Sustainable Lake Management Plan

Gem Lake, Ramsey County, MN

VLAWMO
Vadnais Lake Area Water Management Organization

Prepared by Kristine Jenson, Program Manager
2015

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1. Acknowledgements

VLAWMO wishes to thank the following:

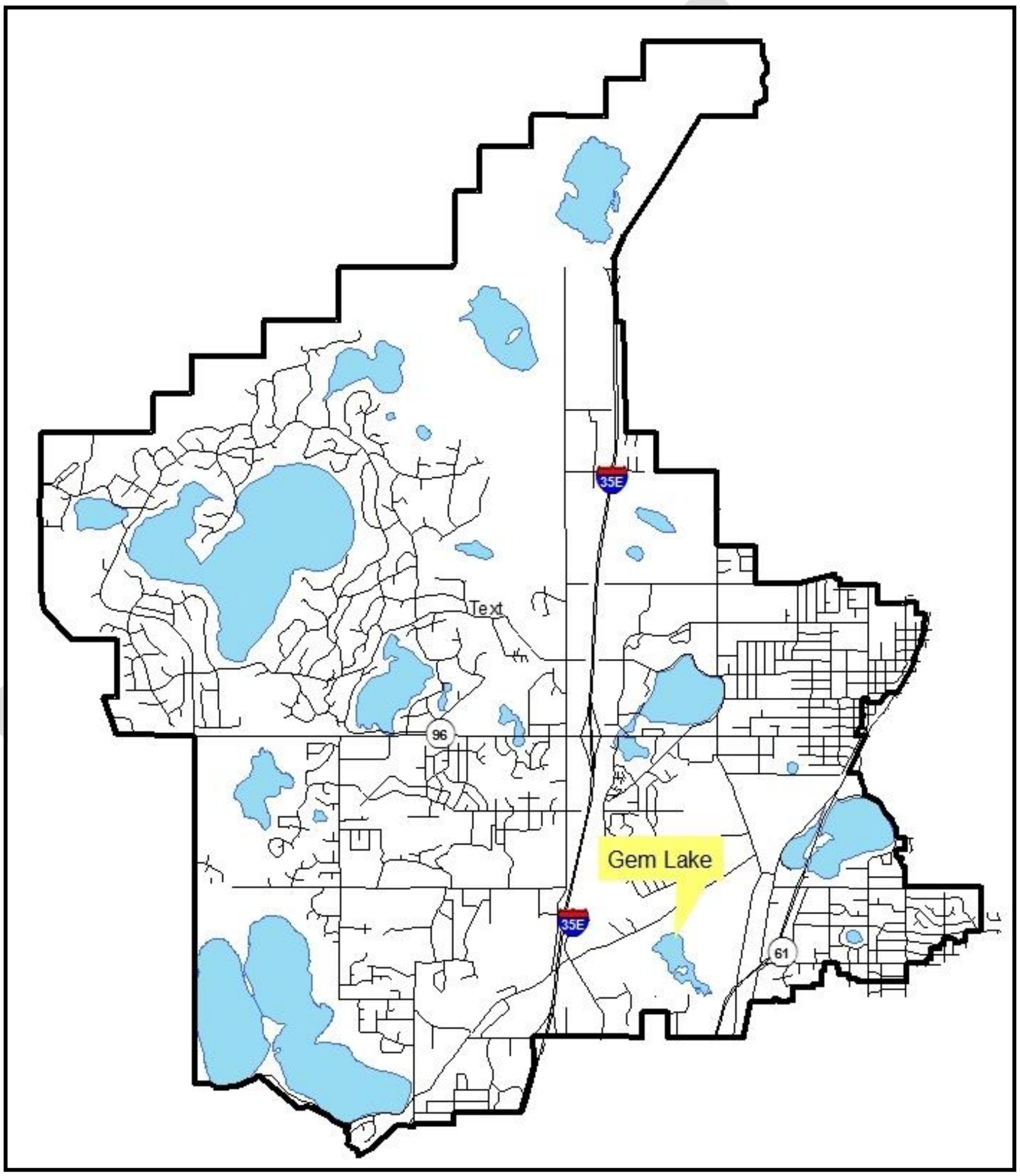
- The City of Gem Lake
- Gem Lake Homeowner's Association
- Gretchen Artig-Swomley for assisting with the VLAWMO Water Quality Monitoring Program for many years and for allowing VLAWMO staff access to calibrate a lake level gauge.
- V. Kathleen Robins for allowing VLAWMO staff to access her property to gather lake samples for the VLAWMO Water Quality Monitoring Program.

VLAWMO's mission is to protect and enhance the water resources within the watershed. Activities include water quality monitoring, wetland protection, and water quality improvement projects. The cornerstone of VLAWMO's success is our vital partnerships; without the help of all those listed above, we would not be able to fulfill our mission. We appreciate all of your work and assistance.

2. Introduction

Gem Lake is located in the City of Gem Lake, Ramsey County (Figure 1) and lies within the Vadnais Lake Area Water Management Organization (VLAWMO) watershed area. Gem Lake is a 22 acre shallow lake with a maximum depth of 16 feet and an average depth of 9 feet. The lake has no public access and is surrounded by private, residential development, mostly on large, wooded lots. The City of Gem Lake has ordinances in effect which prohibit the use of motorized watercraft on the lake as well as regulations regarding the clearing of vegetation along the shoreline.

Figure 1: Location Map



Gem Lake has a subwatershed size of 306 acres. A watershed is the land area that contributes runoff to a particular point along a waterway. Watersheds can be broken down into smaller geographic units called subwatersheds. Section 3.B of this report has more information about the subwatershed.

Gem Lake was listed on the State of Minnesota's 303(d) Impaired Waters List in 2010 due to high levels of nutrients (phosphorus) which inhibit aquatic recreation. Because of this designation, a Total Maximum Daily Load (TMDL) report has been written which investigates possible causes for the high levels of nutrients and how much of a reduction is needed in order to meet the State standards. The TMDL study concluded that Gem Lake must reduce the amount of TP reaching the lake by 24% in order to reach the water quality goals for the lake. Further information regarding nutrients in the lake and the TMDL findings are found in Section 4.F. Additionally, a Retrofit Study was done within the Gem Lake subwatershed to determine the locations for possible future water quality projects (called Best Management Practices or BMPs for short) that would provide a positive impact on Gem Lake. The Retrofit Study report is included as Appendix A to this document. A fish survey was conducted in 2011 and that report is included as Appendix B. This Sustainable Lake Management Plan (SLMP) will look at the overall conditions of the lake and subwatershed area and tie in the findings of previous reports and studies to serve as a tool towards future projects and programs to help protect and enhance the water quality of the lake.

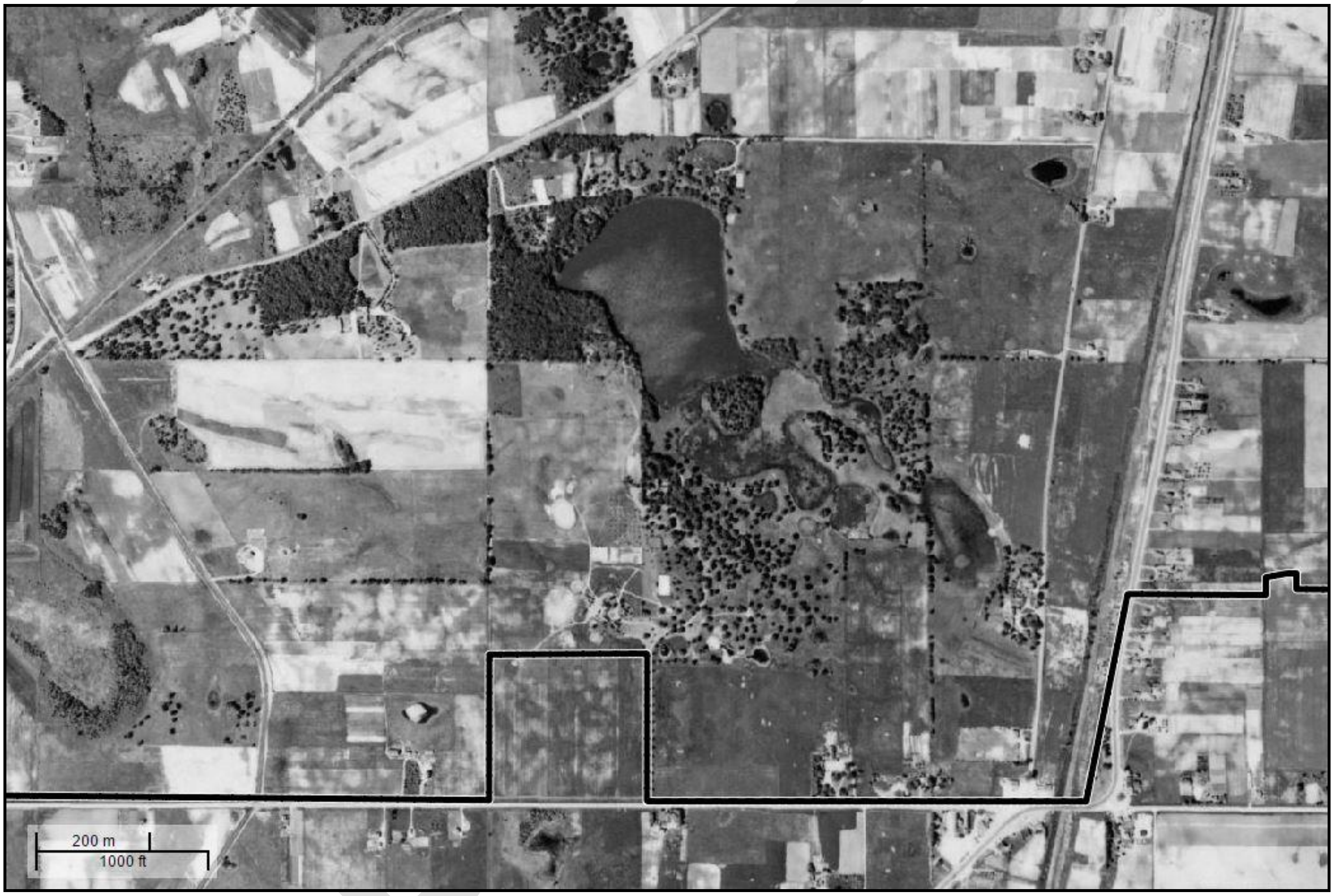
3. Watershed Features

A. History

The City of Gem Lake became incorporated in 1959. Prior to that it was considered part of the Town of White Bear. A detailed history is found in *Farms & Fox Hunts, A History of the City of Gem Lake, Minnesota, 2005*, written by James A. Lindner. According to this document, the land around Gem Lake was first settled by affluent families in the mid to late 1800's who were looking for a more secluded place to relax as opposed to building homes on White Bear Lake, which was more of a tourist attraction. Additionally, the document states that people settled there not necessarily for the lake but to have land for horses and to conduct fox hunts.

Aerial Photo History

Figure 2: 1940 Aerial photo of Gem Lake



In 1940, the area has a few homes near the lake and what agriculture use within the subwatershed. What is now known as Hoffman Road is on the eastern side of the photo with homes built off the east side of the road. The railroad that runs parallel to Hoffman Road is also present.

Figure 3: 1953 Aerial photo of Gem Lake

In 1953, a few more homes are cropping up in the subwatershed area. Highway 61 has been built and some development is occurring on the eastern side of the intersection of what is currently called County Road E and Highway 61.

Figure 4: 1974 Aerial photo of Gem Lake

By 1974, commercial development is occurring at the intersection of Highway 61 and County Road E, along with more residential development along Scheuneman Road. Along the western edge of this photo, you can see that what is now known as Interstate 35E has been built.

Figure 5: 1985 Aerial photo of Gem Lake

In 1985, more development has occurred in the area, especially between Scheuneman Road and the railroad tracks. Additionally, the residential developments around Daniels Farm Road and Big Fox Road are starting to show up.

Figure 6: 2006 Aerial photo of Gem Lake

By 2006, the Hillary Farm residential area begun construction and the Gem Lake Golf Club has been developed.

Figure 7: 2012 Aerial photo of Gem Lake

By 2012, there are more homes in the Hillary Farm area. More homes are planned for the Hillary Farm development.

B. Gem Lake Subwatershed Area

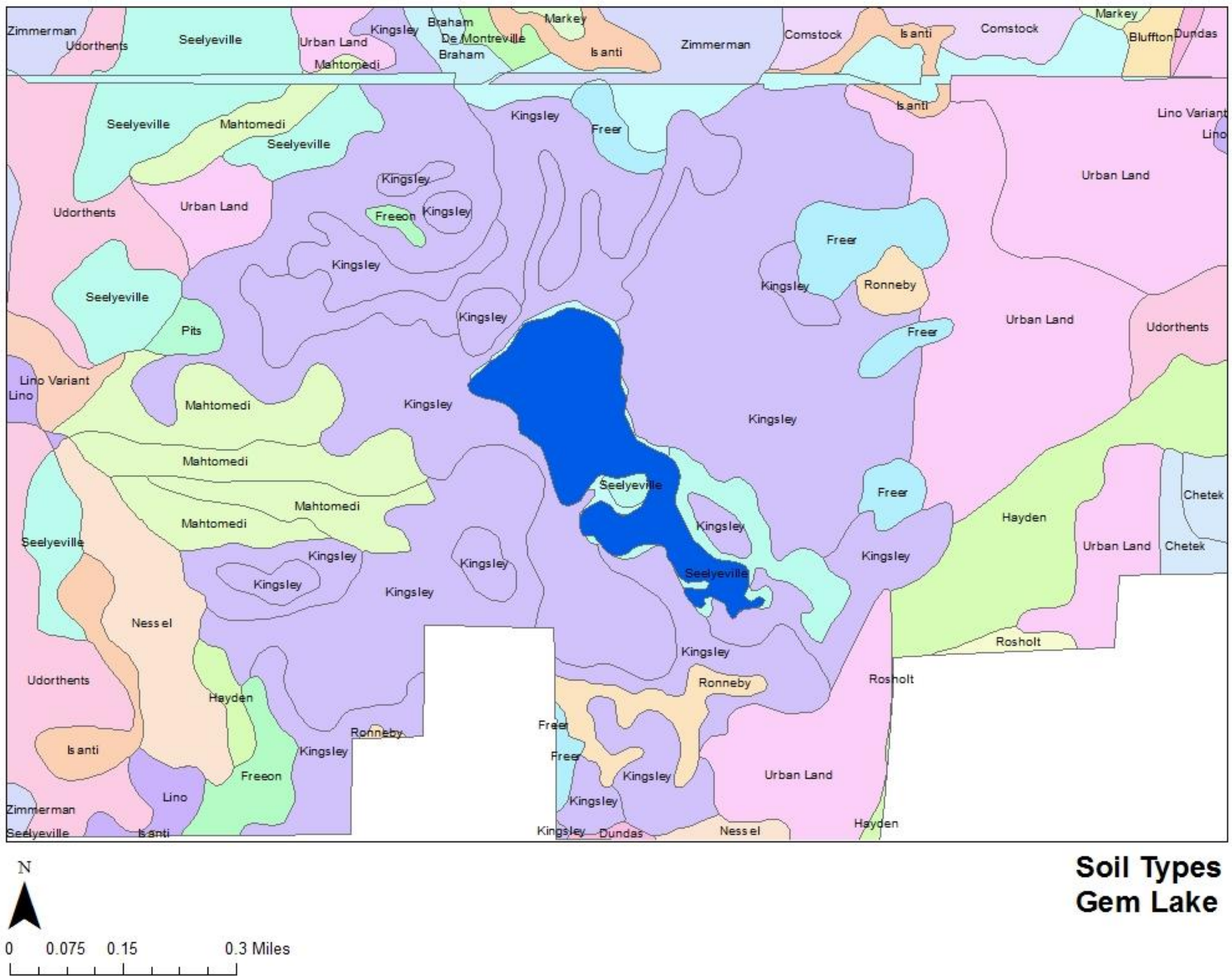
Gem receives water from various sources. The subwatershed is shown in the green area of the map below and is 306 acres in size. The subwatershed area is about 15 times larger than the surface area of the lake. This is relatively small for a subwatershed. A positive aspect of a small subwatershed area is that there is not a lot of land contributing to stormwater runoff into the lake. The land use within the subwatershed is primarily undeveloped or residential. A large source of possible stormwater runoff comes from Highway 61. Gem Lake is slightly unusual in that water doesn't flow out of the subwatershed area. Gem Lake is the end point of stormwater runoff for this area and doesn't outflow into another part of the watershed. That means all stormwater runoff must be filtered and infiltrated within the subwatershed rather than moving on to another waterbody.

Figure 8: Gem Lake Subwatershed

C. **Soils**

The soil directly under and near Gem Lake is Seelyeville which is an organic muck. The soils near the lake are mainly Kingsley and Mahtomedi which tend to be soils that drain easily and are well suited for agriculture and homesites. Mahtomedi soils are found in forest areas as well.

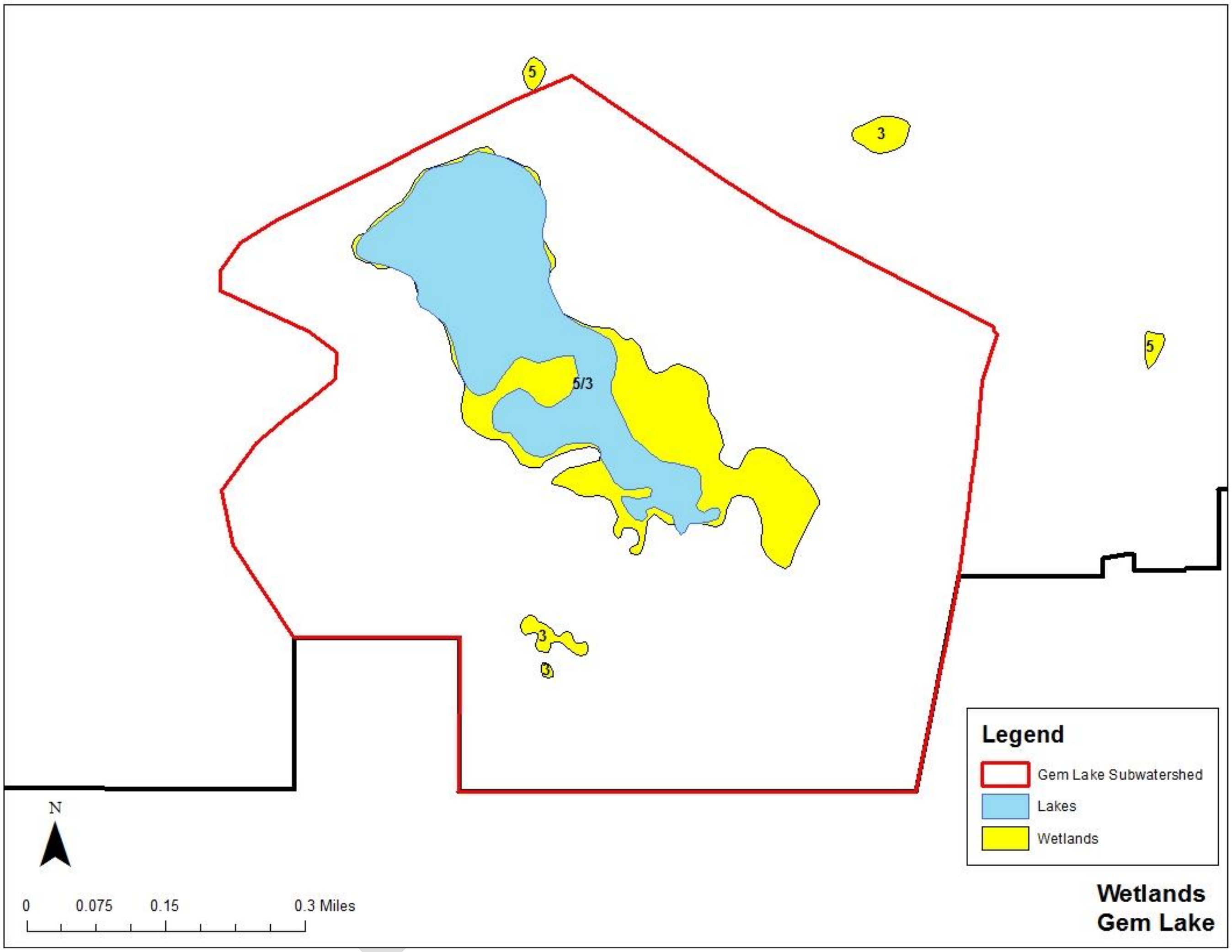
Figure 9: Soils around Gem Lake



D. Wetlands

Gem Lake and the marsh surrounding it is classified as a Type 5/3 according to the Wetland US Fish & Wildlife Circular 39 classification system. Additionally, there are 2 small Type 3 wetlands south of Gem Lake. A Type 3 wetland is described as a shallow marsh. The soil is usually waterlogged in the spring and often covered with more than 6 inches of water. A Type 5 wetland is an open water wetland which included shallow ponds. Water is usually less than 6 feet deep and typically surrounded with vegetation. Both types of wetlands provide habitat for fish, birds, and other wildlife, retain floodwater, and protect water quality.

Figure 10: Wetlands around Gem Lake



4. Lake Features

A. Shoreline Inventory

The land surrounding Gem Lake is low density residential. Homes are situated on large lots and there is a rule protecting the clearing of vegetation around the shoreline. There are no obvious signs of shoreline erosion.

B. Lake Depth

Gem Lake drops in depth rather quickly off the shoreline. VLAWMO's survey found the deepest point was 16 feet.

Figure 11: Gem Lake Depth

C. Fish Survey

Blue Water Science was hired to conduct a fish survey in September 2011. The report is attached as Appendix C. The survey found that the lake had a healthy supply of black crappies. The report concluded that Gem Lake is susceptible to winter fish kills and that if the lake were to experience another fish kill, the crappies would be eliminated and minnows would be the dominant species. Since Gem Lake is land locked, there is no opportunity for fish to migrate naturally. The report also stated that it is not recommended that fish be stocked unless a winter aeration system is installed since the fish would all be lost with a winter kill. Installation of an aeration system was discouraged because the lake is in a natural setting and letting nature take its course is a good management strategy for a lake like Gem which is more conducive to wildlife rather than a recreational fishery.

Crappies from Gem Lake, September 2011

D. Aquatic Vegetation

VLAWMO staff conducted an aquatic vegetation survey on June 30, 2010. Due to Gem's depth, plant life was only found around the perimeter of the lake. Once water depth goes past 4 feet, it gets harder for sunlight to reach down far enough to support plant life. Gem Lake does not have a diverse plant community within its waters. The 3 most abundant plant species found were Clasping-leaf Pondweed, Pickeral Weed, and White Water Lily. However, no invasive plant species were found in the lake which is a positive thing. Results of the survey are located in Table 1.

Figure 12: Aquatic Vegetation Survey Points

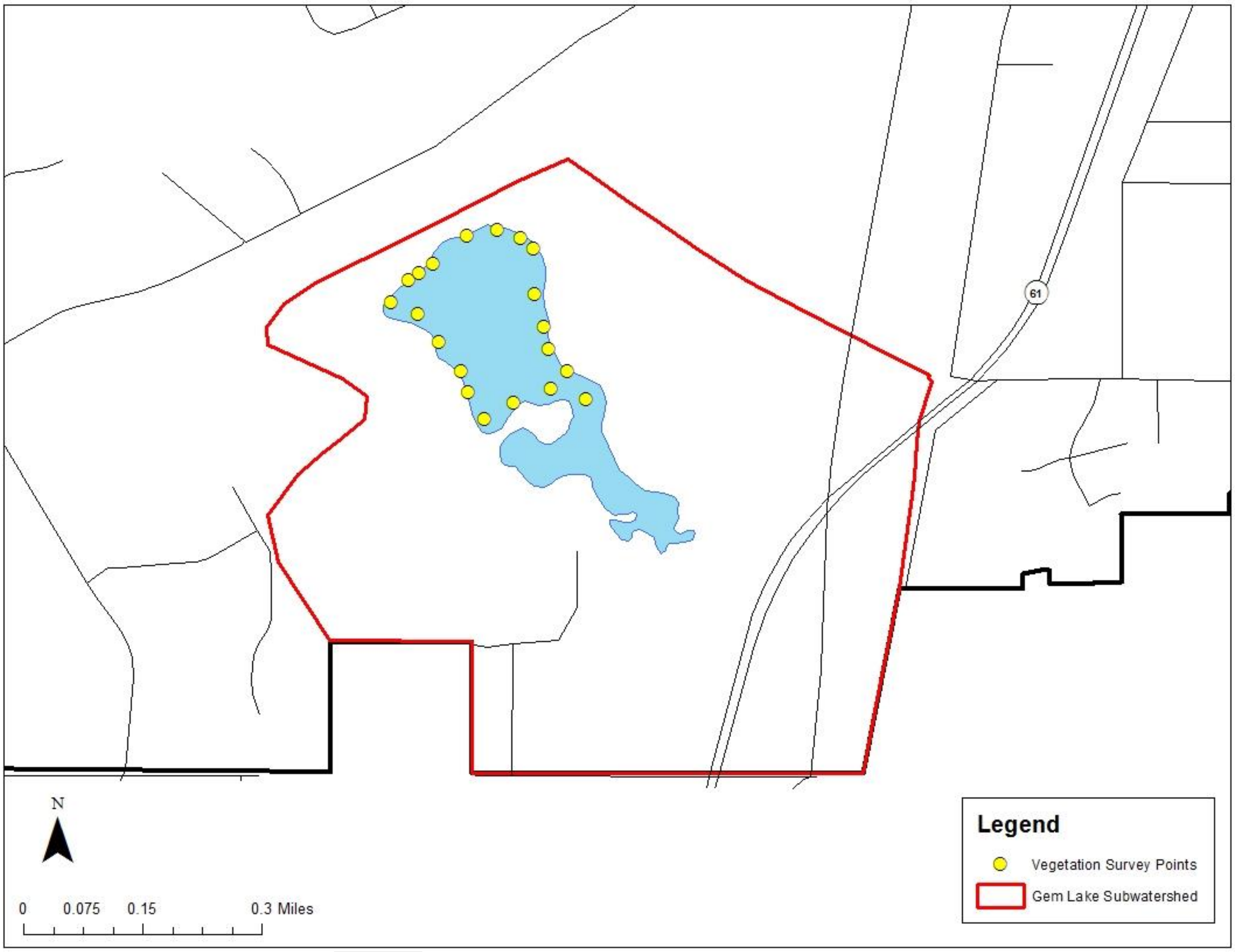


Table 1: Aquatic Vegetation Survey Results

Gem Lake Aquatic Plant Survey 6/30/2010							
GPS Points	Prevalence on a Scale of (1-5)						
	Bushy Pondweeds and Naiads (Najas spp.)	Large-leaf Pondweed	Clasping-leaf Pondweed	Coontail	Pickerel weed	Yellow Water Lily (Nuphar variegatum)	White Water Lily (Nymphaea odorata)
106	1	0	0	0	4	0	2
107	0	0	0	0	4	0	2
108	0	1	0	1	3	0	2
109	0	0	3	0	0	0	0
110	0	0	0	0	0	0	0
111	0	0	0	0	1	0	1
112	0	3	2	1	0	0	3
113	0	3	3	0	0	0	1
114	0	0	0	0	0	0	0
115	0	2	2	0	0	0	0
116	0	0	0	0	0	0	0
117	0	0	0	0	2	5	0
118	0	0	4	0	0	0	5
119	0	0	3	0	0	0	5
120	0	0	2	1	5	3	0
121	1	0	2	3	0	0	0
122	2	2	1	2	0	0	0
123	0	0	1	0	0	0	2
124	0	0	0	0	0	0	0
125	0	0	0	1	0	0	0
TOTALS	**4**	**11**	**23**	**9**	**19**	**8**	**23**

E. Water Quality Summary

Water quality data has been collected on Gem since 1997. Samples from the lake are collected every two weeks from May through September and tested for Total Phosphorus (TP) and Chlorophyll A (Chl A) and a Secchi Depth Transparency (SDT) measurement is taken. Phosphorus is the primary cause of excessive plant and algae growth in lake systems. Phosphorus originates from a variety of sources, many of which are human related. Major sources include human and animal wastes, soil erosion, detergents, septic systems and stormwater runoff. There can also be internal loading of phosphorus in a lake from the sediment. Chl A is a green pigment in algae. Measuring Chl A concentration gives an indication of how abundant algae are in a waterbody. The State of Minnesota has established water quality standards which state that a shallow lake should have TP levels at 60ug/L or below, Chl A levels at 20 ug/L or below and a SDT of 1 meter or greater. When monitoring data shows that a lake is not meeting these standards, they are placed on the Impaired Waters List and a TMDL study is done to determine sources of pollution and set goals for reductions.

As stated earlier in this report, Gem Lake was listed as an Impaired Water by the State of Minnesota due to the high levels of TP and Chl A. Table 2 shows the historical averages of these two water quality indicators. Those numbers in red denote when the data was over the State limits. In the last 4 monitoring seasons, the lake has actually been below the maximum levels. This may be linked to the reconstruction of Highway 61 in 2011 which included improvements to swales along the highway. Those swales filter the pollution in stormwater runoff from the highway and reduce the amount reaching the lake. This data is indicative that the lake may be on the right path towards health.

Table 2: Gem Lake Water Quality Annual Averages

Gem Lake Historical Avg TP/Chl A/SDT			
Year	**TP (ug/L)**	**Chl A (mg/m3)**	**Secchi (m)**
1997	54	23	1.2
1998	33	24	
1999	26	16	1.2
2000	36	17	1.1
2001	56	12	1.8
2002	39	25	1.3
2003	52	20	1.4
2004	49	0	1.5
2005	43	26	0
2006	63	25	0
2007	48	33	1.1
2008	64	17	1.5
2009	89	28	1.3
2010	53	24	1.4
2011	32	6.4	2.1
2012	41	11	2
2013	35	17	2
2014	31	8	2.9

Another water quality indicator VLAWMO monitors is the level of Chloride in the lake. In the spring, just as ice out occurs, a sample is collected. Table 3 shows results from 2010-2014. Since salt is heavily used on roads to clear them of ice and snow, monitoring chloride is important. The State of Minnesota is still working on developing what the limit should be for a lake but given all the discussions that have taken place to date, none of VLAWMO's lakes are in danger of being listed as impaired for chloride levels.

Table 3: Gem Lake Chloride Results

Gem Lake Chloride Results (mg/L)	
2010	35
2011	40
2012	44
2013	45
2014	40

Another measurement of a lake's health is the Tropic State Index. This is used by State and Federal agencies to track overall health. The data gathered from monitoring (TP, Chl A, and SDT) is put into an equation and the results correspond to a characteristics for the lake. Based on 2014 data, Gem Lake falls within the Mesotrophic – Eutrophic lake descriptions. Mesotrophic lakes have moderately clear water but may undergo anoxic (low oxygen) levels in the summer. Eutrophic lakes commonly have low oxygen levels and will often have algae blooms in the summer. Gem Lake is trending to the healthier Mesotrophic classification and will hopefully continue to show clearer water with low TP and Chl A levels.

F. Total Maximum Daily Load (TMDL) Study

Gem Lake was listed on the Minnesota Impaired Waters List in 2010 due to high levels of nutrients (TP). A TMDL report, in its simplest terms, provides us with a goal number to reach for reducing the amount of TP entering the lake. For Gem Lake, the goal set was a 24% reduction and it determined that the reduction would need to come, primarily in the subwatershed area because that is where the sources of TP were coming from, rather than from internal loading in the lake. The good news for Gem Lake is that since 2010, the TP levels for the lake have been below 60ug/L which means it is already meeting the TMDL goals and may be delisted from the Impaired Waters list in the near future. The TMDL report is not included as an appendix due to its large size. However, this report can be found on the VLAWMO website if the reader would like more information.

5. Lake Management Plan for Gem Lake

There are numerous studies and reports done for the Gem Lake Subwatershed which provide recommended projects and programs to protect the health of the lake.

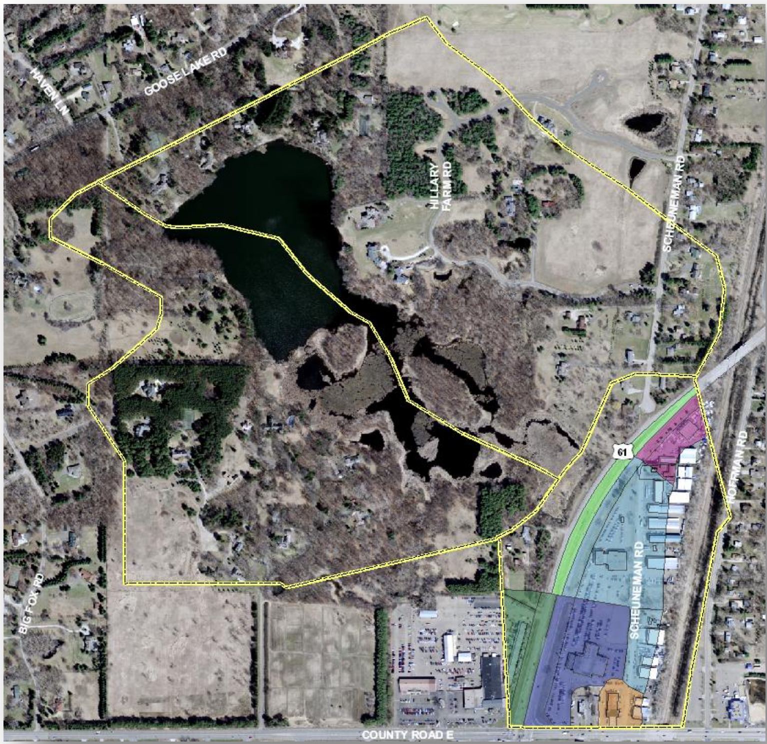
Table 4: Action List for Gem Lake

Action Item	Description	Leader	**Cost Estimate** **$ = <$1,000** **$$ = $1,000-$2,500** **$$$ = $2,500-$5,000** **$$$$ = $5,000-$25,000** **$$$$$ = $25,000-$100,000** **$$$$$$ = >$100,000**
Continued Lake Monitoring	Continue current monitoring program of twice monthly lake sampling to measure nutrient levels, dissolved oxygen and temperature levels.	VLAWMO	$
Enhanced Monitoring	Collect storm samples within the Gem Lake Subwatershed to determine areas of concern.	VLAWMO & Ramsey Co	$$
Swale Feasibility and Installation	Install and/or enhance swales along Highway 61.	VLAWMO, City of Gem Lake, MNDOT	$$$$-$$$$$
Water Quality Improvement Projects	Install water quality improvement projects within the subwatershed.	VLAWMO, City of Gem Lake, MNDOT, Property Owners	$$$-$$$$$

Partnership is vital to achieving our goals in this watershed. VLAWMO will continue to work with the City of Gem Lake, Ramsey County and State agencies to move forward with the action items listed in this SLMP with the goal of protecting and enhancing Gem Lake's water quality.

APPENDIX A – GEM LAKE STORMWATER RETROFIT ASSESSMENT (2012)

Gem Lake Stormwater Retrofit Assessment



Prepared by:

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This report details a subwatershed stormwater retrofit assessment resulting in recommended catchments for placement of Best Management Practice (BMP) retrofits. This document should be considered as *one part* of an overall watershed restoration plan including educational outreach, stream repair, riparian zone management, discharge prevention, upland native plant community restoration, and pollutant source control. The methods and analysis behind this document attempt to provide a sufficient level of detail to rapidly assess sub-watersheds of variable scales and land-uses to identify optimal locations for stormwater treatment. The time commitment required for this methodology was appropriate for *initial assessment* application. This report is a vital part of overall subwatershed restoration and should be considered in light of forecasting riparian and upland habitat restoration, pollutant hot-spot treatment, good housekeeping outreach and education, and others, within existing or future watershed restoration planning.

The assessment's information is discussed followed by a summary of the assessment's results; the methods used and catchment profile sheets of selected sites for retrofit consideration. Lastly, the retrofit ranking criteria and results are discussed and source references are provided.

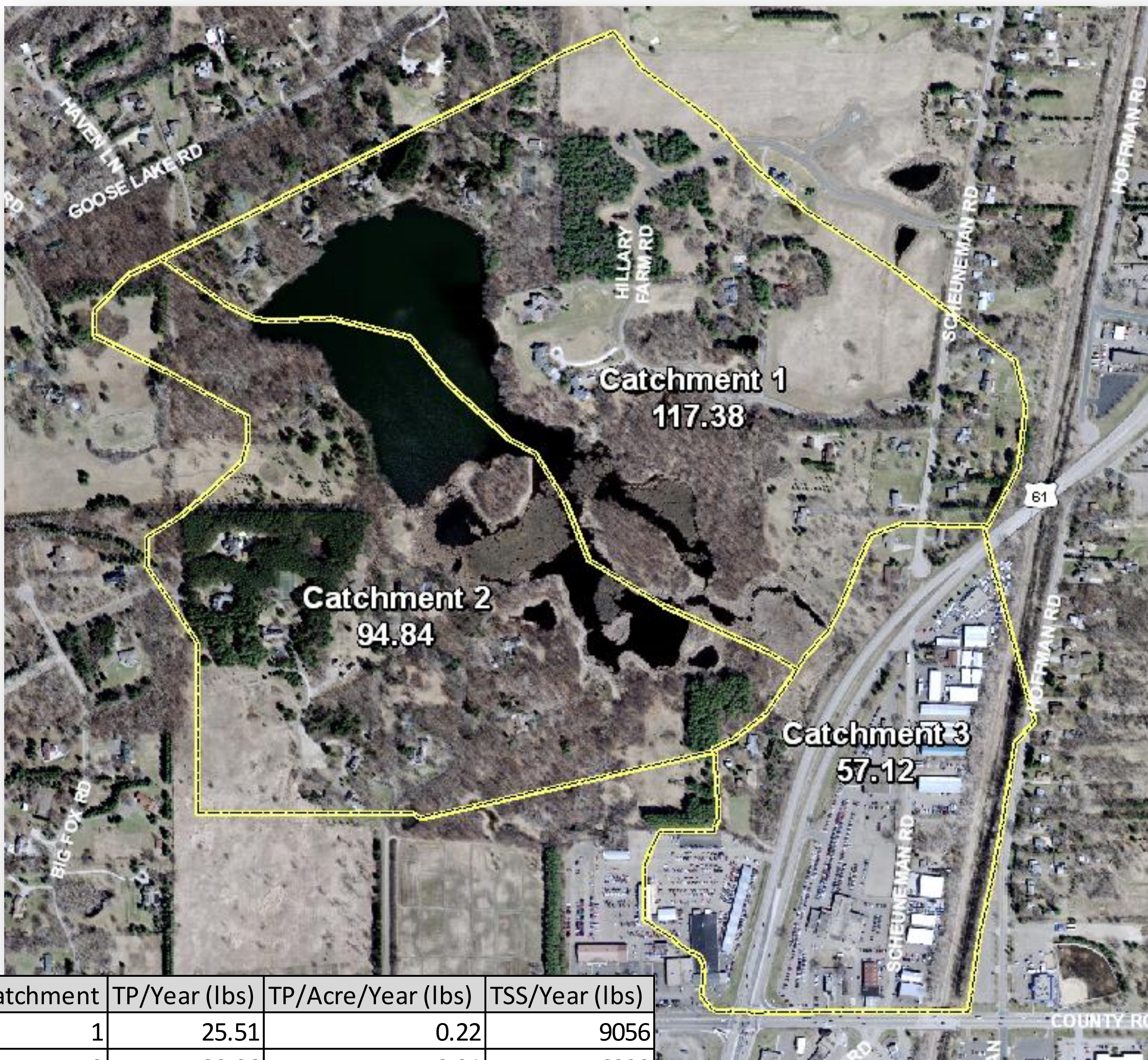
Results of this assessment are based on the development of catchment-specific *conceptual* stormwater treatment best management practices that either supplement existing stormwater infrastructure or provide quality and volume treatment where none currently exists. Relative comparisons are then made between catchments to determine where best to initialize final retrofit design efforts. Final, site-specific design sets (driven by existing limitations of the landscape and its effect on design element selections) will need to be developed to determine a more refined estimate of the reported pollutant removal amounts reported here-in. This typically occurs after the procurement of committed partnerships relative to each specific target parcel slated for the placement of BMPs.

Contents

Executive Summary

The Gem Lake subwatershed was broken into three catchments which were analyzed for annual pollutant loading of total phosphorous (TP) and total suspended solids (TSS). These catchment boundaries were defined by their drainage systems into Gem Lake. The boundaries and their associated annual loads can be seen in Figure 1.

Figure 1. Gem Lake Subwatershed and associated pollutant loads



Catchment	TP/Year (lbs)	TP/Acre/Year (lbs)	TSS/Year (lbs)
1	25.51	0.22	9056
2	20.06	0.21	6920
3	37.75	0.66	28563

Figure 2. comparison of all subcatchments within catchment 3.

Catchment	Loading	TP	TSS	TP Removal	% TP Removal
3-1	Entire system	1.749	1782		
	Current BMP	0.2204	262.4	1.5286	87%
3-2	Entire system	1.5798	1317		
	Current BMP	0.5884	508.7	1.0144	64%
3-3	Entire system	9.173	7121		
	Current BMP	5.152	4120	4.021	44%
3-5	Entire system	5.601	4785		
	Current BMP	3.217	2866	2.384	43%
3-6	Entire system	7.526	5303		
	Current BMP	4.395	3155	3.131	42%

Catchments 1 and 2 share similar land use types consisting of low density residential residence and large open spaces. These two catchments contribute comparatively low TP and TSS levels into Gem Lake and have little opportunity for retrofit BMP's, and therefore were not considered for further analysis within this report. Catchment 3 consists of a mix of commercial land use which is drained via turf grass swales into Gem Lake. In comparison to the other two Catchments, Catchment 3 contributes a large amount of TP and TSS to Gem Lake. Due to the high pollutant load runoff from Catchment 3 it was determined that this area be evaluated further. Therefore, Catchment 3 was broken down in to 9 smaller catchments that were assessed further to determine their individual pollutant loads. Six of the 9 smaller catchments were found to have direct source runoff into Gem Lake (see Appendix A). These catchments were modeled further to determine base loads and loads from current stormwater treatment features, which are turf grass swales within all six catchments. Catchment 3-4 was disregarded because of its little runoff contribution and limited retrofit opportunity. The remaining catchments base loads and current feature pollutant loads can be seen in Figure 2. The threshold to assess for further implementation of retrofit BMP's was set at 50%, so any catchments with current stormwater features that reduced TP 50% or more were not modeled for additional BMP's. As seen in Figure 2, the current grass swales in 3-1 and 3-2 are currently treating 50% or more of the TP load from the impervious areas within the catchment, so these catchments were not modeled for additional BMP's. Below documents the study background, methods, and ranking of the BMP options within catchments 3-3, 3-5 and 3-6.

About this Document

Document Overview

This Subwatershed Stormwater Retrofit Assessment is a watershed management tool to help prioritize stormwater retrofit projects by performance and cost effectiveness. This process helps maximize the value of each dollar spent.

This document is organized into four major sections that describe the general methods used, individual catchment profiles, a resulting retrofit ranking for the subwatershed and references used in this assessment protocol.

Methods

The methods section outlines general procedures used when assessing the subwatershed. It overviews the processes of retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis and project ranking. Project-specific details of each process are defined if different from the general, standard procedures.

Retrofit Profiles

When applicable, each retrofit profile is labeled with a unique ID to coincide with the subwatershed name (e.g., 3-3 for Gem Lake Catchment 3-3). This ID is referenced when comparing projects across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

Within the catchment profiles is a table that summarizes basic catchment information including estimated annual pollutant load (and other pollutants and volumes as specified by the LGU). A brief description of the land cover, stormwater infrastructure and any other important general information is also described here.

Retrofit Recommendation

The recommendation section describes the conceptual BMP retrofit(s) selected for the catchment area and provides a description of why the specific retrofit(s) was chosen.

Cost/Treatment Analysis

A summary table provides for the direct comparison of the expected amount of treatment, within a catchment, that can be expected per invested dollar. In addition, the results of each catchment can be cross-referenced to optimize available capitol budgets vs. load reduction goals.

Site Selection

A rendered aerial photograph highlights properties/areas suitable for retrofit projects. Additional field inspections will be required to verify project feasibility, but the most ideal locations for retrofits are identified here.

Retrofit Ranking

Retrofit ranking takes into account all of the information gathered during the assessment process to create a prioritized project list. The list is sorted by cost per pound of phosphorus treated for each project for the duration of one maintenance term (conservative estimate of BMP effective life). The final cost per pound treatment value includes installation and maintenance costs. There are many possible ways to prioritize projects, and the list provided is merely a starting point. Final project ranking for installation may include:

- Non-target pollutant reductions
- Project visibility
- Availability of funding
- Total project costs
- Educational value
- Others

References

This section identifies various sources of information synthesized to produce the assessment protocol utilized in this analysis.

Methods

Subwatershed Assessment Methods

The process used for this assessment is outlined below and was modified from the Center for Watershed Protection's *Urban Stormwater Retrofit Practices,* Manuals 2 and 3 (Schueler, 2005, 2007). Locally relevant design considerations were also included into the process (*Minnesota Stormwater Manual*).

Step 1: Retrofit Scoping

Retrofit scoping included determining the objectives of the retrofits (volume reduction, target pollutant etc) and the level of treatment desired. This step helped to define preferred retrofit treatment options and retrofit performance criteria.

Step 2: Desktop Retrofit Analysis

The desktop analysis involved computer-based scanning of the subwatershed for potential retrofit catchments and/or specific sites. This step also identified areas that didn't need to be assessed because of existing stormwater infrastructure. Accurate GIS data was extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers included: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography and the storm drainage infrastructure (with invert elevations).

Step 3: Retrofit Reconnaissance Investigation

After identifying potential retrofit sites through this desktop search, a field investigation was conducted to evaluate each site. During the investigation, the drainage area and stormwater infrastructure mapping data were verified. Site constraints were assessed to determine the most feasible retrofit options as well as eliminate sites from consideration. The field investigation may have also revealed additional retrofit opportunities that could have gone unnoticed during the desktop search.

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Sites most likely to be conducive to addressing the LGU goals and appeared to be simple-to-moderate in design/install/maintenance considerations were chosen for a cost/benefit analysis in order to relatively compare catchments/sites. Treatment concepts were developed taking into account site constraints and the subwatershed treatment objectives. Projects involving complex stormwater treatment interactions or pose a risk for upstream flooding will require the assistance of a certified engineer. Conceptual designs, at this phase of the design process, include a cost estimate and estimate of pollution reduction. Reported treatment levels are dependent upon optimal site selection and sizing.

Cost Estimates

Each resulting BMP (by percent TP-removal dictated sizing) was then assigned estimated design, installation and first-year establishment-related maintenance costs given its ft^3 of treatment. In cases where live storage was 1-ft, this number roughly related to ft^2 of coverage. An annual cost/TP-removed for each treatment level was then calculated for the life-cycle of said BMP which included promotional, administrative and life-cycle operations and maintenance costs.

Step 5: Evaluation and Ranking

The results of each site were analyzed for cost/treatment to prescribe the most cost-efficient level of treatment.

Catchment Profiles

The following pages provide catchment-specific information that was analyzed for stormwater BMP retrofit treatment at various levels. The recommended level of treatment reported in the Ranking Table is determined by weighing the cost-efficiency vs. site specific limitations about what is truly practical in terms of likelihood of being granted access to optimal BMP site locations, expected public buy-in (partnership) and crew mobilization in relation to BMP spatial grouping. Each Catchment Profile includes a table showing the data relevant to various levels of treatment associated with different BMP options.

CATCHMENT 3-3

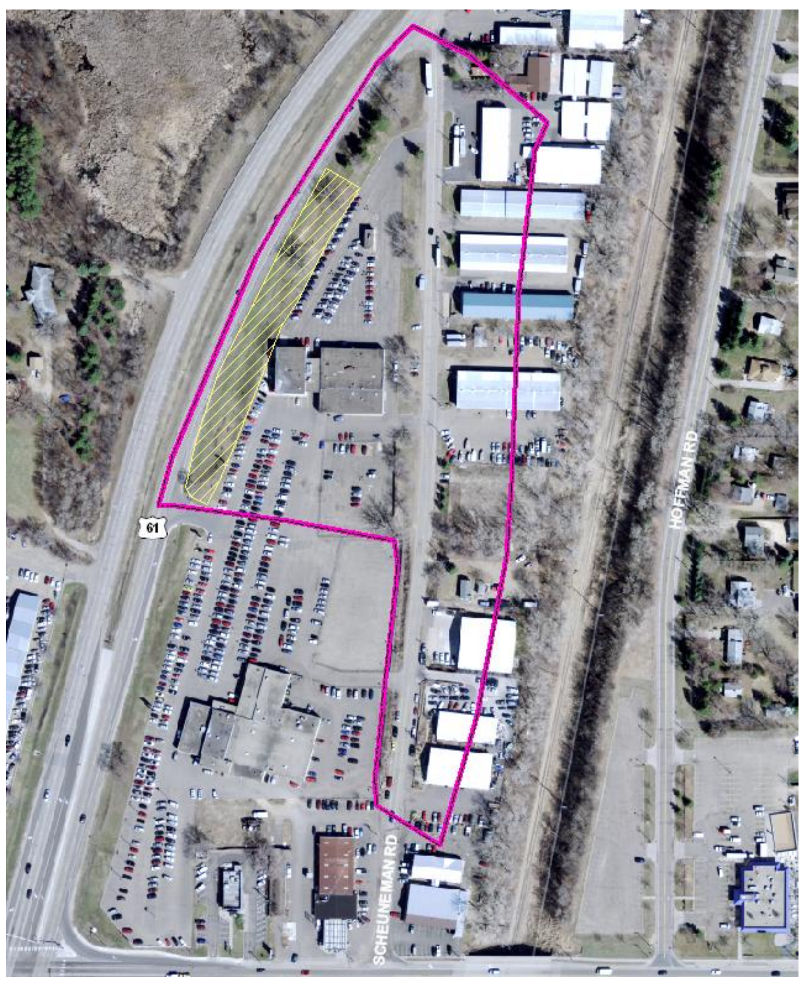
DESCRIPTION

Catchment 3-3 is 11.44 acres of predominantly impervious land cover consisting of commercial land use of buildings, parking lots and a portion of Highway 61. The majority of the catchment sheds water west to southwest and into a grass swale between the structures and Highway 61, which flows south and eventually into Gem Lake. Catchment 3-3 contributes a large volume of water at 16 acre/ft/year. As shown in Figure 3, the current TP load analysis shows that the base load of TP is 9.2 lb/yr and that the current grass swale removes 4 lb/yr leaving 5.2 lb/yr of TP that leaves this catchment. To further reduce the TP loading several BMP scenarios were modeled to determine their cost and efficiency.

Figure 3. Catchment 3-3 Existing Conditions

EXISTING CONDITIONS			
BMP Type	Base Loading	Grass Swale Treatment	
TP (lb/yr)	9.2	5.2	43.84%
TSS (lb/yr)	7121	4120	42.14%
Volume (acre-feet/yr)	16.06	10.43	35.06%

Figure 4. Outline of Catchment 3-3 and area of future BMP locations



RETROFIT RECOMMENDATION

Different sizes and combinations of two BMP types were modeled for Catchment 3-3 and recommended to be installed within the same area as the turf grass swale currently draining the catchment, see Figure 4. These BMP's included replacing the turf grass with native grasses within the swale, bioinfiltration cells within the swale, and a combination of the two.

Figure 5. BMP options, pollutant removal and costs for Catchment 3-3

RETROFIT OPTIONS RetroMarginal Network Treatment By BMP								
BMP Type	Grass Swale		Moderately Complex Bioretention		Moderately Complex Bioretention		Grass Swale and Moderatley Complex Biorentention	
TP (lb/yr)	4.93	46%	4.57	50%	4.70	49%	4.38	52%
TSS (lb/yr)	3944.00	45%	3744.00	47%	3826.00	46%	3587.00	50%
Volume (acre-feet/yr)	10.05	37%	9.13	43%	9.43	41%	8.77	45%
Square feet of practice (or, CU FT of storage for WP, ED, SW)	7000		2000		1485		9000	
Materials/Labor/Design	$14,210		$28,010		$20,852		$42,220	
Unit Promotion & Admin Costs*	$82		$206		$255		$288	
Total Project Cost**	$19,984		$32,122		$24,645		$52,106	
Annual O&M	$1,750		$1,500		$1,114		$3,250	
Term Cost/lb/yr (30 yr)	$570		$558		$432		$1,041	
% Change in TP	2.40%		6.37%		4.98%		8.41%	

Tier 1- Bioinfiltration cells
Bioinfiltration cells can be an effective, inexpensive way to infiltrate runoff. However, the cost can significantly increase if site soils do not drain well and need to be replaced with a soil type that infiltrates at a rate of 0.5 inches per hour or better. The soil survey shows no infiltration information about the soils within these areas. Therefore, before bioinfiltration cells are installed, the soils will have to be assessed for infiltration rates. As seen in Figure 5, two bio infiltration cells were modeled, one sized at 1485 sq ft and another at 2000 sq ft, to reduce the TP levels to 49% and 50% respectively. These bioinfiltration cells were modeled and priced with the assumption that the soils will need to be altered to reach a minimum infiltration rate of 0.5 inches per hour. The 1485 sq ft cell, which would remove another 5% TP compared to the current turf grass swale, is estimated to cost $24,645 with an annual cost of $1,114, which equates to a cost of $432 per year, per lb of TP removed over 30 years. The 2000 sq ft cell, which would remove another 6.4% TP compared to the current turf grass swale, is estimated to cost $32,122 with an annual cost of $1500, which equates to a cost of $558 per year, per lb of TP removed.

Tier 2 - Grass Swale
Another BMP option would be a grass swale. This would require the replacement of the turf grass within the swale with native plants. Grass swales improve the filtering and infiltration of pollutant runoff as well as offer aesthetic and educational value. Installing a native grass swale in lieu of the current turf grass swale would cost a total of $19,984, with an annual maintenance cost of $1,750, which would lower over the years as the grass swale established. This equates to a cost of $570 per year, per lb of TP removed.

Tier 3 – Grass Swale /Bioinfiltration
As seen in Figure 5, a combination grass swale and 2000 sq ft bioinfiltration was modeled together. The combination of these two BMP's would reduce the TP level by 8.41% at a total cost of $52,106.00. This BMP option had the highest cost per lb of TP removed with a $1,041 price per year over 30 years.

Alternative Options
Additional options that were unable to be modeled, but are highly reccomended to be explored further include the installation of berms within the grass swale and/or the rising of the outlet structure. It is recommended that the watershed district's engineer first model for these BMP's to ensure there would

not be an issue with limiting capacity of the system and to determine the treatment and cost analysis before committing to any other options.

CATCHMENT 3-5

DESCRIPTION

Catchment 3-5 is 7.69 acres of predominantly impervious land cover consisting of commercial land use of one large building, parking lots and a portion of Highway 61. The majority of the catchment sheds water west to northwest and into a grass swale between the structures and Highway 61, which flows north and eventually into Gem Lake.

Figure 6. Existing conditions within Catchment 3-5

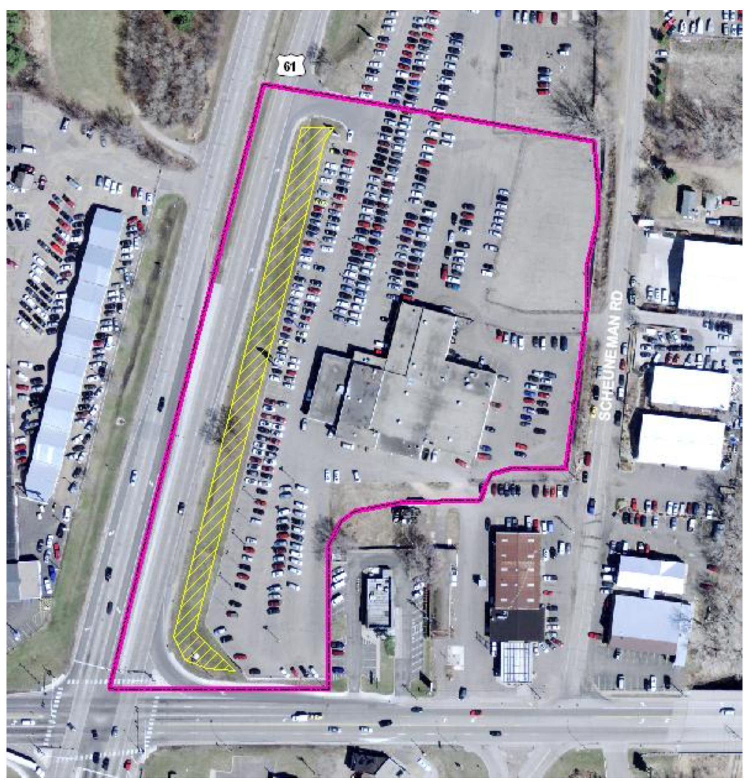
EXISTING CONDITIONS			
BMP Type	Base Loading	Grass Swale Treatment	
TP (lb/yr)	5.6	3.2	42.56%
TSS (lb/yr)	4785	2866	40.10%
Volume (acre-feet/yr)	11.55	7.74	32.97%

As shown in Figure 6, the current TP load analysis shows that the base load of TP is 5.6 lb/yr and that the current grass swale removes 2.4 lb/yr leaving 3.2 lb/yr of TP that leaves this catchment. To further reduce the TP loading several BMP scenarios were modeled to determine their cost and efficiency.

RETROFIT RECOMMENDATION

Different sizes and combinations of two BMP types were modeled for Catchment 3-5 and recommended to be installed within the same area as the turf grass swale currently draining the catchment, see Figure 7. These BMP's included replacing the turf grass with native grasses within the swale, bioinfiltration cells within the swale, and a combination of the two.

Figure 7. Outline of Catchment 3-5 and area of future BMP locations



Tier 1- Bioinfiltration cells
Bioinfiltration cells can be an effective, inexpensive way to infiltrate runoff. However, the cost can significantly increase if site soils do not drain well and need to be replaced with a soil type that infiltrates at a rate of 0.5 inches per hour or better. The soil survey shows no infiltration information about the soils within these areas.

Therefore, before bioinfiltration cells are installed, the soils will have to be assessed for infiltration rates. As seen in Figure 8, two bio infiltration cells were modeled, one sized at 500 sq ft and another at 1000 sq ft, to reduce the TP levels to 48% and 57% respectively. These bioinfiltration cells were modeled and priced with the assumption that the soils will need to be altered to reach a minimum infiltration rate of 0.5 inches per hour. The 500 sq ft cell, which would remove another 6% TP compared to the current turf grass swale, is estimated to cost $9,984 with an annual cost of $375, which equates to a cost of $262 per year, per lb of TP removed. The 1000 sq ft cell, which would remove another 15% TP compared to the current turf grass swale, is estimated to cost $17,518 with an annual cost of $750, which equates to a cost of $416 per year, per lb of TP removed.

Figure 8. BMP options, pollutant removal and costs for Catchment 3-5

RETROFIT OPTIONS RetroMarginal Network Treatment By BMP								
BMP Type	Grass Swale		Moderately Complex Bioretention		Moderately Complex Bioretention		Grass Swale and Moderatley Complex Biorentention	
TP (lb/yr)	2.80	50%	2.90	48%	2.40	57%	2.55	54%
TSS (lb/yr)	2497.00	48%	2661.00	44%	2224.00	54%	2335.00	51%
Volume (acre-feet/yr)	6.77	41%	6.89	40%	5.69	51%	6.09	47%
Square feet of practice (or, CU FT of storage for WP, ED, SW)	6345		500		1000		6845	
Materials/Labor/Design	$12,900		$7,160		$14,110		$20,060	
Unit Promotion & Admin Costs*	$89		$565		$341		$653	
Total Project Cost**	$18,522		$9,984		$17,518		$28,506	
Annual O&M	$1,586		$375		$750		$1,961	
Term Cost/lb/yr (30 yr)	$786		$262		$416		$954	
% Change in TP	7.48%		5.62%		14.64%		11.93%	

Tier 2 - Grass Swale

Another BMP option would be a grass swale. This would require the replacement of the turf grass within the swale with native plants. Grass swales improve the filtering and infiltration of pollutant runoff as well as offer aesthetic value. Installing a native grass swale in lieu of the current turf grass swale would cost a total of $18,522, with an annual maintenance cost of $1,586, which would lower over the years as the grass swale established. This equates to a cost of $786 per year, per lb of TP removed.

Tier 3 – Grass Swale /Bioinfiltration

As seen in Figure 8, a combination grass swale and 500 sq ft bioinfiltration was modeled together. The combination of these two BMP's would reduce the TP level by 12% at a total cost of $28,506. This BMP option had the highest cost per lb of TP removed with a $954 price per year over 30 years.

Alternative Options

Additional options that were unable to be modeled, but are highly reccomended to be explored further include the installation of berms within the grass swale and/or the rising of the outlet structure. It is recommended that the watershed district's engineer first model for these BMP's to ensure there would not be an issue with limiting capacity of the system and to determine the treatment and cost analysis before committing to any other options.

CATCHMENT 3-6

DESCRIPTION

Catchment 3-6 is 8.6 acres of predominantly impervious land cover consisting of a large parking lot, numerous buildings, and a portion of Highway 61. The majority of the catchment sheds water east to a grass swale between the structures and Highway 61, which flows north and eventually into Gem Lake.

Figure 9. Existing conditions within Catchment 3-6

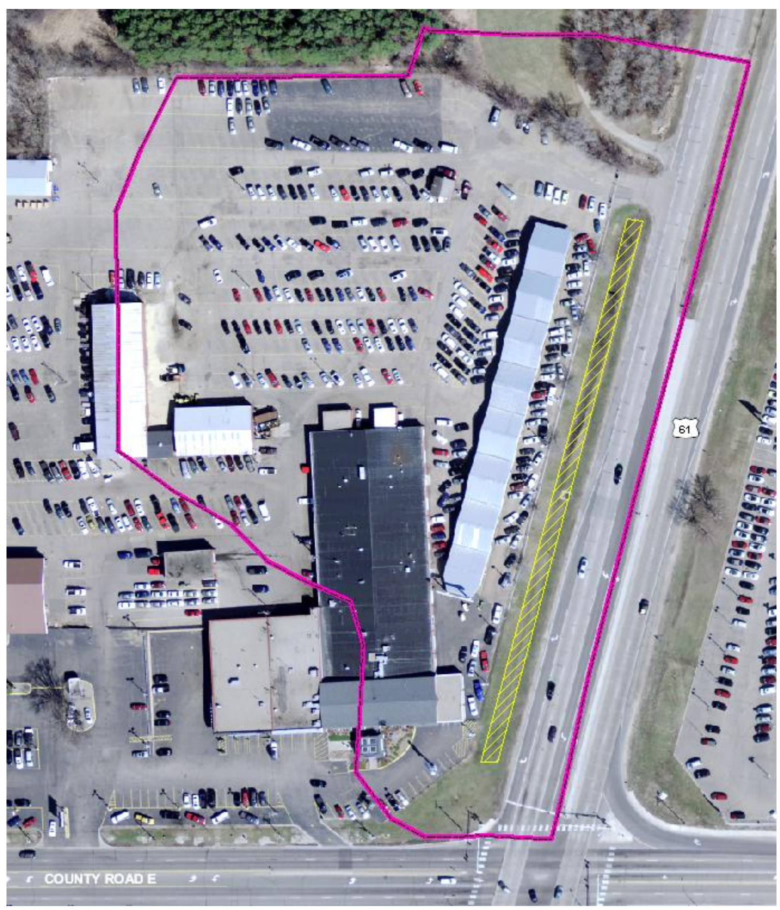
EXISTING CONDITIONS			
BMP Type	Base Loading	Grass Swale Treatment	
TP (lb/yr)	7.5	4.5	40.78%
TSS (lb/yr)	5303	3202	39.62%
Volume (acre-feet/yr)	10.80	7.50	30.56%

As shown in Figure 9, the current TP load analysis shows that the base load of TP is 7.5 lb/yr and that the current grass swale removes 3 lb/yr leaving 4.5 lb/yr of TP that leaves this catchment. To further reduce the TP loading several BMP scenarios were modeled to determine their cost and efficiency.

RETROFIT RECOMMENDATION

Different sizes and combinations of two BMP types were modeled for Catchment 3-6 and recommended to be installed within the same area as the turf grass swale currently draining the catchment, see Figure 10. These BMP's included replacing the turf grass with native grasses within the swale, bioinfiltration cells within the swale, and a combination of the two.

Figure 10. Outline of Catchment 3-5 and area of future BMP locations



Tier 1- Bioinfiltration cells
Bioinfiltration cells can be an effective, inexpensive way to infiltrate runoff. However, the cost can significantly increase if site soils do not drain well and need to be replaced with a soil type that infiltrates at a rate of 0.5 inches per hour or better. The soil survey shows no infiltration information about the soils within these areas. Therefore, before bioinfiltration cells are installed, the soils will have to be assessed for infiltration rates. As seen in Figure 11, a bio

infiltration cell was modeled at 1500 sq ft, to reduce the TP levels to 50% respectively. This bioinfiltration cell was modeled and priced with the assumption that the soils will need to be altered to reach a minimum infiltration rate of 1.0 inches per hour. This cell would remove another 9.46% TP compared to the current turf grass swale, is estimated to cost $24,863 with an annual cost of $1,125, which equates to a cost of $517 per year, per lb of TP removed.

Figure 11. BMP options, pollutant removal and costs for Catchment 3-6

RETROFIT OPTIONS RetroMarginal Network Treatment By BMP						
BMP Type	Grass Swale		Moderately Complex Bioretention		Grass Swale and Moderatley Complex Biorentention	
TP (lb/yr)	4.38	42%	3.75	50%	3.67	51%
TSS (lb/yr)	3146.00	41%	2768.00	48%	2713.00	49%
Volume (acre-feet/yr)	7.37	32%	6.17	43%	6.14	43%
Square feet of practice (or, CU FT of storage for WP, ED, SW)	9450		1500		9950	
Materials/Labor/Design	$19,110		$21,060		$40,170	
Unit Promotion & Admin Costs*	$66		$254		$320	
Total Project Cost**	$25,373		$24,863		$50,237	
Annual O&M	$2,363		$1,125		$3,488	
Term Cost/lb/yr (30 yr)	$1,019		$517		$1,340	
% Change in TP	1.04%		9.46%		10.42%	

Tier 2 - Grass Swale

Another BMP option would be a grass swale. This would require the replacement of the turf grass within the swale with native plants. Grass swales improve the filtering and infiltration of pollutant runoff as well as offer aesthetic value. Installing a native grass swale in lieu of the current turf grass swale would cost a total of $25,373, with an annual maintenance cost of $2,363 which would lower over the years as the grass swale established. This equates to a cost of $1,019 per year, per lb of TP removed.

Tier 3 – Grass Swale /Bioinfiltration

As seen in Figure 11, a combination grass swale and 1500 sq ft bioinfiltration was modeled together. The combination of these two BMP's would reduce the TP level by 10.42% at a total cost of $50,237. This BMP option had the highest cost per lb of TP removed with a $1,340 price per year over 30 years.

Alternative Options

Additional options that were unable to be modeled, but are highly reccomended to be explored further include the installation of berms within the grass swale and/or the rising of the outlet structure. It is recommended that the watershed district's engineer first model for these BMP's to ensure there would not be an issue with limiting capacity of the system and to determine the treatment and cost analysis before committing to any other options.

Retrofit Ranking

As shown in Figure 12, the different BMP options that are listed above for catchments 3-3 3-5 and 3-6 are categorized from lowest term cost of lb/TP/year to the highest term cost. Since this term cost is calculated to determine the lowest cost of TP removal per pound per year over 30 years, this list can be used to give priority to projects with the lowest term cost. As seen below, the most efficient and cost effective measures proposed are the bioinfiltration cells. The percent of TP reduction was not uniform for each proposed BMP modeled, so a TP reduction goal should be considered when deciding on a BMP option for each site.

Figure 12. BMP options, pollutant removal and costs for Catchment 3-3, 3-5 and 3-6

Catchment or Pond ID	Retro Type	Total Est. Term Cost/lb-TP/yr	Square ft of BMPs	TP Reduction (%)	Overall Cost
3-5	B	$262	500	5.62	$9,984
3-5	B	$416	1000	14.64	$17,518
3-3	B	$432	1485	4.98	$24,645
3-6	B	$517	1500	9.46	$24,863
3-3	B	$558	2000	6.37	$32,122
3-3	VS	$570	7000	2.4	$19,984
3-5	VS	$786	6345	7.48	$18,522
3-5	B/VS	$954	6845	11.93	$28,506
3-3	B/VS	$1,041	9000	8.41	$52,106
3-6	B/VS	$1,340	9950	10.42	$50,237

B = Bioretention (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
[1]Estimated overall costs include design, contracted soil core sampling, materials, contracted labor, promotion and administrative costs (including outreach, education, contracts, grants, etc), pre-construction meetings, installation oversight and 30 years of operation and maintenance costs.

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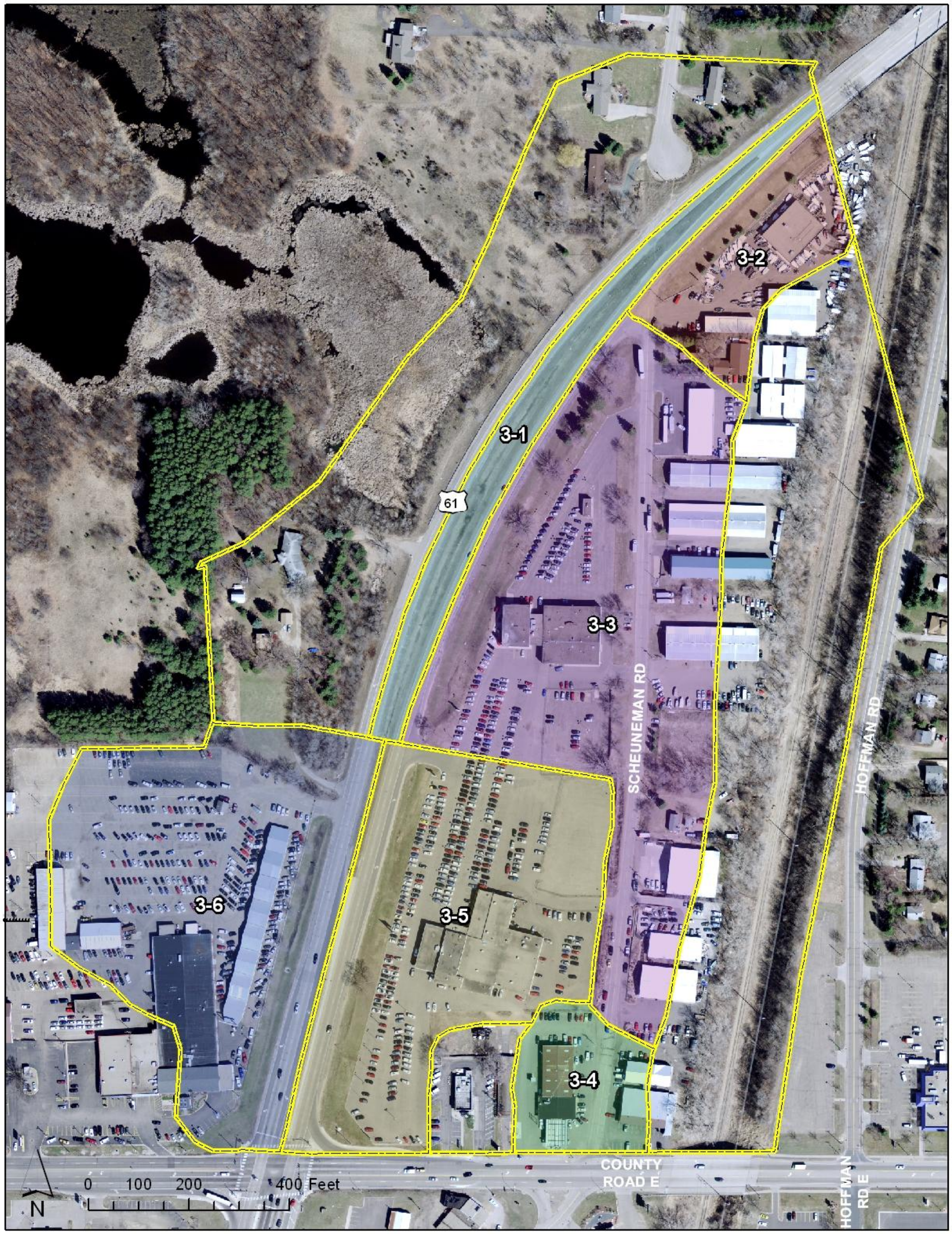
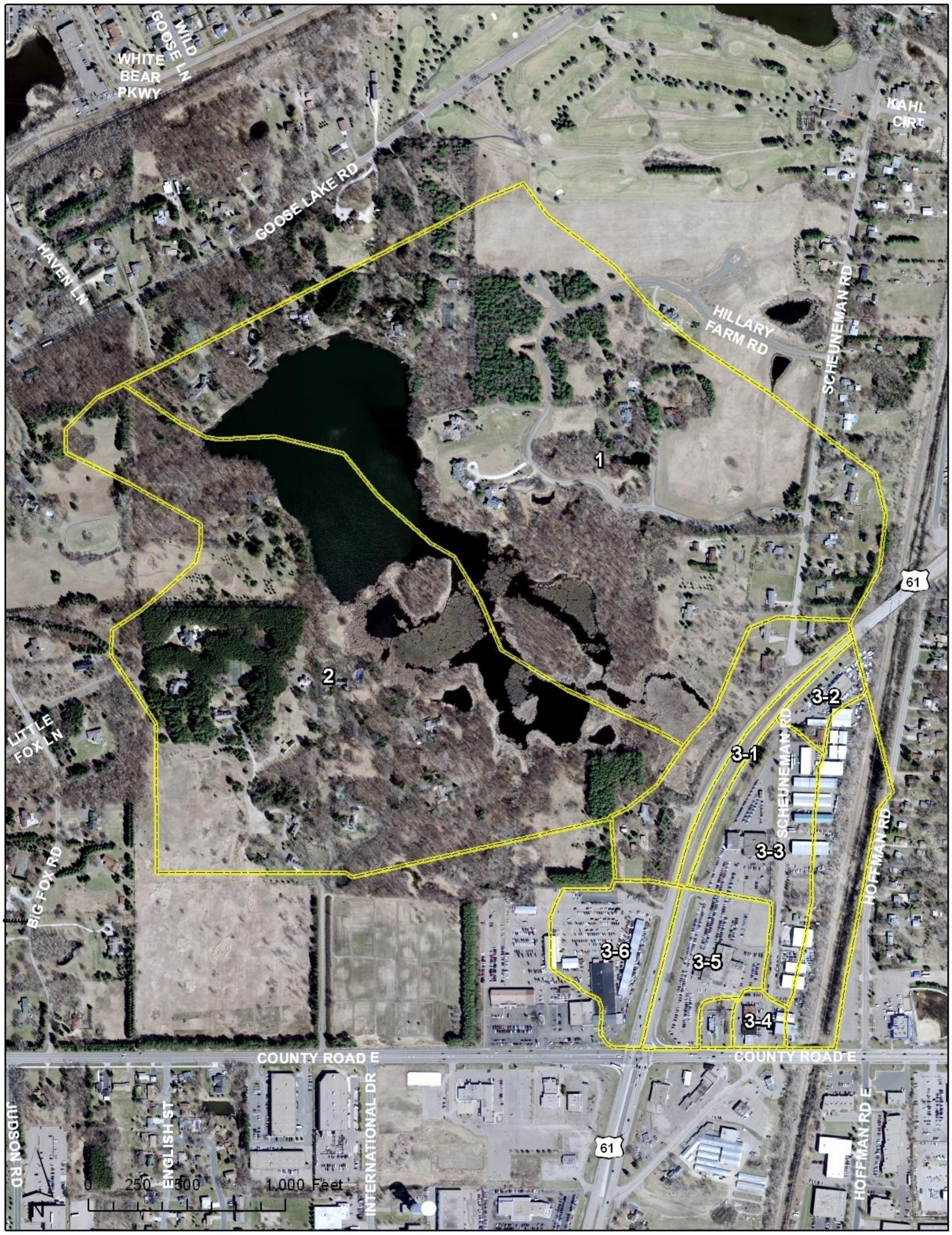
Appendix A: Overview of all catchments within study area 3



Appendix B: All catchments considered in the study area



APPENDIX B – FISH SURVEY OF GEM LAKE (DECEMBER 2011)

Gem Lake Crappies, September, 2011

Fish Survey of Gem Lake (ID #62-0037), Ramsey County, Minnesota in 2011

Survey Dates: September 26-28, 2011

MnDNR Permit Number: 17693

Prepared for:

VLAWMO and MnDNR

Prepared by:

Steve McComas
Blue Water Science

December 2011

Introduction

Gem Lake is a 20-acre lake, located in Ramsey County, Minnesota. In September 2011, VLAWMO sponsored a fish survey conducted by Blue Water Science under permit number 17693 granted from the MnDNR. The objective was to characterize the fish community in Gem Lake.

Methods

Two standard trapnets and one mini-trapnet were used for two days for a total of four standard lifts and two mini-trapnet lifts to survey fish in Gem Lake. The standard trapnet was a MnDNR-style with a 4 x 6 feet square frame with two funnel mouth openings and 50-feet lead. Net mesh size was 3/8 inch. The mini-trapnet was a MnDNR-style with a 2 x 3 feet square frame with one funnel mouth opening and a 25-feet lead. Net mesh size was 1/8 inch. The trapnets were set on Monday morning September 26, 2011. The nets were fished for the following 2 days (September 27 and 28). Trapnet locations are shown in Figure 1 and pictures of a typical trapnet are shown in Figures 2 and 3.

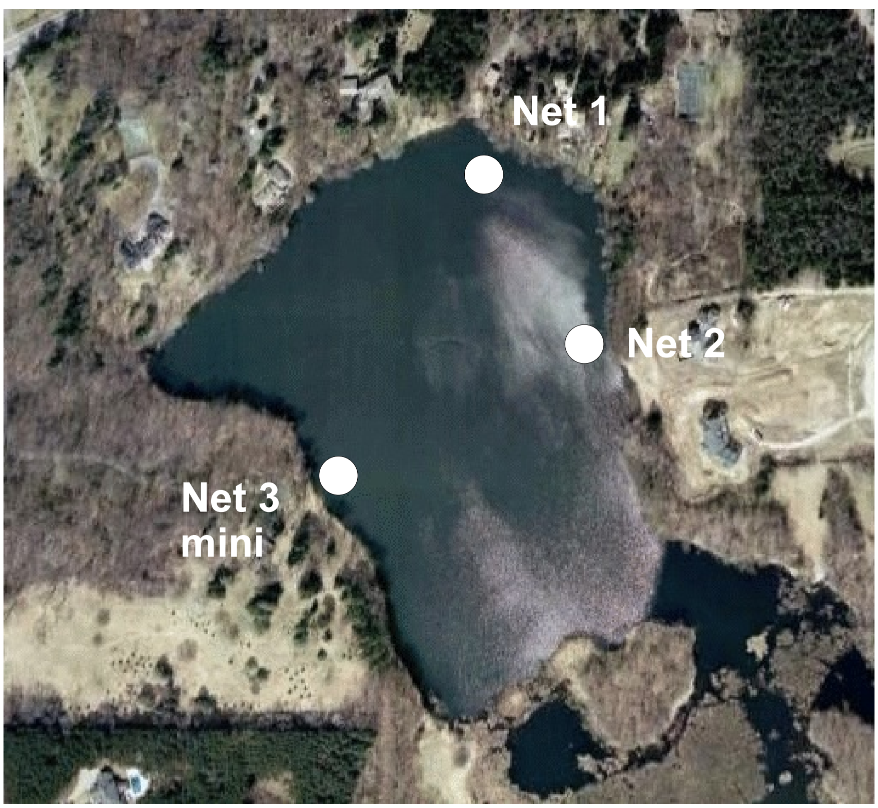


Figure 1. Map of trapnet locations in Gem Lake.

Figure 2. A trapnet is a live fish trap. Fish run into the 50-foot lead net and follow it back through a series of hoops with funnel mouths. Fish end up in the back hoop. The flag marks the end of the back hoop.

Figure 3. Fish are transferred to tubs, then they are counted and measured and released.

Results

In the standard trapnets, black crappies were the only species of fish sampled in Gem Lake on September 27 and 28, 2011. The number of crappies caught per net was high with the average haul of 37 fish per net (Table 1).

In the mini-trapnet sets, two minnow species were caught, but in low numbers (Table 1).

Table 1. Gem Lake trapnet results for the fish survey conducted in September 2011.

	September 27 and 28, 2011				Total Catch (standard)	Fish per Net (n=4)	MnDNR Normal Range	Sept 27 & 28, 2011		Total Catch (mini)
	Standard Trapnet 1		Standard Trapnet 2					Mini-Trapnet 3		
	Day 1	Day 2	Day 1	Day 2				Day 1	Day 2	
Black crappies	28	71	21	29	149	37	2 - 18	7	0	7
Painted turtle	0	0	3	0	3	0.75	NA	0	0	0
Fathead minnow	0	0	0	0	0	--		7	6	13
Mud minnow	0	0	0	0	0	--		0	1	1
TOTAL FISH	28	71	21	29	149			14	7	14

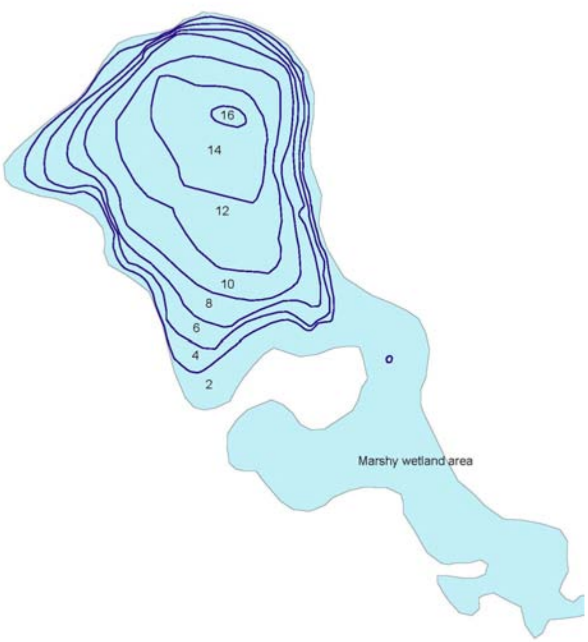


Figure 4. [left] Gem Lake is shallow and prone to winterkill events.
[right] Much of the Gem Lake shoreline is lined with natural vegetation.

Although black crappies were the only species, there were at least a couple of year classes present.

Black crappie lengths are shown in Table 2 and ranged from less than 3 inches up to 9.5 inches in length with the majority of the population was less than 6 inches. However, 27% of the crappies were 8 to 9 inches long.

Table 2. Length frequency of fish species (as total length) for the Gem Lake fish survey.

	Black Crappies	
	Standard Nets	**Mini Nets**
<3	4 (3%)	0
3	28 (19%)	1
3.5	10 (7%)	0
4	35 (24%)	0
4.5	13 (9%)	0
5	10 (7%)	0
5.5	4 (3%)	0
6	0	0
6.5	0	0
7	0	0
7.5	4 (3%)	0
8	20 (13%)	0
8.5	14 (9%)	1
9	7 (5%)	4
9.5	0	1
10	0	0
Total	149	7

Representative Black Crappies of Gem Lake

Figure 5. [left] Smaller sized black crappies.
[right] Normal size distribution of black crappies from a standard fyke net.

Conclusions and Recommendations

The fish community was represented by a single species, black crappies, in the standard trapnet sets and the black crappie abundance was above average for trapnet catches. Gem Lake is relatively shallow and it is likely that winterkills have occurred in the past. A few years ago winterkill probably killed all the fish in the lake and then crappies were introduced, either intentionally or unintentionally. Because Gem Lake is land-locked, immigration of other fish species is unlikely. If there is another severe winterkill, the existing population of crappies will probably be eliminated and minnows will be the dominant species.

Without a winter aeration system, significant fish stocking is not recommended. However, a limited stocking program could be considered to support limited recreational fishing but with the caveat that a future winterkill is inevitable. A limited stocking program would involve two to three breeding pairs of largemouth bass and several dozen bluegill sunfish.

Without winter aeration a boom and bust fishery is likely which is a natural occurrence for shallow lakes like Gem Lake. Therefore, a winter aeration system is not recommended for Gem Lake. Not necessarily because of the costs or liability concerns but rather because this shallow lake is in a natural setting and letting nature take it's course is a good management strategy for a lake like Gem Lake that is more conducive to wildlife rather than a recreational fishery.

Several year classes of crappies were observed in Gem Lake including many in the 8-9 inch range.

Painted turtles were common.

Fathead minnows and crappies from a mini-trapnet.

Minnows were present, but in low numbers. Mudminnow is shown on top and a fathead minnow is on the bottom.

Figure 6. Representative fish pictures.

Appendix A

Minnesota DNR Fish Survey Notification

Steve McComas

From: Steve McComas <mccomas@pclink.com>
Sent: Friday, September 23, 2011 1:14 PM
To: Gerald Johnson; Greg Salo
Cc: Brian Corcoran
Subject: Fish survey notification

Hello all,

Blue Water Science will be conducting a fish survey in Gem Lake (MN ID 62-37), Ramsey County, starting on Monday, September 26. We will set 3 fyke nets on Monday. The nets will be monitored daily and all fish will be weighed and measured and returned to the lake. The nets will be removed from the lake on Wednesday, September 28. The fish survey is sponsored by the Vadnais Lake Area Water Management Organization with the objective to examine possible winterkill effects from last winter on the fish community structure.

This survey is being conducted under the permit number: 17693

Best regards,

Steve McComas
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