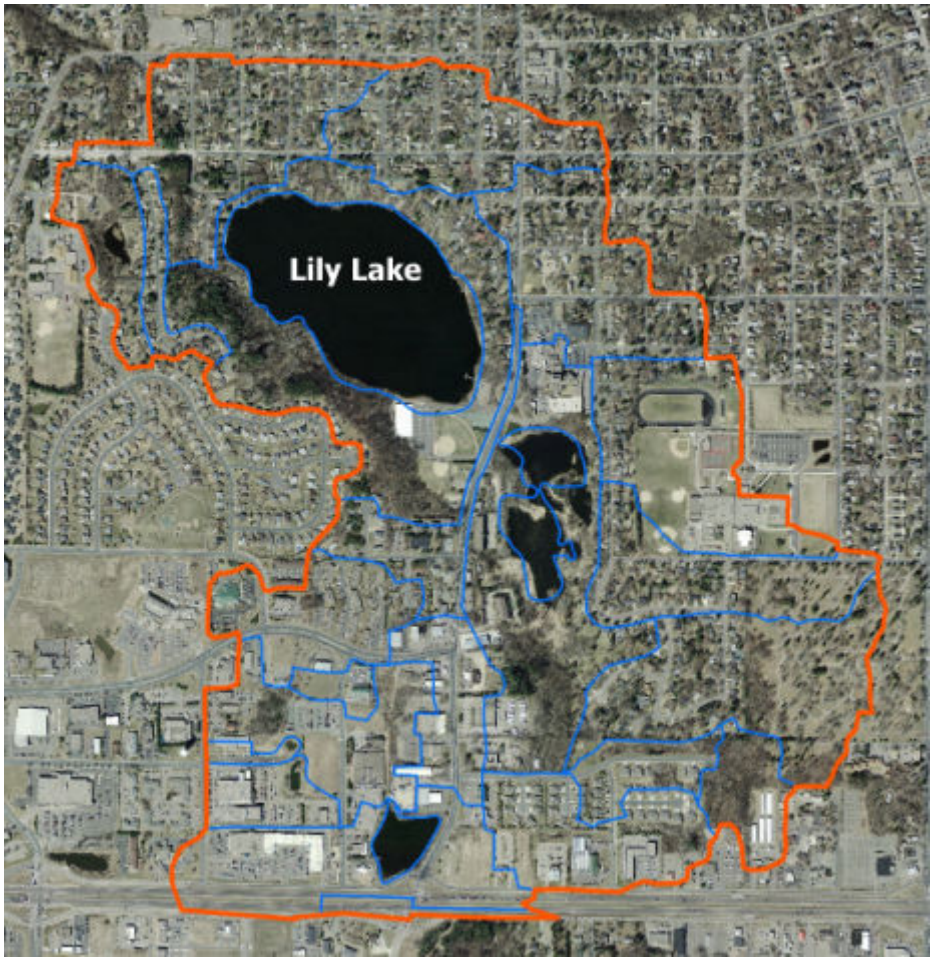
Lily Lake

Stormwater Retrofit Assessment



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With assistance from:

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for the

MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION

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This report details a subwatershed stormwater retrofit assessment resulting in recommended catchments for placement of Best Management Practice (BMP) retrofits that address the goals of the Local Governing Unit (LGU) and stakeholder partners. 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 subwatersheds of variable scales and land-uses to identify optimal locations for stormwater treatment. The time commitment required for this methodology is appropriate for *initial assessment* applications. 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, agricultural and range land management, good housekeeping outreach and education, and others, within existing or future watershed restoration planning.

The assessment's background 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 BMPs 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 and implement BMP projects. 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 in this report. This typically occurs after committed partnerships are developed for each specific target property for which BMPs are planned.

Executive Summary

The 22 catchments of the Lily Lake subwatershed, and their existing stormwater management practices, were analyzed for annual pollutant loading. Stormwater practice options were compared for each catchment, depending on specific site constraints and characteristics. Potential stormwater BMP retrofits were selected by weighing cost, ease of installation and maintenance and ability to serve multiple functions identified by the City of Stillwater and Middle St. Croix Watershed Management Organization (MSCWMO). Twelve of the 29 catchments were selected and modeled at various levels of treatment efficiency. These 12 catchments should be considered the "low-hanging-fruit" within the Lily Lake Subwatershed.

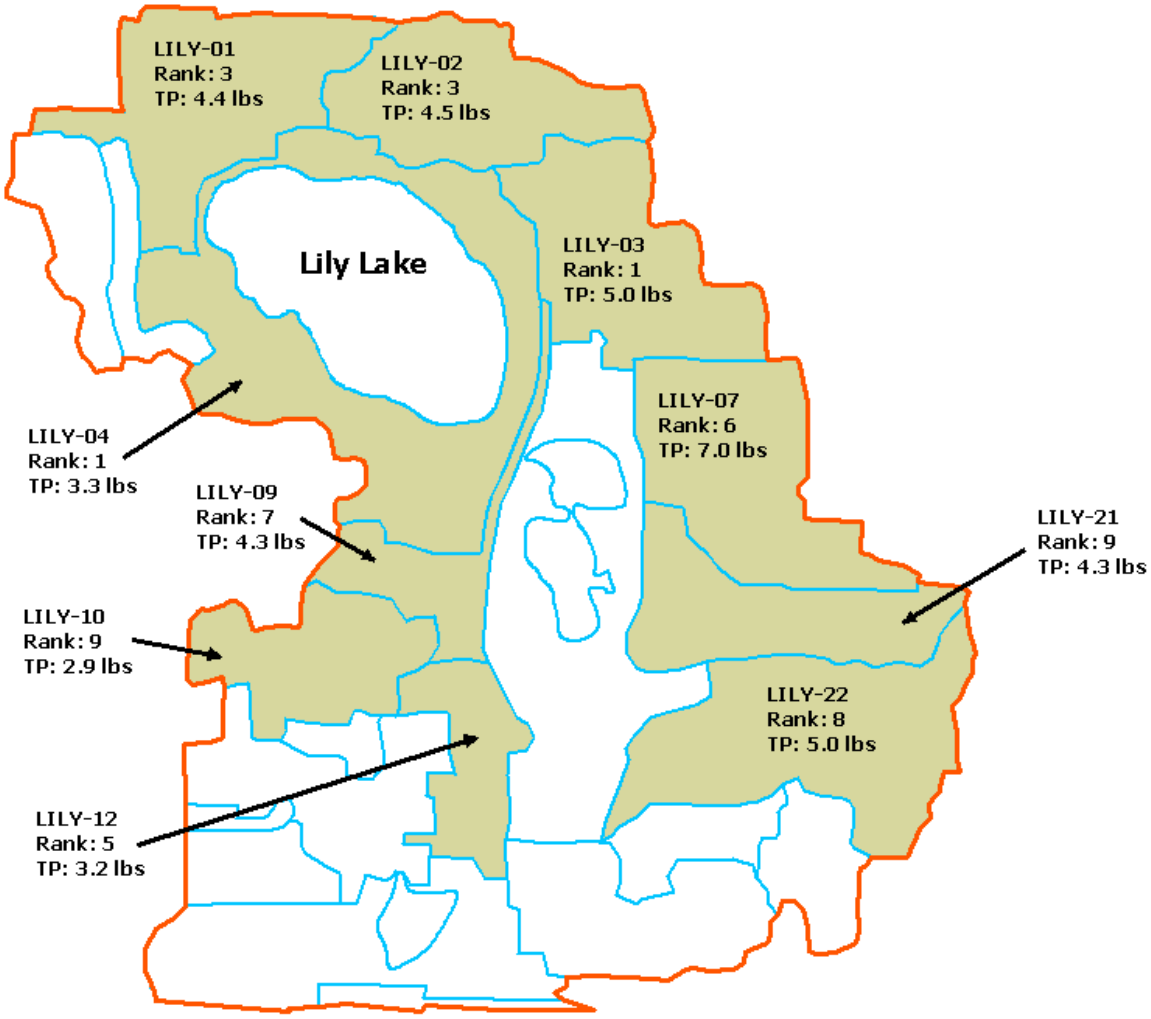
Lily Lake is demonstrating signs of eutrophication, driven by increased phosphorus loading from the contributing subwatershed (Wenck Associates, Inc., 2007). Total phosphorus (TP) is therefore the major target pollutant within the Lily Lake subwatershed. Reducing the annual TP loading to the lake by 145 pounds will allow the lake to meet desired TP concentrations. Treatment levels (percent reduction rates) listed below for retrofit projects that resulted in prohibitive BMP size/number or were too expensive to justify installation are not included. Reported treatment levels are dependent upon optimal BMP location within the catchment and total BMP area. The recommended treatment levels/amounts summarized here are based on a subjective assessment of potential BMP installations, considering estimated public participation and site constraints. Recommended catchment rankings are based on a relative comparison of the cost per pound of phosphorus reduced over the life of the BMPs. A TP reduction of 93.9 pounds (65% of the target reduction) could be achieved for a total cost of $568,087 if recommended BMPs are installed within the top 12 ranked catchments according the table below.

Catchment or Pond ID	Retro Type	BMP area (sq ft)	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Est. Cost[1]	O&M Term (years)	Total Est. Term Cost/lb-TP/30 yr	Rank
LILY-03	B	1,244	10	5.0	4.0	$18,951	30	$313	1
LILY-04	B, PS, VS	773	10	3.3	2.9	$13,552	30	$313	1
LILY-02	B	1,124	10	4.5	3.7	$17,173	30	$315	3
LILY-01	B	1,100	10	4.4	3.6	$16,818	30	$315	3
LILY-12	B	797	10	3.2	2.5	$12,357	30	$316	5
LILY-07	B, VS	1,965	20	7.0	5.8	$22,283	30	$318	6
LILY-09	B	1,151	20	4.3	3.6	$17,573	30	$337	7
LILY-22	B	1,400	20	5.0	4.2	$21,267	30	$352	8
LILY-21	B	1,208	20	4.3	3.6	$18,417	30	$353	9
LILY-10	B, PS, F	713	10	2.9	2.4	$14,696	30	$353	9
[2]P13-W	WD	n/a	50	20	0	$130,000	15	$433	11
[2]P18-W	WD	n/a	50	30	0	$265,000	15	$589	12
TOTAL	-	-	-	**93.9**	**36.3**	**$568,087**	-	-	-

B = Bioretention (infiltration and/or filtration)
F = Filtration (sand curtain, surface sand filter, sump, etc.)
PS = Permeable Surface (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
WD = Wet Detention or wetland creation (new pond)

[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.

[2]See "City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake," Wenck Associates, Inc., October 2007



Top-Ranked Lily Lake Catchments and TP Removal Potential

About this Document

Document Overview

The Stormwater Retrofit Assessment is a subwatershed management tool used to prioritize stormwater BMP retrofit projects based on BMP performance and cost effectiveness. This process helps maximize the value of each dollar spent.

This document is organized into four main sections that describe the general methods used, individual catchment profiles, a retrofit ranking for the subwatershed, and references used in the assessment protocol. The Appendices section provides additional information relevant to the assessment.

Under each section and subsection, project-specific information relevant to that portion of the assessment is provided with an ***Italicized Heading***.

Methods

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

NOTE: the financial, technical, current landscape/stormwater system, and timeframe limits and needs are highly variable from subwatershed to subwatershed. This assessment uses some, or all, of the methods described herein.

Catchment Profiles

Each catchment profile is labeled with a unique ID to coincide with the catchment name (e.g., LILY-08 for Lily Lake catchment number 8). This catchment ID is referenced when comparing results across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

Within each Catchment Summary/Description section is a table that summarizes basic information including catchment size, current land cover, land ownership, and estimated annual pollutant load (target pollutant(s) are specified by the LGU). A table of the principal modeling parameters and values is also reported. A brief description of the land cover, stormwater infrastructure and any other important general information is described.

Retrofit Recommendation

The Retrofit Recommendation section describes the conceptual BMP retrofit(s) selected for the catchment area and provides a description of why each specific retrofit option 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 BMP retrofit projects. Additional field inspections will be required to verify project feasibility, but the most ideal locations for BMP project installations are identified here.

Catchment Ranking

Catchment ranking takes into account all of the information gathered during the assessment process to create a prioritized catchment list. The list is sorted by the cost per pound of phosphorus treated within each catchment for the duration of the 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 within catchments, and the list provided is merely a starting point. Final catchment ranking for installation may include:

- Total amount of pollutant removal
- Non-target pollutant reductions
- BMP project visibility
- Availability of funding
- Total project costs
- Educational value

References

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

Appendices

The Appendices section provides supplemental information and/or data used during the assessment protocol.

Methods

Selection of Subwatershed

Before the subwatershed stormwater assessment begins, a process of identifying a high priority water body as a target takes place. Many factors are considered when choosing which subwatershed to assess for stormwater retrofits. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Assessments supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the assessment also rank highly.

In areas without clearly defined studies, such as TMDL or officially listed water bodies of concern, or where little or no monitoring data exist, metrics are used to score subwatersheds against each other. In large subwatersheds (e.g., greater than 2500 acres), a similar metric scoring is used to identify areas of concern, or focus areas, for a more detailed assessment. This methodology was slightly modified from Manual 2 of the *Urban Stormwater Retrofit Practices* series.

Description of Lily Lake and the Contributing Subwatershed

Lily Lake has a surface area of 35.9 acres, average depth of 18 feet, and an ordinary high water level of 844.8 feet. The lake is located within the City of Stillwater in the northeastern suburban Twin Cities metropolitan area. The Lily Lake subwatershed encompasses approximately 567 acres. Major land uses include approximately 60% residential (single or multi-family) and 10% industrial. The lake drains to Lake McKusick, which ultimately discharges to the St. Croix River. Stormwater is conveyed through a network of storm sewers, channels, and ponds. Much of the development within the subwatershed occurred prior to implementation of regulations requiring stormwater treatment, so there are several areas where minimal treatment of runoff occurs before entering the lake. The most significant phosphorus source (93% of total loading) to Lily Lake is from the contributing watershed. (*City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake*, Wenck Associates, Inc., October 2007)

Washington Conservation District monitors Lily Lake for total phosphorus, chlorophyll-a, Secchi disk depth (transparency), and other parameters. The lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List and currently shows no statistically significant trend (increasing or decreasing) for average total phosphorus (*MSCWMO 2009 Water Monitoring Report*, Washington Conservation District, 2010).

Phosphorus was chosen as the target pollutant of this assessment to address the lake impairment. The direct drainage area (contributing subwatershed) was chosen as the focus of this assessment. This direct drainage area contributes 93% of the phosphorus load to Lily Lake. The only other significant phosphorus source to Lily Lake is atmospheric deposition (7%). The Wenck plan sets a reduction goal of 145 pounds of phosphorus from the direct drainage area for Lily Lake. When achieved, this reduction will allow Lily Lake to meet the MPCA's standard TP concentration of 40 µg/L for deep lakes.

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 includes determining the objectives of the retrofits (volume reduction, target pollutant etc) and the level of treatment desired. It involves meeting with local stormwater managers, city staff, and watershed staff to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to assess in large subwatersheds, a smaller focus area may be determined.

Lily Lake Subwatershed Scoping

Pollutants of concern for this subwatershed were identified as TP, TSS, and volume. Goals of the MSCWMO, WCD, and City of Stillwater were considered as well the results of the *City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake*, Wenck Associates, Inc., October 2007.

Step 2: Desktop Retrofit Analysis

Desktop retrofit analysis involves computer-based scanning of the subwatershed for potential BMP retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure. Accurate and current GIS data is extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography, and storm drainage infrastructure (with invert elevations and flow direction). The following table highlights some important features to look for and the associated potential retrofit project.

Subwatershed Metrics and Potential Retrofit Project Site/Catchment	
Screening Metric	**Potential Retrofit Project**
Existing Ponds	**Add storage and/or improve water quality by excavating accumulated sediment, modifying inlet or outlet, raising embankment, and/or modifying flow routing.**
Open Space	**New regional treatment (pond, bioretention).**
Roadway Culverts	**Add wetland or extended detention water quality treatment upstream.**
Outfalls	**Split flows or add storage below outfalls if open space is available.**
Conveyance system	**Add or improve performance of existing swales, ditches and non-perennial streams.**
Large Impervious Areas (campuses, commercial, parking)	**Stormwater treatment on-site or in nearby open spaces.**
Neighborhoods	**Utilize right of way, roadside ditches or curb-cut raingardens or filtering systems to treat stormwater before it enters storm drain network.**

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 to eliminate sites from consideration. The field investigation revealed additional retrofit opportunities that would have gone unnoticed during the desktop search.

The following stormwater BMPs were considered for each catchment/site:

Stormwater Treated Options for Retrofitting		
Area Treated	**Best Management Practice**	**Potential Retrofit Project**
5-500 acres	Extended Detention	**12-24 hr detention of stormwater with portions drying out between events (preferred over Wet Ponds). May include multiple cells, infiltration benches, sand/peat/iron filter outlets, and modified choker outlet features.**
	Wet Ponds	**Permanent pool of standing water with new water displacing pooled water from previous event.**
	Wetlands	**Depression less than 3 feet deep and designed to emulate wetland ecological functions. Residence times of several days to weeks. Best constructed off-line with low-flow bypass.**
0.1-5 acres	Bioretention	**Use of native sol, soil microbe, and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.**
	Filtering	**Filters runoff through engineered media and passes it through an under-drain. May consist of a combination of sand, soil, compost, peat, compost, and iron.**
	Infiltration	**A trench or sump that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering the infiltration area.**
	Swales	**A series of vegetated, open channel practices that can be designed to filter and/or infiltrate runoff.**
	Other	**On-site, source-disconnect practices such as rain-leader raingardens, rain barrels, green roofs, cisterns, stormwater planters, dry wells and permeable pavements.**

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Sites most likely address pollutant reduction goals and those that may have simple design/install/maintenance considerations are chosen for a cost/benefit analysis that relatively compares catchments/sites. Treatment concepts are developed taking into account site constraints and the subwatershed treatment objectives. Projects involving complex stormwater treatment interactions and those that may pose a risk for upstream flooding require the assistance of a professional engineer. Conceptual designs at this phase of the design process include cost and pollution reduction estimates. Reported treatment levels are dependent upon optimal site selection and sizing.

Modeling of the site is done by one or more methods such as with P8, WINSLAMM or simple spreadsheet methods using the Rational Method. Event mean concentrations or sediment loading files (depending on data availability and model selection) are used for each catchment/site to estimate relative pollution loading of the existing conditions. The site's conceptual BMP design is modeled to then estimate varying levels of treatment by sizing and design element. This treatment model can also be used to properly size BMPs to meet LGU restoration objectives.

General P8 Model Inputs	
Parameter	**Method for Determining Value**
Total Area	Source/Criteria
Pervious Area Curve Number	Values from the USDA Urban Hydrology for Small Watersheds TR-55 (1986). A composite curve number was found based on proportion of hydrologic soil group and associated curve numbers for open space in fair condition (grass cover 50%-75%).
Directly Connected Impervious Fraction	Calculated using GIS to measure the amount of rooftop, driveway and street area directly connected to the storm system. Estimates calculated from one area can be used in other areas with similar land cover.
Indirectly Connected Impervious Fraction	Wisconsin urban watershed data (Panuska, 1998) provided in the P8 manual is used as a basis for this number. It is adjusted slightly based on the difference between the table value and calculated value of the directly connected impervious fraction.
Precipitation/Temperature Data	Rainfall and temperature recordings from 1959 were used as a representation of an average year.
Hydraulic Conductivity	A composite hydraulic conductivity rate is developed for each catchment area based on the average conductivity rate of the low and high bulk density rates by USDA soil texture class (Rawls et. al, 1998). Wet soils where practices will not be installed are omitted from composite calculations.
Particle/Pollutant	The default NURP50 particle file was used.
Sweeping Efficiency	Unless otherwise noted, street sweeping was not accounted for.

Lily Lake Treatment Analysis

For the Lily Lake treatment analysis, each catchment (and each relevant parcel within them) was first assessed for BMP applicability given specific site constraints and soil types. Pedestrian and car traffic flow, parking needs, snow storage areas, obvious utility locations, existing landscaping, surface water runoff flow, project visibility, existing landscape maintenance, available space, and other site-specific factors dictated the selection of one or more potential BMPs for each site.

P8 was used to model catchments and a hypothetical BMP located at its outfall. The BMP was sized from the 10-50% treatment size and results were tabulated in the Catchment Profile section of this document.

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 total cubic feet of treatment. In cases where live storage was 1 foot deep, this number roughly related to square feet of BMP coverage. An annual cost/TP-removed for each treatment level was then calculated for the life of each BMP that includes promotional, administrative and life cycle operations, and maintenance costs.

The following table provides the BMP cost estimates used to assist in cost analysis:

Average BMP Cost Estimates						
BMP	**Median Inst. Cost ($/ft^2)**	**Marginal Annual Maintenance Cost (contracted)**	**O&M Term**	**Design Cost ($70/hr)**	**Installation Oversight Cost ($70/hr)**	**Total Installation Cost (Includes design & 1-yr maintenance)**
Pond Retrofits	$3.00	$500/ac	30	[1]40% above construction	$210 (3 visits)	**$4.21/ft^2**
Extended Detention	$5.00	$1000/ac	30	[1]$2800/ac	$210 (3 visits)	**$12.02*(ft^3^0.75)**
Wet Pond	$5.00	$1000/ac	30	[1]$2800/ac	$210 (3 visits)	**$277.89*(ft^3^0.553)**
Stormwater Wetland	$5.00	$1000/ac	30	[1]$2800/ac	$210 (3 visits)	**$4,800*(DA ac^0.484)**
Dry Swale	$3.00	$0.75/ft^2	30	$280/100 ft^2	$210 (3 visits)	**$6.60/ft^2**
Water Quality Swale[4]	$12.00	$0.75/ft^2	30	$1120/1000 ft^2	$210 (3 visits)	**$13.90/ft^2**
Cisterns	$15.00	[3]$100	30	NA	$210 (3 visits)	**$16.00/ft^2**
French Drain/Dry Well	$12.00	[3]$100	30	20% above construction	$210 (3 visits)	**$15.00/ft^2**
Infiltration Basin (turf)	$15.00	$2000/ac	30	$1120/ac	$210 (3 visits)	**$15.10/ft^2**
Rain Barrels	$25.00	[3]$25	30	NA	$210 (3 visits)	**$25.00/ft^2**

Average BMP Cost Estimates						
BMP	**Median Inst. Cost ($/ft^2)**	**Marginal Annual Maintenance Cost (contracted)**	**O&M Term**	**Design Cost ($70/hr)**	**Installation Oversight Cost ($70/hr)**	**Total Installation Cost (Includes design & 1-yr maintenance)**
Structural Sand Filter (including peat, compost, iron amendments, or similar) [4]	$20.00	$250/25 ln ft	30	$300/25 ln ft	$210 (3 visits)	**$21.50/ft^2**
Impervious Cover Conversion	$20.00	$500/ac	30	$1120/ac	$210 (3 visits)	**$20.10/ft^2**
Stormwater Planter	$27.00	$0.75/ft^2	30	20% above construction	$210 (3 visits)	**$32.20/ft^2**
Rain Leader Disconnect Raingardens	$4.00	$0.25/ft^2	30	[2]$280/100 ft^2	$210 (3 visits)	**$7.00/ft^2**
Simple Bioretention (no engineered soils or under-drains, but w/curb cuts and forebays)	$10.00	$0.75/ft^2	30	[2]$1120/1000 ft^2	$210 (3 visits)	**$11.30/ft^2**
Moderately Complex Bioretention (incl. engineered soils, under-drains, curb cuts, but no retaining walls)	$12.00	$0.75/ft^2	30	[2]$1120/1000 ft^2	$210 (3 visits)	**$13.90/ft^2**
Complex Bioretention (same as MCB, but with 1.5 to 2.5 ft partial perimeter walls)	$14.00	$0.75/ft^2	30	[2]$1400/1000 ft^2	$210 (3 visits)	**$16.20/ft^2**

Average BMP Cost Estimates						
BMP	Median Inst. Cost ($/ft^2)	Marginal Annual Maintenance Cost (contracted)	O&M Term	Design Cost ($70/hr)	Installation Oversight Cost ($70/hr)	Total Installation Cost (Includes design & 1-yr maintenance)
Highly Complex Bioretention (same as CB, but with 2.5 to 5 ft partial perimeter walls or complete walls)	$18.00	$0.75/ft^2	30	[2]$1400/1000ft^2	$210 (3 visits)	**$19.90/ft^2**
Underground Sand Filter	$65.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$91.75/ft^2**
Stormwater Tree Pits	$70.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$98.75/ft^2**
Grass/Gravel Permeable Pavement (sand base)	$12.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$17.55/ft^2**
Permeable Asphalt (granite base)	$10.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$14.00/ft^2**
Permeable Concrete (granite base)	$12.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$17.55/ft^2**
Permeable Pavers (granite base)	$25.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$35.75/ft^2**
Extensive Green Roof	$225.00	$500/1000 ft^2	30	[1]40% above construction	$210 (3 visits)	**$315.50/ft^2**
Intensive Green Roof	$360.00	$750/1000 ft^2	30	[1]40% above construction	$210 (3 visits)	**$504.75/ft^2**

[1]May require a professional engineer. Assume engineering costs to be 40% above construction costs

[2]If multiple projects are slated, such as in a neighborhood retrofit, a design packet with templates and standard layouts, element elevations and components, planting plans and cross sections can be generalized, design costs can be reduced.

[3]Not included in total installation cost (minimal).

[4]Assumed to be 15 feet in width.

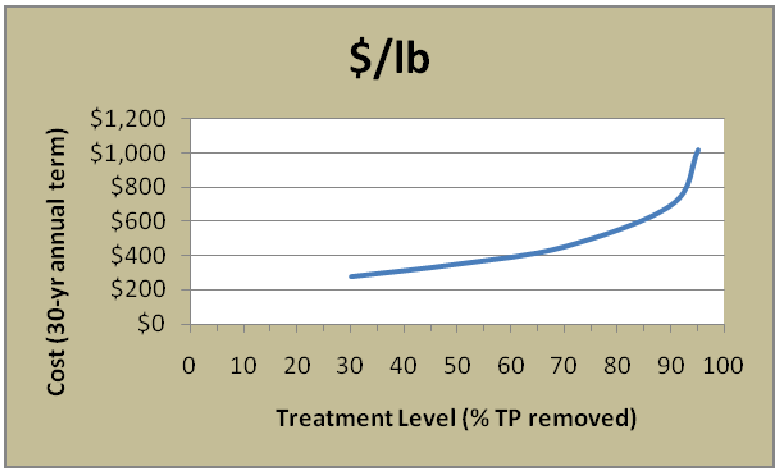
Lily Lake Cost Analysis

For the Lily Lake cost analysis, promotion and administration for each commercial/public property was estimated using a non-linear formula dependent on the surface area of BMPs, as the labor associated with outreach, education and administrative tasks typically are reduced with scale. Annual Operation & Maintenance referred to the ft^2 estimates provided in the preceding table. In cases were multiple BMP types were prescribed for an individual site, both the estimated installation and maintenance-weighted means by ft^2 of BMP were used to produce cost/benefit estimates.

Step 5: Evaluation and Ranking

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

Example chart showing total phosphorus treatment vs. cost:



Lily Lake Evaluation and Ranking

In the Lily Lake evaluation and ranking, the recommended level of treatment for each catchment, as reported in the Executive Summary table, was chosen by selecting the expected level of treatment considering public buy-in and above a minimal amount needed to justify crew mobilization and outreach efforts to the area. Should the cumulative expected load reduction of the recommended catchment treatment levels not meet LGU goals, a higher level of treatment (as described in the Catchment Profile tables) should be selected. The maps associated with each catchment show potential BMP locations as determined by field review. To meet treatment level goals for a catchment, a minimum percentage of potential BMPs (equaling or exceeding the “BMP Surface Area”) must be installed within that catchment.

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.

For development of the Lily Lake catchment profile section, 10 out of 22 catchments were selected as the first-tier areas for stormwater retrofit efforts. Those catchments receiving modern stormwater pond treatment, or in some cases 2 or more levels of treatment, were not modeled or further analyzed in this assessment.

LILY-01

Term Cost Rank = #3

Catchment Summary	
Acres	36.6
Dominant Land Cover	Residential
Parcels	128
Volume (acre-feet/yr)	37.4
TP (lb/yr)	43.7
TSS (lb/yr)	13,737.5

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.49
Hydraulic Conductivity (in/hr)	1.35

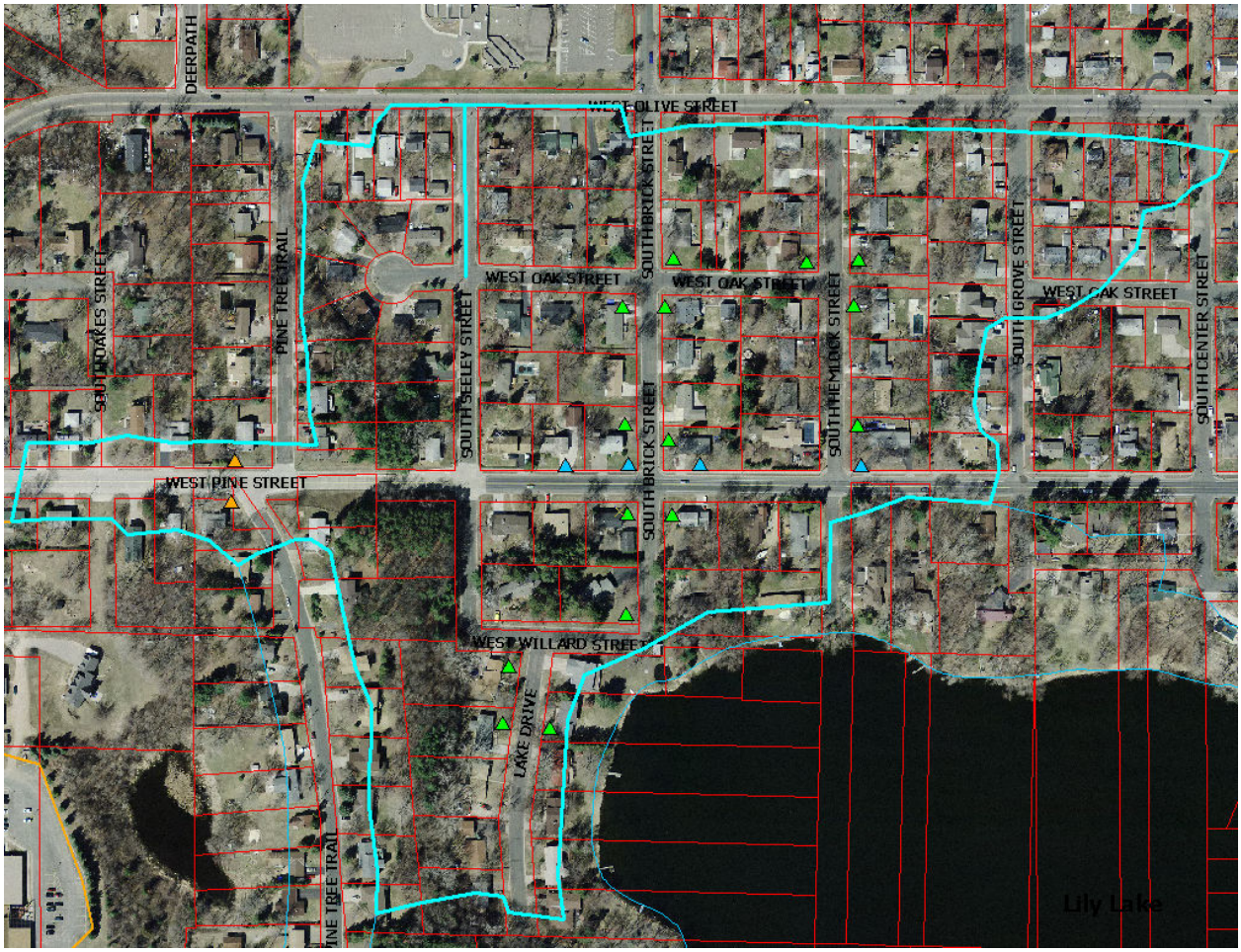
DESCRIPTION

This catchment is comprised of primarily medium-density single-family residential properties. Runoff is collected in the existing storm sewer system and discharged to the lake with little or no water quality treatment.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

A curb cut raingarden initiative within this neighborhood would work well for achieving the desired TP reduction. There are also areas where street bump-outs and curb cut box planters would be the preferred option.



Curb Cut Bioretention Curb Cut Box Planter Bump Out

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	13.1	8.7	4.4
	TSS Reduction (lb/yr)	7,217	5,794	3,952
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	10.9	7.3	3.6
	Volume Reduction (%)	29%	20%	9%
	Live Storage Volume (cubic feet)	4,080	2,450	1,100
Costs	Materials/Labor/Design	$61,200	$36,750	$16,500
	Promotion & Admin Costs	$122	$177	$318
	Total Project Cost	$61,322	$36,927	$16,818
	Annual O&M	$3,060	$1,838	$825
	Term Cost/lb/yr (30 yr)	$390	$353	$315

LILY-02

Term Cost Rank = #3

Catchment Summary	
Acres	29.8
Dominant Land Cover	Residential
Parcels	129
Volume (acre-feet/yr)	38.4
TP (lb/yr)	45.0
TSS (lb/yr)	14,151.2

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.62
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment is comprised of primarily medium density, single-family residential development. Two existing curb cut raingardens exist (Intersection of Owens and Pine Streets). Runoff is collected in the existing storm sewer system and discharged to the lake with little or no water quality treatment.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

This catchment appears to be ideal for a neighborhood BMP retrofit effort. Although the 10% TP reduction level was chosen for the executive summary, the 20% level is also feasible. The term cost/lb/yr at the 20% level is $351, compared to $315 at the 10% level.

Curb Cut Bioretention Curb Cut Box Planter

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	13.5	9.0	4.5
	TSS Reduction (lb/yr)	7,431	5,965	4,066
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	11.2	7.5	3.7
	Volume Reduction (%)	29%	20%	10%
	Live Storage Volume (cubic feet)	4,194	2,519	1,124
Costs	Materials/Labor/Design	$62,910	$37,785	$16,860
	Promotion & Admin Costs	$120	$174	$313
	Total Project Cost	$63,030	$37,959	$17,173
	Annual O&M	$3,146	$1,889	$843
	Term Cost/lb/yr (30 yr)	$389	$351	$315

LILY-03

Term Cost Rank = #1

Catchment Summary	
Acres	33.6
Dominant Land Cover	Residential
Parcels	113
Volume (acre-feet/yr)	42.6
TP (lb/yr)	49.9
TSS (lb/yr)	15,700.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.61
Hydraulic Conductivity (in/hr)	1.35

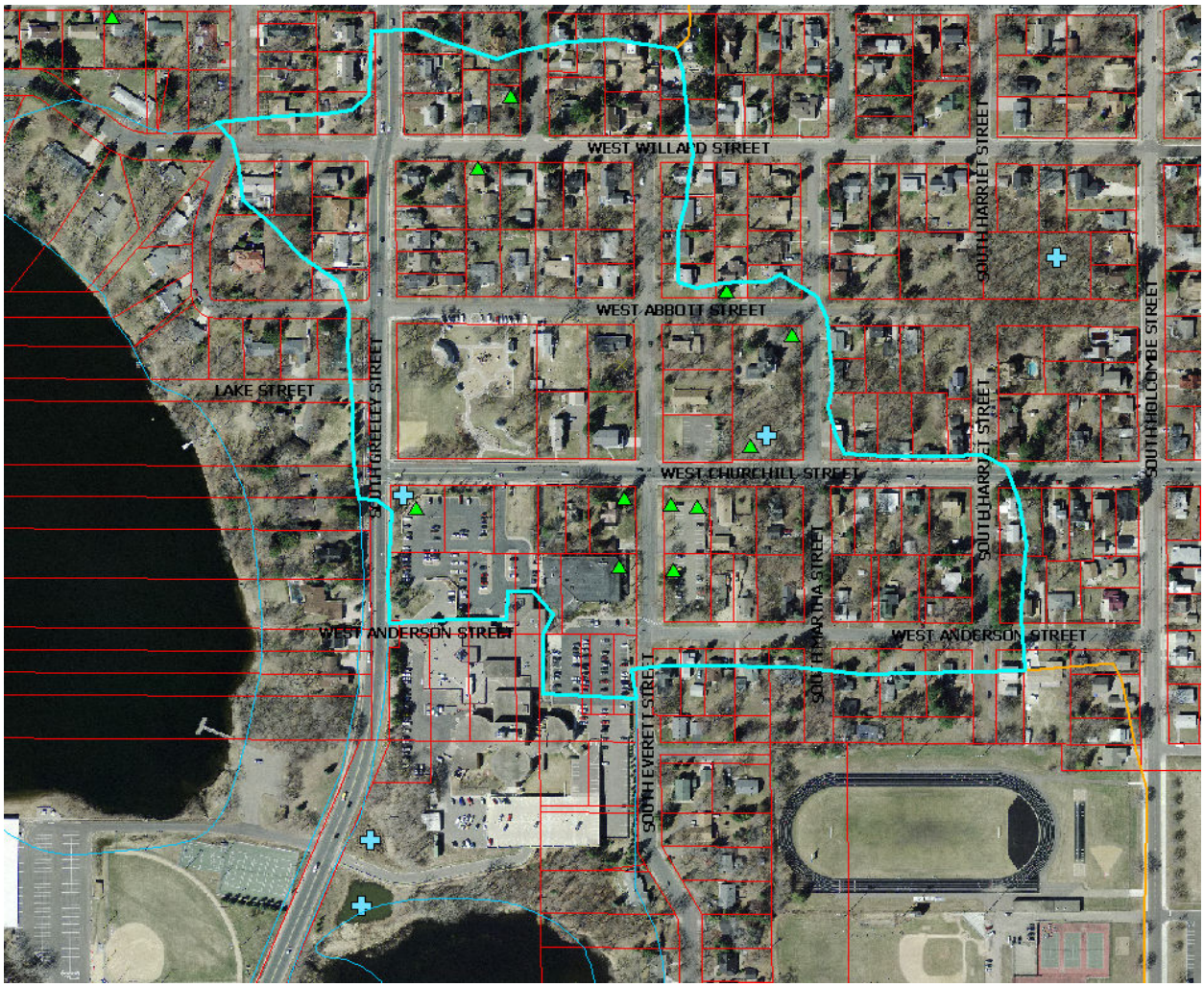
DESCRIPTION

This catchment is comprised of a mixture of medium-density residential development, institutional (one hospital campus), and open space (one large park). There are no constructed stormwater ponds within the catchment. There is one existing stormwater feature that treats water from a portion of the hospital site, although it is assumed to be under-functioning. Stormwater runoff from the rest of the catchment flows through the existing storm sewer system and into a wetland complex (Brick Pond, catchment Lily-08W) before discharging to Lily Lake. The catchment discharge point into Brick Pond and the outlet to Lily Lake are separated by less than 200 feet, creating a short-circuiting situation in which this stormwater likely does not receive much treatment in Brick Pond.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

Several features make this catchment very attractive for retrofitting. In a few locations, modification or additional bioretention surface area could easily be retrofitted into the existing practices to maximize efficiencies. In one location, it may be possible to daylight stormwater sewer lines to an existing major depression that would effectively treat (infiltrate and filter) approximately 1/6th of the catchment. Further investigation into this possibility is highly recommended.



Curb Cut Bioretention (including 2 existing pond retrofits)

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	15.0	10.0	5.0
	TSS Reduction (lb/yr)	8,245	6,618	4,500
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	12.5	8.3	4.0
	Volume Reduction (%)	29%	19%	9%
	Live Storage Volume (cubic feet)	4,654	2,795	1,244
Costs	Materials/Labor/Design	$69,810	$41,925	$18,660
	Promotion & Admin Costs	$111	$161	$291
	Total Project Cost	$69,921	$42,086	$18,951
	Annual O&M	$3,491	$2,096	$933
	Term Cost/lb/yr (30 yr)	$388	$350	$313

LILY-04

Term Cost Rank = #1

Catchment Summary	
Acres	56.9
Dominant Land Cover	Residential
Parcels	103
Volume (acre-feet/yr)	28.7
TP (lb/yr)	33.3
TSS (lb/yr)	10,460.6

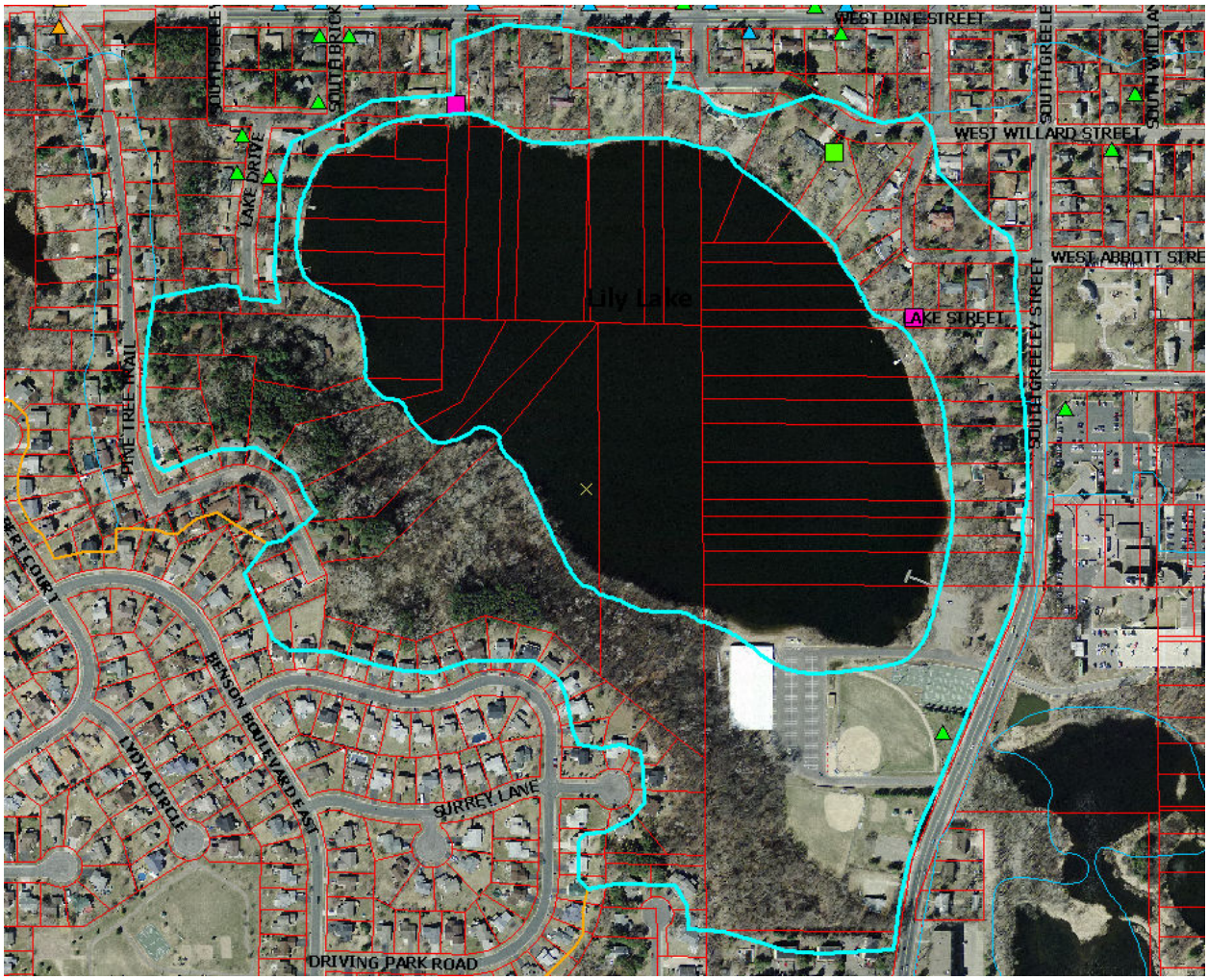
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.24
Hydraulic Conductivity (in/hr)	1.74

DESCRIPTION

This catchment is comprised of primarily low density, single-family residential development with direct drainage to Lily Lake. The catchment includes areas of open space and a City park. A small demonstration shoreline buffer BMP and pervious pavement section exists within the park, as well as a treatment swale that was required when the City repaved the parking lot.

RETROFIT RECEOMMENDATION

The limited BMP opportunities available within this catchment need to be maximized. A combination of bioretention, dry swale and permeable surface retrofitting is recommended. Bioretention areas will be focused in the western half of the catchment and little to no retaining walls would be needed (*see* Lake Dr and the bottom of Brick St S). In two locations, with preference given to the Hemlock Street site, a permeable section of pavement could be installed at the end of a street to at least filter, if not infiltrate, runoff running down the impermeable street. In such cases, care should be made to accommodate the expected volume of both water and sediment entering the permeable system and it is recommended that some form of pre-treatment occur in concert with careful and limited application of sand during winter months. In addition, appropriately timed, and frequency, street sweeping will help reduce long-term maintenance “in-practice” for the permeable patch.



Curb Cut Bioretention Swale Permeable Patch

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	10.0	6.7	3.3
	TSS Reduction (lb/yr)	5,434	4,343	2,926
	TSS Reduction (%)	52%	42%	28%
	Volume Reduction (acre-feet/yr)	8.6	5.8	2.9
	Volume Reduction (%)	30%	20%	10%
	Live Storage Volume (cubic feet)	2,895	1,741	773
Costs	Materials/Labor/Design	$49,215	$29,597	$13,141
	Promotion & Admin Costs	$157	$227	$411
	Total Project Cost	$49,372	$29,824	$13,552
	Annual O&M	$2,171	$1,306	$580
	Term Cost/lb/yr (30 yr)	$382	$343	$313

LILY-07

Term Cost Rank = #6

Catchment Summary	
Acres	35.0
Dominant Land Cover	School
Parcels	44
Volume (acre-feet/yr)	30.0
TP (lb/yr)	35.0
TSS (lb/yr)	10,993.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.41
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

Recommended retrofit efforts focus on the school campus given the reduced amount of time needed for education and outreach and administrative costs in concert with the ease of installation (relatively flat and open conditions). In addition, it is highly likely that a fair amount of volunteer effort can be expected in such locations. Collectively, these attributes make the overall cost, and resulting efficiency, of stormwater bmp retrofits far less expensive than residential retrofitting.

Opportunities exist within and surrounding impervious areas such parking lots, sidewalks and between buildings and walkways in addition to a major opportunity to daylight a stormwater pipe servicing the entire campus. Some required BMPs have already been implemented as a result of an expansion and parking lot retrofit in 2008.

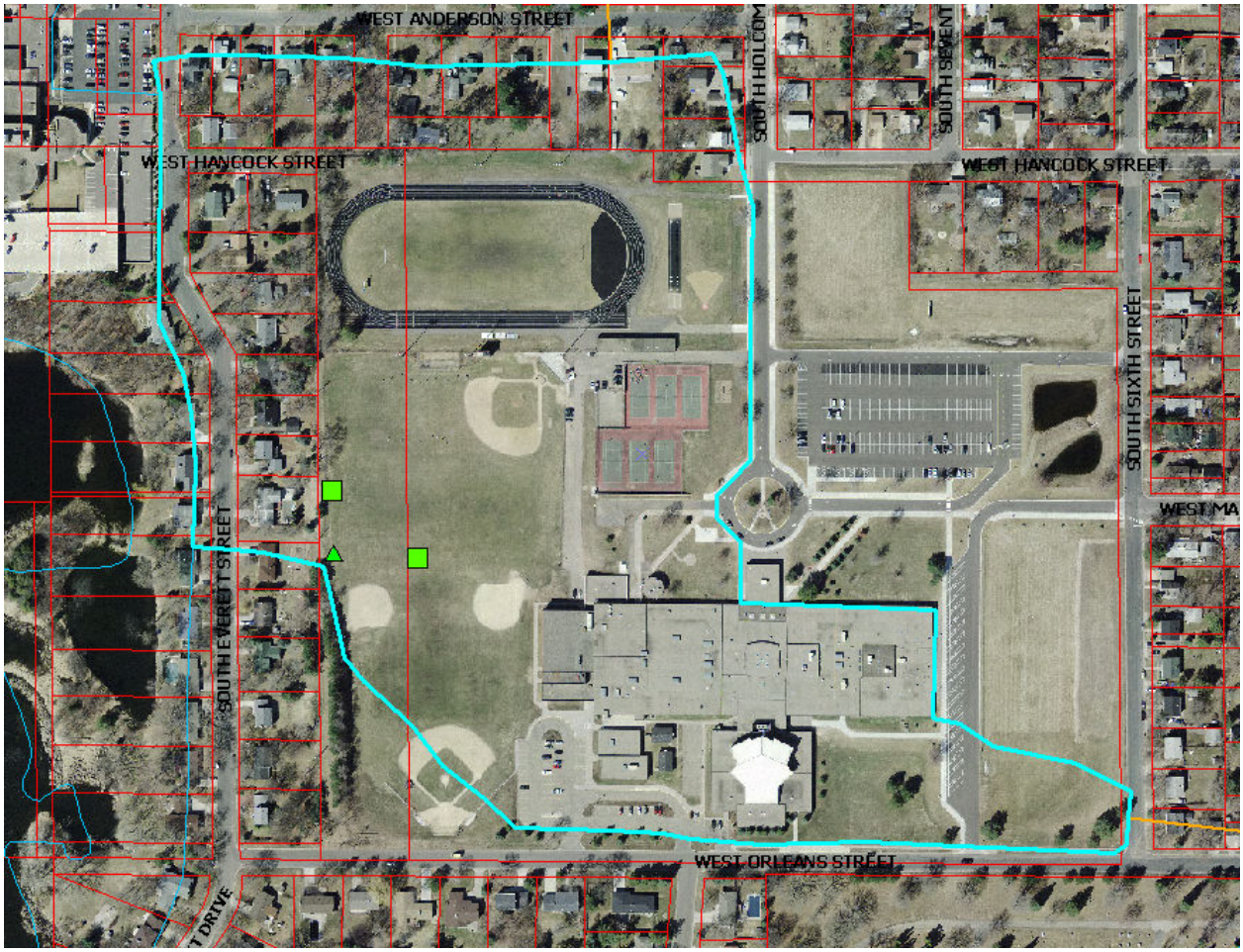
RETROFIT RECOMMENDATION

A combination of bioretention and dry swales servicing the entire campus via curb cut and stormwater pipe daylighting is possible on this campus. Bioretention located off the perimeters of parking lots and sidewalks is possible throughout the campus with no retaining walls needed. As with all other forms of infiltration, it is mandatory to include pretreatment in these designs.

A major opportunity to daylight a stormwater pipe for quality treatment exists on the western side of the property between the two ball fields. This pipe could be opened near the eastern limit of these fields, dumping into a pretreatment forebay. This forebay could then overflow to some combination of wet pond and dry swale system that then discharges to a bioretention cell(s). Emphasis on infiltration should be made with both filtered and overflow runoff being reintroduced to the existing pipe near the western terminus of the property. It is likely this system will need extensive excavation and careful surveying of the invert elevations of the pipe need to be made before committing to this design option.

This site has the ability to treat far beyond the recommended level of 20% TP reduction for far less money than other systems, but until some form of buy-in is expressed, in terms of project scale, a conservative treatment amount is reported here.

For the sake of estimating costs per volume of water treated, we approximated a ft^2 pricing as some marriage of each of these forms of stormwater practices.



Curb Cut Bioretention Swale

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	10.5	7.0	3.5
	TSS Reduction (lb/yr)	5,778	4,640	3,152
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	8.7	5.8	2.8
	Volume Reduction (%)	29%	19%	9%
	Live Storage Volume (cubic feet)	3,272	1,965	871
Costs	Materials/Labor/Design	$37,104	$22,283	$9,877
	Promotion & Admin Costs	$144	$208	$377
	Total Project Cost	$37,248	$22,491	$10,254
	Annual O&M	$2,454	$1,474	$653
	Term Cost/lb/yr (30 yr)	$352	$318	$284

LILY-09

Term Cost Rank = #7

Catchment Summary	
Acres	14.4
Dominant Land Cover	Commercial
Parcels	52
Volume (acre-feet/yr)	18.2
TP (lb/yr)	21.4
TSS (lb/yr)	6,727.4

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.61
Hydraulic Conductivity (in/hr)	1.55

DESCRIPTION

This catchment is comprised of primarily commercial buildings, medium-density multi-family residential properties, and a few single-family residences. It also includes a long section of Greeley Street running close to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. In one location in this catchment, curb bump-outs with bioretention cells would work very well where other stormwater BMPs would be far more difficult to fit in and would reduce impervious surface cover on what appears, at first glance, to be superfluous.

Curb Cut Bioretention Curb Cut Box Planter

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	6.4	4.3	2.1
	TSS Reduction (lb/yr)	3,509	2,810	1,900
	TSS Reduction (%)	52%	42%	28%
	Volume Reduction (acre-feet/yr)	5.4	3.6	1.8
	Volume Reduction (%)	30%	20%	10%
	Live Storage Volume (cubic feet)	1,916	1,151	510
Costs	Materials/Labor/Design	$28,740	$17,265	$7,650
	Promotion & Admin Costs	$212	$308	$557
	Total Project Cost	$28,952	$17,573	$8,207
	Annual O&M	$1,437	$863	$383
	Term Cost/lb/yr (30 yr)	$375	$337	$312

LILY-10

Term Cost Rank = #9

Catchment Summary	
Acres	22.4
Dominant Land Cover	Residential
Parcels	24
Volume (acre-feet/yr)	25.1
TP (lb/yr)	29.4
TSS (lb/yr)	9,264.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.54
Hydraulic Conductivity (in/hr)	1.47

DESCRIPTION

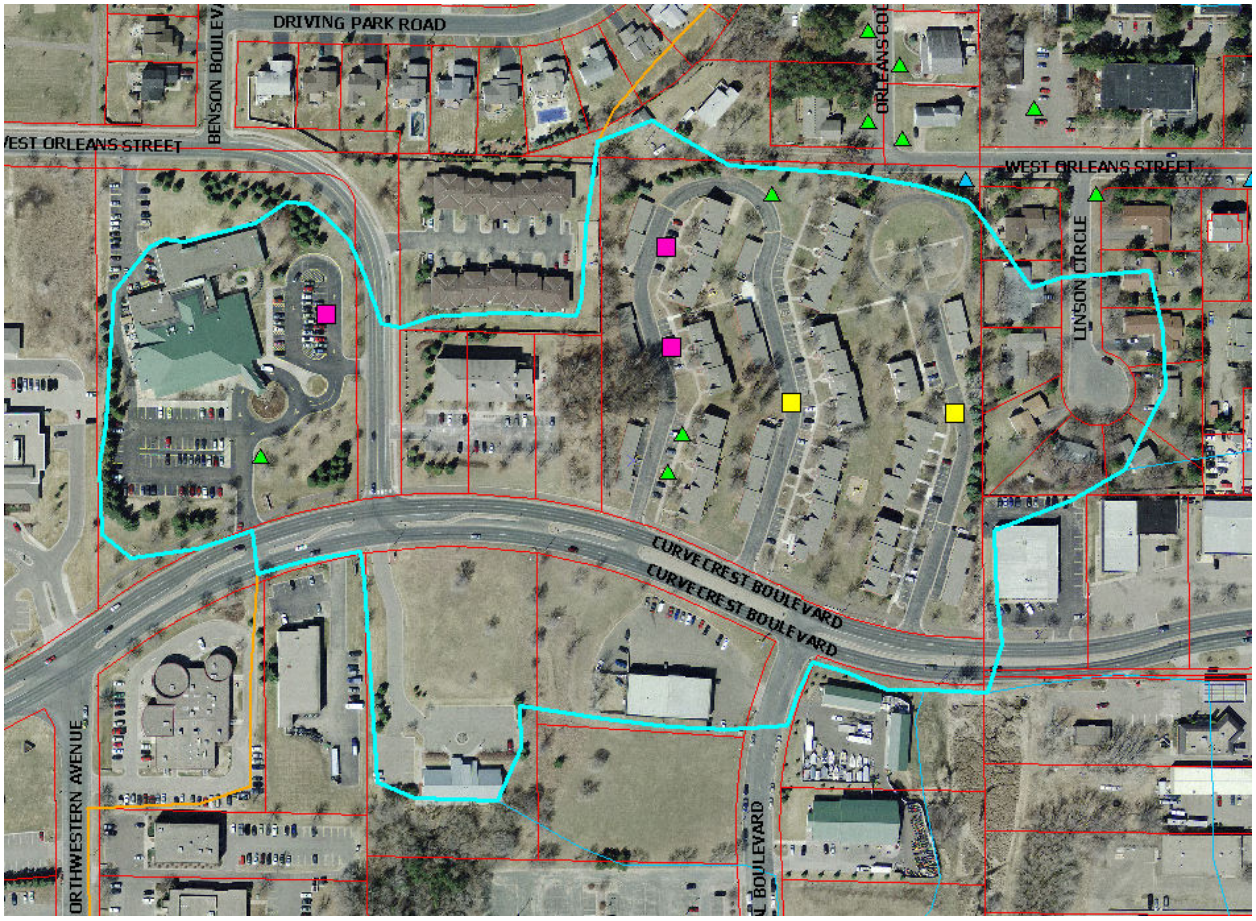
This catchment consists of medium-density multi-family residential areas with smaller areas of commercial properties. Runoff is collected in the existing storm sewer system and flows through one wet detention pond (somewhat short-circuited, but with sand infiltration treatment bench) before discharging to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention, infiltration curtains and permeable surface retrofitting is recommended for this catchment. A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

In two parking locations a permeable section of pavement could be installed to at least filter, if not infiltrate, runoff running down the impermeable driving lanes and from buildings. In such cases, care should be made to accommodate the expected volume of both water and sediment entering the permeable system and it is recommended that some form of pre-treatment occur in concert with careful and limited application of sand during winter months. In addition, appropriately timed, and frequency, street sweeping will help reduce long-term maintenance “in-practice” for the permeable patch.

In a few locations, where neither permeable parking or bioretention is possible, the ribbon gutter could be replaced with a vertical sand filter and grate. Care will need to be taken to design some form of pretreatment, likely in the form of a two-stage channel. Investigation into a similar design, and its effectiveness and maintenance demands, at the U of MN’s Landscape Arboretum should be undertaken before committing to this option.



Curb Cut Bioretention Permeable Surface Infiltration Curtain

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	8.8	5.9	2.9
	TSS Reduction (lb/yr)	4,845	3,883	2,630
	TSS Reduction (%)	52%	42%	28%
	Volume Reduction (acre-feet/yr)	7.4	5.0	2.4
	Volume Reduction (%)	29%	20%	10%
	Live Storage Volume (cubic feet)	2,680	1,610	713
Costs	Materials/Labor/Design	$5,360	$32,200	$14,260
	Promotion & Admin Costs	$166	$241	$436
	Total Project Cost	$5,526	$32,441	$14,696
	Annual O&M	$2,010	$1,208	$535
	Term Cost/lb/yr (30 yr)	$249	$388	$353

LILY-12

Term Cost Rank = #5

Catchment Summary	
Acres	15.2
Dominant Land Cover	Commercial
Parcels	25
Volume (acre-feet/yr)	27.1
TP (lb/yr)	31.8
TSS (lb/yr)	1,011.0

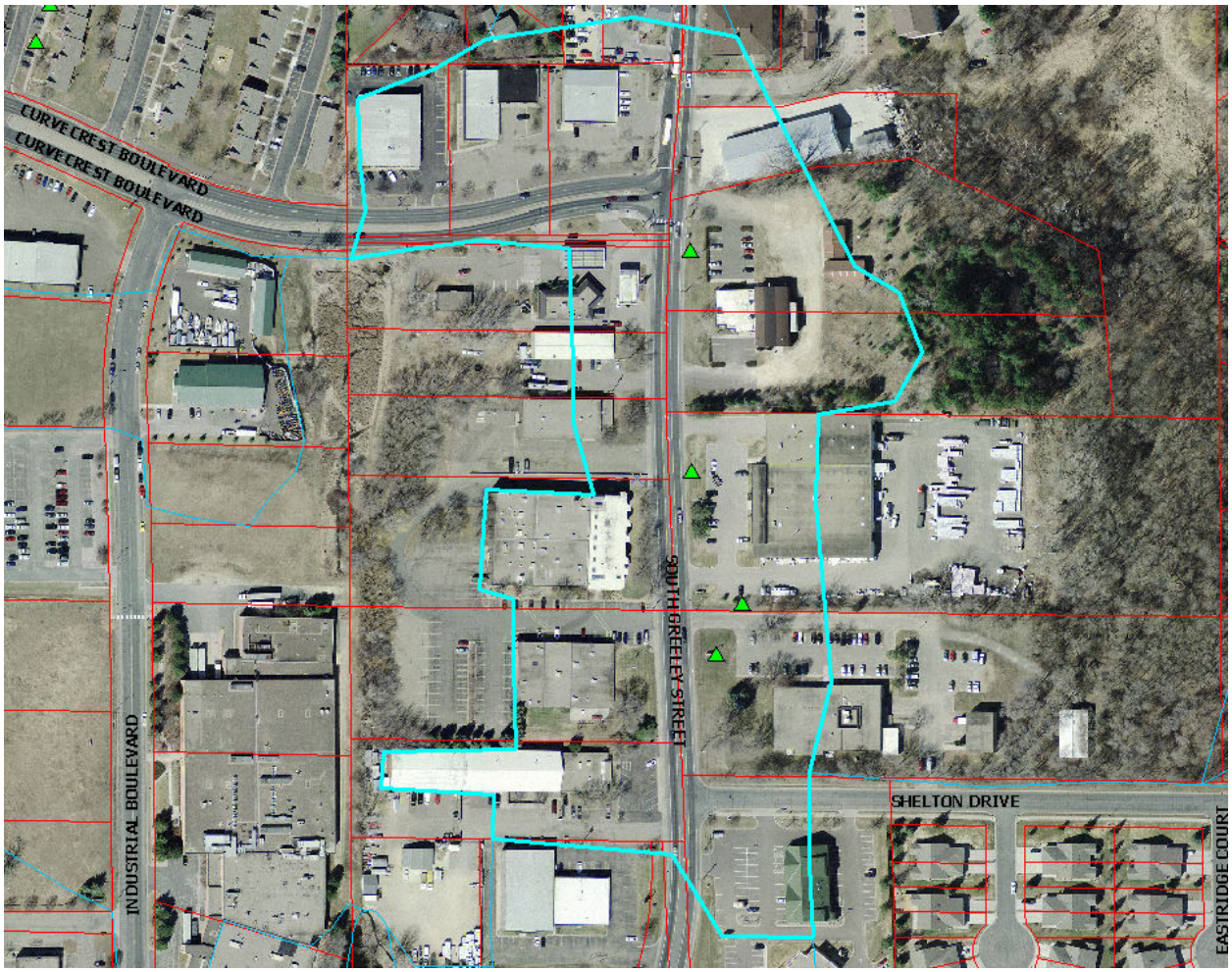
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.86
Hydraulic Conductivity (in/hr)	1.29

DESCRIPTION

This catchment consists of commercial properties and associated highly impervious fraction. Runoff is collected in the existing storm sewer system and flows through Brick Pond (catchment LILY-08W) before discharging to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. In one location in this catchment, curb bump-outs with bioretention cells would work very well where other stormwater BMPs would be far more difficult to fit in and would reduce impervious surface cover on what appears, at first glance, to be superfluous.



▲ Curb Cut Bioretention

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	9.5	6.4	3.2
	TSS Reduction (lb/yr)	5,265	4,230	2,876
	TSS Reduction (%)	521%	418%	284%
	Volume Reduction (acre-feet/yr)	7.9	5.2	2.5
	Volume Reduction (%)	29%	19%	9%
	Live Storage Volume (cubic feet)	2,997	1,800	797
Costs	Materials/Labor/Design	$44,955	$27,000	$11,955
	Promotion & Admin Costs	$153	$222	$402
	Total Project Cost	$45,108	$27,222	$12,357
	Annual O&M	$2,248	$1,350	$598
	Term Cost/lb/yr (30 yr)	$395	$353	$316

LILY-21

Term Cost Rank = #9

Catchment Summary	
Acres	18.4
Dominant Land Cover	Residential
Parcels	56
Volume (acre-feet/yr)	18.4
TP (lb/yr)	21.5
TSS (lb/yr)	6,765.0

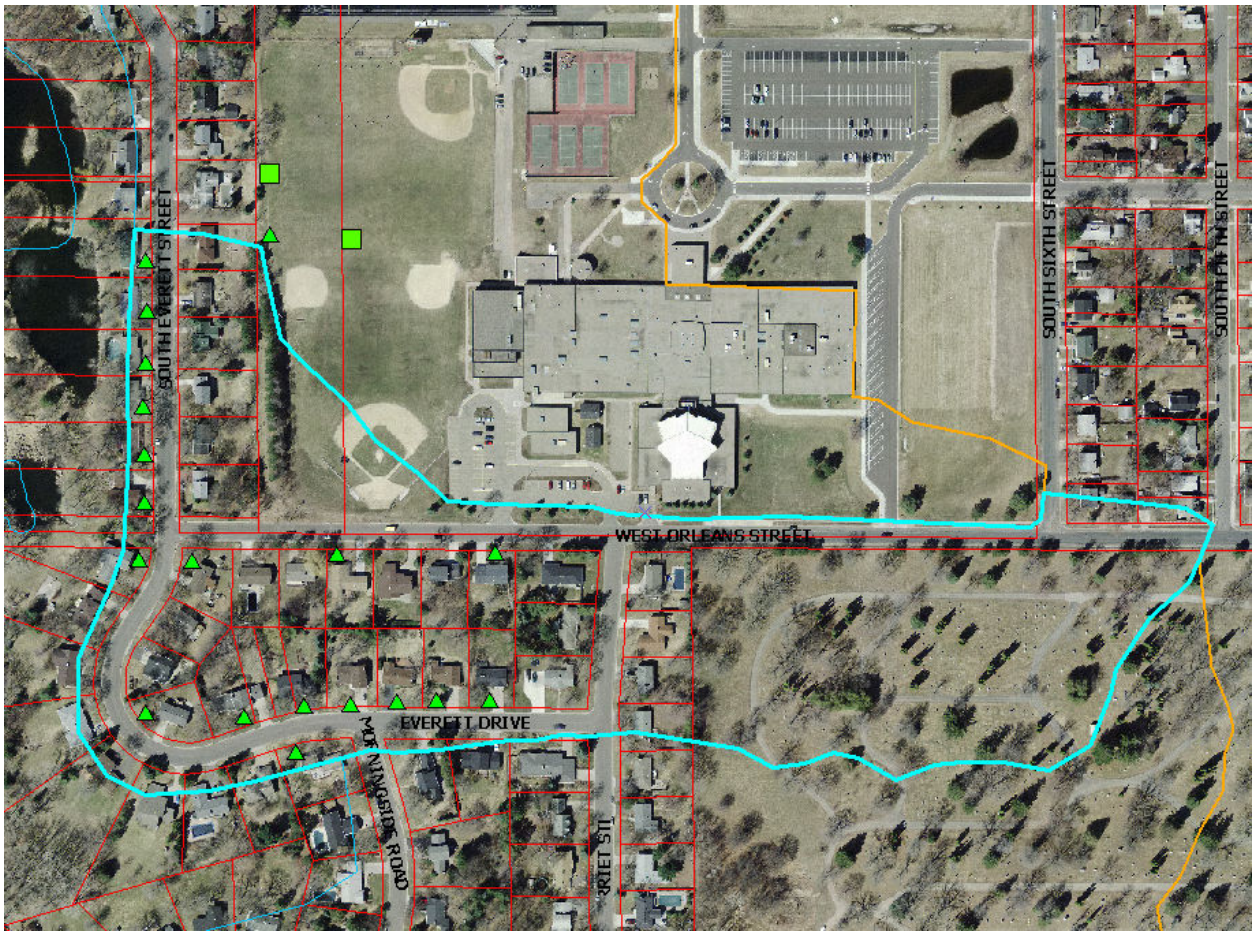
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.48
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment consists mainly of medium density single-family homes. The large cemetery in the eastern half of the catchment was excluded from this study. Runoff is collected in the existing storm sewer system and flows through Brick Pond before discharging to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. In one location in this catchment, curb bump-outs with bioretention cells would work very well where other stormwater BMPs would be far more difficult to fit in and would reduce impervious surface cover on what appears, at first glance, to be superfluous.



Curb Cut Bioretention

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	6.5	4.3	2.2
	TSS Reduction (lb/yr)	3,555	2,854	1,939
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	5.4	3.6	1.7
	Volume Reduction (%)	29%	20%	9%
	Live Storage Volume (cubic feet)	2,010	1,208	535
Costs	Materials/Labor/Design	$30,150	$18,120	$8,025
	Promotion & Admin Costs	$205	$297	$538
	Total Project Cost	$30,355	$18,417	$8,563
	Annual O&M	$1,508	$906	$401
	Term Cost/lb/yr (30 yr)	$388	$353	$312

LILY-22

Term Cost Rank = #8

Catchment Summary	
Acres	20.9
Dominant Land Cover	Residential
Parcels	55
Volume (acre-feet/yr)	21.4
TP (lb/yr)	25.0
TSS (lb/yr)	7,845.0

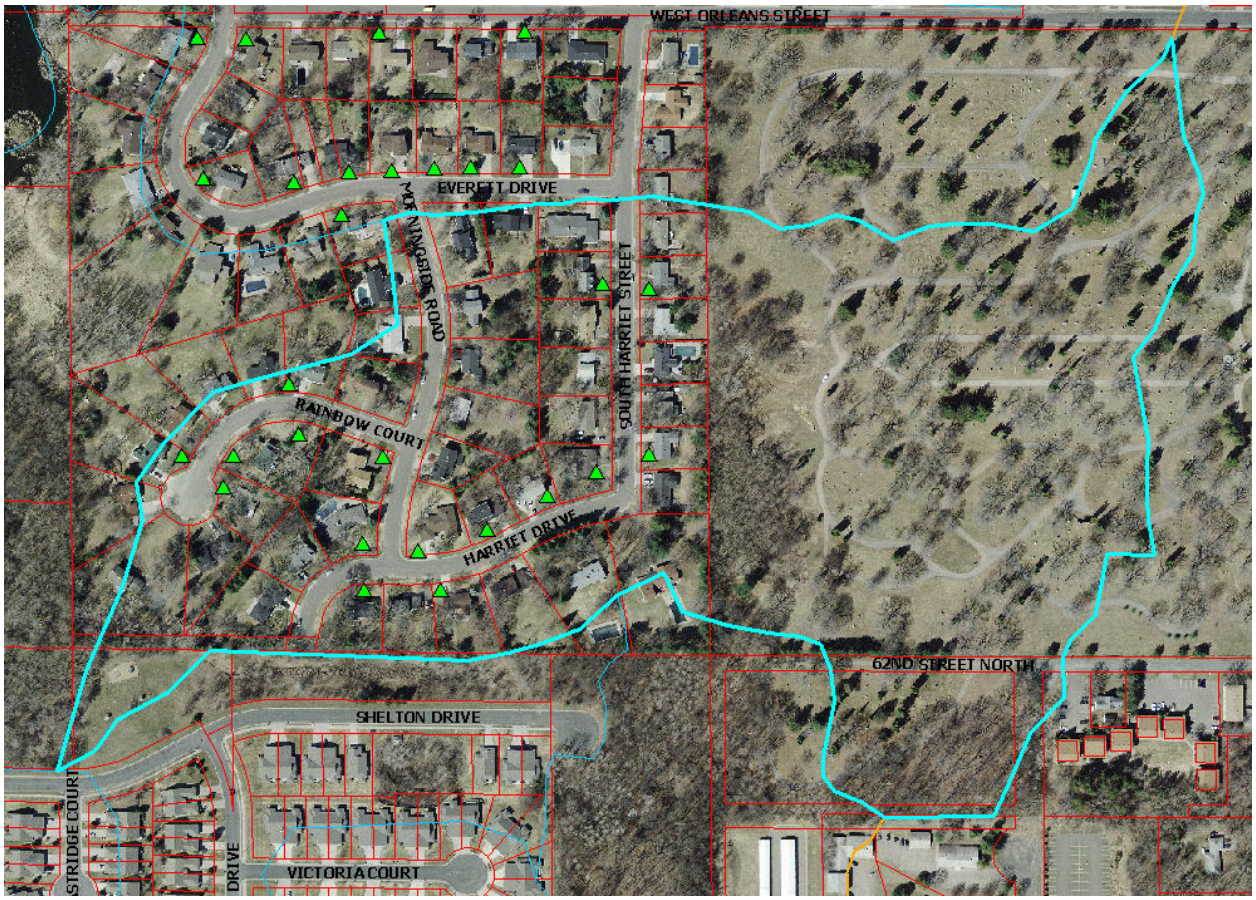
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.49
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment consists mainly of medium density single-family homes. The large cemetery in the eastern half of the catchment was excluded from this study. Runoff is collected in the existing storm sewer system and flows through Brick Pond before discharging to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. In one location in this catchment, curb bump-outs with bioretention cells would work very well where other stormwater BMPs would be far more difficult to fit in and would reduce impervious surface cover on what appears, at first glance, to be superfluous.



Curb Cut Bioretention

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	7.8	5.0	2.5
	TSS Reduction (lb/yr)	4,118	3,308	2,248
	TSS Reduction (%)	52%	42%	29%
	Volume Reduction (acre-feet/yr)	6.2	4.2	2.0
	Volume Reduction (%)	29%	20%	9%
	Live Storage Volume (cubic feet)	2,325	1,400	620
Costs	Materials/Labor/Design	$34,875	$21,000	$9,300
	Promotion & Admin Costs	$184	$267	$483
	Total Project Cost	$35,059	$21,267	$9,783
	Annual O&M	$1,744	$1,050	$465
	Term Cost/lb/yr (30 yr)	$373	$352	$316

Catchment Ranking

Catchment or Pond ID	Retro Type	BMP area (sq ft)	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Est. Cost[1]	O&M Term (years)	Total Est. Term Cost/lb-TP/30 yr	Rank
LILY-03	B	1,244	10	5.0	4.0	$18,951	30	$313	1
LILY-04	B, PS, VS	773	10	3.3	2.9	$13,552	30	$313	1
LILY-02	B	1,124	10	4.5	3.7	$17,173	30	$315	3
LILY-01	B	1,100	10	4.4	3.6	$16,818	30	$315	3
LILY-12	B	797	10	3.2	2.5	$12,357	30	$316	5
LILY-07	B, VS	1,965	20	7.0	5.8	$22,283	30	$318	6
LILY-09	B	1,151	20	4.3	3.6	$17,573	30	$337	7
LILY-22	B	1,400	20	5.0	4.2	$21,267	30	$352	8
LILY-21	B	1,208	20	4.3	3.6	$18,417	30	$353	9
LILY-10	B, PS, F	713	10	2.9	2.4	$14,696	30	$353	9
[2]P13-W	WD	n/a	50	20	0	$130,000	15	$433	11
[2]P18-W	WD	n/a	50	30	0	$265,000	15	$589	12
TOTAL	-	-	-	**93.9**	**36.3**	**$568,087**	-	-	-

B = Bioretention (infiltration and/or filtration)
F = Filtration (sand curtain, surface sand filter, sump, etc.)
PS = Permeable Surface (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
WD = Wet Detention or wetland creation (new pond)

[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.

[2]See "City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake," Wenck Associates, Inc., October 2007

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Appendices

Appendix 1 – Catchments not included in Ranking Table

Catchments not included in ranking table were excluded for a number of reasons, mainly involving connectivity to the receiving water. After BMPs are installed within the priority catchments, it is recommended that the watershed revisit the entire subwatershed to determine other catchments that, while they may be conducive to retrofitting, were not considered a high priority for this report.

Appendix 2 – Summary of Protocol

This protocol attempts to provide a sufficient level of detail to rapidly assess subwatersheds or catchments of variable scales and land uses. It provides the assessor defined project goals that aid in quickly narrowing down multiple potential sites to a point where the assessor can look critically at site-specific driven design options that affect, sometimes dramatically, BMP selection. We feel that the time commitment required for this methodology is appropriate for most initial assessment applications and has worked well thus far for the Lily Lake Assessment.

Appendix 3 – Definitions

The following terms are used throughout this document and define the basic terminology used to talk about watersheds and restoration. Many of the terms can have different meanings in different contexts, so it is imperative to define their use within this document.

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

Bioretention – A soil and plant-based stormwater management BMP used to filter runoff.

Catchment – Land area within a subwatershed generally having a drainage area of 1 – 100 acres for urban areas, where all water drains to a particular point. Several catchments make up a subwatershed. The existing stormwater infrastructure helps to define a catchment; therefore it is critical to obtain accurate stormwater infrastructure mapping information (including, at a minimum, the location of inlets and pipes, flow direction, and outfall locations) before undertaking a stormwater assessment process.

Raingarden – A landscaping feature that is planted with native perennial plants and is used to manage stormwater runoff from impervious surfaces such as roofs, sidewalks, roads, and parking lots.

Retrofit – The introduction of a new or improved stormwater management element where it either never existed or did not operate effectively.

Stormwater – Water that is generated by rainfall or snowmelt that causes runoff and is often routed into drain systems for treatment or conveyance.

Subwatershed – Land area within a watershed generally having a drainage area of more than 500 acres, where all water drains to a particular point. Several subwatersheds make up a watershed. An example would be the Lily Lake subwatershed, which is within the boundaries of the Middle St. Croix Water Management Organization (the watershed). Subwatersheds are entirely based on hydrologic conditions, not political boundaries.

Urban – Any watershed or subwatershed with more than 10% total impervious cover.

Watershed – Land area defined by topography, where all water drains to a particular point. Watershed drainage areas are large, ranging from 20 to 100 square miles or more, and are made up of several subwatersheds. There are currently 8 watersheds located either wholly or partially within Washington County, each defined along political boundaries that attempt to mimic hydrologic boundaries.

Appendix 4 – WCD Subwatershed Selection Process

The Washington Conservation District selected the Lily Lake/Lake McKusick subwatersheds for the MCD assessment program through a competitive process. Watershed organizations in Washington County were asked to nominate subwatersheds that were then scored on 5 equally weighted criteria (maximum of 5 points each). There were 7 nominations, of which 2 were chosen for assessments. The results were as follows:

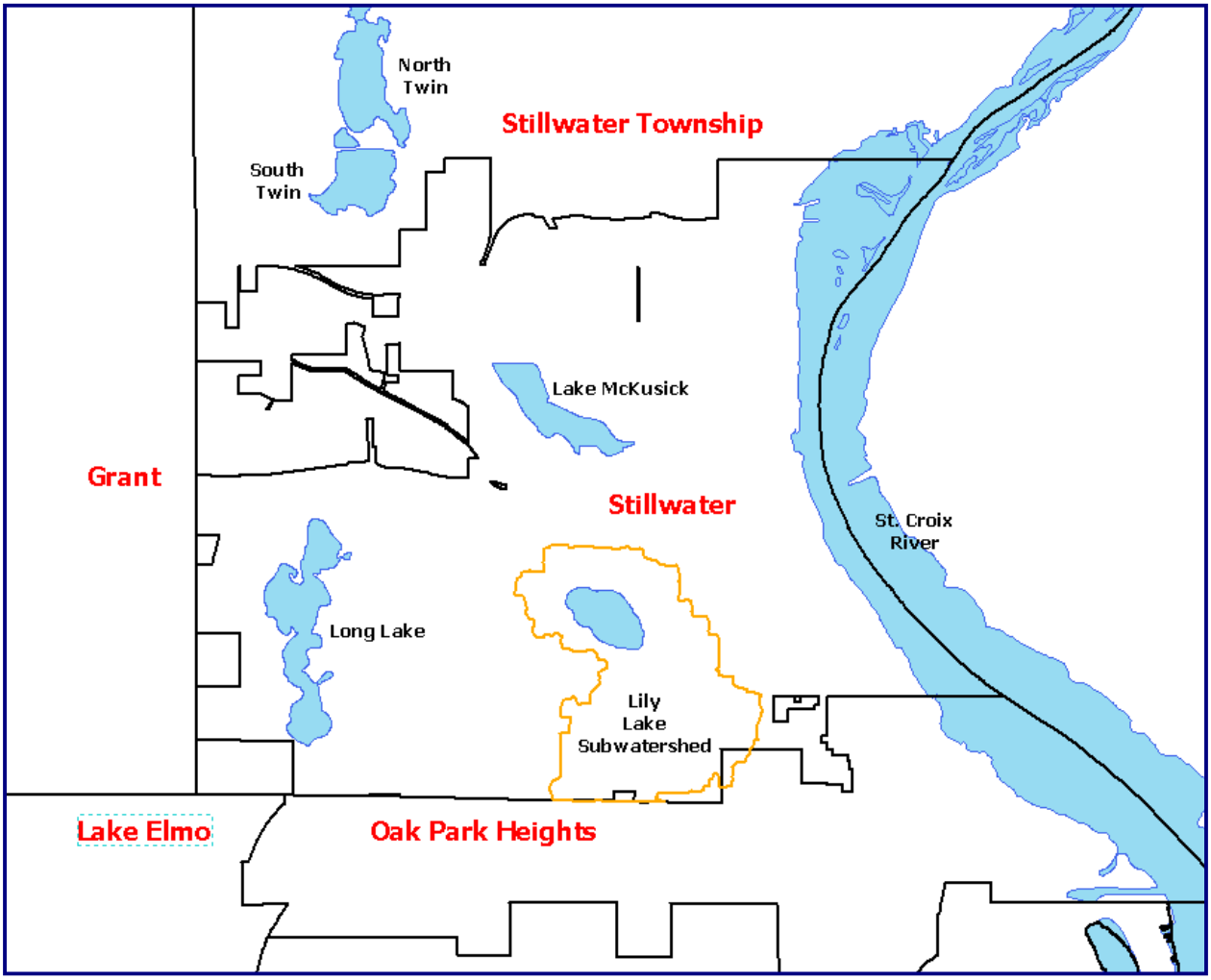
Organization	Subwatershed	C1	C2	C3	C4	C5	TOTAL
RWMWD	Carver Lake	5	5	5	5	5	**25**
MSCWMO	Lily/McKusick	5	5	5	5	5	**25**
VBWD	Raleigh Creek	5	5	5	5	3	23
SWWD	Markgrafs Lake	5	5	0	5	4	19
CLFLWD	CL04	5	5	2	2	4	18
RCWD	N. Clear Lake	5	3	2	0	4	15
RCWD	N. Mahtomedi	5	3	2	0	2	12

Criteria
C1 = urban/suburban
C2 = well-defined subwatershed boundary
C3 = water quality monitoring data
C4 = stormwater infrastructure mapping
C5 = drains to impaired or target water body

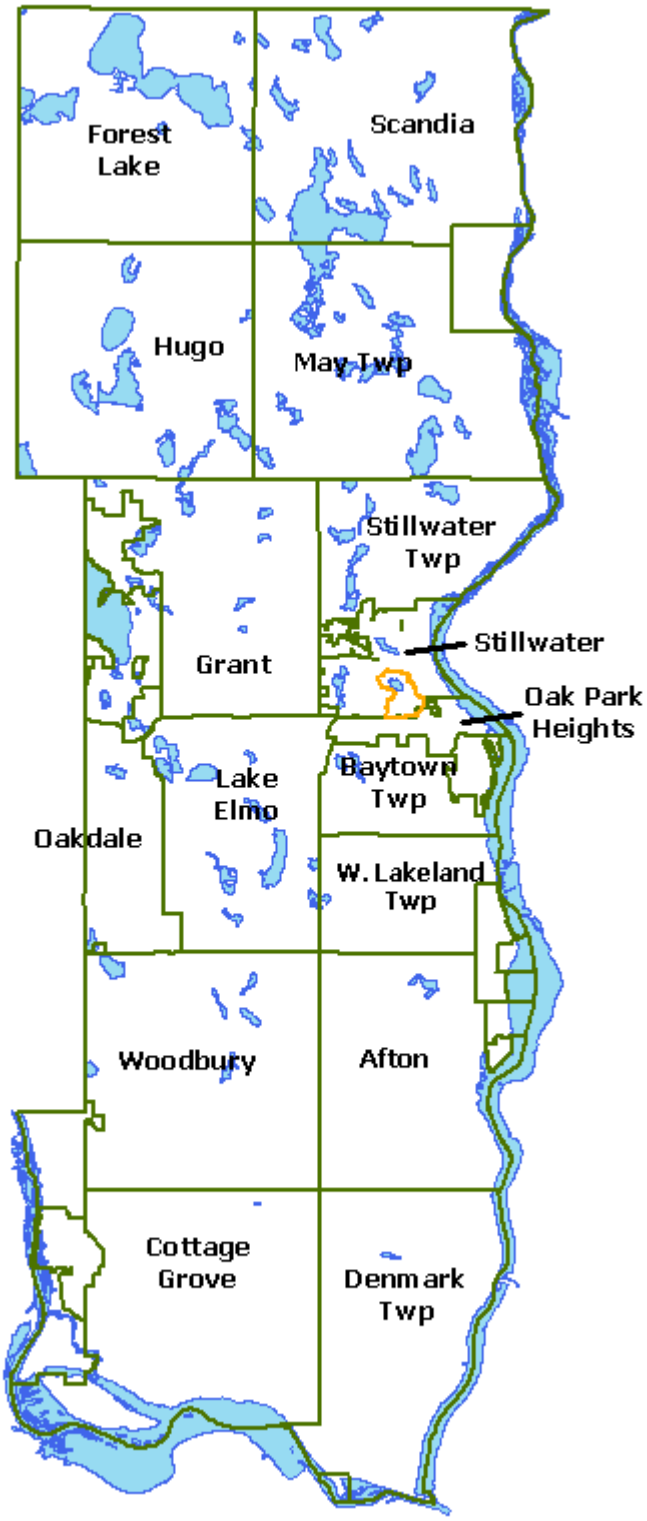
Appendix 5 – Subwatershed Maps

Lily Lake Subwatershed – Aerial Photo (2009)

Lily Lake Subwatershed – 22 Catchments (Priority Catchments are Shaded)



Location of the Lily Lake Subwatershed within Stillwater



Location of the Lily Lake Subwatershed within Washington County

Lake McKusick

Stormwater Retrofit Assessment

Prepared by:

WASHINGTON CONSERVATION DISTRICT

With assistance from:

THE METRO CONSERVATION DISTRICTS

for the

MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION

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Table of Contents

This report details a subwatershed stormwater retrofit assessment resulting in recommended catchments for placement of Best Management Practice (BMP) retrofits that address the goals of the Local Governing Unit (LGU) and stakeholder partners. 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 subwatersheds of variable scales and land-uses to identify optimal locations for stormwater treatment. The time commitment required for this methodology is appropriate for *initial assessment* applications. 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, agricultural and range land management, good housekeeping outreach and education, and others, within existing or future watershed restoration planning.

The assessment's background 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 BMPs 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 and implement BMP projects. 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 in this report. This typically occurs after committed partnerships are developed for each specific target property for which BMPs are planned.

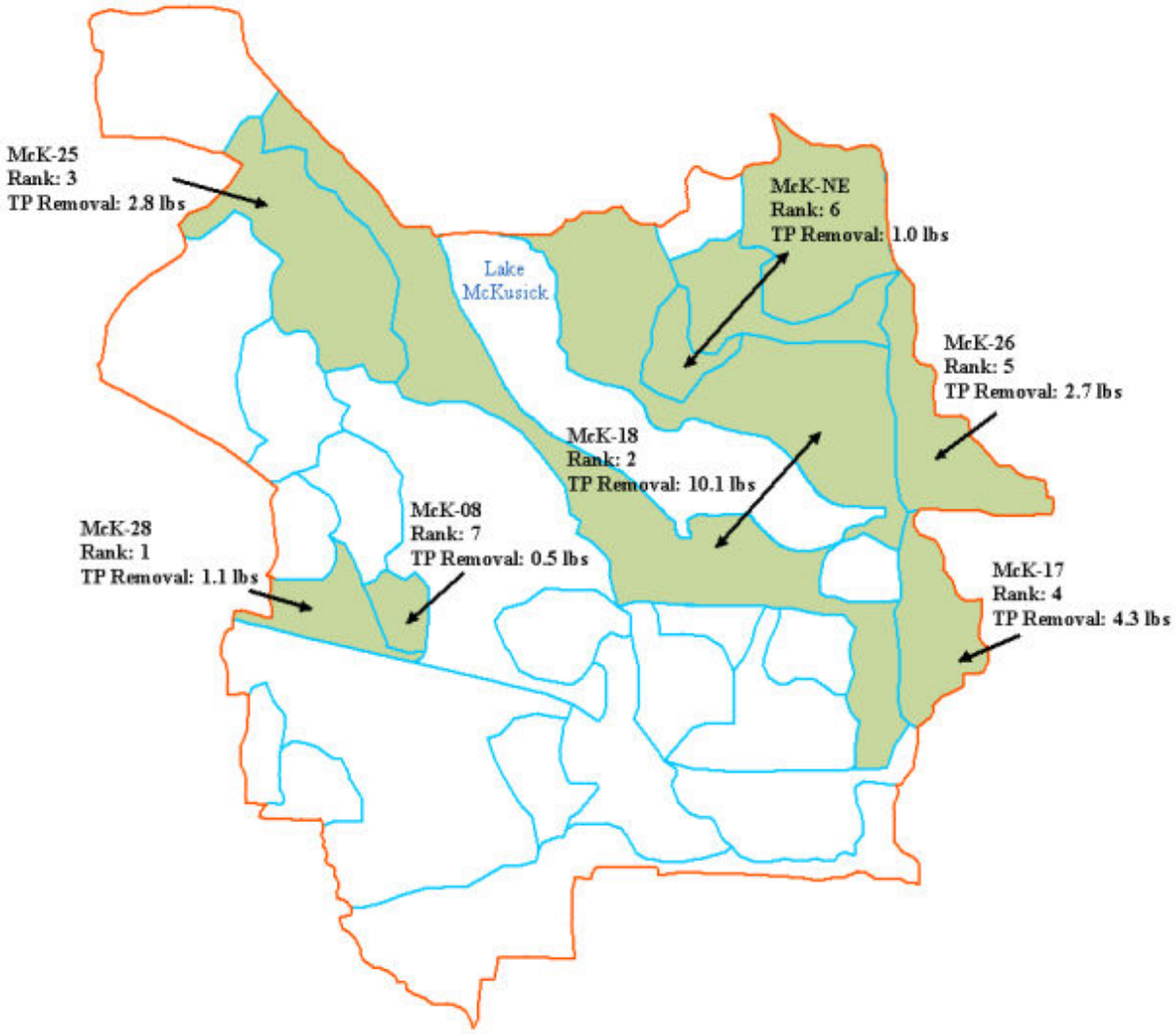
Executive Summary

The 29 catchments of the Lake McKusick subwatershed, and their existing stormwater management practices, were analyzed for annual pollutant loading. Stormwater practice options were compared for each catchment, depending on specific site constraints and characteristics. Potential stormwater BMP retrofits were selected by weighing cost, ease of installation and maintenance and ability to serve multiple functions identified by the City of Stillwater and Middle St. Croix Watershed Management Organization (MSCWMO). Nine of the 29 catchments were selected and modeled at various levels of treatment efficiency. Three small catchments in the northeast portion of the subwatershed sharing a common discharge point were combined into one catchment for this report (catchments 19, 20, and 27 – they will be referred to collectively as "McK-NE"). These nine catchments should be considered the "low-hanging-fruit" within the Lake McKusick Subwatershed.

Total phosphorus (TP) is the major target pollutant within the Lake McKusick subwatershed. Runoff volume reduction should also be considered when ranking priority catchments. Reducing the annual TP loading to the lake by 62 pounds from the subwatershed, in combination with load reductions from other areas, will allow the lake to meet desired TP concentrations. The following table summarizes the assessment results. Treatment levels (percent removal rates) for retrofit projects that resulted in a prohibitive BMP size, or number, or were too expensive to justify installation are not included. Reported treatment levels are dependent upon optimal BMP location within the catchment and total BMP area. The recommended treatment levels/amounts summarized here are based on a subjective assessment of potential BMP installations, considering estimated public participation and site constraints. Recommended catchment rankings are based on a relative comparison of the cost per pound of phosphorus reduced over the life of the BMPs. A TP reduction of 21.0 pounds (34% of the target reduction) could be achieved for a total cost of $103,924, if recommended BMPs are installed within the top 5 ranked catchments according the table below.

Catchment or Pond ID	Retro Type	BMP area (sq ft)	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Est. Cost[1]	O&M Term (years)	Total Est. Term Cost/lb-TP/30 yr	Rank
McK-28	B	200	20	1.1	0.8	$2,774	30	$254	1
McK-18	B	2,820	10	10.1	8.2	$39,273	30	$339	2
McK-25	B	850	10	2.8	2.0	$13,984	30	$394	3
McK-17	B	950	20	4.3	3.8	$30,590	30	$406	4
McK-26	B	715	10	2.7	2.4	$17,303	30	$418	5
McK-NE[2]	ED	n/a	4	1.0	0	$30,250	30	$1,008	6
McK-08	B	500	9	0.5	0.7	$9,984	30	$1,416	7
McK-18SE[3]	WD	n/a	5	5.0	0	$125,000	15	$1,667	8
McK-18NE[3]	WD	n/a	5	5.0	0	$150,000	15	$2,000	9

B = Bioretention (infiltration and/or filtration)
ED = Extended Detention (Pond Maintenance for McK-NE)
WD = New [wet] Detention or Wetland creation
[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.
[2]Combined catchment, includes McK-19, McK-20, and McK-27
[3]See "City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake," Wenck Associates, Inc., October 2007



Top-Ranked Lake McKusick Catchments and TP Removal Potential

About this Document

Document Overview

The Stormwater Retrofit Assessment is a subwatershed management tool used to prioritize stormwater BMP retrofit projects based on BMP performance and cost effectiveness. This process helps maximize the value of each dollar spent.

This document is organized into four main sections that describe the general methods used, individual catchment profiles, a retrofit ranking for the subwatershed, and references used in the assessment protocol. The Appendices section provides additional information relevant to the assessment.

Under each section and subsection, project-specific information relevant to that portion of the assessment is provided with an ***Italicized Heading***.

Methods

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

NOTE: the financial, technical, current landscape/stormwater system, and timeframe limits and needs are highly variable from subwatershed to subwatershed. This assessment uses some, or all, of the methods described herein.

Catchment Profiles

Each catchment profile is labeled with a unique ID to coincide with the catchment name (e.g., McK-08 for Lake McKusick catchment number 8). This catchment ID is referenced when comparing results across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

Within each Catchment Summary/Description section is a table that summarizes basic information including catchment size, current land cover, land ownership, and estimated annual pollutant load (target pollutant(s) are specified by the LGU). A table of the principal modeling parameters and values is also reported. A brief description of the land cover, stormwater infrastructure and any other important general information is described.

Retrofit Recommendation

The Retrofit Recommendation section describes the conceptual BMP retrofit(s) selected for the catchment area and provides a description of why each specific retrofit option 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 BMP retrofit projects. Additional field inspections will be required to verify project feasibility, but the most ideal locations for BMP project installations are identified here.

Catchment Ranking

Catchment ranking takes into account all of the information gathered during the assessment process to create a prioritized catchment list. The list is sorted by the cost per pound of phosphorus treated within each catchment for the duration of the 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 within catchments, and the list provided is merely a starting point. Final catchment ranking for installation may include:

- Total amount of pollutant removal
- Non-target pollutant reductions
- BMP project visibility
- Availability of funding
- Total project costs
- Educational value

References

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

Appendices

The Appendices section provides supplemental information and/or data used during the assessment protocol.

Methods

Selection of Subwatershed

Before the subwatershed stormwater assessment begins, a process of identifying a high priority water body as a target takes place. Many factors are considered when choosing which subwatershed to assess for stormwater retrofits. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Assessments supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the assessment also rank highly.

In areas without clearly defined studies, such as TMDL or officially listed water bodies of concern, or where little or no monitoring data exist, metrics are used to score subwatersheds against each other. In large subwatersheds (e.g., greater than 2500 acres), a similar metric scoring is used to identify areas of concern, or focus areas, for a more detailed assessment. This methodology was slightly modified from Manual 2 of the *Urban Stormwater Retrofit Practices* series.

Description of Lake McKusick and the Contributing Subwatershed

Lake McKusick has a surface area of 45 acres, an average depth of 3 feet, and an ordinary high water level of 851.7 feet. The lake is located within the City of Stillwater in the northeastern suburban Twin Cities metropolitan area. The Lake McKusick subwatershed encompasses approximately 586 acres, including about 192 acres of impervious cover. The primary land use is residential development. The lake ultimately discharges to the St. Croix River. Stormwater is conveyed through a network of storm sewers, channels, and ponds. Much of the development within the subwatershed occurred prior to implementation of regulations requiring stormwater treatment, so there are several areas where minimal treatment of runoff occurs before entering the lake. The most significant phosphorus source to Lake McKusick is from the contributing watersheds. (*City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake*, Wenck Associates, Inc., October 2007)

Washington Conservation District monitors Lake McKusick for total phosphorus, chlorophyll-a, Secchi disk depth (transparency), and other parameters. Although the lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List, it currently is showing a statistically significant improving trend for both average Secchi transparency and average total phosphorus (*MSCWMO 2009 Water Monitoring Report*, Washington Conservation District, 2010).

Phosphorus was chosen as the target pollutant of this assessment to address the lake impairment. The direct drainage area (contributing subwatershed) was chosen as the focus of this assessment. This direct drainage area contributes 18% of the phosphorus load to Lake McKusick. Other phosphorus sources to Lake McKusick include a large annexed area consisting of mostly undeveloped and agricultural land (44%), Long Lake (20%), and Lily Lake (18%). The Wenck plan sets a reduction goal of 62 pounds of phosphorus from the direct drainage area for Lake McKusick. When achieved, this reduction will allow Lake McKusick to meet the MPCA's standard TP concentration of 60 µg/L for shallow lakes. Other efforts are currently underway to address loading from the Long Lake and Lily Lake subwatersheds.

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 includes determining the objectives of the retrofits (volume reduction, target pollutant etc) and the level of treatment desired. It involves meeting with local stormwater managers, city staff, and watershed staff to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to assess in large subwatersheds, a smaller focus area may be determined.

Lake McKusick Subwatershed Scoping

Pollutants of concern for this subwatershed were identified as TP, TSS, and volume. Goals of the MSCWMO, WCD, and City of Stillwater were considered as well the results of the *City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake*, Wenck Associates, Inc., October 2007.

Step 2: Desktop Retrofit Analysis

Desktop retrofit analysis involves computer-based scanning of the subwatershed for potential BMP retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure. Accurate and current GIS data is extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography, and storm drainage infrastructure (with invert elevations and flow direction). The following table highlights some important features to look for and the associated potential retrofit project.

Subwatershed Metrics and Potential Retrofit Project Site/Catchment	
Screening Metric	**Potential Retrofit Project**
Existing Ponds	**Add storage and/or improve water quality by excavating accumulated sediment, modifying inlet or outlet, raising embankment, and/or modifying flow routing.**
Open Space	**New regional treatment (pond, bioretention).**
Roadway Culverts	**Add wetland or extended detention water quality treatment upstream.**
Outfalls	**Split flows or add storage below outfalls if open space is available.**
Conveyance system	**Add or improve performance of existing swales, ditches and non-perennial streams.**
Large Impervious Areas (campuses, commercial, parking)	**Stormwater treatment on-site or in nearby open spaces.**
Neighborhoods	**Utilize right of way, roadside ditches or curb-cut raingardens or filtering systems to treat stormwater before it enters storm drain network.**

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 to eliminate sites from consideration. The field investigation revealed additional retrofit opportunities that would have gone unnoticed during the desktop search.

The following stormwater BMPs were considered for each catchment/site:

Stormwater Treated Options for Retrofitting		
Area Treated	**Best Management Practice**	**Potential Retrofit Project**
5-500 acres	Extended Detention	**12-24 hr detention of stormwater with portions drying out between events (preferred over Wet Ponds). May include multiple cells, infiltration benches, sand/peat/iron filter outlets, and modified choker outlet features.**
	Wet Ponds	**Permanent pool of standing water with new water displacing pooled water from previous event.**
	Wetlands	**Depression less than 3 feet deep and designed to emulate wetland ecological functions. Residence times of several days to weeks. Best constructed off-line with low-flow bypass.**
0.1-5 acres	Bioretention	**Use of native sol, soil microbe, and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.**
	Filtering	**Filters runoff through engineered media and passes it through an under-drain. May consist of a combination of sand, soil, compost, peat, compost, and iron.**
	Infiltration	**A trench or sump that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering the infiltration area.**
	Swales	**A series of vegetated, open channel practices that can be designed to filter and/or infiltrate runoff.**
	Other	**On-site, source-disconnect practices such as rain-leader raingardens, rain barrels, green roofs, cisterns, stormwater planters, dry wells and permeable pavements.**

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Sites most likely address pollutant reduction goals and those that may have simple design/install/maintenance considerations are chosen for a cost/benefit analysis that relatively compares catchments/sites. Treatment concepts are developed taking into account site constraints and the subwatershed treatment objectives. Projects involving complex stormwater treatment interactions and those that may pose a risk for upstream flooding require the assistance of a professional engineer. Conceptual designs at this phase of the design process include cost and pollution reduction estimates. Reported treatment levels are dependent upon optimal site selection and sizing.

Modeling of the site is done by one or more methods such as with P8, WINSLAMM or simple spreadsheet methods using the Rational Method. Event mean concentrations or sediment loading files (depending on data availability and model selection) are used for each catchment/site to estimate relative pollution loading of the existing conditions. The site's conceptual BMP design is modeled to then estimate varying levels of treatment by sizing and design element. This treatment model can also be used to properly size BMPs to meet LGU restoration objectives.

General P8 Model Inputs	
Parameter	**Method for Determining Value**
Total Area	Source/Criteria
Pervious Area Curve Number	Values from the USDA Urban Hydrology for Small Watersheds TR-55 (1986). A composite curve number was found based on proportion of hydrologic soil group and associated curve numbers for open space in fair condition (grass cover 50%-75%).
Directly Connected Impervious Fraction	Calculated using GIS to measure the amount of rooftop, driveway and street area directly connected to the storm system. Estimates calculated from one area can be used in other areas with similar land cover.
Indirectly Connected Impervious Fraction	Wisconsin urban watershed data (Panuska, 1998) provided in the P8 manual is used as a basis for this number. It is adjusted slightly based on the difference between the table value and calculated value of the directly connected impervious fraction.
Precipitation/Temperature Data	Rainfall and temperature recordings from 1959 were used as a representation of an average year.
Hydraulic Conductivity	A composite hydraulic conductivity rate is developed for each catchment area based on the average conductivity rate of the low and high bulk density rates by USDA soil texture class (Rawls et. al, 1998). Wet soils where practices will not be installed are omitted from composite calculations.
Particle/Pollutant	The default NURP50 particle file was used.
Sweeping Efficiency	The City of Stillwater sweeps all streets two times per year. Street sweeping was not accounted for in the model.

Lake McKusick Treatment Analysis

For the Lake McKusick treatment analysis, each catchment (and each relevant parcel within them) was first assessed for BMP applicability given specific site constraints and soil types. Pedestrian and car traffic flow, parking needs, snow storage areas, obvious utility locations, existing landscaping, surface water runoff flow, project visibility, existing landscape maintenance, available space, and other site-specific factors dictated the selection of one or more potential BMPs for each site.

P8 was used to model catchments and a hypothetical BMP located at its outfall. The BMP was sized from the 10-50% treatment size and results were tabulated in the Catchment Profile section of this document.

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 total cubic feet of treatment. In cases where live storage was 1 foot deep, this number roughly related to square feet of BMP coverage. An annual cost/TP-removed for each treatment level was then calculated for the life of each BMP that includes promotional, administrative and life cycle operations, and maintenance costs.

The following table provides the BMP cost estimates used to assist in cost analysis:

Average BMP Cost Estimates						
BMP	**Median Inst. Cost ($/ft^2)**	**Marginal Annual Maintenance Cost (contracted)**	**O&M Term**	**Design Cost ($70/hr)**	**Installation Oversight Cost ($70/hr)**	**Total Installation Cost (Includes design & 1-yr maintenance)**
Pond Retrofits	$3.00	$500/ac	30	[1]40% above construction	$210 (3 visits)	**$4.21/ft^2**
Extended Detention	$5.00	$1000/ac	30	[1]$2800/ac	$210 (3 visits)	**$12.02*(ft^3^0.75)**
Wet Pond	$5.00	$1000/ac	30	[1]$2800/ac	$210 (3 visits)	**$277.89*(ft^3^0.553)**
Stormwater Wetland	$5.00	$1000/ac	30	[1]$2800/ac	$210 (3 visits)	**$4,800*(DA ac^0.484)**
Dry Swale	$3.00	$0.75/ft^2	30	$280/100 ft^2	$210 (3 visits)	**$6.60/ft^2**
Water Quality Swale[4]	$12.00	$0.75/ft^2	30	$1120/1000 ft^2	$210 (3 visits)	**$13.90/ft^2**
Cisterns	$15.00	[3]$100	30	NA	$210 (3 visits)	**$16.00/ft^2**
French Drain/Dry Well	$12.00	[3]$100	30	20% above construction	$210 (3 visits)	**$15.00/ft^2**
Infiltration Basin (turf)	$15.00	$2000/ac	30	$1120/ac	$210 (3 visits)	**$15.10/ft^2**
Rain Barrels	$25.00	[3]$25	30	NA	$210 (3 visits)	**$25.00/ft^2**

Average BMP Cost Estimates						
BMP	**Median Inst. Cost ($/ft^2)**	**Marginal Annual Maintenance Cost (contracted)**	**O&M Term**	**Design Cost ($70/hr)**	**Installation Oversight Cost ($70/hr)**	**Total Installation Cost (Includes design & 1-yr maintenance)**
Structural Sand Filter (including peat, compost, iron amendments, or similar) [4]	$20.00	$250/25 ln ft	30	$300/25 ln ft	$210 (3 visits)	**$21.50/ft^2**
Impervious Cover Conversion	$20.00	$500/ac	30	$1120/ac	$210 (3 visits)	**$20.10/ft^2**
Stormwater Planter	$27.00	$0.75/ft^2	30	20% above construction	$210 (3 visits)	**$32.20/ft^2**
Rain Leader Disconnect Raingardens	$4.00	$0.25/ft^2	30	[2]$280/100 ft^2	$210 (3 visits)	**$7.00/ft^2**
Simple Bioretention (no engineered soils or under-drains, but w/curb cuts and forebays)	$10.00	$0.75/ft^2	30	[2]$1120/1000 ft^2	$210 (3 visits)	**$11.30/ft^2**
Moderately Complex Bioretention (incl. engineered soils, under-drains, curb cuts, but no retaining walls)	$12.00	$0.75/ft^2	30	[2]$1120/1000 ft^2	$210 (3 visits)	**$13.90/ft^2**
Complex Bioretention (same as MCB, but with 1.5 to 2.5 ft partial perimeter walls)	$14.00	$0.75/ft^2	30	[2]$1400/1000 ft^2	$210 (3 visits)	**$16.20/ft^2**

Average BMP Cost Estimates						
BMP	Median Inst. Cost ($/ft^2)	Marginal Annual Maintenance Cost (contracted)	O&M Term	Design Cost ($70/hr)	Installation Oversight Cost ($70/hr)	Total Installation Cost (Includes design & 1-yr maintenance)
Highly Complex Bioretention (same as CB, but with 2.5 to 5 ft partial perimeter walls or complete walls)	$18.00	$0.75/ft^2	30	[2]$1400/1000ft^2	$210 (3 visits)	**$19.90/ft^2**
Underground Sand Filter	$65.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$91.75/ft^2**
Stormwater Tree Pits	$70.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$98.75/ft^2**
Grass/Gravel Permeable Pavement (sand base)	$12.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$17.55/ft^2**
Permeable Asphalt (granite base)	$10.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$14.00/ft^2**
Permeable Concrete (granite base)	$12.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$17.55/ft^2**
Permeable Pavers (granite base)	$25.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$35.75/ft^2**
Extensive Green Roof	$225.00	$500/1000 ft^2	30	[1]40% above construction	$210 (3 visits)	**$315.50/ft^2**
Intensive Green Roof	$360.00	$750/1000 ft^2	30	[1]40% above construction	$210 (3 visits)	**$504.75/ft^2**

[1]May require a professional engineer. Assume engineering costs to be 40% above construction costs

[2]If multiple projects are slated, such as in a neighborhood retrofit, a design packet with templates and standard layouts, element elevations and components, planting plans and cross sections can be generalized, design costs can be reduced.

[3]Not included in total installation cost (minimal).

[4]Assumed to be 15 feet in width.

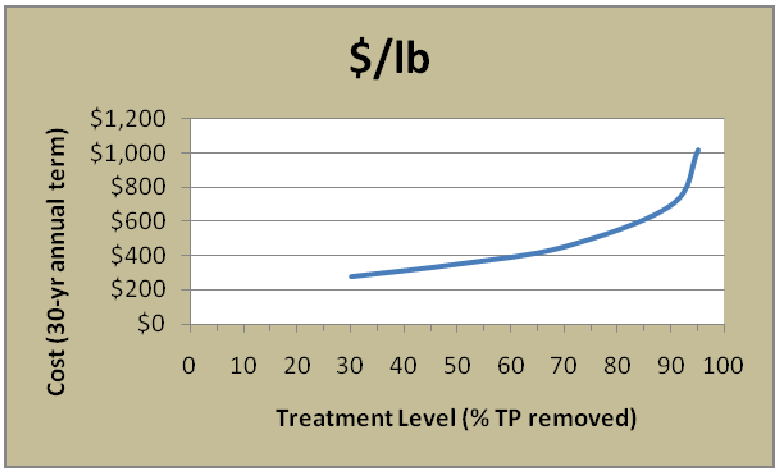
Lake McKusick Cost Analysis

For the Lake McKusick cost analysis, promotion and administration for each commercial/public property was estimated using a non-linear formula dependent on the surface area of BMPs, as the labor associated with outreach, education and administrative tasks typically are reduced with scale. Annual Operation & Maintenance referred to the ft^2 estimates provided in the preceding table. In cases were multiple BMP types were prescribed for an individual site, both the estimated installation and maintenance-weighted means by ft^2 of BMP were used to produce cost/benefit estimates.

Step 5: Evaluation and Ranking

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

Example chart showing total phosphorus treatment vs. cost:



Lake McKusick Evaluation and Ranking

In the Lake McKusick evaluation and ranking, the recommended level of treatment for each catchment, as reported in the Executive Summary table, was chosen by selecting the expected level of treatment considering public buy-in and above a minimal amount needed to justify crew mobilization and outreach efforts to the area. Should the cumulative expected load reduction of the recommended catchment treatment levels not meet LGU goals, a higher level of treatment (as described in the Catchment Profile tables) should be selected. The maps associated with each catchment show potential BMP locations as determined by field review. To meet treatment level goals for a catchment, a minimum percentage of potential BMPs (equaling or exceeding the "BMP Surface Area") must be installed within that catchment.

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.

For development of the Lake McKusick catchment profile section, 9 out of 29 catchments were selected as the first-tier areas for stormwater retrofit efforts. Those catchments receiving modern stormwater pond treatment, or in some cases 2 or more levels of treatment, were not modeled or further analyzed in this assessment.

McK-28

Term Cost Rank = #1

Catchment Summary	
Acres	9.4
Dominant Land Cover	Residential
Parcels	10
Volume (acre-feet/yr)	4.6
TP (lb/yr)	5.3
TSS (lb/yr)	1,661.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.23
Hydraulic Conductivity (in/hr)	1.11

DESCRIPTION

This small catchment is comprised of primarily low-density single-family residential properties, with a strip of open space along West Myrtle Street. Runoff is collected in the existing storm sewer system and discharged to the wetland complex within McK-11. The McK-11 catchment provides some treatment for stormwater before entering to Lake McKusick.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Due to the limited number of parcels available within this catchment, installing two or three small BMPs should be enough to meet the 20% TP reduction estimate of 1.1 pounds.

Curb Cut Bioretention

	Cost/Benefit Analysis	TP Reduction Level		
		30%	20%	12%
Treatment	TP Reduction (lb/yr)	1.6	1.1	0.6
	TSS Reduction (lb/yr)	936	768	590
	TSS Reduction (%)	56%	46%	36%
	Volume Reduction (acre-feet/yr)	1.3	0.8	0.5
	Volume Reduction (%)	28%	17%	10%
	BMP Surface Area (square feet)	350	200	100
Costs	Materials/Labor/Design	$4,855	$2,774	$1,387
	Promotion & Admin Costs	$733	$1,102	$1,826
	Total Project Cost	$5,587	$3,876	$3,213
	Annual O&M	$263	$150	$75
	Term Cost/lb/yr (30 yr)	$280	$254	$303

McK-18

Term Cost Rank = #2

Catchment Summary	
Acres	108.3
Dominant Land Cover	Residential
Parcels	303
Volume (acre-feet/yr)	86.2
TP (lb/yr)	100.6
TSS (lb/yr)	31,600.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.38
Hydraulic Conductivity (in/hr)	1.06

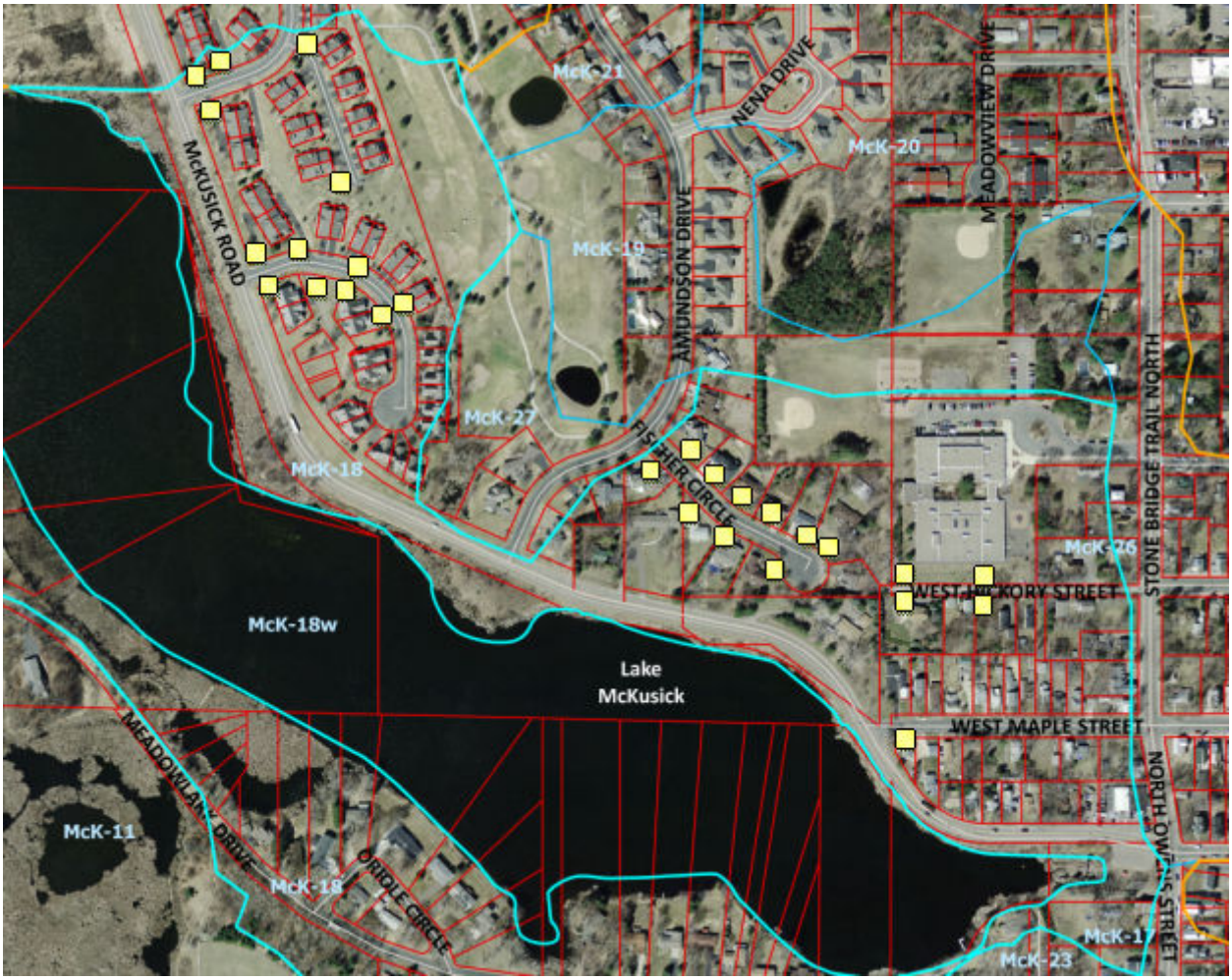
DESCRIPTION

Catchment McK-18 includes the direct drainage areas adjacent to Lake McKusick. It is comprised of primarily medium to medium-high density single/multi-family residential development and open space (wetlands). There are no constructed stormwater ponds within the catchment. There are some existing raingardens (mainly along Meadowlark Drive & Linden Street W) that were constructed by the City when the roads in that area were reconstructed. Stormwater runoff from most of the catchment flows through the existing storm sewer system and directly to Lake McKusick.

RETROFIT RECOMMENDATION

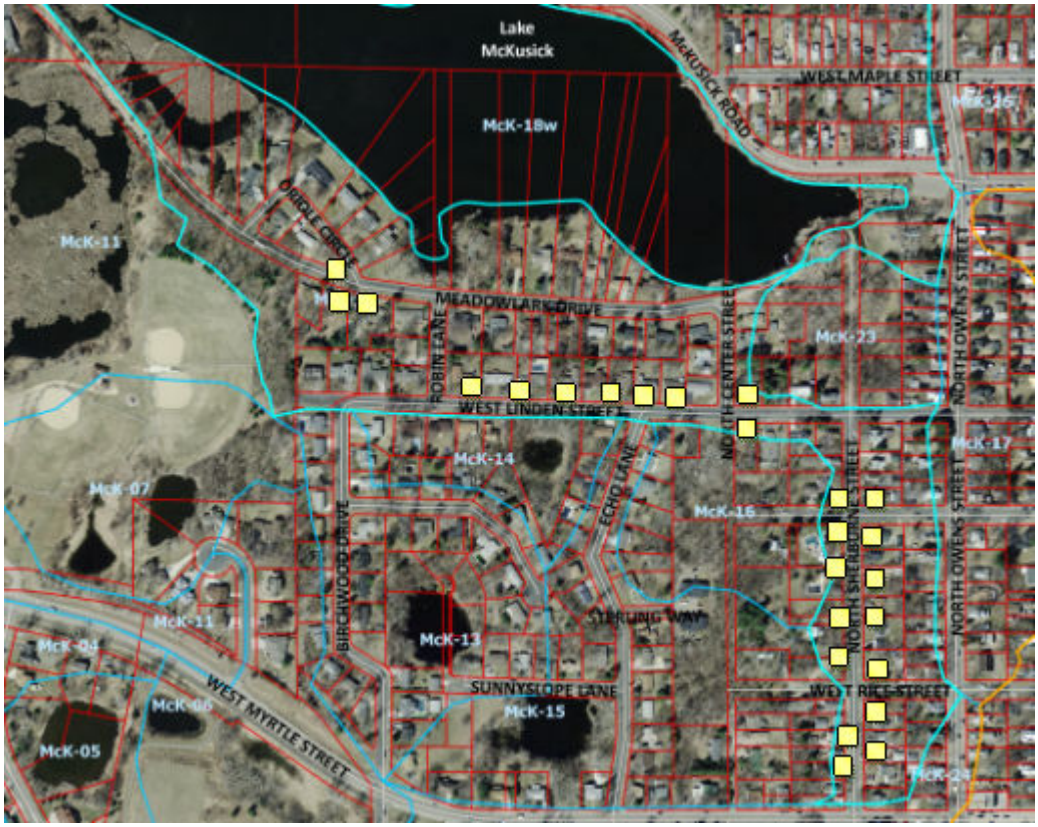
A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

Several features make this catchment very attractive for retrofitting. In a few locations, modification or additional bioretention surface area could easily be retrofitted into the existing practices to maximize efficiencies. This catchment appears to be ideal for a neighborhood BMP retrofit effort. Although the 10% TP reduction level was chosen for the executive summary, the 20% level is also feasible. The term cost/lb/yr at the 20% level is $386, compared to $339 at the 10% level.



Curb Cut Bioretention

	Cost/Benefit Analysis	TP Reduction Level		
			20%	10%
Treatment	TP Reduction (lb/yr)		20.1	10.1
	TSS Reduction (lb/yr)		14,100	9,715
	TSS Reduction (%)		45	31%
	Volume Reduction (acre-feet/yr)		17.1	8.2
	Volume Reduction (%)		20	10%
	BMP Size (square feet)		6,400	2,820
Costs	Materials/Labor/Design		$88,768	$39,113
	Promotion & Admin Costs		$88	$160
	Total Project Cost		$88,856	$39,273
	Annual O&M		$4,800	$2,115
	Term Cost/lb/yr (30 yr)		$386	$339


Lake
McKusick
McK-18w
McK-11
McK-07
McK-14
McK-13
McK-15
McK-16
McK-23
McK-17
McK-05
McK-06
McK-24
McK-25
McK-26
McK-27
WEST MAPLE STREET
McKUSICK ROAD
MEADOWLARK DRIVE
ROBIN LANE
WEST LINDEN STREET
NORTH CENTER STREET
NORTH OWENS STREET
ECHO LANE
BIRCHWOOD DRIVE
STERLING WAY
NORTH SHERBURNE STREET
SUNNYSLOPE LANE
WEST RICE STREET
WEST MYRTLE STREET


McK-29
McK-25
McK-18
McK-22
McK-18w
McK-12
McK-11
McK-10
McK-27
McKUSICK ROAD
LECUYER CIRCLE
LECUYER DRIVE
EAGLE RIDGE TRAIL
EAGLE RIDGE PLACE
EAGLE RIDGE LANE

McK-25

Term Cost Rank = #3

Catchment Summary	
Acres	30.2
Dominant Land Cover	Residential
Parcels	93
Volume (acre-feet/yr)	24.1
TP (lb/yr)	28.1
TSS (lb/yr)	8,810.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.38
Hydraulic Conductivity (in/hr)	0.67

DESCRIPTION

This catchment is comprised of primarily low density, single-family residential development. There are no constructed stormwater ponds within the catchment. There are two existing raingardens, located at the south end of the catchment along Eagle Ridge Trail and at 1013 Eagle Ridge Circle. Stormwater runoff flows through the existing storm sewer system and directly into Lake McKusick.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. Soils within the catchment are not as conducive to infiltration as other areas within the subwatershed; engineered soils/soil replacement may be required.

Several features make this catchment very attractive for retrofitting. This catchment appears to be ideal for a neighborhood BMP retrofit effort. Although the 10% TP reduction level was chosen for the executive summary, the 20% level is also feasible. The term cost/lb/yr at the 20% level is $460, compared to $394 at the 10% level.

Curb Cut Bioretention

	Cost/Benefit Analysis	TP Reduction Level		
			20%	10%
Treatment	TP Reduction (lb/yr)		5.6	2.8
	TSS Reduction (lb/yr)		4,108	2,774
	TSS Reduction (%)		46%	31%
	Volume Reduction (acre-feet/yr)		4.3	2.0
	Volume Reduction (%)		18%	8%
	BMP Size (square feet)		2,000	850
Costs	Materials/Labor/Design		$32,000	$13,600
	Promotion & Admin Costs		$206	$384
	Total Project Cost		$32,206	$13,984
	Annual O&M		$1,500	$638
	Term Cost/lb/yr (30 yr)		$460	$394

McK-17

Term Cost Rank = #4

Catchment Summary	
Acres	13.9
Dominant Land Cover	Residential
Parcels	77
Volume (acre-feet/yr)	18.2
TP (lb/yr)	21.4
TSS (lb/yr)	6,720.0

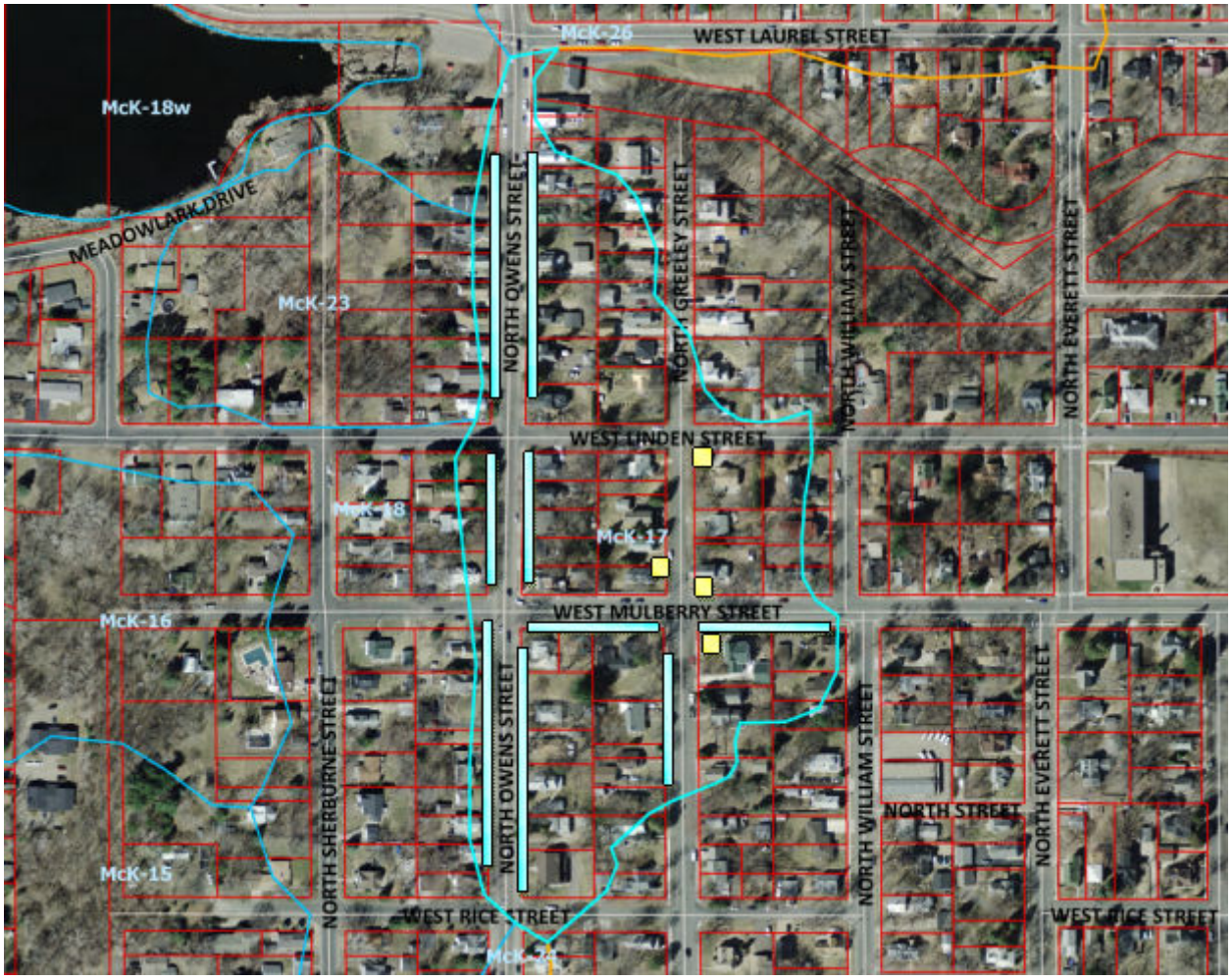
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.63
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment is comprised of medium-high density, single-family residential development. Runoff from this catchment does not receive any stormwater treatment and is discharged to Lake McKusick directly through the existing storm sewer system.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. The opportunities for large curb cut bioretention cells are severely limited in this catchment due to slopes, housing density, and narrow right-of-way.



Curb Cut Bioretention Curb Cut Box Planter Bioretention

	Cost/Benefit Analysis	TP Reduction Level		
			20%	10%
Treatment	TP Reduction (lb/yr)		4.3	2.1
	TSS Reduction (lb/yr)		2,960	2,015
	TSS Reduction (%)		44%	30%
	Volume Reduction (acre-feet/yr)		3.8	1.8
	Volume Reduction (%)		21%	10%
	BMP Size (square feet)		950	560
Costs	Materials/Labor/Design		$30,590	$18,032
	Promotion & Admin Costs		$354	$520
	Total Project Cost		$30,944	$18,552
	Annual O&M		$713	$420
	Term Cost/lb/yr (30 yr)		$406	$494

McK-26

Term Cost Rank = #5

Catchment Summary	
Acres	18.4
Dominant Land Cover	Residential
Parcels	100
Volume (acre-feet/yr)	23.3
TP (lb/yr)	27.4
TSS (lb/yr)	8,615.0

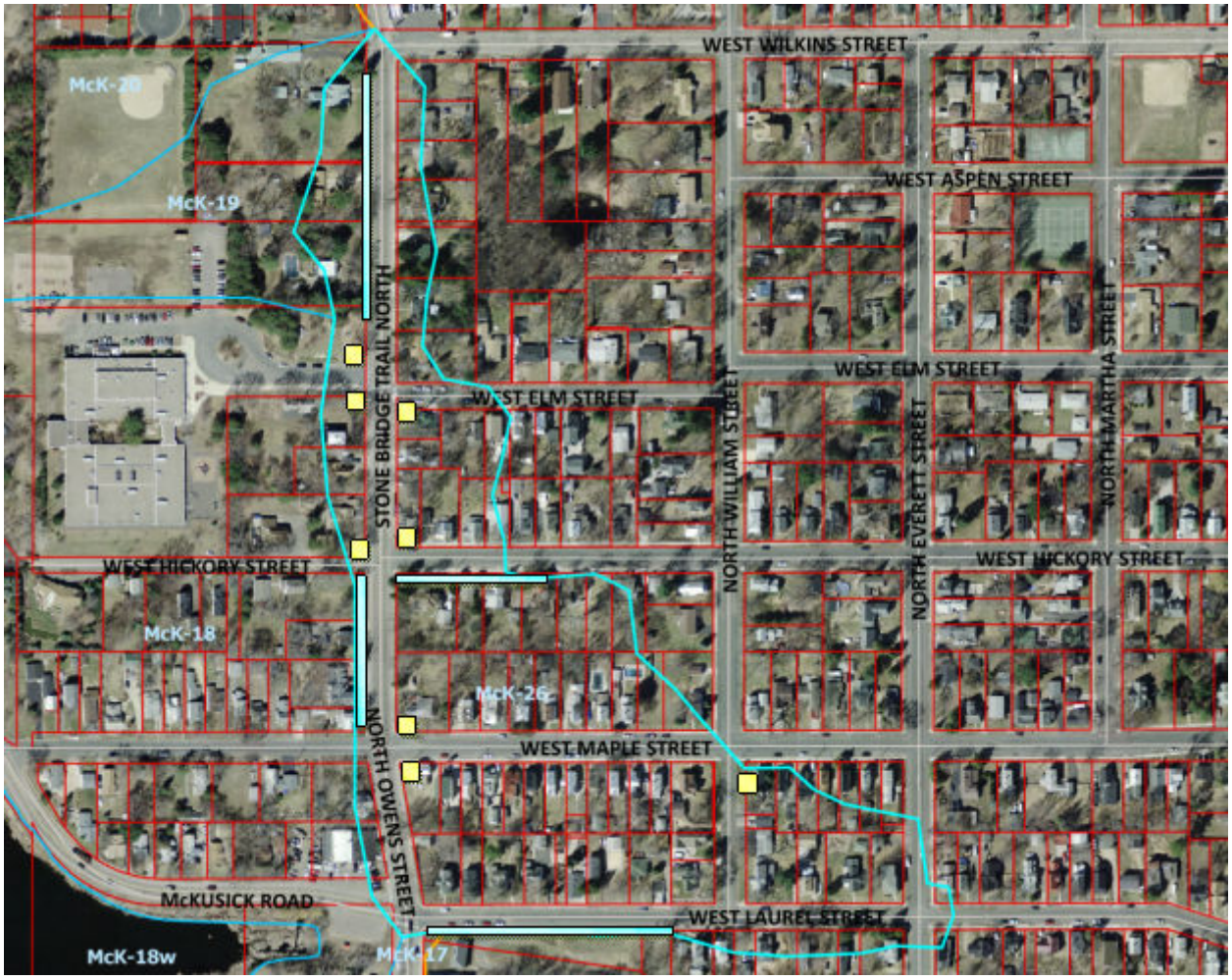
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.61
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment is comprised of primarily medium-high density, single-family residential development. There are no constructed stormwater ponds within the catchment. Stormwater runoff flows through the existing storm sewer system and directly into Lake McKusick.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.



Curb Cut Bioretention Curb Cut Box Planter Bioretention

	Cost/Benefit Analysis	TP Reduction Level		
			20%	10%
Treatment	TP Reduction (lb/yr)		5.5	2.7
	TSS Reduction (lb/yr)		3,800	2,580
	TSS Reduction (%)		44%	30%
	Volume Reduction (acre-feet/yr)		4.9	2.4
	Volume Reduction (%)		21%	10%
	Live Storage Volume (cubic feet)		1,965	871
Costs	Materials/Labor/Design		$39,446	$17,303
	Promotion & Admin Costs		$239	$435
	Total Project Cost		$39,685	$17,738
	Annual O&M		$1,223	$536
	Term Cost/lb/yr (30 yr)		$463	$418

McK-NE

Term Cost Rank = #6

Catchment Summary	
Acres	46.5
Dominant Land Cover	Residential
Parcels	115
Volume (acre-feet/yr)	21.9
TP (lb/yr)	25.2
TSS (lb/yr)	7,887.0

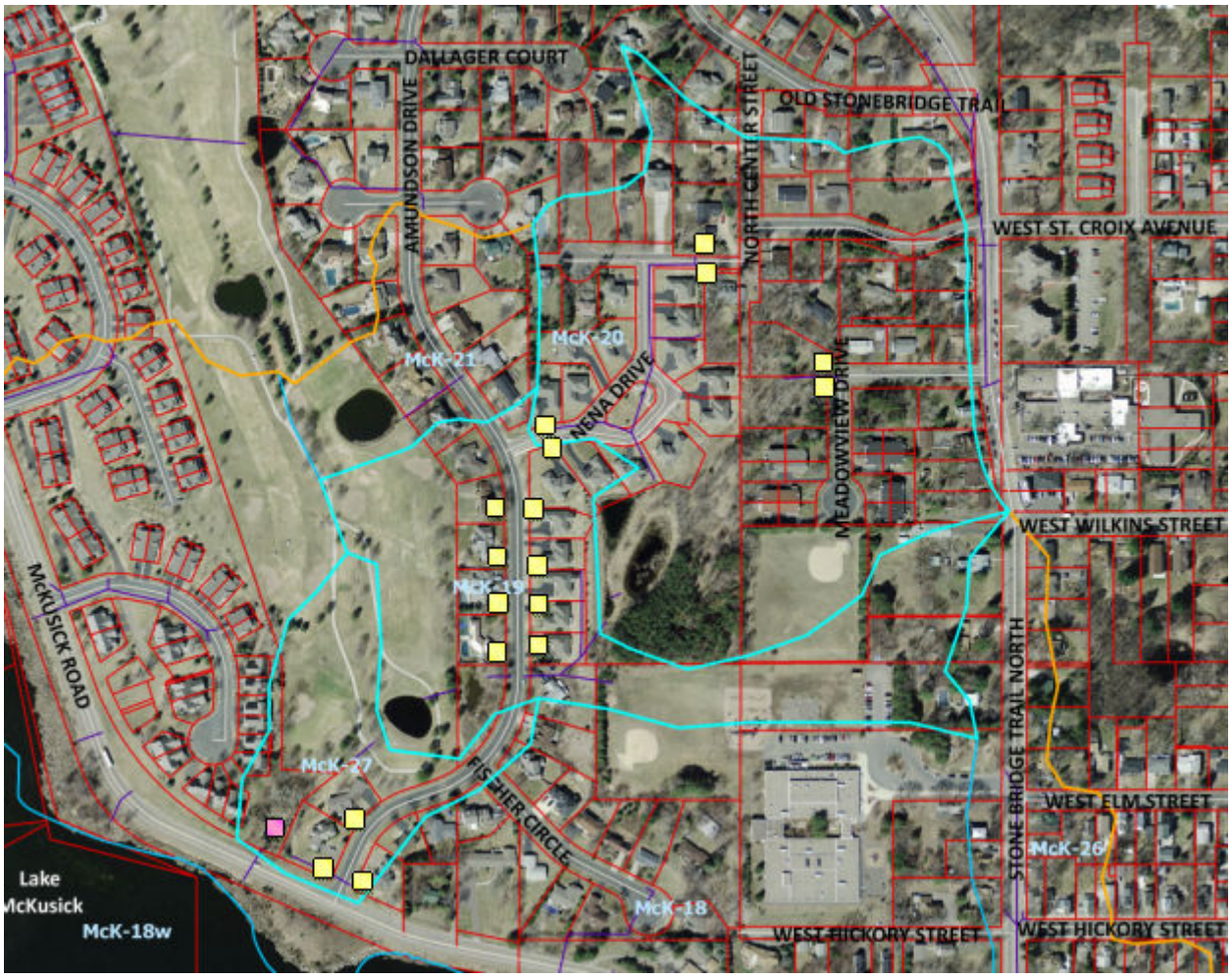
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.22
Hydraulic Conductivity (in/hr)	1.14

DESCRIPTION

Catchments McK-19, McK-20, and McK-27 were combined to form this catchment due to similar characteristics and a common discharge point. This catchment consists of a mixture of low-density single-family residential and open space, including portions of a golf course. Runoff within the catchment is routed through a series of small ponds before discharging to Lake McKusick.

RETROFIT RECEOMMENDATION

A combination of moderately complex bioretention and extended detention is recommended for this catchment. Bioretention will rely on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. It may also be feasible to excavate 3 feet of sediment from the stormwater pond closest to Lake McKusick (within catchment McK-27). The 4% level of treatment shown in the chart below reflects this potential BMP. The other two options reflect bioretention BMPs.



Curb Cut Bioretention Pond Maintenance

	Cost/Benefit Analysis	TP Reduction Level		
		8%	6%	4%
Treatment	TP Reduction (lb/yr)	1.9	1.4	1.0
	TSS Reduction (lb/yr)	357	159	261
	TSS Reduction (%)	3%	1%	2%
	Volume Reduction (acre-feet/yr)	2.4	4.0	0.0
	Volume Reduction (%)	11%	18%	0%
	BMP Surface Area (square feet)	1,500	2,500	n/a
Costs	Materials/Labor/Design	$51,000	$34,960	$30,000
	Promotion & Admin Costs	$254	$175	$250
	Total Project Cost	$54,803	$39,328	$30,250
	Annual O&M	$1,125	$1,875	$0
	Term Cost/lb/yr (30 yr)	$1,554	$2,276	$1,008

McK-08

Term Cost Rank = #7

Catchment Summary	
Acres	4.6
Dominant Land Cover	Residential
Parcels	11
Volume (acre-feet/yr)	4.6
TP (lb/yr)	5.3
TSS (lb/yr)	1,661.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.20
Hydraulic Conductivity (in/hr)	0.82

DESCRIPTION

This small catchment is comprised of medium density, single-family residential development. There is one stormwater pond that receives runoff from the catchment and portions of Eagle Ridge Trail. One raingarden in the catchment is located at 100 Mallard Court. The stormwater pond discharges to the wetland in McK-11, which discharges to Lake McKusick.

RETROFIT RECEOMMENDATION

Moderately complex bioretention is recommended for this catchment, relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls may be necessary. There are relatively few sites where BMPs could be installed in this catchment. Pond maintenance (sediment removal) may be an option.

Curb Cut Bioretention Pond Maintenance

	Cost/Benefit Analysis	TP Reduction Level		
			11%	9%
Treatment	TP Reduction (lb/yr)		0.6	0.5
	TSS Reduction (lb/yr)		113	83
	TSS Reduction (%)		7%	5%
	Volume Reduction (acre-feet/yr)		1.0	0.70
	Volume Reduction (%)		22%	15%
	BMP Size (square feet)		750	500
Costs	Materials/Labor/Design		$10,635	$7,160
	Promotion & Admin Costs		$420	$565
	Total Project Cost		$13,787	$9,984
	Annual O&M		$563	$375
	Term Cost/lb/yr (30 yr)		$1,703	$1,416

Catchment Ranking

Catchment or Pond ID	Retro Type	BMP area (sq ft)	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Est. Cost[1]	O&M Term (years)	Total Est. Term Cost/lb-TP/30 yr	Rank
McK-28	B	200	20	1.1	0.8	$2,774	30	$254	1
McK-18	B	2,820	10	10.1	8.2	$39,273	30	$339	2
McK-25	B	850	10	2.8	2.0	$13,984	30	$394	3
McK-17	B	950	20	4.3	3.8	$30,590	30	$406	4
McK-26	B	715	10	2.7	2.4	$17,303	30	$418	5
McK-NE[2]	ED	n/a	4	1.0	0	$30,250	30	$1,008	6
McK-08	B	500	9	0.5	0.7	$9,984	30	$1,416	7
McK-18SE[3]	WD	n/a	5	5.0	0	$125,000	15	$1,667	8
McK-18NE[3]	WD	n/a	5	5.0	0	$150,000	15	$2,000	9

B = Bioretention (infiltration and/or filtration)
ED = Extended Detention (Pond Maintenance for McK-NE)
WD = New [wet] Detention or Wetland creation
[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.
[2]Combined catchment, includes McK-19, McK-20, and McK-27
[3]See "City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake," Wenck Associates, Inc., October 2007

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Appendices

Appendix 1 – Catchments not included in Ranking Table

Catchments not included in ranking table were excluded for a number of reasons, mainly involving connectivity to the receiving water. After BMPs are installed within the priority catchments, it is recommended that the watershed revisit the entire subwatershed to determine other catchments that, while they may be conducive to retrofitting, were not considered a high priority for this report.

Appendix 2 – Summary of Protocol

This protocol attempts to provide a sufficient level of detail to rapidly assess subwatersheds or catchments of variable scales and land uses. It provides the assessor defined project goals that aid in quickly narrowing down multiple potential sites to a point where the assessor can look critically at site-specific driven design options that affect, sometimes dramatically, BMP selection. We feel that the time commitment required for this methodology is appropriate for most initial assessment applications and has worked well thus far for the Lake McKusick Assessment.

Appendix 3 – Definitions

The following terms are used throughout this document and define the basic terminology used to talk about watersheds and restoration. Many of the terms can have different meanings in different contexts, so it is imperative to define their use within this document.

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

Bioretention – A soil and plant-based stormwater management BMP used to filter runoff.

Catchment – Land area within a subwatershed generally having a drainage area of 1 – 100 acres for urban areas, where all water drains to a particular point. Several catchments make up a subwatershed. The existing stormwater infrastructure helps to define a catchment; therefore it is critical to obtain accurate stormwater infrastructure mapping information (including, at a minimum, the location of inlets and pipes, flow direction, and outfall locations) before undertaking a stormwater assessment process.

Raingarden – A landscaping feature that is planted with native perennial plants and is used to manage stormwater runoff from impervious surfaces such as roofs, sidewalks, roads, and parking lots.

Retrofit – The introduction of a new or improved stormwater management element where it either never existed or did not operate effectively.

Stormwater – Water that is generated by rainfall or snowmelt that causes runoff and is often routed into drain systems for treatment or conveyance.

Subwatershed – Land area within a watershed generally having a drainage area of more than 500 acres, where all water drains to a particular point. Several subwatersheds make up a watershed. An example would be the Lake McKusick subwatershed, which is within the boundaries of the Middle St. Croix Water Management Organization (the watershed). Subwatersheds are entirely based on hydrologic conditions, not political boundaries.

Urban – Any watershed or subwatershed with more than 10% total impervious cover.

Watershed – Land area defined by topography, where all water drains to a particular point. Watershed drainage areas are large, ranging from 20 to 100 square miles or more, and are made up of several subwatersheds. There are currently 8 watersheds located either wholly or partially within Washington County, each defined along political boundaries that attempt to mimic hydrologic boundaries.

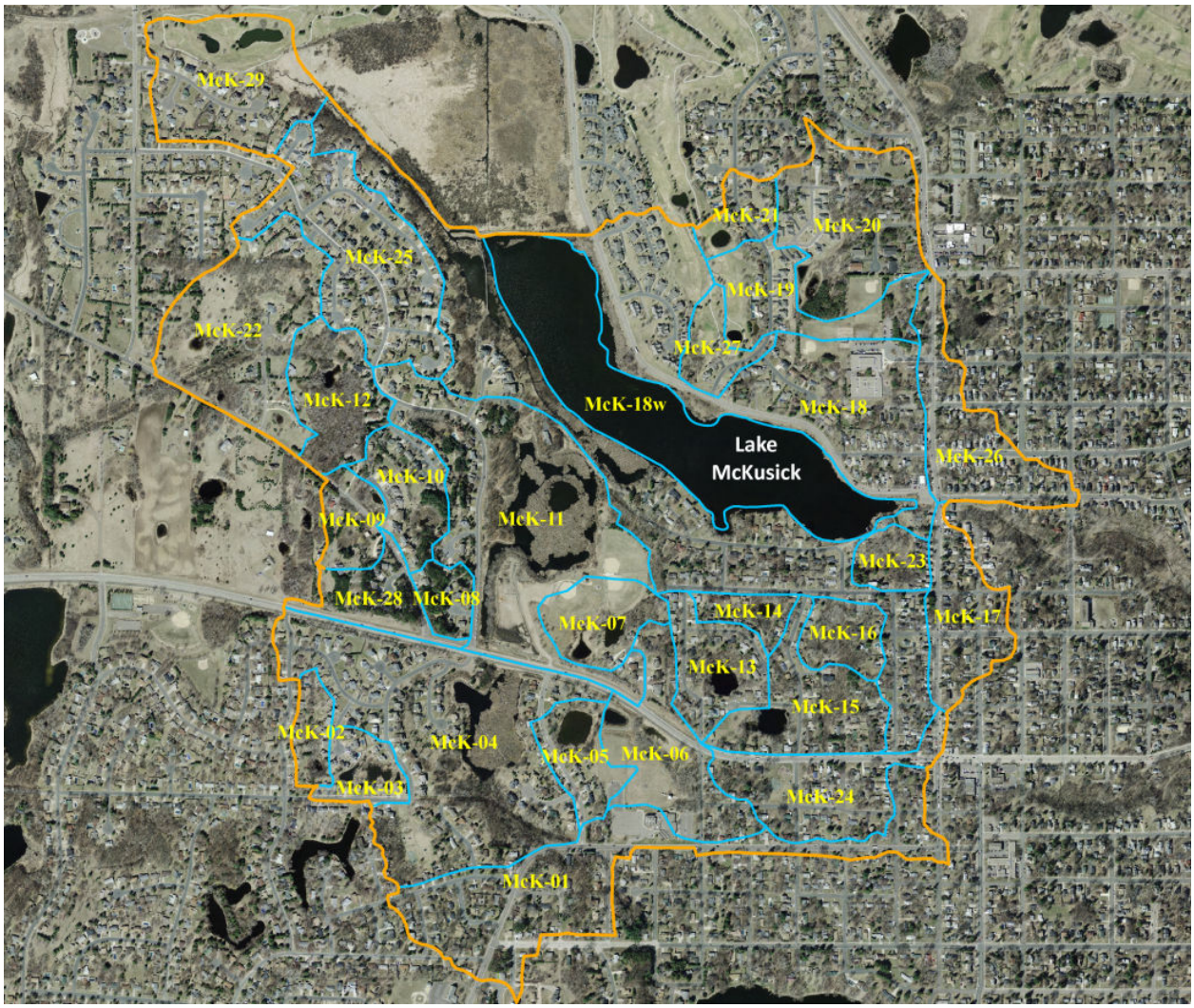
Appendix 4 – WCD Subwatershed Selection Process

The Washington Conservation District selected the Lily Lake/Lake McKusick subwatersheds for the MCD assessment program through a competitive process. Watershed organizations in Washington County were asked to nominate subwatersheds that were then scored on 5 equally weighted criteria (maximum of 5 points each). There were 7 nominations, of which 2 were chosen for assessments. The results were as follows:

Organization	Subwatershed	C1	C2	C3	C4	C5	TOTAL
RWMWD	Carver Lake	5	5	5	5	5	**25**
MSCWMO	Lily/McKusick	5	5	5	5	5	**25**
VBWD	Raleigh Creek	5	5	5	5	3	23
SWWD	Markgrafs Lake	5	5	0	5	4	19
CLFLWD	CL04	5	5	2	2	4	18
RCWD	N. Clear Lake	5	3	2	0	4	15
RCWD	N. Mahtomedi	5	3	2	0	2	12

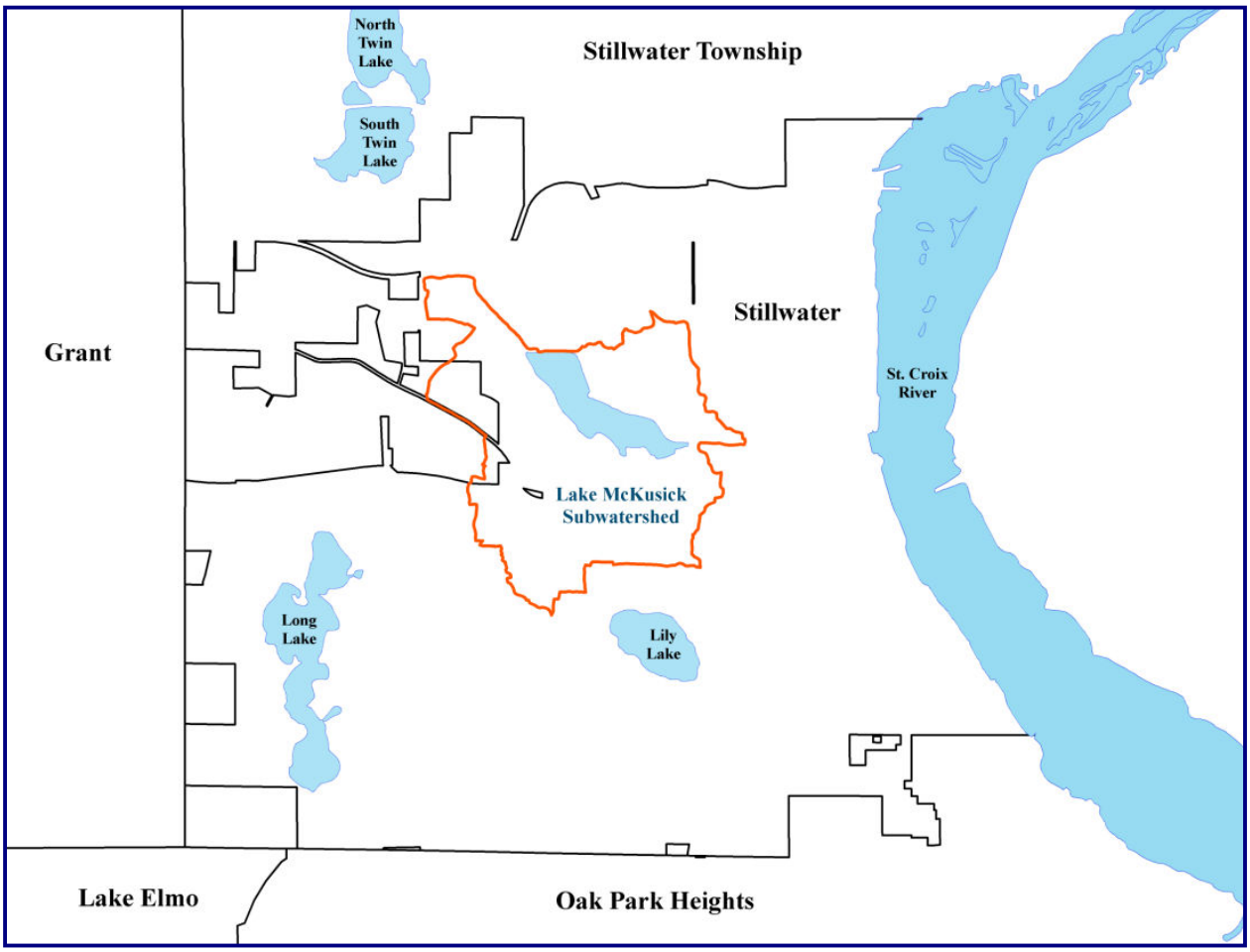
Criteria
C1 = urban/suburban
C2 = well-defined subwatershed boundary
C3 = water quality monitoring data
C4 = stormwater infrastructure mapping
C5 = drains to impaired or target water body

Appendix 5 – Subwatershed Maps

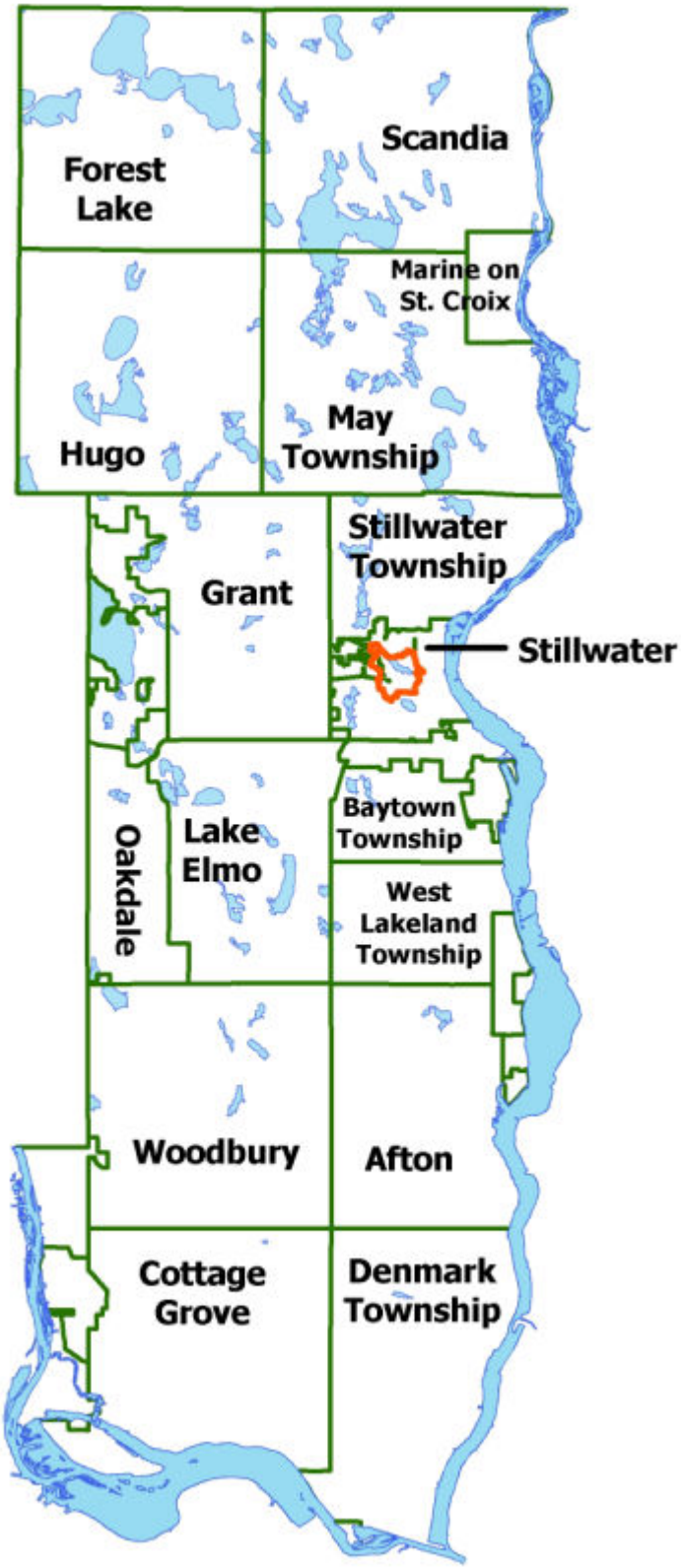


Lake McKusick Subwatershed – Aerial Photo (2009)

Lake McKusick Subwatershed – 29 Catchments (Priority Catchments are Shaded)

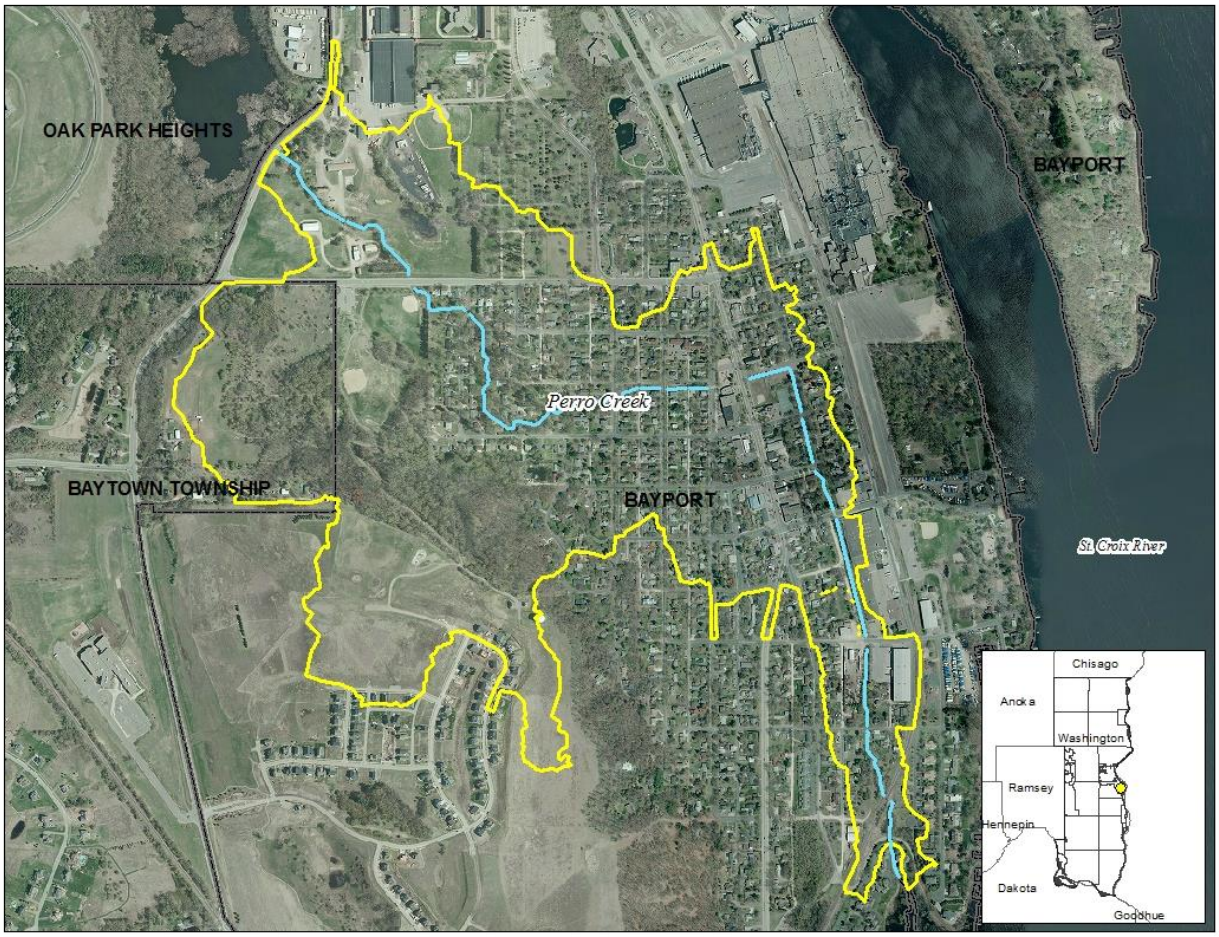


Location of the Lake McKusick Subwatershed within Stillwater



Location of the Lake McKusick Subwatershed within Washington County

Perro Creek
Stormwater Retrofit Analysis



Prepared by:

WASHINGTON CONSERVATION DISTRICT

With assistance from:

THE METRO CONSERVATION DISTRICTS

for the

MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION

Contents

This report details a subwatershed stormwater retrofit analysis resulting in recommended catchments for placement of Best Management Practice (BMP) retrofits that address the goals of the Local Governing Unit (LGU) and stakeholder partners. 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 subwatersheds of variable scales and land-uses to identify optimal locations for stormwater treatment. The time commitment required for this methodology is appropriate for *initial analysis* applications. 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, agricultural and range land management, good housekeeping outreach and education, and others, within existing or future watershed restoration planning.

The analysis's background information is discussed followed by a summary of the analysis'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 analysis are based on the development of catchment-specific *conceptual* stormwater treatment BMPs 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 and implement BMP projects. 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 in this report. This typically occurs after committed partnerships are developed for each specific target property for which BMPs are planned.

Executive Summary

The subwatershed directly discharging to the main channel of Perro Creek, and existing stormwater management practices, were analyzed for annual pollutant loading. The subwatershed was broken into eight catchment areas and evaluated for potential pollutant sources from stormwater discharges. Stormwater practice options were compared for each catchment, depending on specific site constraints and characteristics. Potential stormwater BMP retrofit locations were selected by weighing pollutant loading to the location, feasibility of installation and maintenance.

Perro Creek is a 1.8 mile urban stream that flows though Bayport, MN and discharges to the St. Croix River. Based on creek monitoring data collected upstream of the St. Croix River from 2006-2012, Perro Creek exceeds water quality standards for Total Suspended Solids (TSS), E. Coli, lead and copper. The stream also directly discharges to the St. Croix River and contributes to the Lake St. Croix impairment and TMDL for total phosphorous (TP). Utilizing bioretention based practices to reduce annual TP loading to the St. Croix River by 41.3 pounds will also result in reductions of E. Coli, lead, copper and TSS loads to the St. Croix River.

The following table summarizes the analysis results. Treatment levels (percent removal rates) for retrofit projects that resulted in a prohibitive BMP size, or number, or were too expensive to justify installation are not included. Reported treatment levels are dependent upon optimal BMP location within the catchment and total BMP area. The recommended treatment levels/amounts summarized here are based on a subjective analysis of potential BMP installations, considering estimated public participation and site constraints.

Recommended catchment rankings are based on a relative comparison of the cost per pound of phosphorus reduced over the life of the BMPs. BMP costs are estimated based on the implementation of a minimum of 1,000 square feet of BMPs initiated and constructed for the sole purpose of water quality.

A 30% reduction or 41.3 pounds of total phosphorus and a corresponding 30% (+/- 5%) reduction copper and lead could be achieved for a total cost of $511,595. These results assume water quality projects are designed and installed independent of any other infrastructure improvements. The costs of these practices are substantially lower when designed and installed as part of a larger infrastructure improvement project such as street reconstruction or commercial or institutional building redevelopment.

The process of channelization (practices to straightening and shortening the stream channel) of Perro Creek has been occurring since the establishment of the Bayport area in 1856. Channelization and removal of bank-side vegetative buffers destabilize streams and result in increased discharges of sediment and phosphorous. As part of this analysis, a rapid field analysis was conducted to identify opportunities for stream channel restoration practices to stabilize sloughing banks and restore the creeks sinuosity and native vegetated buffers. The scope of this report does not identify costs and pollutant load analysis for creek restoration projects, but potential practices are included in the catchment summary graphics.

CATCHMENT IMPLEMENTATION PRIORITY To Achieve a 30% Reduction in TP *($ COST/ LB of TP / YR)*				*pre BMP*	*post BMP*	*REDUCTION*
Catchment	**Term Cost/lb/yr (10 yr lifecycle)**	**Total Design and Install** *(no O&M Incl.)*	**# of BMPs**	**TP (lbs/yr)**	**TP (lbs/yr)**	**TP (lbs/yr)**
PC-4	$503	$40,420	8	15.08	10.6	4.5
PC-3	$570	$100,300	20	33.63	23.5	10.1
PC-5	$669	$227,713	30	59.54	41.7	17.9
PC-7	$782	$102,388	8	21.06	14.7	6.3
PC-6	$887	$40,775	6	8.27	5.8	2.5
	average					
TOTALS	**$682**	**$511,595**	**72**	**137.6**	**96.3**	**41.3**

TOTAL CATCHMENTS Treatment Summary (for 30% TP treatment target)			*Design and Installation Costs*			
BMP Identified	**# of BMP**	**TP Reduction (lbs)**	**Cost per SF**	**Cost Per BMP**	**Total Cost**	**Cost per lb TP Built**
Simple Bioretention w/pretreatment	47	27.26	$22.18	$4,990.00	$234,530.00	$183.05
Highly Complex Bioretention w/pretreatment	17	9.86	$45.14	$10,157.50	$172,677.50	$1,030.17
Simple Bioretention w/pretreatment	3	1.74	$22.18	$8,871.11	$26,613.33	$5,098.34
Highly Complex Bioretention w/pretreatment	3	1.74	$45.14	$18,057.78	$54,173.33	$10,378.03
Tree Pits	2	0.7	$146.53	$10,550.48	$21,100.96	$15,072.11
TOTAL *(plus $2500 Total Promo & Admin)*	**72**	41.3			**$511,595.13**	

Top-Ranked Perro Creek Catchments and TP Removal Potential

About this Document

Document Overview

The Stormwater Retrofit Analysis is a subwatershed management tool used to prioritize stormwater BMP retrofit projects based on BMP performance and cost effectiveness. This process helps maximize the value of each dollar spent.

This document is organized into four main sections that describe the general methods used, individual catchment profiles, a retrofit ranking for the subwatershed, and references used in the analysis protocol. The Appendices section provides additional information relevant to the analysis.

Under each section and subsection, project-specific information relevant to that portion of the analysis is provided with an ***Italicized Heading***.

Methods

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

NOTE: the financial, technical, current landscape/stormwater system, and timeframe limits and needs are highly variable from subwatershed to subwatershed. This analysis uses some, or all, of the methods described herein.

Catchment Profiles

Each catchment profile is labeled with a numerical ID for identification purposes (e.g., Catchment PC-5, Catchment PC-7). This numerical ID is referenced when comparing results across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

Within each Catchment Summary/Description section is a table that summarizes basic information including catchment size, current land cover, and estimated annual pollutant load (target pollutant(s) are specified by the LGU). A table of the principal WinSLAMM Standard Land Use model inputs and their corresponding acreage values are also reported. A brief description of the land cover, stormwater infrastructure and any other important general information is described.

Retrofit Recommendation

The Retrofit Recommendation section describes the conceptual BMP retrofit(s) selected for the catchment area and provides a description of why each specific retrofit option 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 capital budgets vs. load reduction goals.

Site Selection

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

Catchment Ranking

Catchment ranking takes into account all of the information gathered during the analysis process to create a prioritized catchment list. The list is sorted by the cost per pound of phosphorus treated within each catchment for the duration of the 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 within catchments, and the list provided is merely a starting point. Final catchment ranking for installation may include:

- Total amount of pollutant removal
- Non-target pollutant reductions
- BMP project visibility
- Availability of funding
- Total project costs
- Educational value

References

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

Appendices

The Appendices section provides supplemental information and/or data used during the analysis protocol.

Methods

Selection of Subwatershed

Before the subwatershed stormwater analysis begins, a process of identifying a high priority water body as a target takes place. Many factors are considered when choosing which subwatershed to assess for stormwater retrofits. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Analyses supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the analysis also rank highly.

In areas without clearly defined studies, such as TMDL or officially listed water bodies of concern, or where little or no monitoring data exist, metrics are used to score subwatersheds against each other. In large subwatersheds (e.g., greater than 2500 acres), a similar metric scoring is used to identify areas of concern, or focus areas, for a more detailed analysis. This methodology was slightly modified from Manual 2 of the *Urban Stormwater Retrofit Practices* series.

Description of Perro Creek and the Contributing Subwatershed

Perro Creek is a 1.8 mile long urban stream that discharges to the St. Croix River. The creek is located within the city of Bayport in the northeastern suburban of the Twin Cities metropolitan area. Perro Creek conveys water from two subwatersheds that encompass a total of 660 acres of urban land use in the cities of Oak Park Heights, Stillwater and Bayport. Stormwater in the Perro Pond subwatershed is conveyed through a network of storm sewers, channels, and ponds. Perro Pond is a 53 acre DNR shallow lake that receives drainage from 340 acres of mixed urban land use primarily from the City of Oak Park Height and a small portion of Stillwater. The outlet of Perro Pond to Perro Creek is an adjustable control structure located on the southern point of Perro Pond. To alleviate flooding in Bayport, the structure is manually closed during the winter by the City of Bayport public works staff. When the southern control structure is closed, Perro Pond discharges directly to the St. Croix River through a series of storm sewers located on the north side of the pond. Stormwater in the Perro Creek direct subwatershed is conveyed to the creek through pipes and channels. The direct discharge subwatershed encompasses 323.7 acres of mixed urban land use from the City of Bayport.

Since 2006, the Washington Conservation District has collected base flow grab samples, automated flow-weighted storm composite samples and duplicate samples according to WCD Standard Operating Procedures (SOP). An automated sampler located about 1 mile upstream of the St. Croix River, continuously monitored stream flow discharge and collects event flow composite samples in the spring and summer. Data collected at this site by the WCD included total discharge, precipitation, and water quality analysis. All stream flow and chemistry data are published in the water quality monitoring reports available on the Middle St. Croix WMO website www.mscwmo.org.

Based on creek monitoring data collected upstream of the St. Croix River from 2006-2012, Perro Creek periodically exceeds water quality standards for Total Suspended Solids (TSS), E. Coli, lead, copper, and zinc. The stream also directly discharges to the St. Croix River and contributes to the Lake St. Croix impairment and TMDL for total phosphorous (TP).

Subwatershed Analysis Methods

The process used for this analysis 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 includes determining the objectives of the retrofits (volume reduction, target pollutant etc) and the level of treatment desired. It involves meeting with local stormwater managers, city staff, and watershed staff to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to assess in large subwatersheds, a smaller focus area may be determined.

Perro Creek Subwatershed Scoping

Pollutants of concern for this subwatershed were identified as TP, TSS, and volume. Goals of the MSCWMO, WCD, and City of Bayport were considered.

Step 2: Desktop Retrofit Analysis

Desktop retrofit analysis involves computer-based scanning of the subwatershed for potential BMP retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure. Accurate and current GIS data is extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography, and storm drainage infrastructure (with invert elevations and flow direction). The following table highlights some important features to look for and the associated potential retrofit project.

Subwatershed Metrics and Potential Retrofit Project Site/Catchment	
Screening Metric	**Potential Retrofit Project**
Open Space	**New regional treatment (pond, infiltration basin).**
Roadway Culverts	**Add wetland or extended detention water quality treatment upstream.**
Outfalls	**Split flows or add storage below outfalls if open space is available.**
Conveyance system	**Add or improve performance of existing swales, ditches and non-perennial streams.**
Large Impervious Areas (campuses, commercial, parking)	**Stormwater treatment on-site or in nearby open spaces.**
Neighborhoods	**Utilize right of way, roadside ditches or curb-cut raingardens or filtering systems to treat stormwater before it enters storm drain network.**

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 to eliminate sites from consideration. The field investigation revealed additional retrofit opportunities that would have gone unnoticed during the desktop search. An in creek analysis of Perro Creek was also conducted as part of this analysis.

The following stormwater BMPs were considered for each catchment/site:

Stormwater Treated Options for Retrofitting		
Area Treated	**Best Management Practice**	**Potential Retrofit Project**
5.1-10.0 acres	Infiltration Basin	**Large and shallow impoundment areas designed to retain and infiltrate stormwater runoff.**
0.1-5.0 acres	Bioinfiltration	**Use of native soil, soil microbe, and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.**
	Biofiltration	**Filters runoff through engineered biologically active media and passes it through an under-drain. May consist of a combination of sand, soil, compost, peat, compost, or iron.**
	Tree Boxes	**A trench or sump that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering the infiltration area.**
	Stream Bank Restoration and Stabilization	**These bioengineered practices are designed to reduce in stream bank erosion and filter and/or infiltrate runoff.**
	Other	**On-site, source-disconnect practices such as rain-leader raingardens, rainleader disconnect, stormwater planters, dry wells and permeable pavements.**

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Sites most likely address pollutant reduction goals and those that may have simple design/install/maintenance considerations are chosen for a cost/benefit analysis that relatively compares catchments/sites. Treatment concepts are developed taking into account site constraints and the subwatershed treatment objectives. Projects involving complex stormwater treatment interactions and those that may pose a risk for upstream flooding require the assistance of a professional engineer. Conceptual designs at this phase of the design process include cost and pollution reduction estimates. Reported treatment levels are dependent upon optimal site selection and sizing.

Modeling of the site is done by WinSLAMM. WinSLAMM uses event mean concentrations based on land use for each catchment/site to estimate relative pollution loading of the existing conditions. The site's

conceptual BMP design is modeled to then estimate varying levels of treatment by sizing and design element. This treatment model can also be used to properly size BMPs to meet restoration objectives.

General WinSLAMM Model Inputs	
Parameters	**Method for Determining Value**
Area	Natural Resource Conservation Service Custom watershed delineation tools from ESRI were used to identify catchments in ArcMap 10.1. Software generated catchment boundaries were field verified and modified when necessary.
Land Use	Using GIS, land areas discharging to Perro Creek were evaluated and assigned Standard Land Uses (SLU) in WinSLAMM 10.1. These SLUs describe the average characteristics of impervious and pervious surfaces in each catchment.
Precipitation/Temperature Data	Rainfall and temperature recordings from Minneapolis 1959 were used as a representation of an average year. Winter season was marked as November 15 to March 18.
Pollutant Probability Distribution	WinSLAMM uses a pollutant value file to determine the pollutant loading from a source area. The default value WI_GEO02 computed from USGS was used for this analysis.
Runoff Coefficient	The default runoff coefficient WI_SL06 was used.
Particulate Solids Concentration	The default WI_GEO01.ppd particle file developed by USGS was used.
Street Delivery Parameter File	The default street dirt delivery files were used to retain total particles that do not reach the outfall based on rain depths and street textures.
Particle Size Distribution	Average of the available outfall particle size distribution data from the National Urban Runoff Program studies.

Perro Creek Treatment Analysis

For the Perro Creek Treatment analysis, each catchment (and each relevant parcel within them) was first assessed for BMP applicability given specific site constraints and soil types. Pedestrian and car traffic flow, parking needs, snow storage areas, obvious utility locations, existing landscaping, surface water runoff flow, project visibility, existing landscape maintenance, available space, and other site-specific factors dictated the selection of one or more potential BMPs for each site.

WinSLAMM was used to model catchments and a hypothetical BMP located at its outfall. The BMP was sized from the 10-30% treatment size and results were tabulated in the Catchment Profile section of this document.

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 total cubic feet of treatment. In cases where live storage was 1 foot deep, this number roughly related to square feet of BMP coverage. An annual cost/TP-removed for each treatment level was then calculated for the life of each BMP that includes promotional, administrative and life cycle operations, and maintenance costs.

The following table provides the BMP cost estimates used to assist in cost analysis:

Average BMP Cost Estimates						
BMP	Description	Installation Materials & Labor	Annual Mainten-ance	Design Cost ($70/hr)	Installation Oversight Cost ($70/hr)	O & M Term
Rain Leader Disconnect Rain Garden	Simple residential raingarden	$7.56	$0.25/ft^2	$280/100 ft^2	$210	10
Infiltration Basin (Turf)	Amended soils with under-drains	$15.10	$2000/acre	$1120/acre	$210	10
Simple Bioinfiltration	No engineered soils or under-drains, but w/curb cuts.	$14.00	$0.75/ft^2	$1200/1000 ft^2	$210	10
Simple Bioinfiltration w/Structural Pretreatment	No engineered soils or under-drains, but w/curb cuts and structural pretreatment	$20.00	$0.75/ft^2	$1200/1000 ft^2	$210	10
Moderately Complex Biofiltration	With engineered soils, under-drains, curb cuts, no structural pretreatment but no retaining walls	$17.00	$1.50/ft^2	$2000/1000 ft^2	$290	10
Moderately Complex Biofiltration w/Structural Pretreatment	Incl. engineered soils, under-drains, curb cuts, structural pretreatment but no retaining walls	$23.00	$0.75/ft^2	$2000/1000 ft^2	$350	10
Complex Biofiltration w/Structural Pretreatment	As MCBwSP but with 1.5-2.5 ft partial perimeter walls	$27.50	$0.75/ft^2	$3750/1000ft^2	$410	10

Highly Complex Biofiltration w/Structural Pretreatment	As CBwSP but with utility or grey infrastructure modifications	$37.50	$0.75/ft^2	$7500/1000ft^2	$470	10
Curb-Cut	Cut with apron	$80.00				
Impervious Cover Conversion		$21.71	$500/acre	$1120/acre	$210	10
Stormwater Tree Pits[2]	6' x 12 ' pit with concrete vault	$140.00	$0.75/ft^2	140% above construction	$210	10
Grass/Gravel Permeable Pavement	Sand base	$18.95	$0.75/ft^2	140% above construction	$210	10
Permeable Asphalt	Granite base	$10.80	$0.75/ft^2	140% above construction	$210	10
Permeable Concrete	Granite base	$15.00	$0.75/ft^2	140% above construction	$210	10
Permeable Pavers	Granite base	$35.75	$0.75/ft^2	140% above construction	$210	10
Extended Detention		(12.98)*(CU-FT^0.75)	$1000/acre	3$2800/acre	$210	10
Wet Pond		(277.89)*(CU-FT^0.553)	$1000/acre	3$2800/acre	$210	10
Perimeter Sand Filter		$259.20				10
Structural Sand Filter	(including peat, compost or iron amendment))	$22.04	$250/25ft	$300/25ft	$210	10
Underground Sand Filter		$99.08	$0.75/ft^2	140% above construction	$210	10
Rain Barrels	Does not include pump or distribution	$25.00	$25	NA	$210	10
Cisterns	Does not include pump or distribution	$16.00	$100	NA	$210	10
Dry Swale[1]	With soil amendments	$7.13	$0.75/ft^2	$280/100 ft^2	$210	10
Water Quality Swale[1]	With soil replacement and check dams	$15.01	$0.75/ft^2	$1120/1000 ft^2	$420	10
French Drain/Dry Well		$15.00	$100	20% above construction	$210	10
Stormwater Planter (ultra urban)	Usually a stormwater disconnect BMP	$35.86	$0.75/ft^2	20% above construction	$210	10

[1] Assumed to be 15 feet in width.

[2] Assumed ultra-urban linear application.

Perro Creek Cost Analysis

For the Perro Creek cost analysis, promotion, installation and administration for each practice was estimated based on the actual costs of similar water quality retrofit projects in Washington and Dakota County from 2010-2013. Project costs assume the implementation of an average of five practices or 1000 cubic feet of treatment per project area. Cost savings occur when water quality practices are designed and installed in conjunction with larger capital improvement projects such as reconstruction or redevelopment. Annual Operation & Maintenance referred to the ft^2 estimates provided in the preceding table.

Step 5: Evaluation and Ranking

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

Perro Creek Evaluation and Ranking

In the Perro Creek evaluation and ranking, the recommended level of treatment for each catchment, as reported in the Executive Summary table, was chosen by selecting the expected level of treatment considering public buy-in and above a minimal amount needed to justify crew mobilization and outreach efforts to the area. Should the cumulative expected load reduction of the recommended catchment treatment levels not meet LGU goals, a higher level of treatment (as described in the Catchment Profile tables) should be selected. The maps associated with each catchment show potential BMP locations as determined by field review. To meet treatment level goals for a catchment, a minimum percentage of potential BMPs (equaling or exceeding the "BMP Surface Area") must be installed within that catchment.

Catchment Profiles

The following pages provide catchment-specific information that was analyzed for stormwater BMP retrofit treatment at various levels. Utilizing GIS each catchment is divided into several different land uses based on WinSLAMM Standard Land Use parameters.

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.

For development of the Perro Creek catchment profile section, 5 out of 9 catchments were selected as the first-tier areas for stormwater retrofit efforts. Those catchments that are land locked or have minimal impervious surface area contributing to Perro Creek were not modeled or further analyzed in this analysis (omitted from the analysis were catchments PC-1, PC-2, PC-8, and PC-9).

WinSLAMM Standard Land Use Codes		
Land Uses	**Codes**	**Definition**
Residential	HDRNA	High Density Residential without Alleys
	HDRWA	High Density Residential with Alleys
	MDRNA	Medium Density Residential without Alleys
	MDRWA	Medium Density Residential with Alleys
	LDR	Low Density Residential
	MFR	Multiple Family Residential
Commercial	STRIPCOM	Strip Commercial
	DOWNTOWN	Commercial Downtown
Industrial	MI	Medium Industrial
	LI	Non-Manufacturing
Institutional	SCH	Education Facilities
	INST	Miscellaneous Institutional
Other	PARK	Parks
	OPEN	Undeveloped
	CEM	Cemetery
Freeway	FREE	Freeways

Catchment PC-4

Term Cost Rank = #1

Base Load Summary *Catchment PC-4*	
Acres	19.4
Volume (acre-feet/yr)	9.0
TP (lb/yr)	15.1
TSS (lb/yr)	3983

WinSLAMM Input Summary *Catchment PC-4*			
Standard Land Use Code	**Acres**	**Standard Land Use Code**	**Acres**
CEM	0.98	MDRWA	11.55
FREE	0.41	MFR	0.31
LDR	0.14	OPEN	1.47
MDRNA	4.58		
TOTAL			**19.44**

DESCRIPTION

This catchment is comprised primarily of medium-density residential properties with gravel alleys. Stormwater runoff discharges into the creek though a deteriorated storm sewer system or through a combination of asphalt-lined or grass-lined ditch system that eventually converges with the storm sewer system.

RETROFIT RECOMMENDATION

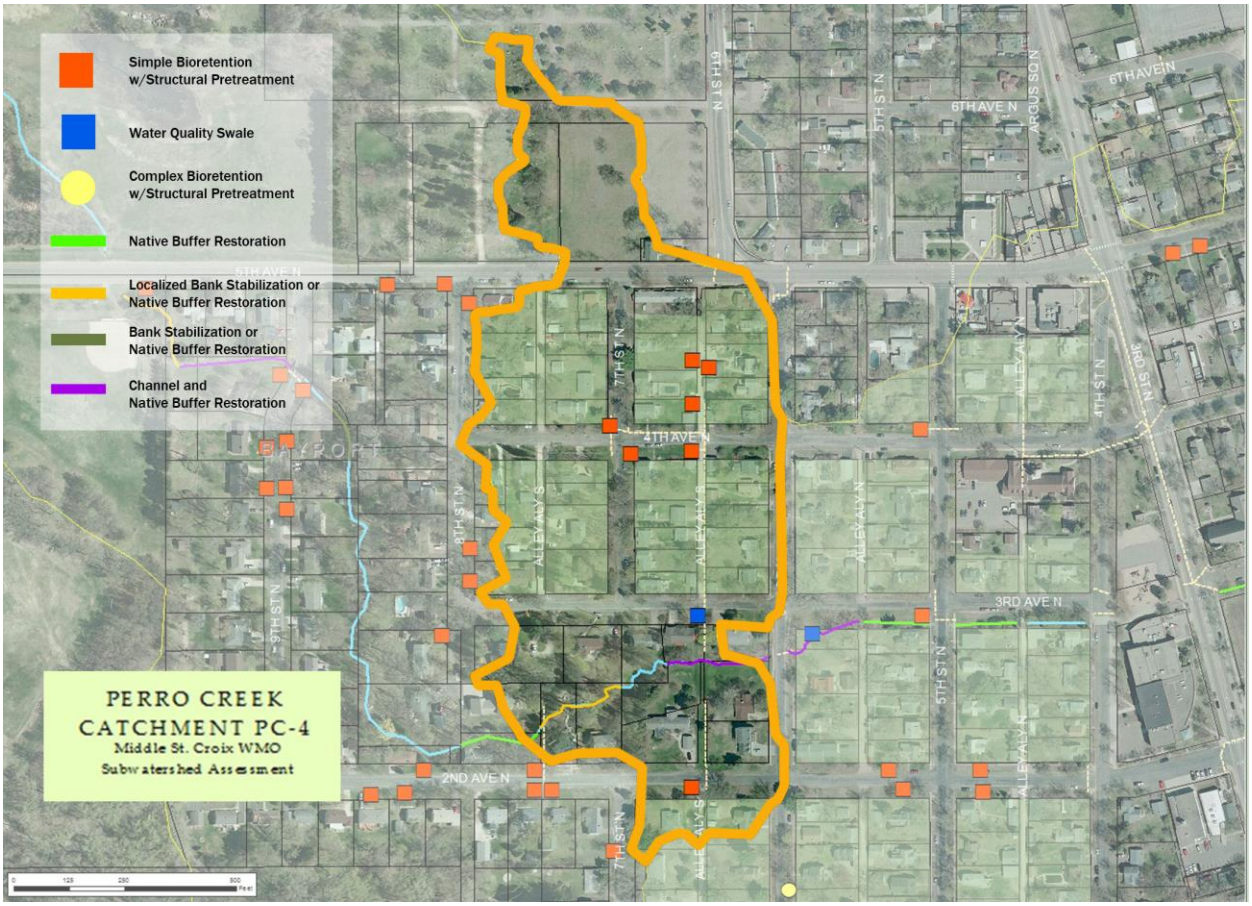
A combination of bioinfiltraiton and biofiltration with coarse sediment pretreatment devices and a water quality swale are recommended for this catchment. In certain locations, elevations may require small retaining walls to achieve level depressional areas required to infiltrate or filtrate stormwater. Modeling indicates eight BMPs will achieve a 30% Total Phosphorous reduction in Catchment PC-4 of 4.5 pounds.

Modeling does not account for increased loading from gravel alleys. It is evident that gravel alleys contribute larger than modeled results for total phosphorous (TP) and total suspended solids (TSS) loading. Therefore, targeted outreach and assistance are prioritized to disconnect contributing impervious areas such as garages and rear lot parking pads from the gravel alleys.

BMP Treatment Summary *(for 30% TP treatment target of Catchment PC-4)*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple Bioretention w/pretreatment	8	225	$22.18	$4,990.00	$39,920.00
TOTAL *(plus $500 Promo & Admin)*	**8**				**$40,420.00**

Catchment PC-4

Term Cost Rank = #1



	Cost/Benefit Analysis *Catchment PC-4*		Reductions		
	Unit	***Baseline***	**10%**	**20%**	**30%**
TREATMENT	**# BMP Projects Needed**	-	2	5	8
	Live Storage Volume (cubic feet)	-	420	839	1,272
	TP (lb/yr)	**15.08**	13.6	12.1	10.6
	TSS (lb/yr)	**3983.0**	3,513	3,043	2,573
	TSS (% reduced)	-	11.8%	23.6%	35.4%
	Volume (acre-feet/yr)	**9.0**	8.1	7.3	6.4
	Volume (% reduced)	-	9.8%	19.5%	29.3%
COST	**Design and Installation**	-	$9,980	$24,950	$39,920
	Promotion & Admin Costs	-	$500	$500	$500
	Total Project Cost	-	$10,480	$25,450	$40,420
	Annual O&M	-	$420	$839	$1,272
	Term Cost/lb/yr (30 yr)	-	**$108**	**$281**	**$503**

Catchment PC-3

Term Cost Rank = #2

Base Load Summary *Catchment PC-3*	
Acres	65.4
Volume (acre-feet/yr)	21.0
TP (lb/yr)	47.0
TSS (lb/yr)	13822

WinSLAMM Input Summary *Catchment PC-3*	
Standard Land Use Code	**Acres**
CEM	4.81
FREE	1.16
INST	0.00
LDR	0.48
MDRNA	25.45
OPEN	26.90
PARK	6.57
TOTAL	**65.37**

DESCRIPTION

This catchment is comprised primarily of medium-density residential properties without alleys. Stormwater runoff discharges into the creek though a deteriorated storm sewer system, through a combination of asphalt lined and grass-lined ditch system, and at the intersection of Perro Creek and 9th street stormwater discharges directly into the creek.

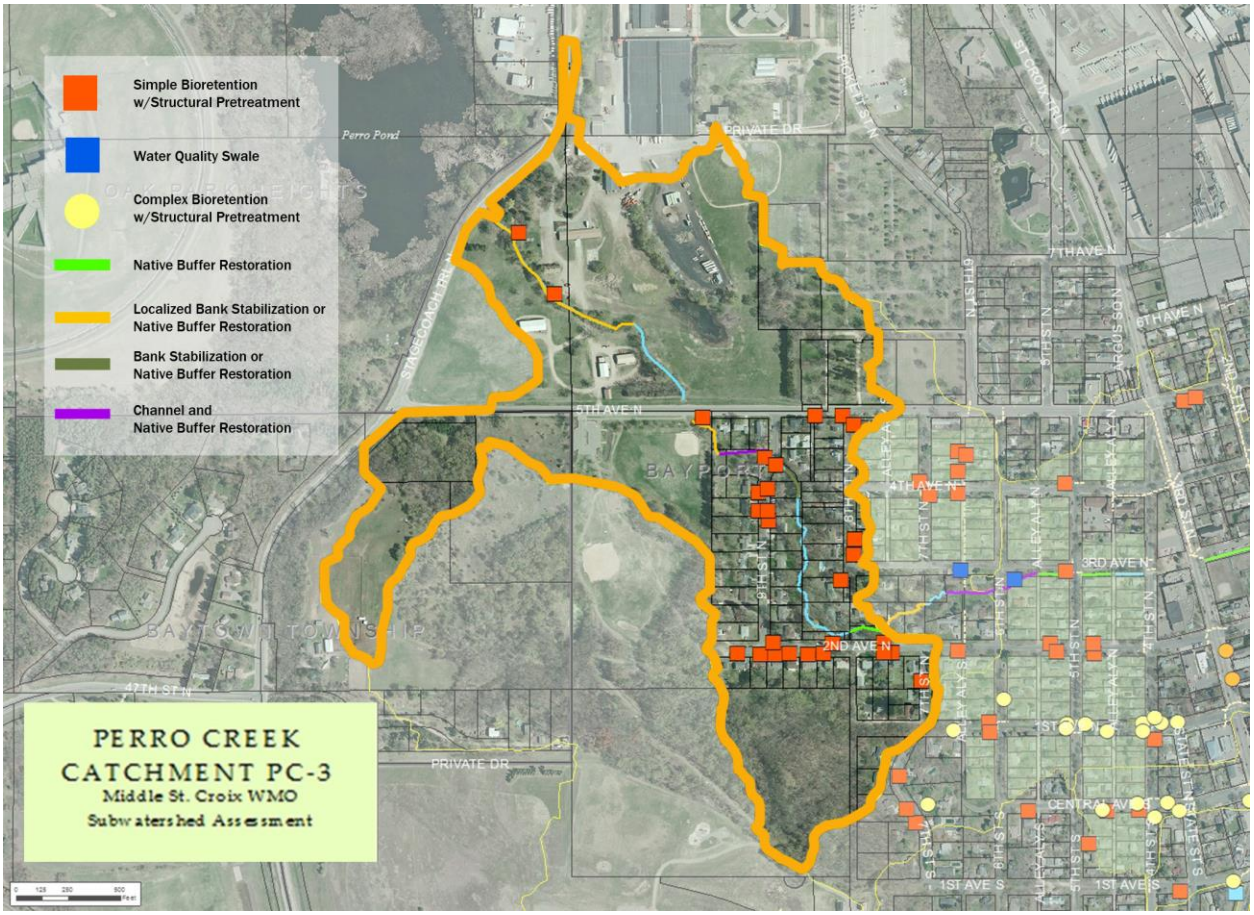
RETROFIT RECOMMENDATION

A combination of bioinfiltraiton and biofiltration with coarse sediment pretreatment devices and a water quality swale are recommended for this catchment. In certain locations, elevations may require small retaining walls to achieve level depressional areas required to infiltrate or filtrate stormwater. Modeling indicates eight BMPs will achieve a 30% Total Phosphorous reduction in Catchment PC-3 of 10.1 pounds.

BMP Treatment Summary *(for 30% TP treatment target of Catchment PC-3)*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple Bioretention w/pretreatment	20	225	$22.18	$4,990.00	$99,800.00
TOTAL *(plus $500 Promo & Admin)*	**20**				**$100,300.00**

Catchment PC-3

Term Cost Rank = #2



	Cost/Benefit Analysis *Catchment PC-3*		*Reductions*		
	Unit	***Baseline***	**10%**	**20%**	**30%**
TREATMENT	**# BMP Projects Needed**	-	7	13	20
	Live Storage Volume (cubic feet)	-	1,117	2,233	3,384
	TP (lb/yr)	**33.63**	30.3	26.9	23.5
	TSS (lb/yr)	**8983.0**	7,950	6,917	5,884
	TSS (% reduced)	-	11.5%	23.0%	34.5%
	Volume (acre-feet/yr)	**21.0**	18.8	16.5	14.3
	Volume (% reduced)	-	10.7%	21.3%	32.0%
COST	**Design and Installation**	-	$34,930	$64,870	$99,800
	Promotion & Admin Costs	-	$500	$500	$500
	Total Project Cost	-	$35,430	$65,370	$100,300
	Annual O&M	-	$1,117	$2,234	$3,385
	Term Cost/lb/yr (30 yr)	-	**$154**	**$326**	**$570**

Catchment PC-5

Term Cost Rank = #3

Base Load Summary *Catchment PC-5*	
Acres	71.4
Volume (acre-feet/yr)	41.8
TP (lb/yr)	59.5
TSS (lb/yr)	17129

WinSLAMM Input Summary *Catchment PC-5*			
Standard Land Use Code	**Acres**	**Standard Land Use Code**	**Acres**
DOWNTOWN	1.30	OPEN	3.68
FREE	2.78	PARK	3.67
INST	4.56	SCH	2.34
MDRNA	19.46	STRIPCOM	2.24
MDRWA	31.40		
TOTAL			**71.43**

DESCRIPTION

This catchment contributes the largest pollutant loads to Perro Creek. It is comprised of primarily medium-density residential properties with gravel alleys. Runoff is collected and conveyed to the creek in one of three ways: though a deteriorated storm sewer system; through a combination of asphalt lined and grass-lined ditch system, and from the streets directly into the creek.

RETROFIT RECOMMENDATION

A combination of bioinfiltraiton and biofiltration with coarse sediment pretreatment devices and a water quality swale are recommended for this catchment. A 10% reduction of TP could be achieved through the use of moderate cost BMPs. Slopes, density of impervious surface and stormwater rates pose challenges for retrofitting stormwater practices to achieve 20 and 30% reductions in this catchment. High cost BMP locations require alteration of street widths and additional stormwater infrastructure. If coordinated with a larger street or stormwater infrastructure project, design and installation costs will be much lower. Through the combination of BMPs identified modeling indicates a 30% TP reduction or 17.9 pounds can be achieved in catchment PC-5.

Modeling does not account for increased loading from gravel alleys. It is evident that gravel alleys contribute larger than modeled results for total phosphorous (TP) and total suspended solids (TSS) loading. Therefore, targeted outreach and assistance are prioritized to disconnect contributing impervious areas such as garages and rear lot parking pads from the gravel alleys.

BMP Treatment Summary *(for 30% TP treatment target of Catchment PC-5)*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple Bioretention w/pretreatment	15	225	$22.18	$4,990.50	$74,857.50
Highly Complex Bioretention w/pretreatment	15	225	$45.14	$10,156.50	$152,347.50
TOTAL *(plus $500 Promo & Admin)*	**30**				**$227,705.00**

Catchment PC-5

Term Cost Rank #3

	Cost/Benefit Analysis *Catchment PC-5*		*Reductions*		
	Unit	***Baseline***	**10%**	**20%**	**30%**
TREATMENT	**# BMP Projects Needed**	-	10	20	30
	Live Storage Volume (cubic feet)	-	1,682	3,363	5,095
	TP (lb/yr)	**59.54**	53.6	47.6	41.7
	TSS (lb/yr)	**17129.0**	15,334	13,539	11,744
	TSS (% reduced)	-	10.5%	21.0%	31.4%
	Volume (acre-feet/yr)	**41.8**	37.5	33.3	29.0
	Volume (% reduced)	-	10.2%	20.4%	30.5%
COST	**Design and Installation**	-	$49,900	$125,638	$227,213
	Promotion & Admin Costs	-	$500	$500	$500
	Total Project Cost	-	$50,400	$126,138	$227,713
	Annual O&M	-	$1,682	$3,363	$5,095
	Term Cost/lb/yr (10 yr)	-	**$125**	**$335**	**$669**

Catchment PC-7

Term Cost Rank = #4

Base Load Summary *Catchment PC-7*	
Acres	30.7
Volume (acre-feet/yr)	16.5
TP (lb/yr)	22.7
TSS (lb/yr)	7793

WinSLAMM Input Summary *Catchment PC-7*			
Standard Land Use Code	**Acres**	**Standard Land Use Code**	**Acres**
FREE	1.29	MI	1.70
LI	4.08	OPEN	4.72
MDRNA	11.41	STRIPCOM	1.02
MDRWA	6.47		
TOTAL			**30.69**

DESCRIPTION

This catchment is comprised of primarily medium-density residential properties without alleys. It also includes stormwater runoff from Hwy 95 and highly impervious light Industrial land uses. Runoff is conveyed to the creek though a deteriorated storm sewer system and at many locations directly discharged from the streets into the creek.

RETROFIT RECOMMENDATION

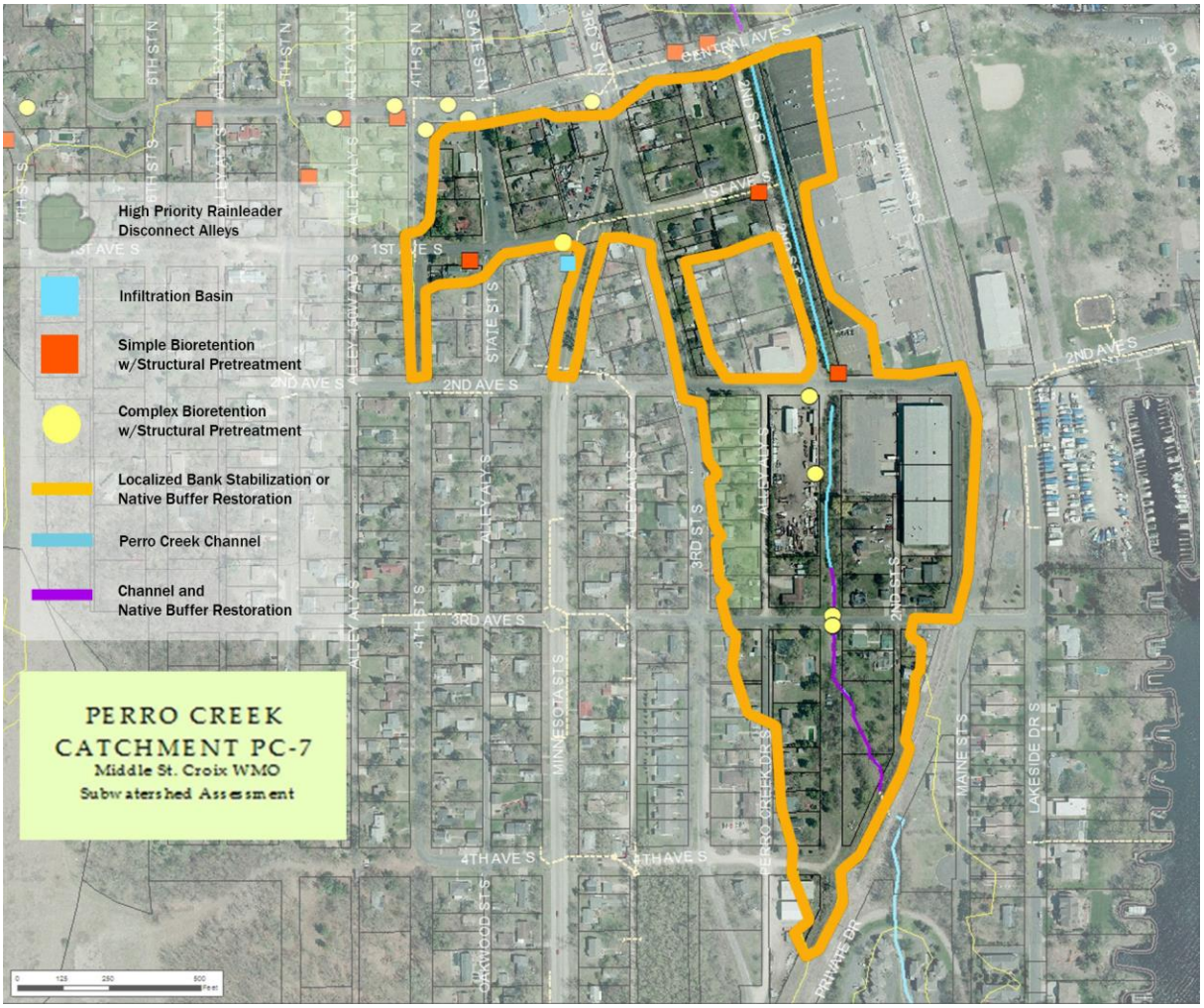
A combination of infiltration basins, bioinfiltraiton, biofiltration and tree pits with coarse sediment pretreatment devices are recommended for this catchment. A potential for a large infiltration basin designed to treat multiple acres of stormwater runoff was identified at the intersection of Minnesota St and 1st Ave S. Modeling indicates 8 BMPs will achieve the 30% TP reduction or 6.3 lbs. in catchment PC-7.

Modeling does not account for increased loading from gravel alleys. It is evident that gravel alleys contribute larger than modeled results for total phosphorous (TP) and total suspended solids (TSS) loading. Therefore, targeted outreach and assistance are prioritized to disconnect contributing impervious areas such as garages and rear lot parking pads from the gravel alleys.

BMP Treatment Summary *(for 30% TP treatment target of Catchment PC-7)*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**sf per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple Bioretention w/pretreatment	3	400	$22.18	$8,871.11	$26,613.33
Highly Complex Bioretention w/pretreatment	3	400	$45.14	$18,057.78	$54,173.33
Tree Pits *(6'x12' surface area, 4' deep cell)*	2	72	$146.53	$10,550.48	$21,100.96
TOTAL *(plus $500 Promo & Admin)*	**8**				**$102,387.63**

Catchment PC-7

Term Cost Rank #4



	Cost/Benefit Analysis *Catchment PC-7*		*Reductions*		
	Unit	***Baseline***	**10%**	**20%**	**30%**
TREATMENT	**# BMP Projects Needed**	-	3	5	8
	Live Storage Volume (cubic feet)	-	408	815	1,236
	TP (lb/yr)	**21.06**	19.0	16.8	14.7
	TSS (lb/yr)	**6555.0**	5,742	4,929	4,117
	TSS (% reduced)	-	12.4%	24.8%	37.2%
	Volume (acre-feet/yr)	**16.5**	14.7	12.9	11.2
	Volume (% reduced)	-	10.2%	20.4%	30.6%
COST	**Design and Installation**	-	$26,613	$62,729	$101,888
	Promotion & Admin Costs	-	$500	$500	$500
	Total Project Cost	-	$27,113	$63,229	$102,388
	Annual O&M	-	$426	$851	$1,290
	Term Cost/lb/yr (30 yr)	-	**$166**	**$426**	**$782**

Catchment # PC-6

Term Cost Rank = #5

Base Load Summary *Catchment PC-6*	
Acres	9.4
Volume (acre-feet/yr)	6.6
TP (lb/yr)	8.3
TSS (lb/yr)	2416

WinSLAMM Input Summary *Catchment PC-6*	
Standard Land Use Code	**Acres**
DOWNTOWN	1.01
FREE	0.72
LI	0.00
MDRNA	1.03
MDRWA	5.97
OPEN	0.23
STRIPCOM	0.44
TOTAL	**9.40**

DESCRIPTION

This catchment is comprised of primarily medium-density residential properties with gravel alleys and highly impervious land uses. Runoff is conveyed to the creek though a storm sewer system and is directly discharged from the streets into the creek at Central Avenue. The western portion of this small catchment is steeply sloped.

RETROFIT RECOMMENDATION

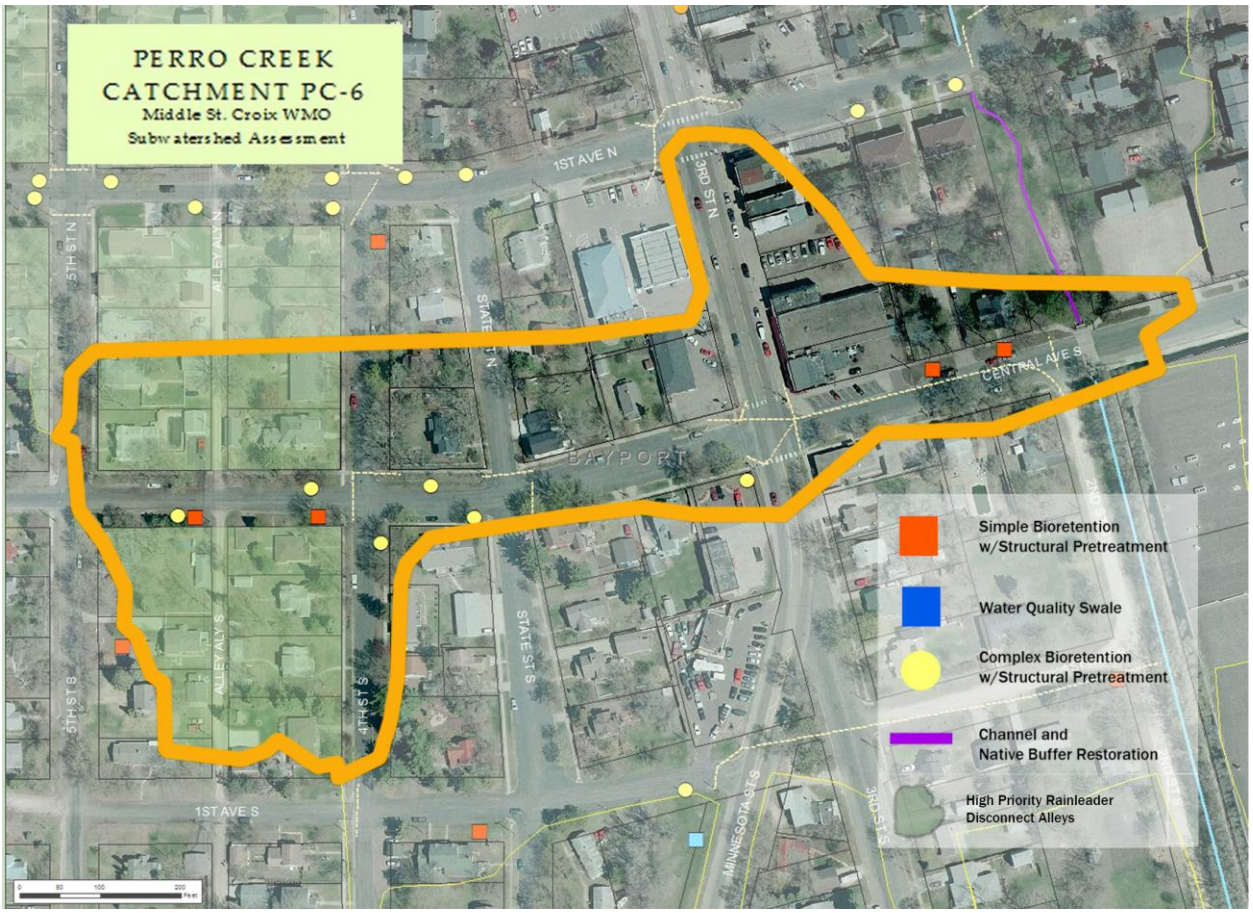
A combination of bioinfiltration and biofiltration with coarse sediment pretreatment devices are recommended for this catchment. A 20% reduction or 1.65 lbs. of TP can be achieved through the use of moderate cost BMPs. Slopes and density of impervious surface pose challenges for retrofitting stormwater practices to achieve 20% and 30% reductions in this catchment. High cost BMP locations require alteration of street widths and additional stormwater infrastructure. If coordinated with a larger street or stormwater infrastructure, practice design and installation costs will be lower. Modeling indicates 6 BMPs will achieve the 30% TP reduction or 2.47 lbs. in catchment PC-6.

Modeling does not account for increased loading from gravel alleys. It is evident that gravel alleys contribute larger than modeled results for total phosphorous (TP) and total suspended solids (TSS) loading. Therefore, targeted outreach and assistance are prioritized to disconnect contributing impervious areas such as garages and rear lot parking pads from the gravel alleys.

BMP Treatment Summary *(for 30% TP treatment target of Catchment PC-6)*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple Bioretention w/pretreatment	4	225	$22.18	$4,990.00	$19,960.00
Highly Complex Bioretention w/pretreatment	2	225	$45.14	$10,157.50	$20,315.00
TOTAL *(plus $500 Promo & Admin)*	**6**				**$40,775.00**

Catchment # PC-6

Term Cost Rank = #5



	Cost/Benefit Analysis *Catchment PC-6*		*Reductions*		
	Unit	***Baseline***	**10%**	**20%**	**30%**
TREATMENT	**# BMP Projects Needed**	-	2	4	6
	Live Storage Volume (cubic feet)	-	349	698	1,058
	TP (lb/yr)	**8.27**	7.4	6.6	5.8
	TSS (lb/yr)	**2416.0**	2,155	1,894	1,633
	TSS (% reduced)	-	10.8%	21.6%	32.4%
	Volume (acre-feet/yr)	**6.6**	5.9	5.2	5.0
	Volume (% reduced)	-	8.1%	16.2%	24.3%
COST	**Design and Installation**	-	$9,980	$19,960	$40,275
	Promotion & Admin Costs	-	$500	$500	$500
	Total Project Cost	-	$10,480	$20,460	$40,775
	Annual O&M	-	$349	$698	$1,058
	Term Cost/lb/yr (10 yr)	-	**$188**	**$415**	**$887**

Catchment Ranking

CATCHMENT IMPLEMENTATION PRIORITY To Achieve a 30% Reduction in TP *($ COST/ LB of TP / YR)*				*pre BMP*	*post BMP*	*REDUCTION*
Catchment	**Term Cost/lb/yr (10 yr lifecycle)**	**Total Design and Install** *(no O&M Incl.)*	**# of BMPs**	**TP (lbs/yr)**	**TP (lbs/yr)**	**TP (lbs/yr)**
PC-4	$503	$40,420	8	15.08	10.6	4.5
PC-3	$570	$100,300	20	33.63	23.5	10.1
PC-5	$669	$227,713	30	59.54	41.7	17.9
PC-7	$782	$102,388	8	21.06	14.7	6.3
PC-6	$887	$40,775	6	8.27	5.8	2.5
	average					
TOTALS	**$682**	**$511,595**	**72**	**137.6**	**96.3**	**41.3**

TOTAL CATCHMENTS Treatment Summary (for 30% TP treatment target)			*Design and Installation Costs*			
BMP Identified	**# of BMP**	**TP Reduction (lbs)**	**Cost per SF**	**Cost Per BMP**	**Total Cost**	**Cost per lb TP Built**
Simple Bioretention w/pretreatment	47	27.26	$22.18	$4,990.00	$234,530.00	$183.05
Highly Complex Bioretention w/pretreatment	17	9.86	$45.14	$10,157.50	$172,677.50	$1,030.17
Simple Bioretention w/pretreatment	3	1.74	$22.18	$8,871.11	$26,613.33	$5,098.34
Highly Complex Bioretention w/pretreatment	3	1.74	$45.14	$18,057.78	$54,173.33	$10,378.03
Tree Pits	2	0.7	$146.53	$10,550.48	$21,100.96	$15,072.11
TOTAL *(plus $2500 Total Promo & Admin)*	**72**	41.3			**$511,595.13**	

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Appendices

Appendix 1 – Catchments not included in Ranking Table

Catchments not included in ranking table were excluded for a number of reasons, mainly involving density of impervious surface and opportunities for BMP retrofits. After BMPs are installed within the priority catchments, it is recommended that the watershed revisit the entire subwatershed to determine other catchments that, while they may be conducive to retrofitting, were not considered a high priority for this report.

Appendix 2 – Summary of Protocol

This protocol attempts to provide a sufficient level of detail to rapidly assess subwatersheds or catchments of variable scales and land uses. It provides the assessor defined project goals that aid in quickly narrowing down multiple potential sites to a point where the assessor can look critically at site-specific driven design options that affect, sometimes dramatically, BMP selection. We feel that the time commitment required for this methodology is appropriate for most initial analysis applications and has worked well thus far for the Perro Creek Analysis.

Appendix 3 – Definitions

The following terms are used throughout this document and define the basic terminology used to talk about watersheds and restoration. Many of the terms can have different meanings in different contexts, so it is imperative to define their use within this document.

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

Biofiltration Basin- A soil and plant based stormwater management practice that infiltrates a portion of stormwater captured, but conveys excess filtered water through an underdrain.

Bioinfiltration Basin – A soil and plant-based stormwater management practice that infiltrates all runoff captured in the basin.

Catchment – Land area within a subwatershed generally having a drainage area of 1 – 100 acres for urban areas, where all water drains to a particular point. Several catchments make up a subwatershed. The existing stormwater infrastructure helps to define a catchment; therefore it is critical to obtain accurate stormwater infrastructure mapping information (including, at a minimum, the location of inlets and pipes, flow direction, and outfall locations) before undertaking a stormwater analysis process.

Raingarden – A landscaping feature that is planted with native perennial plants and is used to manage stormwater runoff from impervious surfaces such as roofs, sidewalks, roads, and parking lots.

Retrofit – The introduction of a new or improved stormwater management element where it either never existed or did not operate effectively.

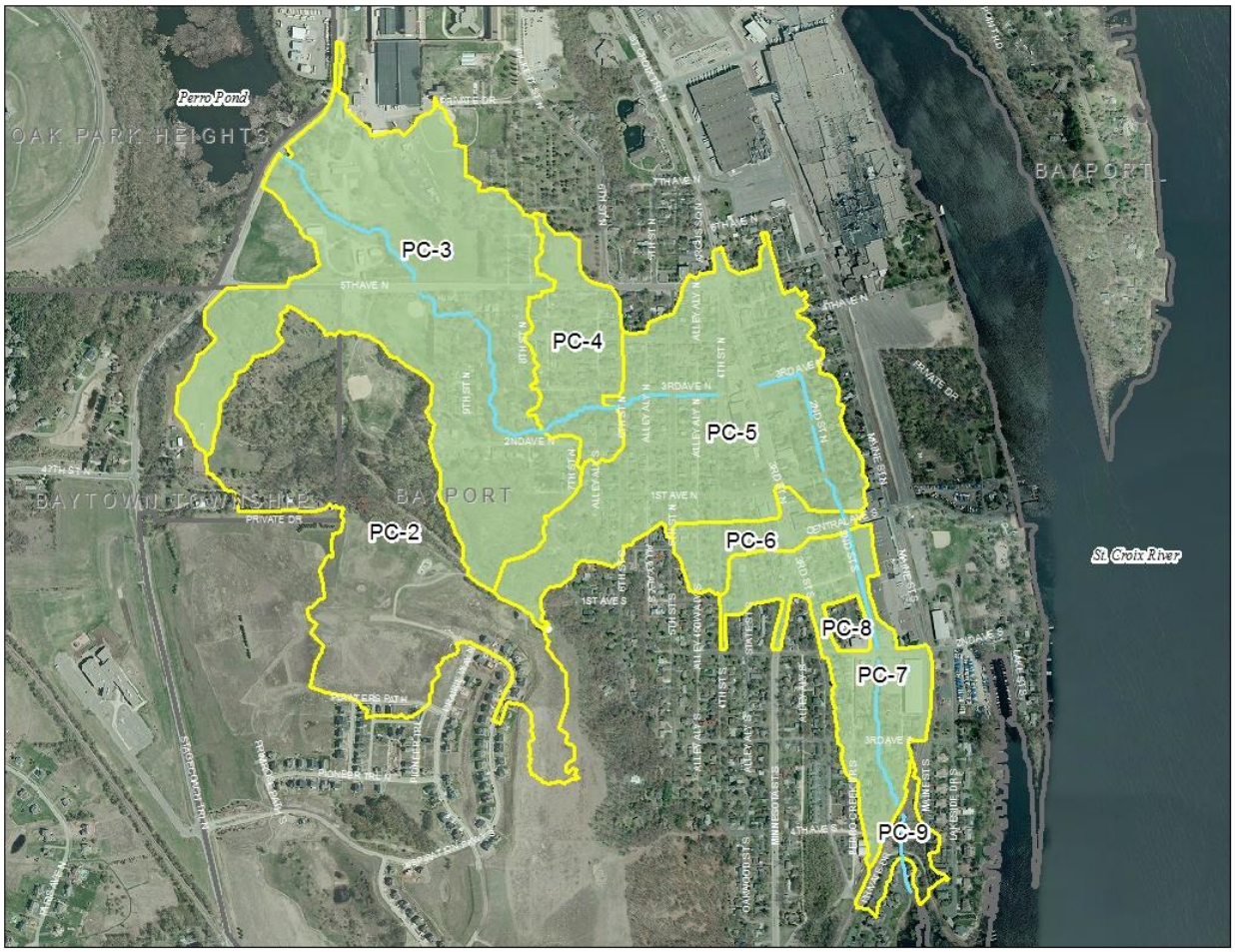
Stormwater – Water that is generated by rainfall or snowmelt that causes runoff and is often routed into drain systems for treatment or conveyance.

Subwatershed – Land area within a watershed generally having a drainage area of more than 500 acres, where all water drains to a particular point. Several subwatersheds make up a watershed. An example would be the Perro Creek subwatershed, which is within the boundaries of the Middle St. Croix Water Management Organization (the watershed). Subwatersheds are entirely based on hydrologic conditions, not political boundaries.

Urban – Any watershed or subwatershed with more than 10% total impervious cover.

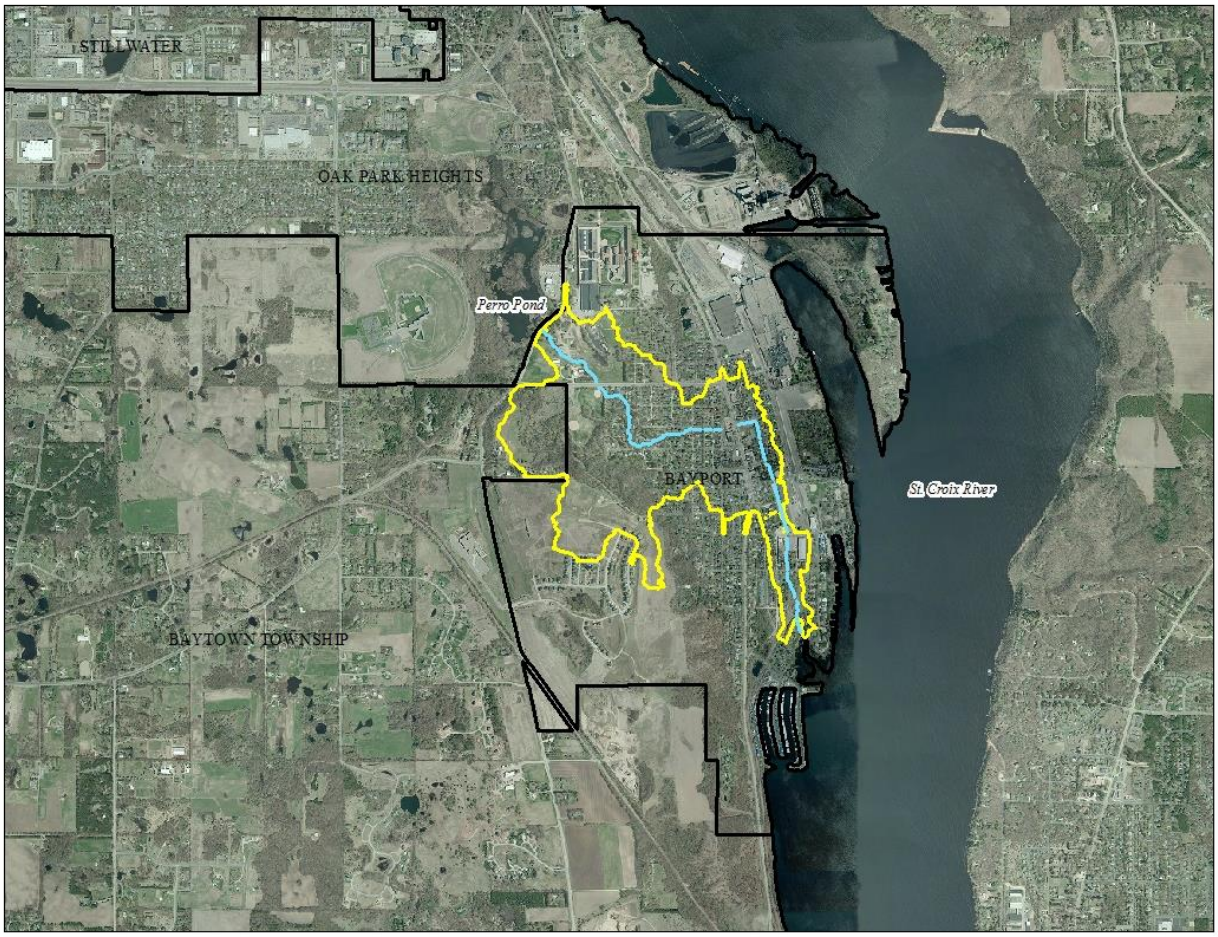
Watershed – Land area defined by topography, where all water drains to a particular point. Watershed drainage areas are large, ranging from 20 to 100 square miles or more, and are made up of several subwatersheds. There are currently 8 watersheds located either wholly or partially within Washington County, each defined along political boundaries that attempt to mimic hydrologic boundaries.

Appendix 4 – Subwatershed Maps

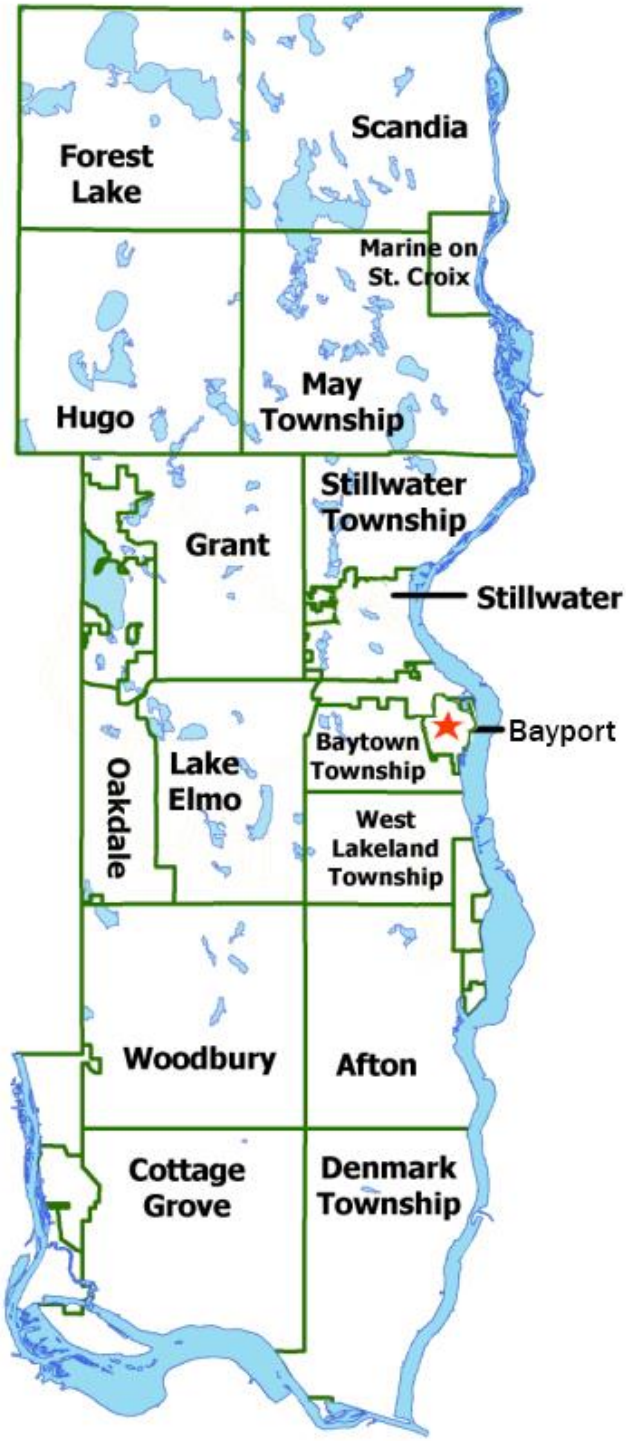


Perro Creek Subwatershed – Aerial Photo (2013)

Priority Catchments are Shaded



Location of the Perro Creek Subwatershed in Bayport, MN

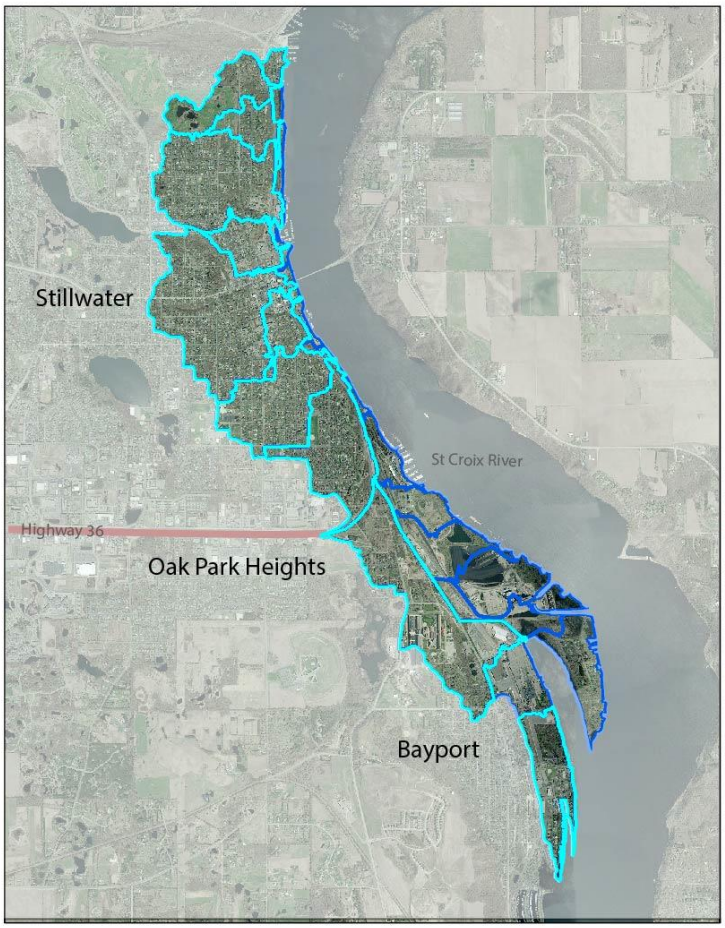


Location of the Perro Creek Subwatershed within Washington County

Appendix 5 – Catchment Maps

Lake St. Croix Direct Discharge Stormwater Retrofit Analysis

October 30, 2014



Prepared by:

WASHINGTON CONSERVATION DISTRICT

With assistance from:

THE METRO CONSERVATION DISTRICTS

for the

MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION

Contents

This report details a subwatershed stormwater retrofit analysis resulting in recommended catchments for placement of Best Management Practice (BMP) retrofits that address the goals of the Local Governing Unit (LGU) and stakeholder partners. This document should be considered as *one part* of an overall watershed restoration plan including redevelopment and new development volume control requirements, erosion and sediment control requirements; inspection, maintenance and operation of existing stormwater quality practices; ongoing education and outreach, voluntary incentive programs and technical design assistance for private landowners.

The methods and analysis behind this document attempt to provide a sufficient level of detail to rapidly assess subwatersheds of variable scales and land-uses to identify optimal locations for stormwater treatment. The time commitment required for this methodology is appropriate for *initial analysis* applications.

The analysis's background information is discussed followed by a summary of the analysis'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 analysis are based on the development of catchment-specific *conceptual* stormwater treatment BMPs 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 and implement BMP projects. 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 in this report. This typically occurs after committed partnerships are developed for each specific target property for which BMPs are planned.

Executive Summary

The subwatershed directly discharging to Lake St. Croix and existing stormwater management practices, were analyzed for annual pollutant loading. The Lake St. Croix Direct Discharge Subwatershed spanning the municipalities of Stillwater, Oak Park Heights, and Bayport was broken into twenty-seven catchment areas and evaluated for potential pollutant sources from stormwater discharges. Stormwater practice options were compared for each catchment, depending on specific site constraints and characteristics. Potential stormwater BMP retrofit locations were selected by weighing pollutant loading to the location, feasibility of installation, and maintenance.

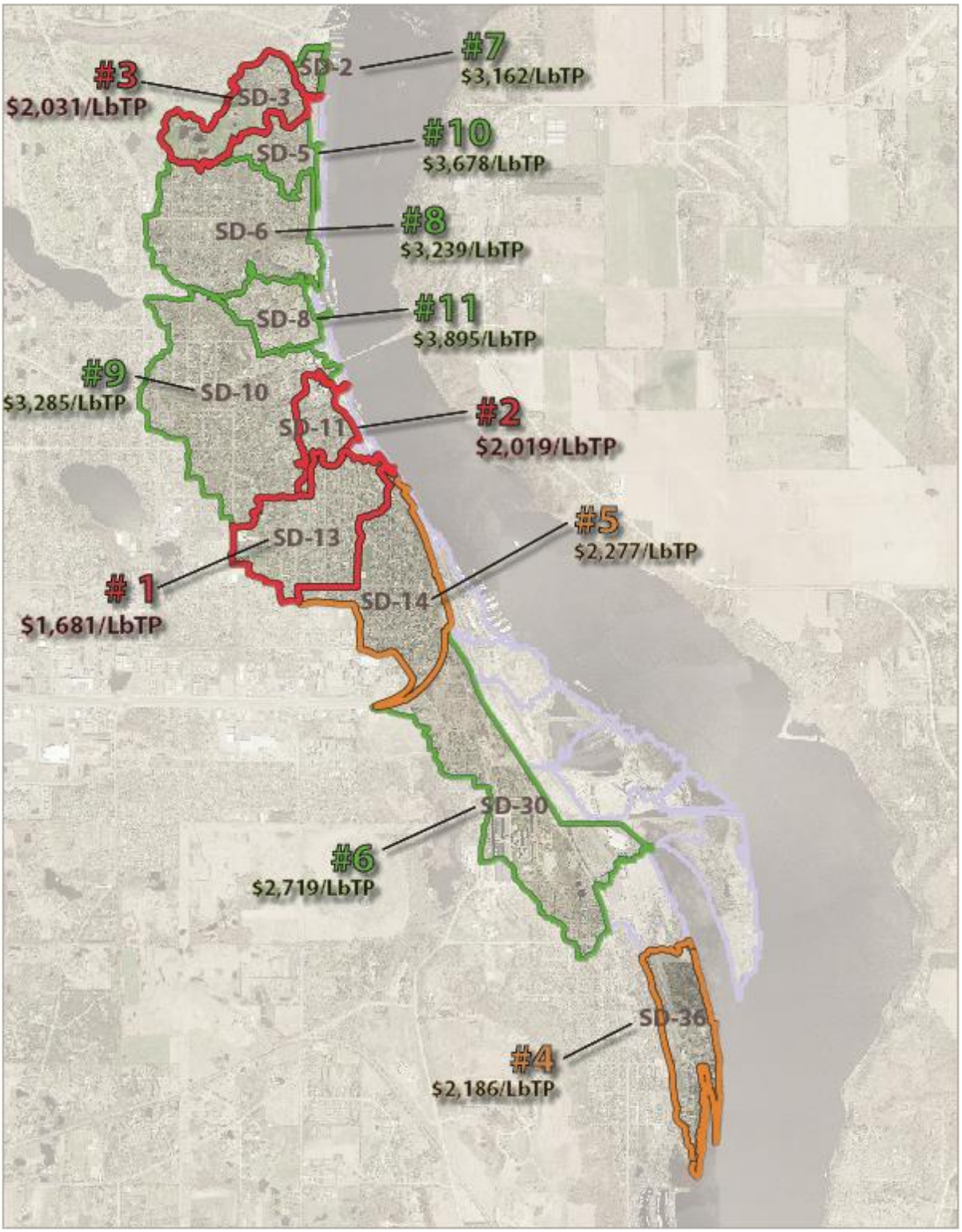
Lake St. Croix is defined as the lower 25 miles of the 7,760 square mile St. Croix Basin between. The lake was designated as an Impaired Water in 2008 for excess phosphorus. The 2012 Lake St. Croix Total Maximum Daily Load (TMDL) Implementation identified 1,521 pounds phosphorous load reduction for the Middle St. Croix Watershed (from the 1992 baseline) is needed to bring Lake St. Croix back to current State water quality standards. The study spatially distributed anthropogenic runoff loads (identified in the Lake St. Croix TMDL) based on land use. This subwatershed analysis identifies targeted practices that will reduce annual TP loading to Lake St. Croix by 78.3 pounds per year.

The following table summarizes the analysis results. Treatment levels (percent removal rates) for retrofit projects that resulted in a prohibitive BMP size, or number, or were too expensive to justify installation are not included. Reported treatment levels are dependent upon optimal BMP location within the catchment and total BMP area. The recommended treatment levels/amounts summarized here are based on a subjective analysis of potential BMP installations, considering estimated public participation and site constraints.

Recommended catchment rankings are based on a relative comparison of the cost per pound of phosphorus reduced over the life of the BMPs. BMP costs are estimated based on the implementation of a minimum of 1,000 square feet of BMPs initiated and constructed for the sole purpose of water quality.

The Lake St. Croix Direct Discharge Subwatershed Analysis prioritizes and targets stormwater retrofit practices that would reduce 78.4 pounds of total phosphorus directly discharging into Lake St. Croix from urban land uses in Stillwater, Oak Park Heights, and Bayport. These results assume water quality projects are designed and installed independent of any other infrastructure improvements. The costs of these practices are substantially lower when designed and installed as part of a larger infrastructure improvement project such as street reconstruction or commercial/institutional building redevelopment.

Top-Ranked Lake St. Croix Catchments and TP Removal Potential



CATCHMENT RANKING: Cost per Lb of TP/Year				Pollutant Reductions Per Catchment			
Rank	Stillwater Direct Catchment	Total Acres	Cost/LbTP/Year	TP (lbs/yr)	TSS (lbs/yr)	WQV (cuft/yr)	Percent TP Reduction
#1	SD-13	148.59	$1,681.47	15.72	3,366	4.92	12.60%
#2	SD-11	43.10	$2,019.05	2.10	3,640	0.67	5.83%
#3	SD-3	81.49	$2,031.59	5.27	955	1.33	16.67%
#4	SD-36	94.93	$2,186.16	6.70	2,706	3.53	9.56%
#5	SD-14	150.61	$2,276.78	23.27	17,381	10.55	19.30%
#6	SD-30	253.12	$2,719.67	0.89	362	0.54	0.56%
#7	SD-2	13.26	$3,162.02	2.97	1,274	1.77	28.89%
#8	SD-6	200.95	$3,239.05	10.44	4,628	6.18	6.56%
#9	SD-10	280.94	$3,284.76	3.61	3,606	1.35	1.63%
#10	SD-5	46.49	$3,678.37	6.74	2,827	4.03	21.14%
#11	SD-8	55.47	$3,895.47	0.65	262	0.39	1.37%
				78.36	41,007.91	35.27	

About this Document

Document Overview

The Stormwater Retrofit Analysis is a subwatershed management tool used to prioritize stormwater BMP retrofit projects based on BMP performance and cost effectiveness. This process helps maximize the value of each dollar spent.

This document is organized into four main sections that describe the general methods used, individual catchment profiles, a retrofit ranking for the subwatershed, and references used in the analysis protocol. The Appendices section provides additional information relevant to the analysis.

Under each section and subsection, project-specific information relevant to that portion of the analysis is provided with an ***Italicized Heading***.

Methods

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

NOTE: the financial, technical, current landscape/stormwater system, and timeframe limits and needs are highly variable from subwatershed to subwatershed. This analysis uses some, or all, of the methods described herein.

Catchment Profiles

Each catchment profile is labeled with a numerical ID for identification purposes (e.g., Catchment SD-5, Catchment SD-7). This numerical ID is referenced when comparing results across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

Within each Catchment Summary/Description section is a table that summarizes basic information including catchment size, current land cover, and estimated annual pollutant load (target pollutant(s)

are specified by the LGU). A table of the principal WinSLAMM Standard Land Use model inputs and their corresponding acreage values are also reported. A brief description of the land cover, stormwater infrastructure and any other important general information is described.

Retrofit Recommendation

The Retrofit Recommendation section describes the conceptual BMP retrofit(s) selected for the catchment area and provides a description of why each specific retrofit option 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 capital budgets vs. load reduction goals.

Site Selection

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

Catchment Ranking

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

- Total amount of pollutant removal
- Non-target pollutant reductions
- BMP project visibility
- Availability of funding
- Total project costs
- Educational value

References

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

Appendices

The Appendices section provides supplemental information and/or data used during the analysis protocol.

Methods

Selection of Subwatershed

Before the subwatershed stormwater analysis begins, a process of identifying a high priority water body as a target takes place. Many factors are considered when choosing which subwatershed to assess for stormwater retrofits. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Analyses supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the analysis also rank highly.

In areas without clearly defined studies, such as a TMDL or officially listed water bodies of concern, or where little or no monitoring data exist, metrics are used to score subwatersheds against each other. In large subwatersheds (e.g., greater than 2500 acres), a similar metric scoring is used to identify areas of concern, or focus areas, for a more detailed analysis. This methodology was slightly modified from Manual 2 of the *Urban Stormwater Retrofit Practices* series.

Description of Lake St. Croix Direct Discharge Contributing Subwatershed

Lake St. Croix is defined as the lower 25 miles of the 7,760 square mile St. Croix Basin between. The lake was designated as impaired water in 2008 for excess phosphorus. The 2012 Lake St. Croix Total Maximum Daily Load (TMDL) Implementation identified 1,521 pounds phosphorous load reduction for the Middle St. Croix Watershed (from the 1992 baseline) to meet State water quality standards for aquatic recreation. The study spatially distributed anthropogenic runoff loads (identified in the Lake St. Croix TMDL) based on land use. The Lake St. Croix Direct Discharge Subwatershed encompasses a total of 1,852.5 acres of urban land use in the cities of Oak Park Heights, Stillwater and Bayport. Stormwater is conveyed through a network of storm sewers and open drainage ways that directly discharge to the Lake St. Croix.

Monitoring for Lake St. Croix is conducted by the Metropolitan Council Environmental Services at the Hwy 36 lift-bridge at Stillwater Minnesota. Flows are calculated by adding USGS flow data for the St. Croix River at St. Croix Falls, Wisconsin and the USGS flow data for the Apple River (Wisconsin). Water quality monitoring at the Stillwater site captures most of the loadings of the Lower St. Croix but does not include the Willow and Kinnickinnic Rivers, small streams, and direct runoff downstream of Stillwater. Data is published in the Lower St. Croix River Watershed Monitoring and Assessment Report, Minnesota Pollution Control Agency, February 2014.

Subwatershed Analysis Methods

The process used for this analysis 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 includes determining the objectives of the retrofits (volume reduction, target pollutant etc) and the level of treatment desired. It involves meeting with local stormwater managers, city staff, and watershed staff to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to assess in large subwatersheds, a smaller focus area may be determined.

Lake St. Croix Direct Discharge Subwatershed Scoping

Pollutants of concern for this subwatershed were identified as total phosphorous (TP), total suspended solids (TSS), and volume. Goals of the MSCWMO, WCD, and Cities of Stillwater, Oak Park Heights, and Bayport were considered in the development of this analysis.

Step 2: Desktop Retrofit Analysis

Desktop retrofit analysis involves computer-based scanning of the subwatershed for potential BMP retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure. Accurate and current GIS data is extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography, and storm drainage infrastructure (with invert elevations and flow direction). The following table highlights some important features to look for and the associated potential retrofit project.

Subwatershed Metrics and Potential Retrofit Project Site/Catchment	
Screening Metric	**Potential Retrofit Project**
Open Space	**New regional treatment (pond, infiltration basin).**
Roadway Culverts	**Add wetland or extended detention water quality treatment upstream.**
Outfalls	**Split flows or add storage below outfalls if open space is available.**
Conveyance system	**Add or improve performance of existing swales, ditches and non-perennial streams.**
Large Impervious Areas (campuses, commercial, parking)	**Stormwater treatment on-site or in nearby open spaces.**
Neighborhoods	**Utilize right of way, roadside ditches or curb-cut raingardens or filtering systems to treat stormwater before it enters storm drain network.**

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 to eliminate sites from consideration. The field investigation revealed additional retrofit opportunities that would have gone unnoticed during the desktop search.

The following stormwater BMPs were considered for each catchment/site:

Stormwater Treated Options for Retrofitting		
Area Treated	**Best Management Practice**	**Potential Retrofit Project**
5.1-10.0 acres	Infiltration Basin	**Large and shallow impoundment areas designed to retain and infiltrate stormwater runoff.**
0.1-5.0 acres	Bioinfiltration	**Use of native soil, soil microbe, and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.**
	Biofiltration	**Filters runoff through engineered biologically active media and passes it through an under-drain. May consist of a combination of sand, soil, compost, peat, compost, or iron.**
	Tree Boxes	**A trench or sump that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering the infiltration area.**
	Gully Stabilization	**Engineered practices designed to reduce down-cutting, sloughing and eroding slopes that discharge directly to receiving waters.**
	Other	**On-site, source-disconnect practices such as rain-leader raingardens, rainleader disconnect, stormwater planters, dry wells and permeable pavements.**

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Sites most likely address pollutant reduction goals and those that may have simple design/install/maintenance considerations are chosen for a cost/benefit analysis that relatively compares catchments/sites. Treatment concepts are developed taking into account site constraints and the subwatershed treatment objectives. Projects involving complex stormwater treatment interactions and those that may pose a risk for upstream flooding require the assistance of a professional engineer. Conceptual designs at this phase of the design process include cost and pollution reduction estimates. Reported treatment levels are dependent upon optimal site selection and sizing.

Modeling of the site is done by WinSLAMM. WinSLAMM uses event mean concentrations based on land use for each catchment/site to estimate relative pollution loading of the existing conditions. The site's conceptual BMP design is then modeled to estimate varying levels of treatment by sizing and design element. This treatment model can also be used to properly size BMPs to meet restoration objectives.

General WinSLAMM Model Inputs	
Parameters	**Method for Determining Value**
Area	Natural Resource Conservation Service Custom watershed delineation tools from ESRI were used to identify catchments in ArcMap 10.1. Software generated catchment boundaries were field verified and modified when necessary.
Land Use	Using GIS, land areas discharging to Lake St. Croix were evaluated and assigned Standard Land Uses (SLU) in WinSLAMM 10.1. These SLUs describe the average characteristics of impervious and pervious surfaces in each catchment.
Precipitation/Temperature Data	Rainfall and temperature recordings from Minneapolis 1959 were used as a representation of an average year. Winter season was marked as November 15 to March 18.
Pollutant Probability Distribution	WinSLAMM uses a pollutant value file to determine the pollutant loading from a source area. The default value WI_GEO02 computed from USGS was used for this analysis.
Runoff Coefficient	The default runoff coefficient WI_SL06 was used.
Particulate Solids Concentration	The default WI_GEO01.ppd particle file developed by USGS was used.
Street Delivery Parameter File	The default street dirt delivery files were used to retain total particles that do not reach the outfall based on rain depths and street textures.
Particle Size Distribution	Average of the available outfall particle size distribution data from the National Urban Runoff Program studies.

Lake St. Croix Direct Discharge Treatment Analysis

For the Lake St. Croix Direct Discharge Treatment analysis, each catchment (and each relevant parcel within them) was first assessed for BMP applicability given specific site constraints and soil types. High bedrock, high surficial groundwater, slope, pedestrian and car traffic flow, parking needs, snow storage areas, obvious utility locations, existing landscaping, surface water runoff flow, project visibility, existing landscape maintenance, available space, and other site-specific factors dictated the selection of one or more potential BMPs for each site.

WinSLAMM was used to model catchments and a hypothetical BMP located at its outfall. BMPs were categorized based on typical sizes for their space (250sqft, 400sqft, etc) and results were tabulated in the Catchment Profile section of this document. BMPs with underdrains were modelled with a 12" ponding depth and those without underdrains were modelled at 6" ponding depths. A 24" depth was used for any replacement soil media with a 60/40 sand/peat ratio. In cases where underlying soils were classified as Urban-mixed fill, the model assumed a 0.2"/hour infiltration rate. In reality, those infiltration rates will vary, and could likely increase the pollutant reduction potential of the proposed

practice. During the design phase, practices will be designed with a more precise infiltration rate (identified through field investigation).

Cost Estimates

Each resulting BMP was assigned estimated design, installation, and annual maintenance costs given its total area of treatment. An annual cost/TP-removed for each treatment level was calculated for the life of each BMP that includes promotional, administrative and life cycle operations, and maintenance costs.

The following table provides the BMP cost estimates used to assist in cost analysis:

Average BMP Cost Estimates						
BMP	Description	Installation Materials & Labor	Annual Maintenance	Design Cost ($70/hr)	Installation Oversight Cost ($70/hr)	O & M Term
Rain Leader Disconnect Rain Garden	Simple residential raingarden	$7.56	$0.25/ft^2	$280/100 ft^2	$210	10
Infiltration Basin (Turf)	Amended soils with under-drains	$15.10	$2000/acre	$1120/acre	$210	10
Simple Bioinfiltration	No engineered soils or under-drains, but w/curb cuts.	$14.00	$1.60/ft^2	$1200/1000 ft^2	$210	10
Simple Bioinfiltration w/Structural Pretreatment	No engineered soils or under-drains, but w/curb cuts and structural pretreatment	$20.00	$1.60/ft^2	$1200/1000 ft^2	$210	10
Moderately Complex Biofiltration	With engineered soils, under-drains, curb cuts, no structural pretreatment but no retaining walls	$17.00	$1.60/ft^2	$2000/1000 ft^2	$290	10
Moderately Complex Biofiltration w/Structural Pretreatment	Incl. engineered soils, under-drains, curb cuts, structural pretreatment but no retaining walls	$23.00	$1.60/ft^2	$2000/1000 ft^2	$350	10
Complex Biofiltration w/Structural Pretreatment	As MCBwSP but with 1.5-2.5 ft partial perimeter walls	$27.50	$1.60/ft^2	$3750/1000ft^2	$410	10

Average BMP Cost Estimates						
Highly Complex Biofiltration w/Structural Pretreatment	As CBwSP but with utility or grey infrastructure modifications	$37.50	$1.60/ft^2	$7500/1000ft^2	$470	10
Curb-Cut	Cut with apron	$80.00				
Impervious Cover Conversion		$21.71	$500/acre	$1120/acre	$210	10
Stormwater Tree Pits[2]	6' x 12 ' pit with concrete vault	$140.00	$0.75/ft^2	140% above construction	$210	10
Grass/Gravel Permeable Pavement	Sand base	$18.95	$0.75/ft^2	140% above construction	$210	10
Permeable Asphalt	Granite base	$10.80	$0.75/ft^2	140% above construction	$210	10
Permeable Concrete	Granite base	$15.00	$0.75/ft^2	140% above construction	$210	10
Permeable Pavers	Granite base	$35.75	$0.75/ft^2	140% above construction	$210	10
Extended Detention		(12.98)*(CU-FT^0.75)	$1000/acre	3$2800/acre	$210	10
Wet Pond		(277.89)*(CU-FT^0.553)	$1000/acre	3$2800/acre	$210	10
Perimeter Sand Filter		$259.20				10
Structural Sand Filter	(including peat, compost or iron amendment))	$22.04	$250/25ft	$300/25ft	$210	10
Underground Sand Filter		$99.08	$0.75/ft^2	140% above construction	$210	10
Rain Barrels	Does not include pump or distribution	$25.00	$25	NA	$210	10
Cisterns	Does not include pump or distribution	$16.00	$100	NA	$210	10
Dry Swale[1]	With soil amendments	$7.13	$0.75/ft^2	$280/100 ft^2	$210	10
Water Quality Swale[1]	With soil replacement and check dams	$15.01	$0.75/ft^2	$1120/1000 ft^2	$420	10
French Drain/Dry Well		$15.00	$100	20% above construction	$210	10
Stormwater Planter (ultra urban)	Usually a stormwater disconnect BMP	$35.86	$0.75/ft^2	20% above construction	$210	10

[1] Assumed to be 15 feet in width. [2] Assumed ultra-urban linear application.

Lake St. Croix Direct Cost Analysis

For the Lake S.t Croix Direct Discharge cost analysis, promotion, installation and administration for each practice was estimated based on the actual costs of similar water quality retrofit projects in Washington and Dakota County from 2010-2014. Project costs assume the implementation of an average of five practices or 1000 cubic feet of treatment per project area. Cost savings occur when water quality practices are designed and installed in conjunction with larger capital improvement projects such as reconstruction or redevelopment. Annual Operation & Maintenance referred to the square foot (ft^2) estimates provided in the preceding table.

Step 5: Evaluation and Ranking

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

Lake St. Croix Direct Discharge Evaluation and Ranking

In the Lake St. Croix evaluation and ranking, the recommended level of treatment for each catchment, as reported in the Executive Summary table, was chosen by selecting the maximum level of treatment achievable considering constraints and public buy-in and above a minimal amount needed to justify crew mobilization and outreach efforts to the area. Should the cumulative expected load reduction of the recommended catchment treatment levels not meet LGU goals, a higher level of treatment (as described in the Catchment Profile tables) should be selected. The maps associated with each catchment show potential BMP locations as determined by field review. To meet treatment level goals for a catchment, a minimum percentage of potential BMPs (equaling or exceeding the "BMP Surface Area") must be installed within that catchment.

Catchment Profiles

The following pages provide catchment-specific information that was analyzed for stormwater BMP retrofit treatment at various levels. Utilizing GIS each catchment is divided into several different land uses based on WinSLAMM Standard Land Use parameters.

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.

For development of the Lake St. Croix Direct Discharge catchment profile section**, 11 out of 25 catchments** were selected as the first-tier areas for stormwater retrofit efforts. Those catchments that are land locked, have minimal impervious surface, high surficial groundwater, steep slopes and/or contaminated soil were not modeled or further analyzed in this analysis.

WinSLAMM Standard Land Use Codes		
Land Uses	**Codes**	**Definition**
Residential	HDRNA	High Density Residential without Alleys
	HDRWA	High Density Residential with Alleys
	MDRNA	Medium Density Residential without Alleys
	MDRWA	Medium Density Residential with Alleys
	LDR	Low Density Residential
	MFR	Multiple Family Residential
Commercial	STRIPCOM	Strip Commercial
	DOWNTOWN	Commercial Downtown
Industrial	MI	Medium Industrial
	LI	Non-Manufacturing
Institutional	SCH	Education Facilities
	INST	Miscellaneous Institutional
Other	PARK	Parks
	OPEN	Undeveloped
	CEM	Cemetery
Freeway	FREE	Freeways

Catchment # SD-13

Term Cost Rank = #1

Base Load Summary *Catchment SD-13*	
Acres	148.6
Volume (acre-feet/yr)	78.8
TP (lb/yr)	124.7
TSS (lb/yr)	33,010

WinSLAMM Input Summary *Catchment SD-13*	
Standard Land Use Code	**Acres**
CEM	2.26
FREE	0.47
INST	1.41
MDRNA	125.13
MFR	0.96
OPEN	3.17
PARK	0.89
SCH	13.46
STRIPCOM	0.84
TOTAL	**148.59**

DESCRIPTION

This catchment is comprised primarily of medium-density residential properties without alleys. Stormwater runoff discharges directly to Lake St. Croix though the storm sewer system. Sidewalks on both sides of the roadway restrict the potential for retrofits in central and eastern portions of this catchment due to space limitations in the right-of-way. Shallow bedrock is known to exist near Quarry Lane and along the bluff edge.

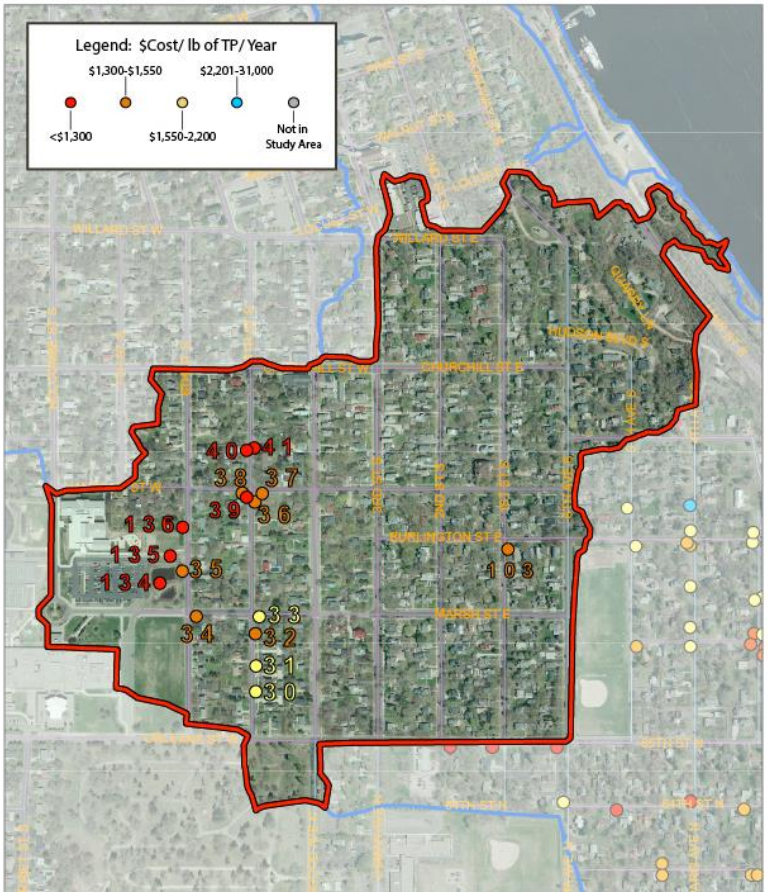
RETROFIT RECOMMENDATION

A combination of bioinfiltration and biofiltration with coarse sediment pretreatment devices and an iron enhanced sand filter are recommended for this catchment. In certain locations, slopes require small to mid-size retaining walls to achieve level depressional areas required to infiltrate or filtrate stormwater. Desktop analysis, field investigation, and modeling indicate sixteen BMPs will achieve a 15.7 pound reduction of Total Phosphorous in Catchment SD-13.

BMP Treatment Summary *Catchment SD-13*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
IESF Filter Bench	1	2000	$30.00	$60,000.00	$60,000.00
Moderately Complex BioIN w/pretreatment	2	250	$24.50	$6,125.00	$12,250.00
Moderately Complex BioFILTER w/pretreatment	2	250	$23.00	$5,750.00	$11,500.00
Moderately Complex BioFILTER w/pretreatment	2	400	$23.00	$9,200.00	$18,400.00
Highly Complex BioFILTERw/pretreatment	7	250	$27.50	$6,875.00	$48,125.00
Highly Complex BioFILTERw/pretreatment	2	400	$27.50	$11,000.00	$22,000.00
TOTAL	**16**				**$172,275.00**

Catchment # SD-13

Term Cost Rank = #1



	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	Baseline	Load with 12.6% TP Reduction	Load Reduction
TREATMENT	TP (lb/yr)	124.69	109.0	-15.7
	TSS (lb/yr)	33010.0	29,644.3	-3,365.7
	TSS (% reduced)	-	*10.2%*	
	Volume (acre-feet/yr)	78.8	73.9	-4.92
	Volume (% reduced)	-	*6.2%*	
	# BMP Projects Needed	-	16	
COST	Design and Installation	-	$193,875	
	Promotion & Admin Costs	-	$7,200	
	Total Project Cost	-	$201,075	
	Annual O&M	-	*$6,320*	
	Term Cost/lb/yr (10 yr)	-	**$1,681**	

*based on cost/benefit of less than $2,000 per lb

Catchment # SD-11

Term Cost Rank = #2

Base Load Summary *Catchment SD-11*	
Acres	43.1
Volume (acre-feet/yr)	33.4
TP (lb/yr)	36.05
TSS (lb/yr)	11,359

WinSLAMM Input Summary *Catchment SD-11*	
Standard Land Use Code	**Acres**
DOWNTOWN	8.19
FREE	1.53
INST	2.99
MDRNA	21.53
OFFPARK	3.00
OPEN	4.95
PARK	0.17
STRIPCOM	0.74
TOTAL	**43.10**

DESCRIPTION

This catchment is comprised of primarily medium-density residential properties but also includes areas of downtown Stillwater. Stormwater runoff discharges directly to Lake St. Croix though the storm sewer system. Slopes, high bedrock and high density impervious surfaces pose challenges for retrofitting stormwater practices to achieve further reductions in this catchment.

RETROFIT RECOMMENDATION

A combination of slope stabilization and biofiltration with coarse sediment pretreatment devices are recommended for this catchment. Desktop analysis, field investigation and modeling indicate two BMPs will achieve a 2.0 pound reduction of Total Phosphorous in Catchment SD-11.

BMP Treatment Summary *Catchment SD-11*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Slope Stab with large basin with regrade	1	400	$37.50	$15,000	$15,000
Highly Complex BioFILTERw/pretreatment	1	400	$37.50	$11,000	$11,000
TOTAL	**2**				**$26,000**

Catchment # SD-11

Term Cost Rank = #2

	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 5.8% TP Reduction	Load Reduction
TREATMENT	**TP (lb/yr)**	**36.05**	34.0	-2.10
	TSS (lb/yr)	**11359.0**	7,719.0	-3,640
	TSS (% reduced)	-	*32.0%*	
	Volume (acre-feet/yr)	**33.4**	32.8	-0.67
	Volume (% reduced)	-	*2.0%*	
	# BMP Projects Needed	-	2	
COST	**Design and Installation**	-	$28,700	
	Promotion & Admin Costs	-	$900	
	Total Project Cost	-	$29,600	
	Annual O&M	-	*$1,280*	
	Term Cost/lb/yr (10 yr)	-	**$2,019**	

Catchment # SD-3

Term Cost Rank = #3

Base Load Summary *Catchment SD-3*	
Acres	81.5
Volume (acre-feet/yr)	7.3
TP (lb/yr)	31.6
TSS (lb/yr)	7,255

WinSLAMM Input Summary *Catchment SD-3*	
Standard Land Use Code	**Acres**
FREE	0.76
LDR	3.44
MDRNA	20.36
OPEN	13.20
PARK	43.73
TOTAL	**81.49**

DESCRIPTION

This catchment is comprised of primarily golf course and woodland properties. Stormwater runoff discharges directly to Lake St. Croix though the storm sewer system. Currently this catchment contains two retrofit stormwater ponds that are significantly undersized to perform effective water quality improvements.

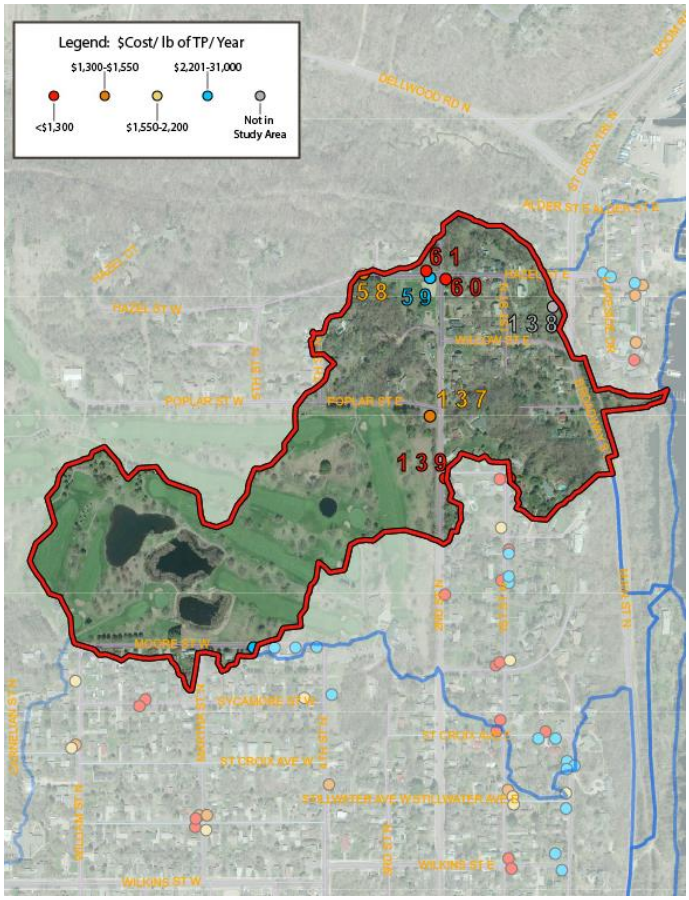
RETROFIT RECOMMENDATION

A combination of biofiltration and bioinfiltration with coarse sediment pretreatment devices and stormwater pond retrofits are recommended for this catchment. Desktop analysis, field investigation and modeling indicate six BMPs will achieve a 5.3 pound reduction of Total Phosphorous in Catchment SD-3.

BMP Treatment Summary *Catchment SD-3*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**sf per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple BiorIN w/pretreatment	1	3000	$13.34	$40,020	$40,020
Moderately Complex BiorFILTER w/pretreatment	4	250	$23.00	$5,750	$23,000
Highly Complex BioIN w/pretreatment	1	250	$27.50	$6,875	$6,875
TOTAL	**6**				**$69,895**

Catchment #SD-3

Term Cost Rank #3



	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 16.7% TP Reduction	Load Reduction
TREATMENT	**TP (lb/yr)**	**31.62**	26.3	-5.27
	TSS (lb/yr)	**7255.0**	6,300.2	-954.8
	TSS (% reduced)	-	*13.2%*	
	Volume (acre-feet/yr)	**18.1**	16.7	-1.33
	Volume (% reduced)	-	*7.4%*	
	# BMP Projects Needed	-	6	
COST	**Design and Installation**	-	$77,995	
	Promotion & Admin Costs	-	$2,700	
	Total Project Cost	-	$80,695	
	Annual O&M	-	*$2,640*	
	Term Cost/lb/yr (10 yr)	-	**$2,032**	

Catchment # SD-36

Term Cost Rank = #4

Base Load Summary *Catchment SD-36*	
Acres	94.9
Volume (acre-feet/yr)	57.3
TP (lb/yr)	70.7
TSS (lb/yr)	25,691

WinSLAMM Input Summary *Catchment SD-36*			
Standard Land Use Code	**Acres**	**Standard Land Use Code**	**Acres**
DUPLEX	3.85	OPEN	14.9
LDR	3.74	PARK	19.3
LI	25.9	STRIPCOM	4.6
MDRNA	20.5		
TOTAL			**94.9**

DESCRIPTION

This catchment located along the banks of the Lake St. Croix and is comprised primarily of light industrial and parks properties. Stormwater runoff discharges into the lake primarily though overland flow and open drainage systems. The majority of Lakeside Drive and 2nd Avenue South and the surrounding areas drain to the City of Bayport's Park locating in the center of this catchment area.

RETROFIT RECOMMENDATION

Bioinfiltraiton with coarse sediment pretreatment devices are recommended for this catchment. In certain locations, elevations may require small retaining walls to achieve level depressional areas required to infiltrate or filtrate stormwater. Desktop analysis, field investigation and modeling indicate eleven BMPs will achieve a 6.7 pound reduction in Total Phosphorous reduction in Catchment SD-36.

Modeling does not account for increased loading from gravel parking lots. It is evident that gravel parking lots contribute larger than modeled results for total phosphorous (TP) and total suspended solids (TSS) loading. Therefore, targeted outreach and assistance are prioritized to private landowners in the catchment to disconnect, reduce or treat runoff from gravel parking lots discharging to Lake St. Croix. At the time of the writing of this plan the watershed is providing assistance to the manufacturing facility located on the north end this catchment to develop a stormwater management master plan.

BMP Treatment Summary *Catchment SD-36*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple BioIN w/pretreatment	2	250	$20.00	$5,000.00	$10,000.00
Moderately Complex BioIN w/pretreatment	1	250	$24.50	$6,125.00	$6,175.00
Moderately Complex BioFILTER w/pretreatment	4	250	$23.00	$5,750.00	$23,000.00
Moderately Complex BioFILTER w/pretreatment	2	400	$23.00	$9,200.00	$18,400.00
Highly Complex BioFILTERw/pretreatment	1	250	$27.50	$6,875.00	$6,875.00
Highly Complex BioFILTERw/pretreatment	1	400	$27.50	$11,000.00	$11,000.00
TOTAL	**11**				**$75,400.00**

Catchment # SD-36

Term Cost Rank = #4

	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 9.6% TP Reduction	Load Reduction
TREATMENT	**TP (lb/yr)**	**70.07**	63.4	-6.70
	TSS (lb/yr)	**25691.0**	22,984.6	-2,706.4
	TSS (% reduced)	-	*10.5%*	
	Volume (acre-feet/yr)	**57.3**	53.8	-3.53
	Volume (% reduced)	-	*6.2%*	
	# BMP Projects Needed	-	11	
COST	**Design and Installation**	-	$90,250	
	Promotion & Admin Costs	-	$4,950	
	Total Project Cost	-	$95,200	
	Annual O&M	-	*$5,120*	
	Term Cost/lb/yr (10 yr)	-	**$2,186**	

Catchment # SD-14

Term Cost Rank = #5

Base Load Summary *Catchment SD-14*	
Acres	150.6
Volume (acre-feet/yr)	77
TP (lb/yr)	120.6
TSS (lb/yr)	32,002

WinSLAMM Input Summary *Catchment SD-14*			
Standard Land Use Code	**Acres**	**Standard Land Use Code**	**Acres**
FREE	9.75	OFFPARK	3.70
INST	1.49	OPEN	18.69
LDR	5.65	PARK	7.95
MDRNA	101.38	SCH	0.37
MFR	0.93	STRIPCOM	0.70
TOTAL			**150.6**

DESCRIPTION

This catchment is comprised primarily of medium-density residential properties without alleys. Stormwater runoff discharges directly to Lake St. Croix though the storm sewer system. The storm sewer system in the northern portion of this catchment discharges at the top of the bluff east of St. Louis Street resulting in an actively eroding gully.

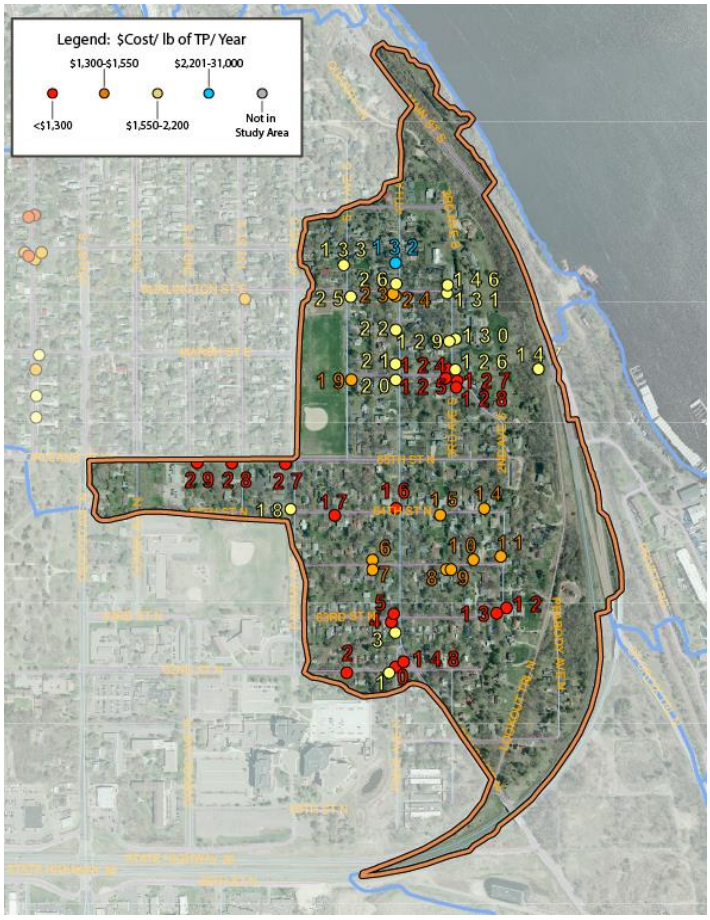
RETROFIT RECOMMENDATION

A combination of bioinfiltration and biofiltration with coarse sediment pretreatment devices and gully stabilization are recommended for this catchment. Desktop analysis, field investigation and modeling indicate forty-three BMPs will achieve a 23.3 pound reduction of Total Phosphorous in Catchment SD-14.

BMP Treatment Summary *Catchment SD-14*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple BioIN w/pretreatment	21	250	$20.00	$5,000.00	$10,000.00
Moderately Complex BioIN w/pretreatment	5	250	$24.50	$6,125.00	$6,175.00
Moderately Complex BioFILTER w/pretreatment	9	250	$23.00	$5,750.00	$23,000.00
Moderately Complex BioFILTER w/pretreatment	5	250	$23.00	$9,200.00	$18,400.00
Highly Complex BioFILTERw/pretreatment	1	800	$27.50	$6,875.00	$6,875.00
Highly Complex BioFILTERw/pretreatment	1	400	$27.50	$11,000.00	$11,000.00
Ravine Stabilization and 24” Pipe	1	1,000	$75.00	$75,000.00	75,000.00
TOTAL	**43**				**$329,750.00**

Catchment # SD-14

Term Cost Rank #5



	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 19.3% TP Reduction	Load Reduction
TREATMENT	TP (lb/yr)	**120.59**	97.3	-23.27
	TSS (lb/yr)	**32002.0**	14,621.0	-17,381
	TSS (% reduced)	-	*54.3%*	
	Volume (acre-feet/yr)	**66.5**	55.9	-10.55
	Volume (% reduced)	-	*13.7%*	
	# BMP Projects Needed	-	43	
COST	Design and Installation	-	$329,750	
	Promotion & Admin Costs	-	$19,350	
	Total Project Cost	-	$349,100	
	Annual O&M	-	*$18,080*	
	Term Cost/lb/yr (10 yr)	-	**$2,277**	

Catchment # SD-30

Term Cost Rank = #6

Base Load Summary *Catchment SD-30*	
Acres	253.1
Volume (acre-feet/yr)	133.3
TP (lb/yr)	158.5
TSS (lb/yr)	133.3

WinSLAMM Input Summary *Catchment SD-30*	
Standard Land Use Code	**Acres**
CEM	10.65
FREE	16.31
INST	50.96
LDR	0.20
LI	29.08
MDRNA	34.86
MDRWA	4.87
MFR	7.69
MI	5.57
OFFPARK	2.47
OPEN	87.20
PARK	1.99
STRIPCOM	1.27
TOTAL	**253.12**

DESCRIPTION

This catchment is comprised of primarily wooded bluff land, prison and medium density residential properties. Runoff is conveyed to Lake St. Croix though open drainage and storm sewer systems.

RETROFIT RECOMMENDATION

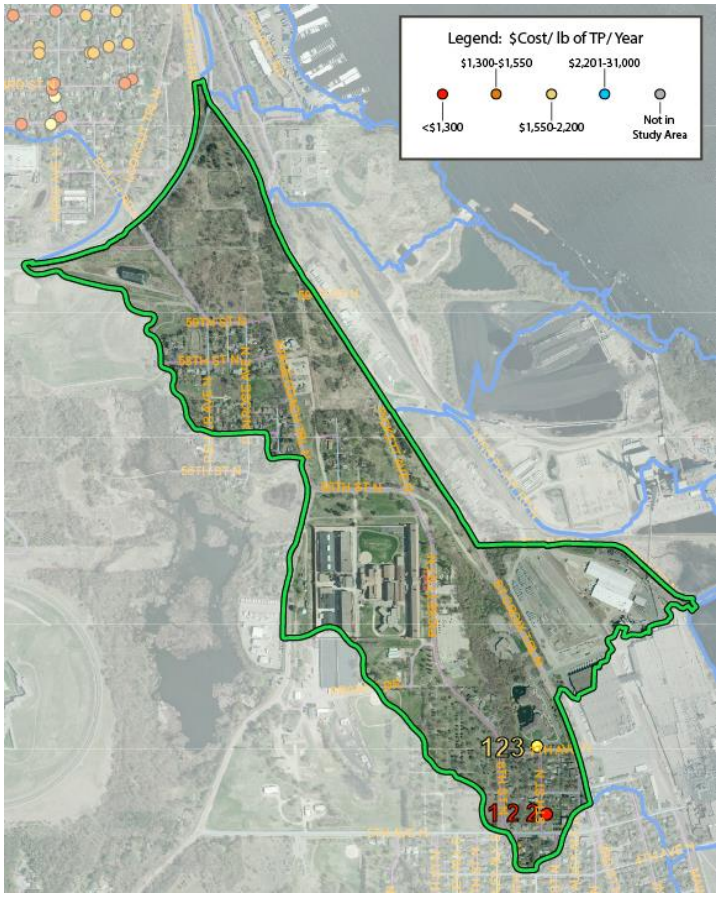
A combination of bioinfiltration and biofiltration with coarse sediment pretreatment devices are recommended for this catchment. Desktop analysis, field investigation and modeling indicate two BMPs will achieve a 0.9 pound reduction of Total Phosphorous in Catchment SD-30.

Modeling does not account for increased loading from gravel parking lots. It is evident that gravel parking lots contribute larger than modeled results for total phosphorous (TP) and total suspended solids (TSS) loading. Therefore, targeted outreach and assistance are prioritized to private landowners in the catchment to disconnect, reduce or treat runoff from gravel parking lots discharging to Lake St. Croix. At the time of the writing of this plan the watershed is providing assistance to the manufacturing facility located on the east end this catchment to develop a stormwater management master plan.

BMP Treatment Summary *Catchment SD-30*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Moderately Complex BioFILTER w/pretreatment	1	250	$23.00	$5,750.00	$5,750.00
Highly Complex BioFILTERw/pretreatment	1	250	$27.50	$6,875.00	$6,875.00
TOTAL	**2**				**$12,625.00**

Catchment # SD-30

Term Cost Rank = #6



	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 0.56% TP Reduction	Load Reduction
TREATMENT	**TP (lb/yr)**	**158.49**	157.6	-0.89
	TSS (lb/yr)	**53088.0**	50,381.6	-362.17
	TSS (% reduced)	-	*0.7%*	
	Volume (acre-feet/yr)	**133.3**	132.7	-0.54
	Volume (% reduced)	-	*0.4%*	
	# BMP Projects Needed	-	2	
COST	**Design and Installation**	-	$15,325	
	Promotion & Admin Costs	-	$900	
	Total Project Cost	-	$16,225	
	Annual O&M	-	*$800*	
	Term Cost/lb/yr (10 yr)	-	**$2,720**	

Catchment # SD-2

Term Cost Rank = #7

Base Load Summary *Catchment SD-2*	
Acres	13.25
Volume (acre-feet/yr)	7.3
TP (lb/yr)	10.3
TSS (lb/yr)	2,774

WinSLAMM Input Summary *Catchment SD-2*	
Standard Land Use Code	**Acres**
FREE	0.48
MDRNA	9.74
OPEN	1.94
STRIPCOM	1.10
TOTAL	**13.25**

DESCRIPTION

This catchment is comprised of primarily medium-density residential properties. Runoff is conveyed to Lake St. Croix though the storm sewer system. The western portion of this small catchment is steeply sloped.

RETROFIT RECOMMENDATION

A combination of bioinfiltration and biofiltration with coarse sediment pretreatment devices are recommended for this catchment. Desktop analysis, field investigation and modeling indicate eight BMPs will achieve a 3.0 pound reduction of Total Phosphorous in Catchment SD-2.

BMP Treatment Summary *Catchment SD-2*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**sf per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple BioIN w/pretreatment	1	250	$20.00	$5,000	$5,000.00
Moderately Complex BiorFILTER w/pretreatment	5	250	$23.00	$5,750	$28,750.00
Highly Complex BioFILTER w/pretreatment	2	250	$27.50	$6,875	$13,750.00
TOTAL	**8**				**$47,500.00**

Catchment # SD-2

Term Cost Rank = #7

	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 28.9% TP Reduction	Load Reduction
TREATMENT	**TP (lb/yr)**	**10.28**	7.3	-2.97
	TSS (lb/yr)	**2774.0**	1,499.8	-1,274.2
	TSS (% reduced)	-	*45.9%*	
	Volume (acre-feet/yr)	**7.3**	5.5	-1.77
	Volume (% reduced)	-	*18.3%*	
	# BMP Projects Needed	-	8	
COST	**Design and Installation**	-	$58,300	
	Promotion & Admin Costs	-	$3,600	
	Total Project Cost	-	$61,900	
	Annual O&M	-	*$3,200*	
	Term Cost/lb/yr (10 yr)	-	**$3,162**	

Catchment # SD-6

Term Cost Rank = #8

Base Load Summary *Catchment SD-6*	
Acres	201
Volume (acre-feet/yr)	101
TP (lb/yr)	159.2
TSS (lb/yr)	7,638

WinSLAMM Input Summary *Catchment SD-6*	
Standard Land Use Code	**Acres**
FREE	2.02
INST	0.76
LDR	0.96
MDRNA	156.04
MFR	8.31
OFFPARK	0.83
OPEN	17.24
PARK	8.13
STRIPCOM	6.66
TOTAL	**200.95**

DESCRIPTION

This catchment is comprised of primarily medium-density residential properties. Runoff is conveyed to Lake St. Croix though a storm sewer system and is directly discharged from the streets into the Lake at Central Avenue. The western portion of this small catchment is steeply sloping.

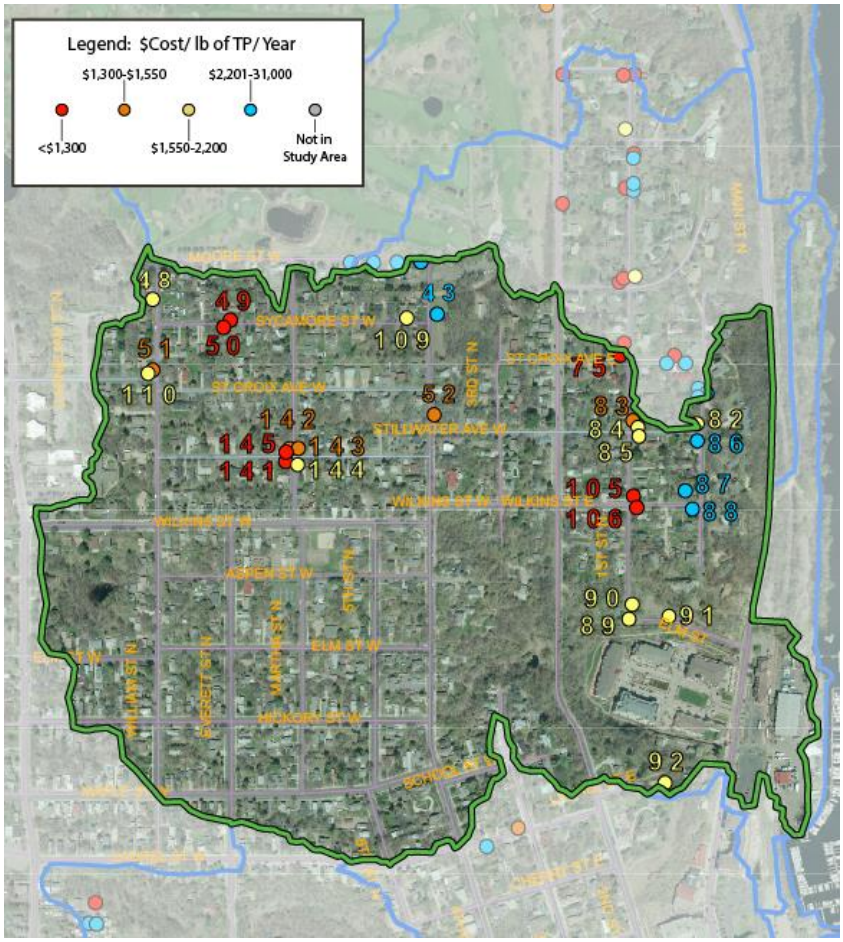
RETROFIT RECOMMENDATION

A combination of bioinfiltration and biofiltration with coarse sediment pretreatment devices are recommended for this catchment. Desktop analysis, field investigation and modeling indicate twenty-eight BMPs will achieve a 10.4 pound reduction of Total Phosphorous in Catchment SD-14.

BMP Treatment Summary *Catchment SD-6*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple BioIN w/pretreatment	10	250	$20.00	$5,000.00	$50,000.00
Moderately Complex BioIN w/pretreatment	2	250	$24.50	$6,125.00	$12,250.00
Moderately Complex BioFILTER w/pretreatment	15	250	$23.00	$5,750.00	$86,250.00
Moderately Complex BioFILTER w/pretreatment	1	800	$23.00	$18,400.00	$18,400.00
TOTAL	**28**				**$166,900.00**

Catchment # SD-6

Term Cost Rank = #8



	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 6.6% TP Reduction	Load Reduction
TREATMENT	**TP (lb/yr)**	**159.19**	148.8	-10.44
	TSS (lb/yr)	**41151.0**	36,522.9	-4,628.1
	TSS (% reduced)	-	*11.2%*	
	Volume (acre-feet/yr)	**101.1**	94.9	-6.18
	Volume (% reduced)	-	*6.1%*	
	# BMP Projects Needed	-	28	
COST	**Design and Installation**	-	$204,700	
	Promotion & Admin Costs	-	$12,600	
	Total Project Cost	-	$217,300	
	Annual O&M	-	*$12,080*	
	Term Cost/lb/yr (10 yr)	-	**$3,239**	

Catchment # SD-10

Term Cost Rank = #9

Base Load Summary *Catchment SD-10*	
Acres	281
Volume (acre-feet/yr)	162
TP (lb/yr)	221
TSS (lb/yr)	63,834

WinSLAMM Input Summary *Catchment SD-10*	
Standard Land Use Code	**Acres**
DOWNTOWN	10.55
FREE	5.47
INST	15.11
MDRNA	195.22
MFR	3.59
OFFPARK	6.02
OPEN	18.12
PARK	17.23
SCH	2.19
STRIPCOM	7.44
TOTAL	**280.94**

DESCRIPTION

This catchment is comprised of primarily medium-density residential properties. Runoff is conveyed to Lake St. Croix though the storm sewer system. Steeply sloping roads and limited right-of-way pose challenges for retrofitting stormwater practices to achieve further reductions in this catchment.

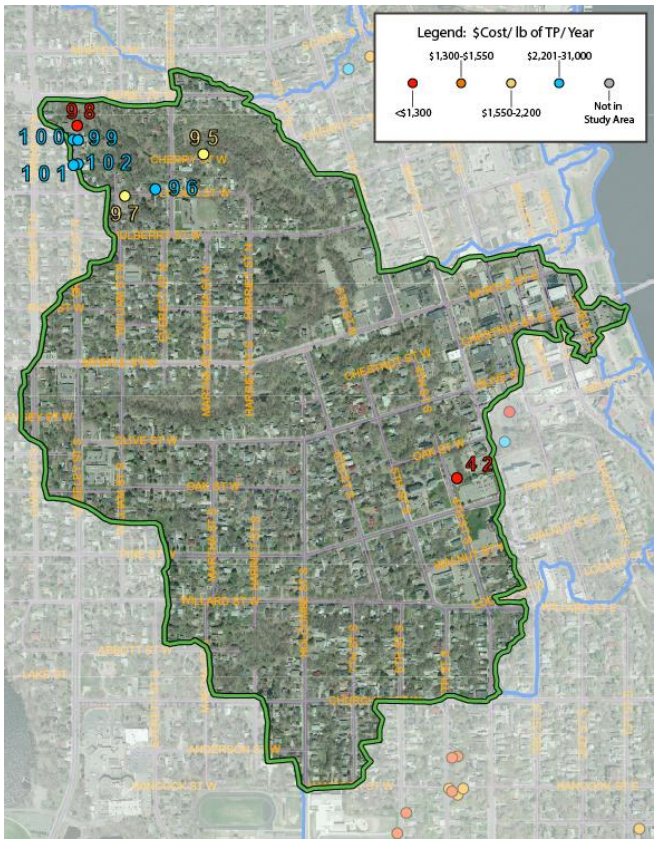
RETROFIT RECOMMENDATION

A combination of bioinfiltration and biofiltration with coarse sediment pretreatment devices and slope stabilization are recommended for this catchment. Desktop analysis, field investigation and modeling indicate nine BMPs will achieve a 3.6 pound reduction of Total Phosphorous in Catchment SD-10.

BMP Treatment Summary *Catchment SD-10*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple BioIN w/pretreatment	5	250	$20.00	$5,000.00	$25,000.00
Moderately Complex BioIN w/pretreatment	2	250	$24.50	$6,125.00	$12,250.00
Moderately Complex BioFILTER w/pretreatment	1	400	$23.00	$9,200.00	$9,200.00
Ravine- Basin and slope stabilization	1	400	$37.50	$15,000.00	$15,000.00
TOTAL	**9**				**$61,450.00**

Catchment # SD-10

Term Cost Rank = #9



	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 1.6% TP Reduction	Load Reduction
TREATMENT	TP (lb/yr)	**221.09**	214.4	-3.61
	TSS (lb/yr)	**63834.0**	61,127.6	-3,606.4
	TSS (% reduced)	-	*5.6%*	
	Volume (acre-feet/yr)	**162.2**	160.9	-1.35
	Volume (% reduced)	-	*0.8%*	
	# BMP Projects Needed	-	9	
COST	Design and Installation	-	$73,600	
	Promotion & Admin Costs	-	$4,050	
	Total Project Cost	-	$77,650	
	Annual O&M	-	*$4,080*	
	Term Cost/lb/yr (10 yr)	**-**	**$3,285**	

Catchment # SD-5

Term Cost Rank = #10

Base Load Summary *Catchment SD-5*	
Acres	46.5
Volume (acre-feet/yr)	18.7
TP (lb/yr)	31.9
TSS (lb/yr)	7,638

WinSLAMM Input Summary *Catchment SD-5*	
Standard Land Use Code	**Acres**
FREE	1.68
LDR	2.09
MDRNA	25.78
OPEN	8.41
PARK	8.53
TOTAL	**46.5**

DESCRIPTION

This catchment is comprised of primarily medium-density residential properties and a combination bluff woodland area and golf course. Runoff is conveyed to Lake St. Croix primarily though the storm sewer system with contributions from open drainage on the west side of the catchment.

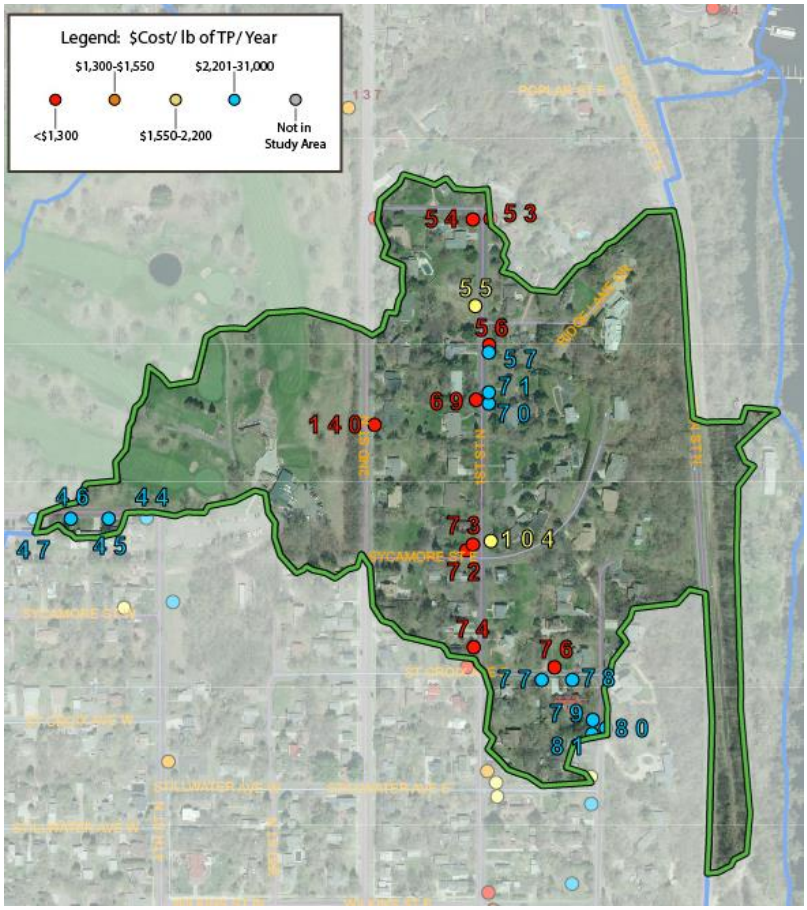
RETROFIT RECOMMENDATION

A combination of bioinfiltration and biofiltration with coarse sediment pretreatment devices and a slope stabilization are recommended for this catchment. Desktop analysis, field investigation and modeling indicate twenty-two BMPs will achieve a 6.7 pound reduction of Total Phosphorous in Catchment SD-5.

BMP Treatment Summary *Catchment SD-5*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Simple BioIN w/pretreatment	8	250	$20.00	$5,000.00	$40,000.00
Moderately Complex BioFILTER w/pretreatment	14	250	$23.00	$5,750.00	$80,500.00
TOTAL	**22**				**120,500.00**

Catchment # SD-5

Term Cost Rank = #10



	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 21.1% TP Reduction	Load Reduction
TREATMENT	**TP (lb/yr)**	**31.91**	25.2	-6.74
	TSS (lb/yr)	**7638.0**	4,810.7	-2,827.3
	TSS (% reduced)	-	*37.0%*	
	Volume (acre-feet/yr)	**18.7**	14.7	-4.03
	Volume (% reduced)	-	*21.5%*	
	# BMP Projects Needed	-	22	
COST	**Design and Installation**	-	$150,200	
	Promotion & Admin Costs	-	$9,900	
	Total Project Cost	-	$160,100	
	Annual O&M	-	*$8,800*	
	Term Cost/lb/yr (10 yr)	-	**$3,678**	

Catchment # SD-8

Term Cost Rank = #11

Base Load Summary *Catchment SD-8*	
Acres	55.5
Volume (acre-feet/yr)	42
TP (lb/yr)	47.5
TSS (lb/yr)	14,604

WinSLAMM Input Summary *Catchment SD-8*	
Standard Land Use Code	**Acres**
DOWNTOWN	7.09
FREE	1.68
HRR	3.39
INST	2.94
LDR	0.40
MDRNA	27.97
MFR	2.92
OPEN	2.76
PARK	2.85
STRIPCOM	3.47
TOTAL	**55.47**

DESCRIPTION

This catchment is comprised of primarily medium-density residential properties. Runoff is conveyed to Lake St. Croix though the storm sewer system. Steep slopes, high bedrock and high density impervious surfaces pose challenges for retrofitting stormwater practices to achieve further reductions in this catchment.

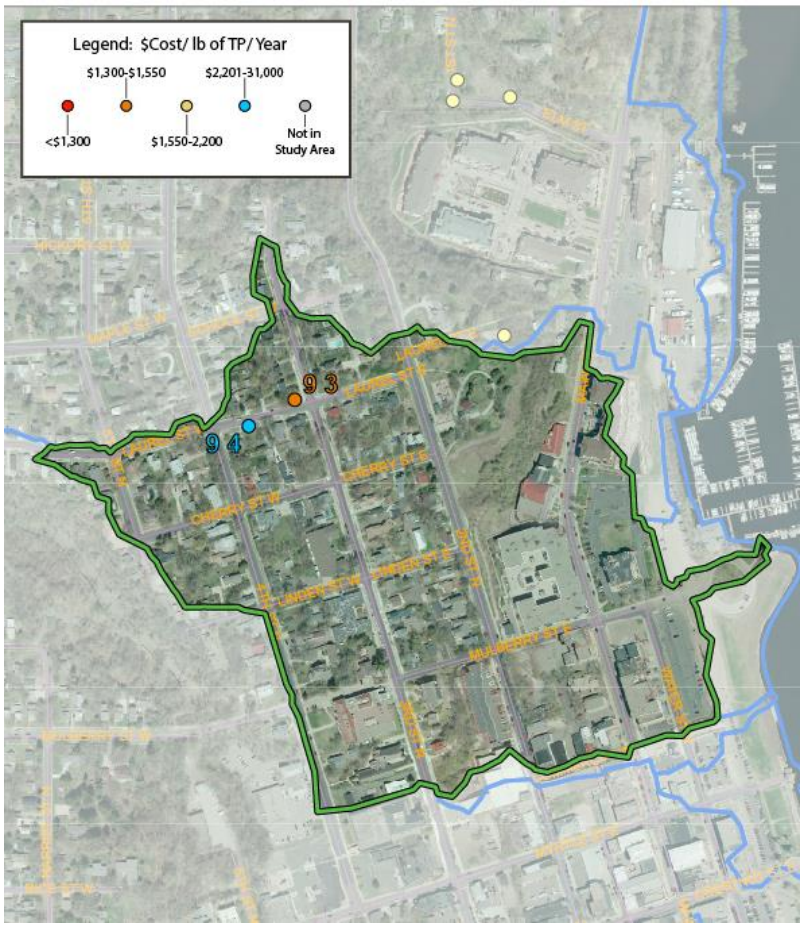
RETROFIT RECOMMENDATION

A combination of bioinfiltration and biofiltration with coarse sediment pretreatment devices and slope stabilization are recommended for this catchment. Desktop analysis, field investigation and modeling indicate two BMPs will achieve a 0.65 pound reduction of Total Phosphorous in Catchment SD-8.

BMP Treatment Summary *Catchment SD-8*			*INSTALLED/DESIGNED*		
BMP Identified	**# of BMP**	**SF per BMP**	**Cost per SF**	**Cost Per BMP**	**Total Cost**
Slope Stabilization w/BioFILTER	1	400	$37.50	$15,000.00	$15,000.00
Highly Complex Bioretention w/pretreatment	1	400	$27.50	$11,000.00	$11,000.00
TOTAL	**2**				**$26,000.00**

Catchment # SD-8

Term Cost Rank = #11



	COST/BENEFIT ANALYSIS	REDUCTIONS		
	Unit	*Baseline*	Load with 1.4% TP Reduction	Load Reduction
TREATMENT	**TP (lb/yr)**	**47.54**	46.8	-0.65
	TSS (lb/yr)	**14604.0**	11,897.6	-261.91
	TSS (% reduced)	-	*1.8%*	
	Volume (acre-feet/yr)	**42.0**	41.6	-0.39
	Volume (% reduced)	-	*0.9%*	
	# BMP Projects Needed	-	2	
COST	**Design and Installation**	-	$16,450	
	Promotion & Admin Costs	-	$900	
	Total Project Cost	-	$17,350	
	Annual O&M	-	*$800*	
	Term Cost/lb/yr (10 yr)	-	**$3,895**	

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Appendices

Appendix 1 – BMP Cost Benefit Ranking Table

Individual BMP Rank	Practice ID	Ranked Cost Lbs TP/YR	BMP_Type	BMP_Size (sf)
1	138	$0.00	IESF Filter Bench (outside watershed)	1
2	134	$805.37	IESF Filter Bench	2000
3	107	$882.35	Slope Stab with large basin with regrade	400
4	118	$948.28	Highly Complex BioFILTER w/pretreatment	400
5	49	$957.77	Moderately Complex BioFILTER w/pretreatment	250
6	141	$957.77	Moderately Complex BioFILTER w/pretreatment	250
7	145	$957.77	Moderately Complex BioFILTER w/pretreatment	250
8	40	$957.77	Moderately Complex BioFILTER w/pretreatment	250
9	0	$958.97	Moderately Complex BioFILTER w/pretreatment	250
10	111	$963.13	Moderately Complex BioFILTER w/pretreatment	250
11	115	$968.42	Moderately Complex BioFILTER w/pretreatment	400
12	60	$983.45	Moderately Complex BioFILTER w/pretreatment	250
13	41	$983.45	Moderately Complex BioFILTER w/pretreatment	250
14	42	$986.84	RAVINE - Basin above with slope stabilization	400
15	148	$1,000.00	Highly Complex BioFILTER w/pretreatment	400
16	128	$1,030.47	Moderately Complex BioFILTER w/pretreatment	250
17	120	$1,045.45	Moderately Complex BioFILTER w/pretreatment	250
18	56	$1,078.77	Moderately Complex BioFILTER w/pretreatment	250
19	69	$1,078.77	Moderately Complex BioFILTER w/pretreatment	250
20	29	$1,078.77	Moderately Complex BioFILTER w/pretreatment	250
21	119	$1,078.77	Moderately Complex BioFILTER w/pretreatment	250
22	98	$1,108.43	Moderately Complex BioFILTER w/pretreatment	400
23	121	$1,108.43	Moderately Complex BioFILTER w/pretreatment	400
24	127	$1,117.64	Moderately Complex BioFILTER w/pretreatment	250
25	140	$1,126.35	Moderately Complex BioFILTER w/pretreatment	250
26	139	$1,144.79	Moderately Complex BioFILTER w/pretreatment	250
27	39	$1,145.16	Highly Complex BioFILTERw/pretreatment	250
28	112	$1,145.16	Highly Complex BioFILTERw/pretreatment	250
29	13	$1,145.16	Highly Complex BioFILTER w/pretreatment	250
30	12	$1,145.83	Highly Complex BioFILTER w/pretreatment	250
31	16	$1,148.91	Simple BioIN w/pretreatment	250
32	64	$1,164.70	Moderately Complex BioFILTER w/pretreatment	250

Individual BMP Rank	Practice ID	Ranked Cost Lbs TP/YR	BMP_Type	BMP_Size (sf)
34	114	$1,186.19	Moderately Complex BioFILTER w/pretreatment	250
35	4	$1,206.44	Simple BioIN w/pretreatment	250
36	5	$1,206.44	Simple BioIN w/pretreatment	250
37	135	$1,226.67	Moderately Complex BioFILTER w/pretreatment	400
38	136	$1,226.67	Moderately Complex BioFILTER w/pretreatment	400
39	124	$1,234.50	Moderately Complex BioFILTER w/pretreatment	250
40	125	$1,234.50	Moderately Complex BioFILTER w/pretreatment	250
41	17	$1,243.75	Simple BioIN w/pretreatment	250
42	2	$1,247.81	Moderately Complex BioFILTER w/pretreatment	250
43	61	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
44	53	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
45	54	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
46	72	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
47	73	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
48	74	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
49	76	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
50	75	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
51	105	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
52	106	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
53	27	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
54	28	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
55	122	$1,291.07	Moderately Complex BioFILTER w/pretreatment	250
56	6	$1,315.23	Simple BioIN w/pretreatment	250
57	7	$1,315.23	Simple BioIN w/pretreatment	250
58	8	$1,315.23	Simple BioIN w/pretreatment	250
59	9	$1,315.23	Simple BioIN w/pretreatment	250
60	10	$1,315.23	Simple BioIN w/pretreatment	250
61	11	$1,315.23	Simple BioIN w/pretreatment	250
62	137	$1,320.79	IESF Filter Bench	3000
63	35	$1,325.30	Highly Complex BioFILTERw/pretreatment	400
64	36	$1,325.30	Highly Complex BioFILTERw/pretreatment	400
65	62	$1,336.54	Simple BioIN w/pretreatment	250
66	58	$1,357.67	Moderately Complex BioFILTER w/pretreatment	250
67	51	$1,375.65	Simple BioIN w/pretreatment	250
68	117	$1,375.65	Simple BioIN w/pretreatment	250
69	142	$1,376.15	Moderately Complex BioFILTER w/pretreatment	250
70	143	$1,376.15	Moderately Complex BioFILTER w/pretreatment	250
71	63	$1,392.58	Highly Complex BioFILTERw/pretreatment	250
72	103	$1,392.58	Highly Complex BioFILTERw/pretreatment	250

Individual BMP Rank	Practice ID	Ranked Cost Lbs TP/YR	BMP_Type	BMP_Size (sf)
74	15	$1,469.77	Simple BioIN w/pretreatment	250
75	83	$1,481.78	Moderately Complex BioFILTER w/pretreatment	250
76	14	$1,488.47	Moderately Complex BioIN w/pretreatment	250
77	19	$1,536.49	Moderately Complex BioIN w/pretreatment	250
78	65	$1,543.67	Highly Complex BioFILTERw/pretreatment	250
79	93	$1,543.67	Highly Complex BioFILTERw/pretreatment	250
80	32	$1,543.67	Highly Complex BioFILTERw/pretreatment	250
81	34	$1,543.67	Highly Complex BioFILTERw/pretreatment	250
82	37	$1,543.67	Highly Complex BioFILTERw/pretreatment	250
83	38	$1,543.67	Highly Complex BioFILTERw/pretreatment	250
84	23	$1,543.67	Highly Complex BioFILTER w/pretreatment	250
85	24	$1,543.67	Highly Complex BioFILTER w/pretreatment	250
86	147	$1,575.63	Ravine Stabilization and 24" pipe	1000
87	55	$1,591.09	Simple BioIN w/pretreatment	250
88	104	$1,591.09	Simple BioIN w/pretreatment	250
89	20	$1,591.09	Simple BioIN w/pretreatment	250
90	22	$1,591.09	Simple BioIN w/pretreatment	250
91	25	$1,591.09	Simple BioIN w/pretreatment	250
92	129	$1,591.09	Simple BioIN w/pretreatment	250
93	130	$1,591.09	Simple BioIN w/pretreatment	250
94	131	$1,591.09	Simple BioIN w/pretreatment	250
95	3	$1,632.13	Simple BioIN w/pretreatment	250
96	33	$1,645.40	Highly Complex BioFILTERw/pretreatment	250
97	110	$1,649.48	Simple BioIN w/pretreatment	250
98	116	$1,649.48	Simple BioIN w/pretreatment	250
99	1	$1,750.45	Simple BioIN w/pretreatment	250
100	133	$1,760.00	Highly Complex BioFILTER w/pretreatment	800
101	84	$1,787.20	Moderately Complex BioFILTER w/pretreatment	250
102	85	$1,787.20	Moderately Complex BioFILTER w/pretreatment	250
103	89	$1,787.20	Moderately Complex BioFILTER w/pretreatment	250
104	90	$1,787.20	Moderately Complex BioFILTER w/pretreatment	250
105	91	$1,787.20	Moderately Complex BioFILTER w/pretreatment	250
106	109	$1,884.93	Moderately Complex BioIN w/pretreatment	250
107	113	$1,884.93	Moderately Complex BioIN w/pretreatment	250
108	92	$1,949.09	Moderately Complex BioIN w/pretreatment	250
109	30	$1,949.09	Moderately Complex BioIN w/pretreatment	250
110	31	$1,949.09	Moderately Complex BioIN w/pretreatment	250
111	18	$1,949.09	Moderately Complex BioIN w/pretreatment	250
112	21	$1,949.09	Moderately Complex BioIN w/pretreatment	250

Individual BMP Rank	Practice ID	Ranked Cost Lbs TP/YR	BMP_Type	BMP_Size (sf)
114	48	$1,965.66	Simple BioIN w/pretreatment	250
115	82	$1,965.66	Simple BioIN w/pretreatment	250
116	144	$1,965.66	Simple BioIN w/pretreatment	250
117	95	$1,965.66	Simple BioIN w/pretreatment	250
118	126	$2,029.07	Simple BioIN w/pretreatment	250
119	146	$2,082.11	Highly Complex BioFILTER w/pretreatment	250
120	123	$2,105.01	Highly Complex BioFILTERw/pretreatment	250
121	97	$2,144.30	Moderately Complex BioIN w/pretreatment	250
122	77	$2,268.34	Simple BioIN w/pretreatment	250
123	86	$2,268.34	Simple BioIN w/pretreatment	250
124	87	$2,268.34	Simple BioIN w/pretreatment	250
125	88	$2,268.34	Simple BioIN w/pretreatment	250
126	132	$2,268.34	Simple BioIN w/pretreatment	250
127	66	$2,333.43	Moderately Complex BioFILTER w/pretreatment	250
128	67	$2,333.43	Moderately Complex BioFILTER w/pretreatment	250
129	68	$2,333.43	Moderately Complex BioFILTER w/pretreatment	250
130	70	$2,333.43	Moderately Complex BioFILTER w/pretreatment	250
131	71	$2,333.43	Moderately Complex BioFILTER w/pretreatment	250
132	80	$2,333.43	Moderately Complex BioFILTER w/pretreatment	250
133	59	$2,406.86	Highly Complex BioIN w/pretreatment	250
134	43	$2,421.05	Moderately Complex BioFILTER w/pretreatment	800
135	79	$2,469.69	Simple BioIN w/pretreatment	250
136	78	$2,720.09	Simple BioIN w/pretreatment	250
137	108	$2,750.00	Highly Complex BioFILTERw/pretreatment	400
138	96	$2,778.72	Moderately Complex BioIN w/pretreatment	250
139	94	$3,347.31	Highly Complex BioFILTERw/pretreatment	250
140	45	$3,455.69	Simple BioIN w/pretreatment	250
141	46	$3,455.69	Simple BioIN w/pretreatment	250
142	47	$3,455.69	Simple BioIN w/pretreatment	250
143	44	$3,455.69	Simple BioIN w/pretreatment	250
144	99	$4,035.37	Simple BioIN w/pretreatment	250
145	100	$4,035.37	Simple BioIN w/pretreatment	250
146	101	$4,035.37	Simple BioIN w/pretreatment	250
147	102	$4,035.37	Simple BioIN w/pretreatment	250
148	57	$8,357.20	Moderately Complex BioFILTER w/pretreatment	250
149	81	$30,624.09	Moderately Complex BioFILTER w/pretreatment	250

Appendix 2 – Catchments not included in Ranking Table

Catchments not included in ranking table were excluded for a number of reasons, mainly involving density of impervious surface and opportunities for BMP retrofits. After BMPs are installed within the priority catchments, it is recommended that the watershed revisit the entire subwatershed to determine other catchments that, while they may be conducive to retrofitting, were not considered a high priority for this report.

Appendix 3 – Summary of Protocol

This protocol attempts to provide a sufficient level of detail to rapidly assess subwatersheds or catchments of variable scales and land uses. It provides the assessor defined project goals that aid in quickly narrowing down multiple potential sites to a point where the assessor can look critically at site-specific driven design options that affect, sometimes dramatically, BMP selection. We feel that the time commitment required for this methodology is appropriate for most initial analysis applications and has worked well thus far for the Lake St. Croix Direct Discharge Analysis.

Appendix 4 – Definitions

The following terms are used throughout this document and define the basic terminology used to talk about watersheds and restoration. Many of the terms can have different meanings in different contexts, so it is imperative to define their use within this document.

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

Biofiltration Basin- A soil and plant based stormwater management practice that infiltrates a portion of stormwater captured, but conveys excess filtered water through an underdrain.

Bioinfiltration Basin – A soil and plant-based stormwater management practice that infiltrates all runoff captured in the basin.

Catchment – Land area within a subwatershed generally having a drainage area of 1 – 100 acres for urban areas, where all water drains to a particular point. Several catchments make up a subwatershed. The existing stormwater infrastructure helps to define a catchment; therefore it is critical to obtain accurate stormwater infrastructure mapping information (including, at a minimum, the location of inlets and pipes, flow direction, and outfall locations) before undertaking a stormwater analysis process.

Raingarden – A landscaping feature that is planted with native perennial plants and is used to manage stormwater runoff from impervious surfaces such as roofs, sidewalks, roads, and parking lots.

Retrofit – The introduction of a new or improved stormwater management element where it either never existed or did not operate effectively.

Stormwater – Water that is generated by rainfall or snowmelt that causes runoff and is often routed into drain systems for treatment or conveyance.

Subwatershed – Land area within a watershed generally having a drainage area of more than 500 acres, where all water drains to a particular point. Several subwatersheds make up a watershed. An example would be the Lake St. Croix subwatershed, which is within the boundaries of the Middle St. Croix Water Management Organization (the watershed). Subwatersheds are entirely based on hydrologic conditions, not political boundaries.

Urban – Any watershed or subwatershed with more than 10% total impervious cover.

Watershed – Land area defined by topography, where all water drains to a particular point. Watershed drainage areas are large, ranging from 20 to 100 square miles or more, and are made up of several subwatersheds. There are currently 8 watersheds located either wholly or partially within Washington County, each defined along political boundaries that attempt to mimic hydrologic boundaries.