City of Grand Marais

STORMWATER MANAGEMENT PLAN

The City of Grand Marais, MN

Cook County Soil and Water Conservation Districts

September 12, 2018

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Cook County Soil and Water Conservation District

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ACRONYMS

ASOS	Automated Surface Observing System
BMP	Best Management Practice
CIP	Capital Improvement Program
DEM	Digital Elevation Model
EPA	Environmental Protection Agency
GI	Green Infrastructure
GIS	Geographic Information Systems
LID	Low Impact Development
LiDAR	Light Detection and Ranging
LSNW	Lake Superior North Watershed
LSN1W1P	Lake Superior North One Watershed, One Plan
MDH	Minnesota Department of Health
MnDNR	Minnesota Department of Natural Resources
MNDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
NA	Not Applicable
NAVD	North American Vertical Datum
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
SWCD	Soil and Water Conservation District
SWE	Snow water equivalent
SWM	Stormwater Management
TMDLs	Total Maximum Daily Loads
1W1P	One Watershed, One Plan

GLOSSARY

Aggregate - A broad category of particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates, and available in various particulate size gradations.

Aquifer - A body of permeable rock that can contain or transmit groundwater.

ASOS – Automated sensor suites that are designed to serve meteorological and aviation observing needs. There are currently more than 900 ASOS sites in the United States. These systems generally resport at hourly intervals, cut also report special observations if weather conditions change rapidly and cross aviation operation thresholds.

Best Management Practice (BMP) - One of many different structural or non–structural methods used to treat runoff, including such diverse measures as ponding, street sweeping, filtration through a rain garden and infiltration to a gravel trench.

Climate Change - A long-term change in climate measures such as temperature and rainfall. Changes in climate have a large impact on water quality as well as lake and wetland water levels and stream and river flows.

Detention Facility – Any facility that detains, delays the release of runoff for instance a dry basin that has an orifice level with the bottom of the basin so that all of the water eventually drains out and it remains dry between storms.

Digitize - To measure the geographic boundaries of a landscape feature and to determine its geospatial size and orientation. This is typically done on-screen in Geographic Information System (GIS)

E. coli – *Escherichia coli* (abbreviated as *E. coli*) is a fecal coliform bacteria that comes from human and animal waste. The Environmental protection agency uses *E. coli* measurements to determine whether fresh water is safe for recreation.

Evapotranspiration – The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.

Filtration - The technique of removing pollutants from runoff as it infiltrates through the soil or other medium.

Geomorphology - The study of the processes responsible for the shape and form, or morphology, of watercourses; describes the processes whereby sediment (e.g., silt, sand, gravel) and water are transported from the headwaters of a watershed to its mouth.

Green Infrastructure - Green Infrastructure (GI) incorporates the natural environment and constructed systems in an integrated network to provide multiple benefits and support resilient communities. GI is designed to reduce the effects of development on stormwater by maintaining or engineering some of the flood reduction functions of predevelopment conditions. Examples of GI include: underground storage, tree trenches along roads and sidewalks, bioswales along unimproved roads, permeable pavement, blue roofs and green roofs, retention ponds in open areas, wetland preservation and restoration, stream re-meandering, vegetation management in upland areas.

Groundwater - Water located below ground in the spaces present in soil and above the bedrock.

Groundwater Recharge - Water moving through the soil surface and deeper underground to become groundwater.

Hydraulics – The movement of water through specific hydraulic structures such as pipes and ponds.

Hydrology - The movement of water. Often used in reference to water movement as runoff over the soil after a rainfall event as it contributes to surface water bodies.

Hydrologic Soil Groups -

A soil classification system based on the ability to convey and store water; divided into four groups:

a) Well drained sands and gravel, high infiltration capacity, high leaching potential and low runoff potential;
b) Moderately drained fine to coarse grained soils, moderate infiltration capacity, moderate leaching potential and moderate runoff potential;
c) Fine grained, low infiltration capacity, low leaching potential and high runoff potential;
d) Clay soils, very low infiltration capacity, very low leaching potential and very high runoff potential.

Impervious Surfaces - Surfaces that severely restrict the movement of water through the surface of the earth and into the soil below. Impervious surface typically refers to manmade surfaces such as non-porous asphalt or concrete roadways, buildings, and heavily compacted soils.

Infiltration - Penetration of water through the ground surface.

Invasive Species - Organisms not endemic to a geographic location they often displace native species and have the potential to cause environmental change.

Low Impact Development - A stormwater management strategy that seeks to mitigate the impacts of increased urban runoff and stormwater pollution by managing it as close to its source as possible. It comprises a set of site design approaches and small scale stormwater management practices that promote the use of natural systems for infiltration and evapotranspiration, and rainwater harvesting.

Metadata – A set of data that describes and gives information about other data.

Nutrients - A group of chemicals that are needed for the growth of an organism. Within surface water systems, nutrients such as phosphorus and nitrogen can lead to the excessive growth of algae.

Peak flows - Term typically used to quantify the highest discharge of a stream or rover

Pollutant - A substance that makes land, water, air, etc., dirty and not safe or suitable to use.

Protection - Strategies that protect high quality and threatened resources that are essential to prevent further degradation and future impairment of surface and groundwater.

Restoration - Strategies that seek to restore or improve the quality of a resource which is currently not meeting water quality standards and has been identified as being impaired.

Retention Facility - A facility that retains or eliminates runoff by storing, infiltrating and/or evapotranspiring stormwater runoff.

Runoff - water from rain, snow melt, or irrigation that flows over the land surface.

Stream Channel - A natural waterway, formed by fluvial processes, that conveys running water.

Total Suspended Solids (TSS) - A measure of the amount of particulate material in suspension in a water column.

Turbidity - The cloudiness of the water that is caused by large numbers of individual particles that are generally invisible to the naked eye.

Stormwater BMPs - Methods used to control the speed and total amount of stormwater that flows off a site after a rainstorm and used to improve the quality of the runoff water.

Stormwater Infrastructure - Methods used to convey and/or control the speed and total amount of stormwater that flows off a site after a rainstorm and used to improve the quality of the runoff water.

Subwatershed - A smaller geographic section of a larger watershed unit with a typical drainage area between 2 and 15 square miles and whose boundaries include all the land area draining to a specified point.

Stream Connectivity - The term used to define the longitudinal connection a stream has along its length and the lateral connection a stream has with its floodplain and adjacent uplands.

Total Maximum Daily Loads (TMDLs) - The total amount of a pollutant or nutrient that a water body can receive and still meet state water quality standards. TMDL also refers to the process of allocating pollutant loadings among point and nonpoint sources.

Water Quality - Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular use. In the case of surface waters, uses are typically swimming and fishing.

1. INTRODUCTION

1.1. Background

The City of Grand Marais and Cook Soil and Water Conservation District partnered in the development of the 2018-2027 Stormwater Management Plan for the Grand Marais Watershed. The City of Grand Marais adopted its last Stormwater Management Plan in 2001. This plan served as a guide to the City as it managed its infrastructure and surface water resources over the last 15 years. The 2001 Stormwater Management Plan made a number of recommendations for improvements to the system, most of which have been implemented by the City and its local partners.

Today there are still stormwater management issues related to aging infrastructure, increased land development pressure, flooding, public safety, property damage, pollutant loads to Lake Superior and beach closures that need to be addressed. An additional public health concern is that the public water intake for the City of Grand Marais on Lake Superior is located within half a mile of the harbor storm water outlets into Lake Superior. Pollutant laden stormwater runoff quickly discharges to Lake Superior and may be routed to the public water supply system intake. This updated Stormwater Management Plan addresses these issues, as well as others identified during the community engagement process, by evaluating existing and proposed drainage conditions and making prioritized recommendations for policies, upgrades and improvements and new stormwater Best Management Practices (BMPs) that will address existing and future landuse needs.

Additionally, the City of Grand Marais is the first community along the North Shore to develop a stormwater management plan since the adoption of the Lake Superior North One Watershed, One Plan (LSN1W1P). By completing this stormwater management plan, the City of Grand Marais will be eligible for funding through the Board of Water and Soil Resources Clean Water Funds which are distributed to the Counties of Cook and Lake and the SWCD's of Cook and Lake. Per the Memorandum of Agreement for the Implementation of the LSNW One Watershed One Plan, the Counties of Lake and Cook agree to "assist with securing funding and administering funding responsibilities as mechanisms to accomplish tasks within the Plan". Implementation of stormwater quality improvement projects as identified in an updated stormwater management plan is one of the implementation strategies identified in the LSN1W1P.

1.2. Plan Objectives

The broad objectives for the City of Grand Marais' 2018-2027 Stormwater Management Plan are as follows:

- Characterize the drainage area to the City of Grand Marais to better understand how the system operates under existing and future conditions.
- Identify gaps in the information needed to properly characterize the drainage area.
- Utilize a hydrologic and hydraulic model to assess storm sewer infrastructure and potential water quality and water quantity improvement projects.
- Create a GIS integrated map that will memorialize the hydrologic and hydraulic data accompanying the stormwater management plan and serve as a tool for city staff and other public entities to understand how changes within the watershed will impact the drainage system and water resources.
- Engage the public and local business owners in the identification of stormwater-related issues and potential solutions.
- Develop a 10-year implementation plan that identifies the steps the City of Grand Marais needs to take to address existing and anticipated stormwater management issues.

2. WATERSHED ASSESSMENT

2.1. Location

The City of Grand Marais is located in Cook County along the northwestern shore of Lake Superior. Located along Minnesota Highway 61, Grand Marais is 100 miles northeast of Duluth and 40 miles south of the Canada-US border. Downtown Grand Marais is located on a harbor which is protected on one side by Artist's Point, a natural geologic formation. The land surrounding Grand Marais is steep in nature and slopes up to form Sawtooth Bluff. Historically, the downtown area was a marsh that in early fur-trading days was approximately 20 acres in size. Over time, this marsh was filled in as early settlements grew to support the vibrant community that exists today. Much of the downtown area remains close to the level of Lake Superior making drainage of this developed portion of the City a challenge.

2.2. Watershed

2.2.1. Drainage Area to the City of Grand Marais

The City is located at the bottom of a 3,220-acre watershed that extends from the ridgeline (approximately 2 miles inland) to Lake Superior. The stormwater management plan considers the entire watershed intersecting the City to Lake Superior, excluding the northernmost portion that drains to the headwaters of Fall River.

As illustrated in Figure 2-1, the main drainage features in this watershed through the City include Village Ditch (Nature Boy Creek), the 3rd Street bypass, the East and West Campground drainages and the Downtown drainage area. Areas draining directly to Lake Superior are referred to as the Waterfront. The largest drainage areas that are tributary to distinct outfall locations are the Village Ditch drainage (1,140 acres at the outfall to Lake Superior), the West Campground drainage (649 acres at the outfall to Lake Superior), and the 3rd Street Bypass drainage (239 acres at the outfall to Lake Superior). The remaining drainage areas are generally much smaller and most drain to multiple outfalls. Notably, the Downtown drainage area is tributary to no fewer than 10 outfall locations, at least 8 of which are defined by storm sewer outfalls.

2.2.2. Drainage System Overview

In addition to Village Ditch, there are eight unnamed creeks that collect and convey flow from the upper watershed through the City (see Figure 2). They range from intermittent flow meandering through the forest floor, to perennial baseflow in well-defined channels. The beds of the creeks are mostly cobbles and/or bedrock. The banks of the creeks are composed of loam/clay soils and cobbles.

Several of the major drainageways appear to have been constructed specifically to divert water away from downtown. In its run on the south side of Gunflint Trail., Village Ditch runs nearly perpendicular to the overall watershed slope – likely a contributing factor to water periodically overtopping its low, artificial southern bank, during which times it floods adjacent community recreational facilities. Likewise, the 3rd Street storm sewer network runs perpendicular to the slope along 3rd Street from 5th Avenue W to its convergence with the 5th Street storm sewer network at Hwy 61. High capacity catch basins on the northern side of most of the intersections with 3rd Street are indicative of a concerted effort to prevent runoff between 3rd Street and 5th Street from reaching downtown.

A detailed description of the city's stormsewer system is provided in Section 4.0 of the Stormwater Management Plan.

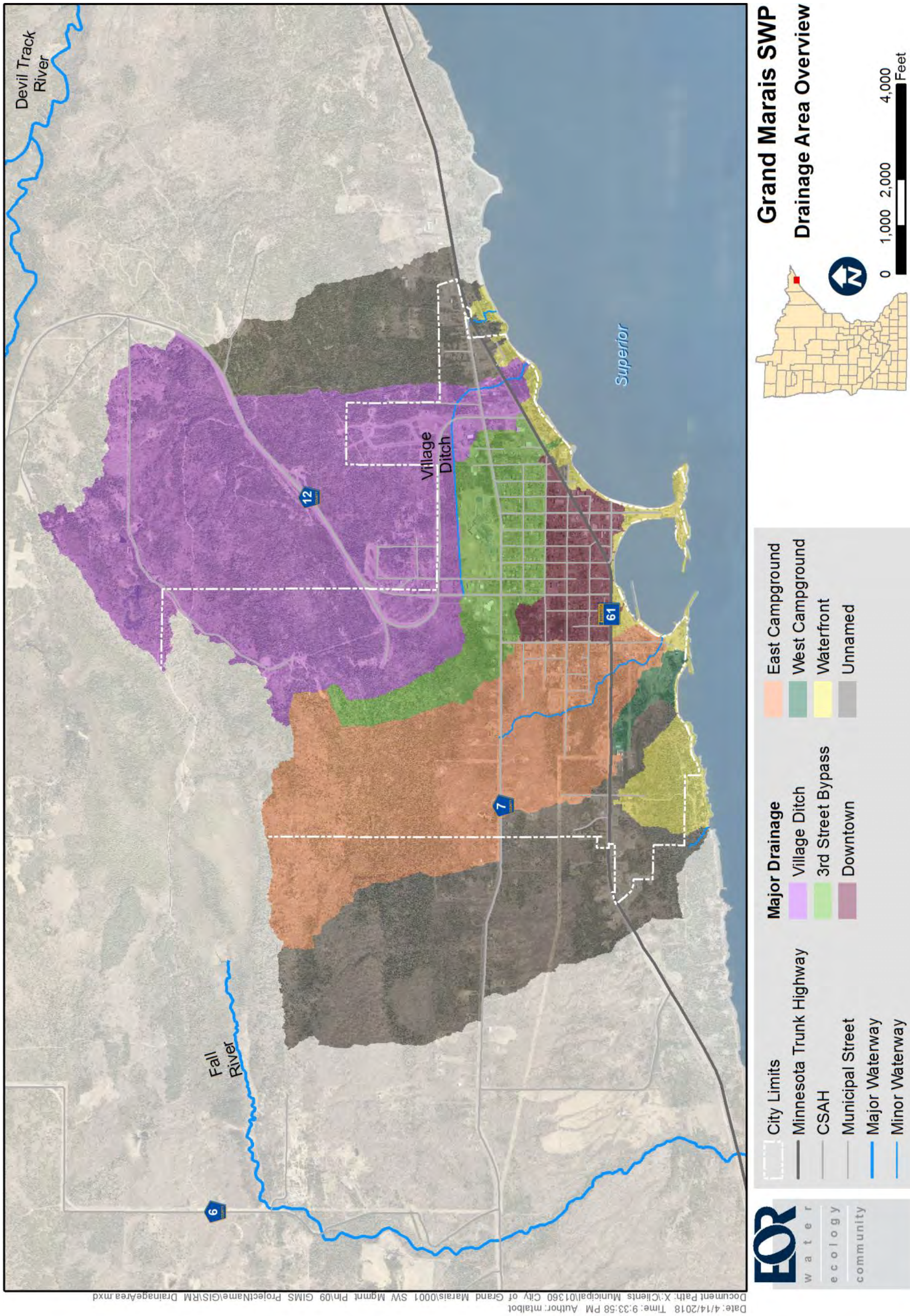


Figure 2-1: Overview of the Stormwater Management Plan study area and major drainages.

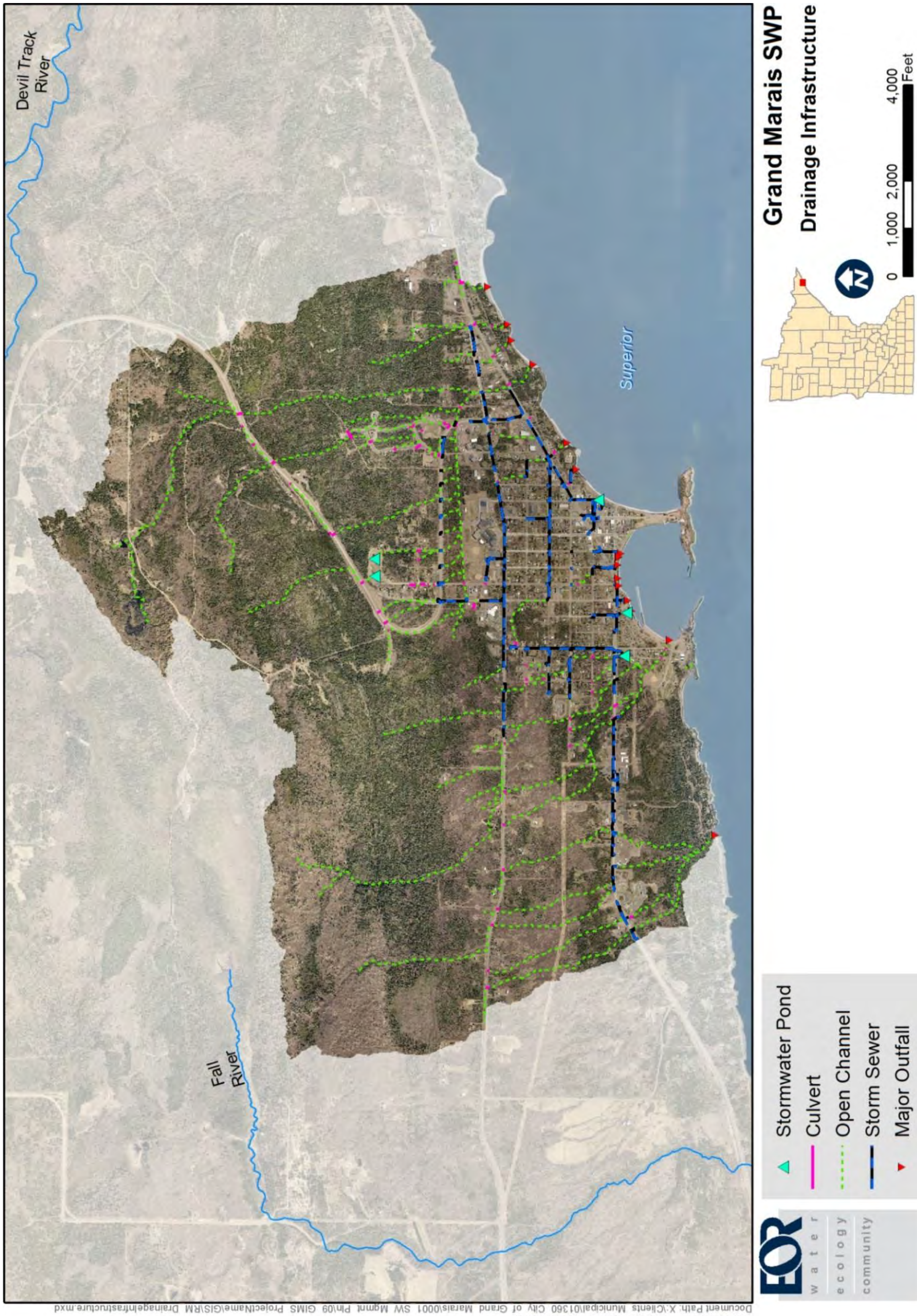


Figure 2-2: Overview of drainage infrastructure within the study area.

2.3. Climate and Precipitation

2.3.1. Climate

Grand Marais has a climate with extremes in temperature, low humidity and moderate winds, as expected for a mid-latitude inland location. The lake has a slight warming effect in the winter and slight cooling effect in the summer, contributing to Grand Marais having the coolest summer temperatures of any weather station in Minnesota. As illustrated in

Figure 2-3, the coldest and warmest months on average between 1981 and 2010 were January and August, respectively; February had the least precipitation, while June had the most.

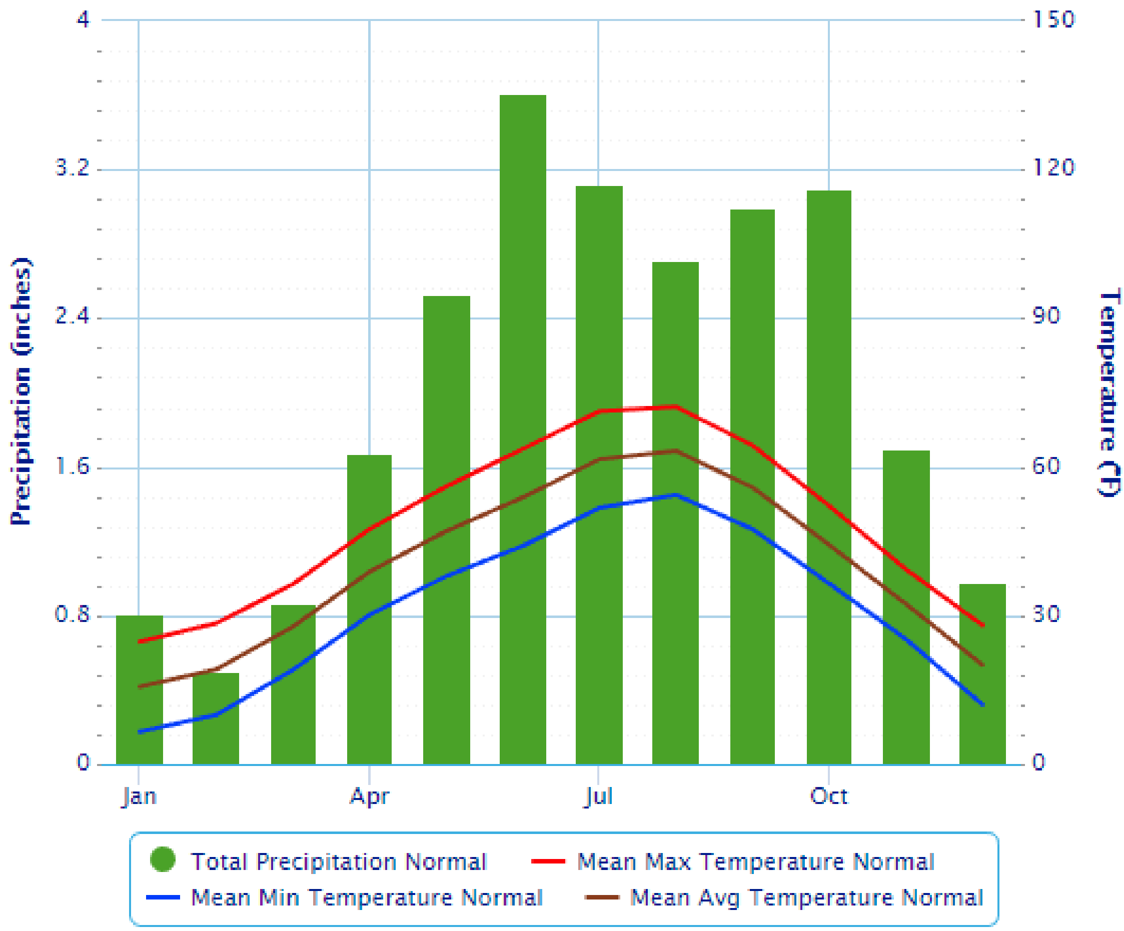


Figure 2-3. Monthly Climate Normals (1981-2010) for Grand Marais, MN (Source: U.S. Climate Data)

The temperatures recorded at the Grand Marais Weather Station from 1981 to 2010 are summarized in Table 2-1. Daily mean temperatures range from a low of 15.6°F in January to a high of 63.2°F in August, with an average annual temperature of 39.9°F.

Table 2-1. Temperature Data from Grand Marais Weather Station 213282 (1981-2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daily Max (°F)	24.7	28.4	36.3	47.4	56	63.6	71.2	72.1	64.3	52.1	39.3	28
Daily Mean (°F)	15.6	19.1	27.7	38.8	47	53.8	61.5	63.2	55.8	44.2	32.3	20
Daily Min (°F)	6.5	9.9	19	30.1	37.9	44	51.7	54.3	47.4	36.4	25.2	12

Source: NOAA Online Weather Data

Figure 3 shows a comparison of trends in annual temperature range. The annual range is the difference between the hottest and coldest months, taking monthly mean temperatures in each case. In general terms, it is approximately the difference between the average of the January maximum and minimum temperatures and the July maximum and minimum temperatures. As Figure 3 demonstrates, the trend since 1970 shows warming of 0.63 degrees per decade (or 6.3 degrees per century).

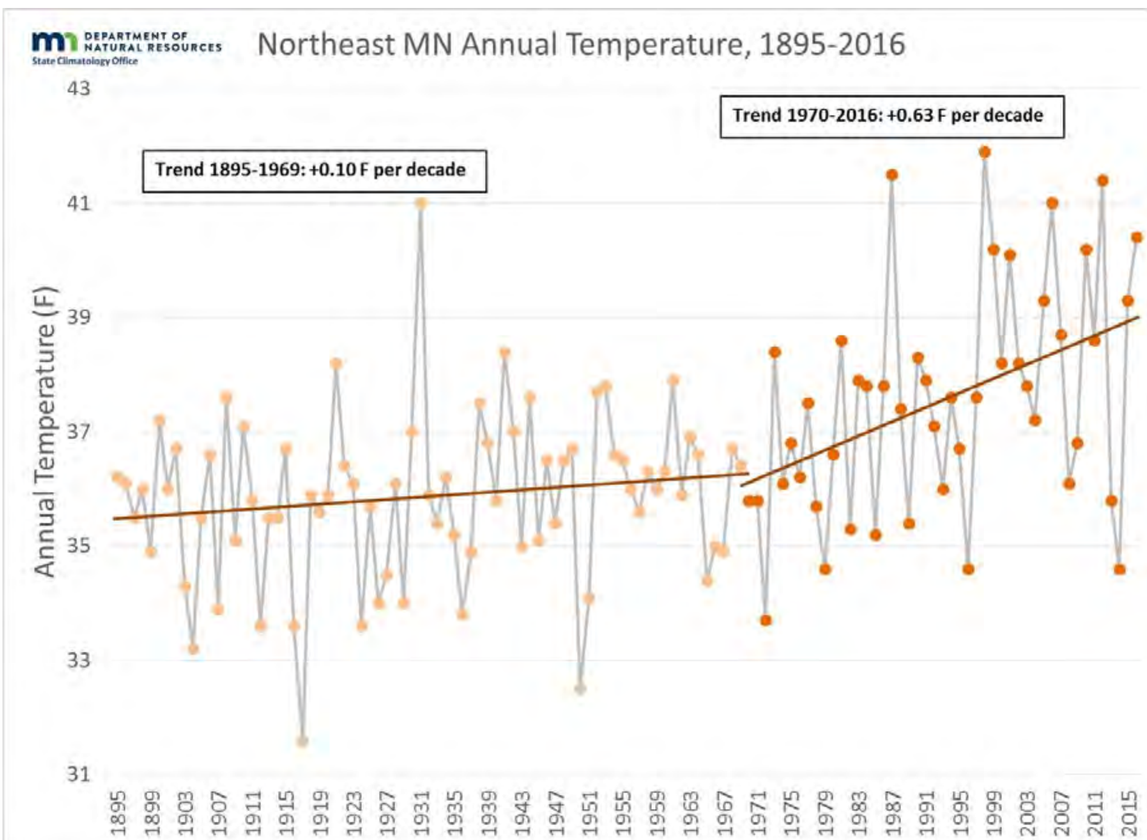


Figure 2-4. Comparison of Linear Statistical Trends for Annual Temperature in Northeast Minnesota (Source: Minnesota DNR, Division of Ecological Services)

As discussed by the Interagency Climate Adaptation Team in "Adapting to Climate Change in Minnesota" (Moss, 2013) and in the "Minnesota Climate & Health Profile Report" (Minnesota Department of Health, 2015), one side effect of these increased temperatures is a marked decline in the number of days per year that Lake Superior is covered with ice (Figure 2-5) – a significant contributing factor to warming water temperatures and increased evaporation from the lake surface. Other impacts of increasing temperatures in the northeastern portion of the State include changes to soil frost depth and duration, side effects of warmer waters (e.g. increases instances of low DO and hypoxia, increased frequency of algal blooms, thermal resistance to vertical mixing, stresses cold water fisheries) and increases in terrestrial invasive species since warmer temperatures allow them to survive more easily, multiply and expand their ranges.

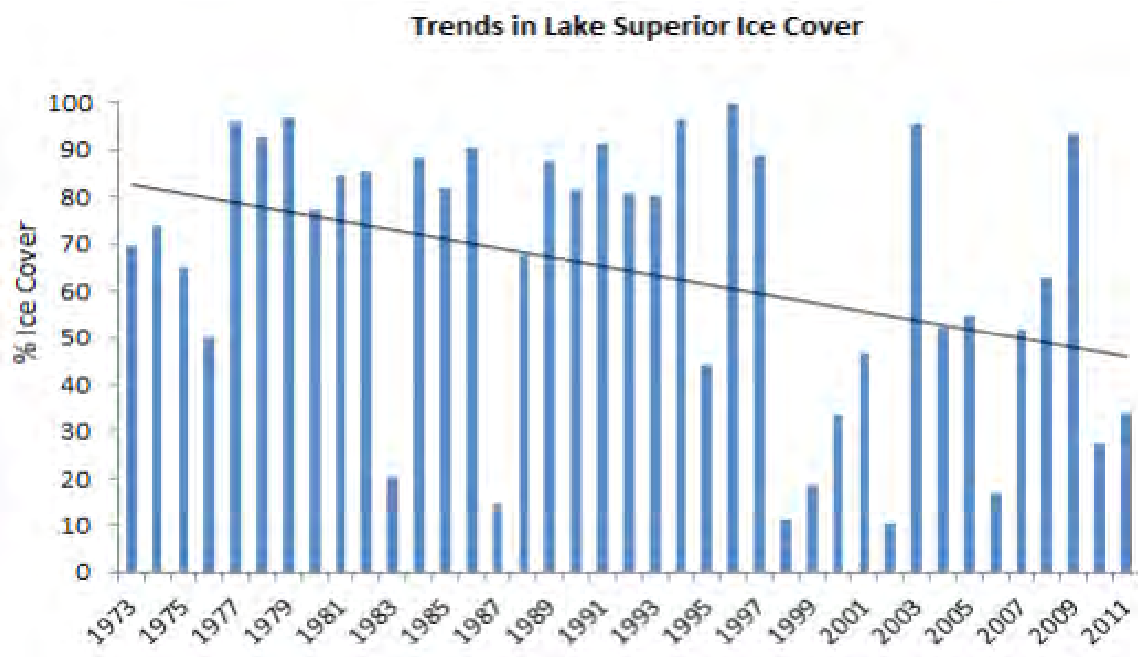
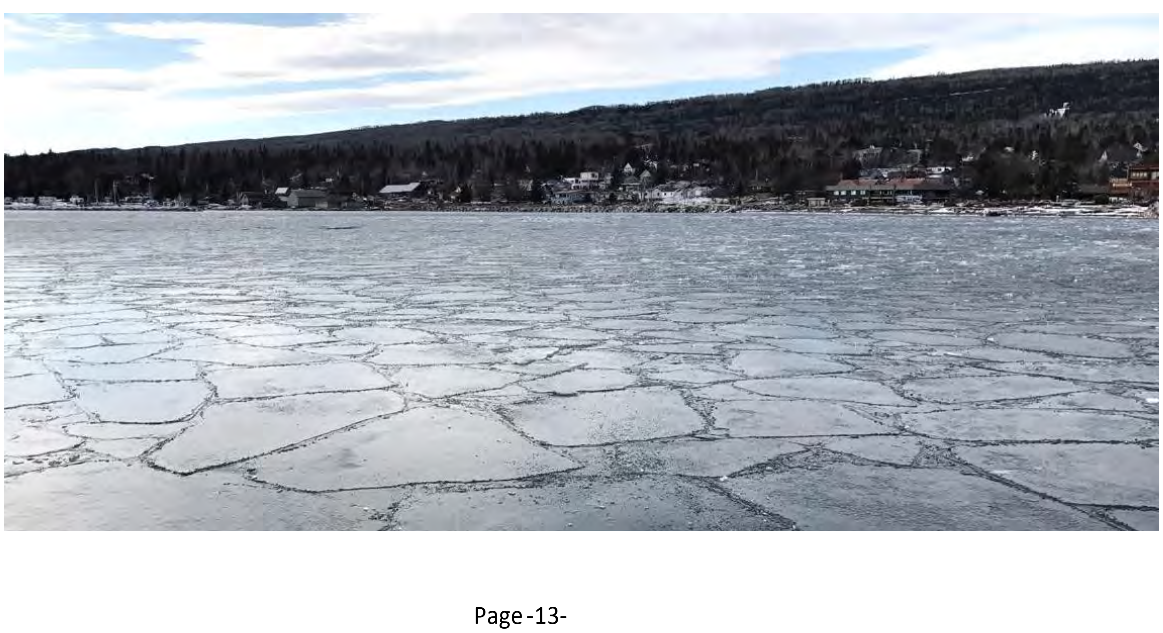


Figure 2-5: (Figure 4.14, page 25 of the Minnesota Climate & Health Profile Report)



2.3.2. Precipitation

The precipitation recorded at the Grand Marais weather station 213282 from 1981 to 2010 is summarized in Table 2-2. The average total annual precipitation at the station during that same period is 24.6 inches, with an average annual snow accumulation of 42.1 inches. For perspective, the average snow water equivalent (SWE) at the time of melt is approximately 0.10 inches of water per inch of snow, which means that about 4.2 inches or 17% of annual precipitation comes in the form of snowfall; however, the SWE varies considerably and this should be considered merely a rough approximation. Additionally, as shown in Figure 2-6, proximity to the lake significantly influences the partitioning of rainfall between rain and snow, with significantly more snowfall occurring away from the lake and at higher elevations[1].

Table 2-2. Precipitation Data from Grand Marais Weather Station 213282 from 1981-2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Precip. (in)	0.81	0.5	0.87	1.67	2.53	3.61	3.12	2.71	3	3.1	1.7	0.98
Snowfall (in)	13.6	6.1	5.9	2.1	0	0	0	0	0	0.1	3.7	10.6

(Source: NOAA Climate Data Online)

[1] This significant difference between snowfall next to and away from the lake may explain the apparent discrepancy between the values in Table 2-2 and Figure 2-6, since accurately estimating and displaying values is inherently difficult at a large scale (i.e. statewide) when such a large gradient is present.

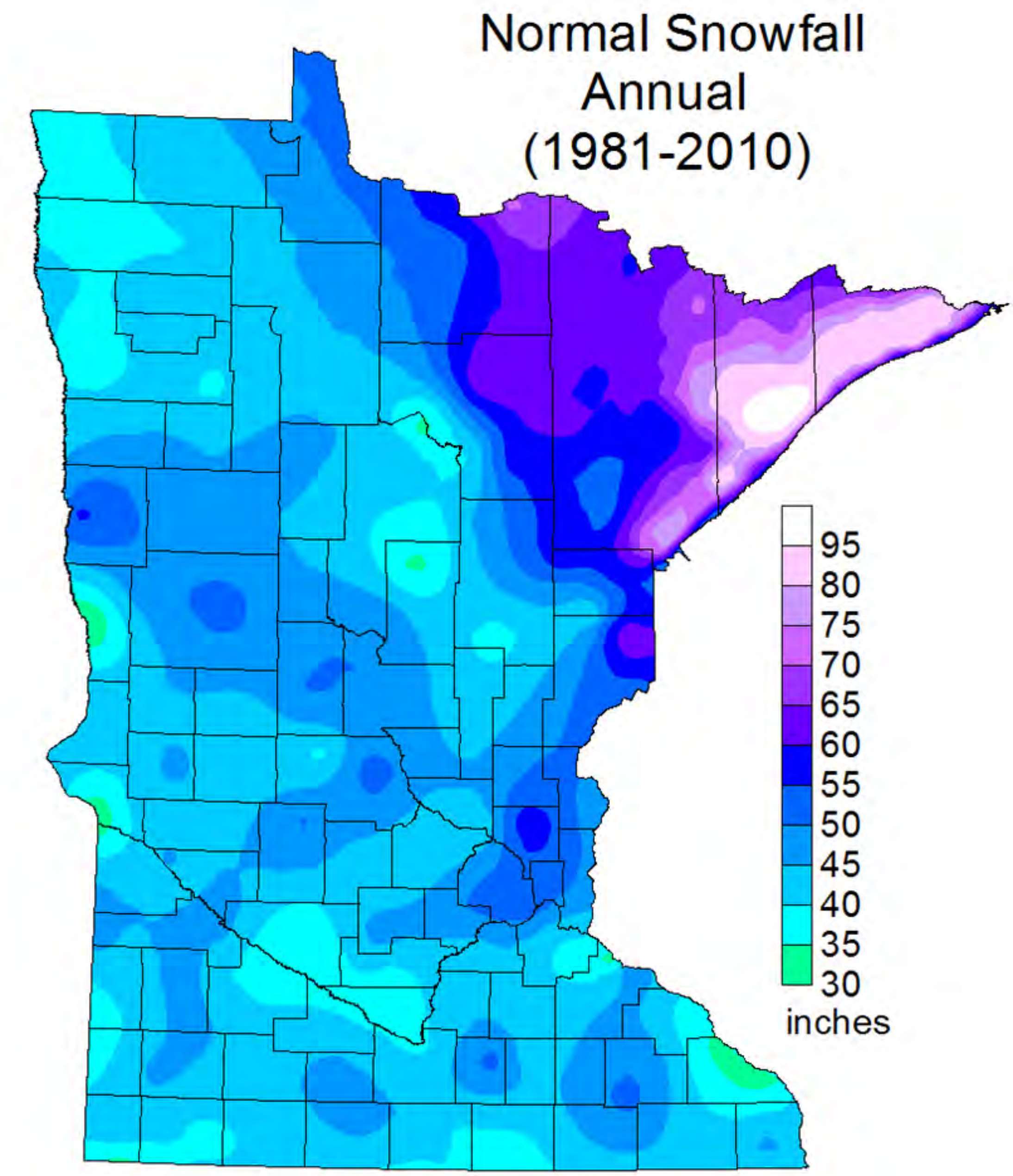


Figure 2-6: Normal annual snowfall (1981-2010) for Minnesota (Source: MPCA).

Figure 2-7 shows a comparison of 20th century precipitation averages by decade (1900-1990) to the averages for the period since 1990 (1990-2015). This comparison illustrates that on average it has been 4 percent wetter over the last 20 years than it was over the last century.

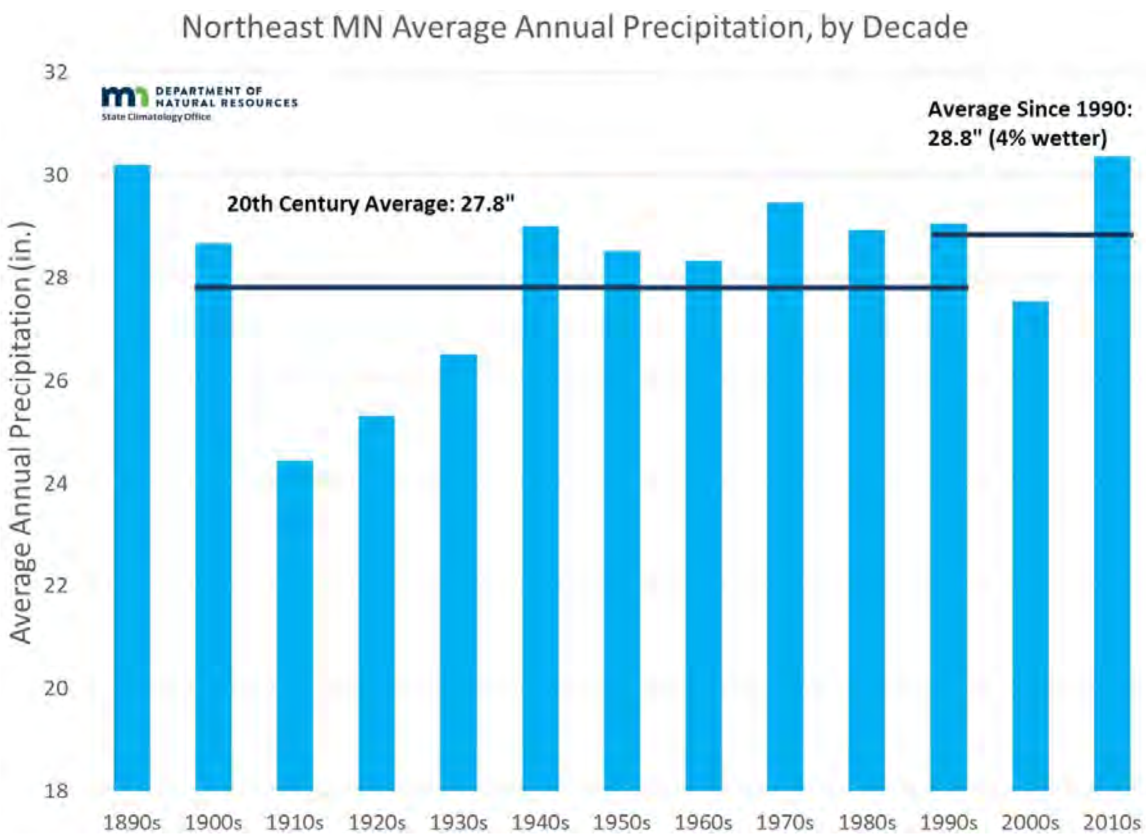


Figure 2-7. Comparison of 20th Century Precipitation Averages to the Period since 1990 in Northeast Minnesota (Source: Minnesota DNR, Division of Ecological Services)

Generally speaking, the impacts of changes in precipitation patterns and more extreme events include increased risk of flooding, increased variability of streamflows, increased velocity of water during high flow periods, soil loss, decreased groundwater recharge (rain from extreme events falls too quickly to be absorbed in the ground) and overwhelming of existing infrastructure. Additionally, increased flooding results in increased watershed loads of sediment and nutrients.

In the context of Grand Marais specifically, the upshot of all of this is manifold. As an example, there is a potential for areas that currently flood (e.g. downtown) to experience increasingly frequent and/or severe flooding, while areas that do not currently flood will not necessarily remain high and dry in the future. As another example, sediment loading and associated pollutant loading due to increased runoff as well as increased bank scour and failure (e.g. as Village Ditch widens to accommodate more frequent large storms) has the potential to increase in the coming years in the absence of proactive measures. More broadly, the impacts of the compounded effects of a warmer lake may be difficult to predict with certainty, but it stands to reason that however Lake Superior changes, its influence on Grand Marais' climate will remain, meaning that those changes will have a direct and tangible impact on the community as the 21st century progresses.

2.4. Physical Geography

2.4.1 Topography

The watershed is characterized by a steep grade with an aspect that is essentially perpendicular to the shore of Lake Superior. The highest point in the watershed is 1,545 ft. and the lowest point is at the lake surface (see), which had a median elevation between January 1st 2000 and December 31st 2017 of 601.31 ft. in the NAVD 88 datum[2] (ranging between 599.35 ft. and 603.72 ft.). Since this 945 ft. (+/-) elevation change occurs in approximately 2 miles, the watershed has an average slope of around 9%; the slope at specific locations within the watershed varies greatly, from flat (0%) to extremely steep (>60%)[3], as shown in .

2.4.2 Geology and Soils

The geomorphology of the Grand Marais Area is dominated by volcanic lava flows eroded down to a resistant basalt plume, the most obvious remnant being Devil's Ridge. The step-like topography from Devil's Ridge to the flat land in the downtown area reflects the eroded top layers of the ancient lava flows. The relatively flat area "upland" from the harbor beach is a remnant wetland.

The soils in the study area are varied as shown in , but most major components are stony, rock-outcrop complexes with high slopes – consistent with the prevalence of shallow bedrock as indicated in . Soil survey information is regularly updated and posted to the Web Soil Survey, published by the USDA Natural Resources Conservation Service (NRCS). Soil data is available from the database for Cook County is summarized in the Table on the following page.

[2] Lake level readings from NOAA are reported in the International Great Lakes Datum of 1986 (IGLD 85), which was the reference used in developing the NAVD 88 datum.

[3] Slope calculations were performed using a resampled LiDAR DEM with 30-meter horizontal resolution.

Table 2-3, Description and distribution of hydrologic soil groups in the Grand Marais watershed

Soil Type	Parent Material	Depth to Restrictive Feature	Hydrologic Soil Group
Ahmeek	Coarse-loamy ablation till over dense coarse-loamy lodgment till	30 to 80 inches to densic material	C
Aquents	Loamy alluvium, sandy beach materials and dredge materials	More than 80 inches	B/D
Augustana	Coarse-loamy drift over friable fine-loamy till over dense coarse-loamy lodgment till	60 to 80 inches to densic material	C
Badriver	Firm clayey till	More than 80 inches	C/D
Barto	Gravelly drift	8 to 20 inches to lithic bedrock	D
Canosia	Coarse-loamy ablation till over dense coarse-loamy lodgment till	30 to 60 inches to densic material	C/D
Eldes	Coarse-loamy drift over friable fine-loamy till over dense coarse-loamy lodgment till	60 to 80 inches to densic material	B/D
Forbay	Coarse-loamy drift over friable fine-loamy till	20 to 40 inches to lithic bedrock	C
Giese	Drift over till	30 to 60 inches to densic material	C/D
Greysolon	Gravelly drift	20 to 40 inches to lithic bedrock	B/D
Hegberg	Coarse-loamy drift over friable fine-loamy till over dense coarse-loamy lodgment till	60 to 80 inches to densic material	B/D
Hermantown	Coarse-loamy ablation till over dense coarse-loamy lodgment till	30 to 60 inches to densic material	C/D
Mesaba	Gravelly drift	20 to 40 inches to lithic bedrock	B
Normanna	Coarse-loamy ablation till over dense coarse-loamy lodgment till	30 to 60 inches to densic material	B/D
Odanah	Firm clayey till	More than 80 inches	C
Sanborg	Firm clayey till	More than 80 inches	C/D
Udifluvents	Stratified loamy alluvium	More than 80 inches	A/D
Wahbegon	Friable fine=loamy till over dense coarse-loamy lodgment till	60 to 80 inches to densic material	B/D

2.4.3. Surface Water Features

Creeks - In addition to Village Ditch, there are eight unnamed creeks that collect and convey flow from the upper watershed through the City. They range from intermittent flow meandering through the forest floor, to perennial baseflow in well-defined channels. The beds of the creeks are mostly cobbles and/or bedrock. The banks of the creeks are composed of loam/clay soils and cobbles.

Wetlands – The wetlands in the study area are primarily along the northern boundary with the majority located in the Village Ditch watershed. As shown in , they consist of coniferous and shub wetlands, bog, and wet meadow. Though the wetlands are relatively small in size their function of storing and filtering runoff high in the watershed is critical to the protection of downstream natural resources and city infrastructure.

Lakes – As the defining feature of the City, the role of Lake Superior in influencing everything from tourism to flooding to weather in Grand Marais cannot be overstated. The water surface elevation of the lake is of particular importance, as it influences flooding both directly (through wave action during large storms) and indirectly (through defining tailwater elevations for stormwater infrastructure). Between 2000 and 2017, the water surface elevation fluctuated between 599.35' at its lowest and 603.72' at its highest, with an average elevation during that period of 601.36'. As illustrated in Figure 2-8 and Figure 2-9, the elevation can vary substantially within a calendar year, with an average range of 1.99 feet. A significant increase in water surface elevation has been observed from 2012 to 2017, with the average annual elevation increasing 1.77 feet from 600.77' to 602.54'.

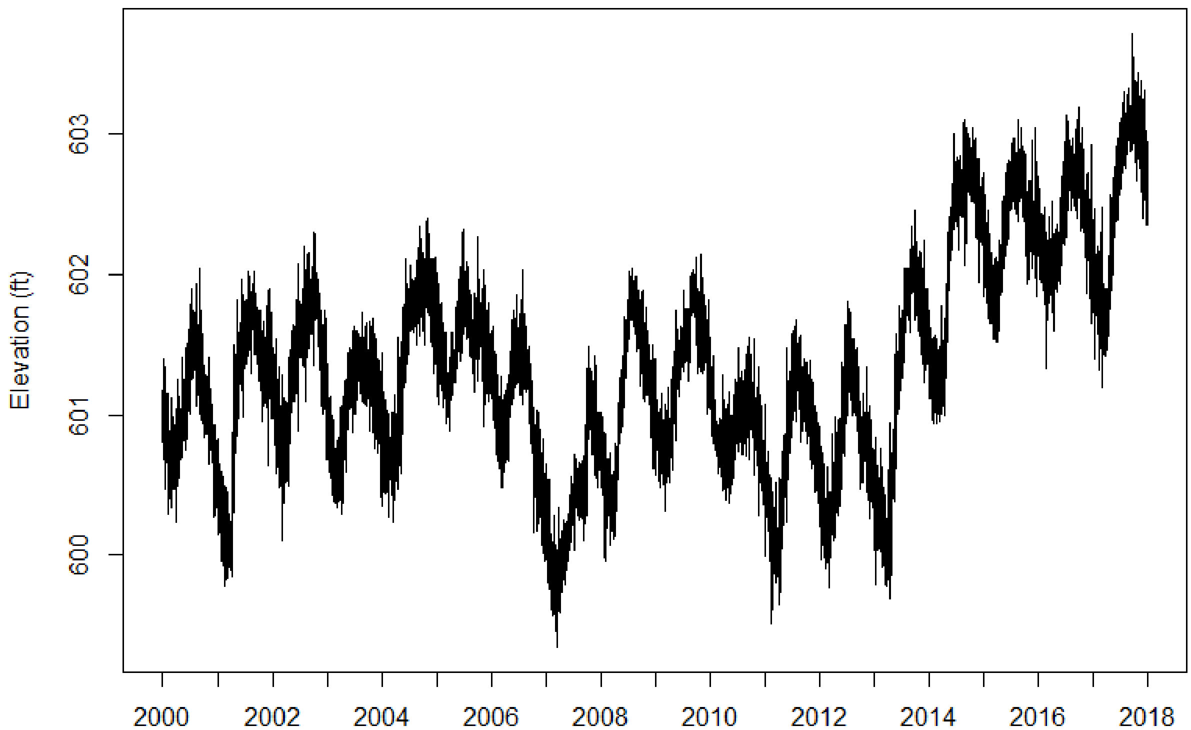


Figure 2-8: Lake Superior hourly water surface elevation at Grand Marais from 2000 to 2017 (Source: NOAA)

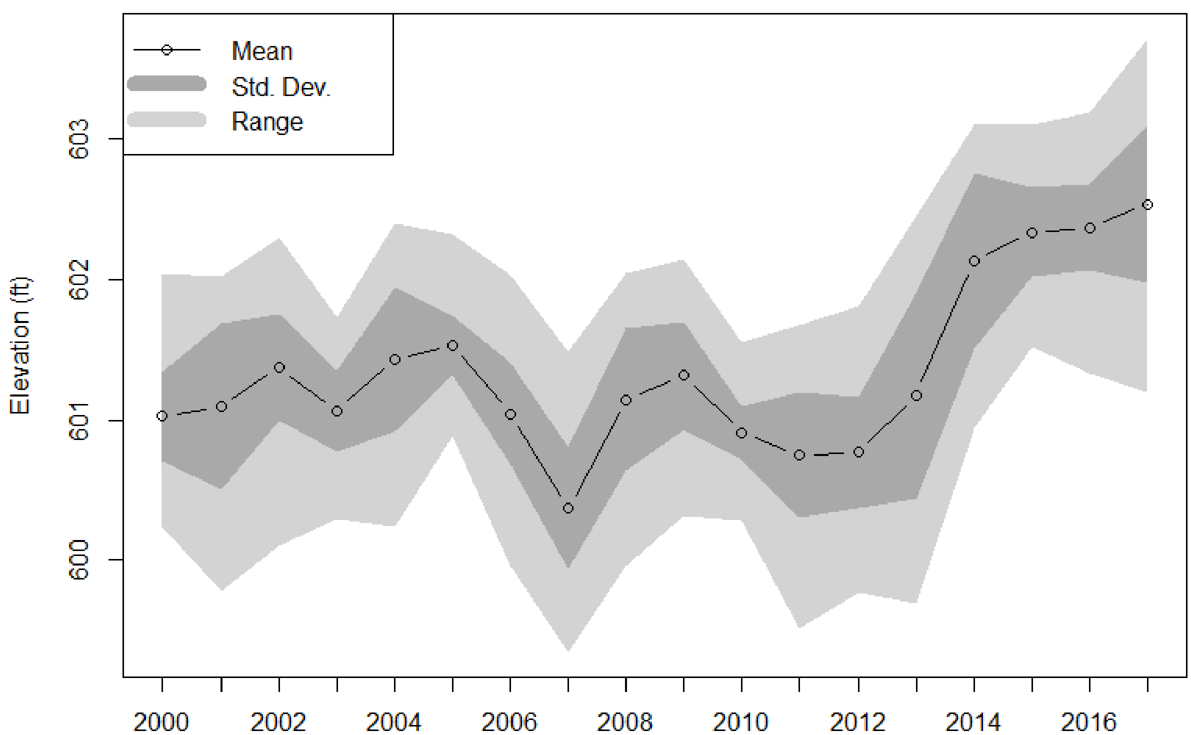


Figure 2-9: Lake Superior annual mean water surface elevation at Grand Marais from 2000 to 2017 (Source: NOAA)

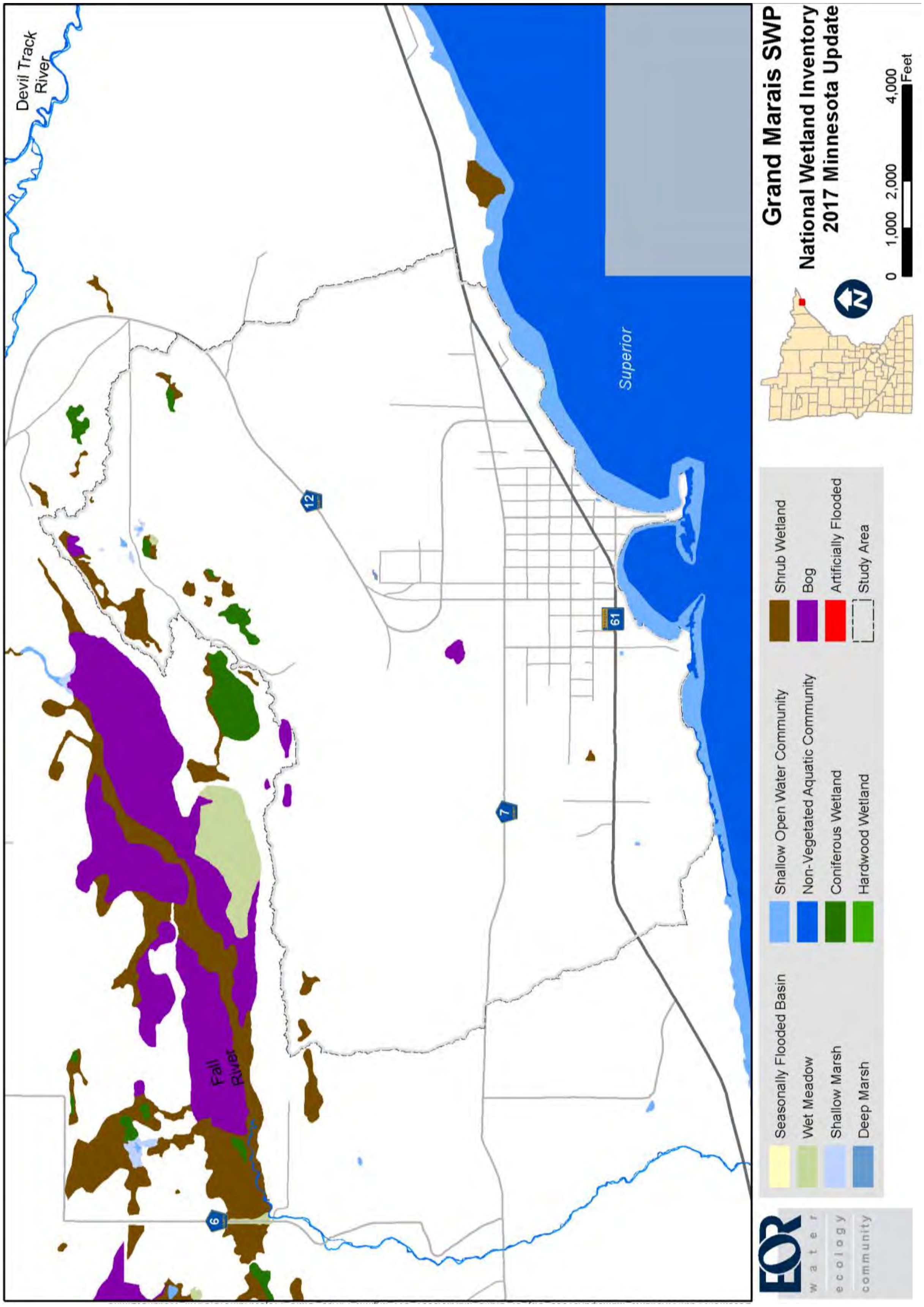


Figure 2-10: Wetlands in and adjacent to the study area

2.4.4. Groundwater

The geology of the Grand Marais area features a thin layer of glacial sediments overlying bedrock. The glacial sediments are associated with the Superior Lobe glaciation. The underlying bedrock is fractured Precambrain igneous rock associated with the North Shore Volcanics Formation.

Groundwater flow is predominantly through the fractures and bedding planes in the bedrock. Groundwater flow is to the south-southeast toward Lake Superior. The depth to groundwater may be close to ground surface near Lake Superior. Away from the lake, the depth to groundwater may vary significantly depending on the nature of the glacial sediments and the occurrence of fractures in the bedrock.

Grand Marais takes its drinking water from Lake Superior, but most of the residences outside of town rely on domestic wells for drinking water. Typical wells penetrate 20 feet or less of glacial sediments and then extend into bedrock for a total depth of 100 to more than 250 feet. Hydraulic fracking is commonly used to improve well yield.

Groundwater quality in the Northeast Region around Grand Marais is considered good when compared to other areas with similar aquifers, but with some exceedances of drinking water criteria in arsenic, beryllium, boron, manganese and selenium. Concentrations of chemicals within the Precambrian aquifers were comparable to similar aquifers throughout the state and concentrations of major cations and anions were lower in the surficial and buried drift aquifers when compared to similar aquifers statewide (MPCA, 1999). Many of the exceedances identified were attributed to the natural geochemistry.

Several locations in downtown Grand Marais have past or current concerns about groundwater contamination from leaking underground storage tanks or spills. Both active and sealed monitoring wells are found near these sites.

2.4.5. Unique Features, Fish & Wildlife Habitat and Scenic Areas

The Grand Marais watershed contains a number of unique features and scenic areas which contribute to the overall quality of life in the watershed. These unique historic and natural areas are summarized in the following table.

Table 2-4. Unique Features and Scenic Areas in the Drainage Area to Grand Marais

Feature	Description
Grand Marais Campground and Marina	The City of Grand Marais's municipal campground is located on the southern end of town on a peninsula edged by the Harbor on one side and Lake Superior on the other side.
Gunflint Trail Scenic Byway	One of three nationally designated scenic byways in the Superior National Forest. It runs approximately 57 miles along the Gunflint Trail from Grand Marais to Trail's End Campground.
Lake Superior	One of the largest freshwater lakes, containing 10% of the earth's fresh water. The lake's 32,000 square mile surface area stretches across the border between the United States and Canada. There are two countries, three states, one province and many First Nations surrounding Lake Superior's magnificent shoreline.
Lake Superior State Water Trail: Caribou River to Grand Marais and Grand Marais to Pigeon River	The Grand Maris to Pigeon River potion of the Water Trail covers approximately 42 miles of Lake Superior's shoreline in eastern Cook County. Minnesota state water trails are stretches of river or lake that are mapped and managed especially for canoeing, kayaking, boating and camping. There are 35 Minnesota state water trails.
Superior National Forest	Part of the United States National Forest System, the Superior National Forest comprises over 3,900,000 acres of woods and waters. The majority of the forest is multiple-use, including both logging and recreational activities such as camping, boating and fishing.
Pincushion Mountain Trail System	Pincushion Mountain provides a spectacular view to the City of Grand Marais and Lake Superior. Recreational trails make this location a popular stop on the way up the Gunflint Trail.
Lake Superior Harbor and Artist Point	Artists Point is the island located at the end of the spit of land that forms the harbor in Grand Marais. The lighthouse is at the end of the breakwater.

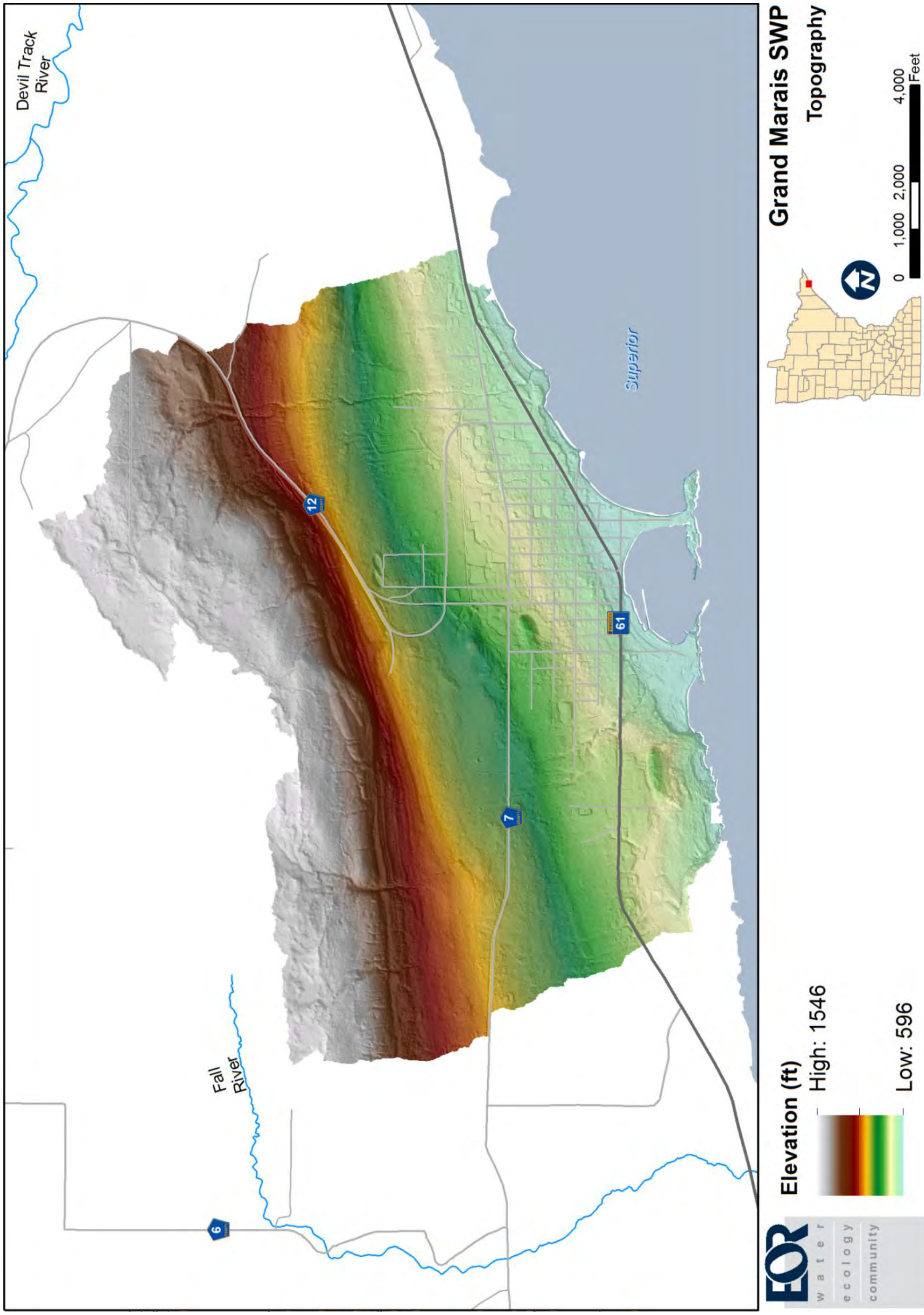


Figure 2-11: LidDAR-derived elevation model of the study area.

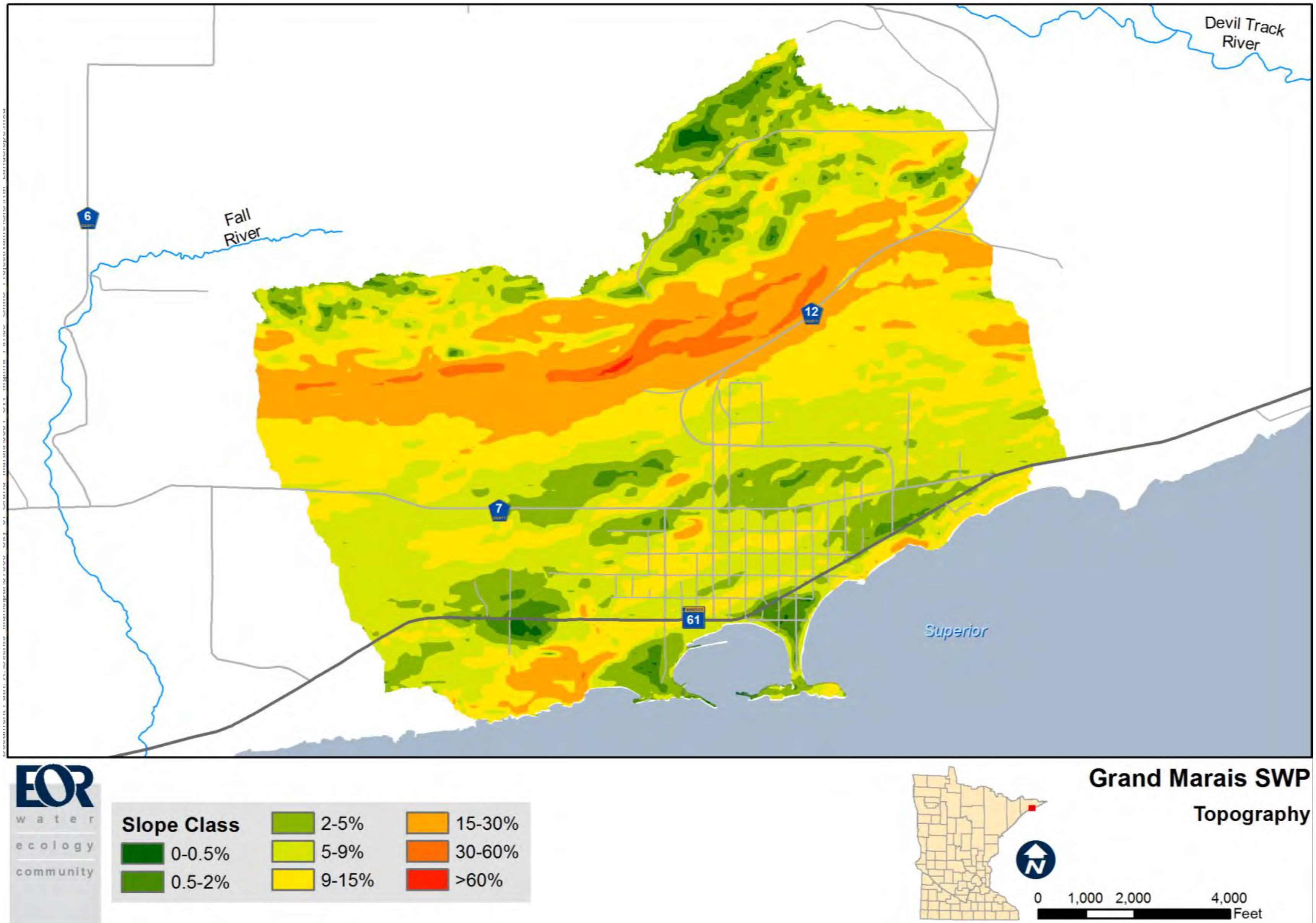


Figure 2-12: Terrain slope classification in the study area.

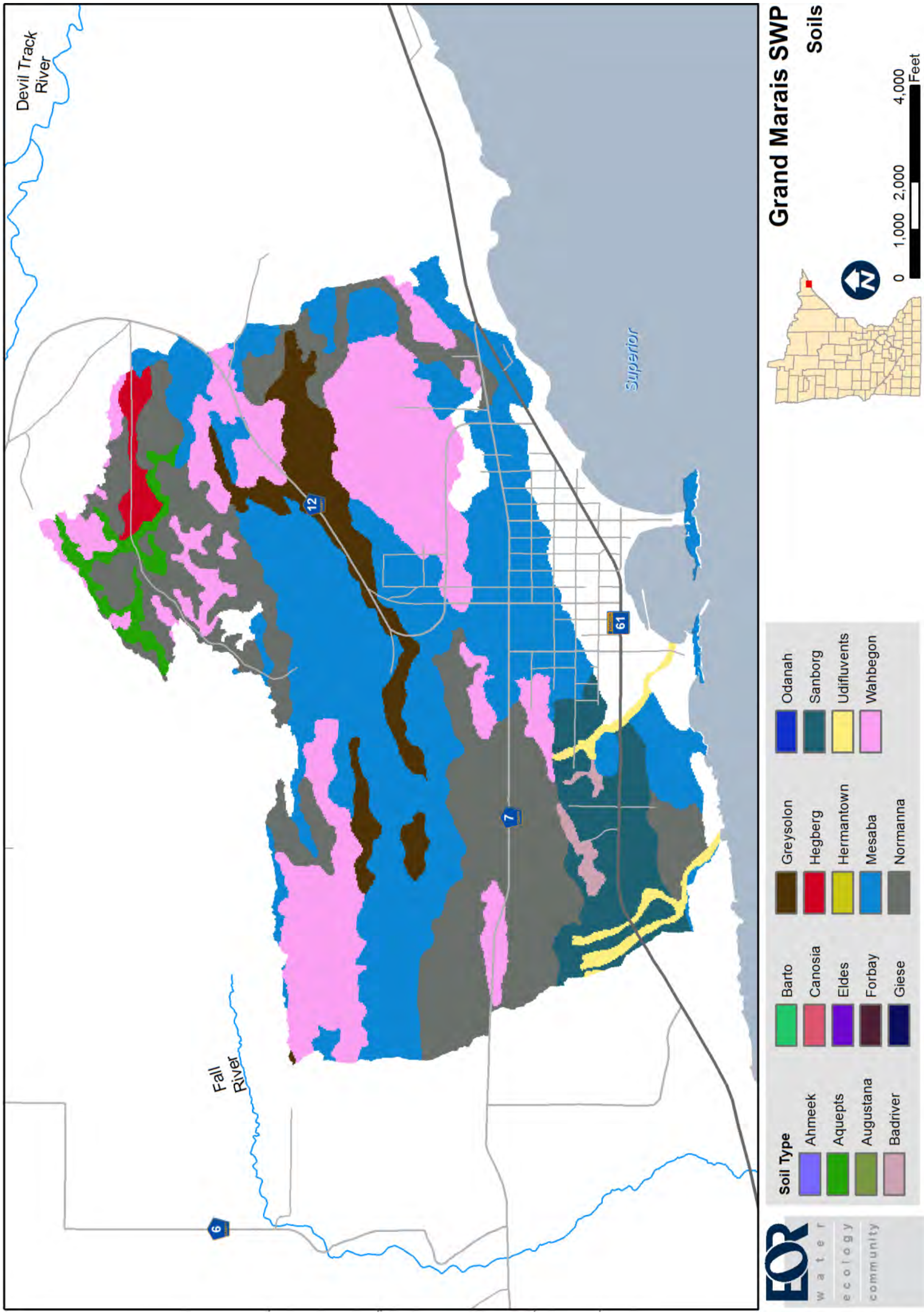


Figure 2-13: Soil series in the study area.

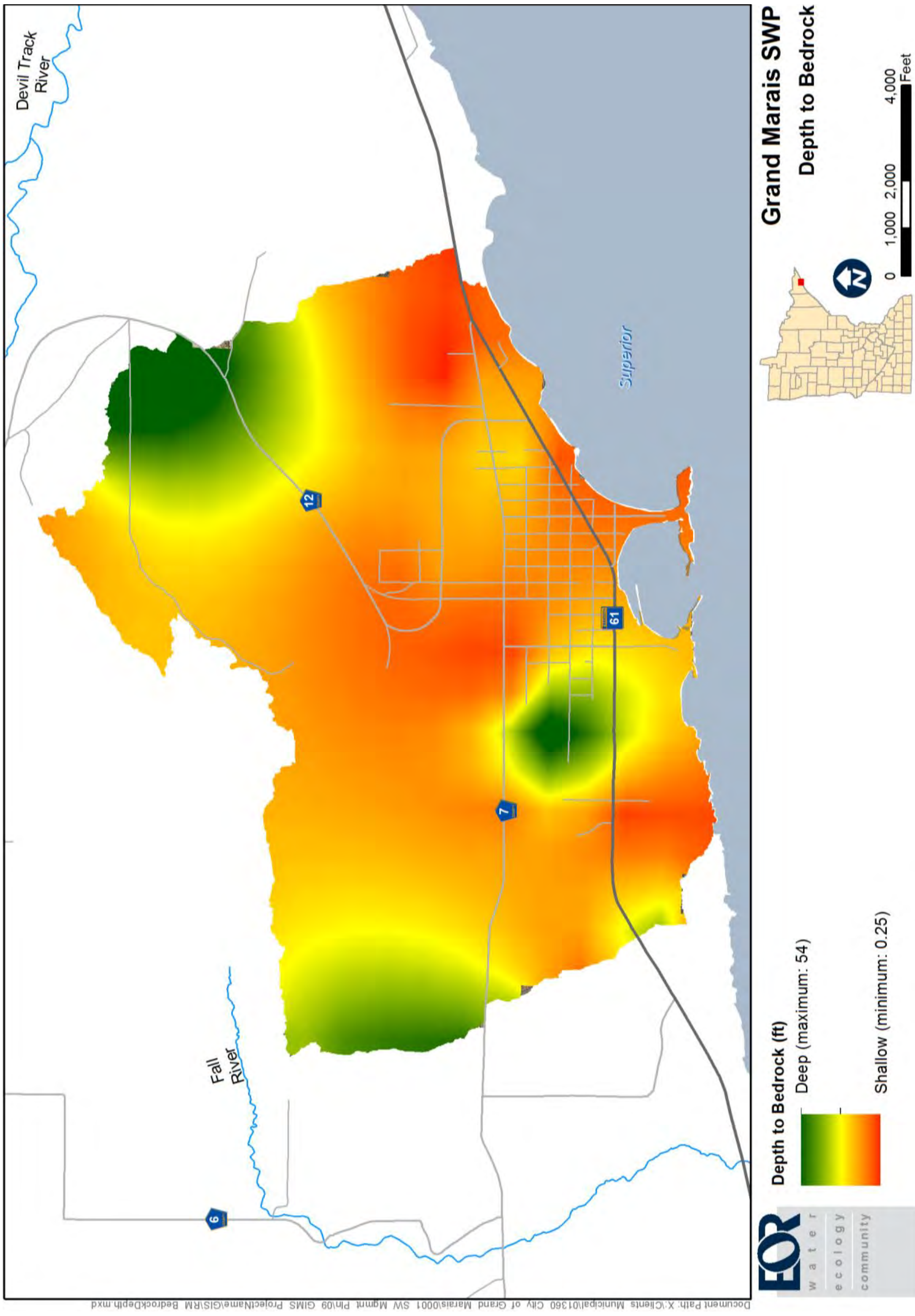


Figure 2-14: Depth to bedrock in the study area from the 2011 University of Minnesota 250 m raster – resampled to 15 m for display and geoprocessing)

2.5. Land Use and Land Cover

2.5.1. Land Use

Historical Land Use

In historic times, the Grand Marais area was vegetated with forested and wetland areas that sloped downwards in a series of steps created from lava flows (former lake plains and banks) towards Lake Superior. Intermittent creeks traversed the area trending northwest to southeast, mimicking the way the majority of the surface drainage migrated. Most of the precipitation from storm events would have either been retained by the wetland/lowland and forested areas which permitted infiltration (allowing run off to seep into the soil) or was absorbed by vegetation (evapotranspiration). The remaining precipitation that was not retained would have been released slowly into the creeks which then transported the run off to Lake Superior with larger storms and spring runoff generating more surface flow. The wetland areas next to the Grand Marais harbor formed a delta that served to filter and hold water coming down gradient.

Present Land Use

shows current land use across the city (courtesy of Cook County, November 2017), lumped into five categories: residential (single-family), multi-family residential, commercial, institutional, and public/other. shows this same underlying information classified instead into six ownership classes: private, tax forfeit, municipal, county fee, state, and federal. Private land ownership (residential and commercial) dominates the majority of the city's core, while areas near and away from the lake are generally publicly owned (city, state, and federal lands). Most of the residential properties are single-family homes, with a handful of scattered multi-family dwellings.

Future Land Use

The City of Grand Marais is in the process of developing its Comprehensive Plan. While the current footprint of Grand Marais spreads out along the coastline and Highway, there are some future development plans that the City wanted to include in the analysis performed for the Stormwater Management Plan. These development plans include the Cedar Grove Business Park (under fully built conditions), Sawtooth Bluff Regional Park (with the improvements identified in the Master Plan) and the Northstar Development.

2.5.2. Land Cover

Land cover plays a major role in determining what happens to precipitation when it hits the landscape. Vegetation intercepts precipitation, slows the rate at which it travels, and returns moisture to the atmosphere via transpiration. Water use by different types of vegetation varies significantly. Trees and native grasses, with their extensive root systems, allow more water to soak into the soil than lawns, which have very shallow roots and are more likely to allow the water to run off more quickly. Larger plants also use up more water creating more capacity in the soil to absorb precipitation. Impervious surfaces significantly increase the volume of water that runs off the landscape and increases the rate at which this water enters downstream waterbodies.

The National Land Cover Database (NLCD) is a tool that provides valuable information for natural resource managers and planners as well as water resource managers as it categorizes the landscape in terms of its land cover. The NLCD consists of a 30 meter by 30 meter grid, with each grid cell classified as one of 12 land classes found in the study area. The percentage breakdown of land cover within the watershed (as of the 2011 NLCD update) is shown in Figure 2-15. Prominent land covers present in the watershed include Forest/Woodland at 66% of the watershed and Wetland at 3.5% of the watershed. Developed areas with imperviousness greater than 20% (low, medium, and high intensity) occupy approximately 18% of the watershed, with the majority of the development located in the southeast portion of the watershed.

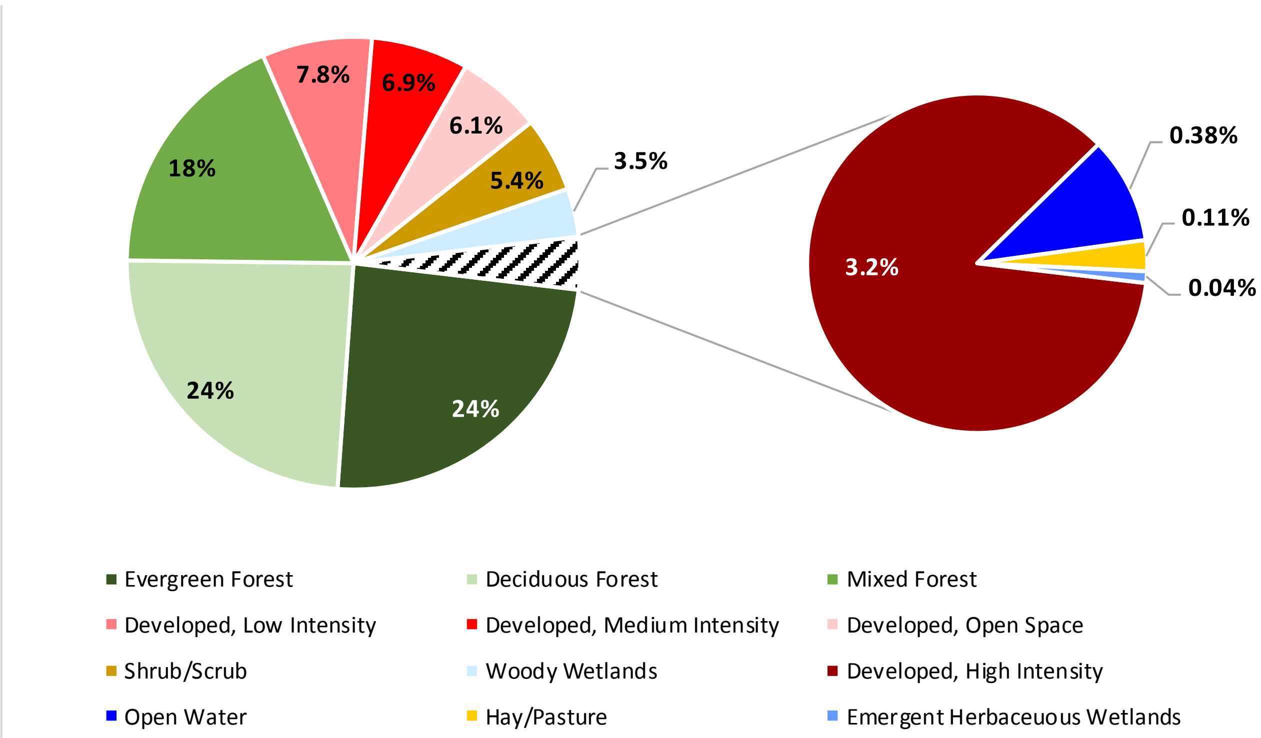


Figure 2-15: NLCD (2011) land cover distribution within the study area

The University of Minnesota last produced an update to the Minnesota Land Cover Classification System (MLCCS) in 2013. While a detailed land use reclassification was not performed for Grand Marais as it was in portions of Minnesota, the MLCCS dataset also includes an estimate of impervious cover in the form of a 15 meter by 15 meter grid, with each grid cell classified according to the percentage of surfaces that are impervious (Figure 2-19). Impervious surfaces occupy a total of 7.7% of the watershed, with values ranging from 0% to 100%.

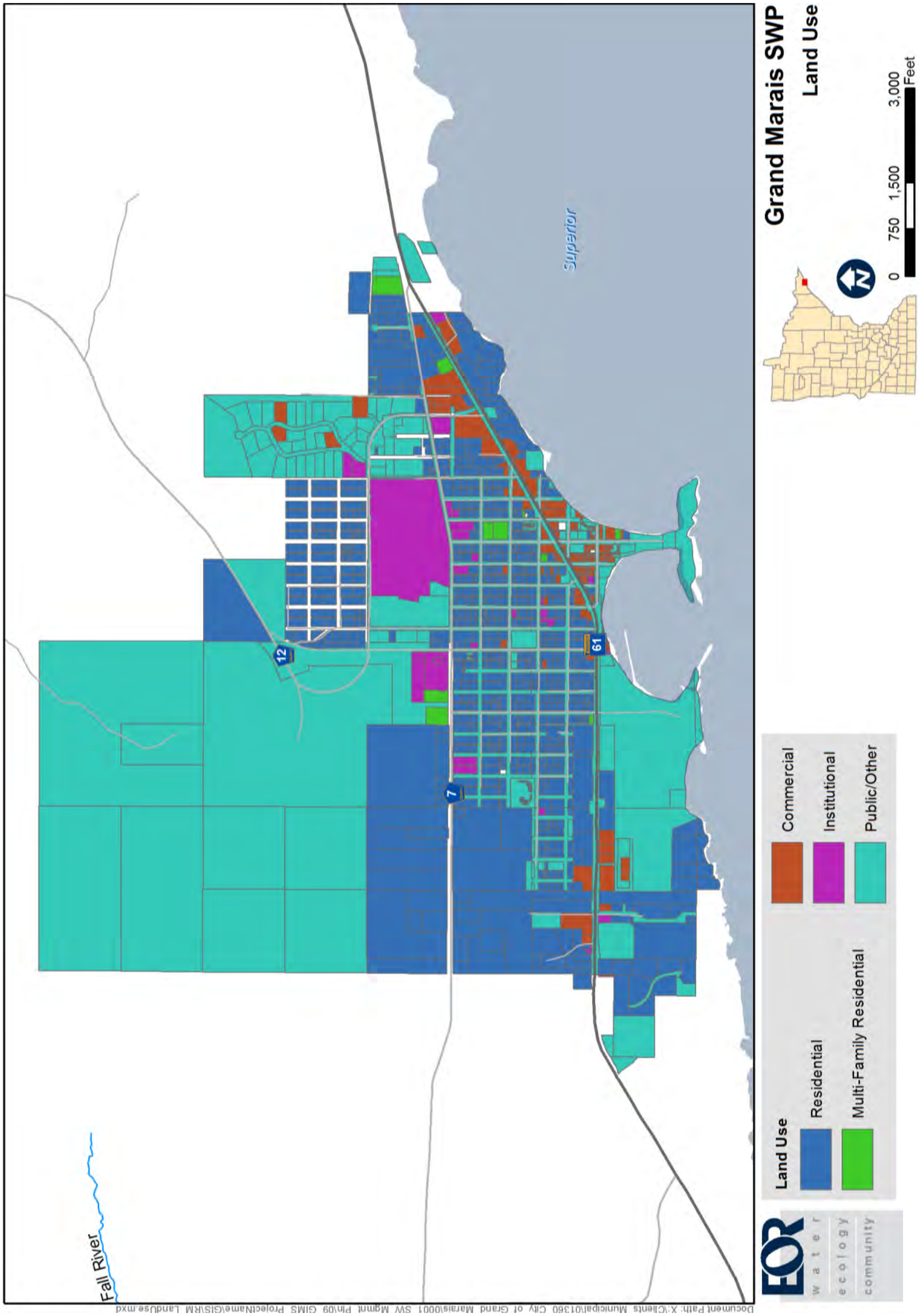


Figure 2-16: Land use classification in the study area

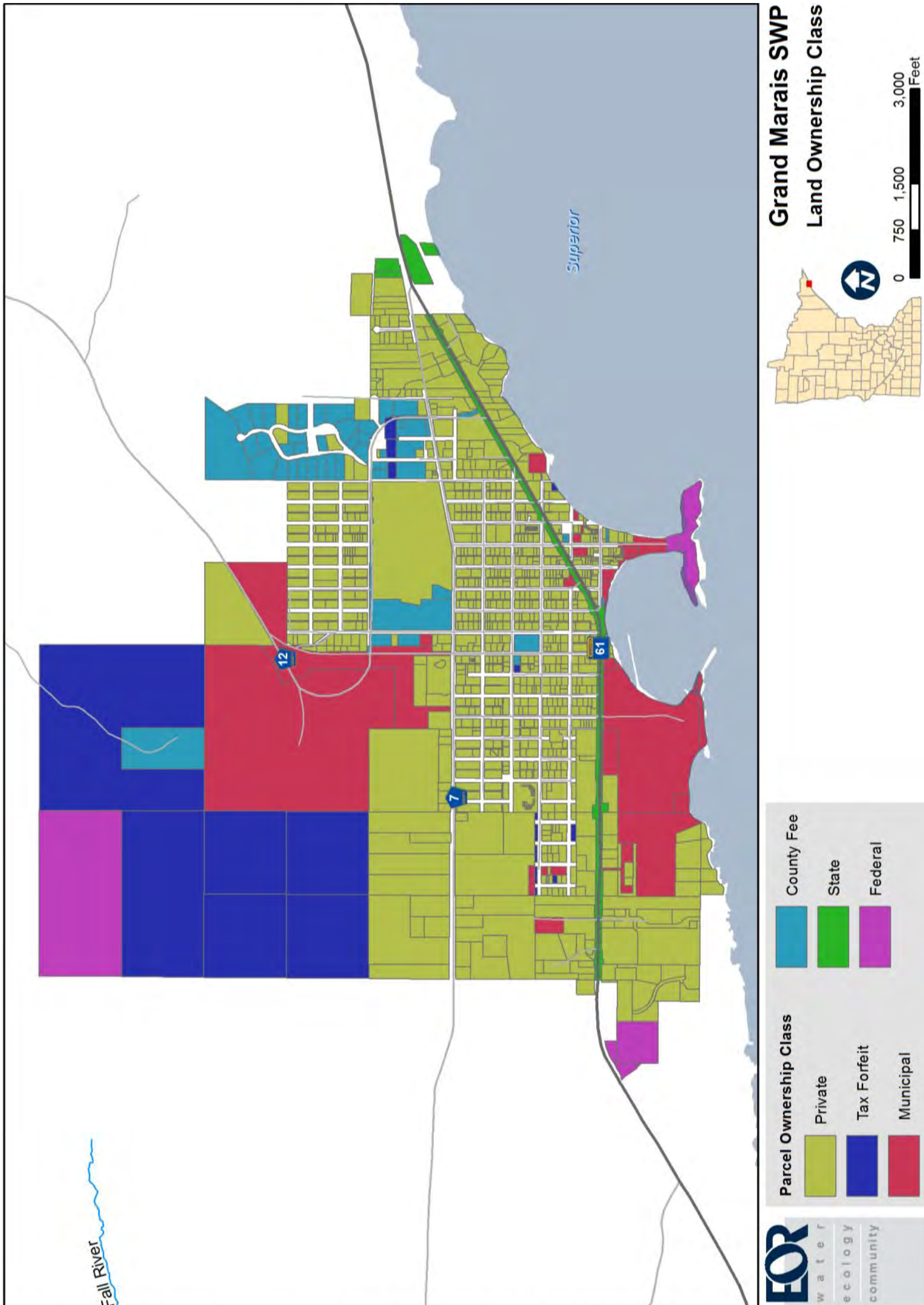


Figure 2-17: Land ownership classification in the study area

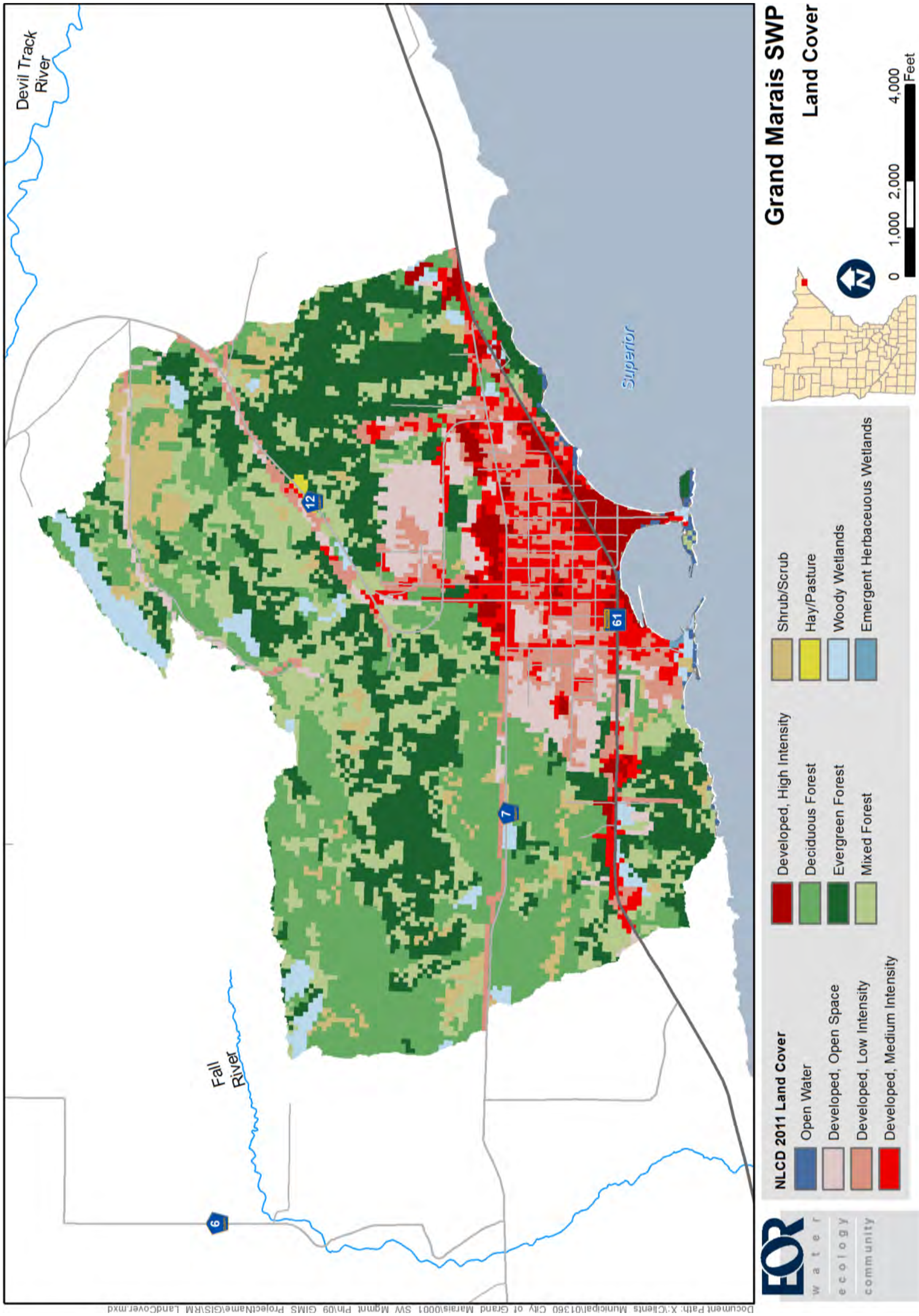


Figure 2-18: Land cover classification in the study area

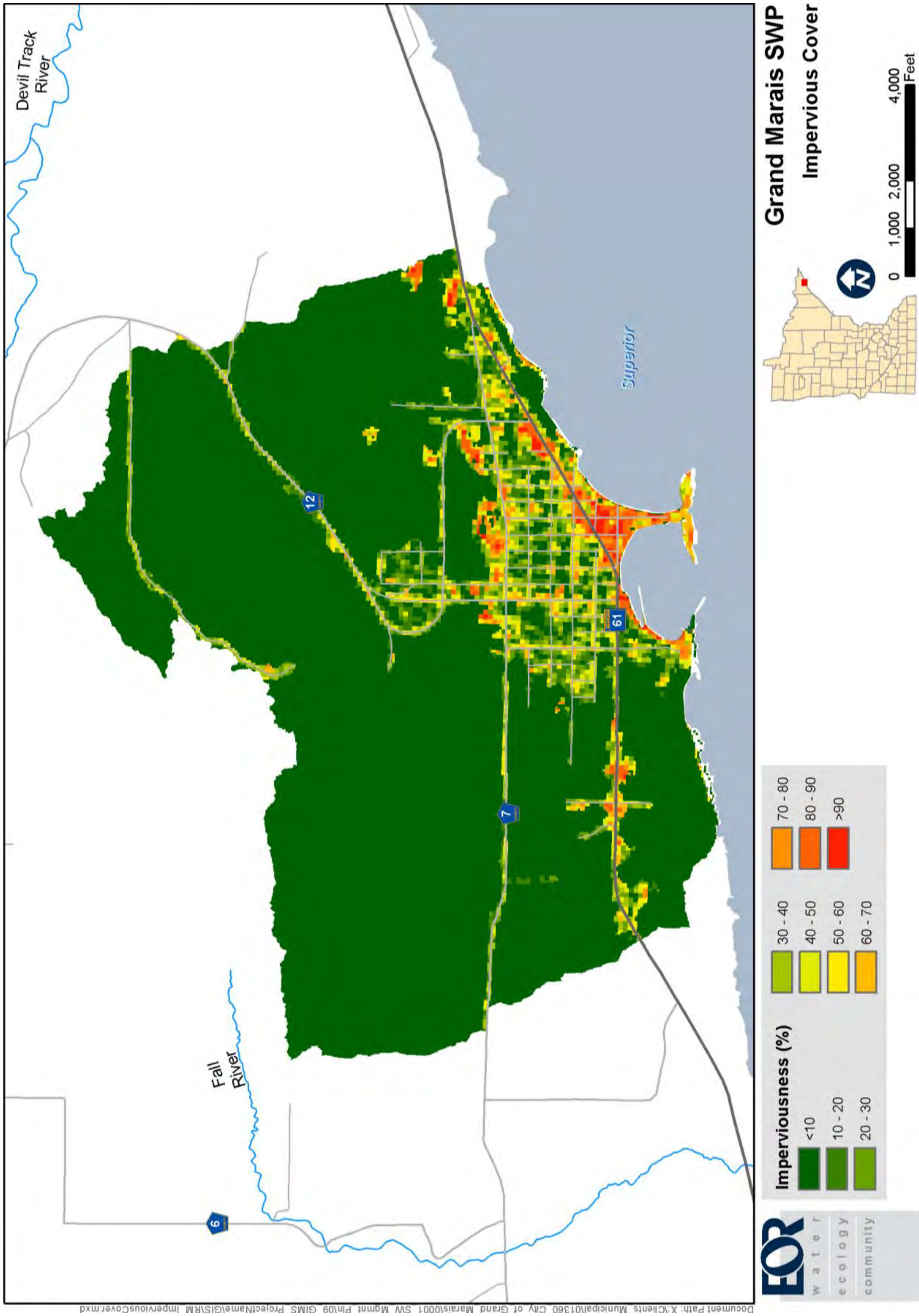


Figure 2-19: Impervious cover in the study area

2.6. Monitoring Data

2.6.1. Summary of Available Monitoring Data

Water Quantity

Water level monitoring data was available in Village Ditch at two locations: one located downstream of the County Highway Department facilities and another upstream of County Highway 7. Data was initially collected by ICECOR as part of the 2001 Storm Water Management Plan, and Cook County continued to collect data by various means between 2002 and 2005. In 2009, following construction of the Creechville stormwater retention ponds and a 100 Year rain event, Cook County SWCD reinitiated monitoring on the Village Ditch to assist in evaluation of the effectiveness of the 2001 Stormwater Management Plan. Water level and rainfall data was collected at the Creechville stormwater retention ponds as part of the 2009 monitoring effort. Data received from the City included flow for portions of 2001 and 2005. Neither the original water level data nor the stage-discharge relationships were located, so flow data were used in an "as is" condition. However, as shown in Figure 2-20 and Figure 2-21, certain characteristics of these data (e.g. daily fluctuations, negative flow values) are indicative of potential issues with quality control during either collection or processing. As such, the data were used only as a general guide for model calibration (this will be discussed further in a later section).

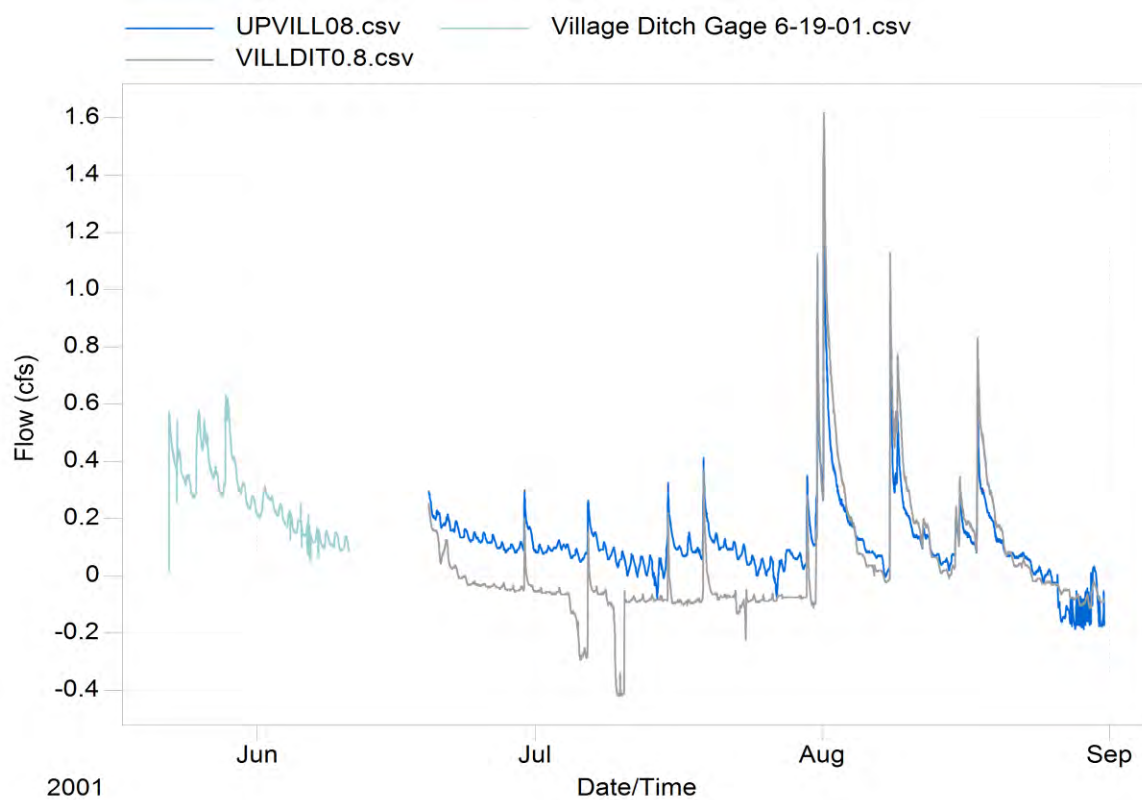


Figure 2-20: Flow data collected in Village Ditch during the summer of 2001

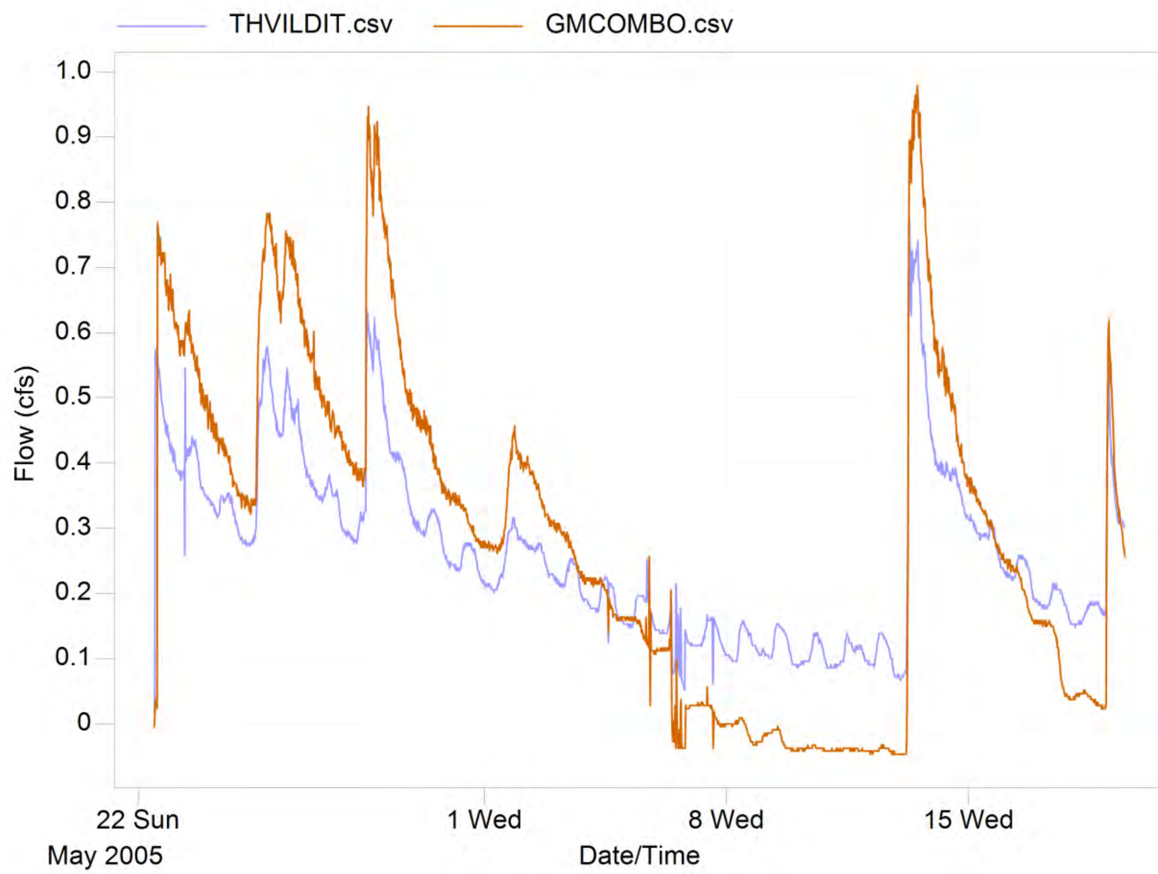


Figure 2-21: Flow data collected in Village Ditch during the summer of 2005

Water levels in both of the Creechville Storm Water Ponds were monitored as part of the summer 2009 Nature Boy Creek Monitoring project. While these data are summarized in Appendix B of the Nature Boy Creek Monitoring Plan (reproduced here in Figure 2-22 and Figure 2-23), electronic versions of either the water level or rainfall data were not located. The data appear to suffer from some of the same issues as the Village Ditch monitoring data, and so they were used in much the same capacity: as a general guide for model calibration.

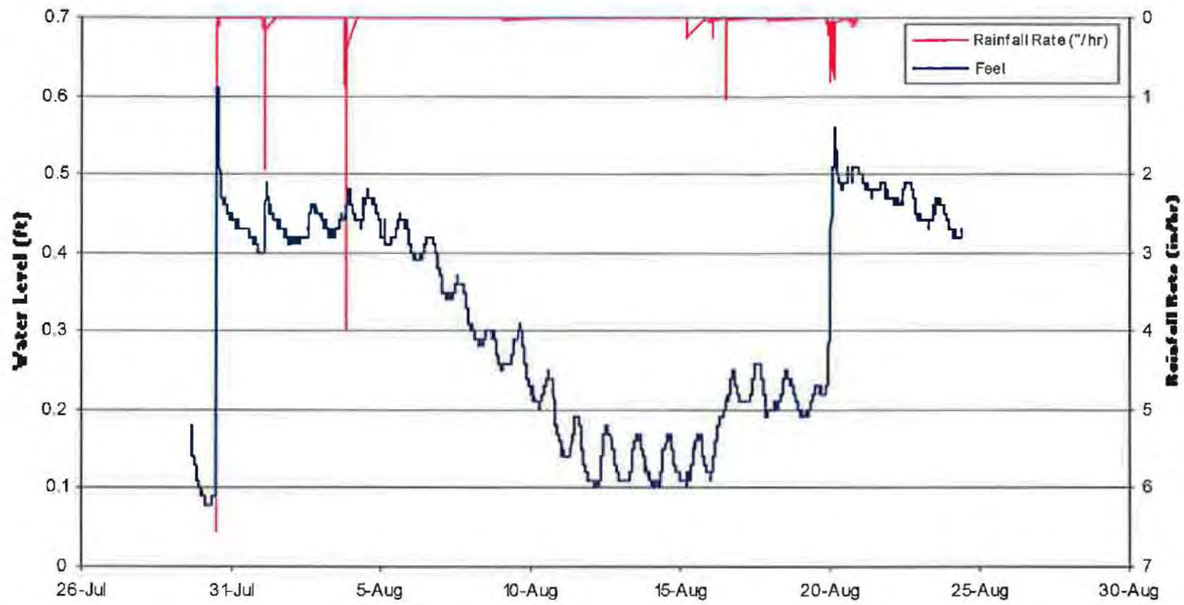


Figure 2-22: Water level data in Creechville Storm Water Pond #1 from 2009 (from the Nature Boy Creek Monitoring Plan)

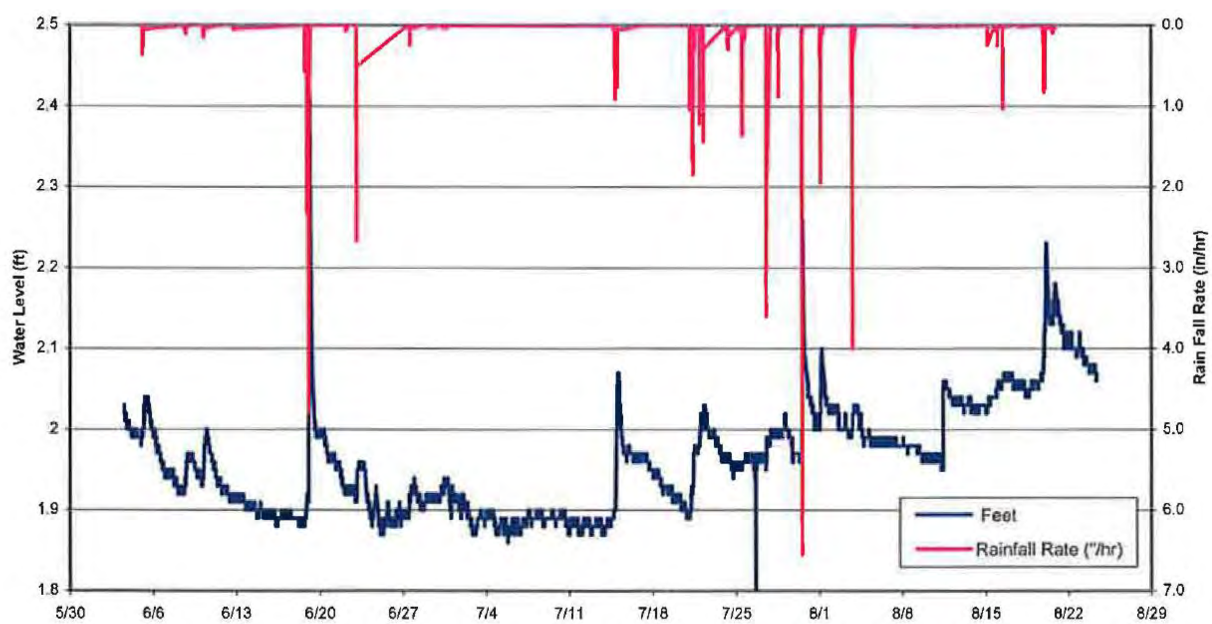


Figure 2-23: Water level data in Creechville Storm Water Pond #2 from 2009 (from the Nature Boy Creek Monitoring Plan)

Water Quality

Water quality data has been collected by Cook SWCD at 5 water quality monitoring sites in Lake Superior near Grand Marais (Table 2-4). Parameters collected from the water surface include: Secchi depth transparency, total phosphorus, chlorophyll-a, inorganic nitrogen (nitrate-nitrite), total suspended solids, total volatile solids, *Escherichia coli* and chloride. A depth profile was also taken of dissolved oxygen, temperature, specific conductance and pH at one meter increments from the surface to the lake bottom at each monitoring station. There were approximately 10 samples collected each year from the surface water between May and October in 2014 and 2016.

All the water quality parameters had very low concentrations, indicative of the highly oligotrophic (low nutrient, clear water) nature of Lake Superior. Many measurements were near detection limit. There were 2 bacteria readings that were above detection limit but still quite low (16-17 cfu), one at -206 in 2014 and one at -212 in 2016. Secchi depth transparency measurements had a wide range, from 3 meters to greater than 10 meters, while Chlorophyll-a (algae) and total suspended solids concentrations varied little. This is typical of highly oligotrophic lakes where very small changes in particles (algae and suspended solids) can have a very large effect on water clarity when water transparency is already very deep.

The Minnesota Department of Health also conducts bacteria monitoring at the Grand Marais Campground and Grand Marais Downtown beaches to determine if the beach water is safe for recreational activities and minimize the risk of recreational water illnesses.

Recommendations for future monitoring are discussed in Section 6.7**.**

Table 2-4. Lake Superior Water Quality Monitoring Stations near Grand Marais, MN.

Project ID	Station ID (16-0001-00-XXX)	Years of Data
Site 1	-203	2014-2016
Site 2	-204	2014-2016
Site 3	-205	2014-2016
Site 4	-206	2014-2016
Site 5	-212	2015-2016

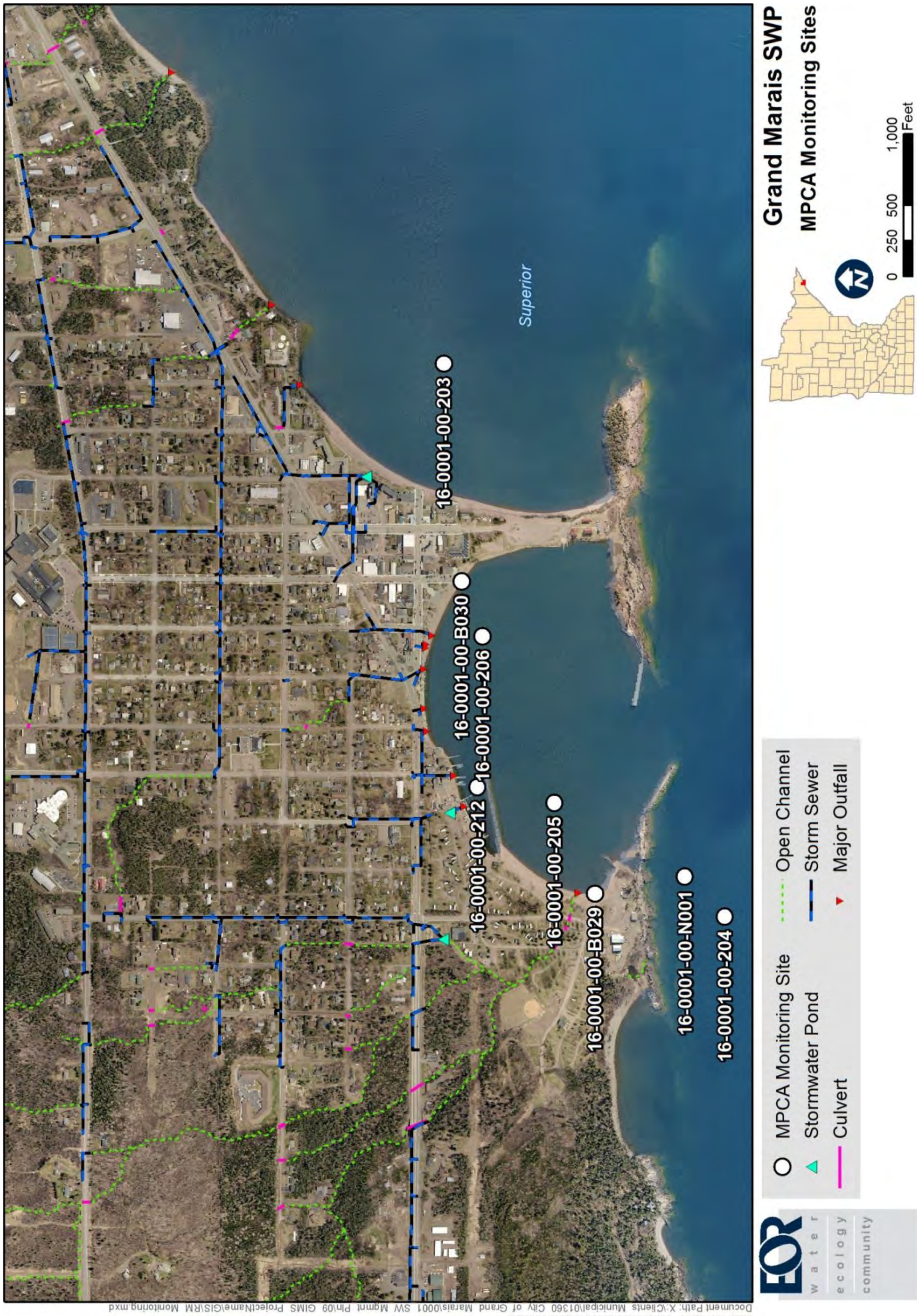


Figure 2-24. Water Quality Monitoring Sites in Lake Superior

2.7. Water Use

2.7.1. Grand Marais Municipal Water Supply

The City of Grand Marais operates as a community public water system and provides drinking water to its residents from Lake Superior. According to the Minnesota Department of Health's Source Water Assessment (2018), the city's water supply is considered vulnerable since it is surface water and subject to activities in the watershed. The water is treated for human consumption at the treatment plant as described on the Minnesota Department of health's website. The City of Grand Marais does not have a source water protection plan at this point in time.

2.7.2. Wastewater Treatment Plant

The Grand Marais waste water treatment plant is located on the north side of the city at 321 2nd Street East. The facility is a Class B and a Type IV sludge disposal facility. The facility has continuous discharge to Lake Superior. The original facility was designed to treat an average flow of up to 0.375 million gallons per day but an expansion in 1988 increased its capacity so that it can now treat an average wet weather design flow of up to 0.99 million gallons per day to a higher water quality treatment standard. The facility has the ability to bypass untreated discharges of wastewater to Lake Superior via the outfall sewer.

Figure 2-25. Water Quality Monitoring Sites in Lake Superior

3. COMMUNITY ENGAGEMENT

Community engagement was a critical component of developing the Stormwater Management Plan. Over the course of the project, the City of Grand Marais held meetings to engage residents, local business owners, stakeholder groups, city staff and SWCD staff in the planning process. A postcard advertising how residents, business owners, community members and stakeholders could be engaged in the plan development process was mailed to the residents of Grand Marais in early December 2017 prior to the first community engagement meeting. A summary of the community engagement activities held at each stage of the plan development process is provided below. The postcard and meeting summaries from the community engagement process can be found in Appendix A.

Issues Identification

1. On December 20, 2017 the City of Grand Marais, Cook SWCD and consultants hosted a "Water Conversation" to consult with stakeholders on the issues and concerns that should be addressed in the Stormwater Management Plan. The goals of this Water Conversation included:
    - *To describe the evolution of stormwater management and the purpose of a Stormwater Management Plan.*
    - *To characterize the drainage area to the City of Grand Marais.*
    - *To help identify concerns or vulnerabilities for consideration in the Grand Marais Stormwater Management Plan development process.*
    - *To connect stakeholders with one another, and work together to become better stewards of the watershed.*

    The prioritized list of issues identified at this meeting was used to inform the concerns addressed within the timeframe of this Stormwater Management Plan.

2. On December 21, 2017 the consultants conducted an abbreviated Water Conversation with City Staff to identify observations and concerns related to stormwater management. Since City Staff is familiar with the generation and impacts of stormwater runoff, goals for this meeting were focused on sharing local knowledge of the system and documenting where there are issues and concerns in the system.

3. In addition, the City of Grand Marais developed a survey to engage those members of the public that could not attend the first community engagement meeting. The goal of the survey was to give residents, local business owners and stakeholders the opportunity to identify issues and concerns related to stormwater management in the City of Grand Marais. The survey included a map of the City that could be toggled so the user could zoom in or out of the aerial imagery locate where they have concerns and provide comments related to their concern.

4. Information shared at the December 20, 2017 meeting was posted to the City's website including the presentation given by the project consultant and maps shared with meeting participants. In addition, the meeting summary was also posted to the City's website for people to access after the meeting.

5. Following the December 20, 2017 community engagement meeting WTIP North Shore Community Radio broadcast a number of interviews with city staff, SWCD staff and the project consultants to share information about the meeting and the planning process.

Identification and Prioritization of Potential Solutions

1. On January 25, 2018 the City of Grand Marais, Cook SWCD and consultants hosted the second public engagement meeting for the Stormwater Management Plan. The goal of this meeting was to discuss possible solutions to alleviating the highest priority issues identified during the first public engagement meeting: flooding in the downtown parking lot and along Village Ditch and water quality in the harbor. The goals of this meeting included:

   - *To describe the existing conditions Hydrologic & Hydraulic model (PC-SWMM) and the information it provides about the existing drainage system.*
   - *To characterize available water quality monitoring information to identify pollutants of concern.*
   - *To describe the types of solutions available for addressing flooding and water quality issues in the drainage area to Grand Marais.*
   - *To solicit feedback from meeting participants on the potential solutions and to identify the stormwater management approach the City should focus on in the timeframe of this Stormwater Management Plan.*

   Information collected at this meeting was used to further guide the stormwater management approach that would be taken to city council members for review and approval. In general terms, participants emphasized the need to take a holistic approach to stormwater management: to implement a suite of improvements which would reduce flooding but not eliminate flooding in the downtown area. They also recognized that the next step was to establish measurable goals for flooding in downtown, water quality improvements to the harbor and peak flow rates in Village Ditch.

2. Information shared at the December 20, 2017 meeting was posted to the City's website including the presentation given by the project consultant and maps shared with meeting participants. In addition, the meeting summary was also posted to the City's website for people to access after the meeting.

3. Following the January 25, 2018 community engagement meeting WTIP North Shore Community Radio broadcast a second series of interviews with city staff, SWCD staff and the project consultants to share information about the meeting and the planning process.

Establishing Allowable Thresholds

Following the January 25, 2018 meeting, city staff took the lead in identifying allowable thresholds for flooding in the downtown area and for identifying the suite of solutions included in the 10-year implementation plan. This included reviewing a map of flooding extent (footprint) at various heights above the trench drain located in the downtown parking lot with adjacent business owners, residents and city council members to establish a preliminary goal for flooding: no more than 12-inches of flooding for no more than 12 hours (see Figure 8). This preliminary goal was used for scenario planning and to identify the suite of stormwater management improvements needed to achieve this goal.

Figure 3-1. Downtown flooding extents (footprint) at various heights above the trench drain in the parking lot

4. STORMWATER INFRASTRUCTURE

4.1. Characterization of Stormwater Infrastructure System

4.1.1. Overview

The stormwater infrastructure within the study area consists of at least 72 culverts 24” in diameter or larger, along with over 41,800 linear feet of storm sewers with 379 mapped catch basins and 68 mapped manhole junctions. The stormwater infrastructure is served by a total of five regional (i.e. large-scale) stormwater ponds: two large ponds were constructed in series along the south side of Gunflint Trail and intercept drainage from approximately 99 acres of hillside on the north side of Gunflint Trail; the pond located on the SW corner of the intersection of Hwy 61 and 8th Avenue W intercepts 145 acres of drainage to the north of Hwy 61; the pond located adjacent to the North House Folk School intercepts 27 acres of drainage to the north of Hwy 61; and the pond located south of the intersection of E 1st Street & 1st Avenue E (behind Cook County Whole Foods CO-OP) intercepts approximately 32 acres of drainage from the immediate vicinity in downtown Grand Marais. A sixth pond was until recently located south of the Cook County High School on the north side of 5th Street, but most of this feature was filled to make room for a parking area when the YMCA was built in 2012-13.

4.1.2. Design Characteristics

The stormwater conveyance system within and around the City varies considerably both in terms of function and design. Several streets (among them Highway 61, 8th Avenue W, 5th Street, and 3rd Street) are serviced by typical curb and gutter design with regularly spaced catch basins that discharge to trunk storm sewers. A large portion of the drainage area, however, relies on overland flow – whether defined (e.g. gutters, roadside ditches) or undefined (e.g. sheet flow) – to convey water to the nearest catch basin, culvert, ditch, or other element of the drainage infrastructure. Notably, 1st Street, 2nd Street, and 4th Street are all mostly devoid of stormwater infrastructure; instead, runoff is conveyed downslope via sheet and/or gutter flow along the street before discharging into a storm sewer network. This characteristic may be a contributing factor to flooding in downtown, since catch basins rarely operate at 100% capture efficiency even under ideal conditions and are even more prone to bypass when located at the downstream end of long, steep slopes. Additionally, a large proportion of catch basins rely solely on grate inlets, which are less efficient than combination inlets when used on a continuous grade and are much more prone to clogging.

There are 12 catch basin locations that consist of 45° curb cuts with one or more combination inlets at the downstream end. These are all located at the downslope ends of the upslope roads intersecting with 3rd Street (namely 3rd Avenue W, 2nd Avenue W, 1st Avenue W, 1st Avenue E, 2nd Avenue E, and 3rd Avenue E). These catch basins appear to be intended to act as high capacity inlets that service the steep two-block-long drainage area between 3rd Street and 5th Street. While the degree to which they perform as intended is unknown, after inspecting these features in the field it is suspected that even these catch basins may experience bypass on a regular basis. This may be caused by such factors as grate clogging, formation of ice or snow ridges due to difficulties with plowing these features, improper/inadequate construction of the curb cut slope, or simply by high velocity runoff bypassing the curb cuts and catch basins during larger events.

4.1.3. Drainage Characteristics

Overall, the drainage area serviced by storm sewers is composed of a mix of rural section roads and curb & gutter systems. Unlike typical urban stormwater systems, the infrastructure in Grand Marais typically conveys runoff from both directly and indirectly connected impervious and pervious areas alike. There are many locations at which channelized surface water is directed underground into a network of storm sewers and, conversely, where storm sewers daylight to open channels. This characteristic presents unique challenges, such as the potential for more rapid accumulation of sediment in pipes and channels (due to the direct connection of sediment sources to storm sewers), as well as increased risk of scour and erosion at pipe discharge locations. However, it also presents some unique opportunities, since stormwater that is already being conveyed in open channels may be more easily treated through the implementation of practices that promote detention, retention, and/or filtration.

4.1.4. Water Quality

Most of the City's stormwater is discharged to Lake Superior untreated. The five stormwater ponds discussed previously service a combined 303 acres, or about 19% of the roughly 1,600 acres[4] that are tributary to at least one network of storm sewers. On top of this, the existing ponds appear to be broadly underutilized both in terms of rate control and water quality treatment. The remaining 1,600 acres of the study area discharge to the lake through a series of artificial and natural channels conveyed beneath roadways by culverts – largely without detention or treatment of any kind.

4.1.5. Maintenance

Maintenance of the stormwater infrastructure appears to be an ongoing issue. Due likely to a combination of substantial sediment sources and low pipe slopes, the storm sewers servicing downtown have accumulated sediment to the point of impairing their function. This sedimentation has the effect of exacerbating existing flooding issues, which in turn contributes to the maintenance issues by promoting further sedimentation in the storm sewers – a feedback loop that must be resolved in a systematic and holistic manner in order to have lasting impacts. Additionally, although not in itself a contributing factor to flooding, the interchanging of storm and sanitary manhole covers observed throughout the City makes inspection and maintenance of storm sewers more cumbersome than necessary.

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[4] This excludes most of the village ditch drainage and other areas that are primarily conveyed through a system of culverts and open channels.

4.2. Evaluation of Stormwater Infrastructure System

4.2.1. Data Collection and Gap Analysis

Initial data related to the stormwater infrastructure was provided by the City and Cook Soil and Water Conservation District (SWCD) in a variety of formats. The existing XPSWMM model – constructed as part of the 2001 Storm Water Management Plan – was first converted to GIS format and analyzed for apparent spatial accuracy first using aerial photography. Then, through comparison with a LiDAR-derived digital elevation model, it was determined that while the model appeared to be accurate (and thus useful) in portions of the study area, other areas were flagged for further investigation. A GIS database was constructed to track the locations of links (i.e. pipes, channel segments) and nodes (i.e. manhole junctions, catch basins, pipe ends) and associated metadata (e.g. pipe size/shape/material, invert elevations, data sources). A variety of plan sets (both with and without as-built elevations) were received and used to fill gaps where possible, including:

- Creechville Stormwater Basin, Creechville Road Drainage System, Village Ditch South Embankment, Village Ditch Channel Improvement, HGA, Inc. 2004
- City of Grand Marais 2008 Street and Utility Project, SEH, Inc. 2008
- Cook County Community Center Storm Sewer Design, BARR 2008
- C.P. 16-62-01:County Road 62W Storm Sewer, Ditch Repair, and Shouldering, Cook Co. Highway Dept 2011
- S.P. 16-612-59:CSAH 12 Grading, Aggregate Base, Storm Sewer, Curb & Gutter, Subgrade Excavation, and Bituminous Surfacing, MnDOT 2003
- S.P. 16-615-01:CSAH 15 Grading, Storm Sewer, Aggregate Base, Curb & Gutter, Concrete Walk, Subgrade Excavation, and Bituminous Surfacing, MnDOT 2007
- S.P. 16-615-19:CSAH 7 Grading, Storm Sewer, Aggregate Base, Curb & Gutter, Concrete Walk, Subgrade Excavation, and Bituminous Surfacing, MnDOT 2007
- Construction Plans 2002 Gunflint Utilities, RLK, Inc. 2002
- Downtown Infrastructure Improvements, RLK, Inc. 2004
- Cedar Grove Business Park, 2008
- 2nd Street-9th Ave West Improvements, RLK, Inc. 2006
- S.P. 1602-50 Highway 61 Pavement Resurface & Rehabilitation, MnDOT 2018

Finally, a field survey was conducted to spot check the validity of existing storm sewer data and fill remaining gaps in the database. Figure 4-1 summarizes the various datasets used.

Highest priority was placed on trunk sewers and major crossings. Financial constraints prohibited a complete system inventory, particularly with respect to individual catch basin leads and minor drainage networks. For these minor elements, where other data were unavailable the existing XPSWMM model was used as a starting point, after which incorrect catch basin and manhole locations were corrected using aerial photography, and invert elevations were frequently estimated by offsetting LiDAR surface elevations.

While enough information was validated to complete construction of a useable model with relatively high confidence in the accuracy of a majority of the data, there remain elements of the model that are recommended for further review and refinement as part of future efforts. These recommendations are discussed in in Section 6.7.

4.2.2. Hydrologic and Hydraulic Model Construction

Background

A significant portion of the City's 2018-2027 Stormwater Management Plan relies on the results of a Stormwater Management Model (SWMM). The existing XPSWMM model developed in 2001 had a number of shortcomings that were addressed in this update. First and foremost, the model had little accompanying documentation, making it difficult to definitively determine the validity of many of the assumptions made during its construction. Second, the model was assumed to be significantly out of date, as there was little evidence that it had been consistently updated as new projects were completed in the intervening years since its initial development. Additionally, upon review of the model itself, several issues were discovered that would have required significant effort to rectify in situ, including:

- Limited use of surveyed elevation data, which had a significant number of unacceptable vertical deviations from the 2011 statewide LiDAR elevation data, as well as horizontal deviations from the locations of structures visible on the City's pictometry dataset
- Use of generalized channel cross sections for a majority of stream and ditch conveyance links
- Inadequate subcatchment/watershed delineation, probably derived from 10-foot topographic contours (likely all that was available at the time)
- Incomplete coverage of the study area

Taken together, these issues called into question the usefulness of the model as a starting point – notwithstanding the platform itself, which is not GIS-based and has a number of proprietary features that introduce difficulties in model conversion and translation. Additionally, the XPSWMM computational engine was developed as an offshoot of a deprecated version of EPASWMM (SWMM4), and therefore deviates from the contemporary version of EPASWMM (SWMM5). In short, while XPSWMM was cutting-edge software in 2001, significant developments have taken place since then in the field of storm water modeling.

In the end, it was deemed more efficient to rebuild the model from the ground up. As such, the City's model was redeveloped in PCSWMM – a software package that is GIS-based and supports both long-term stable and bleeding-edge releases of the EPASWMM engine. PCSWMM also supports the OpenSWMM engine, which adds support for additional features (including parallelization, leading to significant reductions in computational times) without compromising the integrity of the EPA-approved results. Some other benefits of PCSWMM include: ensured forward compatibility with new EPASWMM features; streamlined model updating through use of its integrated GIS engine; and efficient recalibration using the Sensitivity-Based Radio Tuned Calibration (SRTC) tools.

As discussed in Section 4.2 and summarized in Figure 4-1, data contained within the existing XPSWMM model was cross-validated with other data sources (e.g. GIS datasets, plan sets), all of which were checked against data collected during field visits in the fall of 2017.

Hydrology

Following substantial completion of the GIS database, a hydrologic and hydraulic (H/H) model was constructed in PCSWMM using the OpenSWMM5.1.912 computational engine. Major hydraulic components were used to define pour points for watershed delineation – primarily major crossings and catch basin clusters (i.e. intersections) were used. Following hydrocorrection of the DEM and drainage enforcement for curbs and other breaklines, watershed delineation was performed using the NRCS Engineering Tools, resulting in 272 subcatchments ranging in size from 0.1 to 189 acres in size[5]. Horton hydrology was used, and hydrologic parameters were derived from a variety of datasets, including:

- **Preliminary Bedrock Geologic Map of Minnesota – 2016 update:** depth to bedrock, used to define the maximum infiltration volume for Horton hydrology
- **Minnesota Land Cover Classification and Impervious Surface Area by Landsat and LiDAR: 2013 update - Version 2:** used to define subcatchment percent imperviousness
- **Gridded Soil Survey Geographic Database – 2016 update:** used to define the maximum and minimum infiltration rates for Horton hydrology
- **National Land Cover Dataset – 2011 update**: used to define land cover classes, which were used to estimate depressional storage depths and surface roughness coefficients
- **LiDAR Elevation, Arrowhead Region, NE Minnesota – Spring 2011**: used to define subcatchment slopes

Subcatchment flow lengths were estimated by dividing subcatchment area by the total curb length (or road length in rural areas) within each subcatchment; this parameter was then modified by applying an upper limit of 300 feet. Finally, aquifer parameters were initialized to be consistent with subcatchment hydrology and used predominantly for calibration of baseflow.

[5] Since the density of drainage infrastructure is higher in the more urban portions of the watershed, these areas generally had smaller subcatchments than the outlying rural portions.

Hydraulics

Hydraulic elements were parameterized according to pipe material and configuration. Culvert codes were used where appropriate, and all other entry and exit losses for all other pipes were set = 0.5, with the exception of locations where pipes discharged into open water, where exit losses were set = 1. Manning's roughness was set according to pipe material in place for a number of years: 0.013 for PVC, HDPE, and ductile iron pipes; 0.014 for concrete pipes; and 0.023 for corrugated metal pipes. Pipe slopes were set automatically using invert elevations and pipe lengths, which were defined previously through construction of the GIS database. Dual drainage elements (i.e. open channels used to convey curb and gutter flow) were constructed in areas where catch basin bypass or surcharge was suspected, or where overflow pathways were otherwise required.

A total of 41 outfalls were identified along the shore of Lake Superior, 24 of which were used for waterfront drainage areas. Outfalls were set to use a time series of observed lake levels to define tailwater conditions.

The dynamic wave formulation was used to perform flow routing; inertial terms were dampened, and Hazen-Williams was used as the force main equation. A 5-second routing time step was used with a minimum variable time step of 0.5 seconds, along with a conduit lengthening time step of 30 seconds. In addition to the rainfall/runoff and flow routing routines, both snow melt and groundwater were simulated.

Climatology

Climate data was acquired from the Iowa Environmental Mesonet (IEM) portal for the Grand Marais (GNA) Automated Surface Observing System (ASOS) weather station. Data were acquired for the period of record (July 31st 1998 to December 31st 2017), including precipitation depth, air temperature, dew point, relative humidity, wind speed, and barometric pressure.

Rainfall data were used directly as an input to SWMM. These data were analyzed and determined to be sufficiently complete for use in the simulation – excepting the period from 2002-2007, which had a large number of missing data points.

Climate data were aggregated and processed into a daily climate file consisting of daily maximum and minimum temperature, daily evaporation depth, and average wind speed; daily evaporation depth – used in the water balance for both open water surfaces and subcatchments – was estimated using the Priestly-Taylor equation, which is a simplified version of the Penman equation and uses psychrometric data to estimate potential evaporation. Temperature data are only used in the snow melt routine; the default SWMM settings were used for this routine, as these parameters are notoriously difficult to parameterize accurately, particularly without access to high-quality measurements of snowfall and snow accumulation.

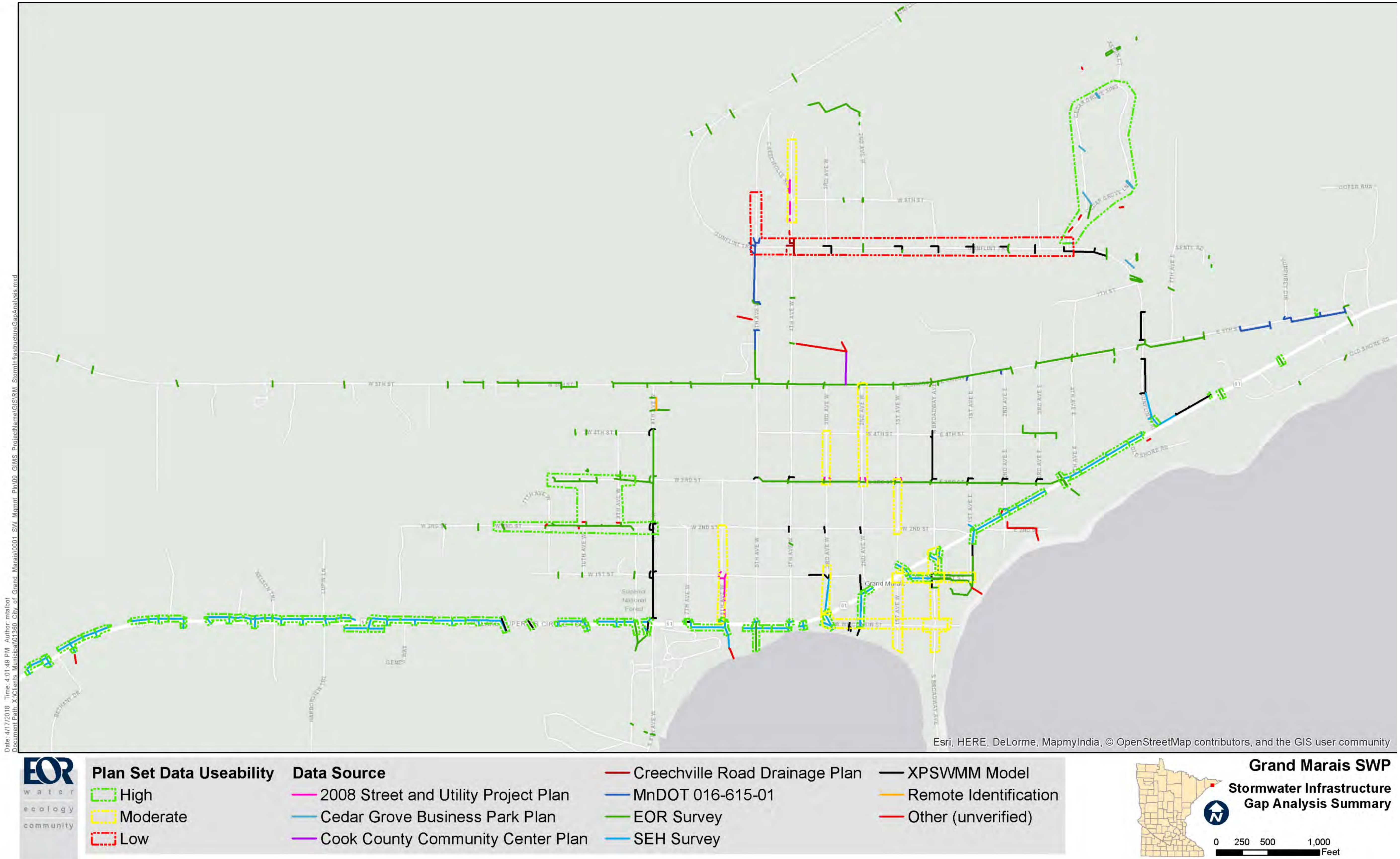

Figure 4-1: Summary of stormwater infrastructure gap analysis and data sources used to construct the hydrologic and hydraulic model.

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4.2.3. Model Calibration

Village Ditch Flow Calibration

Flow monitoring data was available in Village Ditch downstream of the Gunflint Trail for two periods: June 19th to August 31st 2001, and May 22nd to June 19th 2005. The data from 2005 were not able to be used for calibration or validation due to the high number of missing days in the ASOS weather data during this period, so the model was calibrated using the 2001 data. The primary calibration parameters were the groundwater coefficients (used for baseflow calibration), and the percent routing and Horton infiltration parameters (used for stormflow calibration). As shown in

Figure 4-2, the observed data contained a significant amount of noise, likely indicating a lack of correction for barometric pressure during data processing. Additionally, negative flows were reported during several periods. Even with these data issues, the calibration falls within acceptable ranges with R2 = 0.685 and NSE = 0.682 for data between June 22nd and August 22nd.

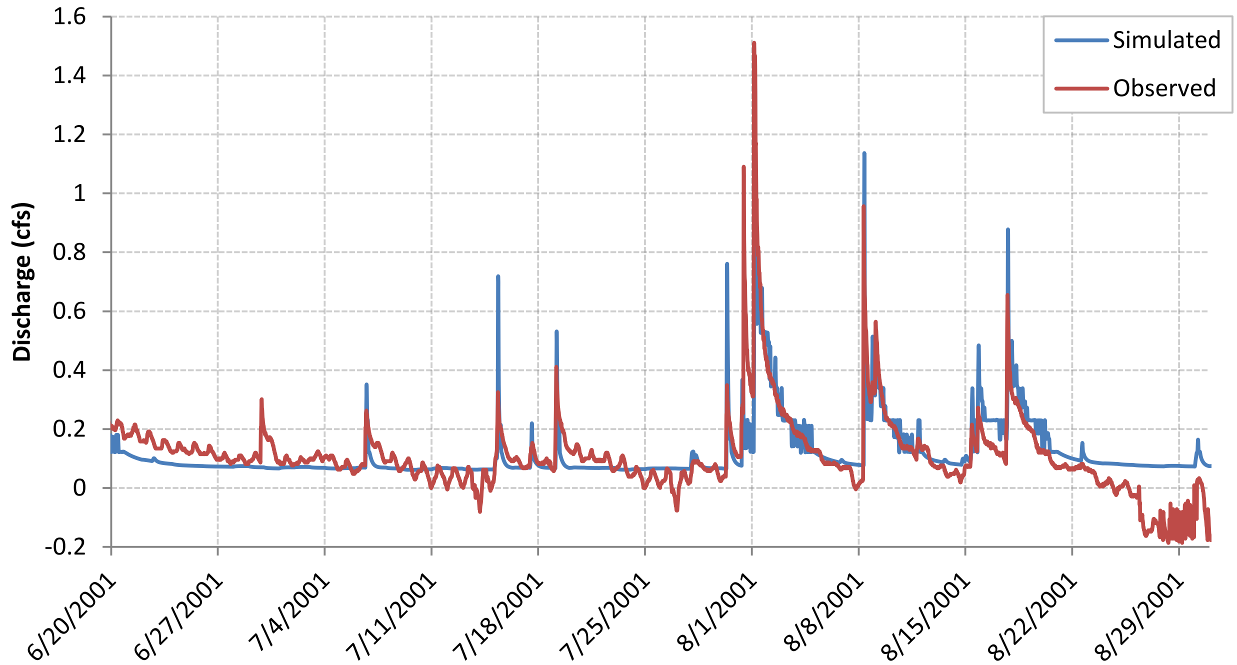

Figure 4-2: Simulated vs. observed streamflow data in Village Ditch in 2001.

Downtown Flood Duration Validation

Although no monitoring data has been collected in the downtown area, a qualitative validation of the stormwater model was performed by running a continuous simulation for 2017 and comparing the predicted ponding in the Cook County Whole Foods CO-OP parking lot to observations by City and SWCD staff, among others. In general, the duration of ponding in the parking lot was used as the independent variable for this analysis, and the ponding duration during the October 26th 2017 event in particular – estimated at slightly less than 24 hours – was used to fine tune key parameters in the model. By far the most sensitive parameter was the rate of discharge from the pond behind the Cook County Whole Foods CO-OP, which lacks a defined outlet and is instead connected to Lake Superior via seepage through the berm that separates them. A value of 0.55 cfs was set as the maximum allowable flow rate through this berm, which corresponded to a predicted ponding duration of 21.4 hours for the October 26th 2017 event.

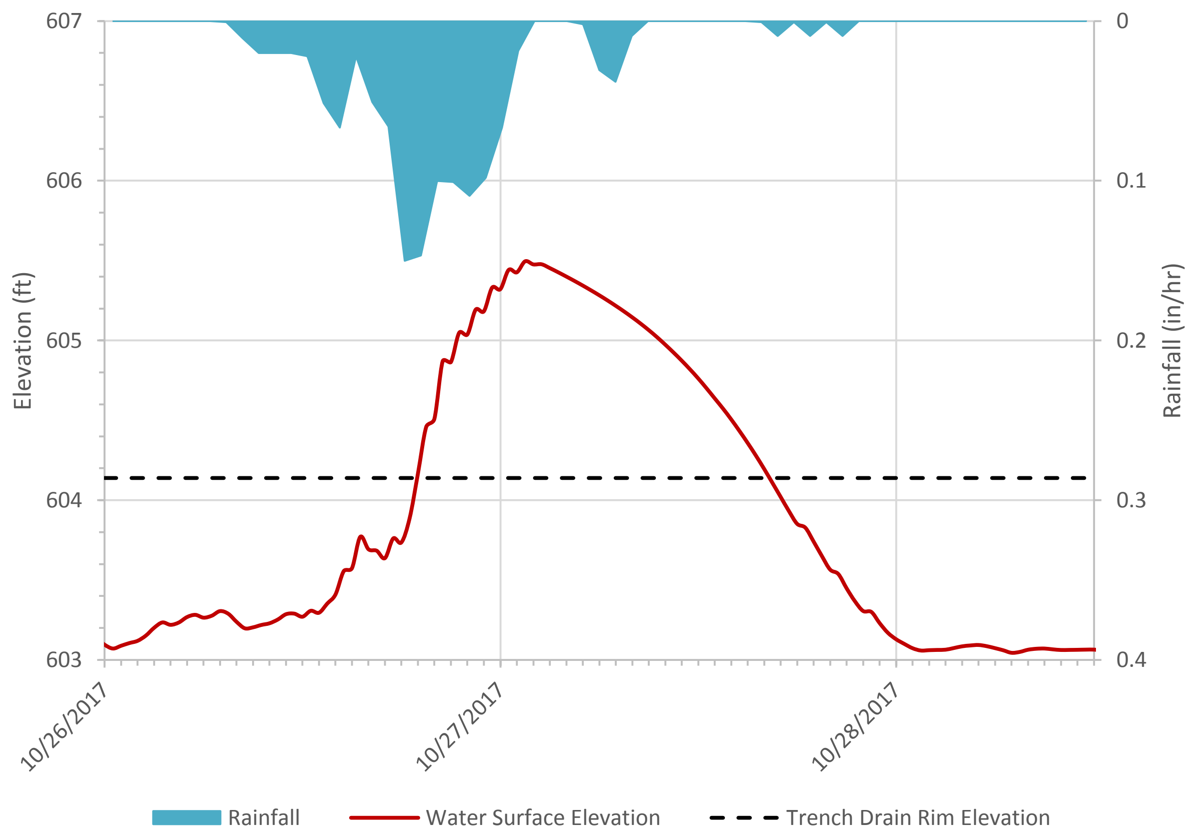

Figure 4-3: Water surface elevation in the Cook County Whole Foods CO-OP parking lot following the October 26th, 2017 storm

4.2.4. Scenario Development

Once calibration was completed, a number of model scenarios were constructed to evaluate the existing conditions of the storm sewer infrastructure. These included both a continuous (long-term historic) simulation and a set of design storm (short-term synthetic) simulations. Figure 4-4 shows the rainfall data used in the continuous simulation (resampled to a uniform 1-hour time step), and Figure 4-5 shows the scalable (i.e. 1-inch storm depth) MSE 4 MN design storm distribution. The following scenarios were used to evaluate existing conditions:

- Continuous Simulation (April-October 2017)
- NOAA Atlas 14 24-hour Design Storm Simulations (using the MSE 4 MN Storm Distribution):
  - *1-inch* - *1-year (2.10-inch)*
  - *2-year (2.43-inch)* - *5-year (3.01-inch)*
  - *10-year (3.53-inch)* - *25-year (4.30-inch)*
  - *50-year (4.93-inch)* - *100-year (5.60-inch)*

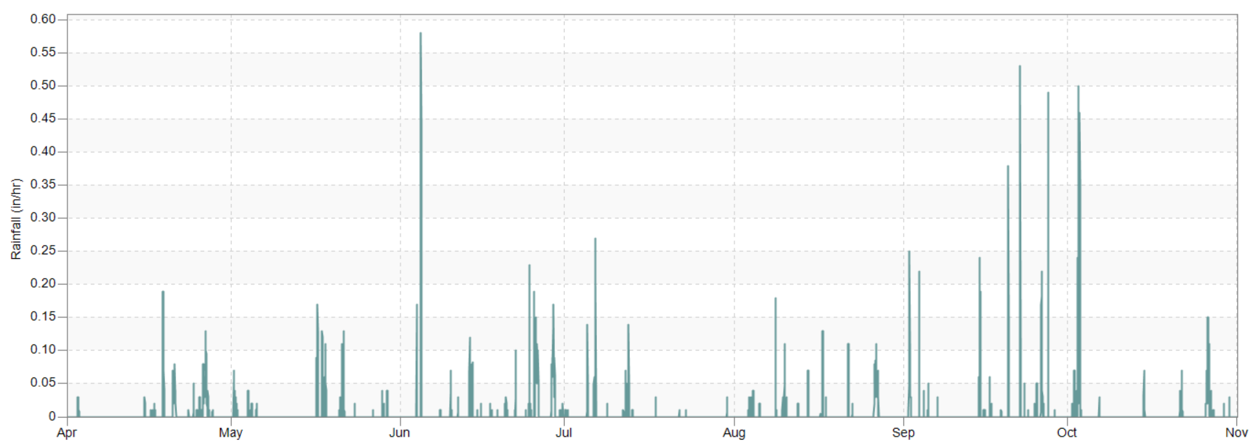

Figure 4-4: Rainfall data used in the 2017 continuous simulation

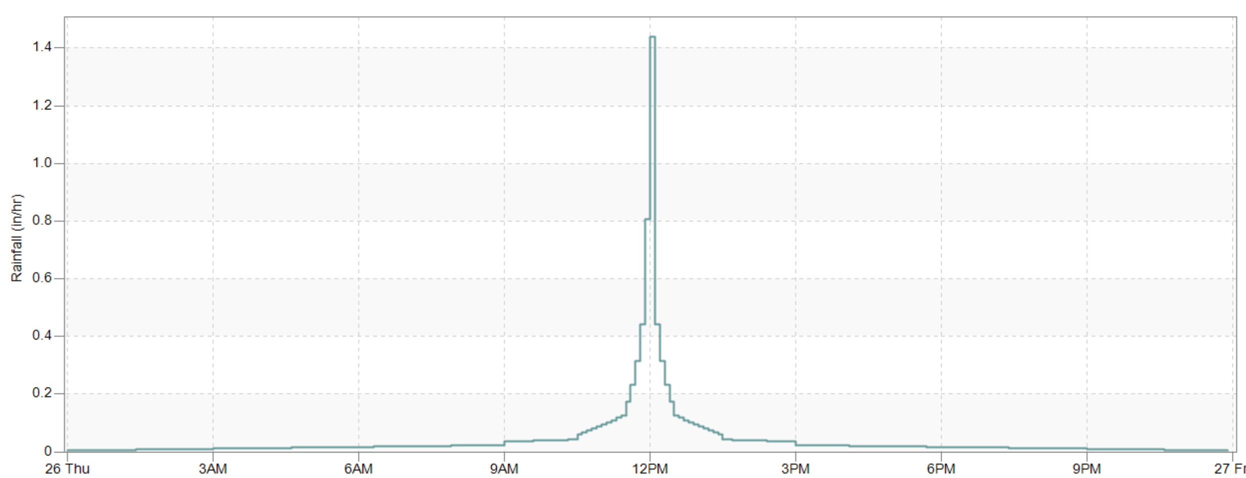

Figure 4-5: Rainfall distribution used in the design storm simulations (1-inch, 24-hour MSE 4 is shown)

4.2.5. Pipe Capacity Assessment

To locate any potential issues related to pipe capacity limitations, the model was run for the 2-, 10-, and 25-year, 24-hour Atlas 14 design storms (2.43", 3.53", and 4.3", respectively) using the MSE 4 MN rainfall distribution (Figure 4-5). In SWMM, a pipe is considered "capacity limited" if the upstream end of the pipe is surcharged *and* the slope of the hydraulic grade line is greater than the slope of the pipe, and as such this measure is not influenced by tailwater conditions. highlights the pipes that were identified as capacity limited for 15 minutes or longer during one or more of these scenarios.[6] Notably, the downtown area had the highest density of pipes with capacity issues – likely caused primarily by low pipe slopes as this is the flattest area in the City.

4.2.6. Inlet Capacity Assessment

Due to the predominance of steep slopes in the City, it was desirable to attempt to simulate the potential impacts of catch basin bypass on flooding in downtown. Figure 4-6 shows the reduction factor used in an equation to calculate flow that can be safely conveyed in a gutter given varying street slope and storm size. Its inclusion here is intended to help illustrate the importance of proper catch basin design in a city with steep slopes like Grand Marais where, for example, the Avenues between 2nd and 3rd Streets have slopes of 7% on average.

Accurately simulating catch basin performance is challenging. In this case, the degree of difficulty was partly because subcatchments were not delineated to individual catch basins but rather to clusters of catch basins (necessary to reduce model complexity), and because the catch basins in a given cluster had widely varying capacities. Additionally, simulating bypass during large storm events proved far easier than simulating bypass during small events, so it is likely that the model results significantly underestimate catch basin bypass during the 2017 continuous simulation. Therefore, while the resulting model scenario sheds light on the potential for catch basin bypass to exacerbate flooding in downtown, the results should be looked at as an estimate of this contribution.

Even considering these limitations, the model suggests a significant amount of inlet bypass – particularly along 3rd Street. Between 5th Ave W and 3rd Ave E, it was estimated that nearly 20% of runoff volume from the 2-year, 24-hour Atlas 14 design storm bypasses the 3rd Street storm sewer network and makes its way via gutter flow to the downstream inlets at Highway 61. Since the downtown storm sewer network is already capacity limited for this event, the system was largely unable to capture these additional flows and stormwater was conveyed in the gutter along Highway 61 to the southwest where it eventually discharges to the harbor.

This bypass has several implications on flooding downtown for the 2-year, 24-hour storm. First, it exacerbates flooding in the Cook County Whole Foods CO-OP parking lot, increasing

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[6] It should be noted that a number of storm sewers along Highway 61 to the west of the City (not shown in) were also identified as capacity limited.

overall inflow by about 4% and the duration of flooding by about 3 hours. Second, it has the effect of decreasing the impact of any solutions to said flooding, since any increase in the capacity of the downtown storm sewer network will – up to a point – simply lead to an increase in inflows to the network at Highway 61. Finally, excessive gutter flow such as this (as much as 7 cfs was predicted) during an event as frequent as the 2-year, 24-hour storm is a public safety concern.

It is worth noting that the proportion of inlet bypass reported above is low even for an optimized system of inlets, and is likely to be much greater than this in reality. This assumption is reinforced by the results of the field investigation, which revealed a number of catch basins that appear to be mostly or completely ineffective, even during small storms. While it is difficult and time consuming to make a more accurate estimate, the number of ineffective inlets and the lack of inlet redundancy (i.e. multiple inlets in series) in most areas imply that total inlet bypass could be 50% or more for the 10-year storm event – which is a common event used for designing storm sewer networks.

highlights selected inlets that were identified in the field as having significant potential to bypass. Notably, the intersections of 3rd Street with Broadway Ave and 1st Ave E are the most influential on flooding in downtown. The intersection with 1st Ave W is also a location of concern, but the high degree of bypass at the downstream inlet near Highway 61 actually serves to divert runoff away from the Cook County Whole Foods CO-OP parking lot, sending it instead to the southwest to a storm sewer network tributary to the harbor. This inlet has been identified as a candidate for elimination, but this should only be performed in conjunction with the installation of new inlets along Highway 61 to reduce risks to public safety; this issue is discussed further in Section 5.0 regarding potential strategies for diverting runoff away from downtown.

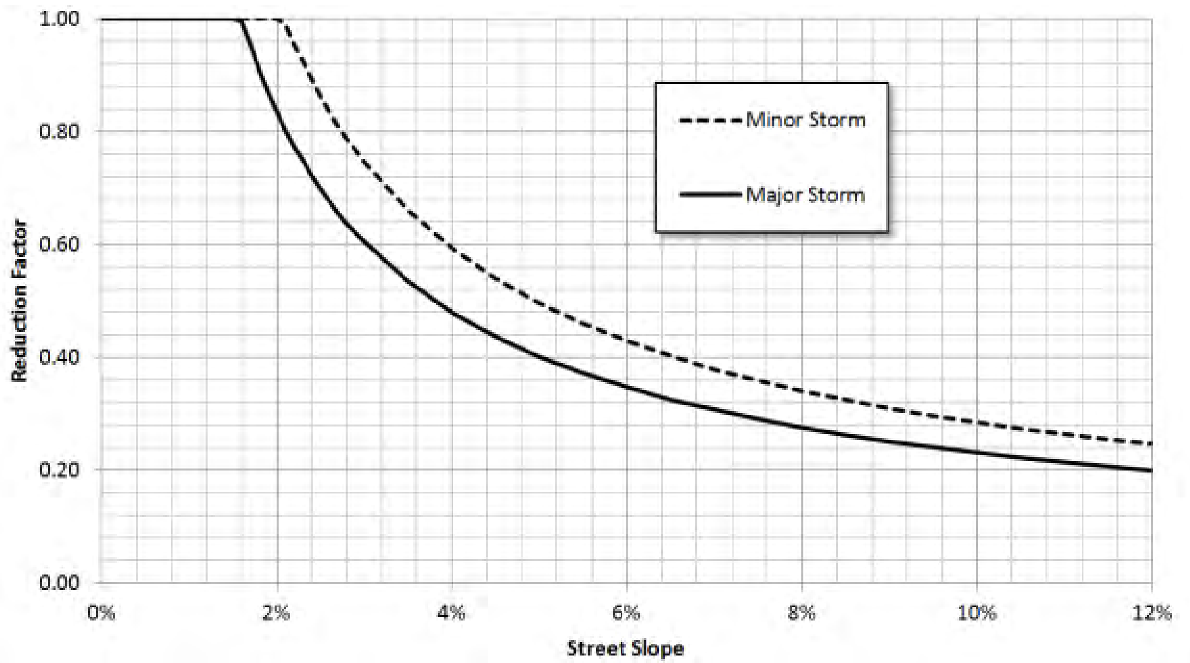

Figure 4-6: Reduction factor for gutter flow[7], illustrating the dependence of safely allowable gutter flow on street slope and storm size.

[7] From the Colorado Urban Drainage and Flood Control District's Urban Storm Drainage Criteria Manual, Chapter 7: Streets, Inlets, and Storm Drains.

4.2.7. System Capacity Assessment

Pipe capacity and inlet capacity are distinct issues, but it is the combination of these properties – along with the addition of catch basin surcharge – that determines the capacity of the storm sewer network to convey stormwater from the street to an outfall for a given event. It is not possible to provide a single answer to the question of system capacity across the study area due to the number of factors involved and the spatial variability of system performance.

For example, the 3rd Street storm sewer network has a very high capacity in terms of pipe conveyance (>4.3 inches of rain), but there are multiple inlets that are bypassed for even a small amount of rain (>0.05 inches of rain). Therefore, with proper reconstruction of inlets, this network has the potential to be very effective at capturing and conveying runoff, even for large storm events.

Conversely, the storm sewer network downtown has both pipe capacity and tailwater issues limiting its conveyance capacity, but as its inlets are located in flat or depressional areas they are therefore adequate – even if not optimal – for capturing runoff. Increasing inlet capacity downtown will have little to no effect on ponding in the Cook County Whole Foods CO-OP parking lot without first addressing the conveyance capacity issues, and/or finding solutions to reduce the amount of runoff that reaches downtown.

All this is to say that each storm sewer system in the City is unique, and a prescriptive and targeted approach to infrastructure improvements is required to provide cost-beneficial solutions to the City's flooding issues. Specific recommendations are discussed in Section 7 of the Plan.

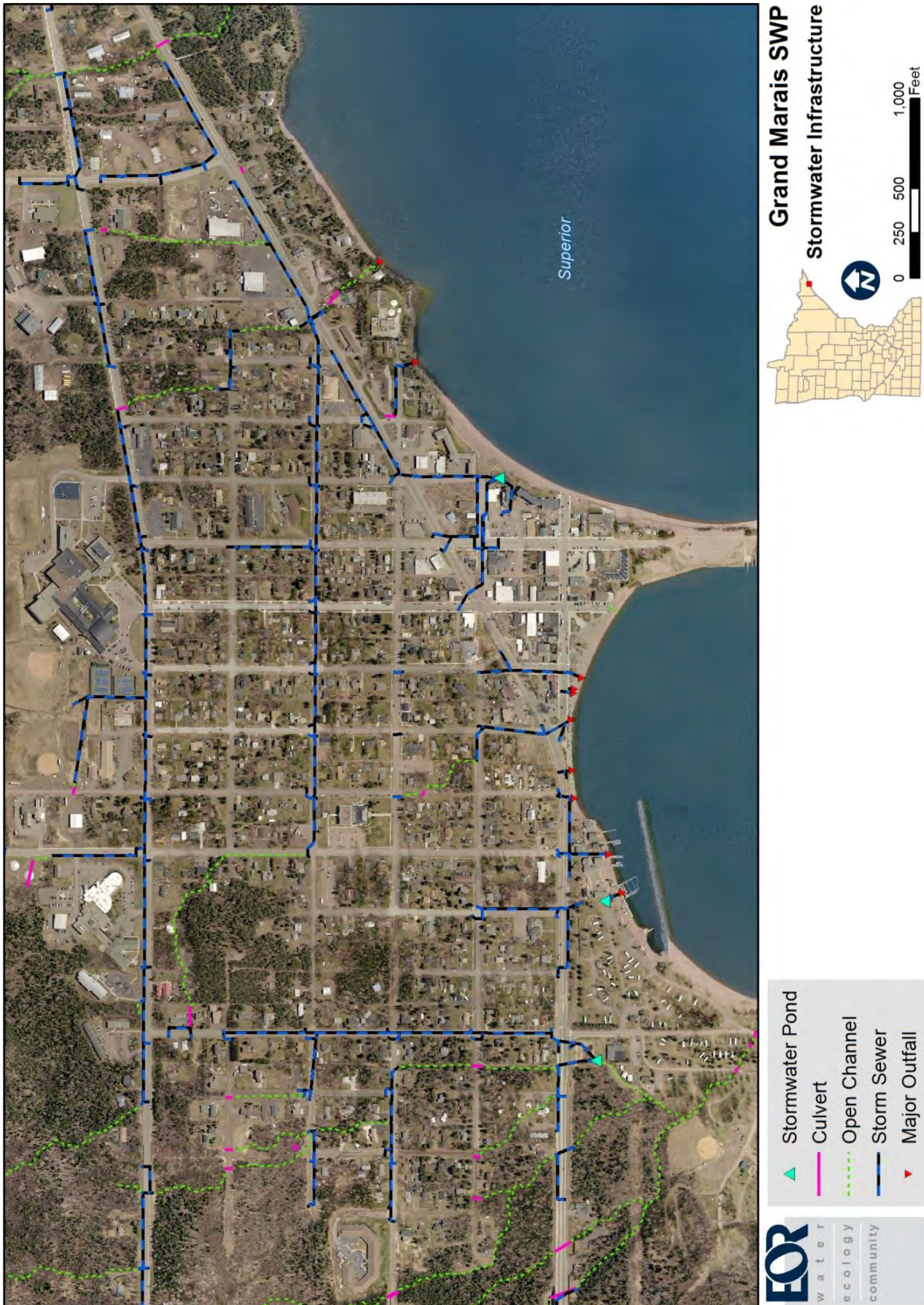

Figure 4-7: Overview of stormwater infrastructure in the vicinity of downtown.

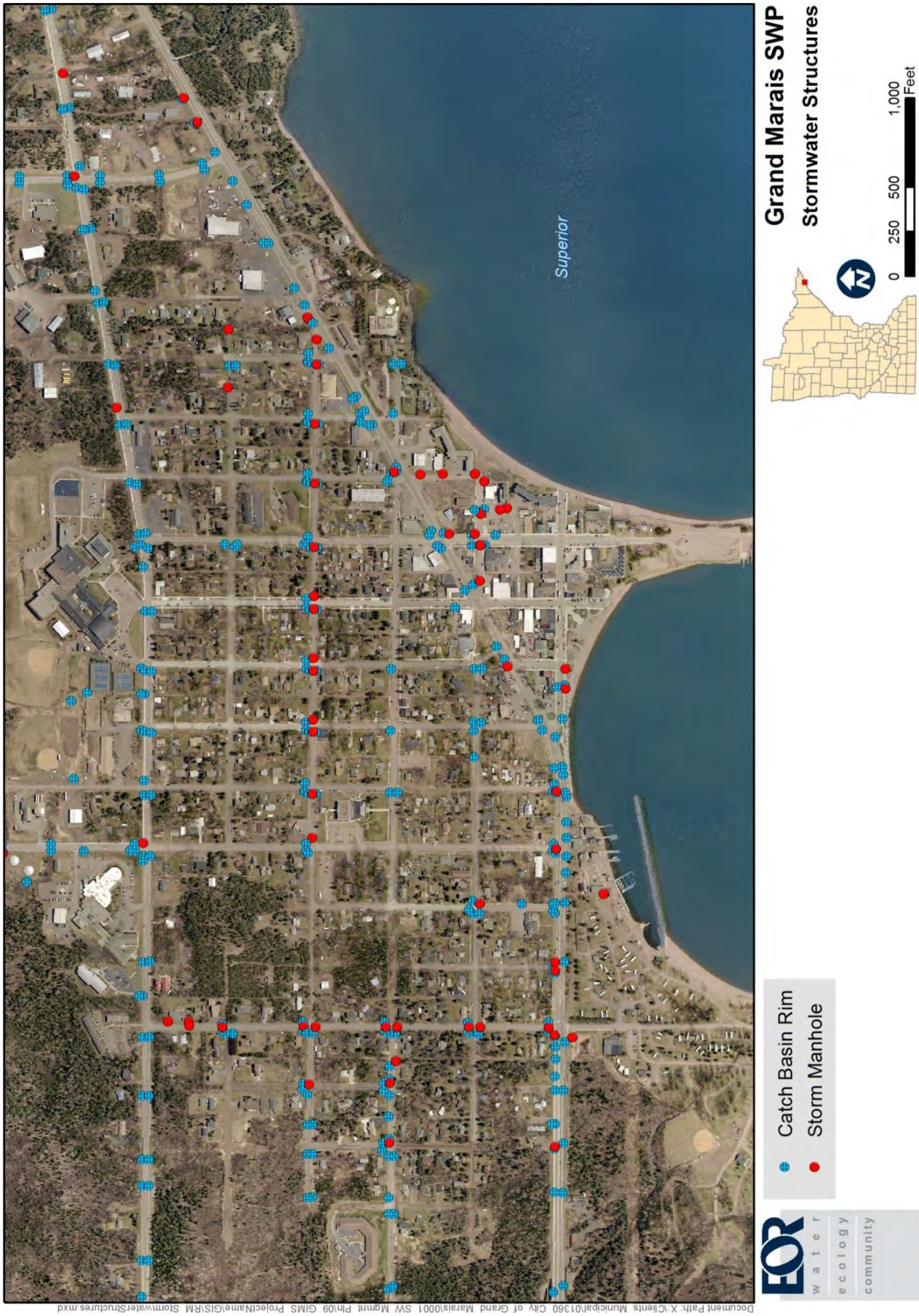

Figure 4-8: Overview of stormwater structures in the vicinity of downtown.

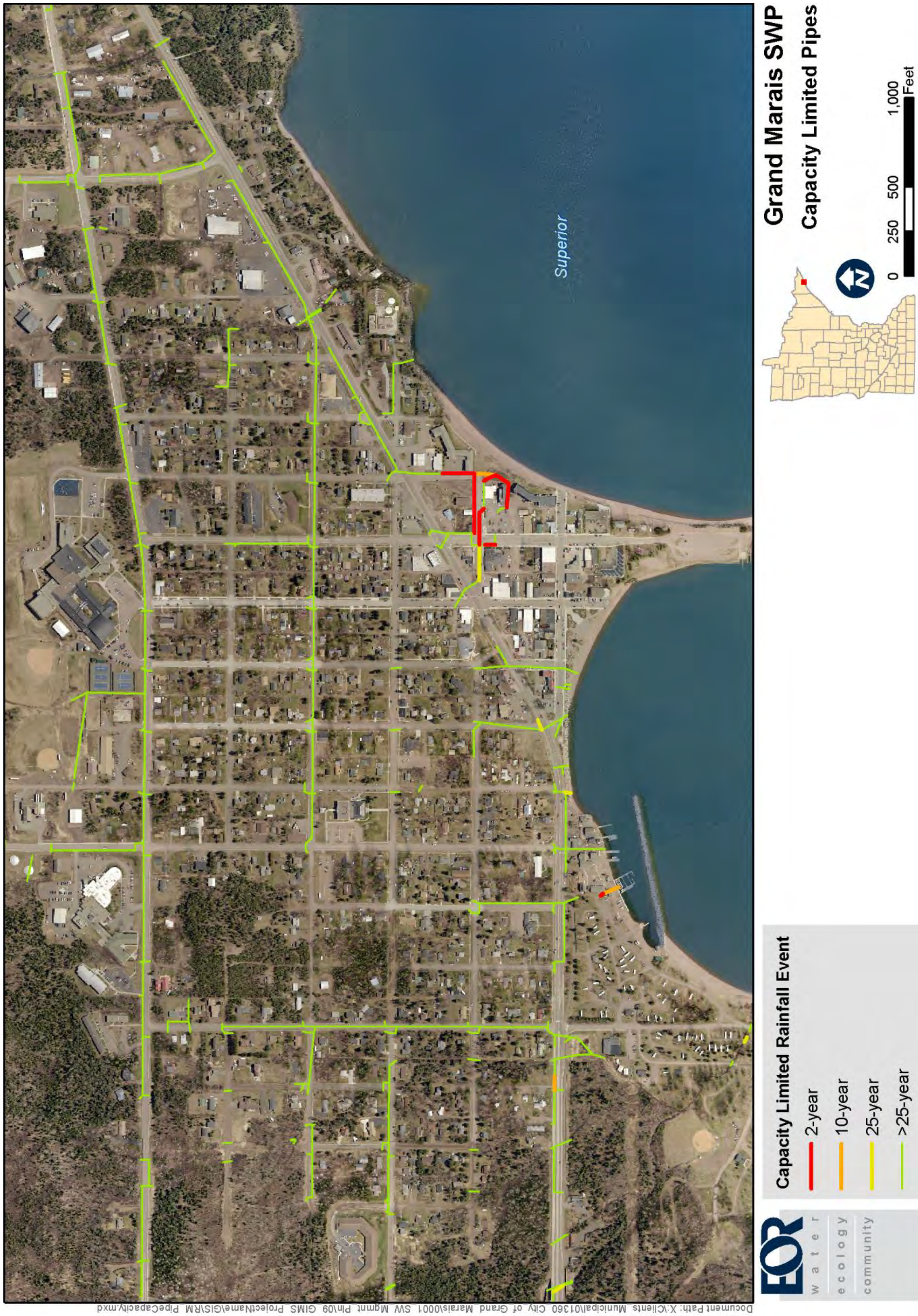

Figure 4-9: Capacity limited pipes in the vicinity of downtown.

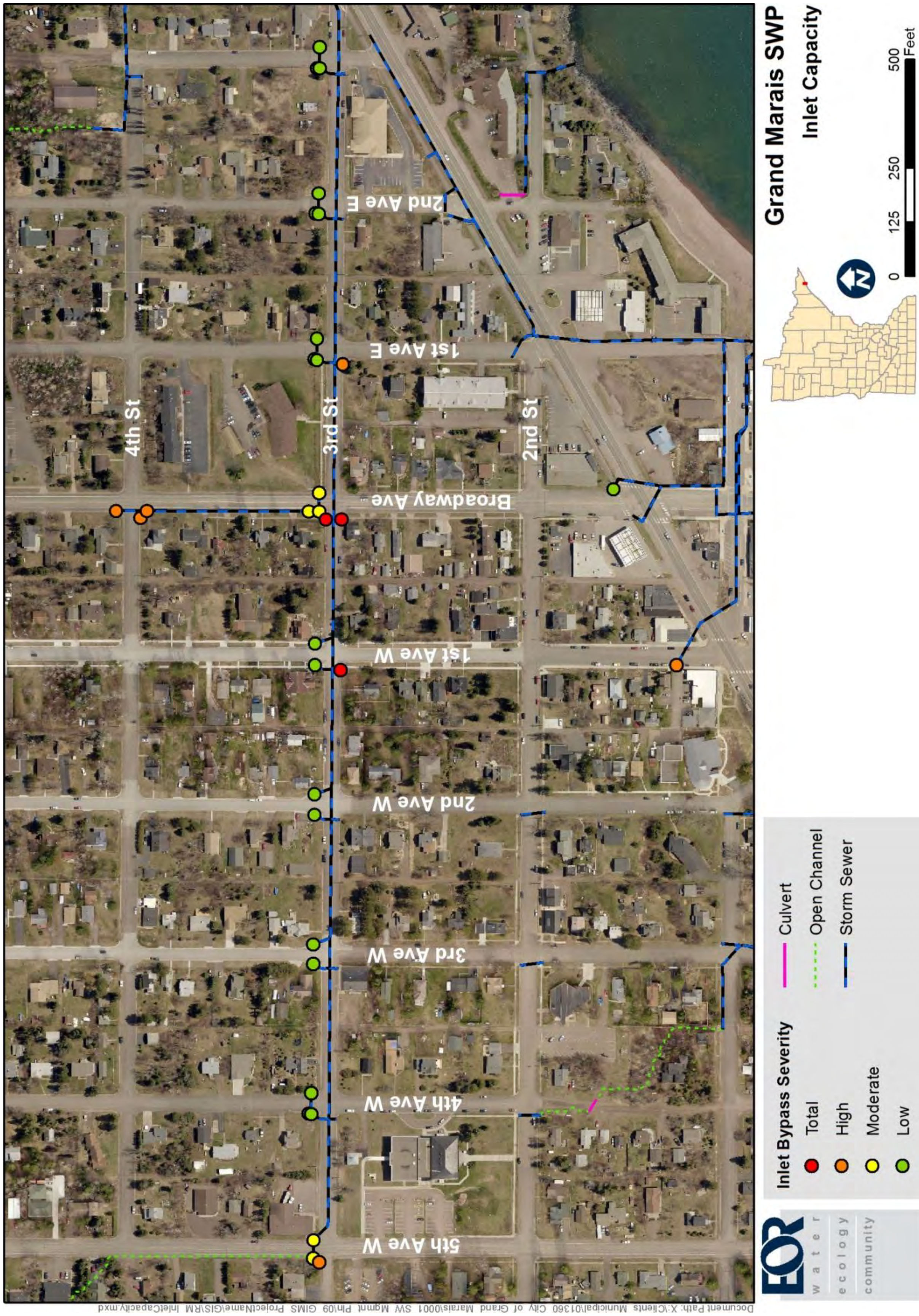

Figure 4-10: Inlets with identified capacity issues in the vicinity of downtown.

4.3. Analysis of Downtown Flooding

Preliminary discussions with City Council indicated that the goal for allowable flooding in the Cook County Whole Foods CO-OP parking lot should be *no more than 12 inches (above the trench drain inlet) for no more than 12 hours* (see for reference). The continuous simulation analysis using the 2017 rainfall record was used to evaluate flooding in downtown Grand Marais relative to this goal. The model was run for a warmup period from August 1st 2016 to February 28th 2017, and results were reported from March 1st 2017 through October 31st 2017. During this period, a total of 17 rainfall events produced ponding in the parking lot, as summarized in Table 4-1. Of these rainfall events, 11 produced ponding in excess of 12 inches deep, and only three events produced ponding in excess of 12 inches deep for 12 hours or more. The smallest rainfall event for which any ponding occurred was just 0.23", and the smallest event that produced more than 12 inches of ponding was 0.99". The largest 24-hour rainfall event during the simulation period was 2.5", corresponding roughly to a 2-year return period.

Model outputs were analyzed in an attempt to determine the best predictor(s) of ponding in the parking lot during the 2017 simulation period. Of the variables analyzed – which included total event rainfall, mean rainfall intensity, peak rainfall intensity, and mean lake level – total event rainfall was by far the best predictor of ponding duration, with $R^2 = 0.7543$, as shown in Figure 4-11: Plot of rainfall depth vs. ponding duration in the Cook County Whole Foods CO-OP parking lot during the 2017 simulation period. When the two outliers were removed from the data, R^2 increased to 0.8683. These outliers correspond to the events on 9/27 and 10/1, during which the level of Lake Superior was at its peak; this implies that although lake level was not overall a good predictor of ponding, very high lake levels likely exacerbate ponding that would occur regardless. The primary conclusion of this analysis is that an increase in rainfall depth correlates with an increase in ponding duration, where each inch of rainfall leads to approximately 16.9 hours of ponding.[8]

[8] This conclusion is valid for small storms only (>0.5 inches and <2.5 inches) since the largest rainfall event observed during 2017 was 2.5 inches in 24 hours.

Table 4-1: Predicted ponding events in the Cook County Whole Foods CO-OP parking lot during the 2017 simulation period.

Event	Rainfall Start	Total Rainfall (in)	Rainfall Duration (hr)	Ponding Duration (hr)	Flooding* Duration (hr)	Max Ponded Depth (in)
1	4/18/2017 7:35	0.80	10.3	9.0	0.0	8.9
2	6/4/2017 13:45	0.62	3.5	11.4	3.1	13.7
3	6/24/2017 9:40	0.51	8.7	4.9	0.0	6.7
4	6/25/2017 9:35	1.40	18.5	23.8	9.5	15.4
5	6/28/2017 11:40	1.29	19.0	23.3	12.5	16.8
6	7/6/2017 7:40	0.40	4.5	1.1	0.0	1.7
7	8/8/2017 13:30	0.31	4.3	0.6	0.0	1.0
8	8/26/2017 14:35	1.11	19.5	18.6	0.0	10.7
9	9/1/2017 22:50	0.96	9.2	18.8	9.4	16.1
10	9/3/2017 20:45	0.23	2.2	0.0	0.0	0.1
11	9/14/2017 19:30	0.90	10.8	17.0	6.1	15.4
12	9/20/2017 3:55	0.51	3.1	9.5	0.0	11.9
13	9/22/2017 8:40	0.64	3.5	12.7	4.3	14.5
14	9/26/2017 2:40	0.86	9.5	16.8	6.9	14.9
15	9/27/2017 11:35	0.99	3.5	45.5	37.4	25.7
16	10/1/2017 21:35	2.50	23.8	68.4	57.3	28.1
17	10/26/2017 7:25	1.25	25.3	21.4	9.8	16.3

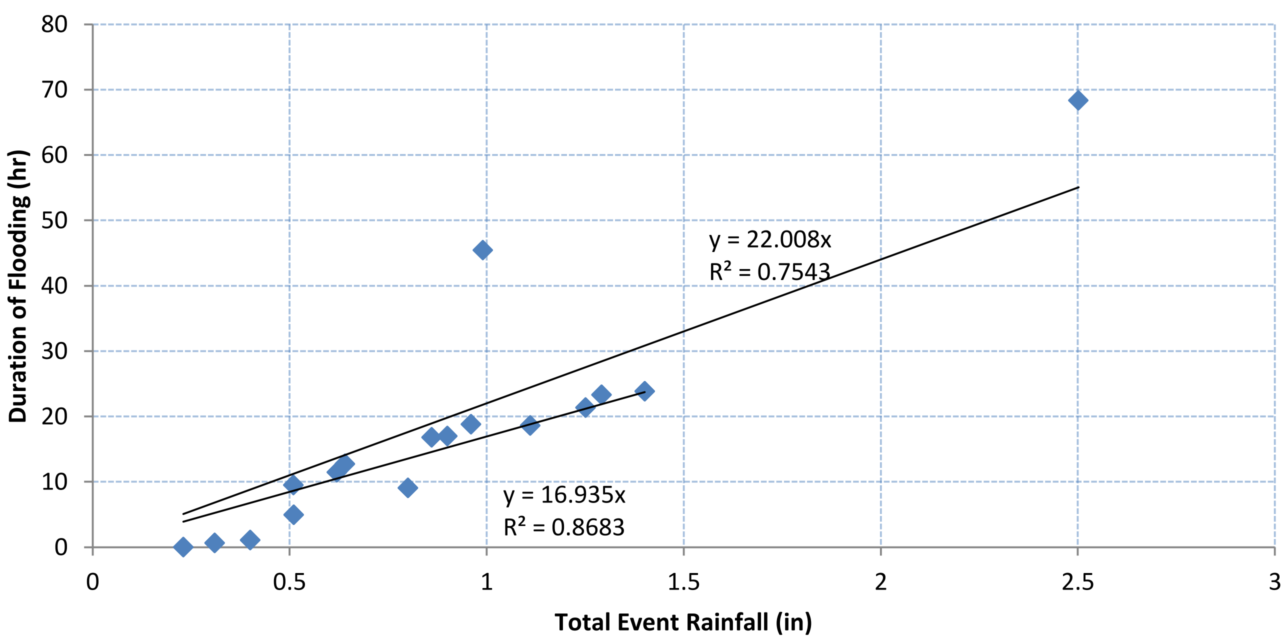

Figure 4-11: Plot of rainfall depth vs. ponding duration in the Cook County Whole Foods CO-OP parking lot during the 2017 simulation period.

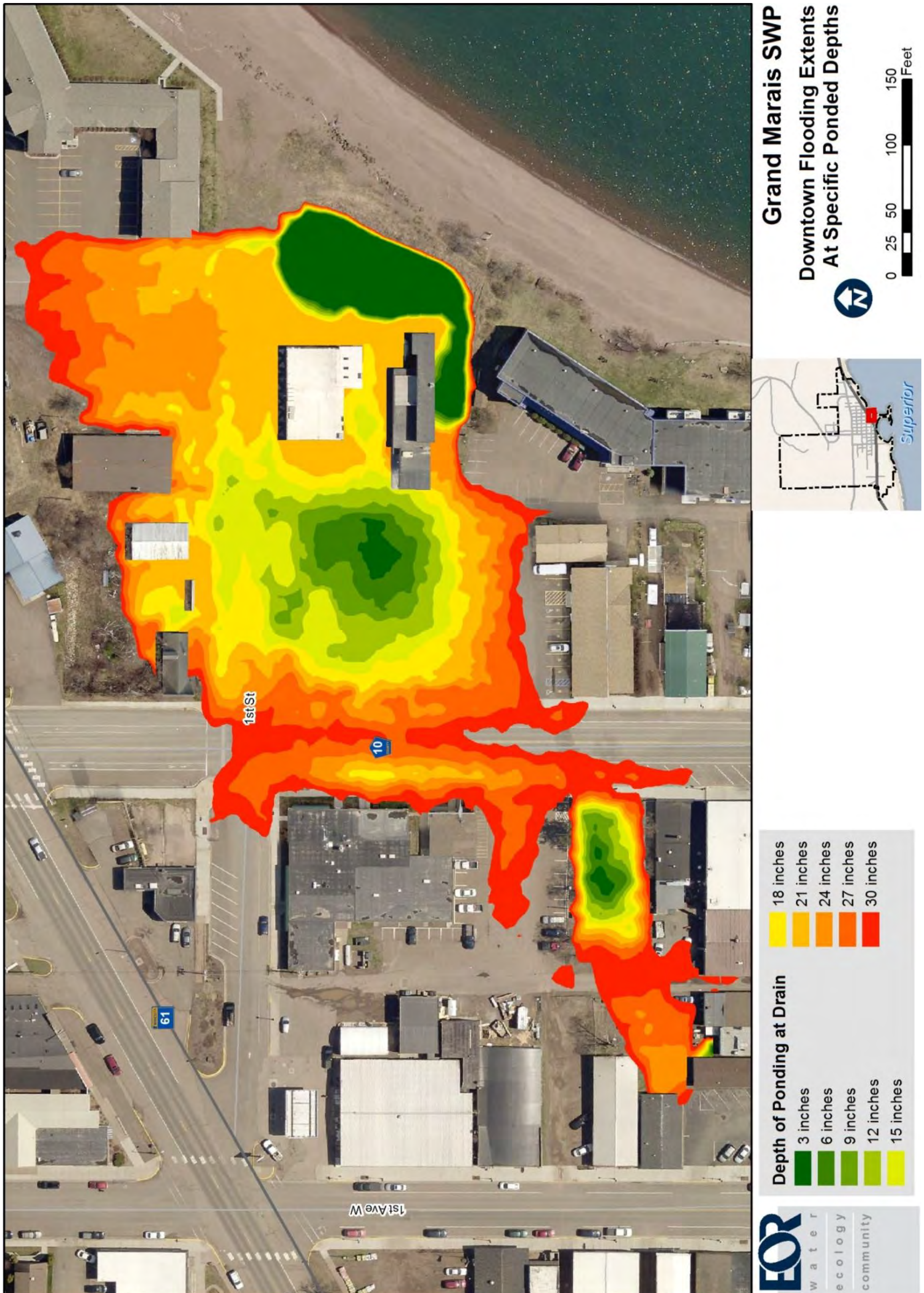

Figure 4-12: Downtown flooding extents from the LiDAR inundation analysis

4.4. Identification of New and Retrofit BMP Opportunities

Given the amount of flooding that takes place in the City of Grand Marais, it was clear that the solution to this issue requires taking a multi-faceted approach to stormwater management. Identifying sites in the watershed where new stormwater management features could be located or where existing BMPs could be retrofit to enhance performance was a critical step in the development of the stormwater management approach for this Plan.

A desktop review using GIS was combined with a windshield survey of the city to identify potential BMP opportunities. First, a set of field maps was generated that identified areas generally suitable for BMPs based on land use and ownership, land cover, soils, and topography. Next, a multi-day field survey was conducted to evaluate specific locations for suitability based on criteria that were more difficult to assess remotely, such as relative landscape relief, existing vegetation size and density, and proximity to downspouts and other potential storm water diversion opportunities. Potentially suitable BMP sites were lumped into one of the following seven categories[9]:

- **Raingardens** include small features that could generally fit in the right-of-way between curb and either sidewalk or property lines, and are located primarily in residential areas.
- **Bioretention** sites include both tree trenches and large-scale raingardens, and were generally assumed to differ from raingardens in both size and level of design (e.g. presence of an underdrain).
- **Rainwater harvesting** sites mainly include a few key buildings identified in the downtown area, but could be considered for any commercial structure with owners amenable to the idea of reusing rooftop runoff, either for watering or as part of a greywater system.
- **Road improvements** targeted, for the most part, streets that are either in disrepair or that may be wider than necessary for the portions of the City that they serve; their overall impervious footprint could be reduced either through narrowing or through incorporation of "bump-out" or median raingardens as part of planned reconstruction.
- **Parking lot improvements** also target potential impervious footprint reduction, but additionally include unpaved parking areas that were perceived as being sediment sources contributing to water quality and infrastructure maintenance issues.
- **Regional ponding** sites targeted drainage areas and/or existing drainage ways that could be intercepted or redirected to a proposed impoundment for the purposes of water quality treatment and rate control.
- **Bank stabilization** sites were identified at several locations, including in ravines and streams as well as along the lakeshore. These sites present both a public safety risk and a significant sediment source.

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[9] Not including rain barrels, which were sited on a random sample of residential buildings for BMP scenario planning.

After the sites were categorized, approximate footprints were digitized (if this was not already performed while in the field), and a cost-benefit analysis was performed using typical design and construction costs, and expected pollutant removal efficiencies. Average BMPs costs used were derived from a number of sources including the MPCA and from EOR's project experience, and are shown in Table 4-2. Pollutant loading was approximated by estimating TSS loads from the drainage area to each BMP; these values were estimated from a combination of sources for the aggregated land use classes shown in Table 4-3. Pollutant removals were estimated by assuming that 100% of TSS was removed from runoff retained by BMPs and that 60% of TSS was removed from runoff that was detained by BMPs.

Table 4-2: Capital cost assumptions used for BMP cost estimation (average costs from multiple sources).

BMP Type	Capital Cost	Units
Bioretention	$ 13.50	$/ft^2
Raingarden	$ 33.00	$/ft^2
Rainwater Harvesting	$ 30,000.00	$/unit
Rain Barrels	$ 175.00	$/unit

Table 4-3: TSS load assumptions by land use class (estimated using a combination of sources).

Land Use Class	TSS Load (lbs/yr)
Developed, High Intensity	221
Developed, Medium Intensity	111
Developed, Low Intensity	76
Natural Areas	35
Open Water	0

Drainage areas to BMPs were estimated spatially where feasible (e.g. rooftop or parking lot areas), otherwise a drainage area to footprint ratio was assumed that varied by BMP type (see Table 4-4).

Table 4-4: Summary of LID drainage area estimation methodologies.

BMP Type	Drainage Area Estimation Method
Bioretention	10:1 drainage area to footprint ratio, with drainage area assumed to be 100% impervious
Raingarden	
Rainwater Harvesting	Delineated
Road Improvement	10% of footprint converted to Bioretention with a 10:1 drainage area to footprint ratio
Parking Lot Improvement	
Regional Ponding	Delineated
Bank Stabilization	N/A

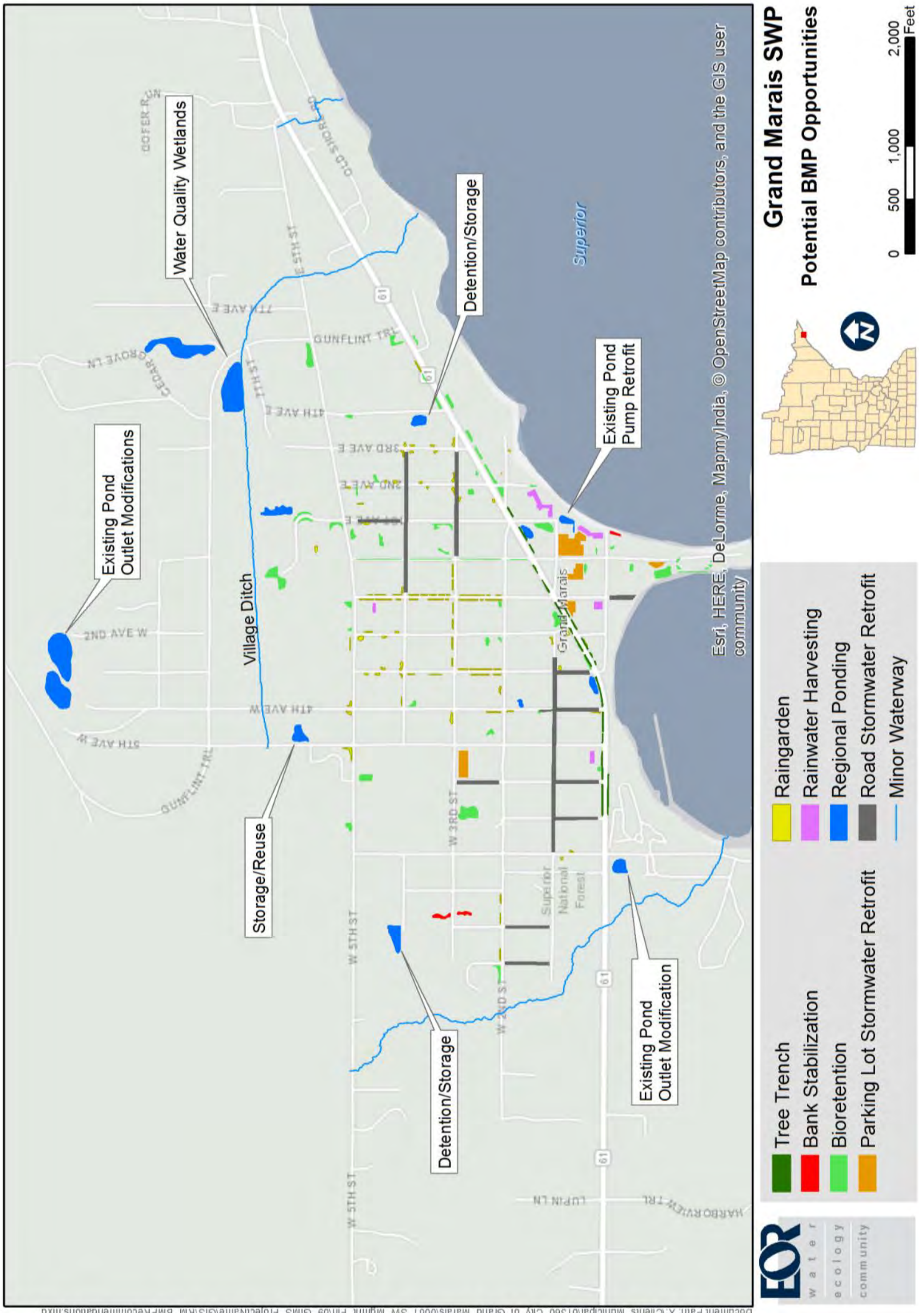


Figure 4-133: Potential new and retrofit BMP opportunities.

5. ASSESSMENT OF PRIORITY CONCERNS

The City of Grand Marais developed a prioritized set of issue statements and corresponding goals and policies for the management of stormwater in the watershed based on the modeling analysis and input from the public, members of the business community, City Council, City Staff and Cook Soil and Water Conservation District Staff. These issue statements, goals and policies serve as a guide for City Council to direct the preparation of the implementation plan which is located in Section 8.0.

5.1. Review of Existing Plans, Studies and Other Reports

The first step in identifying issues and concerns is to review previously conducted planning efforts and supporting documentation. Information was collected from several entities including the City of Grand Marais, Cook County and the SWCD, MnDOT, MnDNR, and the MDH. The documents cover an abundance of topics and were studied to glean information outlining known issues, prior goals, policies, and proposed corrections, as well as nullification of projects through further analysis. As such, the following documents, in conjunction with stakeholder input, assisted in determining what remains to be addressed within the 10-year timeframe of this stormwater management plan.

- *Storm Water Management Plan for City of Grand Marais, ICECOR 2001*
- *Grand Marais/Cook County, Minnesota Storm Water Drainage Analysis for the Downtown Area Tributary to the Storm Water Basin at 1st Avenue East, in Preparation for the Grand Marais Corridor Trail Improvements Report, HGA, Inc. 2002*
- *Grand Marais Area Municipal Watershed Assessment Presentation, McCann 2002*
- *Grand Marais Phase I Summary and Phase II Options and Recommendations, BARR 2002*
- *Storm Water Ordinances Memorandum, Cook SWCD 2003*
- *Village Ditch Water Quality Monitoring and Water Level Monitoring, Cook County Water Management Program 2005*
- *Highway 61 Stormwater Natural Drainage and Retrofit Identification Project, BSWR 2008*
- *Nature Boy Creek Monitoring – Summer 2009 Summary Report, Cook SWCD, 2009*
- *Grand Marais Creechville Retention Ponds, Review of Existing Status and Recommendations Memorandum, CCLNS Joint Powers Board #3 2009*
- *Gunflint Trail Stormwater Pond Analysis and Dredging Design, SEH, Inc. 2009*
- *Grand Marais Small Scale Stormwater Demonstration Projects, Cook SWCD 2009*
- *Stories From the Coast: The First Ten Years of Minnesota's Lake Superior Coastal Program, MnDNR 2009*
- *Minnesota Lake Superior Beach Monitoring and Notification Program Final Report, MDH 2012*
- *Grand Marais Supply Plan Third Generation for 2016-2018, MnDNR 2015*
- *North Shore Management Plan Update, North Shore Management Board, 2016*
- *Sawtooth Bluff Visioning and Master Plan (Draft), ARDC 2018*

5.2. Priorities Identified During Community Engagement Process

As Section 3.0 of the Plan describes, the City of Grand Marais hosted a series of Water Conversations where members of the public, business community and other stakeholder groups were invited to participate in the identification and prioritization of issues and concerns related to stormwater management and natural resources protection and restoration. One of the main outcomes of this process is a list of issues and concerns that were prioritized by both the public as well as City Staff. This list of issues and concerns is presented in Table 4 in order of how they were ranked during the prioritization exercise. Those issues and concerns that received the highest number of votes in total are identified as higher priority than those that received fewer votes or no votes during the prioritization exercise. The following high priority issues and concerns are addressed in the 10-year timeframe of this stormwater management plan:

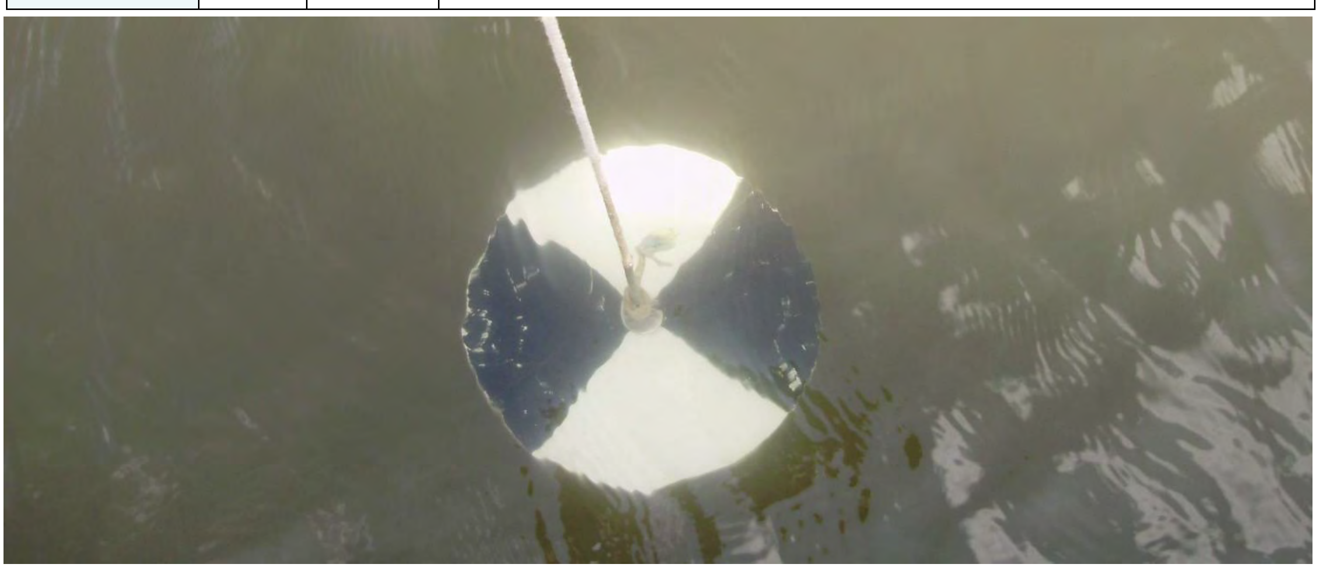
- *Flooding*
- *Water Quality*
- *Natural Resources Health*
- *Regulatory Controls and Design Standards*
- *Operations and Maintenance*
- *Community Awareness and Involvement*
- *Monitoring and Data Assessment*

The remaining issues and concerns are either solutions or strategies to addressing the previously mentioned issues (e.g. ineffective/aging infrastructure) or they were outside the scope of stormwater management plan (e.g. seiche).

Table 5-1. Issues and concerns identified and prioritized during Community Engagement Process

Issue/ Concern	Prioritization (higher # = higher priority)		Issue Statement
	Public	City Staff	
Flooding	6	1	Downtown Grand Marais is subject to flooding after smaller precipitation events. This is a concern to residents, local business owners and the City for the following reasons: public safety, property damage, impacts to tourism and economic development, and operation and maintenance costs.
Water Quality	1	4	Due to a general deficiency of water quality best management practices, a large proportion of the City's stormwater discharges directly to Lake Superior without treatment. There are a number of sediment sources in the watershed including gravel alleys, streets and parking lots, road sanding, and bank erosion along Village Ditch and other drainage-ways. In August of 2017, Grand Marais Beach was subject to a beach advisory as elevated *E. coli* levels indicated the presence of fecal contamination. The lack of monitoring data makes the targeted implementation of cost-effective solutions difficult.
Ineffective/ Aging Infrastructure	2	2	While the drainage infrastructure at large is relatively new (most of the system replaced within the last 40 years) the physical setting creates barriers that need to be addressed. Lack of water quality BMPs and temporary erosion and sediment control in construction zones combined with steep slopes and erodible soils means that an excessive amount of sediment is making its way into the stormwater infrastructure, reducing capacity and necessitating increased frequency of maintenance.
Natural Resource Health	2	2	Many residents of the watershed are concerned about the health of remaining natural areas within the City such as natural channels and streams including the Village Ditch. Significant bank erosion along these channels is encroaching on private property and contributing to high sediment loads within the channels, which ultimately discharges to Lake Superior without treatment.
Wetland Management	3	--	Historic loss of wetlands and unregulated filling of wetlands has reduced the storage capacity of the landscape. Wetland restoration is needed to help regain the functions and ecosystem services provided by wetlands.
Regulatory Controls/ Design Standards	3	--	The physical setting of the watershed makes for a very flashy system. Steep topography, combined with shallow depth to bedrock means that most of the stormwater runoff generated on the landscape travels downstream via surface runoff or shallow groundwater flow. New development will increase the rate and volume and reduce the quality of stormwater reaching downtown Grand Marais and Lake Superior. The City needs to adopt design standards to address these changes in land use including new development and redevelopment activity.
Public Safety	--	2	The physical setting of the watershed and the condition of the drainage system causes a number of public safety concerns including the discharge of sump pumps to city streets in winter, flooding in downtown Grand Marais, and pollutant loads to the harbor, Lake Superior, and the area near the public water intake. Lack of fencing around existing stormwater ponds in active tourist areas is perceived as a risk to children and pets.

Stormwater Practices	2	--	The City's stormwater conveyance system contains a number of stormwater Best Management Practices that are under-sized, under-utilized, and/or in need of more routine maintenance.
Community Awareness and Involvement	2	--	Residents, local business owners, city council and staff need to be better informed about stormwater management so they understand the impact of their land use decisions and can help address priority concerns by being better stewards of the watershed and implementing solutions at the individual lot level.
Operations and Maintenance	--	1	Numerous sediment sources and lack of water quality features contribute to long-term stormwater infrastructure maintenance issues. Interchanging of storm and sanitary manhole covers throughout the City makes inspection and maintenance of storm sewers cumbersome.
Cost	--	--	The City of Grand Marais has limited funds to implement all of the activities identified in the Stormwater Management Plan. Residents and members of the local business community need to understand the costs associated with addressing stormwater management related concerns in order to help prioritize solutions and understand the limitations of the system.
Drainage Issues	--	--	Historic absence of comprehensive planning related to the drainage system at large has resulted in multiple localized drainage issues such as ditches terminating and discharging to streets, under- and over-sized infrastructure elements, and under-performing practices, among myriad other issues.
Changes in Precipitation Patterns (Climate Change)	--	--	Precipitation in the Lake Superior watershed has been well above average for the past few years. As a result, water levels on Lake Superior are near record highs. These high water levels can decrease the capacity of storm sewers that discharge at below the elevation of the lake. Extreme precipitation events and/or back-to-back rainfall events are also contributing to the increased frequency, duration, and severity of flooding in downtown Grand Marais.
Seiche	--	--	In October of 2017 a massive storm surge called a seiche – combined with large waves – pushed rocks onto the shore and caused downtown Grand Marais to operate as a landlocked basin. High water levels exacerbated existing storm sewer capacity issues, and wave action contributed additional volume to flooding. Until a seiche recedes, flooded areas will tend to remain inundated for extended periods of time.



5.3. Hwy 61 Road Reconstruction Project

The Minnesota Department of Transportation (MNDOT) has plans to implement the Highway 61 reconstruction project in the summer of 2019. This project includes the stretch of Highway 61 from 1.8 miles north of Cutface Creek to 0.1 miles south of County Road 14. The project entails reconstruction and resurfacing of Highway 61 to improve road performance, accessibility and safety and drainage. As this project is a road-diet (there will be less impervious surface post project than there is under current conditions) MNDOT is not required to provide stormwater treatment in conjunction with the project. However, the City of Grand Marais identified a number of infrastructure improvements and stormwater management practices that could be constructed in conjunction with MNDOT's project that would achieve the goals identified in this stormwater management plan. Due to the timing of this project, these improvements and stormwater management practices are a high priority for implementation.

6. GOALS AND OBJECTIVES

This section of the Stormwater Management Plan identifies the City's goals for addressing the issues and concerns identified during the planning process (as described in Section 5.0 *Assessment of Priority Concerns).* This section also clarifies how the issues and goals of the Stormwater Management Plan address the other concerns identified during the Community Engagement Process: those issues and concerns that are either an implementation strategy to a broader issue or are addressed by a broader issue.

6.1. Flooding

The detailed modeling analysis performed for the Stormwater Management plan illustrates that flooding of the downtown area cannot be resolved in its entirety. There are certain components of the system that preclude the City's ability to eliminate the ponding of water in the parking lot. As a result, the following figure (Figure X) was developed to assist the City of Grand Marais in establishing an acceptable level of ponding in the parking lot. After reviewing these ponding footprints with residents, members of the downtown business community and City Council, the following goal for allowable flooding was established.

GOAL 1: No more than 12 inches of flooding in the downtown parking lot for no more than 12 hours for a 2-year, 24-hour rainfall event.

This goal address the following concerns expressed during the Community Engagement Process in the following manner:

Public Safety

This Stormwater Management Plan identifies the steps the City of Grand Marais needs to take to alleviate flooding in the downtown area. These improvements will result in less standing water for a shorter period of time, thereby minimizing property damage, reducing business interruption, and improving public safety by getting stormwater off streets that currently experience ponding and significantly reducing the flood footprint in the downtown area.

Stormwater Practices

This Stormwater Management Plan identifies a number of improvements to existing stormwater management practices that will address issues related to performance including retrofitting existing practices and improving maintenance practices. In addition, the Plan includes a number of new stormwater management practices designed to provide additional storage and water quality treatment prior to discharging to Lake Superior.

Ineffective/Aging Infrastructure

This Stormwater Management Plan identifies a number of improvements to the City's stormsewer system that will improve performance and reduce flooding. These improvements include addressing inlet capacity issues, new diversions within the existing storm sewer system and improvements to the maintenance of the system.

6.2. Water Quality

The City of Grand Marais has established the following goals to address water quality in Lake Superior:

GOAL 2: Maintain or improve lake water quality conditions by reducing pollutant loads to Lake Superior.

GOAL 3: Identify the source of fecal contamination causing beach closures by partnering with the University of Minnesota to complete microbial source tracking during a future beach closure to determine the source of fecal contamination, such as birds, humans, or dogs.

GOAL 4: Reduce the number of beach closures.

GOAL 5: Better characterize the quality and quantity of tributary discharge to Lake Superior by working with Cook County SWCD and state agencies to conduct water quality sampling in the following locations to better detect the impacts of stormwater runoff on lake water quality in the near shore zone: Village Creek ditch, Grand Marais Beach tributary outfall, Lake Superior nearer to the two tributary outfalls.

These goals address the following concerns expressed during the Community Engagement Process in the following manner:

Stormwater Practices

This Stormwater Management Plan identifies a number of improvements to existing stormwater management practices that will address issues related to water quality treatment including retrofitting existing practices and improving maintenance practices. In addition, the Plan includes a number of new stormwater management practices designed to provide additional storage and water quality treatment prior to discharging to Lake Superior.

Ineffective/Aging Infrastructure

The City will strive to incorporate stormwater management with capital improvements that address flood reduction. For example, as drainage areas are diverted from downtown to reduce flooding, it must be recognized that there will be loss of water quality treatment for this flow unless water quality treatment is built into the design of these diversions.

6.3. Natural Resources Health

In general, the health of natural resources near to or coincident with portions of the City's drainage infrastructure is an important consideration that can be overlooked if too much focus is placed on simply conveying stormwater to an outfall. Village Ditch in particular is one such feature that serves both as a major component of the drainage infrastructure and a stream corridor – although other similar, lesser conveyances across the City have similar attributes. While its drainage area is largely undeveloped, Village Ditch is showing signs of instability including bank stabilization and erosion issues which contribute sediment loads to Lake Superior.

GOAL 6: Reduce erosive flows, flooding and pollutant loads downstream of the Gunflint Trail by employing a natural channel design approach to harness the additional functions that the Village Ditch drainage system could provide including restoring adjacent wetland systems, re-connecting with the floodplain and restoring natural habitat.

GOAL 7: Address stormwater management needs in the Industrial Park by evaluating wetland impacts, considering on-lot treatment options as well as regional opportunities to mimic pre-development hydrology prior to discharge to the Village Ditch system.

This goal address the following concerns expressed during the Community Engagement Process in the following manner:

Wetland Management

This project would entail delineating wetlands associated with the Village Ditch system and restoring the functions of these wetlands.

6.4. Regulatory Controls and Design Standards

Construction stormwater pollution prevention is regulated under the National Pollution Discharge Elimination System (NPDES) and is enforced by the MPCA. "Any activity associated with road building, landscaping clearing, grading or excavation disturbing more than an acre or as part of a larger development or sale" requires a permit. Under this permit, a site must be designed to meet the Minimal Impact Design Standard.

In addition, discharges to Lake Superior must incorporate the Best Management Practices (BMPs) outlined in C.1, C.2, and C.3 of Appendix A as follows:

1. <u>During construction</u>:
   a. Stabilization of all exposed soil areas must be initiated immediately to limit soil erosion but in no case completed later than seven (7) days after the construction activity in that portion of the site has temporarily or permanently ceased.
   b. Temporary sediment basin requirements described in Part III.C. must be used for common drainage locations that serve an area with five (5) or more acres disturbed at one time.
2. <u>Post construction</u>:
   The water quality volume that must be retained on site by the project's permanent stormwater management system described in Part III.D. shall be one (1) inch of runoff from the new impervious surfaces created by the project.

3. Buffer zone:
   The Permittee(s) shall include an undisturbed buffer zone of not less than 100 linear feet from the special water (not including tributaries) and this buffer zone shall be maintained at all times, both during construction and as a permanent feature post construction, except where a water crossing or other encroachment is necessary to complete the project. The Permittee(s) must fully document the circumstance and reasons that the buffer encroachment is necessary in the SWPPP and include restoration activities. Replacement of existing impervious surface within the buffer is allowed under this permit. All potential water quality, scenic and other environmental impacts of these exceptions must be minimized by the use of additional or redundant BMPs and documented in the SWPPP for the project.

While these stormwater management and erosion and sediment control requirements provide enhanced protection for Minnesota's water resources, they may not meet the unique stormwater management needs of the City of Grand Marais. As this Stormwater Management Plan demonstrates, the City of Grand Marais is particularly sensitive to peak flow rates and volumes which need to be controlled to reduce downstream flooding.

GOAL 8: Develop policies and guidelines that address existing and future development including redevelopment. Consider the need to adopt smaller thresholds and/or the development of an overlay zone and performance standards specific to flood-related concerns in the downtown area.

GOAL 9: Develop an effective Stormwater Plan Review Process including development of draft ordinances, estimated plan review process, inspection and maintenance requirements and finally adoption of ordinances through a public process.

This goal address the following concerns expressed during the Community Engagement Process in the following manner:

Drainage Issues

The adoption of regulatory controls would ensure that new development and redevelopment activity would fit within the existing drainage system and would not cause adverse impacts to downstream properties and/or resources.

6.5. Operations and Maintenance

The City of Grand Marais regularly inspects stormwater infrastructure including outfalls, sediment basins and ponds annually. Repairs, replacements and maintenance are conducted as needed. Streets are swept at least twice in spring to remove excess sand and salt from plowing operations and at least twice in the fall after most of the leaves have fallen.

The need for operation and maintenance activities related to stormwater infrastructure throughout the City is likely higher than what is typical for a City of this size. This observation is in light of evidence that excessive sediment loading to pipes, structures, and existing BMPs may be derived from certain hotspots across the City, including primarily unpaved streets, street shoulders, and parking lots. With one eye on eventually addressing some of these issues through a combination of paving, vegetation, and pretreatment, the City may want to consider a more vigilant and targeted approach to keeping infrastructure in some portions of the system free of sediment and debris. This is particularly true in flat areas (i.e. downtown) where existing pipe gradients are likely not high enough to facilitate self-cleaning of sediment during any size storm event. Additionally, the clearing of snow and debris from catch basin inlets – particular upstream of downtown – is of particular importance, as it helps maintain full capacity of these structures, thus preventing bypass from causing or exacerbating flooding downstream.

GOAL 10: Maintain existing storm sewer management system including maintenance of ponds and pond outlet structures.

GOAL 11: Require maintenance agreements and development planning to ensure that stormwater management structures and facilities are maintained in perpetuity as originally designed.

GOAL 12: Eliminate sediment sources associated with gravel shoulders and alleys via conversion to a paved or porous paved surface.

6.6. Community Awareness and Involvement

The City of Grand Marais is a small community with a population of approximately 1,400 people. Promoting stormwater education and outreach not only teaches residents how to minimize the impact of development by mimicking natural hydrology but it serves to help them understand how susceptible the community is to flooding. The City of Grand Marais recognizes the role individual homeowners can play in stormwater management and seeks to promote environmental stewardship.

GOAL 13: Build local capacity for stormwater management by hosting public education and outreach events and allowing for public participation and involvement.

6.7. Monitoring and Data Assessment

While not identified during the community engagement process, the need for additional monitoring data was identified during the Plan development process. The model developed and used for this project has, in its current state, a relatively high degree of certainty in certain areas – particularly areas like downtown, where the hydraulics are well-defined (with some exceptions) and the hydrology is highly dependent on the parameterization of imperviousness in the drainage areas (which is also relatively well-defined). However, other areas of the model are highly uncertain, such as the drainage areas to the Creechville ponds and Village Ditch, and the campground drainages. This is primarily due to the fact that these watersheds are largely covered by steep, natural areas – the modeling of which requires quality calibration data in order to adequately simulate both base flow and storm flow. The resulting uncertainties are related to the parameters used for infiltration, time of concentration, and seepage in channels and ponds. While attempts have been made using professional judgement to assess these areas, it is not currently possible to provide a feasibility-level analysis related to such issues as:

- Crossing capacity along Village Ditch
- Channel capacity and bank stability along the lower part of Village Ditch
- Bank overtopping in the upper part of Village Ditch (at 4th & 5th Ave W)
- Redesign/optimization of the outlet structures in the Creechville Ponds
- Redesign/optimization of the outlet structure in the Highway 61 & 8th Ave pond

GOAL 14: Work with Cook County SWCD and state agencies to collect water quality data in the following locations:

- Village Ditch
- East Campground outfall
- Harbor

GOAL 15: Work with Cook County SWCD and state agencies to collect flow data in the following locations:

- Discharge in Village Ditch at 5th Ave W (or 4th Ave W)
- Discharge in Village Ditch at 7th Ave E (or an adjacent crossing)
- Water levels at both of the Creechville pond outlets
- Water levels at the Hwy 61 & 8th Ave W pond outlet
- Water levels in the Cook County Whole Foods CO-OP pond

GOAL 16: Refine H&H model and revise calibration upon completion of flow data collection.

7. CORRECTIVE ACTIONS AND IMPLEMENTATION PLAN

This Stormwater Management plan identifies the programmatic activities as well as the capital improvement projects the City of Grand Marais needs to take in the next 10 years to address the issues and concerns identified during the plan development process.

7.1. Flooding

A number of flood reduction scenarios were simulated using the newly-constructed hydrologic and hydraulic model. Individual flood reduction strategies were simulated separately, and then a set of combined implementation scenarios were simulated to assess progress toward meeting the flood reduction goal for downtown. The results of this analysis are provided in Table 7-1. Figure 7-2 and Figure 7-3 identify the potential locations of the improvement scenarios in the City.

As Table 7-1 demonstrates, the Combined Scenario which is highlighted in yellow (3rd St Inlet Bypasses Fixed, Diversions (A + B), 1 cfs pump + 1st St pipe upsizing and New BMPs)) achieves the goal for a 2-year, 24-hour design storm[10] (equivalent to 2.5 inches of rainfall being delivered in 24 hours) as illustrated in Figure 7-1. If all of the improvements in the Combined Scenario were implemented prior to such an event, there would have been ponded water above the drain tile inlet for a total of 15 hours with a maximum depth of 11.2 inches.

It is important to note that this is not the only combination of flood reduction strategies that could meet the flood reduction goal, but it is the most effective of the combinations analyzed here at reducing both the frequency and severity of flooding. It is the combination of upstream practices like LID and stormwater diversions (which are proactive and tend to help reduce the frequency of flooding for smaller events, but may not significantly reduce the severity of large flooding events) and downstream practices like pumping (which are retroactive and tend to help reduce the severity of flooding, but do relatively little to reduce flood frequency) that comprises an effective an comprehensive management strategy like the one outlined here.

Achieving this goal – the elimination of flooding for the 2-year, 24-hour design storm – significantly reduces the chances of flooding in any given year. Model results suggest, in fact, that flooding would be completely eliminated during the 2017 simulation period (which was relatively wet and during which flooding was exacerbated by very high lake levels). However, it should be noted that the combination of flood reduction solutions evaluated in the Combined Scenario does not eliminate flooding altogether. Still, when run for a 10-year 24-hour design storm (3.53 inches in 24 hours), the Combined Scenario results in a significant improvement over existing conditions, with the maximum ponded depth above the inlet reduced from 34 to 21 inches and the flood duration reduced from 98 to 21 hours. Similarly, when run for the 25-year design storm (*4.3 inches in 24-*

[10] In 2017, the largest rainfall event closely approximated a 2-year, 24-hour rainfall event in terms of depth and duration. However, the design storm is more conservative since its peak intensity is higher.

hours), the maximum ponded depth above the inlet is reduced from 39 to 25 inches and the flood duration is reduced from 135 to 32 hours.

Recommendations for implementation are shown in Table 7-2, including initiation of a city-wide rain barrel program as well as construction of 25,000 ft^2 of bioretention and two rainwater harvesting sites within the drainage area to downtown.

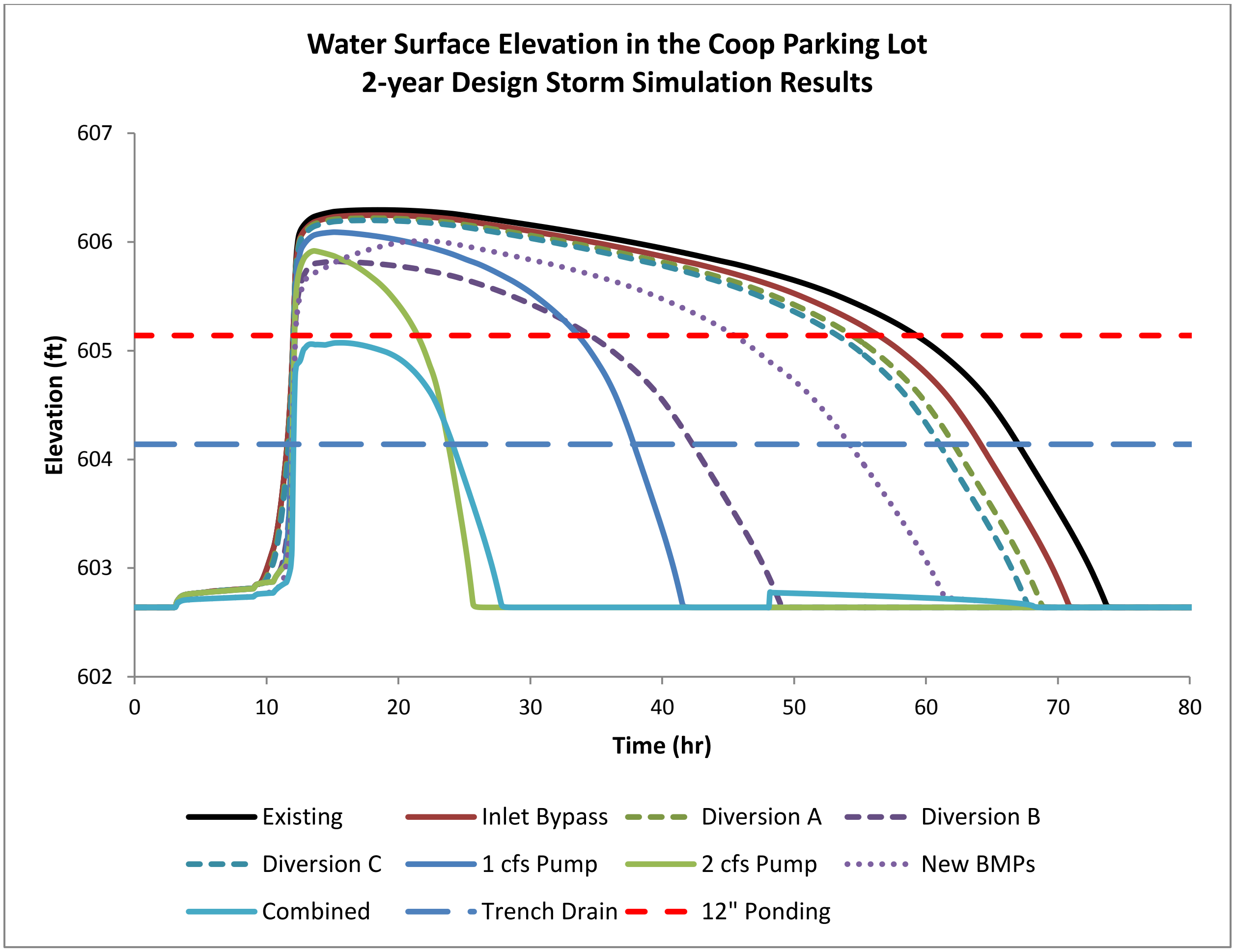


Figure 7-1. Ponding in the Cook County Whole Foods CO-OP parking lot for various model scenarios

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Date: 5/15/2018 Time: 12:16:19 PM Author: mtalbot

Figure 7-2: Locations of potential storm sewer diversions

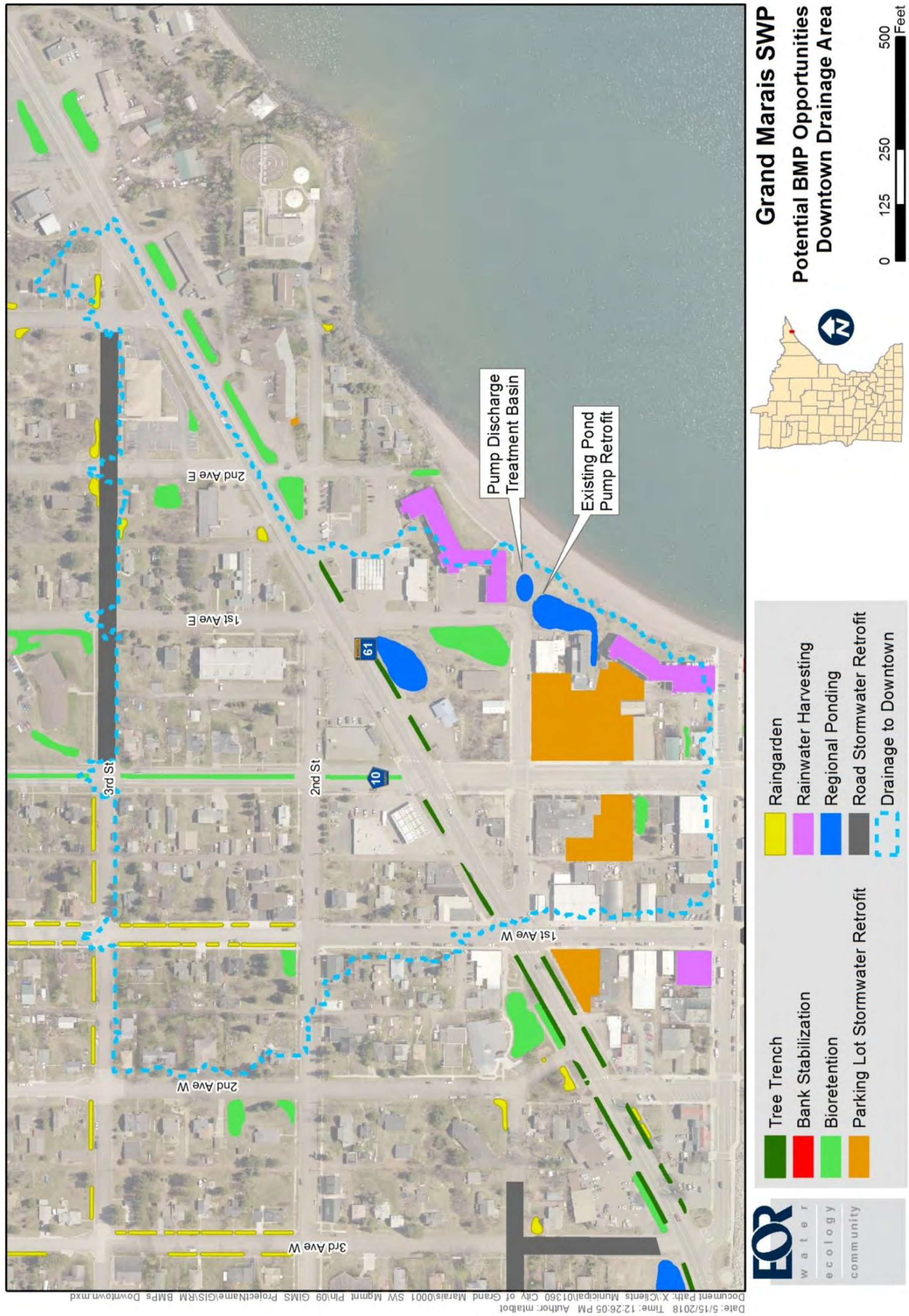

Figure 7-3: Locations of potential BMPs opportunities in the downtown drainage area

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Table 7-1: Downtown flooding scenarios for the 2-year, 24-hour design storm

Scenario	Ponded Depth Above Inlet [inches]	Change in Depth [inches]	Ponding Duration: Time Above Inlet [hours]	Flooding Duration: Time above 12 in. [hours]	Flood Duration Reduction: [hours]	Construction Cost Estimate* [$]	Cost per hr Flood Reduction [$/hour]	Pros (+) and Cons (-) beyond flood reduction
	A	B	C	D	E	F	G	
Existing Conditions	25.8	-	55	47	-	-	-	NA
3rd Street Inlet Bypasses Fixed *Intersection reconstruction from Broadway to 3rd Avenue E*	25.3	-0.5	53	44	3	$239,250	$82,500	+ Routes stormwater away from downtown + Provides **capacity** in downtown stormsewer – Runoff not treated before discharge to harbor
Diversion Option A *Disconnect catch basin at 1st Ave W and Highway 61*	25.5	-0.3	53	45	2	$8,700	$4,265	+ Routes storm water away from downtown + Provides **capacity** in downtown stormsewer – Runoff not treated before discharge to lake
Diversion Option B *Diversion along 2nd St from Broadway to cul-de-sac*	20.2	-5.1	30	25	22	$482,850	$22,948	+ Routes additional stormwater away from downtown + Provides **capacity** in downtown stormsewer – Runoff not treated before discharge to lake
Diversion Option C *Low-flow diversion from 2nd Ave E across Hwy 61*	25.0	-0.3	50	44	3	$75,000	$23,810	+ Routes additional stormwater away from downtown + Provides **capacity** in downtown stormsewer – Runoff not treated before discharge to lake
Coop Pond Pumping *0.5 cfs pump + upsize 1st St stormsewer*	24.3	-1.0	52	46	1	$537,388	$451,600	+ Allows City to manage system for storage capacity + Address conveyance capacity limitations caused by lake level – Permitting requirements – Pumped water filtered, but water quality performance likely reduced for larger rainfall events – Maintenance Requirements
Coop Pond Pumping *1.0 cfs pump + upsize 1st St stormsewer*	23.2	-2.1	26	24	23	$555,350	$23,670	
Coop Pond Pumping *1.5 cfs pump + upsize 1st St stormsewer*	21.5	-3.8	16	15	32	$571,268	$17,900	
Coop Pond Pumping *2.0 cfs pump + upsize 1st St stormsewer*	21.0	-4.3	12	12	35	$583,382	$16,400	
Coop Pond Pumping *1.0 cfs pump only*	23.4	-1.9	26	24	23	$152,250	$6,700	
Coop Pond Pumping *2.0 cfs pump only*	21.4	-3.9	12	12	35	$180,282	$5,100	
New BMPs • *Bioretention† (24,500 ft^2)* • *Raingardens (7,300 ft^2)* • *Rainwater Harvesting (2 sites)* • *Tree Trenches (1,000 linear ft)*	22.5	-2.8	42	36	11	$712,054	$64,149	+ Mimics natural hydrology (addresses rate and volume) + Improved water quality to the harbor + Habitat + Improved Aesthetics + Property Values – Maintenance Requirements
Combined Scenario: • *3rd St Inlet Bypasses Fixed* • *Diversions (A + B)* • *1 cfs pump + 1st St pipe upsizing* • *New BMPs*	11.2	-14.1	12	0	47	$1,998,204	$42,245	+ Compounded flood reduction benefit realized by addressing system as a whole + Meets preliminary goal discussed by Council for 2-yr, 24-hr event + All other pros from the incorporated scenarios – All other cons from the incorporated scenarios

**Does not include costs associated with permitting (if needed), operation and maintenance of these facilities.*

†Includes parking lot and road improvements.

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Water Quality

The Stormwater Management Plan identifies a number of Best Management Practices (BMPs) designed to address water quality issues – particularly in the harbor. These BMPs are located in two separate drainage areas to the harbor: direct drainage to the harbor and drainage through the municipal campground.

In the direct drainage to the harbor, a total of 58,000 ft^2 of potential bioretention[11], 9,700 ft^2 of potential raingardens, and two potential rainwater harvesting sites were identified. If all of these practices were implemented, it was estimated that more than 3,000 lbs of TSS could be kept out of the harbor each year. In the absence of a defined water quality goal, implementation recommendations were made assuming that roughly 30-40% of these sites could be feasibly constructed. While this may seem like an aggressive implementation goal, the bioretention projects would still only treat around 5% of the 105-acre drainage area.

In the campground drainage, a number of major sediment sources were identified including two unpaved roads with high grade and two critical areas of bank instability (shown in Figure 7-4). A potential detention location was identified upstream, which could help reduce peak flow rates through these areas of bank instability. Additionally, the existing stormwater pond at 8th Ave W and Highway 61 was identified as having high potential for design optimization through excavation and outlet reconfiguration. While it is difficult to estimate the current rate of TSS loading due to erosion and bank failures, it was estimated that at least 5,000 lbs of TSS could be kept out of the harbor each year through implementation of these projects.

Recommendations for implementation are shown in Table 7-2, which include initiation of a city-wide residential raingarden program, construction of 20,000 ft^2 of bioretention and 1,000 linear feet of tree trenches within the drainage area to the harbor, improvements to the 8th Ave pond, and bank stabilization at two locations.

7.2. Natural Resources Health

Natural resources across the city will benefit from many of the project and programmatic recommendations already discussed. Improving the health of Village Ditch, however, requires additional management in the watershed upstream of Gunflint Trail, which is still a developing area of the city. As shown in Figure 7-5, several BMP opportunities were identified in the drainage area to Village Ditch. The Creechville Stormwater Pond retrofits aim to help address channel instability in the ditch by detaining stormwater during large storm events, as well as reducing sediment loads to the channel. The Water Quality Wetlands aim: to help address channel instability through the creation channel-adjacent storage; to reduce overall discharge volumes by promoting retention through evaporation; and to create wildlife habitat and recreational opportunities.

[11] This includes the estimated bioretention footprint associated with the parking lot and road stormwater retrofit opportunities, as well as 1,000 linear feet of tree trenches along highway 61.

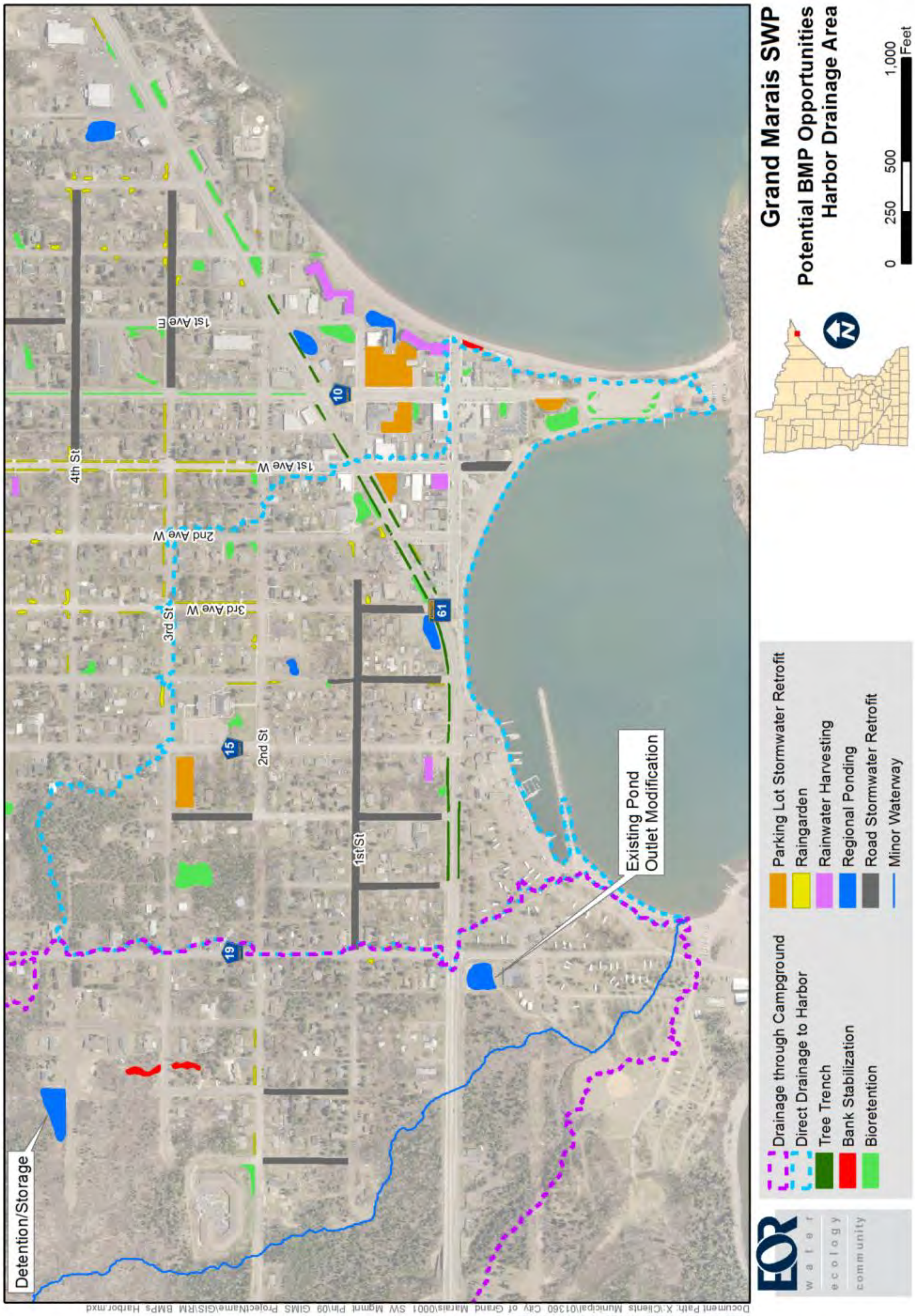

Figure 7-4: Locations of potential BMPs opportunities in the harbor drainage area

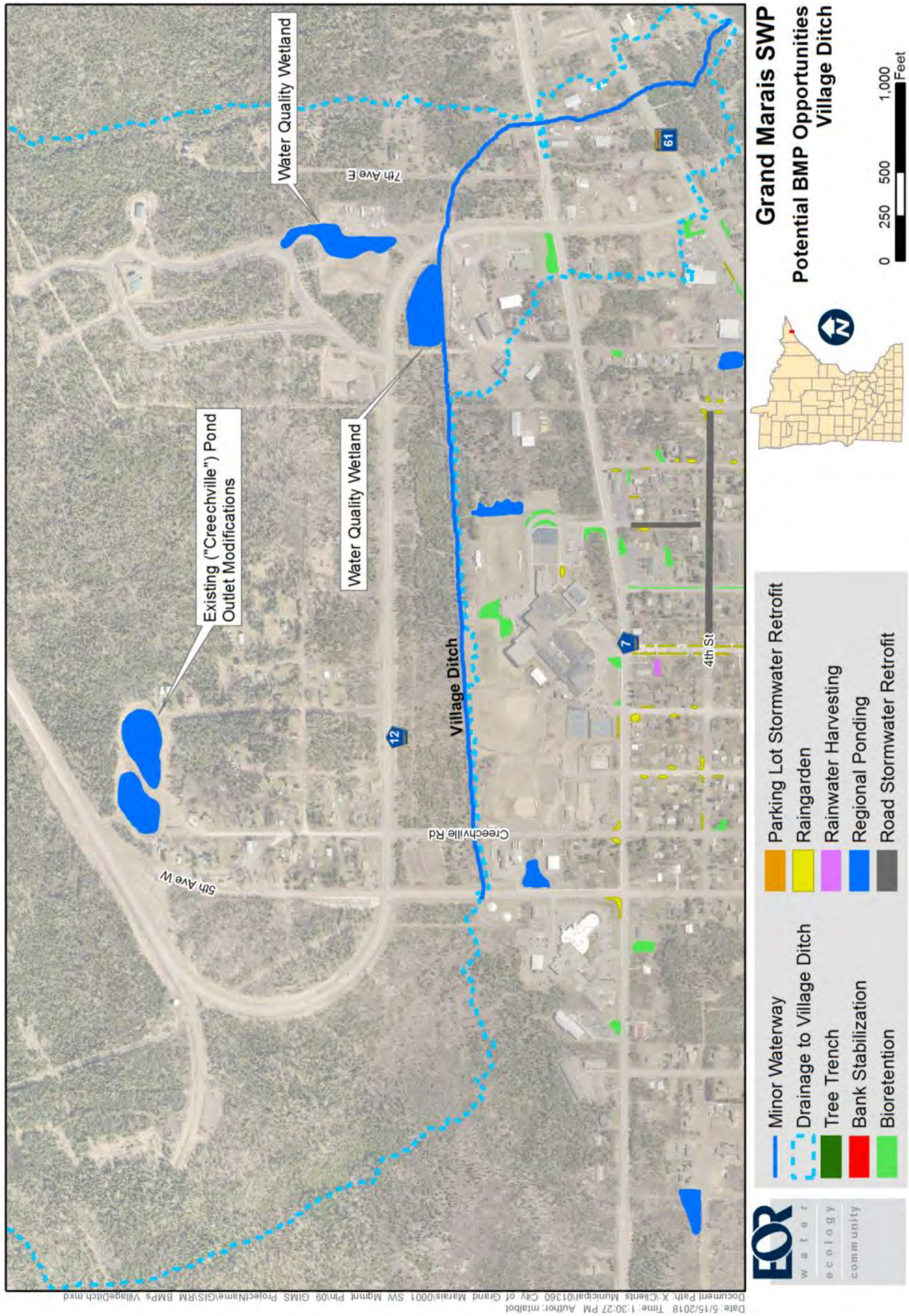

Figure 7-5: Locations of potential BMPs opportunities in the Village Ditch drainage area

7.3. Regulatory Controls and Design Standards

Develop policies and guidelines that address existing and future development including redevelopment. Consider the need to adopt smaller thresholds and/or the development of an overlay zone and performance standards specific to flood-related concerns in the downtown area. Develop an effective Stormwater Plan Review Process including development of draft ordinances, estimated plan review process, inspection and maintenance requirements and finally adoption of ordinances through a public process.

7.4. Operations and Maintenance

Maintain existing storm sewer management system including maintenance of ponds and pond outlet structures. Require maintenance agreements and development planning to ensure that stormwater management structures and facilities are maintained in perpetuity as originally designed. Eliminate sediment sources associated with gravel shoulders and alleys via conversion to a paved or porous paved surface.

7.5. Community Awareness and Involvement

Build local capacity for stormwater management by hosting public education and outreach events and allowing for public participation and involvement.

7.6. Monitoring and Data Assessment

Work with Cook County SWCD and state agencies to collect flow data in the following locations:

- Discharge in Village Ditch at 5th Ave W (or 4th Ave W)
- Discharge in Village Ditch at 7th Ave E (or an adjacent crossing)
- Water levels at both of the Creechville pond outlets
- Water levels at the Hwy 61 & 8th Ave W pond outlet
- Water levels in the Cook County Whole Foods CO-OP pond

Table 7-2: Implementation Plan

Implementation Activity	Schedule and Estimated Cost											Potential Funding Sources / Authority	Partners						Measurable Outcomes
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	10-Year Total		Non-Profit/ Community Groups / Volunteers	U of M Extension	Businesses/ Landowners	School District	Cook County / SWCD	State/Federal Agencies	
FLOODING																			
3rd Street Inlet Bypasses Fixed *Intersection reconstruction from Broadway to 3rd Avenue E*	--	--	--	--	$119,625	$119,625	--	--	--	--	$239,250								
Diversion Option A *Disconnect catch basin at 1st Ave W and Highway 61*	--	$8,700	--	--	--	--	--	--	--	--	$8,700							X	
Diversion Option B *Diversion along 2nd St from Broadway to cul-de-sac*	--	$482,850	--	--	--	--	--	--	--	--	$482,850							X	
Coop Pond Pumping *1.0 cfs pump + upsize 1st St stormsewer*	--	--	$400,000	$155,350	--	--	--	--	--	--	$555,350								
New BMPs in Downtown Drainage • *Bioretention† (25,000 ft^2)* • *Rainwater Harvesting (2 sites)*	--	--	--	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$700,000							X	
Rainbarrel Program - Obtain rainbarrels, advertise rainbarrel program, and create education and outreach materials to assist residents with the installation, operation and maintenance of their rainbarrels.	--	--	--	--	$17,500	$17,500	$17,500	--	--	--	$52,500						X	X	
Subtotal	*$0*	*$491,550*	*$400,000*	*$255,350*	*$237,125*	*$237,125*	*$117,500*	*$100,000*	*$100,000*	*$100,000*	*$2,038,650*								
WATER QUALITY																			
New BMPs in Harbor Drainage Area • *Bioretention† (20,000 ft^2)* • *Tree Trenches (1,000 linear ft)*		$200,000	--	--	--	$100,000	$100,000	$100,000	$100,000	$100,000	$700,000								
8th Avenue Pond Retrofit - Detailed investigation of the BMP including how it is connected to the existing infrastructure system - Design surveying - Proximity to underground utilities - Geotechnical evaluation - Development of concept plans and construction documents - Permitting - Stakeholder administration	--	--	--	--	--	--	$80,000	--	--	--	$80,000								Capture, retain and treat stormwater runoff to reduce pollutant loads to the harbor and Lake Superior.
3rd St & 10th Ave W Drainage Bank Stabilization			$20,000	$75,000							$95,000								
Bacteria Source Assessment	--	--	--	--	$20,000	--	--	--	--	--	$20,000						X	X	
Residential Raingarden Program	--	--	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$200,000								
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	10-Year Total								

Implementation Activity	Schedule and Estimated Cost 2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	10-Year Total	Potential Funding Sources / Authority	Partners: Non-Profit/ Community Groups / Volunteers	U of M Extension	Businesses/ Landowners	School District	Cook County / SWCD	State/Federal Agencies	Measurable Outcomes
Subtotal	$0	$200,000	$45,000	$100,000	$45,000	$125,000	$205,000	$125,000	$125,000	$125,000	$1,095,000								
NATURAL RESOURCES HEALTH																			
Village Ditch Enhancement - Geomorphic assessment - Feasibility - Natural channel design	--	$30,000	$30,000	--	--	--	--	$120,000	$120,000	$120,000	$420,000						X		
Creechville Pond Retrofit Feasibility							$30,000				$30,000								
Address Stormwater Management needs in Industrial Park				$175,000	$175,000						$350,000								
Subtotal	$0	$30,000	$30,000	$175,000	$175,000	$0	$30,000	$120,000	$120,000	$120,000	$800,000								
REGULATORY CONTROLS AND DESIGN STANDARDS																			
Develop Stormwater Management Ordinance for Development and Redevelopment	--	--	$25,000	--	--	--	--	--	--	--	$25,000								Adopted stormwater management a GreenStep City Best Practice
Develop Stormwater Ordinance Review Protocols and Applicant Guidance				$10,000							$10,000								
Stormwater Management Ordinance Implementation					$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$60,000								
Subtotal	$0	$0	$25,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$95,000								
OPERATIONS AND MAINTENANCE																			
Stormwater BMP Maintenance			$10,000	$10,000	$10,000	$10,000	$20,000	$20,000	$20,000	$20,000	$120,000								
Private Stormwater BMP Inspection	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$4,500								
Road and Alley Reconstruction to Eliminate Sediment Source						$100,000	$100,000	$100,000	$100,000	$100,000	$500,000								
Street Sweeping	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$25,000								
Reduce de-icing salt use to prevent surface water and groundwater pollution											$0								GreenStep City Best Practice
Subtotal	$3,000	$3,000	$13,000	$13,000	$13,000	$113,000	$123,000	$123,000	$123,000	$122,500	$649,500								
COMMUNITY AWARENESS AND INVOLVEMENT																			
Public Education and Outreach	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$5,000								
Use high-visibility public sites for retrofit projects and include educational signage and interpretation.			$2,500		$2,500		$2,500		$2,500		$10,000								GreenStep City Best Practice
Use retrofit demonstration sites for outdoor classrooms, educational events, and field trips.			$500	$500	$500	$500	$500	$500	$500	$500	$4,000								GreenStep City Best Practice
Use volunteer labor to help with retrofit project light construction, planting, mulching, and maintenance.				$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$7,000								GreenStep City Best Practice
Subtotal	$500	$500	$3,500	$2,000	$4,500	$2,000	$4,500	$2,000	$4,500	$2,000	$26,000								
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	10-Year Total								

Implementation Activity	Schedule and Estimated Cost											Potential Funding Sources / Authority	Partners						Measurable Outcomes
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	10-Year Total		Non-Profit/ Community Groups / Volunteers	U of M Extension	Businesses/ Landowners	School District	Cook County / SWCD	State/Federal Agencies	
MONITORING AND DATA ASSESSMENT																			
Water Quality Sampling • *Village Ditch* • *Grand Marais Tributary Outfall* • *Lake Superior nearer to the two tributary outfalls*		$25,000	$25,000								$50,000						X	X	
Flow Data Collection • *Discharge in Village Ditch at 5th Ave W (or 4th Ave W)* • *Discharge in Village Ditch at 7th Ave E (or an adjacent crossing)* • *Water levels at both of the Creechville pond outlets* • *Water levels at the Hwy 61 & 8th Ave W pond outlet* • *Water levels in the Cook County Whole Foods CO-OP pond*		$25,000	$25,000								$50,000						X	X	
H&H Model Calibration/Refinement			$15,000	$20,000							$35,000								
Subtotal	$0	$50,000	$65,000	$20,000	$0	$0	$0	$0	$0	$0	$135,000								
TOTALS:	**$3,500**	**$775,050**	**$581,500**	**$575,350**	**$484,625**	**$487,125**	**$490,000**	**$480,000**	**$482,500**	**$479,500**	**$4,839,150**								
	2018	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**10-Year Total**								