Pleasant Charley Deep Subwatershed:

Urban Stormwater Retrofit Analysis

Prepared for the Vadnais Lake Area Water Management Organization by:
Ramsey Conservation District, December 2015

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Front Cover:
Swans on Pleasant Lake
Photograph by Kristine Jenson, VLAWMO Program Manager

VLAWMO
Vadnais Lake Area
Water Management Organization

Executive Summary

This assessment identifies optimal locations for implementing cost-effective best management practices to improve environmental water quality in the Pleasant Charley Deep subwatershed of Ramsey County. These practices consist of general recommendations as well as *retrofits* to the existing drainage system to filter stormwater runoff, thereby reducing the amount of total phosphorus (TP) and total suspended solids (TSS) reaching the lakes. TP concentration, specifically, is a key indicator in whether a lake is considered impaired. Reducing TP will improve water quality for this important water management area. Charley and Pleasant Lakes form the start of the chain of lakes water supply for Saint Paul Regional Water Services, yet these lakes often exceed the MPCA standards in total phosphorus (MPCA EDA, 2014). Deep Lake (which drains into Pleasant Lake) bears even higher nutrient and sediment loads. This study was conducted with the objective of furthering clean water stewardship in line with the goals of the Vadnais Lake Area Water Management Organization (VLAWMO).

This subwatershed was divided into three catchments based on drainage to each of the three lakes: Pleasant Catchment, Charley Catchment and Deep Catchment. The catchments were then modeled using WinSLAMM software to determine base loading of TP and TSS. Based on initial results, two catchments (Charley and Pleasant) were prioritized for best management practice (BMP) retrofitting. After desktop and field analyses, 28 bioretention projects were identified, designed, and priced. Many additional recommendations for retrofits were also made for specific areas. Bioretention project areas were modeled for their capacity for pollutant reduction, and the final result is a ranked list of these projects in order of lowest cost per pound of phosphorus removed. Additional priority areas and alternative BMP recommendations are discussed in the Results sections of each catchment. Contaminant loading values and costs presented are estimates based on models and pricing for comparable projects. More detailed studies should be completed prior to the implementation of any individual project presented herein.

In the areas of North Oaks with underground stormwater infrastructure, bioretention systems (rain gardens) were found to be the most appropriate practice, given the predominantly low-density residential land use and the high infiltration rates of the native soil. While the institutional areas (school or church parking lots) have higher costs due to the larger sizes and extra construction costs, they also carry the benefits of greater pollution reduction, higher likelihood of appropriate maintenance, and stronger potential to raise awareness on clean water efforts due to their elevated visibility. Alternative BMPs suggested, such as bioswales, alum treatments and iron-enriched sand filters, are recommended in different areas without underground stormwater infrastructure.

This document includes background information, methods, assessment results, conclusions and recommendations. When implemented, these projects will help improve existing water quality, benefit the lake ecosystems, and enhance the quality of this important surface water drinking source that serves about 80% of the Ramsey County population. This is the final study in a series of Stormwater Retrofit Analyses for the VLAWMO region.

The following table, also found in the Results section, shows the estimated cost and modeled phosphorus and suspended solids removal for each of the bioretention retrofits proposed in this document. The map below shows the locations of each of these features as well as additional recommended retrofits and treatments for the Pleasant-Charley-Deep subwatershed.

ID	Catchment	Bioretention Type	TSS removed lb/year	TP removed lb/yr	BMP area ft2	Total Initial Cost	Annual O&M	Cost/lb P removed/yr (30 yr)
1	Pleasant	simple	205	0.641	300	$ 5,250	$ 225	$ 612
2	Pleasant	simple	405	1.228	300	$ 5,250	$ 225	$ 320
3	Pleasant	simple	340	1.002	300	$ 5,250	$ 225	$ 392
4	Pleasant	simple	367	1.077	300	$ 5,250	$ 225	$ 364
5	Pleasant	simple	163	0.484	300	$ 5,250	$ 225	$ 811
6	Pleasant	complex	722	1.291	1350	$ 50,625	$ 1,013	$ 2,065
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21	Charley	complex	180	0.607	300	$ 11,250	$ 225	$ 976
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23	Charley	complex	196	0.664	300	$ 11,250	$ 225	$ 892
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27	Charley	complex	384	1.195	300	$ 11,250	$ 225	$ 496
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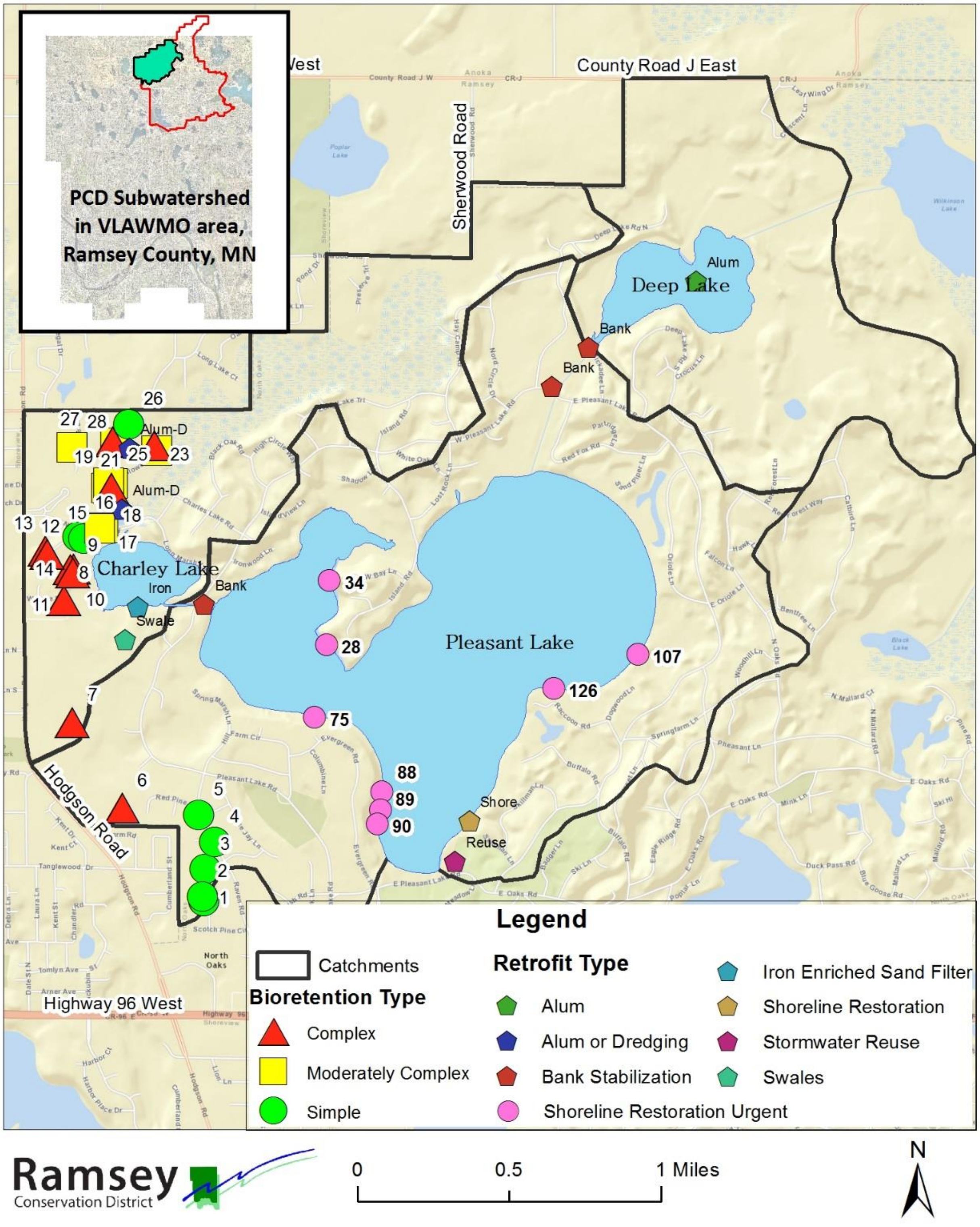
Pleasant Charley Deep Retrofit Locations



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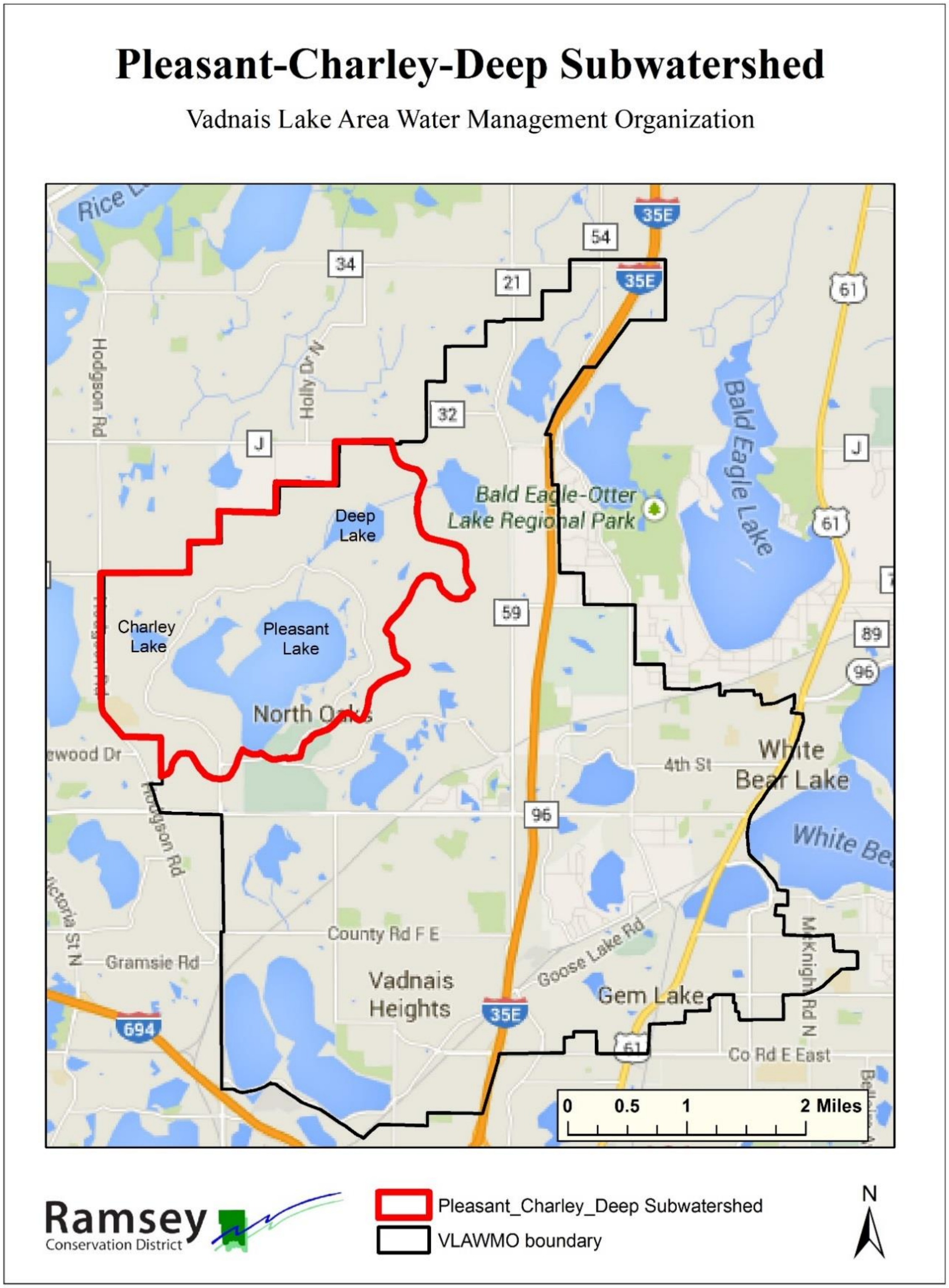

Figure 1. Boundary of Pleasant Charley Deep Subwatershed within VLAWMO boundary. Northern Ramsey County, MN

Introduction

The Pleasant Charley Deep (PCD) subwatershed is a 3250 - acre area located in north central Ramsey County, Minnesota (Figure 1), based on a unit of the Department of Natural Resource's Level 8 hydrologic catchment area. With the private community of North Oaks comprising the entirety of the subwatershed, most of the land in the PCD watershed is composed of low-density residential land use, and only one section of one street (Wildflower Way) has right-of-way status, as it provides access to the entry point of pumped Mississippi River water into Charley Lake (used as a drinking water source for St. Paul). Figure 2 shows a schematic of the St. Paul surface water supply system.

It should be noted that the PCD watershed is not a hydrologically closed system. The pollutant base loading reported in this document is based on modeled results from WinSLAMM software, which considers only surface runoff within the catchment boundaries to model TP and TSS loading. However, it must be taken into account that there are additional sources of this pollution – namely, the Mississippi River and Wilkinson Lake. For reference, the amount of river water pumped annually by St Paul Regional Water Services into Charley Lake is roughly ten times the amount of Charley Catchment's annual rainfall, or enough water to completely replace the lake's storage every 1-3 days, depending on the variable pumping rate.

The water pumped from the Mississippi River to Charley Lake has a phosphorus load over twice the standard for deep lakes (the river water averages 85 µg/L of TP at its point of entry, where the deep lake standard is 40 µg /L for Charley Lake) (SPRWS, 2015). Though rates fluctuate greatly, an average of about 30 million gallons of water from the Mississippi River is pumped into Charley Lake every day by way of an 8-mile pipe conveying water from the station at Fridley (SPRWS, 2015). By the time the water reaches Charley Lake's outlet, the phosphorus load is reduced to an average of 69 µg/L, but it still exceeds the standard as it pours into Pleasant Lake (MPCA EDA, 2014). See Figure 3 for a glimpse of average TP concentrations in the regularly measured water bodies involved the PCD subwatershed's hydrology.

Figure 2. Saint Paul Supply System Schematic (Metropolitan Council, 2014).

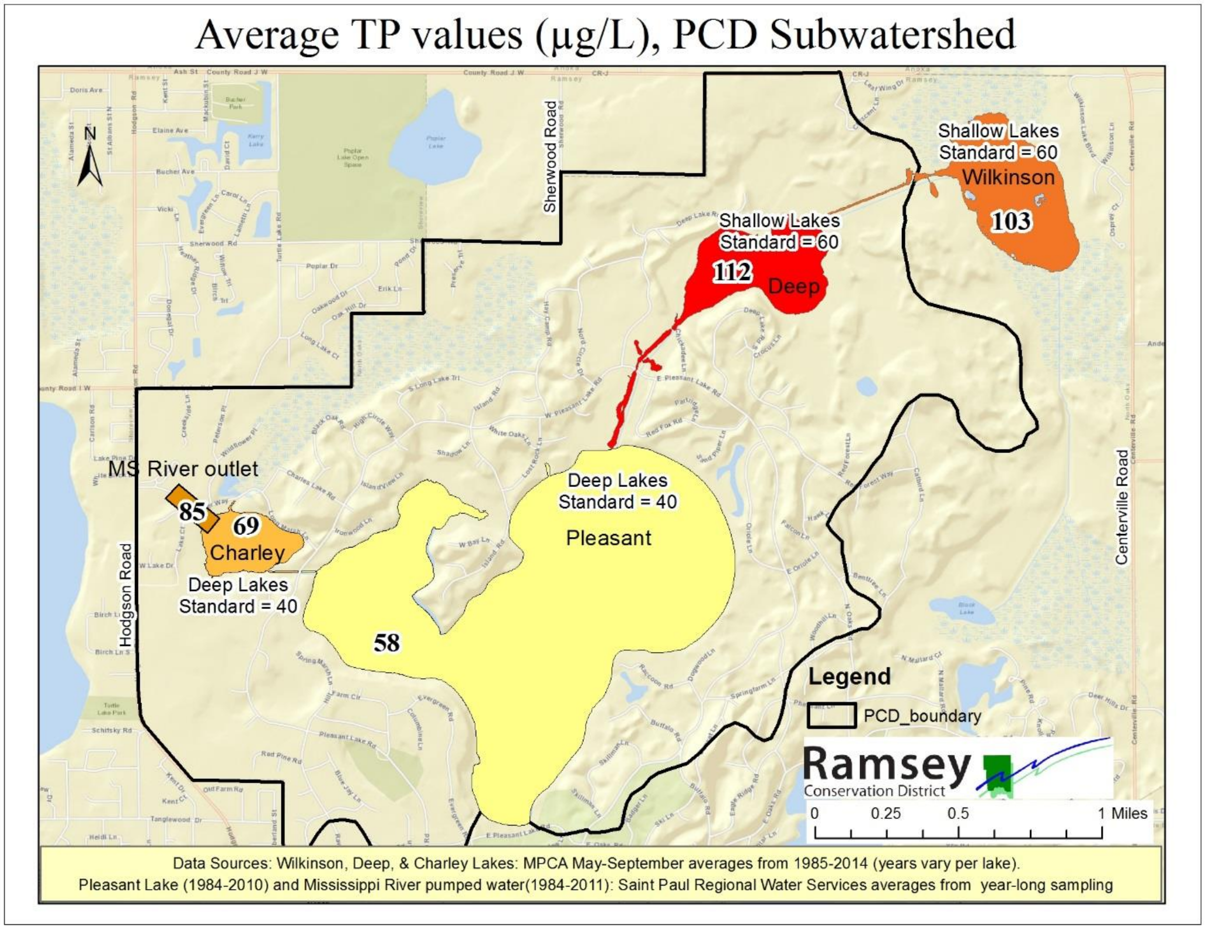

Figure 3. Average Total Phosphorus values and associated shallow or deep MPCA standards for PCD Lakes and Wilkinson Lake. Mississippi River TP values were measured at the Fridley Pump Station, from which water is conveyed to Charley Lake. Water generally flows toward the south in this map.

Another external source of TP into the PCD watershed is Wilkinson Lake, which flows into Deep Lake, which in turn flows into Pleasant Lake via a system of canals. As seen in Figure 3, Wilkinson and Deep Lakes have phosphorus levels exceeding the shallow lake standard (60 µg/L), reaching double the standard at their outlet points (MPCA, 2015 and SPRWS, 2005). These external sources of turbidity and nutrients could account for discrepancies between the low pollutant outputs modeled for the PCD subwatershed in WinSLAMM and the relatively high pollutant levels measured in the lakes. Internal loading of phosphorus from sediment accumulated at lake bottoms is another likely factor in some elevated TP measurements.

Pollutant modeling in this analysis is based on surface runoff within catchment boundaries. The PCD subwatershed is characterized largely by low density residential land use (49%), water bodies (23%), and undeveloped or green spaces (26%). Contaminant loading is relatively small with such low-impact land use. The predominant soil type in the area is loamy fine sand, which is beneficial for rain gardens and other stormwater BMPs due to its high infiltration rate.

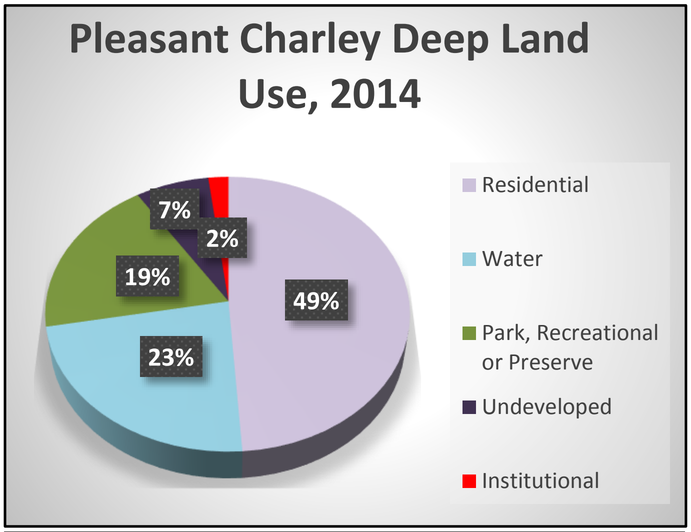

Figure 4. Land Use/Land Cover in the Pleasant Charley Deep Subwatershed based on GIS data and 2014 satellite imagery.

While only Pleasant Lake is listed as impaired for nutrients and eutrophication (according to the 2014 MPCA Proposed TMDL list), all lakes frequently exceed MPCA lake standard levels for TP, and water quality monitoring for Deep and Charley Lakes indicates that they, too, could be considered impaired. The MPCA Water Quality Summaries for Deep and Charley Lakes state insufficient data to determine their recreational or fish consumption impairment, but the Trophic State Indices, based on about 40 samples, reveal eutrophic and hypereutrophic conditions. Deep's overall Trophic State Index (TSI) is listed as 64, the same value as Wilkinson Lake, which is listed as impaired. Charley's overall TSI is listed at 57, which is greater than Pleasant Lake (56), which is also listed as impaired (MPCA EDA, 2014).

Table 1 shows average values of TP as provided by the St Paul Regional Water Services and the MPCA EDA website in the three subwatershed lakes as well as Wilkinson Lake and the Mississippi River at the Fridley Pump Station, from where it is pumped to Charley Lake. The MPCA standards listed below are for lakes in the CHF ecoregion (MPCA, 2014). In general, the SPRWS dataset has higher phosphorus readings, which is likely due to their deeper sampling location and sampling position near the lake's outlet.

Table 1. Average TP values. Values were averaged from datasets provided by the St Paul Regional Water Services and the Minnesota Pollution Control Agency Environmental Data Access website. The MPCA Standard is 40 µg/L for deep lakes (over 15ft maximum depth) and 60 µg/L for shallow lakes. All datasets were subject to a TrimMean of 5% to reduce the impact of extreme outliers (possible errors). *MPCA's Pleasant dataset was averaged after the removal of the 5 extreme outliers over the first standard deviation (a 5% TrimMean would have resulted in the value 229).

Sampling Location	Total Phosphorus (µg/L) - Averages from MPCA and SPRWS Sources				
	MPCA Standard	MPCA	Sampling Period (May-September)	SPRWS	Sampling Period (Year-Round)
Wilkinson	60	103	1998-2014	132	1997-2005
Deep	60	112	1985, 2009-2014	125	1984-1994
MS River	-	-	-	85	1984-2011
Charley	40	69	1985, 2009-2014	83	1984-2005
Pleasant	40	87*	1979,1985, 2010-2011	58	1984-2010

Values subjected to a 5% TrimMean to remove extreme outliers.

***MPCA's Pleasant dataset was averaged after the removal of the 5 extreme outliers over the first standard deviation.**

Table 2 lists TSS loading at the outlets of the PCD lakes and in the Mississippi River at the Fridley Pump Station.

Table 2. Average TSS values. Values were averaged from St Paul Regional Water Services monitoring data from 1984-2005 (individual lakes vary). All datasets were subject to a TrimMean of 5% to reduce the impact of extreme outliers

Sampling Location	TSS (mg/L) - Averages from SPRWS Sampling		
	Typical values for ecoregion	TSS (mg/L)	Sampling Period (Year-Round)
Deep	2-6	**16.48**	1984-1994
MS River	4.8-16	**15.81**	1984-2005
Charley	2-6	**14.18**	1984-1998
Pleasant	2-6	**6.44**	1984-1998

Typical values for North Central Hardwood Forest ecoregion from MPCA EDA, 2015
SPRWS TSS values subjected to a 5% TrimMean to remove extreme outliers.

Within each of the three catchments, runoff flows to the corresponding lake after first passing through ditches, stormwater ponds or wetlands; in some areas of Charley and Pleasant catchments, runoff is conveyed instead through stormwater infrastructure. Charley and Deep Lakes are classified as Eutrophic Grade C and C-, respectively, indicating anoxic hypolimnia and problems with algal scum and macrophytes (VLAWMO, 2014). Improving water quality within this important chain of lakes drinking supply area is what prompted this study. Specifically, the objectives are to reduce:

Total Phosphorus (TP): a nutrient that can contribute to the eutrophication of surface water bodies

Total Suspended Solids (TSS): particles suspended (not dissolved) in water that can cause turbidity and harm aquatic life

Methods

In this analysis, the methods used were based on models developed by the Center for Watershed Protection. In summary, these investigative methods include Retrofit Scoping, Desktop Retrofit Analysis, Retrofit Reconnaissance Field Investigation, and Retrofit Ranking. After these methods were completed, a Treatment Analysis based on cost estimates was conducted for most retrofits. A summary of the methods used is described below.

Retrofit Scoping

The subwatershed was divided into three catchments – one per lake – based on drainage boundaries (Figure 5). Each catchment was then analyzed using standard land use files in WinSLAMM software to determine a base load of TP and TSS. The WinSLAMM parameters and standard land use files used can be seen in Appendix A. These base loads were used to identify and prioritize catchments with a greater pollutant load for retrofits. For consistency with previous studies conducted with VLAWMO, neither street-sweeping nor small-scale BMPs were taken into account during the base load modeling, although North Oaks does sweep streets once per year. The natural treatment system consisting of a network of wetlands and stormwater ponds was, however, taken into account via elimination from the model as pollution sources. This land cover, with its associated soil classification of muck, is a natural filter and sink for pollutants, and WinSLAMM does not account for this soil type. For this reason, the acres of wetland classified as muck soil were removed from the model, thus reducing the overall base loads in all catchments. All steps used to calculate the base load modeling were done consistently for all three catchments so that an overall precise comparison could be made between them. More precise pollutant loads for each retrofit opportunity found within the drainage areas are presented below in the results.

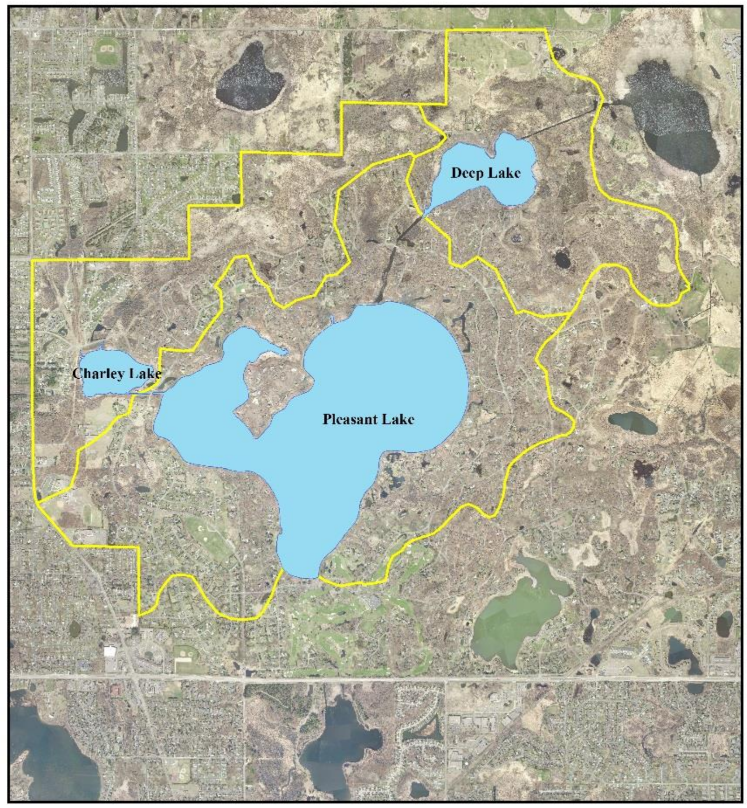

Figure 5. Division of subwatershed into 3 lake catchments

Desktop Retrofit Analysis

A desktop search for potential retrofit locations was conducted for each catchment to identify potential retrofit opportunities. GIS layers including land use, elevation, soils, hydrologic boundaries, cadastral information, high-resolution aerial photography, water quality data, and storm drainage infrastructure were reviewed to determine potential retrofit placement.

Many BMP retrofits in this study were concentrated around areas with stormwater infrastructure in order to intercept urban runoff before entering untreated into underground stormwater conveyance systems. In other areas, BMPs were suggested to treat water in or before entering lakes or stormwater ponds. Due to the Deep Catchment's plethora of stormwater BMPs and wetlands and its low base contaminant load, land-based BMP retrofits were prioritized in Pleasant and Charley catchments. Since Deep Lake has high internal phosphorus loading, however, treatment is recommended for the lake itself.

Retrofit Reconnaissance Investigation

After identifying potential retrofit sites through the desktop search, a field investigation was conducted to evaluate previously identified sites, identify additional sites, and determine the type of BMP. During the investigation, the drainage area and stormwater infrastructure mapping data were verified. All roads in the study area were driven. Site constraints were assessed to determine the most feasible retrofit options as well as to eliminate unfeasible sites from consideration. At this stage, some shoreline restoration options were discarded due to lack of public access. The North Oaks Homeowners Association does, however, spend around $30,000 annually on shoreline preservation projects, and many additional shoreline restoration projects are on their priority list (NOHOA, 2015). New housing developments were visited and their Stormwater Pollution Prevention Plans were reviewed.

Treatment Analysis/Cost Estimates

Retrofit Neighborshed Delineation

After the retrofit sites were identified, the bioretention basins' individual drainage areas or "neighborsheds," consisting of runoff from surrounding streets, buildings, and landscaped areas were delineated using GIS and contour data. See an example in Figure 6. This information, in conjunction with land cover and NRCS soil survey data, was used to model the pollutant loads from these sites. The neighborshed acreage was entered into the WinSLAMM program along with its corresponding land use

Figure 6. An example neighborshed and the source areas that are entered into WinSLAMM

and soil type. To maintain consistency, all standard file data used in WinSLAMM, listed in Appendix A, was the same for each site modeled.

Retrofit Modeling & Sizing

Appropriate retrofits were identified and customized, depending on the neighborshed size, the soil type, the type of infrastructure present, and the slope of the retrofit area. The retrofit/treatment types identified include: swales, alum treatment, iron-enhanced sand filtration, shoreline restoration, bank stabilization, and bioretention. The majority of residential bioretention BMPs modeled were sized at 300 square feet due to the space afforded by the low-density residential area and the capacity to treat large amounts of stormwater. Designs and sizes may vary, depending on the individual sites and homeowner's preferences. Bioretention retrofits were then entered into each neighborshed WinSLAMM model to determine their capability to reduce TP and TSS for the given area. Many suggested BMPs were not modeled at this time, since they do not fit WinSLAMM models or they occur in unfinished construction sites where newly graded soils do not match Digital Elevation Model data available.

Retrofit Types

Swales – Grassed or Bioswales This practice is primarily used for treatment of surface runoff before it reaches a water body. It consists of a vegetation-filled drainage course with gently sloping sides, often accompanied by check dams and/or rain gardens to assist the vegetation in slowing flow, increasing infiltration, and improving removal of pollutants from stormwater. This BMP is a good option in parts of North Oaks where mowed grass ditches are the primary form of stormwater conveyance.

Alum treatment (Aluminum Sulfate) This chemical treatment is used for water bodies such as ponds or small lakes in order to precipitate out phosphorus, rendering it unavailable for algae, and thus improving water clarity as it reduces total phosphorus. This treatment is most effective in water bodies with predominantly internal nutrient loading.

Iron-enhanced sand filtration This can be used either as a separate BMP or as a retrofit to an existing stormwater pond, as it is presented in this assessment. While the filter itself can take many forms, the basic principle is that iron filings are mixed in with sand to make a porous medium. As stormwater filters through, phophates and other dissolved constituents bind with the iron, and are thus removed from the water. This is a successful technique for reducing phosphorus levels, but it requires maintenance and must not be submerged underwater for long periods of time.

Shoreline restoration This is appropriate along degraded shorelines of Pleasant, Charley, and Deep Lakes. The process largely consists of establishment or maintenance of a native vegetation buffer along the shoreline to filter runoff and prevent wave erosion.

Bank stabilization This practice is particularly appropriate along the canals connecting the lakes. Depending on the force of flow and the level of bank erosion, stabilization may consist of native plug or live stake planting of shrubs, trees, or other vegetation with strong roots. In cases with higher flows and severe undercutting, regrading, riprap, and other reinforcement may be needed in conjunction with vegetation.

Bioretention This type of retrofit is effective at intercepting stormwater runoff for treatment before entering stormwater conveyance systems. A bioretention basin, also referred to as a rain garden, consists of a depression utilizing native soils or engineered soils (depending on the infiltrative capacity of the soil), along with native vegetation. An underdrain with connection to the existing storm sewer system is recommended if infiltration capability is limited by underlying soils or soil compaction. It is important to properly design and install the engineered soils so that the bioretention basins take no less than 24 hours to drain but no more than 48 hours, so the underdrain can be installed with a plug that can be removed in the event of poor drainage. The bioretention basins in this study fall within the categories listed below:

- Simple Bioretention – Includes engineered soils, native vegetation, and an underdrain. No concrete work necessary.
- Moderately Complex Bioretention - Includes engineered soils, native vegetation, engineered soils, an underdrain, a curb cut, and a forebay. No retaining wall necessary.
- Complex Bioretention – Includes engineered soils, native vegetation, underdrain, a curb cut, a forebay, a retaining wall with sand/rock columns.

A schematic of the bioretention basin and example modeling parameters used within WinSLAMM can be seen in Appendix B.

Retrofit Cost Estimates

Costs were not estimated for all retrofit types due to time, access, or data restrictions, but all proposed bioretention features were modeled, with associated cost estimates listed in sections below. Each was assigned an estimated materials, design, and installation cost given its ft^2 of treatment. These cost estimates were derived from recent installation costs provided by design and construction professionals, updated in December of 2015. A cost-per-lb of TP removed was then calculated for the 30-year life cycle of each retrofit, using the (total 1st year cost + 29 years * annual maintenance) / (30 year * TP removed (lb/yr)). This value was used for the cost-benefit ranking of the retrofits. Costs will vary depending on contractor, selected materials, slope and soils of the land, and other variables. Total first year cost used in calculations was the midpoint between the Lower and Upper Range costs seen in Table 3.

Table 3. Average Bioretention BMP Cost Estimates, revised December 2015

Average BMP Design and Installation Estimates, December 2015		
Bioretention BMP Description	**Lower Range ($/ft²)**	**Upper Range ($/ft2)**
Simple Bioretention: Includes engineered soils, native vegetation, and an underdrain. No concrete work necessary.	$15.00	$20.00
Moderately Complex Bioretention: Includes engineered soils, native vegetation, engineered soils, an underdrain, a curb cut, and a forebay. No retaining wall necessary.	$30.00	$35.00
Complex Bioretention: Includes engineered soils, native vegetation, underdrain, a curb cut, a forebay, a retaining wall with sand/rock columns.	$35.00	$40.00

Note: Estimate does not include 30-year Operation & Maintenance Cost

Results

Catchment Comparison

The three catchments and their total modeled TP and TSS base loads from surface runoff are listed in Table 4 below. This information was used in prioritizing catchments for retrofit installation. While Charley and Pleasant catchments have similar values for pounds of pollutants/acre, Deep catchment has lower values in both TP and TSS, so it received less priority in the retrofit assessment for surface runoff retrofits. Furthermore, much of Deep catchment is a natural resource area or preserve (Metropolitan Council, 2010), and the Rapp Farms housing development (currently under construction) has excavated an extensive system of stormwater ponds to pre-treat their surface runoff. For these reasons, recommendations in the Deep Catchment pertain specifically to Deep Lake and its canals to treat internal loading, while more extensive retrofits were proposed in the Pleasant and Charley Catchments.

Table 4. Base loads for Pleasant, Charley, and Deep catchments, as modeled in WinSLAMM

Drainage Area	Acres	Total TP lbs/ Year	TP lbs/Acre/Year	Total TSS lbs/ Year	TSS lbs/Acre/Year
Pleasant	1844	315	.17	74,297	40.30
Charley	728	133	.18	35,803	49.17
Deep	678	98	.14	19,520	28.78

Catchment Results

The following section shows results per catchment, including maps and tables showing retrofit locations and the TP and TSS reduction per retrofit. Maps include detailed retrofit locations as well as an overview map (Figure 7) to show all proposed retrofits within the subwatershed area.

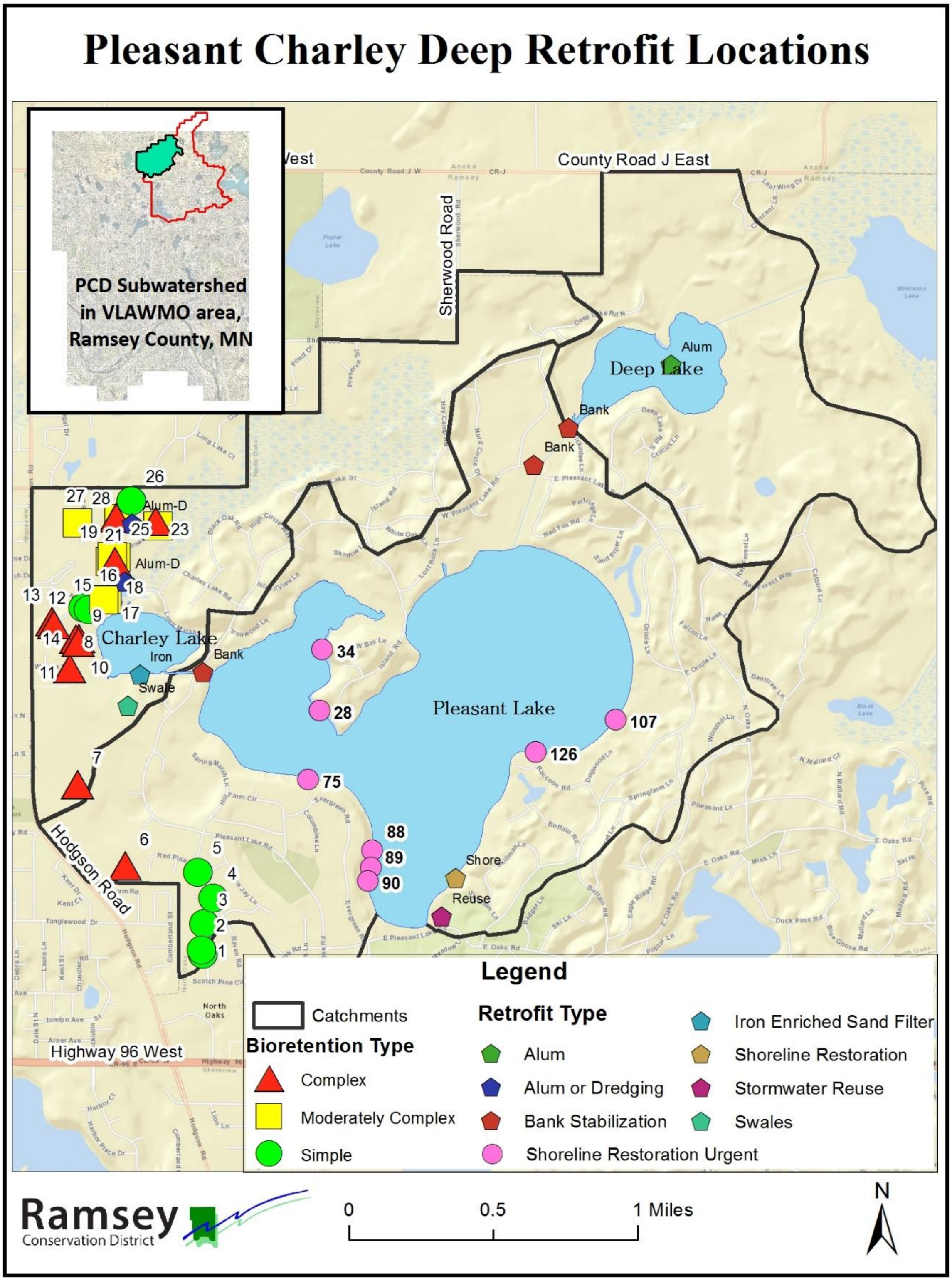

Figure 7. Map of proposed retrofits and BMP sites in Pleasant Charley Deep subwatershed.

Below is a guide to the column headings for Table 5's retrofit summary:

- ID – a unique site ID number per proposed retrofit
- Catchment – hydrologic division of land whose water flows in toward the lake
- Bioretention Type – Simple, Moderately Complex, or Complex bioretention BMP
- TSS Removed – the Total Suspended Solids removed by the retrofit (lb/year)
- TP Removed – the Total Phosphorus removed by the retrofit (lb/year)
- BMP area – proposed size of modeled retrofit (square feet)
- Total Initial cost– cost estimates of materials, labor, and design for 1st year implementation
- Annual O & M – estimated Operation & Maintenance cost per year (30 year term)
- Cost/lb P Removed/yr – Cost per pound of TP removed in the 30 year life span. Retrofits are ranked from lowest to highest by this number in results tables found in catchment results below.

Table 5. Results for the 28 proposed bioretention retrofits

ID	Catchment	Bioretention Type	TSS removed lb/year	TP removed lb/yr	BMP area ft2	Total Initial Cost	Annual O&M	Cost/lb P removed/yr (30 yr)
1	Pleasant	simple	205	0.641	300	$ 5,250	$ 225	$ 612
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28	Charley	moderate	515	1.43	300	$ 9,750	$ 225	$ 379

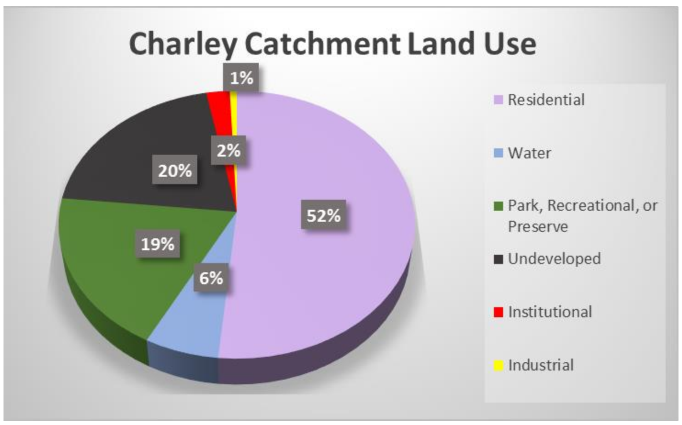
A size of 300 ft^2 was determined to be appropriate for rain gardens in this residential area, maximizing the benefit of runoff treatment without excessive encroachment on homeowners' lawns. Sizes and designs may be adapted to individual properties.

Charley Lake Catchment

DESCRIPTION

Charley Catchment Base Load	
Acres	728.2
TP (lbs/yr)	133
TP(lbs)/Acre/Yr	0.18
TSS (lbs/yr)	35,803
TSS(lbs)/Acre/Yr	49.17

The elongated Charley Lake catchment has a more newly developed western half, near Hodgson Rd, and an eastern half that is mostly undeveloped or natural preserve, with some single family homes in forested areas bordering the Pleasant Lake catchment. This catchment is unique in that it is the direct recipient for pumped Mississippi River water, at the northwest corner of the lake.



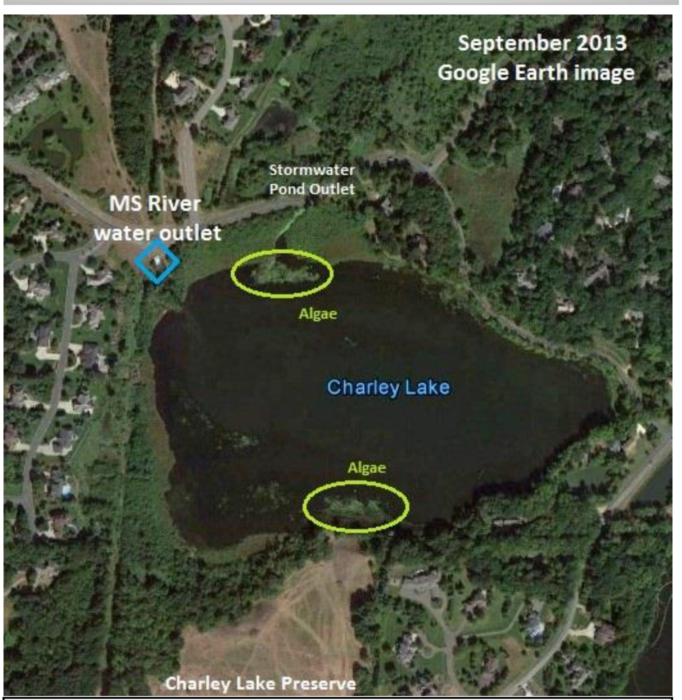


Figure 8. This September 2013 image shows algal blooms at the outlets of both Charley Lake Preserve's construction site, and at the Stormwater Pond Outlet for lawn runoff from homes at Peterson & Wildflower roads.

At the southern tip of the catchment, Chippewa Middle School and Peace United Methodist Church comprise the institutional land use. Both have runoff that largely drains west to Hodgson Rd's stormwater infrastructure, though one retrofit was identified for a section of school property that drains inward toward Charley Lake.

Just south of Charley Lake, a new housing development called Charley Lake Preserve is currently being completed. The full-turf lawns and ditches of this neighborhood are a departure from North Oaks' more traditional, wooded residential areas, and the increased runoff from those lawns and ditches- particularly the acres that drain to Charley Lake – create opportunities for BMPs to reduce runoff and treat water before entering the lake, particularly with the high amounts of lawn clippings and fertilizers of the runoff and the minimal treatment the water receives before entering the lake.

To the west and north of Charley Lake, there is a range of single and multi-family homes with a mix of turf lawns and trees. The runoff from these homes enters stormwater ponds by way of stormwater infrastructure. Water from the stormwater ponds enters Charley Lake after passing through canals, providing some level of treatment. Nevertheless, water entering Charley Lake from the stormwater pond outlet provides phosphorus and other nutrients to Charley Lake, prompting algal blooms (see Figure 8). A great concentration of suggested retrofits is found in this area of the catchment, where stormwater can be intercepted before it reaches the stormwater conveyance infrastructure.

The Mississippi River canal entering Charley Lake, while stabilized, should be monitored regularly for needed maintenance due to the high flow passing through this confined area. In areas of undercutting and erosion, additional riprap can be added to the channel with native plantings and perennials to help stabilize the banks.

The soils within the area where retrofit opportunities were identified consists of loamy fine sand with the exception of Chippewa Middle School, where the soil is loam.

RETROFIT RECOMMENDATION

Charley Lake has a diverse mix of retrofit recommendations, comprised of swales, bioretention, bank stabilization, iron enhanced sand filters, and alum treatment. This is due to the diversity of stormwater conveyance methods and loading sources to Charley Lake. To contrast two housing developments, for instance, the residential area northwest of Charley Lake uses catch basins and underground stormwater infrastructure before eventual outlet to the lake, so rain gardens (bioretention) of various complexity are recommended for this area to intercept polluted stormwater for treatment before it goes underground. South of Charley Lake, however, mowed turf ditches are the stormwater conveyance path, affording opportunities to reduce and treat stormwater in the ditch itself, with a larger 'neighborshed' of all the runoff uphill of it.

In the northeast parking lot of Chippewa Middle School, a complex bioretention retrofit is proposed for water draining toward Charley Lake. In Retrofit #7, four parking spots would be removed to create a raingarden to reduce runoff causing a gully just north of the site (Figure 9).

Figure 9. Location for retrofit 7 (left). Proposed removal of 4 parking lots and installation of rain garden to treat Chippewa Middle School runoff currently causing gully formation (right).

Due to the large turnover of fast-moving water in Charley Lake, internal loading is far outweighed by the external loading of nutrients from the Mississippi River water, in addition to nutrients contributed by runoff from neighboring residential areas. The stormwater ponds that hold runoff before discharge into Charley Lake could benefit from retrofits as well, as discussed below.

In the residential areas north and west of Charley Lake, the stormwater ponds and canals have adequate vegetative buffers, so the external phosphorus loading can be reduced at the street level – by using BMPs such as rain gardens to filter lawn runoff before it enters the ponds. Internal phosphorus loading of the stormwater ponds themselves can be reduced through BMPs such as dredging or aluminum sulfate treatments.

To the south of the lake, there is little space between Charley Lake and the outlet for 28.5 acres of drainage of the new housing development, Charley Lake Preserve. A review of the SWPPP of the NURP pond designed to slow runoff before entering the lake showed that only runoff for ½ inch of rain would be detained, and all additional water would flow directly to the lake without settling out. For this reason, we have several recommendations for Charley Lake Preserve to improve treatment and reduce erosion at the outlet point as well as to improve treatment and reduce runoff in the neighborhood before the water reaches the pond.

Though the stormwater pond cannot be thoroughly evaluated until construction is complete, initial assessment shows room for improvement in its effectiveness. The North Oaks Homeowners Association noticed overflow of the stormwater pond, causing erosion on the footpath between the pond and the lake (NOHOA, 2015). The design should only permit overflow in 100-year precipitation events, so the capacity of the pond could be enhanced. Native plantings would improve stabilization and enhance infiltration and evapotranspiration of stormwater. Even with the stormwater pond functioning as designed, there is little phosphorus removal for the 28 acres of runoff that are directed toward it, so an additional BMP would be very helpful in reducing algal blooms at the outlet of this stormwater pond into the lake.

Figure 10. Location for proposed iron enriched sand filter. Filter can take form of a bench in the Charley Lake Preserve stormpond (left) or as an installation in the rip-rap at the outlet (right).

A very effective retrofit for the stormwater pond would be an iron-enhanced sand filter that could either be placed within the stormwater pond as a bench feature, or positioned at the outlet in the rip-rap area before draining to Charley Lake. Iron-enhanced sand filters have high pollutant removal rates for removing phosphates from water, often used in conjunction with existing ponds to improve the quality of impaired water (MPCA, 2015).

Figure 11. (Left) Charley Lake Preserve's hydrologic divide between runoff flowing southeast toward Pleasant Catchment and the 28.5 acres of urban runoff flowing north toward the Charley Stormwater Pond. (Right) A typical mowed tuf-lined ditch in the Charley Lake Preserve housing development.

In the Charley Lake Preserve development, turf-lined ditches are the stormwater conveyance method for the 28.5 acres of developed land that drain to the NURP pond. Since mowed grass is a leading contributor of phosphorus to stormwater, we suggest implementation of one or a combination of the following measures to decrease this nutrient loading:

- Stop or reduce mowing of the ditches
- Convert ditches to grassed swales or bioswales with periodic check dams to reduce/retard water flow
- Strategically place rain gardens in ditches to capture and infiltrate water before it reaches the stormwater pond.

These BMPS are meant to slow the rate of stormwater conveyance, reduce or filter pollutants, and promote stormwater infiltration. Design, modeling, and placement for these BMPs can be determined once the new elevation data is available for analysis.

In addition, homeowners can take the following measures to improve lake water quality:

- If using lawn fertilizers, only use phosphorus-free varieties
- Use lawnmowers with bags to collect grass-clippings
- Reduce or stop mowing the ditch in front of their homes

The neighborhood in the northwest corner of the Charley catchment was identified as a potential location for multiple clusters of bioretention cells of varied complexity. The retrofits along Lake Court and Charley Lake Court (Sites 8-15) should receive higher priority than the other bioretention sites in this catchment (Sites 16-28) since the latter are located near stormwater ponds intended to provide some level of pretreatment. Site 26, however, should also receive priority because it is an industrial lot, where piles of salt are stored for street-salting; the simple raingarden proposed at that lot's outlet could feature salt-tolerant vegetation which would purify and reduce the salinity of the water before entering the canals leading to Charley Lake. If all 22 bioretention cells are installed in this catchment, it is modeled that 17.0 lbs of TP and 5,665 lbs of TSS would be filtered out per year, resulting in a 12.8% and 15.8% decrease, respectively, from the base load at total project cost of $240,000, not including annual maintenance.

See table and maps below for specific results.

Table 6. Ranked bioretention retrofits for Charley Lake catchment

ID	Bioretention Type	TSS removed lb/year	TP removed lb/yr	BMP area ft2	Total Initial Cost	Annual O&M	Cost/lb P removed/yr (30 yr)
28	moderate	515	1.43	300	$ 9,750	$ 225	$ 379
26	simple	374	1.279	300	$ 5,250	$ 225	$ 307
8	complex	415	1.259	300	$ 11,250	$ 225	$ 471
10	complex	464	1.432	300	$ 11,250	$ 225	$ 414
27	complex	384	1.195	300	$ 11,250	$ 225	$ 496
11	complex	514	1.144	300	$ 11,250	$ 225	$ 518
9	complex	507	1.1313	300	$ 11,250	$ 225	$ 524
24	moderate	286	0.812	300	$ 9,750	$ 225	$ 668
22	moderate	219	0.751	300	$ 9,750	$ 225	$ 722
23	complex	196	0.664	300	$ 11,250	$ 225	$ 892
13	complex	187	0.629	300	$ 11,250	$ 225	$ 942
25	complex	184	0.618	300	$ 11,250	$ 225	$ 959
21	complex	180	0.607	300	$ 11,250	$ 225	$ 976
14	simple	99	0.379	300	$ 5,250	$ 225	$ 1,036
15	simple	111	0.368	300	$ 5,250	$ 225	$ 1,067
18	moderate	152	0.508	300	$ 9,750	$ 225	$ 1,068
16	moderate	197	0.444	300	$ 9,750	$ 225	$ 1,222
12	complex	143	0.463	300	$ 11,250	$ 225	$ 1,280
20	moderate	126	0.421	300	$ 9,750	$ 225	$ 1,289
7	complex	254	0.959	900	$ 33,750	$ 675	$ 1,853
19	moderate	85	0.262	300	$ 9,750	$ 225	$ 2,071
17	moderate	73	0.226	300	$ 9,750	$ 225	$ 2,400

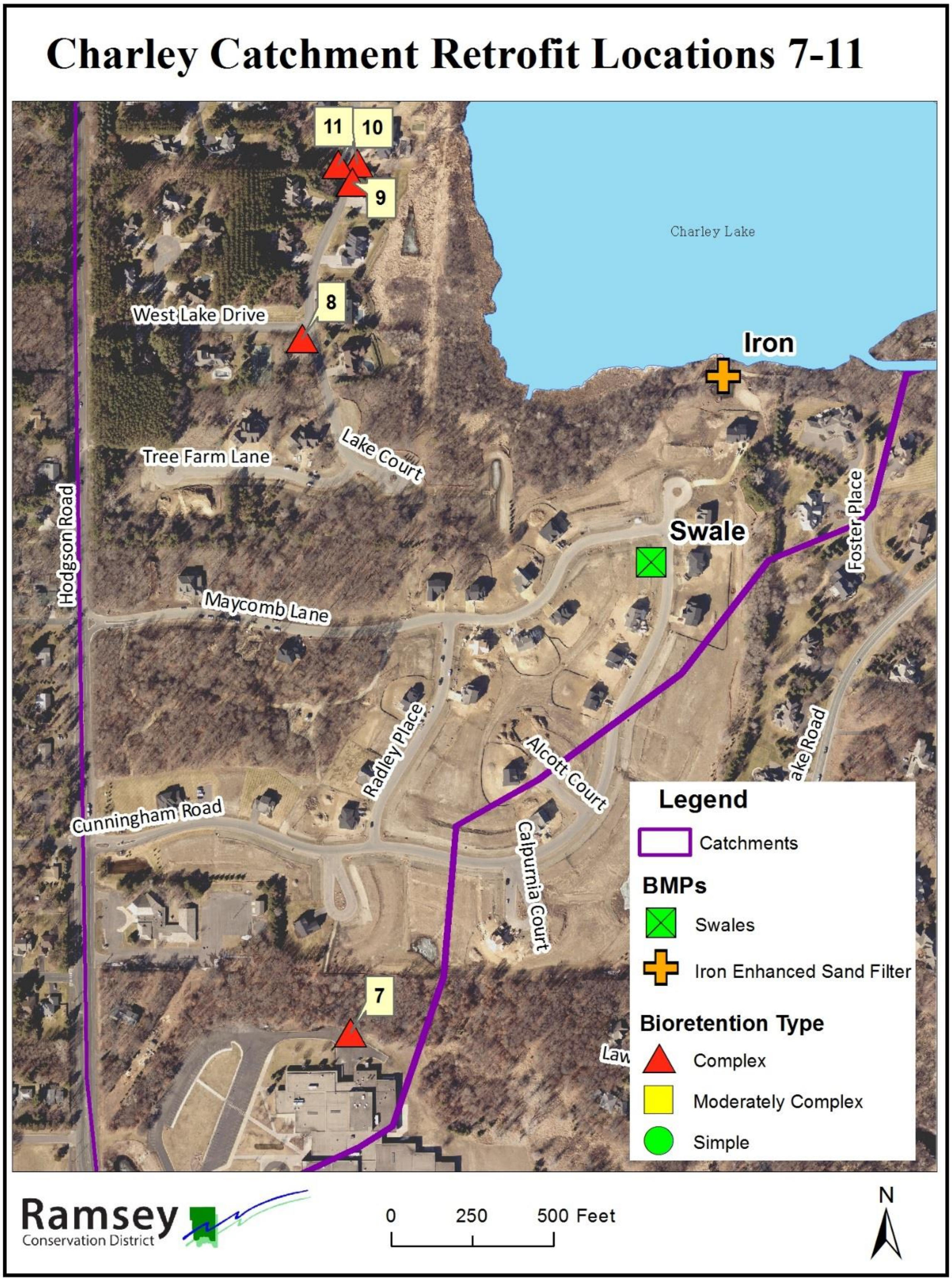


Figure 12. Proposed retrofit locations for the area south of Charley Lake (7-11)

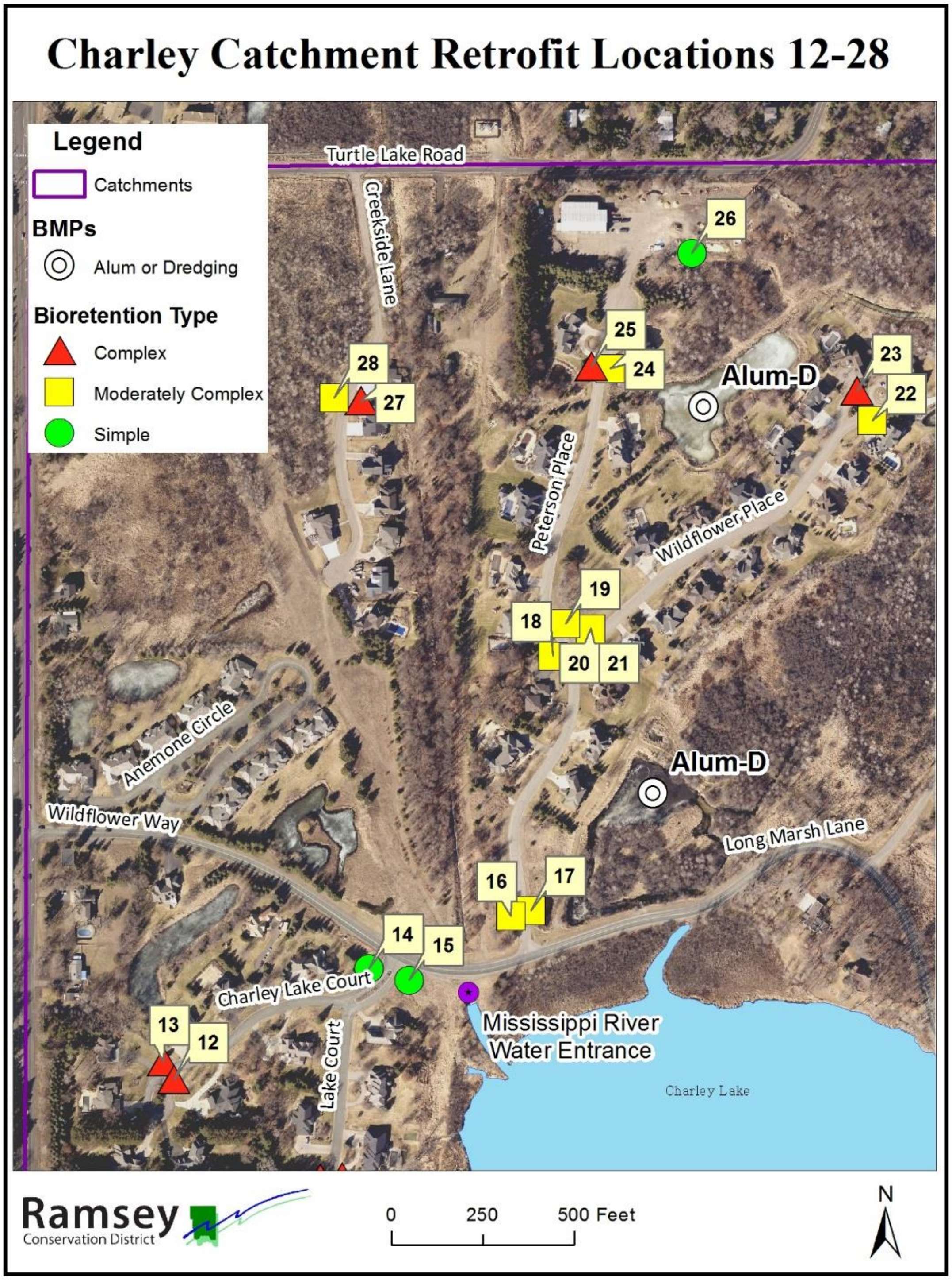


Figure 13. Retrofit locations for the area northwest of Charley Lake (12-28)

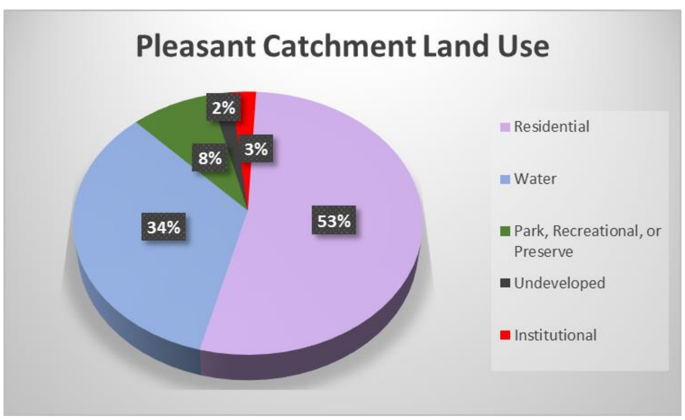
Pleasant Lake Catchment

DESCRIPTION

Pleasant Catchment Base Load	
Acres	1843.5
TP (lbs/yr)	315
TP(lbs)/Acre/Yr	0.17
TSS (lbs/yr)	74,297
TSS(lbs)/Acre/Yr	40.30

The majority of this catchment is composed of low-density residential land use, with small institutional, recreational, and undeveloped portions. Water enters Pleasant Lake via canals from Deep Lake and Charley Lake, as well as from a large number of wetland drainage areas. Much of the area directly surrounding Pleasant Lake around the north and east is composed of wetlands, serving as a natural buffer and barrier for pollutants. The peninsula in the northwest section of the catchment could have potential for shoreline restoration BMPs, but lack of access to the private shoreline prohibited the field investigation of practices currently in place protecting the lake in this area. Nevertheless, NOHOA had identified existing needed shoreline restoration sites that are included in the retrofit recommendations below.

The only stormwater infrastructure in this catchment is located in the southwest corner, and rather than curb cuts, the drainage is mostly beehive storm drains in depressions from curb-less road areas. For this reason, simple bioretention retrofits were proposed. To the west, Hodgson Road marks the catchment boundary. Two additional BMPs were considered at the entrances to the Incarnation Lutheran Church on Hodgson Rd but were discarded because the stormwater does not drain into Pleasant Lake. The soils within the area where retrofit opportunities were identified consist of loamy fine sand which would allow for simple bioretention if found to not be compacted or polluted.



In 2013, an oxygenation system with branches in the east and west sides of Pleasant Lake was installed with the objective of improving water quality and reducing phosphorus load (Laur, 2013). Samplings from both sides of Pleasant Lake by St Paul Regional Water Services over 2012-2015 indicate a stark drop in phosphorus levels after the introduction of this system (Figure 14). Water from Pleasant Lake, after passing southward toward the McCarrons treatment plant, is used by St Paul Regional Water Services to supply over 400,000 residents.

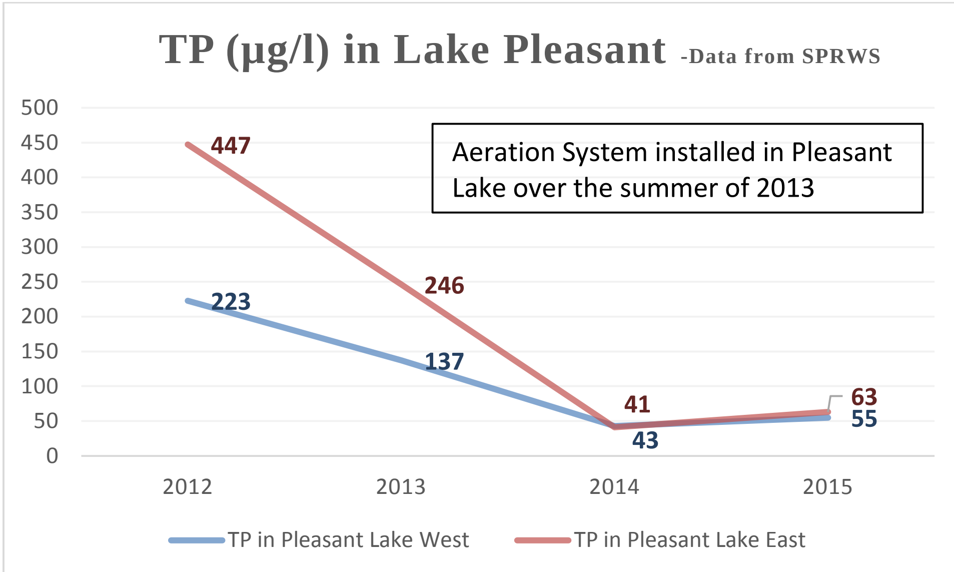


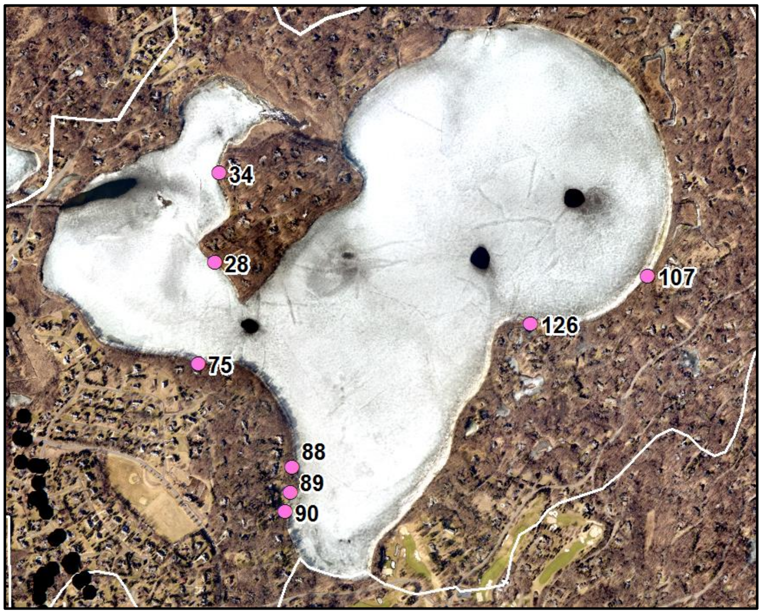
Figure 14. Reduction in phosphorus in Lake Pleasant after the introduction of an oxygenation system. Data from St Paul Regional Water Services. Values shown are annual averages of monthly samples taken May-October (for 2012, April –September). Note: All data were included in the averages, including outliers. (*ie*, if Pleasant Lake East's highest 2012 value of 2115 µg/l had been excluded, the average would be 336 µg/l).

RETROFIT RECOMMENDATION

The recommendations for the Pleasant Catchment range from bank stabilization in the Charley-Pleasant canal to shoreland restorations to bioretention basins, with additional commentary on the North Oaks Golf area.

One beneficial project the North Oaks Golf Club has considered (and many local courses have implemented) is the use of stormwater runoff as irrigation for the green. This practice would save millions of gallons of water from being pumped from Pleasant Lake annually and would filter pollutants and nutrients from stormwater runoff. Golf courses have the space to store stormwater runoff and can incorporate ponds into their landscape in an aesthetic and functional way. As a large industry and water user, golf courses have the opportunity to show leadership in responsible water stewardship (Dunbar, 2014).

The retrofit recommendations in this section are a product of reconnaissance visits, meetings with VLAWMO and NOHOA to identify the greatest areas of concern, modeled pollutant loading reductions from designed bioretention basins, and an assessment of work already conducted to improve shorelines around Pleasant Lake.



Though RCD staff did not visit shoreline private property, a Pleasant Lake Shoreline Evaluation was conducted in 2009 by Great River Greening to identify and rank the most urgent erosion problem sites along the shore. Of the original 17 sites listed as urgent by the study, NOHOA oversaw the correction of 9 of those sites, in addition to dozens of other high priority areas. The 8 remaining urgent sites are listed in this study in the following map and table. The original waypoint numbers were maintained for ease of reference to the original document.

Figure 15. Map of the urgent sites identified in 2009 by Great River Greening Pleasant in the Lake Shoreline Evaluation that are unaddressed as of December 2015 (source: NOHOA, 2015)

Table 7. Pleasant Lake Shoreline "urgent" erosion areas that have not yet been addressed

ID#	Problem	Recommendation
28	Trailside erosion and buckthorn.	Remove buckthorn and plant native vegetation
34	Steep trailside erosion	Install soft armor wall system, revegetate
75	5' sheer bank, trailside erosion	Willow and other live stakes for stabilization
88	Mowing up to water, erosion near trail	Regrade, replant transitional zone, live stakes
89	Mowing up to water, erosion near trail	Regrade, replant transitional zone, live stakes
90	Mowing up to water, erosion near trail	Regrade, replant transitional zone, live stakes
107	Undercutting of trail	Soft-wall system, revegetate about 50' shoreline
126	Buffer was mowed, erosion near trail	Shoreline restoration for at least 100 feet

The Pleasant Lake Shoreline Evaluation, held by NOHOA, has more detail.

In addition to the urgent sites identified by Great River Greening, RCD has identified additional opportunities to restore shoreline along one part of the golf course and stabilize banks along the channels connecting the lakes.

At the northwest corner of the North Oaks Golf Club at in the backyard of 5 Skillman Lane, there is a gap in the vegetated area with a very thin vegetative buffer between the sloping, highly mown lawn and Pleasant Lake. This site, in addition to the back yards of residences on Evergreen Rd seen across the lake (see image below) would benefit from a stronger vegetative buffer. In the case of the Evergreen Rd, additional shoreline stabilization may be required since these sites were highlighted in the 2009 study as urgent erosive threats to the Pleasant Lake Trail and shoreline. A turf to native vegetation conversion would be beneficial as a strip between the lawn and the lake.

Figure 16. (Top left) Aerial view of lawns on Evergreen Lane (and resultant algal bloom) (lawns visible in bottom image) and the backyard of 5 Skillman Lane (close-up in the upper-right hand photo). These lawns would benefit from shoreline restoration BMPs.

The channel connecting Charley Lake to Pleasant Lake, particularly just east of W Pleasant Lake Rd, has erosion and undercutting of the north bank (Figure 17). Though rock is visible from past stabilization, this section of the channel requires improved stabilization to prevent further lost soil and collapsing trees, which are visible on the south bank.

Figure 17. Erosion on the Charley-Pleasant channel, just east of W Pleasant Lake Rd.

Additionally, there is bank erosion north of the E Pleasant Lake Rd bridge on the Deep-Pleasant channel. This is a section of the channel that is narrower than the rest, where water must travel faster, and with this force through the bottleneck of the bridge area, erosion has occurred on both banks north of the bridge, but not south, where the channel is considerably wider. In Figure 18, small trees on both banks can be seen falling inward as soil is slumping. Additional bank stabilization is suggested here to reduce the amount of soil and nutrients directly entering the system.

Figure 18. Proposed bank stabilization site, north of the E Pleasant Lake Rd bridge on the Deep-Pleasant channel

North of this road bridge, a pedestrian bridge near the end of Chickadee Rd also shows signs of minor erosion around the foundations of the bridge on the north side, so this is another area where preventative maintenance of streambank stabilization would be helpful to reduce erosion in the channel. The channel should be monitored for sedimentation levels to determine at what point dredging would be beneficial to remove accumulated sediment with trapped phosphorus, which is a source for internal nutrient loading.

NOHOA leadership has expressed its concern about the variability of the pumping rate of Mississippi River water into Charley Lake (Figure 19), which they feel increases the shoreline's vulnerability to erosion due to fluctuations in shoreline water levels (NOHOA, 2015). Their concern is that buffers and other restoration projects are jeopardized with the changing water level.

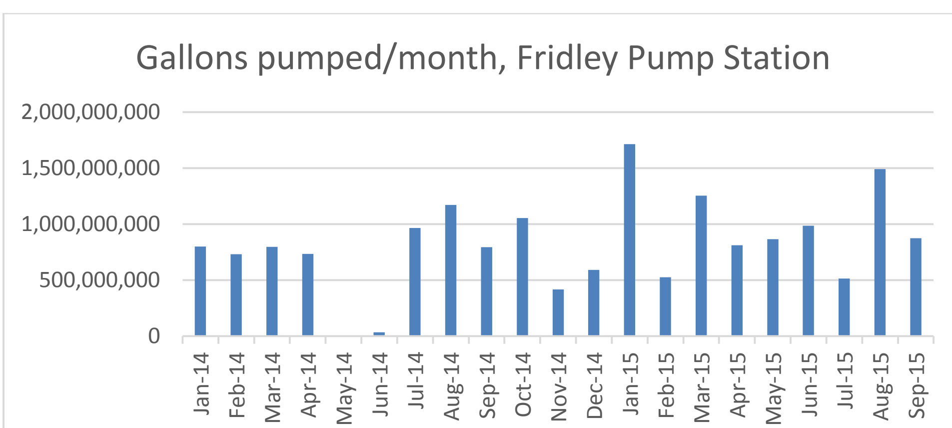


Figure 19. Gallons of Mississippi River pumped monthly to Charley Lake from Fridley Pump Station (source: SPRWS, 2015).

In the southwest of Pleasant Catchment, where stormwater infrastructure is concentrated, bioretention retrofits are proposed. Five residential locations were identified for retrofits in the Scotch Pine/Raven Road area (see map below). Simple bioretention retrofits were chosen due to the simple beehive stormwater structures in depressions beside the roads without necessitating curb cuts or retaining walls. The proposed retrofit in the east parking lot of Incarnation Lutheran Church is in an area prone to flooding (Figure 20) where drainage is currently inadequate. This bioretention basin is considered complex because several parking spaces would need to be removed, and the compacted soils would need to be excavated and replaced by engineered soils. If all proposed bioretention retrofits are installed within this catchment, it is modeled that 5.72 lbs of TP and 2202 lbs of TSS would be removed from the catchment, resulting in a 1.8% and 3.0% decrease from the base load, respectively, at an initial total project cost of $76,875.

Table 8. Ranked bioretention retrofits for Pleasant Lake catchment

ID	Bioretention Type	TSS removed lb/year	TP removed lb/yr	BMP area ft2	Total Initial Cost	Annual O&M	Cost/lb P removed/yr (30 yr)
2	simple	405	1.228	300	$ 5,250	$ 225	$ 320
4	simple	367	1.077	300	$ 5,250	$ 225	$ 364
3	simple	340	1.002	300	$ 5,250	$ 225	$ 392
1	simple	205	0.641	300	$ 5,250	$ 225	$ 612
5	simple	163	0.484	300	$ 5,250	$ 225	$ 811
6	complex	722	1.291	1350	$ 50,625	$ 1,013	$ 2,065

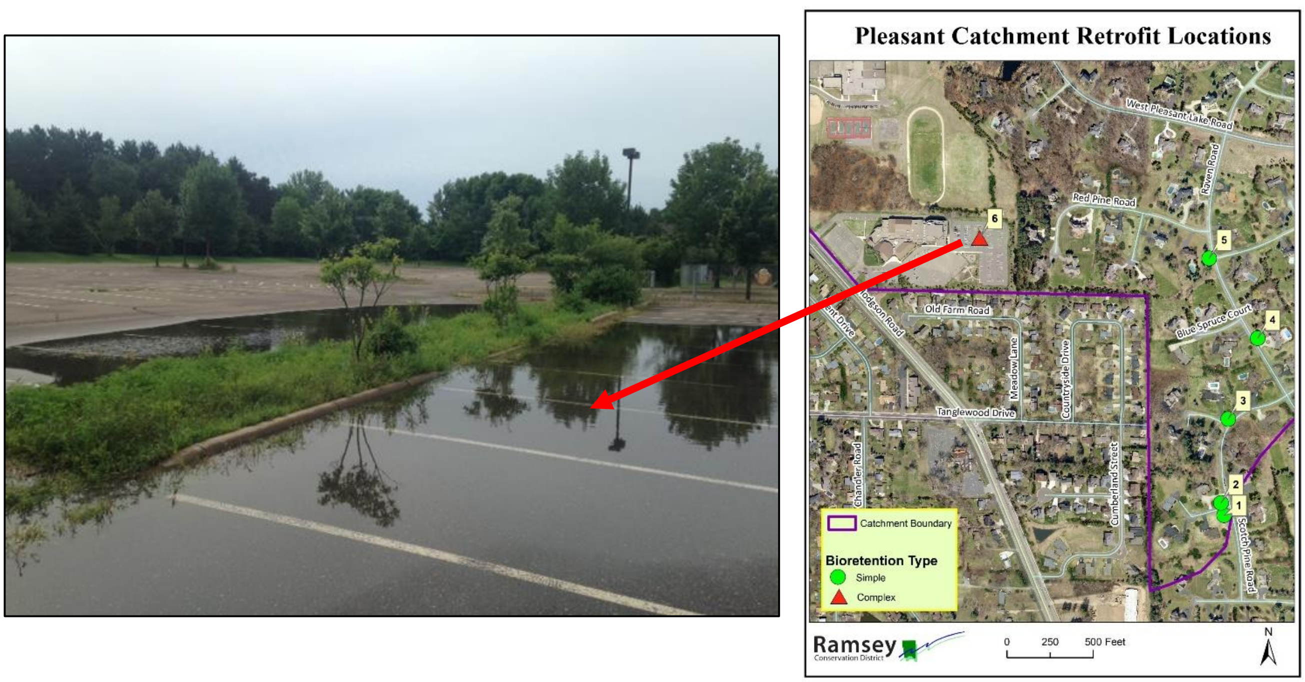


Figure 20. Flooding at Site 6 (left) in the Pleasant catchment (August 2015), Incarnation Lutheran Church parking lot. The proposed BMP involves removing some parking spaces to expand the vegetated area, creating a raingarden to which most of the back parking lot drains. (Right). Map of bioretention sites 1-6, Pleasant Catchment.

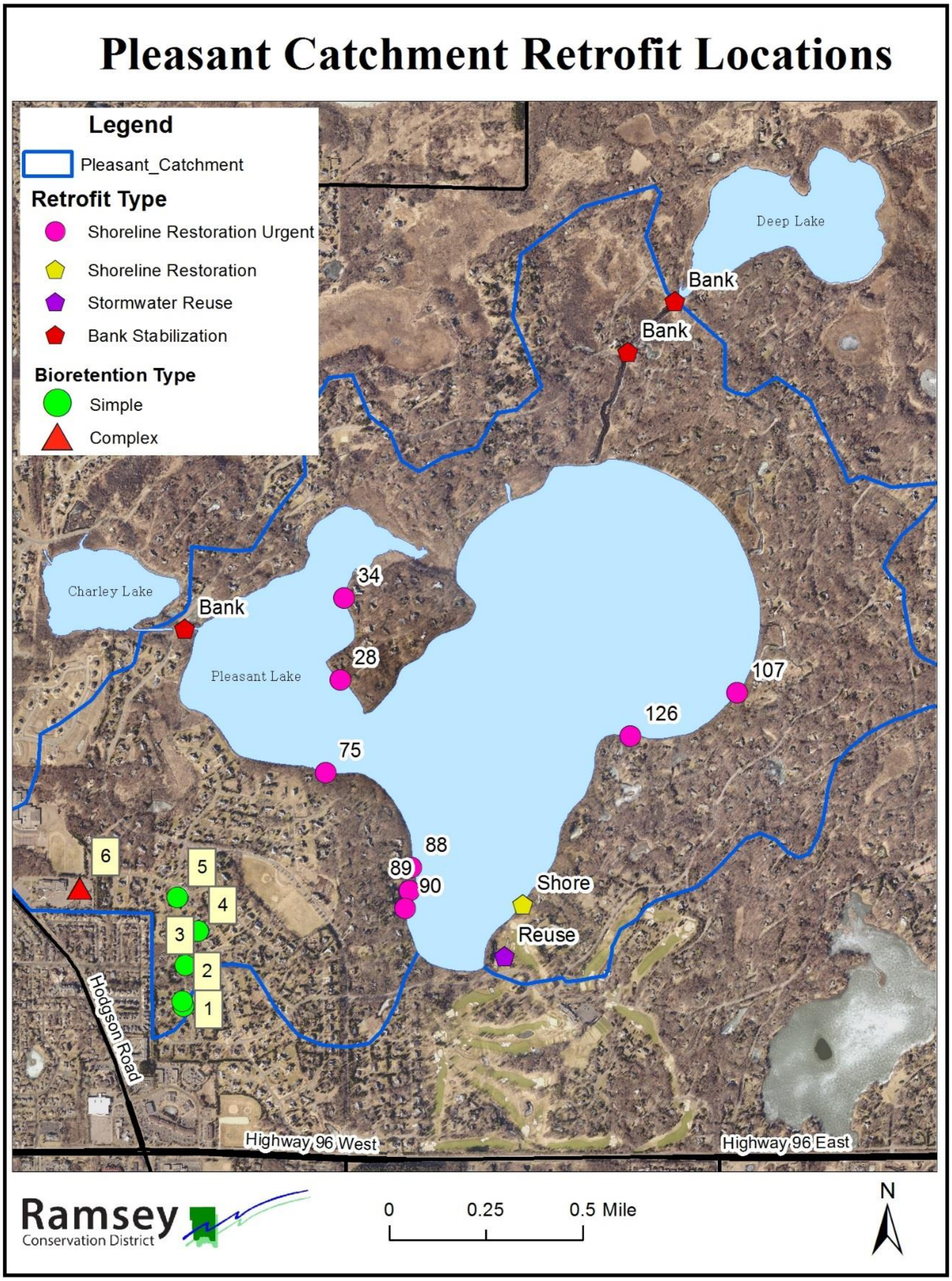


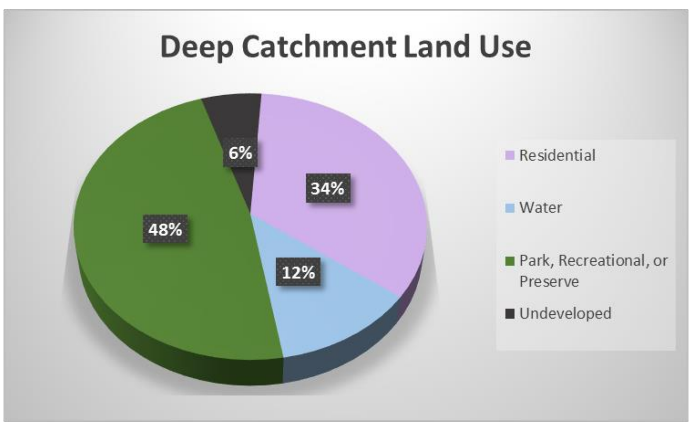
Figure 21. Retrofit locations for the Pleasant catchment, southwest of Pleasant Lake

Deep Lake Catchment

DESCRIPTION

Deep Catchment Base Load	
Acres	678.2
TP (lbs/yr)	98
TP(lbs)/Acre/Yr	0.14
TSS (lbs/yr)	19,520
TSS(lbs)/Acre/Yr	28.78

Two thirds of the Deep Lake catchment is composed of water, preserve or undeveloped land, with one third of land use being residential. There are two types of residential areas – an older densely wooded area in the south, and a new development with turf lawns in the north. The old residential area in Deep Catchment is at low risk for introducing excess nutrients to the lake. The new residential development, Rapp Farms, is treating its runoff locally with stormwater ponds and infiltration trenches with ample distance between the ponds on the lake, reducing risk of external loading from this source as well. Rapp Farms is exceeding the requirements for stormwater treatment and providing an average of 70% phosphorus reduction to surface runoff, according to their Stormwater Pollution Prevention Plan. Due to the relatively low modeled nutrient contribution to the catchment, retrofits in this area were concentrated on Deep Lake itself, which has the highest concentration of total phosphorus and total suspended solids of the three lakes, and the canal conveying water from Deep Lake to Pleasant Lake, which falls mostly in the Pleasant catchment.



To address concerns of erosion and invasive species along the canal between Deep and Pleasant Lakes, VLAWMO and the Ramsey Conservation District, along with the Conservation Corps and North Oaks Homeowners Association, conducted a shoreline restoration project in September 2015 to remove invasive species, plant native vegetation, and install rip-rap for improved bank stabilization at the point of entry to Pleasant Lake.

RETROFIT RECOMMENDATION

Deep Lake-the lake with the highest nutrient concentration and the lowest external loading in the subwatershed-is most likely receiving most of its phosphorus internally (interaction with the shallow, phosphorus-rich sediment bed) as well as an external source, the impaired Wilkinson Lake, which is connected via canal. For this reason, potential solutions are directed toward Deep Lake itself, with potential future work in Wilkinson Lake and the canal that connects them.

The treatment recommendation for Deep Lake is aluminum sulfate application. For ponds and small lakes with largely internal loading, "alum" is a common treatment to reduce phosphorus in the water (DNR, 2003). Alum, when mixed with water, forms an aluminum hydroxide precipitate, that then binds with phosphorus to form aluminum phosphate and settles out at the bottom, further binding with phosphorus in bottom sediment. A Wisconsin study found this treatment effective in six out of nine shallow lakes, controlling phosphorus for at least eight years (DNR, 2003). Limnologists and alum professionals should be consulted prior to using this treatment to determine whether alum should be used at this lake (factors such as pH are important to consider for the health of aquatic life) and if so, at what dosage (Barr, 2005).

Dredging, though costly, is another potential method for reducing internal nutrient loading, since much of the phosphorus accumulates in sediment at the bottom of lakes or canals with slow-moving water. Depth of accumulated sediment was not measured in this study, so further study, including a cost-benefit analysis, will be necessary before choosing this option to reduce internal nutrient loading. A comparison of alum treatment versus dredging to reduce phosphorus in lakes can be reviewed in the Internal Phosphorus Load Study: Kohlman and Keller Lakes study performed by Barr in 2005.

Conclusions and Recommendations

The objective of the study was to present a detailed review of the drainage area within the Pleasant Charley Deep subwatershed in order to identify the most cost-effective retrofits to existing stormwater conveyance practices that could be implemented to improve water quality, reduce runoff, reduce TP and TSS, and enhance groundwater recharge.

If all 28 of the proposed bioretention retrofits were implemented, models indicate an annual reduction of 1.8% TP and 3.0% TSS in the Pleasant catchment and 12.8% TP and 15.8% TSS in the Charley catchment (Table 9).

Table 9. Total annual reduction of TP and TSS from base load if all 28 bioretention features are implemented, as modeled by WinSLAMM.

Catchment	Pollutant	Total Reduction (lb/year)	Base Load (lb/year)	% Reduction
Pleasant	TP	5.723	315	1.8%
	TSS	2202	74297	3.0%
Charley	TP	16.981	133	12.8%
	TSS	5665	35803	15.8%

In addition to modeled bioretention basins, a number of additional best management practices were recommended, including iron enhanced sand filters, alum treatment or dredging, stormwater reuse, shoreline restoration, bank stabilization, and swales. These practices require further study, as some are dependent on elevation data from newly graded and developed sites and some require specialists, such as a limnologist to make recommendations on alum treatment in lakes and stormwater ponds.

The community of North Oaks directs the majority of its stormwater to its lakes by way of ditches, wetlands, and stormwater ponds for pre-treatment. In areas where this stormwater collects at catch basins for conveyance, stormwater interception is recommended in strategic locations for bioretention and filtration. In areas with predominant ditch conveyance-especially in turf-dominated landscapes such as Charley Lake Preserve-we recommend the conversion of mowed turf ditches to grassed swales or bioswales with intermittent check dams and/or bioretention to slow and filter water directed toward the lakes.

While most residents of North Oaks have homes in wooded areas with minimal phosphorus runoff impact, the new developments-particularly those in Charley Catchment such as Charley Lake Preserve (and Rapp Farms in Deep Catchment)-have turf lawns that have larger potential for phosphorus loading to stormwater. Both of these new housing developments designed their stormwater capture and treatment just before the MIDS (Minimal Impact Design Standards) were set. The MIDS is a low-impact development approach stating that new developments shall capture and retain on site 1.1 inches of runoff from new impervious surfaces (MPCA Water, 2014). While both developments used the ½ inch requirement for their runoff, Charley Lake Preserve’s case designed the stormwater pond about 80 ft south of Charley Lake to meet this basic requirement, while Rapp Farms exceeded many times over the storage requirement with stormwater ponds, in addition to filtration trenches. For this reason, more retrofits have proposed systemically for Charley Lake Preserve.

Homeowners can also do their part by following best practices such as infrequent mowing of ditches, use of phosphorus-free lawn fertilizers, and collecting grass clippings and leaves before this lawn waste enters the stormwater conveyance to lakes, where they increase the nutrient load, leading to algal blooms and murky, odorous water. Lakeshore homeowners, by ordinance of the City of North Oaks, may not use fertilizers containing phosphorus, and furthermore, no vegetation may be trimmed or removed within 20 ft of the Ordinary High Water Level of any public water without prior approval of the City Forester, but further education and enforcement of these ordinances could be promoted internally (153.052 Shoreland Alterations (B)).

This assessment represents one of many components of a comprehensive watershed restoration plan – other important components include: educational outreach, buffer zone management, discharge prevention, upland native plant community restoration, and pollutant source control. The implementation of the retrofits described in this assessment would greatly improve the water quality in the impaired PCD lake system, which is a crucial part of the Chain of Lakes used by St. Paul Regional Water Services for potable water supply for 80% of Ramsey County residents.

Appendix A.

WINSLAMM modeling parameters and files used in the assessment

File Name	Date Created/ Last Modified	Created By	Description
"CPZ:" These files contain the sediment particle size distributions developed from monitored data. The files area used in the evaluation of control practices that rely upon particle settling for pollution control.			
NURP.CPZ	5/16/88	Pitt/UA	Summarizes NURP outfall particle size data
"PPD" (Pollutant Probability Distribution) files describe the pollutant concentrations found in source areas.			
WI_GEO01.ppd	11/26/02	Horwatich/USGS	USGS/DNR pollutant probability distribution file from Wisconsin monitoring data.
"PRR" (Particulate Residue Reduction) files describe the fraction of total particulates that remains in the drainage system (curbs and gutters, grass swales, and storm drainage) after rain events end due to deposition. This fraction of the total particulates does not reach the outfall, so the outfall values are reduced by the fraction indicated in the .PRR file.			
WI_DLV01.prr	7/8/01	Horwatich/USGS	USGS/DNR particulate residue reduction file for the delivery system from Wisconsin monitoring data.
"RSV" (Runoff coefficient file). These coefficients, when multiplied by rain depths, land use source areas, and a conversion factor, determine the runoff volumes needed by WinSLAMM.			
WI_SL06 Dec06.rsv	12/18/06	Horwatich/USGS	USGS/DNR runoff volumetric coefficient file from Wisconsin monitoring data. Use for all versions of WinSLAMM starting from v 9.2.0.
"STD" (Street Delivery File): These files describe the fraction of total particulates that are washed from the streets during rains, but are subsequently redeposited due to lack of energy in the flowing water.			
WI_Com Inst Indust Dec06.std	12/12/06	Horwatich/USGS	USGS/DNR street delivery file from Wisconsin monitoring data. Use for all versions of WinSLAMM starting from v 9.2.0 for Industrial, Commercial and Institutional land uses.
WI_Res and Other Urban Dec06.std	12/07/06	Horwatich/USGS	USGS/DNR street delivery file from Wisconsin monitoring data. Use for all versions of WinSLAMM starting from v 9.2.0 for Residential and Other Urban land uses.
Freeway Dec06.std	7/12/05	Pitt/UA	Street delivery file developed to account for TSS reductions due to losses in a freeway delivery system based upon early USDOT research. Renamed Freeway.std
"PSC" (Particulate Solids Concentration): Values in this file, when multiplied by source area runoff volumes and a conversion factor, calculate particulate solids loadings (lbs).			
WI_AVG01.psc	11/26/02	Horwatich/USGS	USGS/DNR particulate solids concentration file from Wisconsin monitoring data.
"RAN" (Rain Files):			
MN Minneapolis 59.RAN	NA	NA	A n event-record of rainfall for the year 1959, considered as an average year, in the form of Start Date, Start Time, End Date, End Time and Rainfall (in inches).
Settings			
Parameter	**Description**		
Start/End Date	Defines the modeling period in reference to the rain file data. In this case, the entire one year period was selected (i.e., 01/02/59-12/28/59).		
Winter Season Range	Set to begin on November 7th and end on March 17th.		
Drainage System	Set to "Curb and gutter, valleys, or sealed swales in fair condition.		

WINSLAMM Standard Land Use Codes

RESIDENTIAL LAND USES

- Medium Density Residential without Alleys (MDRNA): 2 - 6 units/acre.
- Low Density Residential (LDR): Same as HDRNA except the density is 0.7 to 2 units/acre.
- Duplexes (DUP): Housing having two separate units in a single building.
- Multiple Family Residential (MFRNA): Housing for three or more families, from 1 - 3 stories in height. Units may be adjoined up-and-down, side-by-side; or front-and-rear. Includes building, yard, parking lot, and driveways. Does not include alleys.
- Suburban (SUB): Same as HDRNA except the density is between 0.2 and 0.6 units/acre.

INDUSTRIAL LAND USES

- Medium Industrial (MI): This category includes businesses such as lumber yards, auto salvage yards, junk yards, grain elevators, agricultural coops, oil tank farms, coal and salt storage areas, slaughter houses, and areas for bulk storage of fertilizers.

- Non-Manufacturing (LI): Those buildings that are used for the storage and/or distribution of goods waiting further processing or sale to retailers. This category mostly includes warehouses, and wholesalers where all operations are conducted indoors, but with truck loading and transfer operations conducted outside.

INSTITUTIONAL LAND USES

- Education (SCH): Includes any public or private primary, secondary, or college educational institutional grounds. Includes buildings, playgrounds, athletic fields, roads, parking lots, and lawn areas.
- Miscellaneous Institutional (INST): Churches and large areas of institutional property not part of CST and CDT.

OTHER URBAN LAND USES

- Parks (PARK): Outdoor recreational areas including municipal playgrounds, botanical gardens, arboretums, golf courses, and natural areas.
- Undeveloped (OSUD): Lands that are private or publicly owned with no structures and have a complete vegetative cover. This includes vacant lots, urban fringe areas slated for development, greenways, and forest areas.

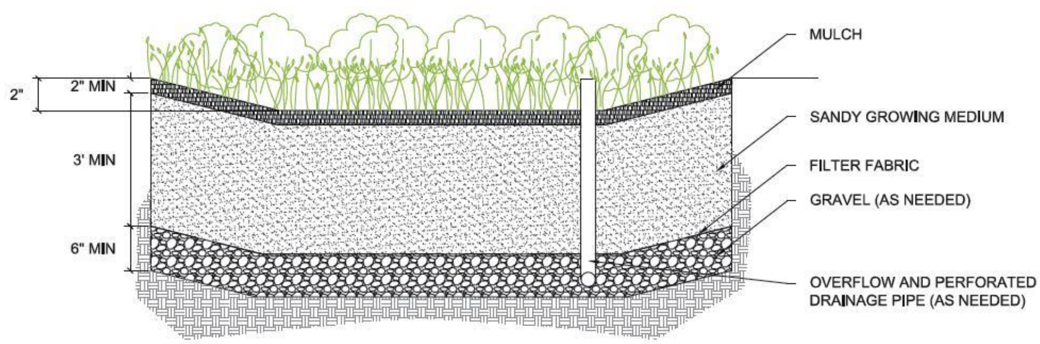
Appendix B.

Bioretention:

Curb cut raingarden, with 1.5-2ft perimeter wall, in a residential area.

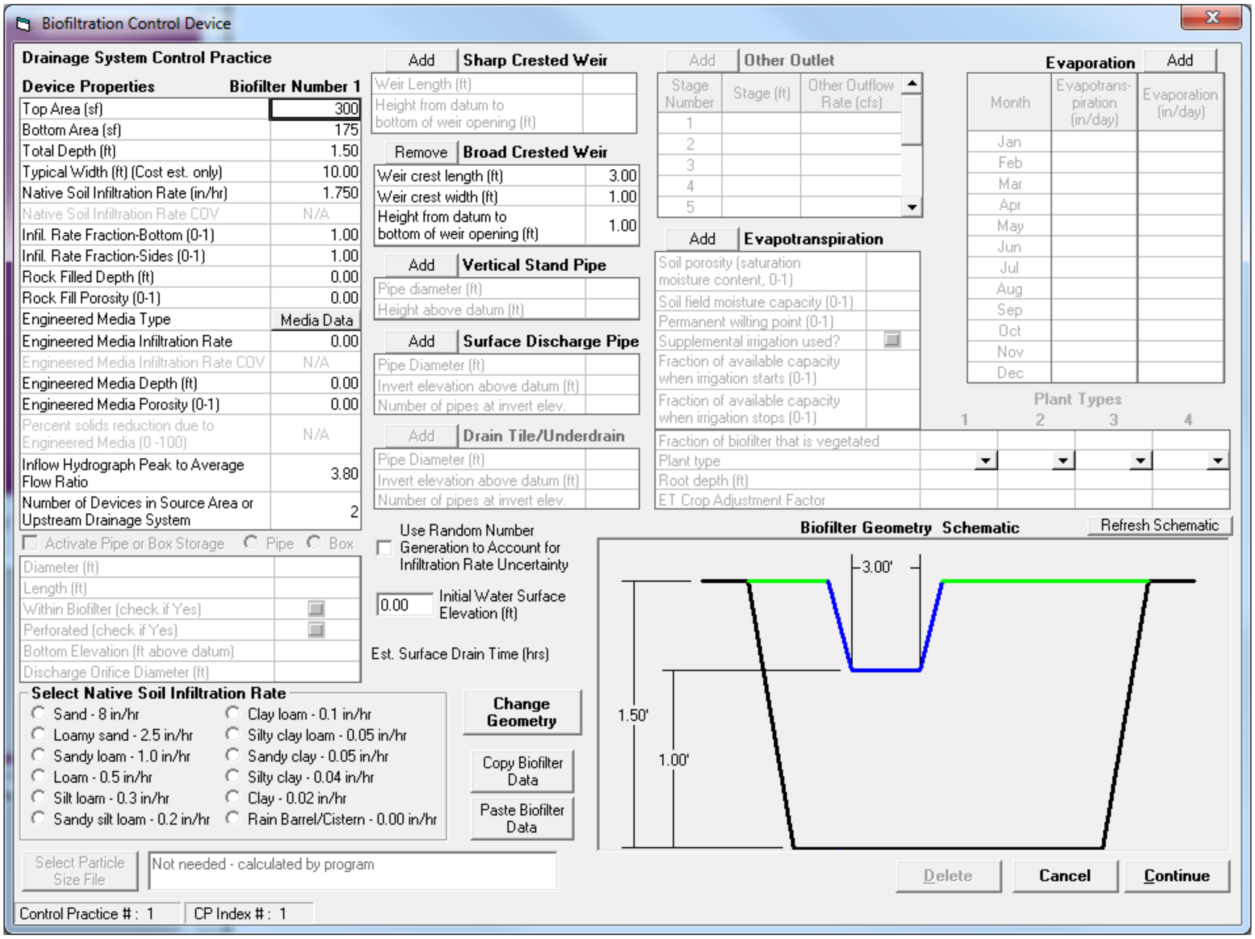
Bioretention design

SCHEMATIC



Adapted from:
Designing Rain Gardens (Bioretention Areas)
http://legacy.ncsu.edu/classes-a/bae/cont_ed/bioretention/lecture/design_rain.pdf
Accessed 01/22/2008

Graphic courtesy of Charles River Watershed Association, Weston, MA. www.charlesriver.org.



Precipitation data used for modeling was the year 1999, since its annual rainfall (30.54 inches) best resembles the area's average annual rainfall (30.61 inches) (DNR, 2015).

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