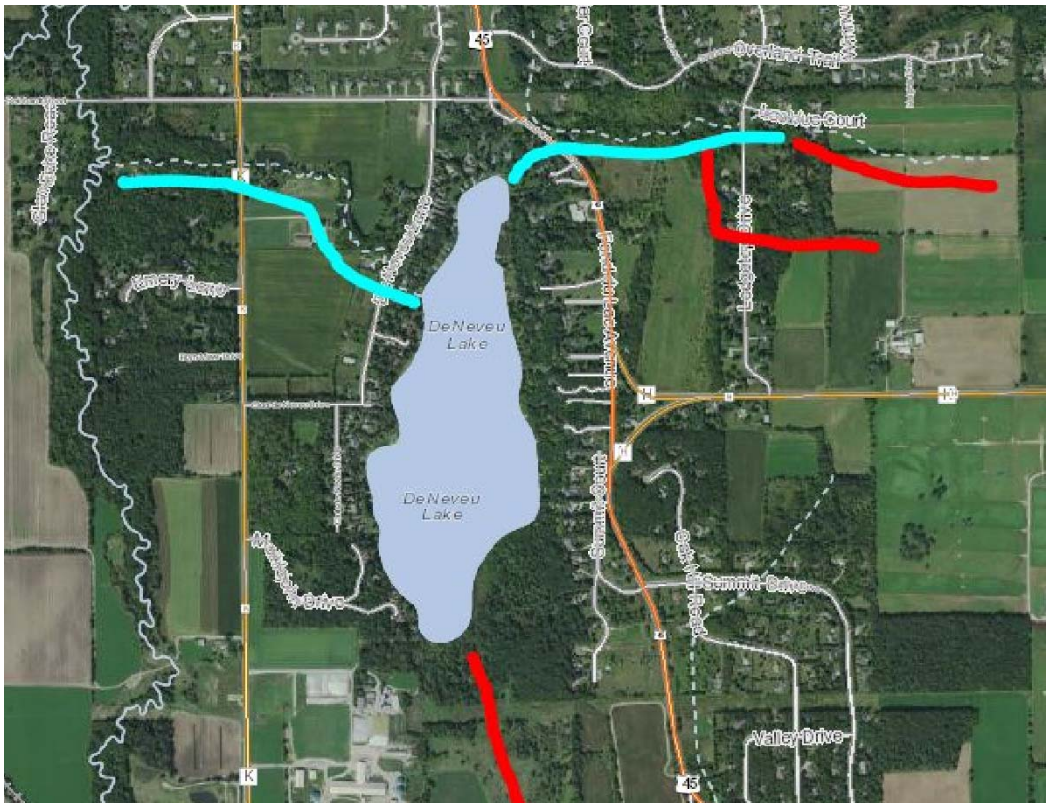
Source: Wisconsin DNR

The DNR indicates the lake bottom consists of 30% sand, 20% gravel, 0% rock, and 50% muck. Fish within Lake DeNeveu include Panfish (abundant), Largemouth Bass (common), Northern Pike (present), and Walleye (present).

B. Navigable Streams

McMAHON requested a navigability determination from DNR for waterways draining into and out of Lake DeNeveu. Exhibit 3 depicts the navigability map provided by the DNR. In Exhibit 3, the blue waterway segments are navigable streams and the red waterway segments are not navigable streams. DNR navigability determinations are typically valid for five (5) years.

Exhibit 3 – Navigable Streams



Source: DNR (2017)

C. Historic Drainage Patterns

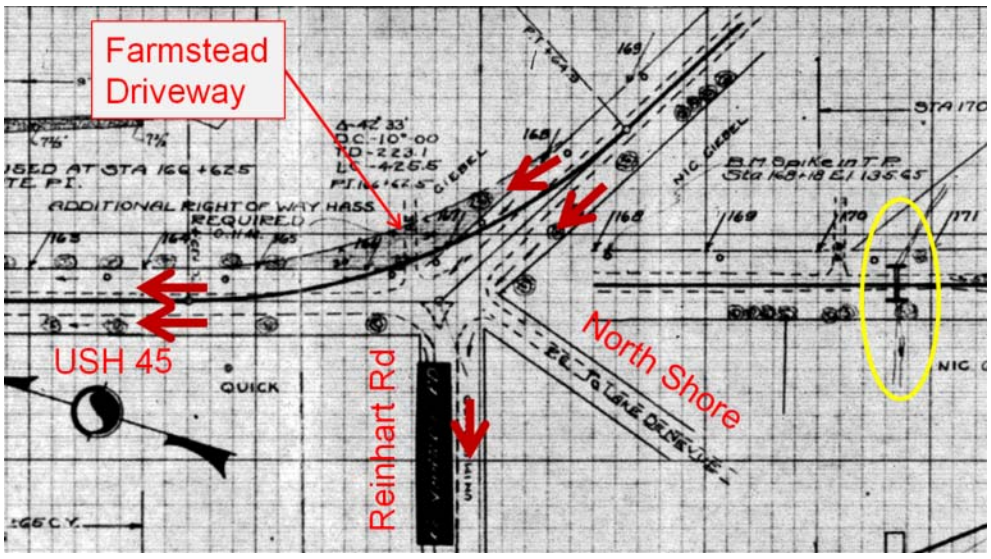
As part of the study, available documents were gathered to evaluate historical drainage patterns within the watershed. Documents included aerial photographs, United States Geological Survey (USGS) maps, DNR maps, WisDOT highway plans, County highway plans, and subdivision plans. Determining the historic stream channel alignment at the northeast corner of Lake DeNeveu was of particular interest to stakeholders. Below is a chronology of documents and associated observations.

- **1937** – Figure 6 depicts a 1937 photograph. Based on the 1937 photograph, a road surface is located within the USH 45 and CTH H right-of-ways, no road surface is located within the Ledgetop Drive and Overland Trail right-of-ways, very few residential homes are located along the east shore of Lake DeNeveu, no gravel pit is located along Ledgetop Drive, and an east-west farmstead driveway is located just east of the USH 45 and Reinhardt Road intersection.

- **1944** – Exhibit 4 depicts the WisDOT highway plans for USH 45, which are dated 1944. Based on the highway plans, an existing USH 45 cross culvert is located at station 170+69 (yellow circle), which is about 400 feet southeast of the USH 45 and Reinhardt Road intersection. At this location, a 36-inch diameter corrugated culvert

with a 16 foot length was identified for removal on the plans. The 36-inch culvert was replaced with a 6 foot by 4 foot concrete culvert with a 30 foot length. The USH 45 plans indicate the stream passing through the USH 45 culvert at station 170+69 flows to Lake DeNeveu. The USH 45 plans also indicate an east-west farmstead driveway is located just east of the USH 45 and Reinhardt Road intersection.

Exhibit 4 – USH 45 Plans (1944)



Source: WisDOT (1944)

Based on the highway plans, an existing USH 45 cross culvert was located at station 187+18, which is about 2,000 feet southeast of the USH 45 and Reinhardt Road intersection. The 14-inch diameter corrugated culvert is shown to be eliminated, such that runoff flows along the highway ditch to station 170+69.

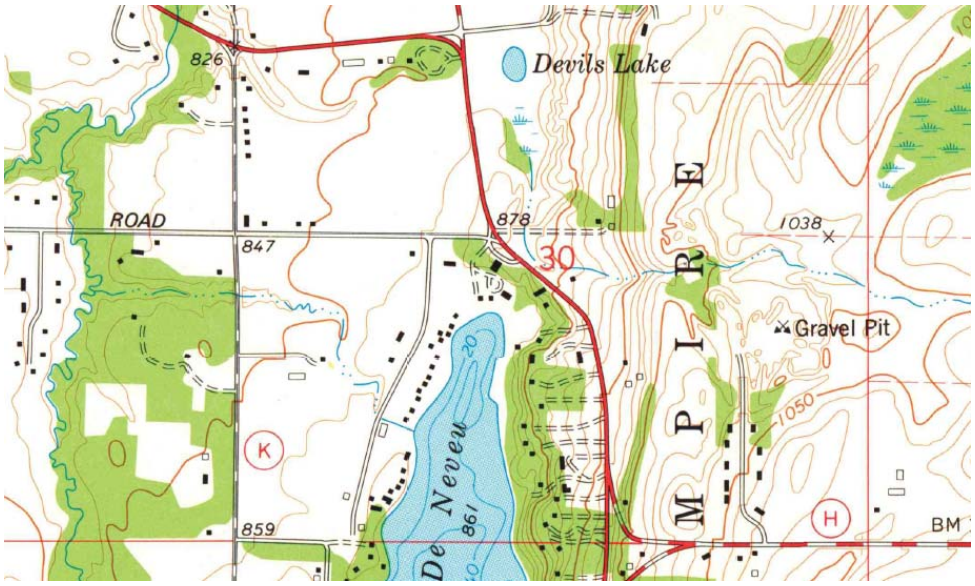
Based on the highway plans, an existing USH 45 cross culvert is located at station 193+64, which is about 2,700 feet southeast of the USH 45 and Reinhardt Road intersection. The 12-inch diameter corrugated culvert is identified for removal and replacement with a 2 foot by 2 foot concrete culvert with a 28 foot length.

Based on the highway plans, a new USH 45 cross culvert is proposed at station 204+50, which is about 3,800 feet southeast of the USH 45 and Reinhardt Road intersection. The culvert is a 2 foot by 2 foot concrete culvert with a 28 foot length.

- **1972** – Figure 5 depicts a 1972 photograph. Based on the 1972 photograph, no road surface is located within the Overland Trail right-of-way, a road is located within the south portion of the Ledgetop Drive right-of-way, a gravel pit is located north of the houses along Ledgetop Drive, many residential homes are now located along the east shore of Lake DeNeveu, and an east-west farmstead driveway is located just east of the USH 45 and Reinhardt Road intersection (same driveway as 1937 photo).

- **1974** – Exhibit 5 depicts the 1974 USGS map. Based on the map, the northeast waterway flows north across the farmstead driveway and into Devils Lake, rather than through the USH 45 culvert and into Lake DeNeveu. A gravel pit is depicted.

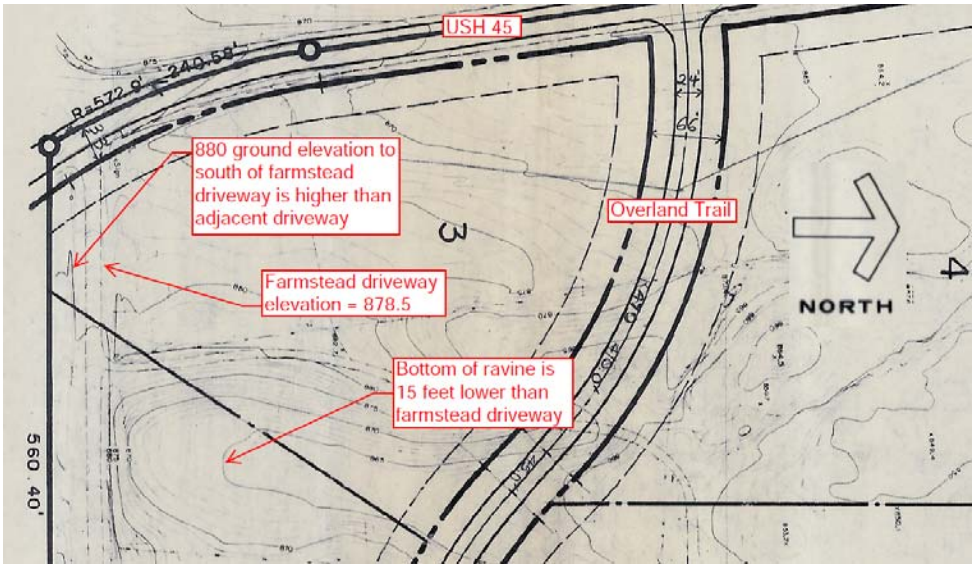
Exhibit 5 – USGS Quadrangle Map (1974)



Source: USGS (1974)

- **1978** – Exhibit 6 depicts the preliminary plat for the Overland Heights Subdivision. Based on the preliminary plat, the ground elevations to the south of the farmstead driveway are ± 1.5 feet higher than the adjacent driveway in 1978. The ground elevations also indicate a swale paralleled the south side of the farmstead driveway. No farmstead driveway culverts are shown on the preliminary plat.

Exhibit 6 – Overland Heights Preliminary Plat (1978)



Source: Fond du Lac County (1978)

- **1990** – Figure 4 depicts a 1990 photograph. Based on the 1990 photograph, a road surface is located within the Overland Trail and Ledgetop Drive right-of-ways. A pond is located within the former gravel pit along Ledgetop Drive. Low areas are visible within the cropland that is located east of Ledgetop Drive.

- **2000** – Figure 3 depicts a 2000 photograph. Based on the 2000 photograph, a road surface is located along the cul de sac associated with the Overland Trail right-of-way, including new residences. In addition, a new residential driveway and home are located east of the USH 45 and Reinhardt Road intersection. Low areas are visible within the cropland that is located east of Ledgetop Drive.

- **2010** – Figure 2 depicts a 2010 photograph. Based on the 2010 photograph, a road surface is located along the Lac Vue Court right-of-way, including new residences. In addition, a new residential home is located along the east side of Ledgetop Drive, just south of the pond. Low areas are visible within the cropland that is located east of Ledgetop Drive.

- **2015** – Exhibit 7 depicts the 2015 USGS map. Based on the map, the waterway at the northeast corner of Lake DeNeveu flows north across a residential driveway and into Devils Lake, rather than through the USH 45 culvert and into Lake DeNeveu.

Exhibit 7 – USGS Quadrangle Map (2015)

Source: USGS

Based on the above chronology, it is McMAHON's opinion that the stream at the northeast corner of Lake DeNeveu is not depicted correctly on the 1974 and 2015 USGS maps. It is McMAHON's opinion that the USH 45 plans clearly indicate that a large cross culvert was removed and replaced at station 170+69 in 1944 and that the stream flowed through the USH 45 culvert to Lake DeNeveu, rather than to Devils Lake. Also, stakeholders agree that the northeast stream flowed through the USH 45 culvert to Lake DeNeveu during 2015, despite being depicted on the 2015 USGS map as flowing to Devils Lake. In other communities, McMAHON has observed streams incorrectly depicted on USGS maps as well.

D. Watershed

1972 was selected as the historical point of reference for this study. The 1972 drainage areas are based on the 1972 aerial photograph and the contours provided on 1974 USGS quadrangle map. The drainage areas for DeNeveu Creek are based on the Total Maximum Daily Load (TMDL) sub-basin boundary provided by the DNR. The 1972 drainage areas are depicted in Figure 7.

2015 was selected as the current condition for this study. Within the study area, the 2015 drainage areas are based on the LiDAR contours provided by Fond du Lac County. The drainage areas for DeNeveu Creek are based on the Total Maximum Daily Load (TMDL) sub-basin boundary provided by the DNR. The 2015 drainage areas are depicted in Figure 8.

Culverts currently located within the watershed are depicted in Figure 8. More detailed information for six of these culverts is summarized in Table 1. The Table 1 information was derived from field observations, LiDAR, and available plans. About 1 foot sediment has accumulated in Culvert CV-D2a since 1944.

Table 1 – Culverts

Culvert ID	Location	Culvert Size	Culvert Material	Top Road Elev. (ft)	US Invert Elev. (ft)	DS Invert Elev. (ft)
CV-D2a	USH 45	6'x3'	Conc. Box	887.5	881.0	880.5
CV-D2b	Ledgetop Dr	24"	CMP	1021.2	1015.8	1015.0
CV-D2d	Ledgetop Dr	36"	CMP	1035.7	1020.8	1019.5
CV-D3	USH 45	30"	CMP	953.5	950.8	950.0
CV-D4	USH 45	24"	CMP	964.5	961.0	960.8
CV-D5	USH 45	30"	CMP	975.8	970.0	968.0

E. Soils

Soil information was obtained from the U.S. Department of Agriculture, National Resource Conservation Service (NRCS) Soil Survey. NRCS hydrologic soil groups are depicted in Figure 9. Soils within the study area are summarized in Table 2. The NRCS has classified soil types into four (4) Hydrologic Soil Groups (HSG). The four (4) hydrologic soil groups (i.e. A, B, C, and D) are classified according to the minimum infiltration rate of the soil column. Group A soils have the highest infiltration rate or lowest runoff potential, whereas Group D soils have the lowest infiltration rate or highest runoff potential.

Table 2 – NRCS Soil Information

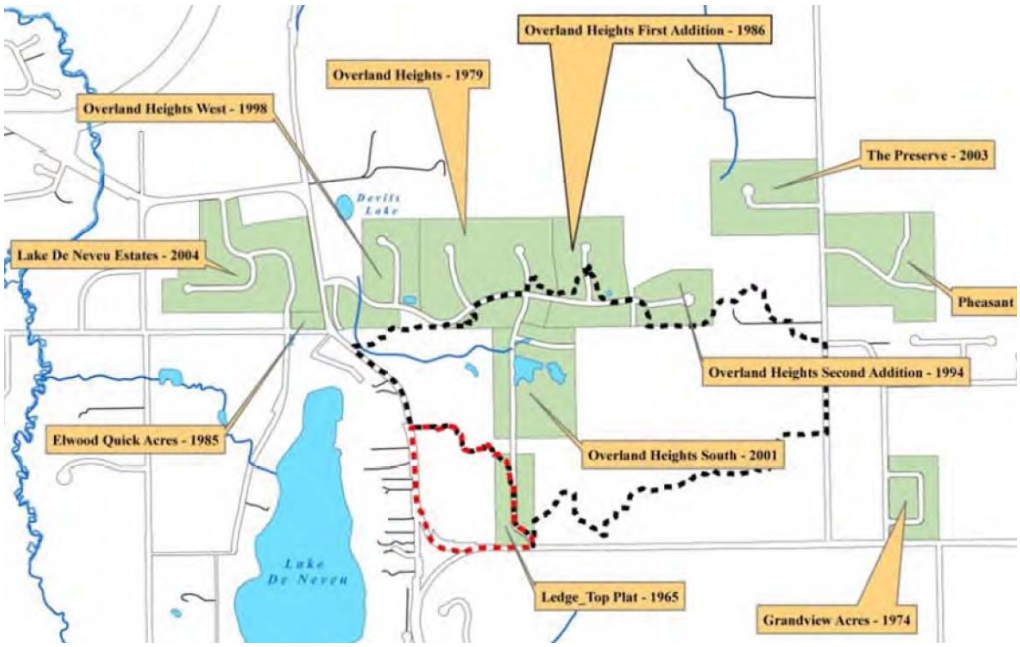
Soil Name	Soil Map Symbol	Soil Texture	HSG	Area (acres)	Percent of Study Area (%)
Adrian	Ak	Mucky peat	D	22.7	3.5%
Ashkum	AtA	Silty clay loam	D	8.0	1.2%
Beecher	BcB	Silt loam	D	75.3	11.6%
Brookston	BsA	Silt loam	D	1.2	0.2%
Dodge	DdB	Silt loam	C	17.2	2.7%
-	GP	Gravel pit	C	4.6	0.7%
Hochheim	HmC2	Loam	D	11.5	1.8%
Hochheim	HmD2	Loam	D	1.1	0.2%
Hochheim	HoC3	Soils	B	6.3	1.0%
Hochheim	HoD3	Soils	B	12.2	1.9%
Hochheim	HoE3	Soils	B	1.6	0.3%
Houghton	Hu	Mucky peat	D	18.0	2.8%
Juneau	JuA	Silt loam	D	1.3	0.2%
Knowles	KwC2	Silt loam	C	5.4	0.8%
Knowles	KwE2	Silt loam	C	3.5	0.5%
Lamartine	LmB	Silt loam	B	8.4	1.3%
Mayville	MoB	Silt loam	C	11.6	1.8%
Morley	MzdB	Silt loam	C	31.5	4.9%
Morley	MzdB2	Silt loam	C	32.7	5.0%
Morley	MzdC2	Silt loam	C	5.6	0.9%
Morley	MzdD2	Silt loam	C	51.0	7.9%
Morley	MzeD3	Soils	C	28.9	4.5%
Palms	Pc	Mucky peat	D	2.4	0.4%
St. Charles	ScA	Silt loam	B	12.0	1.9%
Theresa	ThB	Silt loam	C	37.3	5.7%
Theresa	ThB2	Silt loam	C	72.8	11.2%
Theresa	ThC	Silt loam	C	10.2	1.6%
Theresa	ThC2	Silt loam	C	58.6	9.0%
Theresa	ThD2	Silt loam	C	2.9	0.5%
Theresa	TrD3	Soils	C	1.8	0.3%
Virgil	VgA	Silt loam	D	11.4	1.8%
-	W	Water	D	80.6	12.4%
Total				649.6	100.0%

F. Land Uses

Land uses, impervious surfaces (i.e. roofs, driveways, roads, etc.), vegetation, and soil compaction can influence flooding, infiltration volumes, runoff volumes, peak discharge rates, and water quality. For example, the addition of impervious surfaces can reduce infiltration into underlying soils and increase runoff volume. Similar hydrologic changes

occur when woodlands or wetlands are converted to agriculture or if soils are compacted as compared to historic levels. Exhibit 8 identifies some of these land use changes, such as new subdivisions.

Exhibit 8 – Subdivision Plats (1965-2004)



Source: ECWRPC

Although multiple options existed, year 1972 was selected as the historical point of reference for this study. Year 1972 was selected due to the availability of a good quality aerial photograph that was close in date to the 1974 USGS map, which provided contours. The 1972 land uses are depicted in Figure 10 and summarized in Table 3.

Table 3 – Land Uses

Land Uses	1972 (acres)	2015 (acres)	Change (%)
Agriculture	239.7	168.2	-30%
Commercial	2.5	2.5	0%
Farmstead	10.2	18.6	82%
Grass	115.3	62.6	-46%
Road / Highway	19.9	30.9	55%
Residential	61.1	162.9	167%
Water	87.7	87.9	0%
Wetlands	32.5	32.4	0%
Woods	76.5	83.6	9%
Total	645.4	649.6	1%

2015 was selected as the current condition for this study. Within the study area, the 2015 land uses are based on the most recent aerial photograph from Fond du Lac County. The 2015 land uses are depicted in Figure 11 and summarized in Table 3.

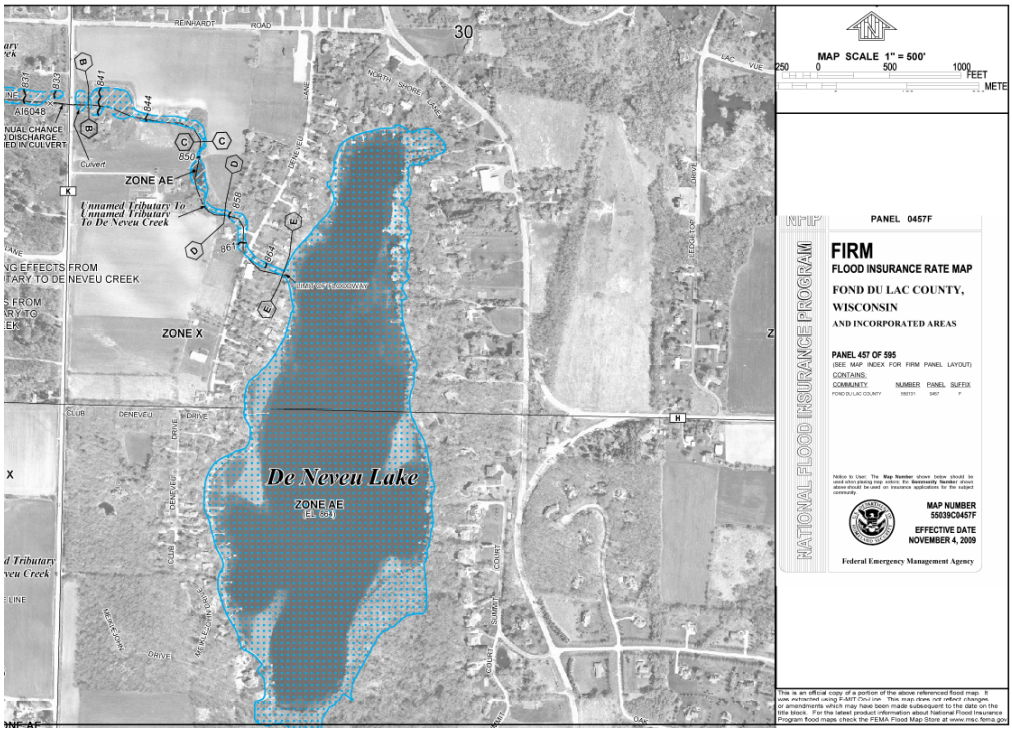
As shown Table 3, the residential, farmstead, and road land uses increased by 167, 82, and 55 percent, respectively. Grass and agriculture land uses decreased by 46 and 30 percent, respectively. These land use changes increased the amount of impervious surface within the Lake DeNeveu watershed.

The Town of Empire adopted a new Comprehensive Plan in 2007. According to the plan, the majority of land uses within the study area are to remain unchanged in the future.

G. FEMA 100-Year Floodplain

As shown in Exhibit 9, the Federal Emergency Management Agency (FEMA) mapped a 100-year floodplain for Lake DeNeveu, including the stream located west of Lake DeNeveu. No regulatory 100-year floodplain is mapped along the streams located east of Lake DeNeveu.

Exhibit 9 – FEMA 100-Year Floodplain



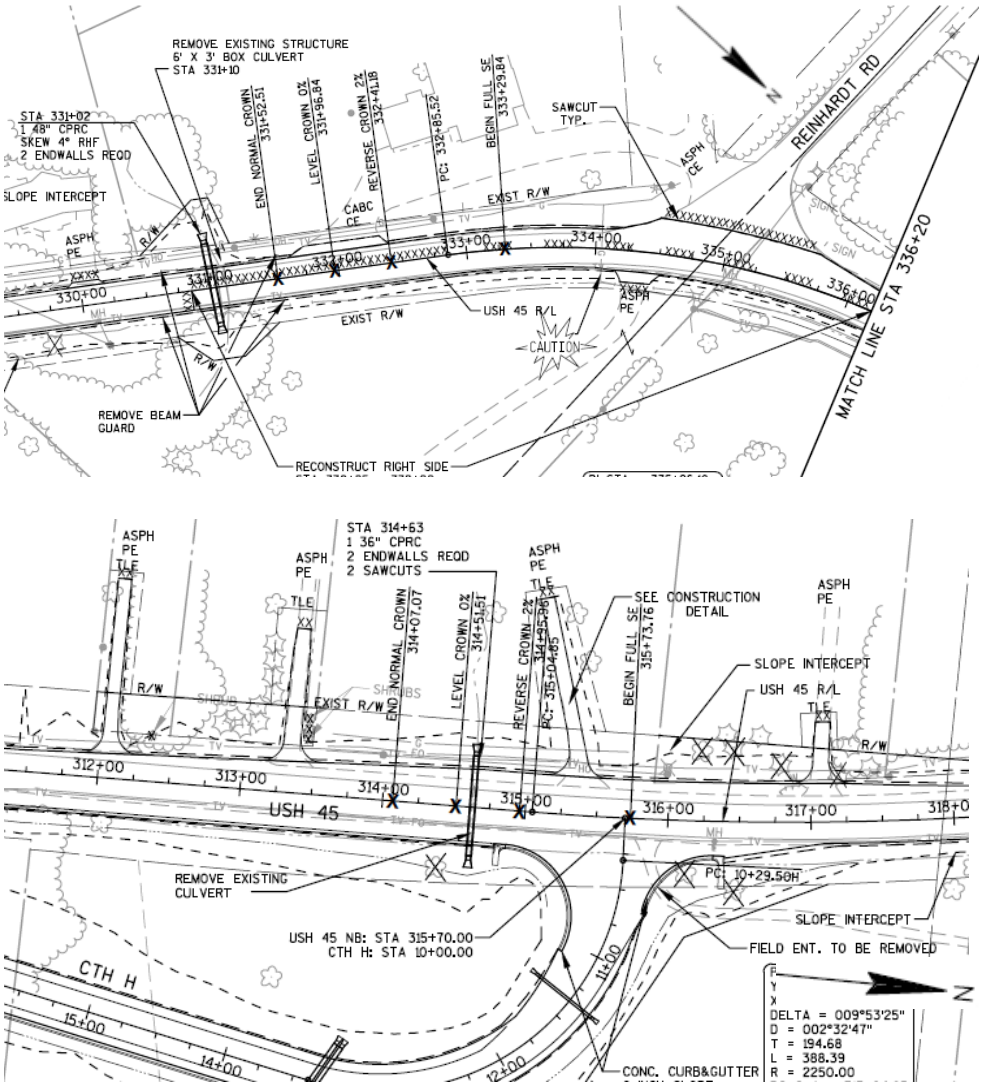
Source: FEMA

H. Proposed USH 45 Plans

The WisDOT intends to resurface USH 45 between the City of Fond du Lac and Village of Eden. The proposed project does not widen the pavement or alignment of the highway, but the intersection of CTH H and USH 45 is to be realigned in order to improve public safety and function. This work by the WisDOT is planned for construction during 2018.

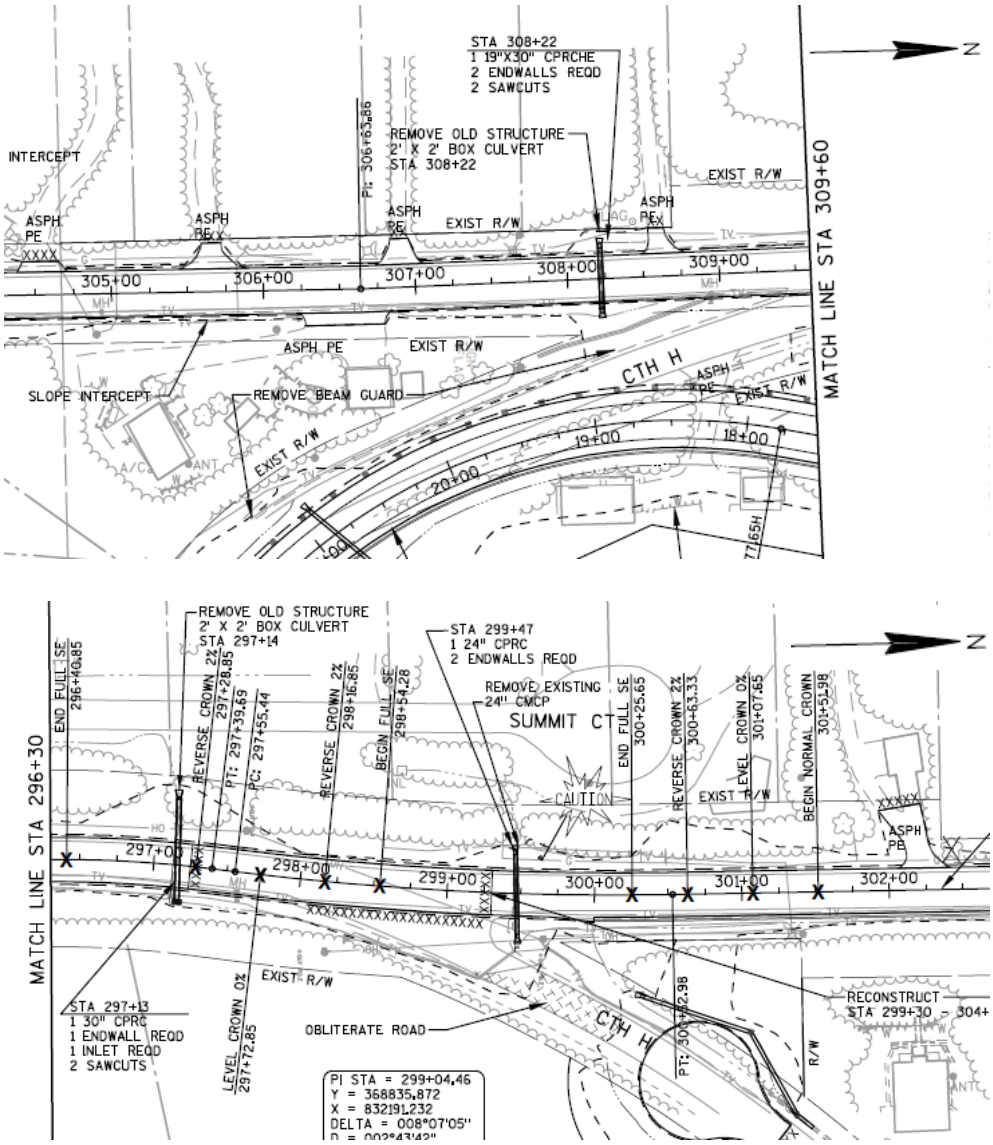
Exhibit 10 indicates the existing 6'x3' concrete box culvert (18 square feet) along USH 45 is to be removed and replaced with a 48-inch reinforced concrete culvert (12.5 square feet). As indicated in Exhibit 4, the 1944 highway plans indicate this existing culvert is a 6'x4' concrete box culvert (24 square feet). The proposed 48-inch culvert is 30% smaller than the 6'x3' concrete box culvert and 48% smaller than the 6'x4' concrete box culvert.

Exhibit 10 – USH 45 Upgrades



Source: WisDOT Plans

Exhibit 11 – USH 45 Upgrades



Source: WisDOT Plans

I. Groundwater & Bedrock

Groundwater interacts with surface water within the study area. An existing spring-fed pond is located at the top of the escarpment, just east of Ledgetop Drive. Based on stakeholder observations, this spring provides a small, but constant flow of water into the northeast stream. In addition, stakeholders indicated numerous springs and seeps emanate from the bedrock along the Niagara Escarpment. Exhibit 12 depicts areas where groundwater is within 2 feet of the ground surface and bedrock is within 5 feet of the ground surface. No drain tile information is available for the study area.

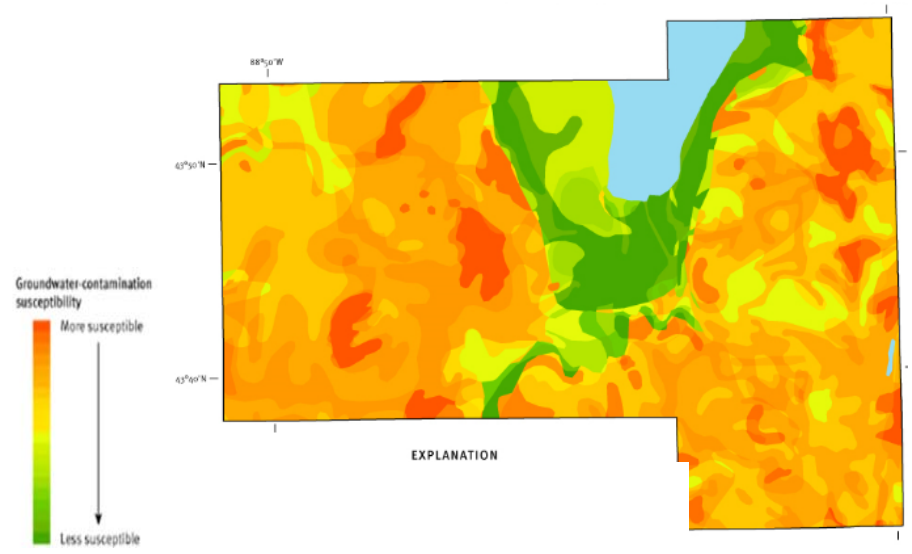
Exhibit 12 – Depth to Groundwater & Bedrock

Source: ECWRPC

J. Groundwater Susceptibility

In order to help identify areas sensitive to groundwater contamination, the DNR developed a composite Groundwater Contamination Susceptibility Map, which is depicted in Exhibit 13. The map can be used to determine potential groundwater problems. The map doesn't show areas that will be contaminated, or areas that cannot be contaminated. Susceptibility of groundwater to pollutants is defined here as the ease with which a contaminant can be transported from the land surface to the top of the groundwater table. Many materials that overlie the groundwater offer good protection from contaminants that might be transported by infiltrating waters. The amount of protection offered by the overlying material varies, however, depending on the materials. Thus, in some areas, the overlying soil and bedrock materials allow contaminants to reach the groundwater more easily than in other areas.

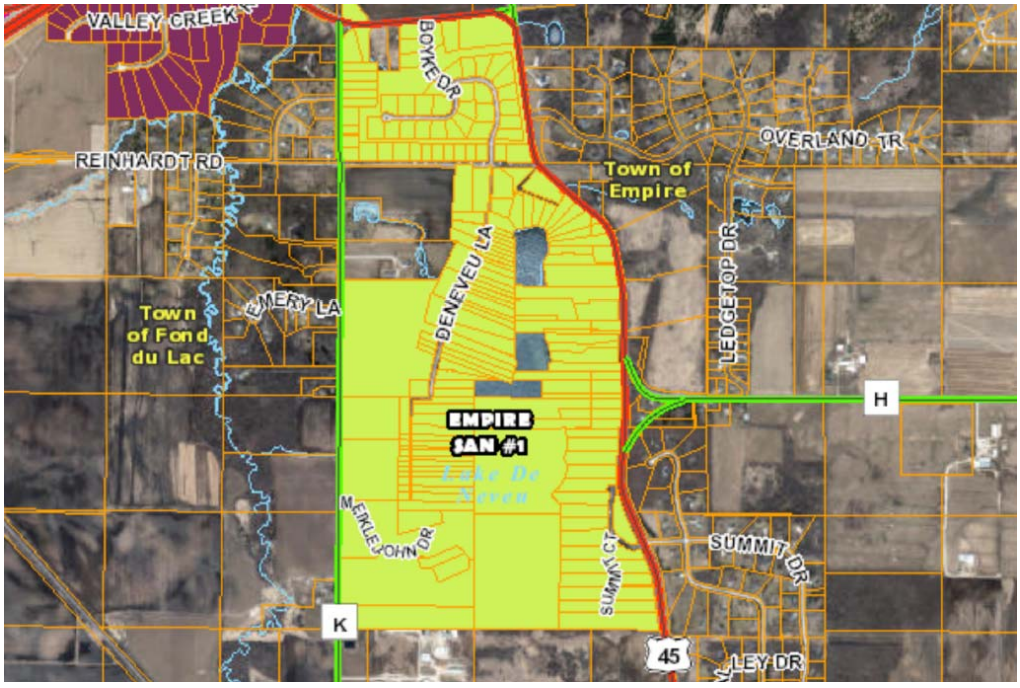
Exhibit 13 – Groundwater Contamination Susceptibility Map for Fond du Lac County



Source: Protecting Wisconsin's Gro undwater Through Comprehensive Planning

Exhibit 14 identifies residential properties served by public sanitary sewers within the Empire Sanitary District #1. Residential properties located east of USH 45 appear to be served by private septic systems.

Exhibit 14 – Empire Sanitary District #1 Sanitary Sewer Service Area



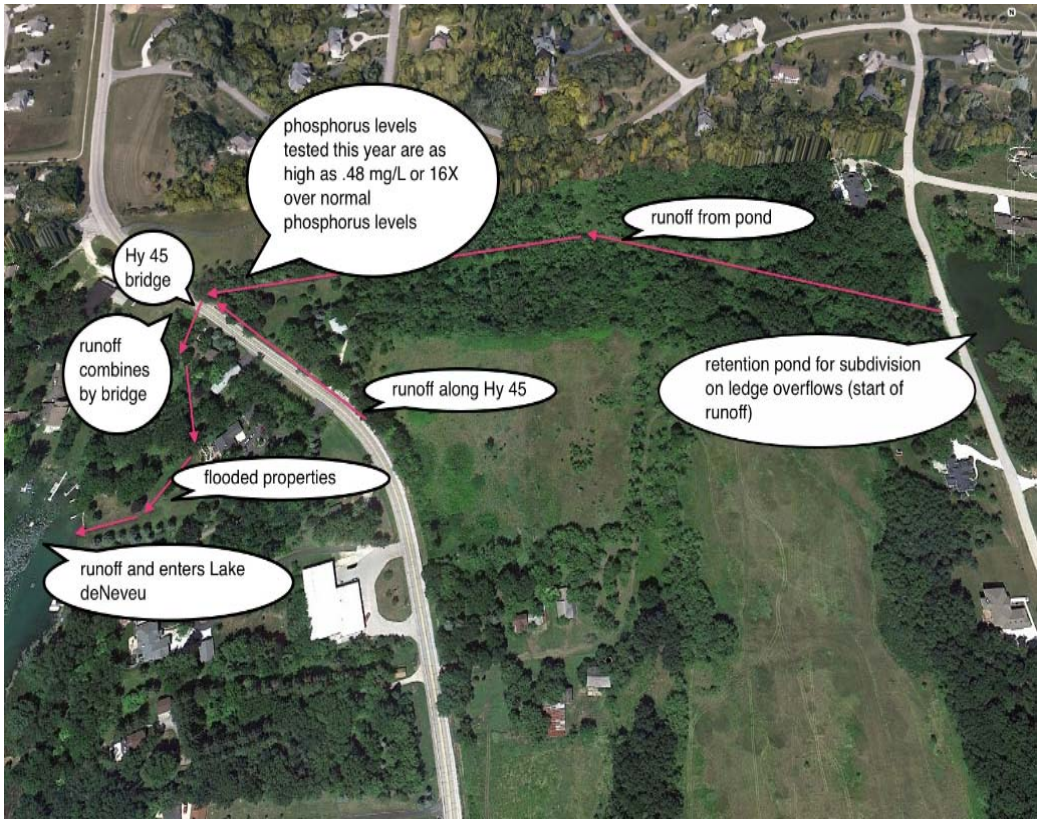
Source: Fond du Lac County GIS

K. Surface Water Quality

The East Branch of DeNeveu Creek is currently a 303(d) listed water body through the Clean Water Act. The East Branch of DeNeveu Creek is impaired by elevated water temperature and degraded habitat and the pollutant of concern is total phosphorus. Based on information from the DNR, DeNeveu Creek is proposed for 303(d) listing due to excess total phosphorus. The DNR is currently developing a Total Maximum Daily Load (TMDL) for the Upper Fox River Basin to address excess total phosphorus and total suspended solids within DeNeveu Creek, East Branch of DeNeveu Creek, Lake Winnebago, and other water bodies located within the Upper Fox River Basin.

The DeNeveu Lake Association and DNR have been monitoring water quality within Lake DeNeveu for the past seven (7) to nine (9) years. Exhibit 15 summarizes the DeNeveu Lake Association's phosphorus sampling results for the northeast stream at the USH 45 culvert crossing.

Exhibit 15 – Lake DeNeveu Water Quality



Source: Lake DeNeveu Association (www.lakedeneveu.com)

III. HYDROLOGIC & HYDRAULIC ANALYSIS

A. Methodology

The hydrologic and hydraulic analysis was performed using XP's Stormwater Management Model (XP-SWMM version 18.1). XP-SWMM is a dynamic computer program capable of modeling complex watersheds and stormwater conveyance systems. The XP-SWMM runoff module and the U.S. Department of Agriculture, Natural Resource Conservation Service (NRCS) Technical Release 55 hydrologic method were used to simulate the rainfall - runoff process. The TR-55 methodology requires that various hydrologic parameters be developed for each drainage area. These hydrologic parameters include drainage area size, runoff curve number, and time of concentration. Runoff hydrographs were developed for each drainage area. The hydrographs include information such as peak flow rates, time of peak flow rates, and runoff volumes.

The XP-SWMM hydraulics module was used to combine, split, and route each runoff hydrograph through the stormwater conveyance system. The stormwater conveyance system is comprised of a network of streams, ditches, culverts, overland flow paths, and detention facilities. Combined, the individual components convey surface runoff through the stormwater conveyance system.

B. Rainfall

Rainfall information was obtained from Chapter 2 of the USDA Natural Resources Conservation Service (NRCS) Engineering Field Handbook Notice 210-WI-132, "Estimating Runoff and Peak Discharges" and represents a mean rainfall depth for Fond du Lac County. The 24-hour rainfall depths are summarized in Table 4. The NRCS 24-hour, MSE4 rainfall distribution was used for this study.

Table 4 – 24-Hour Rainfall Depth

Rainfall Event	Rainfall Depth (inches)
2-Year	2.55
10-Year	3.69
100-Year	6.16

C. Runoff Curve Number

A composite runoff curve number was computed for each drainage area and land use condition. Runoff curve number computations were based on land uses, vegetation, percent imperviousness, and hydrologic soil groups. For this study, the following assumptions were used to compute composite runoff curve numbers: average antecedent moisture condition, average runoff condition, good hydrologic condition for pervious areas, and directly connected impervious areas. Impervious areas were assumed to have a curve number of 98 and pervious grass areas were assumed to have

a curve number of 74 (HSG C). Curve numbers for the agriculture land use were determined based upon a seven year dairy crop rotation. The runoff curve numbers (RCN) for each drainage area and land use condition are summarized in Table 5.

D. Time of Concentration

Times of concentrations were computed for each drainage area and land use condition. Time of concentration is defined as the time it takes runoff to travel from the hydraulically most distant point of the drainage area to a downslope point of interest. Time of concentration calculations are typically comprised of three (3) segments or flow regimes: sheet flow, shallow concentrated flow, and open channel flow. The time of concentration influences the shape and peak flow rate of the drainage area's runoff hydrograph. The time of concentrations (Tc) for each drainage area and land use condition are summarized in Table 5.

E. Hydrologic Parameters

The hydrologic parameters for each drainage area and land use condition are summarized in Table 5. As shown in Table 5, the 2015 study area is 4.2 acres larger than the 1972 study area, which is a result of drainage area changes along Overland Trail.

Table 5 – Hydrologic Parameters

Drainage Area ID	1972 Land Use			2015 Land Use		
	Area (acres)	RCN	Tc (min)	Area (acres)	RCN	Tc (min)
D1	347.2	83	121	347.2	84	121
D2a	107.5	79	65	57.6	75	44
D2b	20.6	77	30	74.8	80	57
D2c	51.8	82	53	51.8	81	53
D2d	32.4	82	40	32.4	81	40
D2e	31.1	83	33	31.1	82	33
D3	28.5	80	23	28.5	74	23
D4	4.6	80	25	4.6	82	25
D5	21.7	75	37	21.7	79	37
Study Area	645.4			649.6		
N1	5,665.6	81	1,140	5,665.6	81	1,140
N2	62.8	83	69	62.8	83	69
V1a	85.2	77	45	85.2	77	45
V1b	63.3	76	47	63.3	76	47

F. Peak Water Surface Elevation Results

The 1972 peak water surface elevations are based on the 1972 hydrologic parameters and the 1972 hydraulic conveyance system. The upstream (US) peak water surface elevations for the 1972 condition are summarized in Table 6. For reference, the points of interest and flooding limits associated with Table 6 are depicted in Figure 12.

Table 6 – Peak Water Surface Elevations (1972 Condition)

Point of Interest	Location	US Culvert Elev. (ft)	Overland Elev. (ft)	US Peak Water Elev. (ft)		
				2-Year	10-Year	100-Year
1	Reinhardt Rd.	815.7	827.0	820.6	821.8	822.7
2	CTH K	832.3	845.8	833.6	834.0	834.6
3	Lake DeNeveu	-	-	862.6	863.0	864.0
4	USH 45	881.0	886.0	884.1	887.0	887.4
5	Ledgetop Dr.	-	-	1009.6	1010.0	1010.5
6	Low Area	-	1062.5	1063.1	1063.4	1063.8
7	Ledgetop Dr.	1020.8	1034.0	1022.4	1024.4	1029.7
8	Low Area	-	1051.5	1051.7	1051.9	1052.2
9	USH 45	950.8	953.5	953.3	953.4	953.6
10	USH 45	961.0	963.0	962.0	962.4	963.8
11	USH 45	970.0	976.3	971.4	972.6	974.5
12	Devils Lake	-	850.0	845.9	848.0	850.2

The 2015 peak water surface elevations are based on the 2015 hydrologic parameters and the 2015 hydraulic conveyance system. The upstream peak water surface elevations for the 2015 condition are summarized in Table 7. For reference, the points of interest and flooding limits associated with Table 7 are depicted in Figure 13.

Table 7 – Peak Water Surface Elevations (2015 Condition)

Point of Interest	Location	US Culvert Elev. (ft)	Overland Elev. (ft)	Peak Water Surface Elev. (ft)		
				2-Year	10-Year	100-Year
1	Reinhardt Rd.	815.7	827.0	820.6	821.8	822.7
2	CTH K	832.3	845.8	833.6	834.0	834.6
3	Lake DeNeveu	-	-	862.6	863.1	864.1
4	USH 45	881.0	886.0	883.3	886.6	887.4
5	Ledgetop Dr.	-	1021.2	1020.9	1021.7	1022.2
6	Low Area	-	1062.5	1063.1	1063.4	1063.8
7	Ledgetop Dr.	1020.8	1034.0	1022.2	1024.2	1029.6
8	Low Area	-	1051.5	1051.7	1051.9	1052.2
9	USH 45	950.8	953.5	952.6	953.4	953.5
10	USH 45	961.0	963.0	962.0	962.5	963.8
11	USH 45	970.0	976.3	971.7	973.1	974.5
12	Devils Lake	-	850.0	845.9	848.0	850.2

G. Peak Discharge Results

The 1972 peak discharges are based on the 1972 hydrologic parameters and the 1972 hydraulic conveyance system. Similarly, the 2015 peak discharges are based on the 2015 hydrologic parameters and the 2015 hydraulic conveyance system. A comparison of downstream peak discharges for the 1972 and 2015 conditions are summarized in Table 8. For reference, the points of interest and flooding limits associated with Table 8 are depicted in Figures 12 and 13.

Table 8 – Peak Discharge Comparison (1972 vs. 2015)

Point of Interest	Location	1972 Peak Discharge (cfs)			2015 Peak Discharge (cfs)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
1	Reinhardt Rd.	282	559	1,254	282	559	1,255
2	CTH K	31	60	127	31	60	127
3	Lake DeNeveu	1	6	26	1	6	27
4	USH 45	84	169	360	56	125	361
5	Ledgetop Dr.	11	25	60	30	76	266
6	Low Area	19	43	99	17	41	96
7	Ledgetop Dr.	25	66	97	21	63	97
8	Low Area	12	31	51	10	30	50
9	USH 45	23	47	104	14	35	88
10	USH 45	4	7	16	4	8	17
11	USH 45	9	21	53	12	26	59
12	Devils Lake	0	0	32	0	0	18

H. Peak Velocity Results

The 1972 peak stream velocities are based on the 1972 hydrologic parameters and the 1972 hydraulic conveyance system. Similarly, the 2015 peak velocities are based on the 2015 hydrologic parameters and the 2015 hydraulic conveyance system. A comparison of downstream peak velocities for the 1972 and 2015 conditions are summarized in Table 9. For reference, the points of interest and flooding limits associated with Table 9 are depicted in Figures 12 and 13.

Table 9 – Peak Stream Velocity Comparison (1972 vs. 2015)

Point of Interest	Location	1972 Peak Velocity (fps)			2015 Peak Velocity (fps)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
1	Reinhardt Rd.	1.6	2.1	3.1	1.6	2.1	3.1
2	CTH K	2.8	2.9	3.6	2.8	2.9	3.6
4	USH 45	5.3	6.6	8.7	4.6	6.0	8.7

I. Peak Storage Volume Results

The 1972 peak storage volumes are based on the 1972 hydrologic parameters and the 1972 hydraulic conveyance system. Similarly, the 2015 peak storage volumes are based on the 2015 hydrologic parameters and the 2015 hydraulic conveyance system. A comparison of upstream peak storage volumes for the 1972 and 2015 conditions are summarized in Table 10. For reference, the points of interest and flooding limits associated with Table 10 are depicted in Figures 12 and 13.

Table 10 – Peak Storage Volume Comparison (1972 vs. 2015)

Point of Interest	Location	1972 Storage Vol. (ac-ft)			2015 Storage Vol. (ac-ft)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
3	Lake DeNeveu	48.9	90.6	184.9	49.7	93.1	186.8
5	Ledgetop Dr.	-	-	-	2.1	4.7	6.4
6	Low Area	1.1	1.8	3.2	1.1	1.8	3.2
8	Low Area	1.1	1.4	2.0	1.0	1.4	2.0

J. Results Comparison (1972 vs. 2015)

Below are a few observations when comparing the 1972 and 2015 results:

- At Point of Interest 4, the 2-year and 10-year peak discharges are lower during 2015, as compared to 1972, due to construction of the pond along the east side of Ledgetop Drive. The 100-year peak discharge is essentially unchanged at this location since the Ledgetop Drive road surface is overtopped during the 100-year rainfall event.

- At Point of Interest 9, the 2-year, 10-year and 100-year peak discharges are lower during 2015, as compared to 1972, due to conversion of cropland to grassland within Drainage Area D3.

IV. WATER QUALITY ANALYSIS

A. Methodology

The SNAP-Plus (Soil Nutrient Application Planner) software was used to evaluate phosphorus reductions for cropland best management practices (BMPs). The SNAP-Plus software is used by cropland producers to manage nutrients, particularly as it relates to manure and fertilizer applications. SNAP-Plus is also used to estimate potential phosphorus discharges associated with surface runoff and evaluate phosphorus reduction benefits of BMPs such as tillage (conventional, mulch till, zone till, and no till) and cover crops.

V. ALTERNATIVES ANALYSIS

For this Lake DeNeveu study, three (3) stormwater alternatives were evaluated with computer models. The three (3) alternatives were selected after considering Fond du Lac County goals, stakeholder concerns, implementation costs, and the feasibility of obtaining regulatory permits. Other alternatives were considered for the study, but were not modeled. Each of the three (3) alternatives is summarized herein, including modeling results.

A. Alternative 1

Alternative 1 is depicted in Figure 14. Alternative 1 consists of 3,600 feet of 54-inch storm sewer along Reinhardt Road. The 54-inch storm sewer is a high flow by-pass for the stream located at the northeast corner of Lake DeNeveu. At USH 45, high stream flows are diverted into the 54-inch storm sewer and then discharged into the Reinhardt Road stream crossing, which is located 1,400 feet west of CTH K. Low stream flows are to continue through the USH 45 culvert crossing, which is a navigable stream based on Exhibit 3. Maintaining low flows in the stream channel will likely be a DNR Chapter 30 Permit requirement. The 54-inch storm sewer is proposed to be 1 foot higher than the stream bed elevation on the east side of the USH 45 culvert and then drop several feet into a storm manhole. Along Reinhardt Road, the 54-inch storm sewer is anticipated to be about 8 feet below the ditch bottom. Alternative 1 also includes 1,700 linear feet of 24-inch storm sewer along USH 45, between culvert CV-D2a and culvert CV-D3. The 24-inch storm sewer is designed to convey stormwater runoff to the 54-inch storm sewer. Lastly, Alternative 1 assumes cropland located within the study area (168 acres) is converted from conventional tillage to mulch tillage with cover crops.

Table 11 summarizes peak water surfaces elevations for Alternative 1.

Table 11 – Peak Water Surface Elevations (Alternative 1)

Point of Interest	Location	US Culvert Elev. (ft)	Overland Elev. (ft)	Peak Water Surface Elev. (ft)		
				2-Year	10-Year	100-Year
1	Reinhardt Rd.	815.7	827.0	820.6	821.8	822.7
2	CTH K	832.3	845.8	833.6	834.0	834.6
3	Lake DeNeveu	-	-	862.5	862.9	863.8
4	USH 45-D2a	881.0	886.0	882.6	883.3	886.8
5	Ledgetop-D2b	-	1021.2	1020.8	1021.7	1022.2
6	Low Area	-	1062.5	1063.0	1063.3	1063.7
7	Ledgetop-D2d	1020.8	1034.0	1022.1	1023.7	1029.4
8	Low Area	-	1051.5	1051.7	1051.9	1052.2
9	USH 45-D3	950.8	953.5	946.5	947.0	953.4
10	USH 45-D4	961.0	963.0	962.0	962.5	963.8
11	USH 45-D5	970.0	976.3	971.7	973.1	974.5
12	Devils Lake	-	850.0	845.9	847.5	850.0

Table 12 compares peak water surface elevations for Alternative 1 to the peak water surface elevations for the 2015 condition. As shown in Table 12, peak water elevations are lower at several locations, particularly Points of Interest 4 and 9. Point of Interest 12 is lower due to less overland flow from culvert CV-D2a (Point of Interest 4). Also, Table 12 indicates that each 10-year peak water surface elevation is unchanged or decreased.

Table 12 – Peak Water Surface Elevation Comparison (2015 vs. Alternative 1

Point of Interest	Location	US Culvert Elev. (ft)	Overland Elev. (ft)	10-Year Peak Water Elev. (ft)		
				2015	Alt. 1	Change
1	Reinhardt Rd.	815.7	827.0	821.8	821.8	0.0
2	CTH K	832.3	845.8	834.0	834.0	0.0
3	Lake DeNeveu	-	-	863.1	862.9	-0.2
4	USH 45-D2a	881.0	886.0	886.6	883.3	-3.3
5	Ledgetop-D2b	-	1021.2	1021.7	1021.7	0.0
6	Low Area	-	1062.5	1063.4	1063.3	-0.1
7	Ledgetop-D2d	1020.8	1034.0	1024.2	1023.7	-0.5
8	Low Area	-	1051.5	1051.9	1051.9	0.0
9	USH 45-D3	950.8	953.5	953.4	947.0	-6.4
10	USH 45-D4	961.0	963.0	962.5	962.5	0.0
11	USH 45-D5	970.0	976.3	973.1	973.1	0.0
12	Devils Lake	-	850.0	848.0	847.5	-0.5

Table 13 compares the Alternative 1 peak discharges to the 2015 peak discharges. As shown in Table 13, the peak discharges are lower at several locations, particularly Points of Interest 4 and 9. Also, Table 13 indicates that each peak discharge is unchanged or decreased.

Table 13 – Peak Discharge Comparison (2015 vs. Alternative 1)

Point of Interest	Location	2015 Peak Discharge (cfs)			Alt. 1 Peak Discharge (cfs)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
1	Reinhardt Rd.	282	559	1,255	282	557	1,244
2	CTH K	31	60	127	31	60	127
3	Lake DeNeveu	1	6	27	1	4	16
4	USH 45-D2a	56	125	361	33	55	181
5	Ledgetop-D2b	30	76	266	27	66	254
6	Low Area	17	41	96	14	36	91
7	Ledgetop-D2d	21	63	97	19	62	96
8	Low Area	10	30	50	9	28	50
9	USH 45-D3	14	35	88	0	0	38
10	USH 45-D4	4	8	17	4	8	17
11	USH 45-D5	12	26	59	12	26	59
12	Devils Lake	0	0	18	0	0	0

Table 14 compares the Alternative 1 flow velocities to the 2015 flow velocities. As shown in Table 14, the flow velocities are lower at Point of Interest 4. Also, Table 14 indicates that each peak flow velocity is unchanged or decreased.

Table 14 – Peak Stream Velocity Comparison (2015 vs. Alternative 1)

Point of Interest	Location	2015 Peak Velocity (fps)			Alt. 1 Peak Velocity (fps)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
1	Reinhardt Rd.	1.6	2.1	3.1	1.6	2.1	3.1
2	CTH K	2.8	2.9	3.6	2.8	2.8	3.6
4	USH 45-D2a	4.6	6.0	8.7	3.7	4.3	6.5

Table 15 compares the Alternative 1 peak storage volumes to the 2015 peak storage volumes. As shown in Table 15, the peak storage volumes are lower at several locations, particularly Point of Interest 3. The lower storage volumes are a direct result of the cropland BMPs and storm sewer by-pass. Also, Table 14 indicates that each peak storage volume is unchanged or decreased.

Table 15 – Peak Storage Volume Comparison (2015 vs. Alternative 1)

Point of Interest	Location	2015 Storage Vol. (ac-ft)			Alt. 1 Storage Vol. (ac-ft)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
3	Lake DeNeveu	49.7	93.1	186.8	45.1	79.6	158.3
5	Ledgetop-D2b	2.1	4.7	6.4	1.8	4.5	6.3
6	Low Area	1.1	1.8	3.2	1.0	1.6	3.0
8	Low Area	1.0	1.4	2.0	1.0	1.3	1.9

The proposed cropland management practices (mulch tillage and cover crops) are anticipated to reduce cropland phosphorus discharges by approximately 57%, as compared to conventional tillage. Conversion of cropland to grassland or woodland is estimated to reduce cropland phosphorus discharges by approximately 96%, as compared to conventional tillage.

The opinion of probable cost for Alternative 1 is $1.4 million. If the WisDOT installs the storm sewer along USH 45 as part of the 2018 highway resurfacing project, the costs are anticipated to be less. This opinion of probable cost does not include the cropland BMPs since it is assumed that NRCS and/or DATCP will provide cost sharing for the cropland BMPs.

B. Alternative 2

Alternative 2 is depicted in Figure 15. Alternative 2 consists of a ravine dam structure upslope of USH 45 and 3,000 feet of 24-inch storm sewer or grass ditch along Reinhardt Road and CTH K. The 24-inch storm sewer is a high flow by-pass for the stream located at the northeast corner of Lake DeNeveu. At USH 45, high stream flows are diverted into the 24-inch storm sewer and then discharged into the CTH K stream crossing, which

is located 500 feet south of Reinhardt Road. Low stream flows are to continue through the USH 45 culvert crossing, which is a navigable stream based on Exhibit 3. Maintaining low flows in the stream channel will likely be a DNR Chapter 30 Permit requirement. The 24-inch storm sewer is proposed to be 1 foot higher than the stream bed elevation on the east side of the USH 45 culvert and then drop several feet into a storm manhole. Along Reinhardt Road, the 24-inch storm sewer is anticipated to be about 5 feet below the ditch bottom. Alternative 2 also includes 1,700 linear feet of 24-inch storm sewer along USH 45, between culvert CV-D2a and culvert CV-D3. The 24-inch storm sewer is designed to convey stormwater runoff to the 24-inch storm sewer along Reinhardt Road. Lastly, Alternative 2 assumes cropland located within the study area (168 acres) is converted from conventional tillage to mulch tillage with cover crops.

Table 16 summarizes peak water surfaces elevations for Alternative 2.

Table 16 – Peak Water Surface Elevations (Alternative 2)

Point of Interest	Location	US Culvert Elev. (ft)	Overland Elev. (ft)	Peak Water Surface Elev. (ft)		
				2-Year	10-Year	100-Year
1	Reinhardt Rd.	815.7	827.0	820.6	821.8	822.7
2	CTH K	832.3	845.8	833.8	834.3	834.9
3	Lake DeNeveu	-	-	862.5	863.0	863.9
4	USH 45-D2a	881.0	886.0	882.7	883.5	886.2
5	Ledgetop-D2b	-	1021.2	1020.8	1021.7	1022.2
6	Low Area	-	1062.5	1063.0	1063.3	1063.7
7	Ledgetop-D2d	1020.8	1034.0	1022.1	1023.7	1029.4
8	Low Area	-	1051.5	1051.7	1051.9	1052.2
9	USH 45-D3	950.8	953.5	946.5	947.0	953.4
10	USH 45-D4	961.0	963.0	962.0	962.5	963.8
11	USH 45-D5	970.0	976.3	971.7	973.1	974.5
12	Devils Lake	-	850.0	845.9	847.5	849.9

Table 17 compares peak water surface elevations for Alternative 2 to the peak water surface elevations for the 2015 condition. As shown in Table 17, peak water elevations are lower at several locations, particularly Points of Interest 4 and 9. Point of Interest 12 is lower due to less overland flow from culvert CV-D2a (Point of Interest 4). Also, Table 17 indicates that each 10-year peak water surface elevation is decreased, except at CTH K, which is a concern.

Table 17 – Peak Water Surface Elevation Comparison (2015 vs. Alternative 2)

Point of Interest	Location	US Culvert Elev. (ft)	Overland Elev. (ft)	10-Year Peak Water Elev. (ft)		
				2015	Alt. 2	Change
1	Reinhardt Rd.	815.7	827.0	821.8	821.8	0.0
2	CTH K	832.3	845.8	834.0	834.3	+0.3
3	Lake DeNeveu	-	-	863.1	863.0	-0.1
4	USH 45-D2a	881.0	886.0	886.6	883.5	-3.1
5	Ledgetop-D2b	-	1021.2	1021.7	1021.7	0.0
6	Low Area	-	1062.5	1063.4	1063.3	-0.1
7	Ledgetop-D2d	1020.8	1034.0	1024.2	1023.7	-0.5
8	Low Area	-	1051.5	1051.9	1051.9	0.0
9	USH 45-D3	950.8	953.5	953.4	947.0	-6.4
10	USH 45-D4	961.0	963.0	962.5	962.5	0.0
11	USH 45-D5	970.0	976.3	973.1	973.1	0.0
12	Devils Lake	-	850.0	848.0	847.5	-0.5

Table 18 compares the Alternative 2 peak discharges to the 2015 peak discharges. As shown in Table 18, the peak discharges are lower at several locations, particularly Points of Interest 4 and 9. Also, Table 18 indicates that each peak discharge is decreased, except at CTH K, which is a concern.

Table 18 – Peak Discharge Comparison (2015 vs. Alternative 2)

Point of Interest	Location	2015 Peak Discharge (cfs)			Alt. 2 Peak Discharge (cfs)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
1	Reinhardt Rd.	282	559	1,255	282	558	1,252
2	CTH K	31	60	127	46	89	157
3	Lake DeNeveu	1	6	27	1	5	21
4	USH 45-D2a	56	125	361	34	63	136
5	Ledgetop-D2b	30	76	266	27	66	254
6	Low Area	17	41	96	14	36	91
7	Ledgetop-D2d	21	63	97	19	62	96
8	Low Area	10	30	50	9	28	50
9	USH 45-D3	14	35	88	0	0	41
10	USH 45-D4	4	8	17	4	8	17
11	USH 45-D5	12	26	59	12	26	59
12	Devils Lake	0	0	18	0	0	0

Table 19 compares the Alternative 2 flow velocities to the 2015 flow velocities. As shown in Table 19, the flow velocities are lower at Point of Interest 4. Also, Table 19 indicates that each peak flow velocity is decreased, except at CTH K, which is a concern. Higher stream velocities can result in future erosion.

Table 19 – Peak Stream Velocity Comparison (2015 vs. Alternative 2)

Point of Interest	Location	2015 Peak Velocity (fps)			Alt. 2 Peak Velocity (fps)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
1	Reinhardt Rd.	1.6	2.1	3.1	1.6	2.1	3.1
2	CTH K	2.8	2.9	3.6	2.8	3.2	3.8
4	USH 45-D2a	4.6	6.0	8.7	3.8	4.5	5.9

Table 20 compares the Alternative 2 peak storage volumes to the 2015 peak storage volumes. As shown in Table 20, the peak storage volumes are lower at several locations, particularly Point of Interest 3. The lower storage volumes are a direct result of the cropland BMPs and storm sewer by-pass. Also, Table 20 indicates that each peak storage volume is decreased, except at Ravine Dam, which is not a concern since the storage area is proposed to be located within a permanent easement. The Ravine Dam is proposed to have a 30.6 acre-foot storage volume and an 18.5 foot structural height.

Table 20 – Peak Storage Volume Comparison (2015 vs. Alternative 2)

Point of Interest	Location	2015 Storage Vol. (ac-ft)			Alt. 2 Storage Vol. (ac-ft)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
3	Lake DeNeveu	49.7	93.1	186.8	45.9	84.1	175.3
	Ravine Dam	-	-	-	0.6	6.4	30.6
5	Ledgetop-D2b	2.1	4.7	6.4	1.8	4.5	6.3
6	Low Area	1.1	1.8	3.2	1.0	1.6	3.0
8	Low Area	1.0	1.4	2.0	1.0	1.3	1.9

The proposed cropland management practices (mulch tillage and cover crops) are anticipated to reduce cropland phosphorus discharges by approximately 57%, as compared to conventional tillage. Conversion of cropland to grassland or woodland is estimated to reduce cropland phosphorus discharges by approximately 96%, as compared to conventional tillage.

The opinion of probable cost for Alternative 2 is $1.2 million with storm sewer along Reinhardt Road and CTH K and $1.0 million with a grass ditch along portions of Reinhardt Road and CTH K. The opinion of probable cost includes an allowance to acquire a permanent easement for the ravine dam and associated flood storage. If the WisDOT installs the storm sewer along USH 45 as part of the 2018 highway resurfacing project, the costs are anticipated to be less. This opinion of probable cost does not include the cropland BMPs since it is assumed that NRCS and/or DATCP will provide cost sharing for the cropland BMPs.

C. Alternative 3

Alternative 3 is depicted in Figure 16. Alternative 3 consists of lowering the Quarry pond, converting the Quarry Pond to a Code 1001 Wet Detention Pond, and installing

500 feet of 30-inch storm sewer at the northeast corner of Lake DeNeveu. The 30-inch storm sewer is a high flow by-pass for the stream located at the northeast corner of Lake DeNeveu. At USH 45, high stream flows are diverted into the 30-inch storm sewer and then discharged directly into Lake DeNeveu. Low stream flows are to continue through the USH 45 culvert crossing, which is a navigable stream based on Exhibit 3. Maintaining low flows in the stream channel will likely be a DNR Chapter 30 Permit requirement. The 30-inch storm sewer is proposed to be 1 foot higher than the stream bed elevation on the east side of the USH 45 culvert and then drop several feet into a storm manhole. The 30-inch storm sewer is anticipated to be about 6 feet below the ground. Alternative 3 also includes 1,100 feet of 24-inch storm sewer on private property, between culvert CV-D3 and Lake DeNeveu.

Table 21 summarizes peak water surfaces elevations for Alternative 3.

Table 21 – Peak Water Surface Elevations (Alternative 3)

Point of Interest	Location	US Culvert Elev. (ft)	Overland Elev. (ft)	Peak Water Surface Elev. (ft)		
				2-Year	10-Year	100-Year
1	Reinhardt Rd.	815.7	827.0	820.6	821.8	822.8
2	CTH K	832.3	845.8	833.6	834.0	834.6
3	Lake DeNeveu	-	-	862.6	863.1	864.2
4	USH 45-D2a	881.0	886.0	882.6	883.6	886.7
5	Ledgetop-D2b	-	1021.2	1017.1	1018.8	1022.0
6	Low Area	-	1062.5	1063.1	1063.4	1063.8
7	Ledgetop-D2d	1020.8	1034.0	1022.2	1024.1	1029.6
8	Low Area	-	1051.5	1051.7	1051.9	1052.2
9	USH 45-D3	950.8	953.5	945.6	946.1	953.3
10	USH 45-D4	961.0	963.0	962.0	962.5	963.8
11	USH 45-D5	970.0	976.3	971.7	973.1	974.5
12	Devils Lake	-	850.0	845.9	847.5	850.0

Table 22 compares peak water surface elevations for Alternative 3 to the peak water surface elevations for the 2015 condition. As shown in Table 22, peak water elevations are lower at several locations, particularly Points of Interest 4, 5 and 9. Point of Interest 12 is lower due to less overland flow from culvert CV-D2a (Point of Interest 4). Also, Table 22 indicates that each 10-year peak water surface elevation is unchanged or decreased.

Table 22 – Peak Water Surface Elevation Comparison (2015 vs. Alternative 3)

Point of Interest	Location	US Culvert Elev. (ft)	Overland Elev. (ft)	10-Year Peak Water Elev. (ft)		
				2015	Alt. 3	Change
1	Reinhardt Rd.	815.7	827.0	821.8	821.8	0.0
2	CTH K	832.3	845.8	834.0	834.0	0.0
3	Lake DeNeveu	-	-	863.1	863.1	0.0
4	USH 45-D2a	881.0	886.0	886.6	883.6	-3.0
5	Ledgetop-D2b	-	1021.2	1021.7	1018.8	-2.9
6	Low Area	-	1062.5	1063.4	1063.4	0.0
7	Ledgetop-D2d	1020.8	1034.0	1024.2	1024.1	-0.1
8	Low Area	-	1051.5	1051.9	1051.9	0.0
9	USH 45-D3	950.8	953.5	953.4	946.1	-7.3
10	USH 45-D4	961.0	963.0	962.5	962.5	0.0
11	USH 45-D5	970.0	976.3	973.1	973.1	0.0
12	Devils Lake	-	850.0	848.0	847.5	-0.5

Table 23 compares the Alternative 3 peak discharges to the 2015 peak discharges. As shown in Table 23, the peak discharges are lower at several locations, particularly Points of Interest 4, 5, and 9. Also, Table 23 indicates that each peak discharge is unchanged or decreased, except the 100-year peak discharge at Reinhardt Road and the Lake DeNeveu outlet, which are a slight concern. These peak discharge increases can likely be mitigated with a larger Quarry Pond or some cropland BMPs.

Table 23 – Peak Discharge Comparison (2015 vs. Alternative 3)

Point of Interest	Location	2015 Peak Discharge (cfs)			Alt. 3 Peak Discharge (cfs)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
1	Reinhardt Rd.	282	559	1,255	282	559	1,260
2	CTH K	31	60	127	31	60	127
3	Lake DeNeveu	1	6	27	1	6	33
4	USH 45-D2a	56	125	361	34	69	177
5	Ledgetop-D2b	30	76	266	22	39	160
6	Low Area	17	41	96	17	41	96
7	Ledgetop-D2d	21	63	97	21	64	97
8	Low Area	10	30	50	10	30	50
9	USH 45-D3	14	35	88	0	0	26
10	USH 45-D4	4	8	17	4	8	17
11	USH 45-D5	12	26	59	12	26	59
12	Devils Lake	0	0	18	0	0	0

Table 24 compares the Alternative 3 flow velocities to the 2015 flow velocities. As shown in Table 24, the flow velocities are lower at Point of Interest 4. Also, Table 24 indicates that each peak flow velocity is unchanged or decreased.

Table 24 – Peak Velocity Comparison (2015 vs. Alternative 3)

Point of Interest	Location	2015 Peak Velocity (fps)			Alt. 3 Peak Velocity (fps)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
1	Reinhardt Rd.	1.6	2.1	3.1	1.6	2.1	3.1
2	CTH K	2.8	2.9	3.6	2.8	2.9	3.6
4	USH 45-D2a	4.6	6.0	8.7	3.8	4.7	6.4

Table 25 compares the Alternative 3 peak storage volumes to the 2015 peak storage volumes. As shown in Table 25, the peak storage volumes are higher within Lake DeNeveu (Point of Interest 3), which is a slight concern. The peak storage volume increases in Lake DeNeveu can likely be mitigated with a larger Quarry Pond or some cropland BMPs. The higher storage volumes in Quarry Pond (Point of Interest 5) are a direct result of lowering the pond's normal water surface elevation about 5 feet and increasing the storage capacity, as compared to current conditions. The Quarry Pond is proposed to have a 17.2 acre-foot storage volume.

Table 25 – Peak Storage Volume Comparison (2015 vs. Alternative 3)

Point of Interest	Location	2015 Storage Vol. (ac-ft)			Alt. 3 Storage Vol. (ac-ft)		
		2-Year	10-Yr	100-Yr	2-Year	10-Yr	100-Yr
3	Lake DeNeveu	49.7	93.1	186.8	52.0	93.5	195.8
5	Ledgetop-D2b	2.1	4.7	6.4	3.3	7.4	17.2
6	Low Area	1.1	1.8	3.2	1.1	1.8	3.2
8	Low Area	1.0	1.4	2.0	1.0	1.4	2.0

Conversion of the Quarry Pond to a Code 1001 Wet Detention Pond is anticipated to reduce cropland phosphorus discharges located upslope of the wet detention pond by approximately 60%, as compared to conventional tillage.

The opinion of probable cost for Alternative 3 is $750,000. If the WisDOT installs the storm sewer along USH 45 as part of the 2018 highway resurfacing project, the costs are anticipated to be less. The opinion of probable cost assumes no additional easement or land acquisition is needed, since the Quarry Pond is assumed to already be located within a permanent easement.

VI. SUMMARY

For this study, the County requested that McMAHON's scope be limited to flood and runoff mitigation at the north and east side of Lake DeNeveu. When evaluating strategies, the County requested that McMAHON consider the ability to permit and obtain approval for the alternatives.

Current drainage system performance was a consideration when the alternatives were identified and evaluated. Changing a drainage system has the potential to create new problems

or merely push an existing problem to a new location. For example, if the stream at the northeast corner of Lake DeNeveu was rerouted away from Lake DeNeveu and into Devils Lake, McMAHON anticipates that runoff volumes and consequently, water levels within Devils Lake will increase, which may create problems for a new group of landowners.

Bedrock was a consideration when the alternatives were identified and evaluated. For example, the USH 45 and CTH H triangle intersection appears to have a shallow depth to bedrock, which can significantly increase wet detention pond costs due to the required rock blasting.

Groundwater protection was a consideration when the alternatives were identified and evaluated. The USH 45 corridor appears to contain shallow bedrock and groundwater. Stormwater treatment systems located within bedrock or groundwater have the potential to contaminate groundwater, unless liners are used to protect groundwater. Bioretention and other structural treatment systems that rely on infiltration are not effective at phosphorus removal if a clay or synthetic liner is needed to protect groundwater.

Failing septic systems can be source of phosphorus. Exhibit 14 identifies residential properties served by public sanitary sewers owned by the Empire Sanitary District #1. Residential properties located east of USH 45 appear to be served by private septic systems. Private septic systems in close proximity to bedrock or groundwater have the potential to contribute phosphorus to Lake DeNeveu, particularly if the septic system is leaking or failing.

For this study, three (3) alternatives were evaluated. Costs ranged from $750,000 to $1.4 million. Below are various recommendations for the County to consider when selecting an alternative.

A. Implementation

It is recommended that the County select one (1) alternative for implementation. The County can select one (1) of the study alternatives or assemble a new alternative. Each alternative has pros and cons. Also, each stakeholder may prefer a different alternative. As such, public education and involvement are recommended when selecting an alternative for implementation. Although this stormwater study provides opinions of probable cost and performance summaries, the study does not take into consideration intangibles such as public sentiment, public opinion, land availability, etc. McMAHON can facilitate a discussion during the presentation and provide expertise to assist with selecting an alternative.

B. Inter-Governmental Agreements

It is recommended that the County consider inter-governmental agreements when implementing the selected alternative. For example, it may be more cost effective to work with the WisDOT to implement specific components as part of the USH 45 resurfacing project.

C. Water Quality Trading

It is recommended that the County evaluate water quality trading opportunities before implementing cropland practices. The costs for achieving compliance with state-wide phosphorus criteria are not uniform among dischargers. For example, a wastewater treatment plant discharger may find compliance with phosphorus criteria more cost-effectively achieved by trading with cropland landowners. Water quality trading is allowed between wastewater treatment facilities, agricultural landowners, and urban dischargers. Water quality trading may provide a funding source to assist with implementation of cropland practices.

D. Funding Sources

Below is a discussion of various funding sources which may be available to the County. Depending on the project, funding options may be used individually or in combination.

- Debt / Bonds: General obligation and revenue bonds may be used to secure funding for stormwater projects. Property taxes and revenue fees are used for debt payments.

- Special Assessments: Special assessments may be used to generate funds for a specific project. Property owners that benefit from the project pay the assessment fee. Typically, other funding sources are needed until property owners pay the assessment.

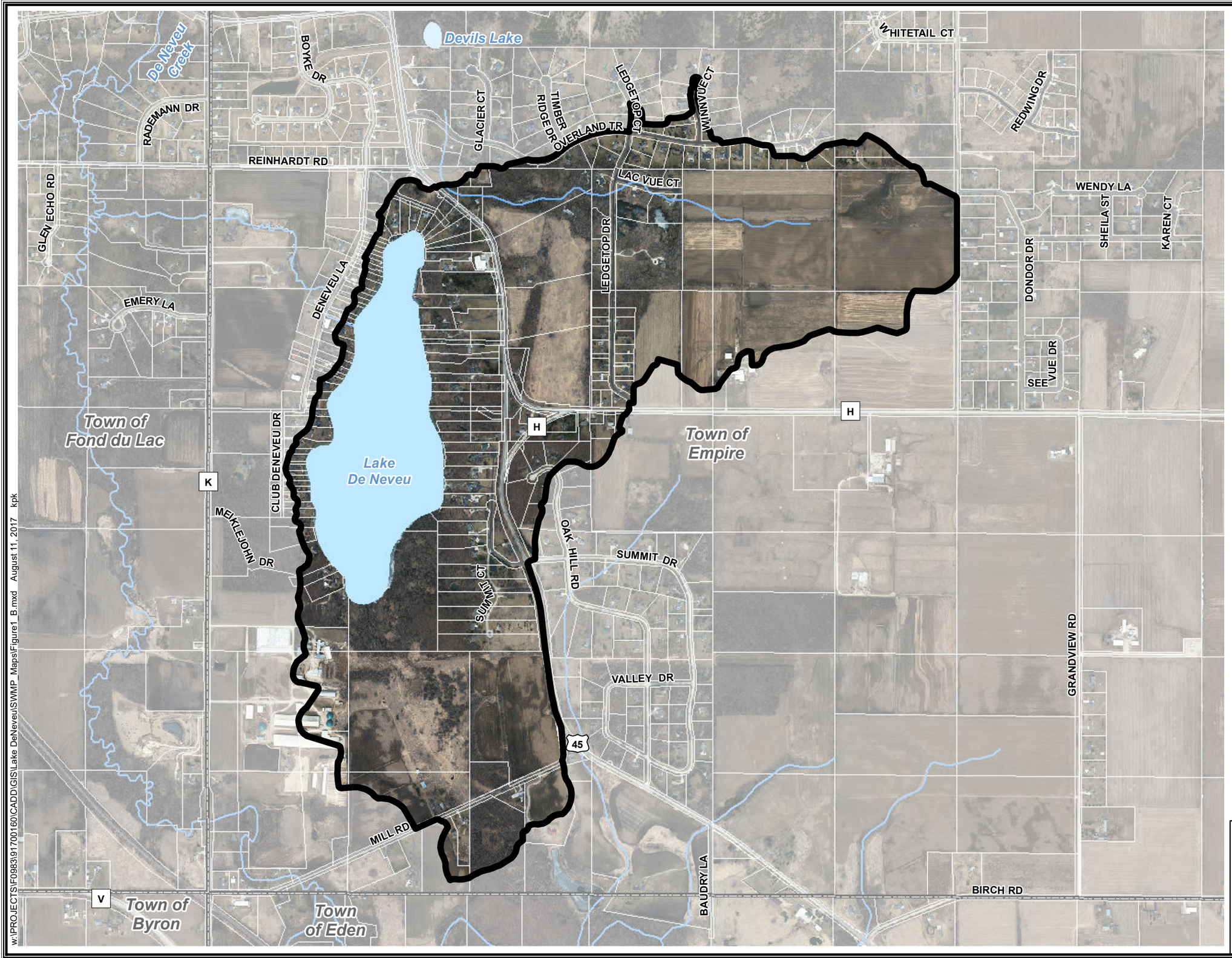
- Impact Fees: Impact fees may be charged to developers for stormwater projects that benefit the development. Impact fees are usually paid during initial stages of development. Typically, projects include regional stormwater facilities or improvements to deficient downstream infrastructure. Often, other funding sources are needed to pay for project costs until developers and property owners are required to pay the impact fee. Impact fees are recommended as needed to fund the municipal stormwater program.

- Stormwater Utility / Lake District: Stormwater utilities generate revenue for stormwater related projects by charging property owners an annual service fee. Annual fees are based upon the amount of runoff generated by a property. Properties with more impervious area (i.e. roofs, driveways, etc.) are charged a higher fee as compared to properties with less impervious area. All properties, including tax exempt properties, pay the service fee.

- Grants / Loans: State and federal grant / loans are available for certain stormwater projects. Typically, only a certain percent of the total project cost is eligible for grant / loan money with remaining revenues to be generated by the applicant.

Below are a few grant / loan programs which the Town may or may not be familiar with. Grant applications are recommended.

- Urban Non-Point Source and Stormwater Construction Grant
- Targeted Runoff Management Construction Grant
- Community Development Block Grant
- Clean Water Fund



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Mapped Features

- Study Area Boundary
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 2015-16; WDNR, 2013.

Disclaimer: The property lines, right-of-way lines, and other property information on this drawing were developed or obtained as part of the County Geographic Information System or through the County property tax mapping function. McMAHON ASSOCIATES, INC. does not guarantee this information to be correct, current, or complete. The property and right-of-way information are only intended for use as a general reference and are not intended or suitable for site-specific uses. Any use to the contrary of the above stated uses is the responsibility of the user and such use is at the user's own risk.

0 1,000 2,000 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

FIGURE 1
STUDY AREA
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN

BOYKE DR
REINHARDT RD
GLACIER CT
TIMBER RIDGE DR
OVERLAND TR CT
LEDGETOP CT
WINNVUE CT
GRANDVIEW RD
45
NORTH SHORE LA
LAC VUE CT
K
DENEVEU LA
Gravel Pit
1960's-1980's
Low Area
Low Area
LEDGETOP DR
45
H
H
K
CLUB DENEVEU DR
Lake
De Neveu
SUMMIT CT
Town of
Empire
MEIKLEJOHN DR
45
SUMMIT DR
OAK HILL RD

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FOND DU LAC COUNTY ESTABLISHED 1836

Mapped Features

- Study Area Boundary
- Area of Interest
- Culvert
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 2010-16; WDNR, 2013.

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N

0 600 1,200 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

FIGURE 2
HISTORIC PHOTO (2010)
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN

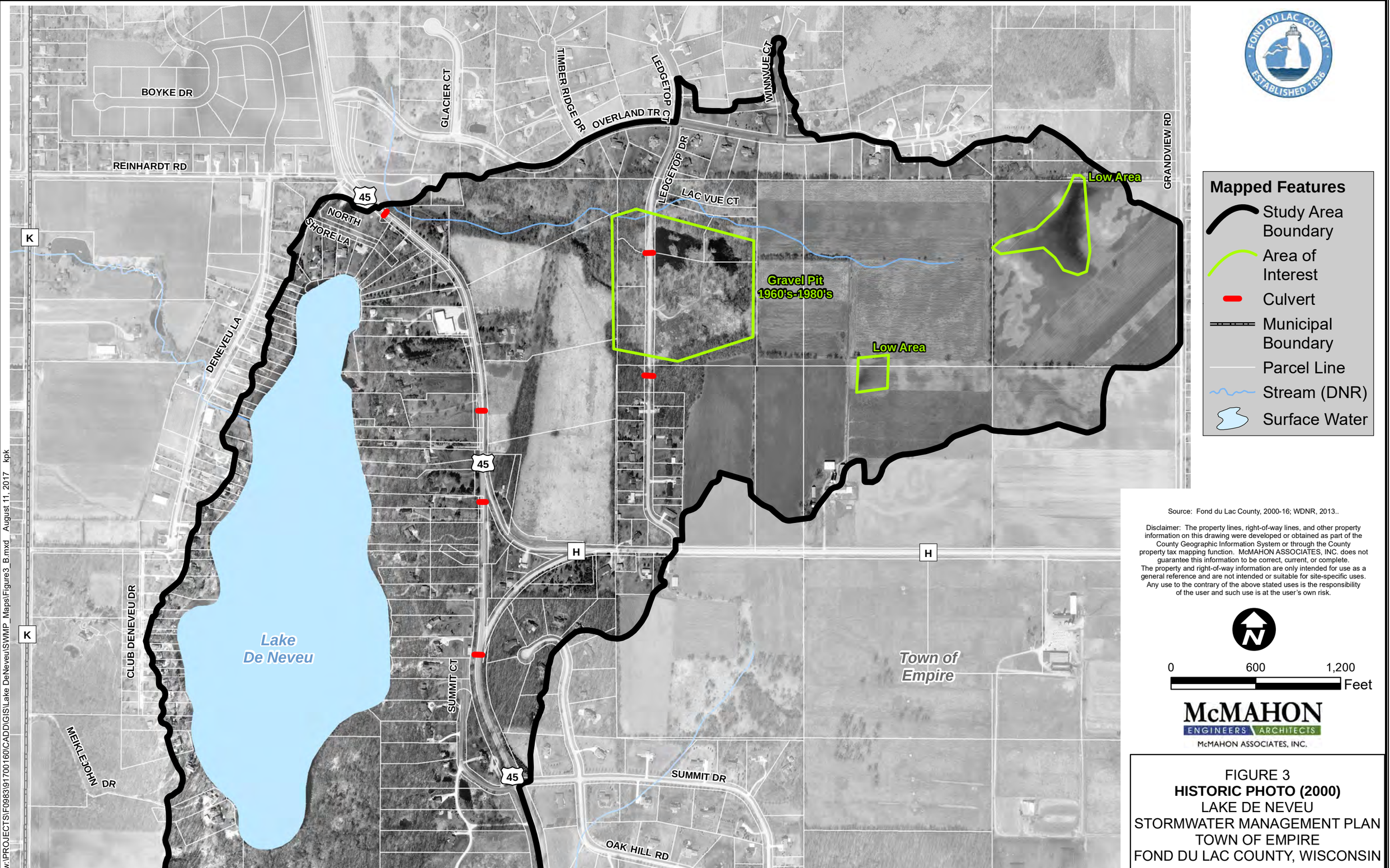

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FIGURE 3
HISTORIC PHOTO (2000)
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN

BOYKE DR
REINHARDT RD
GLACIER CT
TIMBER RIDGE DR
OVERLAND TR CT
LEDGETOP DR
LEDGETOP CT
WINNVUE CT
GRANDVIEW RD
LAC VUE CT
45
NORTH SHORE LA
K
DENEVEU LA
EMERY LA
H
Low Area
Gravel Pit
1960's-1980's
Low Area
CLUB DENEVEU DR
SUMMIT CT
MEIKLEJOHN DR
SUMMIT DR
OAK HILL RD
Lake
De Neveu
Town of
Empire

Mapped Features

- Study Area Boundary
- Area of Interest
- Culvert
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 1990-2016; WDNR, 2013.

0 600 1,200 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

FIGURE 4
HISTORIC PHOTO (1990)
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN

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Farmstead Building 1930's-1980's

Farmstead Building 1930's-1980's

Driveway 1930's-1980's

BOYKE DR

REINHARDT RD

GLACIER CT

LEDGETOP CT

WINNVUE CT

OVERLAND TR

LAC VUE CT

NORTH SHORE LA

45

K

DENEVEU LA

Gravel Pit 1960's-1980's

Low Area

Low Area

GRANDVIEW RD

Town of Empire

LEDGETOP DR

H

H

Lake De Neveu

CLUB DENEVEU DR

SUMMIT CT

45

K

MEIKLEJOHN DR

SUMMIT DR

OAK HILL RD

Mapped Features

- Study Area Boundary
- Area of Interest
- Culvert
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 1972-2016; WDNR, 2013.

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0 600 1,200 Feet

McMAHON ENGINEERS ARCHITECTS

McMAHON ASSOCIATES, INC.

FIGURE 5
HISTORIC PHOTO (1972)
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN

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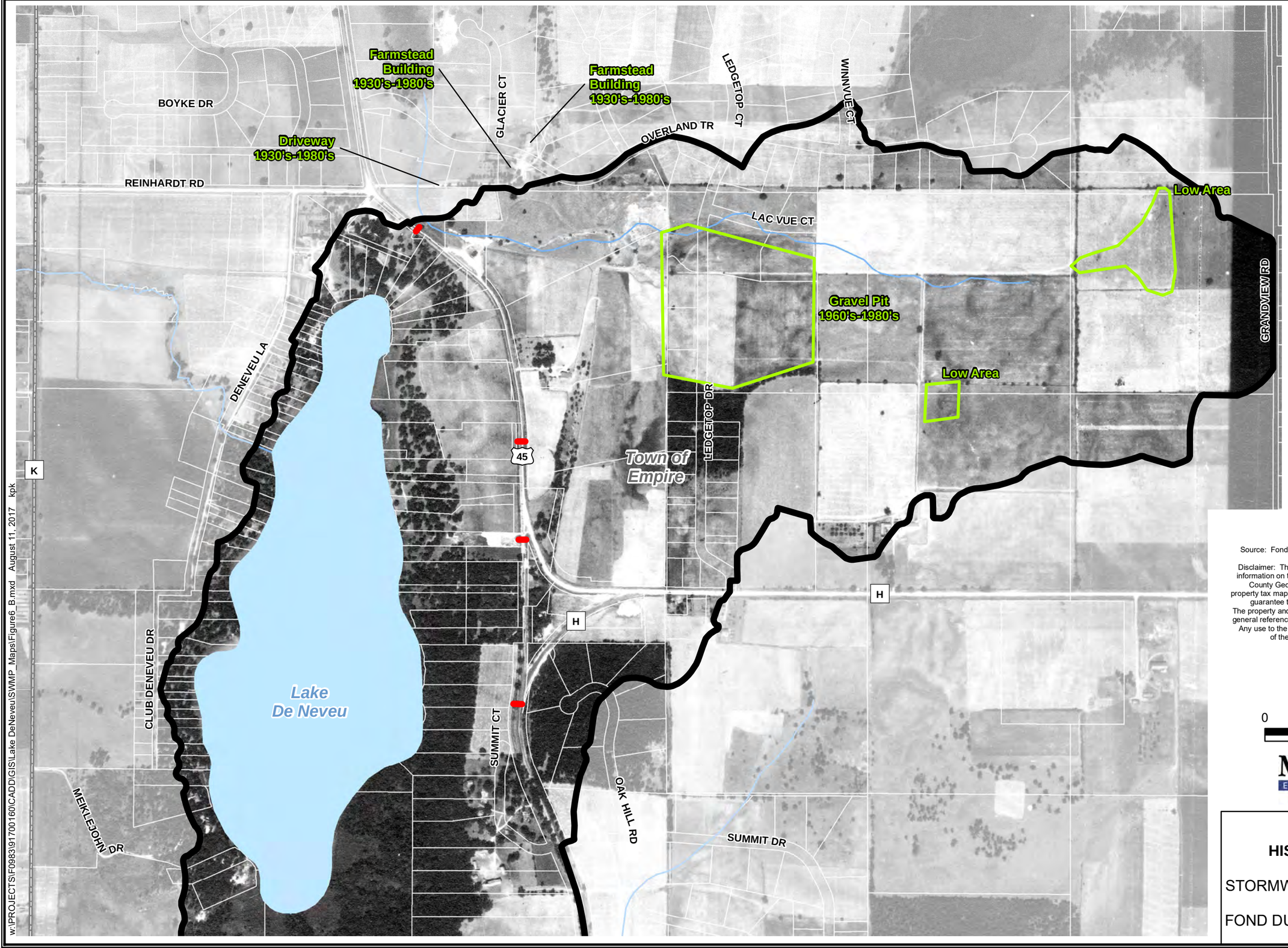

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FOND DU LAC COUNTY ESTABLISHED 1836

Mapped Features

- Study Area Boundary
- Area of Interest
- Culvert
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 2015-16; WDNR, 2013; USDA, 1937

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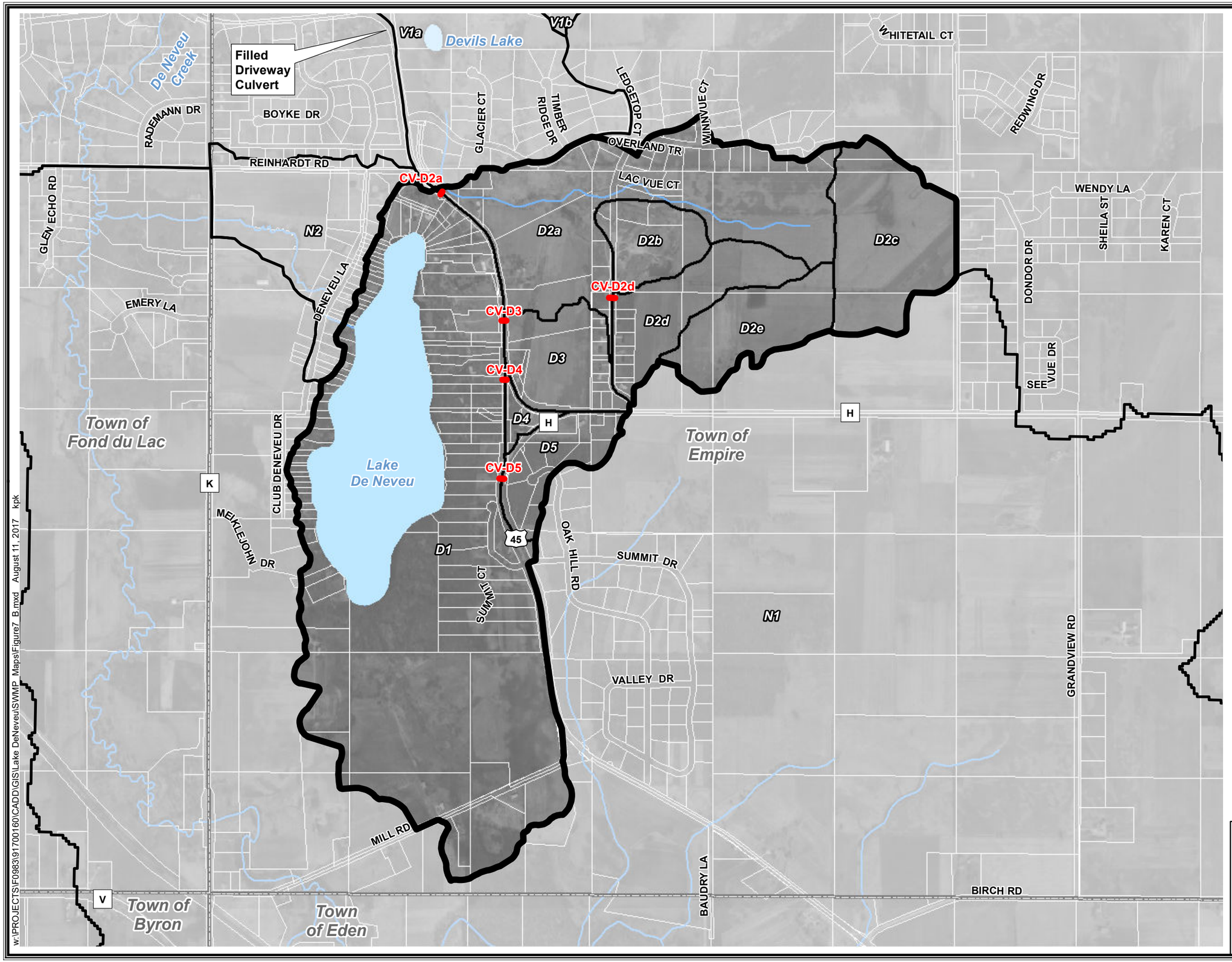
N

0 600 1,200 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

FIGURE 6
HISTORIC PHOTO (1937)
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN



Mapped Features

- Drainage Area and ID (D1)
- Study Area Boundary
- Culvert and ID (CV-D3)
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 2015-16; WDNR, 2013.

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0 1,000 2,000 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

FIGURE 7
1972 DRAINAGE AREAS
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN

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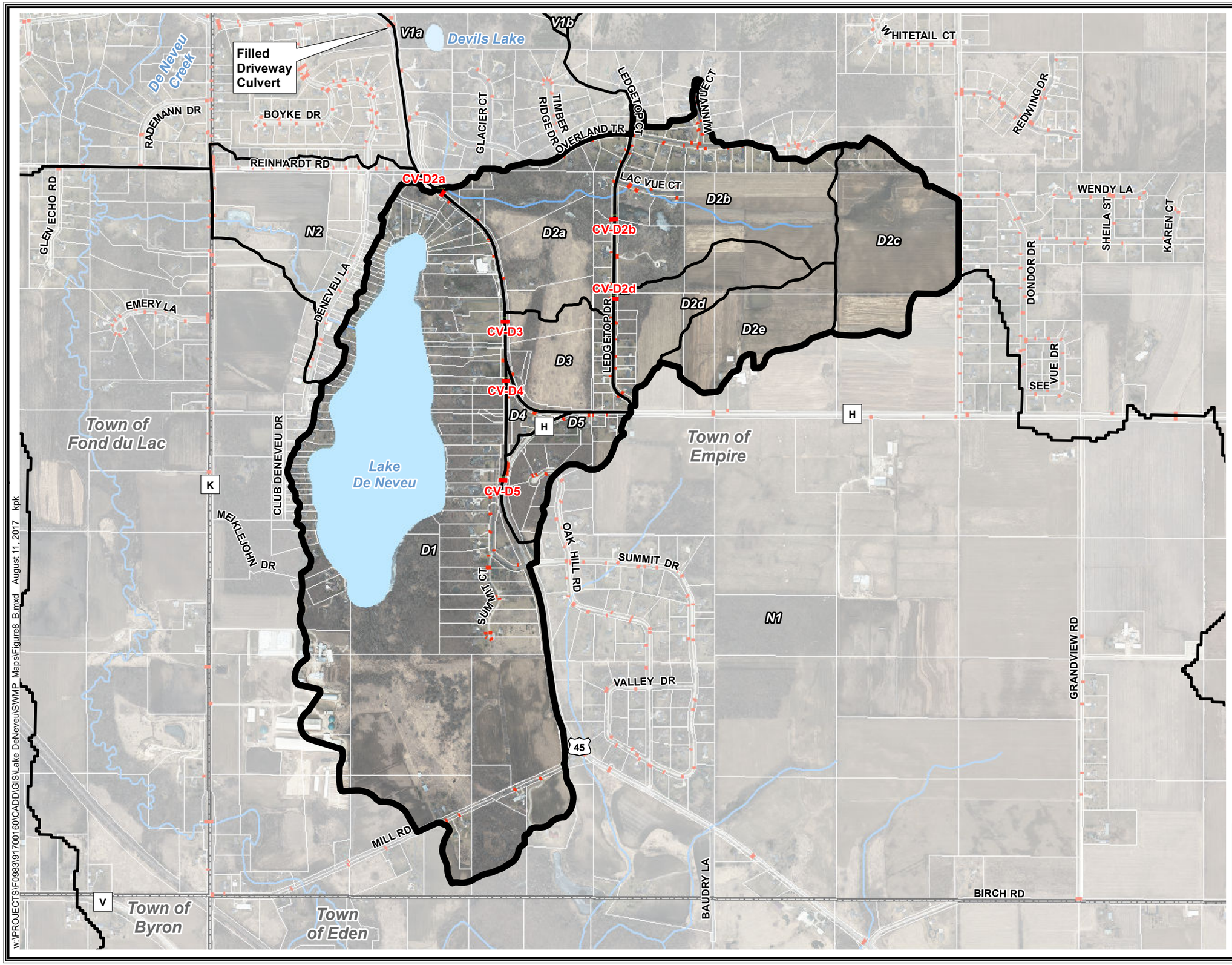

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Mapped Features

- Drainage Area and ID (D1)
- Study Area Boundary
- Culvert and ID (CV-D3)
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 2015-16; WDNR, 2013.

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0 1,000 2,000 Feet

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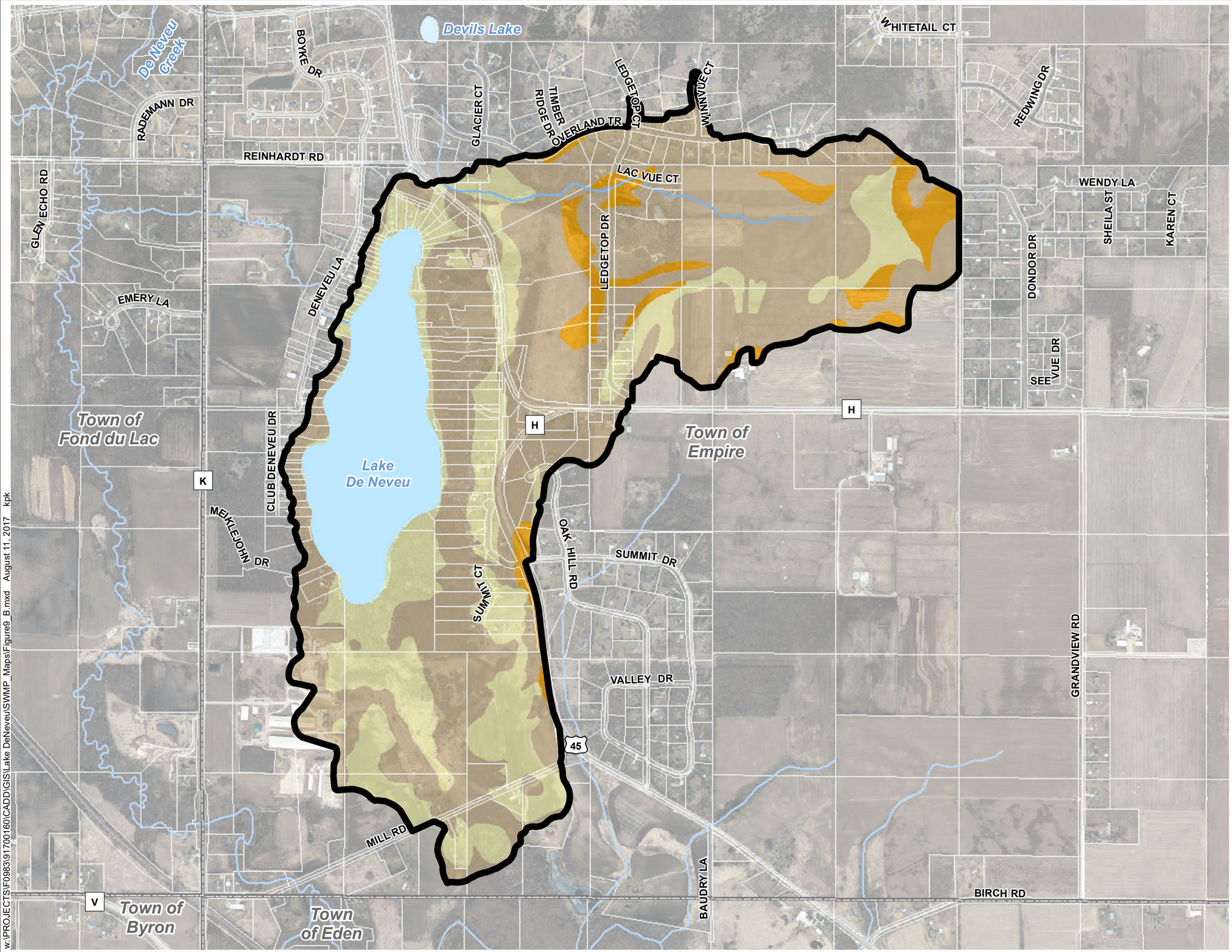
McMAHON ASSOCIATES, INC.

FIGURE 8
2015 DRAINAGE AREAS
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN



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Hydrologic Soil Group (HSG)

- HSG A (NA)
- HSG B
- HSG C
- HSG D

Other Mapped Features

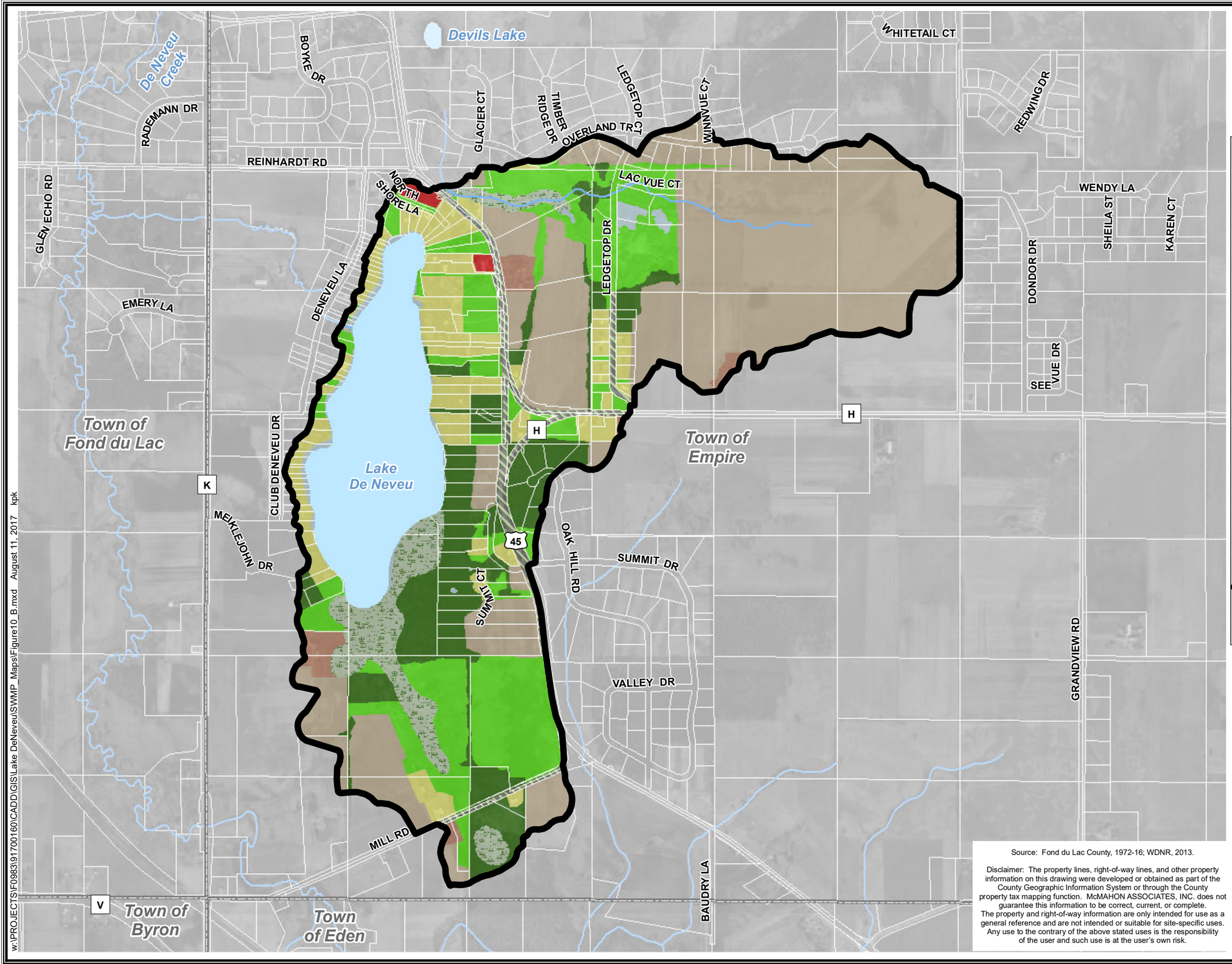
- Study Area Boundary
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 2015-16; WDNR, 2013; USDA, 2015.

0 1,000 2,000 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

FIGURE 9
SOILS
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN



SLAMM Standard Land Uses

Residential
- LDR - Low Density Single Family Residential (0.5 acre to 1.5 acre lots)
- MFR - Multi-Family Residential (3 or more families, 1-3 story height)

Institutional
- SCHOOL - Public or Private School
- UNIV - University, College, Technical School, etc.
- MISC - Miscellaneous Facilities (Churches, Institutional Property)

Commercial
- CSTRIP - Strip Commercial Areas (Courthouses, Police Stations, etc.)

Industrial
- LIGHTI - Light Industrial Areas (storage and distribution of goods for retail or sale)
- QUARRY - Aggregate Extraction and Excavation (Excludes road ROW)

Open Space
- CEM - Cemeteries, including grounds, roads, and buildings)
- PARK - Outdoor Recreational Areas (golf course, arboretums, botanical gardens, municipal playgrounds, and natural areas)
- RAIL - Railroad ROW (Excludes road ROW, storage yards)
- FRMSTD - Farmsteads, including limited houses, buildings, driveways and parking areas
- AGRIC - Agriculture fields
- GRASS - Undeveloped land that is vegetated (Excludes road ROW)
- WOODS - Forested or Wooded Areas with Leaf Litter
- WETLND - DNR Wetland Inventory Map
- WATER - Waters of the State and Other Open Waters
- WATER_SWPOND - Open water associated with stormwater pond

Transportation
- HWY - State or County Highway

Other Mapped Features
- Study Area Boundary
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

0 1,000 2,000 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

Source: Fond du Lac County, 1972-16; WDNR, 2013.

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FIGURE 10
1972 LAND USE
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN

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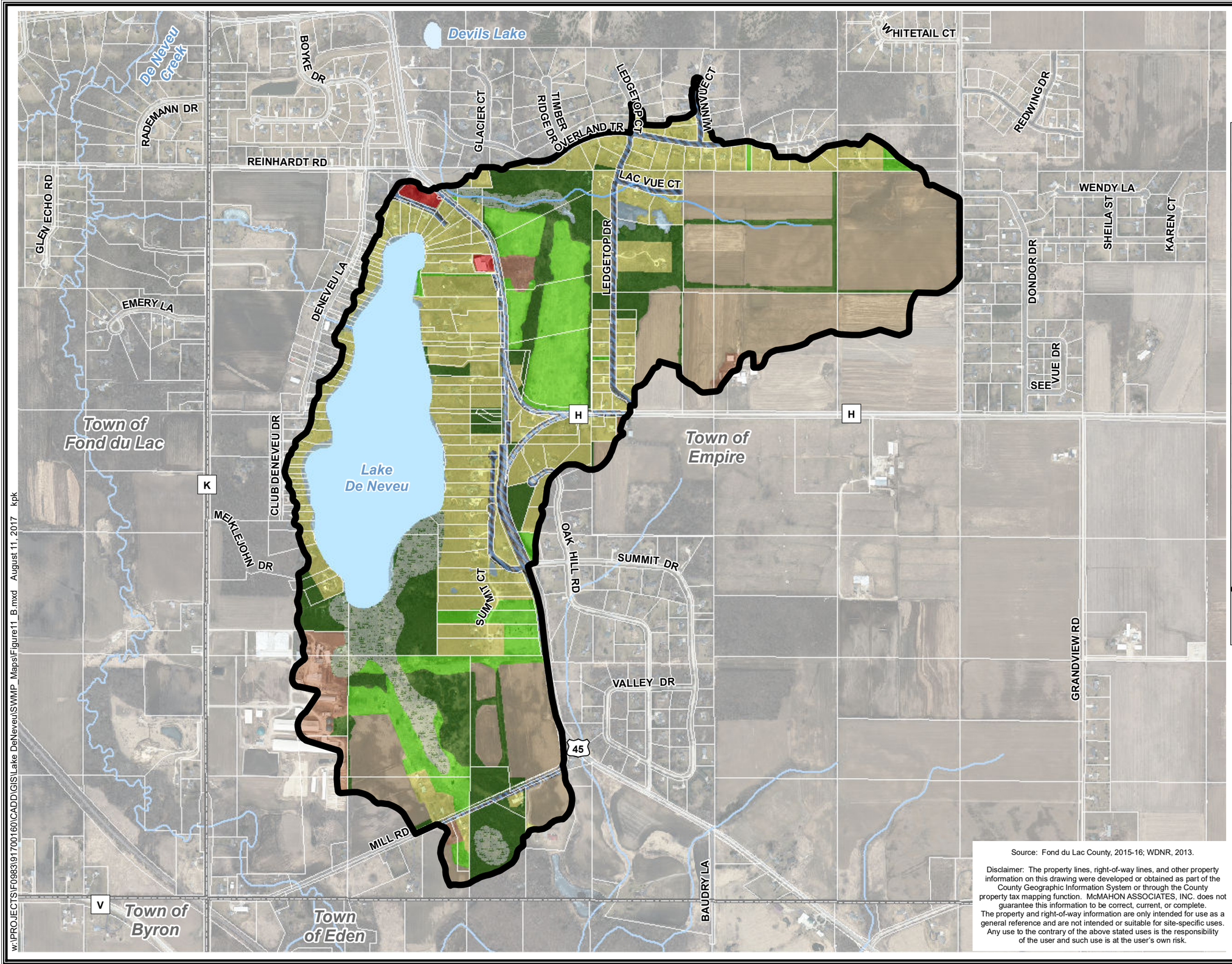

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SLAMM Standard Land Uses

Residential
- LDR - Low Density Single Family Residential (0.5 acre to 1.5 acre lots)
- MFR - Multi-Family Residential (3 or more families, 1-3 story height)
- MOBR - Mobile home or trailer park residential

Institutional
- SCHOOL - Public or Private School
- UNIV - University, College, Technical School, etc.
- HOSP - Medical facilities, including nursing homes, hospitals, etc.
- MISC - Miscellaneous Facilities (Churches, Institutional Property)

Commercial
- CSTRIP - Strip Commercial Areas (Courthouses, Police Stations, etc.)

Industrial
- LIGHTI - Light Industrial Areas (storage and distribution of goods for retail or sale)
- QUARRY - Aggregate Extraction and Excavation (Excludes road ROW)

Open Space
- CEM - Cemeteries, including grounds, roads, and buildings)
- PARK - Outdoor Recreational Areas (golf course, arboretums, botanical gardens, municipal playgrounds, and natural areas)
- RAIL - Railroad ROW (Excludes road ROW, storage yards)
- FRMSTD - Farmsteads, including limited houses, buildings, driveways and parking areas
- AGRIC - Agriculture fields
- GRASS - Undeveloped land that is vegetated (Excludes road ROW)
- WOODS - Forested or Wooded Areas with Leaf Litter
- WETLND - DNR Wetland Inventory Map
- WATER - Waters of the State and Other Open Waters
- WATER_SWPOND - Open water associated with stormwater pond

Transportation
- HWY - State or County Highway

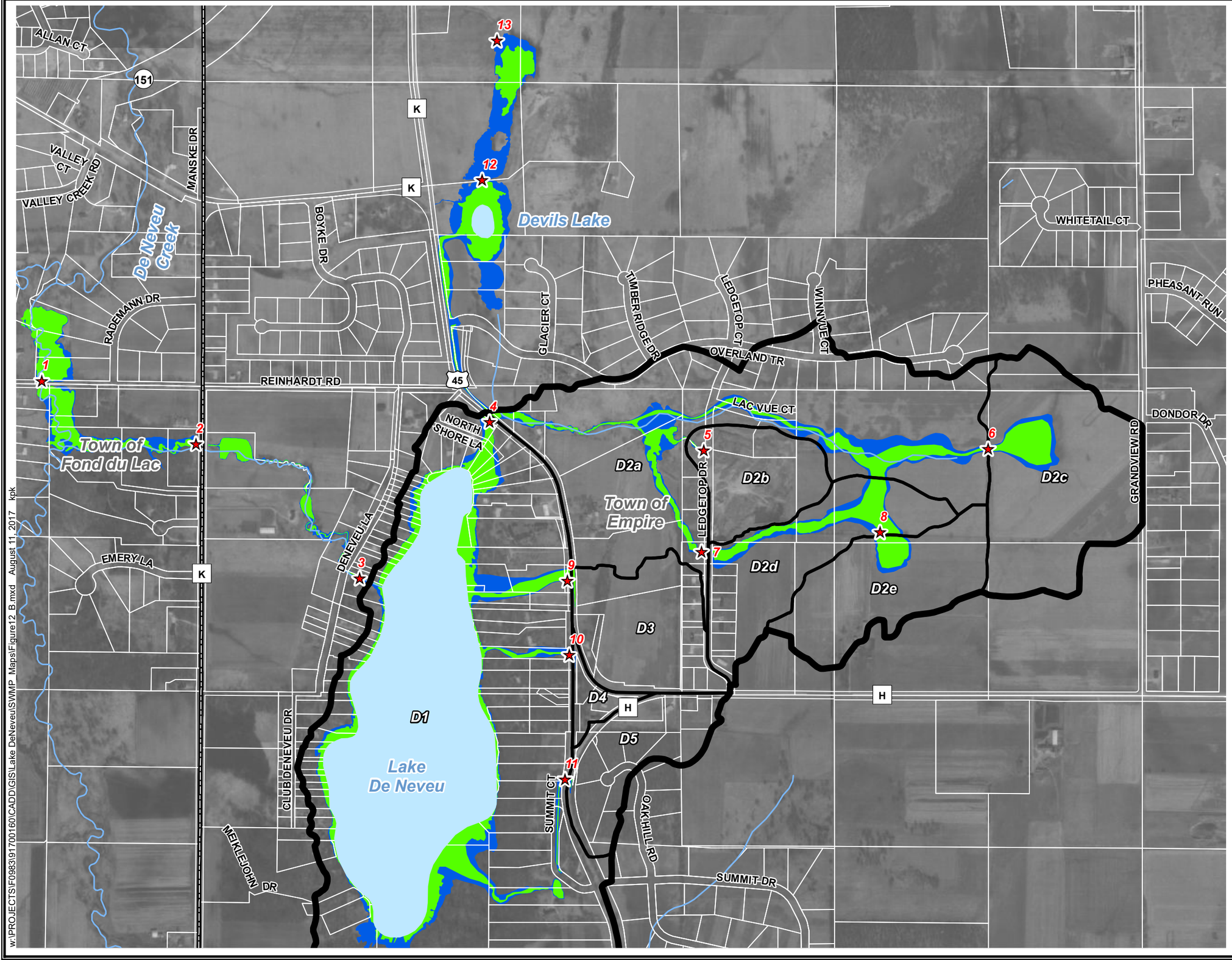
Other Mapped Features
- Study Area Boundary
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

0 1,000 2,000 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

Source: Fond du Lac County, 2015-16; WDNR, 2013.

FIGURE 11
2015 LAND USE
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN



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10 Year Flooding Limits

100 Year Flooding Limits

Other Mapped Features

- Point of Interest
- Study Area Boundary
- Drainage Area and ID
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 1972-2016; WDNR, 2013.

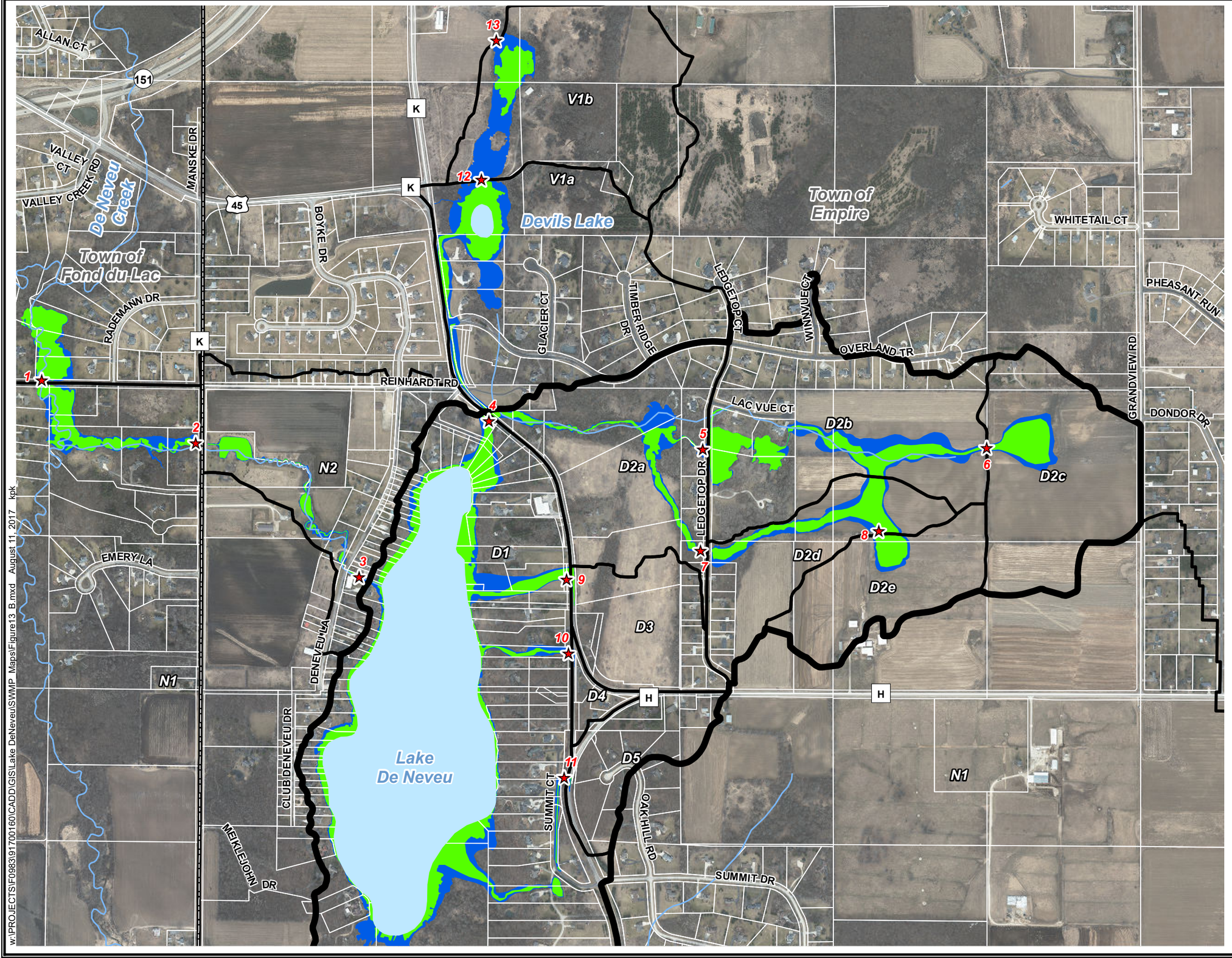
Disclaimer: The property lines, right-of-way lines, and other property information on this drawing were developed or obtained as part of the County Geographic Information System or through the County property tax mapping function. McMAHON ASSOCIATES, INC. does not guarantee this information to be correct, current, or complete. The property and right-of-way information are only intended for use as a general reference and are not intended or suitable for site-specific uses. Any use to the contrary of the above stated uses is the responsibility of the user and such use is at the user's own risk.

0 800 1,600 Feet

McMAHON ENGINEERS ARCHITECTS

McMAHON ASSOCIATES, INC.

FIGURE 12
1972 FLOODING LIMITS
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN



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10 Year Flooding Limits

100 Year Flooding Limits

Other Mapped Features

1 Point of Interest

Study Area Boundary

D2e Drainage Area and ID

Municipal Boundary

Parcel Line

Stream (DNR)

Surface Water

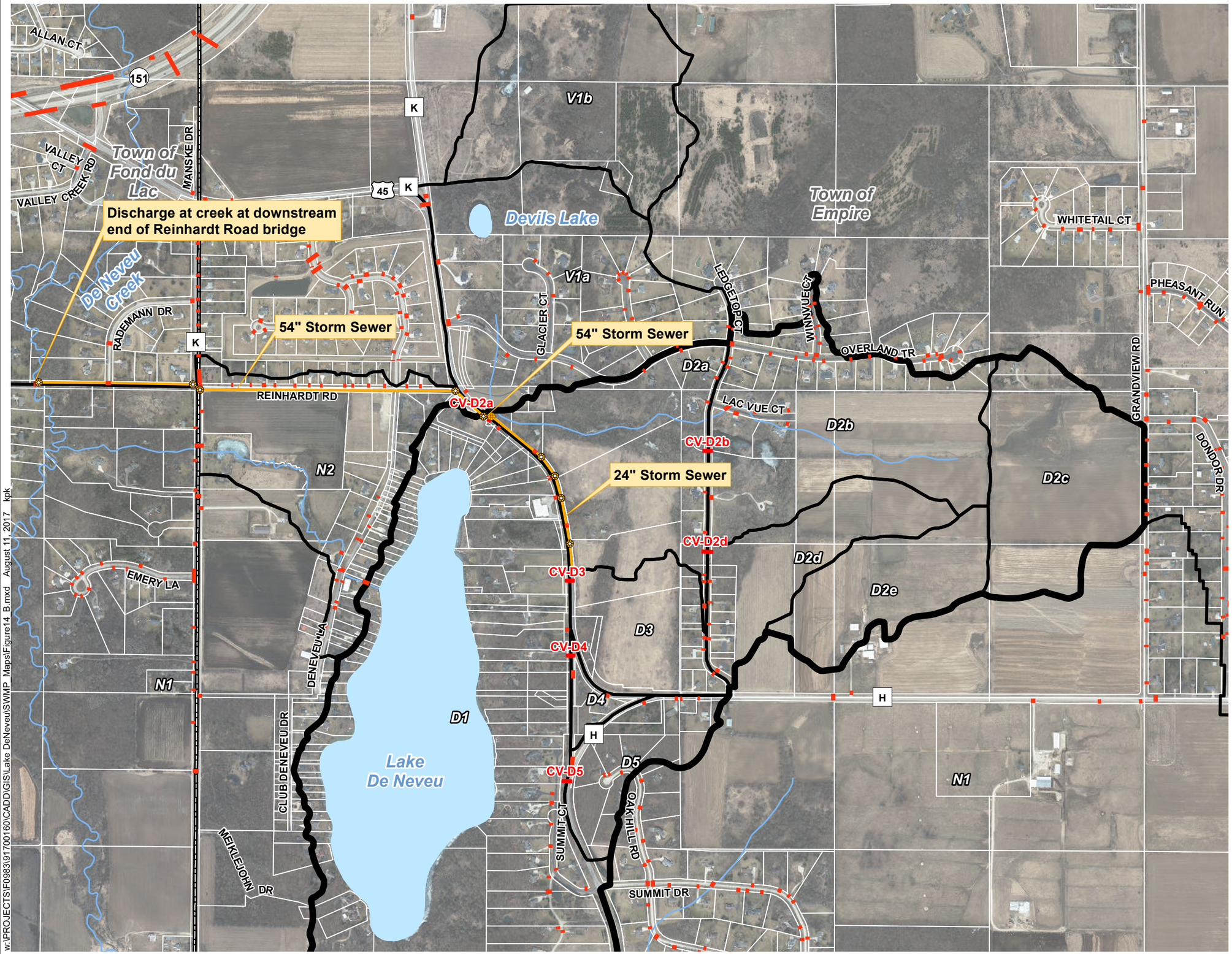
Source: Fond du Lac County, 2015-16; WDNR, 2013.

0 800 1,600 Feet

McMAHON ENGINEERS ARCHITECTS

McMAHON ASSOCIATES, INC.

FIGURE 13
2015 FLOODING LIMITS
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN



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Proposed Alternative

Other Mapped Features

- Study Area Boundary
- D1 Drainage Area and ID
- CV-D3 Culvert and ID
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 2015-16; WDNR, 2013.

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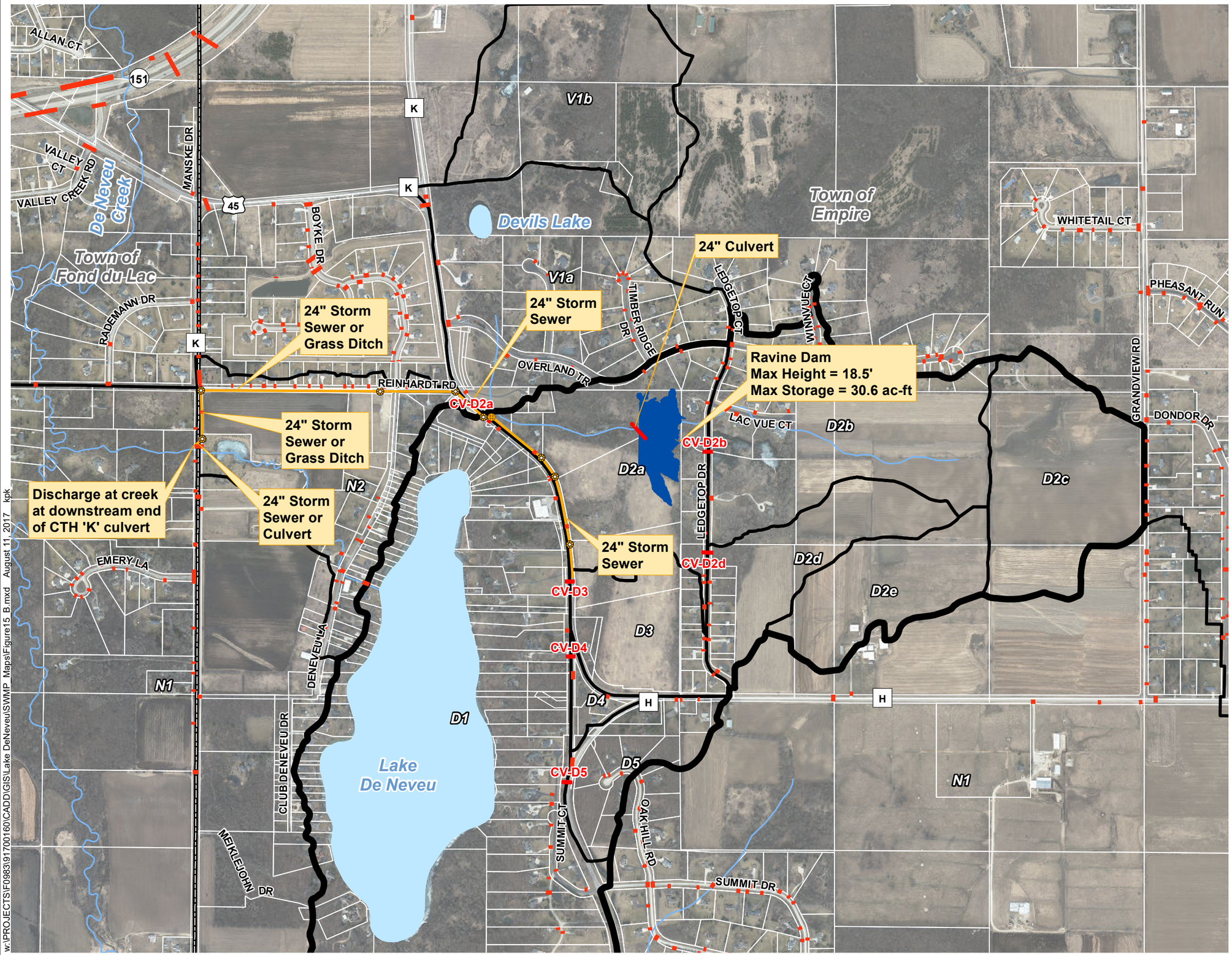
0 800 1,600 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

FIGURE 14
ALTERNATIVE 1
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN



Source: Fond du Lac County, 2015-16; WDNR, 2013.

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FIGURE 15
ALTERNATIVE 2
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN

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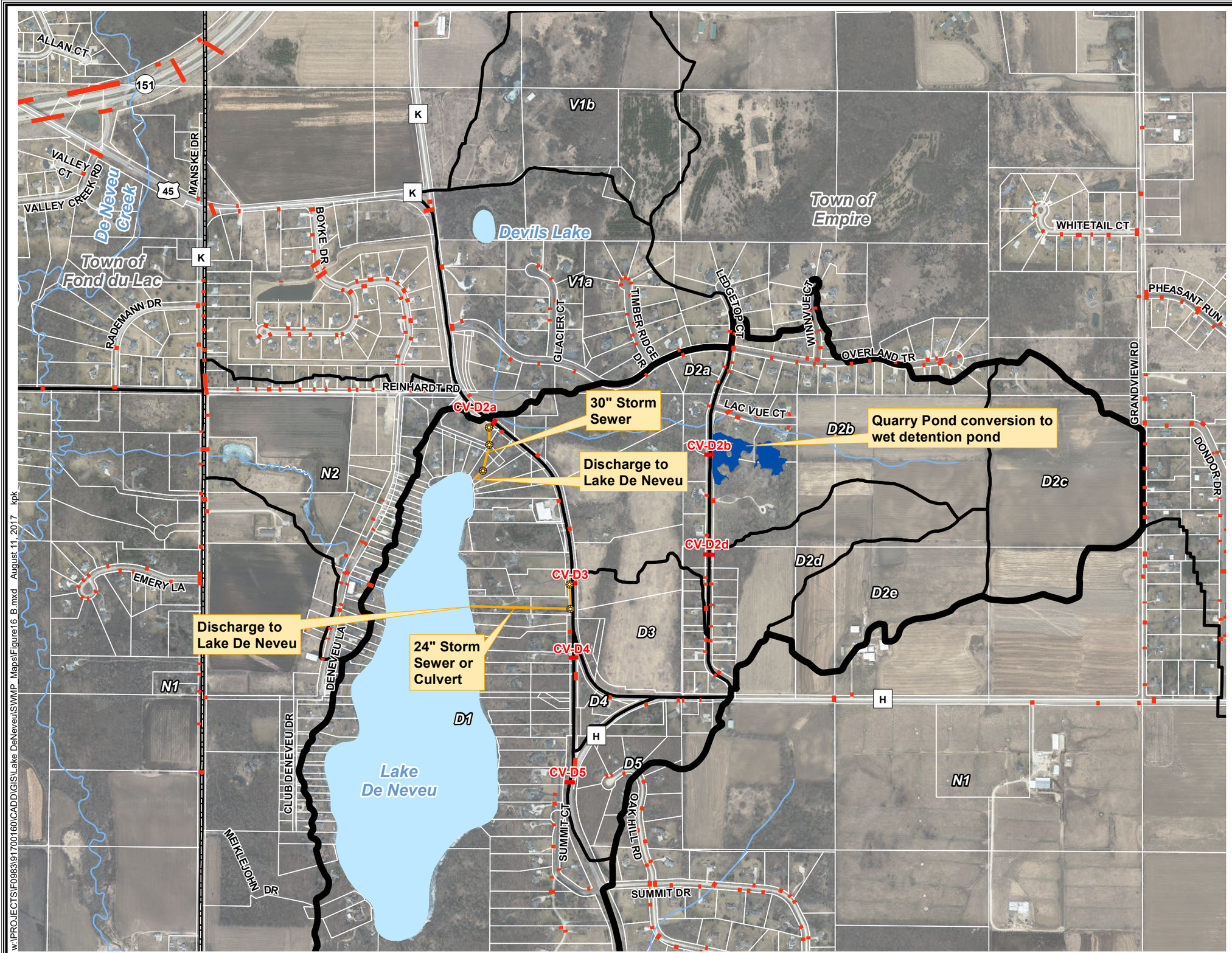

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FOND DU LAC COUNTY ESTABLISHED 1836

- Proposed Alternative
- CV-D3 Culvert and ID
- Wet Detention Pond

Other Mapped Features

- Study Area Boundary
- D1 Drainage Area and ID
- Municipal Boundary
- Parcel Line
- Stream (DNR)
- Surface Water

Source: Fond du Lac County, 2015-16; WDNR, 2013.

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N

0 800 1,600 Feet

McMAHON ENGINEERS ARCHITECTS
McMAHON ASSOCIATES, INC.

FIGURE 16
ALTERNATIVE 3
LAKE DE NEVEU
STORMWATER MANAGEMENT PLAN
TOWN OF EMPIRE
FOND DU LAC COUNTY, WISCONSIN