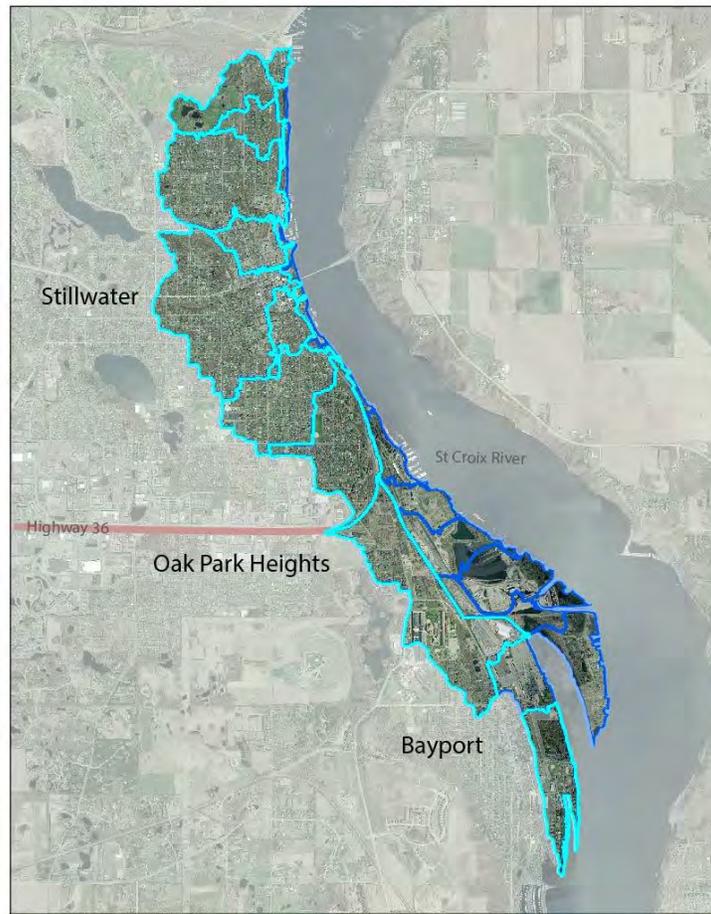


# Lake St. Croix Direct Discharge Stormwater Retrofit Analysis

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October 30, 2014



*Prepared by:*



*With assistance from:*

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*for the*

*MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION*

## Contents

<b>EXECUTIVE SUMMARY .....</b>	<b>4</b>
<b>ABOUT THIS DOCUMENT .....</b>	<b>6</b>
DOCUMENT OVERVIEW .....	6
<i>Methods</i> .....	6
<i>Catchment Profiles</i> .....	6
<i>Catchment Ranking</i> .....	7
<i>References</i> .....	7
<i>Appendices</i> .....	7
<b>METHODS .....</b>	<b>8</b>
SELECTION OF SUBWATERSHED.....	8
DESCRIPTION OF LAKE ST. CROIX DIRECT DISCHARGE CONTRIBUTING SUBWATERSHED.....	8
SUBWATERSHED ANALYSIS METHODS .....	9
<i>Step 1: Retrofit Scoping</i> .....	9
<i>Step 2: Desktop Retrofit Analysis</i> .....	9
<i>Step 3: Retrofit Reconnaissance Investigation</i> .....	9
<i>Step 4: Treatment Analysis/Cost Estimates</i> .....	10
<i>Step 5: Evaluation and Ranking</i> .....	14
<b>CATCHMENT PROFILES .....</b>	<b>14</b>
CATCHMENT # SD-13.....	16
CATCHMENT # SD-11.....	18
CATCHMENT # SD-3.....	20
CATCHMENT # SCD-36 .....	22
CATCHMENT SD-14 .....	24
CATCHMENT # SD-30.....	26
CATCHMENT # SD-2.....	28
CATCHMENT # SD-6.....	30
CATCHMENT # SD-10.....	32
CATCHMENT # SD-5.....	34
CATCHMENT # SD-8.....	36
<b>REFERENCES.....</b>	<b>38</b>
<b>APPENDICES.....</b>	<b>39</b>
APPENDIX 1 – BMP COST BENEFIT RANKING TABLE .....	39
APPENDIX 2 – CATCHMENTS NOT INCLUDED IN RANKING TABLE .....	43
APPENDIX 3 – SUMMARY OF PROTOCOL.....	43
APPENDIX 4 – DEFINITIONS.....	43

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.

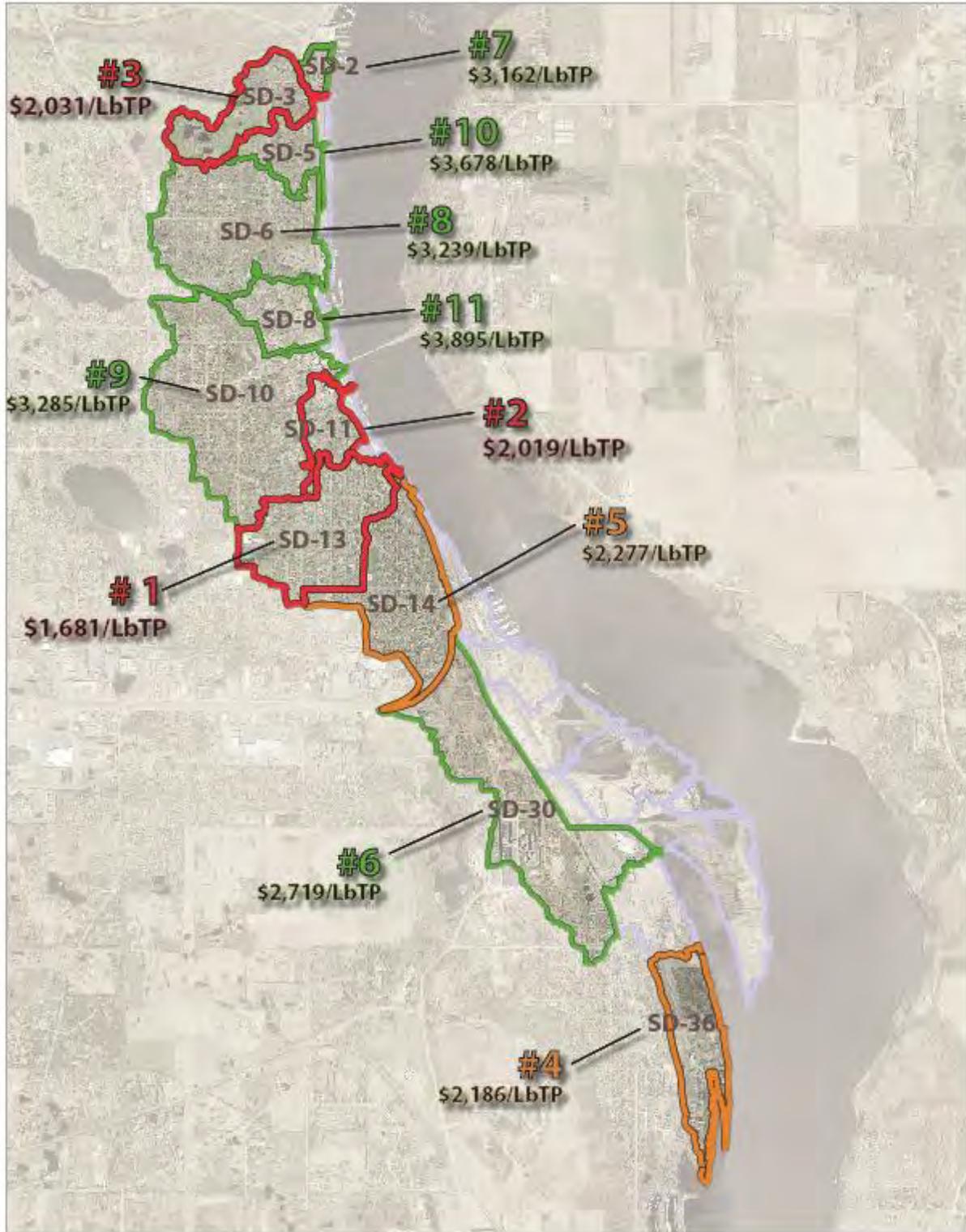
Lake St. Croix is defined as the lower 25 miles of the 7,760 square mile St. Croix Basin between. The lake was designated as an Impaired Water in 2008 for excess phosphorus. The 2012 Lake St. Croix Total Maximum Daily Load (TMDL) Implementation identified 1,521 pounds phosphorous load reduction for the 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 (lb/yr)	ISS (lb/yr)	WQY (lb/yr)	Percent TP Reduction
#1	SD-13	149.59	\$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	\$2,186.18	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	0.38	1.37%
				78.56	41,007.91	53.27	

## 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***

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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***

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

### ***Appendices***

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

## Methods

### Selection of Subwatershed

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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

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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.
	Bioinfiltration	Use of native soil, soil microbe, and plant processes to treat, evapotranspire, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.
0.1-5.0 acres	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.

<b>General WinSLAMM Model Inputs</b>	
<b><u>Parameters</u></b>	<b><u>Method for Determining Value</u></b>
<b>Area</b>	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.
<b>Land Use</b>	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.
<b>Precipitation/Temperature Data</b>	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.
<b>Pollutant Probability Distribution</b>	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.
<b>Runoff Coefficient</b>	The default runoff coefficient WI_SL06 was used.
<b>Particulate Solids Concentration</b>	The default WI_GEO01.ppd particle file developed by USGS was used.
<b>Street Delivery Parameter File</b>	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.
<b>Particle Size Distribution</b>	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 <sup>2</sup>	\$280/100 ft <sup>2</sup>	\$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 <sup>2</sup>	\$1200/1000 ft <sup>2</sup>	\$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 <sup>2</sup>	\$1200/1000 ft <sup>2</sup>	\$210	10
Moderately Complex Biofiltration	With engineered soils, under-drains, curb cuts, no structural pretreatment but no retaining walls	\$17.00	\$1.60/ft <sup>2</sup>	\$2000/1000 ft <sup>2</sup>	\$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 <sup>2</sup>	\$2000/1000 ft <sup>2</sup>	\$350	10
Complex Biofiltration w/Structural Pretreatment	As MCBwSP but with 1.5-2.5 ft partial perimeter walls	\$27.50	\$1.60/ft <sup>2</sup>	\$3750/1000ft <sup>2</sup>	\$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 <sup>2</sup>	\$7500/1000ft <sup>2</sup>	\$470	10
Curb-Cut	Cut with apron	\$80.00				
Impervious Cover Conversion		\$21.71	\$500/acre	\$1120/acre	\$210	10
Stormwater Tree Pits <sup>2</sup>	6' x 12' pit with concrete vault	\$140.00	\$0.75/ft <sup>2</sup>	140% above construction	\$210	10
Grass/Gravel Permeable Pavement	Sand base	\$18.95	\$0.75/ft <sup>2</sup>	140% above construction	\$210	10
Permeable Asphalt	Granite base	\$10.80	\$0.75/ft <sup>2</sup>	140% above construction	\$210	10
Permeable Concrete	Granite base	\$15.00	\$0.75/ft <sup>2</sup>	140% above construction	\$210	10
Permeable Pavers	Granite base	\$35.75	\$0.75/ft <sup>2</sup>	140% above construction	\$210	10
Extended Detention		(12.98)*(CU-FT <sup>0.75</sup> )	\$1000/acre	3\$2800/acre	\$210	10
Wet Pond		(277.89)*(CU-FT <sup>0.553</sup> )	\$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 <sup>2</sup>	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 <sup>1</sup>	With soil amendments	\$7.13	\$0.75/ft <sup>2</sup>	\$280/100 ft <sup>2</sup>	\$210	10
Water Quality Swale <sup>1</sup>	With soil replacement and check dams	\$15.01	\$0.75/ft <sup>2</sup>	\$1120/1000 ft <sup>2</sup>	\$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 <sup>2</sup>	20% above construction	\$210	10

<sup>1</sup> Assumed to be 15 feet in width. <sup>2</sup> Assumed ultra-urban linear application.

### *Lake St. Croix Direct Cost Analysis*

For the Lake St. 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<sup>2</sup>) 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

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

<b>WinSLAMM Input Summary</b> <i>Catchment SD-13</i>	
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
<b>TOTAL</b>	<b>148.59</b>

### DESCRIPTION

This catchment is comprised primarily of medium-density residential properties without alleys. Stormwater runoff discharges directly to Lake St. Croix through 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.

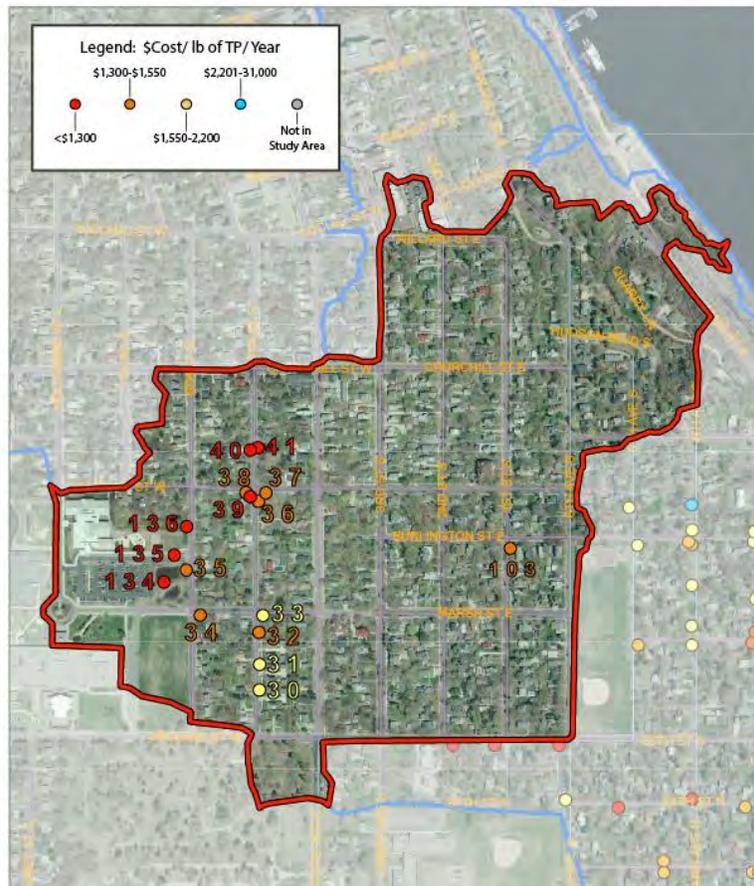
### RETROFIT RECOMMENDATION

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.

<b>BMP Treatment Summary</b> <i>Catchment SD-13</i>			<i>INSTALLED/DESIGNED</i>		
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
<b>TOTAL</b>	<b>16</b>				<b>\$172,275.00</b>

## Catchment # SD-13

Term Cost Rank = #1



		COST/BENEFIT ANALYSIS		REDUCTIONS	
		Unit	Baseline	Load with 12.6% TP Reduction	Load Reduction
<b>TREATMENT</b>	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	
<b>COST</b>	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

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

<b>WinSLAMM Input Summary</b> <i>Catchment SD-11</i>	
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
<b>TOTAL</b>	<b>43.10</b>

### 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 through 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.

<b>BMP Treatment Summary</b> <i>Catchment SD-11</i>	<i>INSTALLED/DESIGNED</i>				
	<b># of BMP</b>	<b>SF per BMP</b>	<b>Cost per SF</b>	<b>Cost Per BMP</b>	<b>Total Cost</b>
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
<b>TOTAL</b>	<b>2</b>				<b>\$26,000</b>

## Catchment # SD-11

Term Cost Rank = #2



		COST/BENEFIT ANALYSIS		REDUCTIONS	
		Unit	Baseline	Load with 5.8% TP Reduction	Load Reduction
<b>TREATMENT</b>	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	
<b>COST</b>	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

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

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

### DESCRIPTION

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

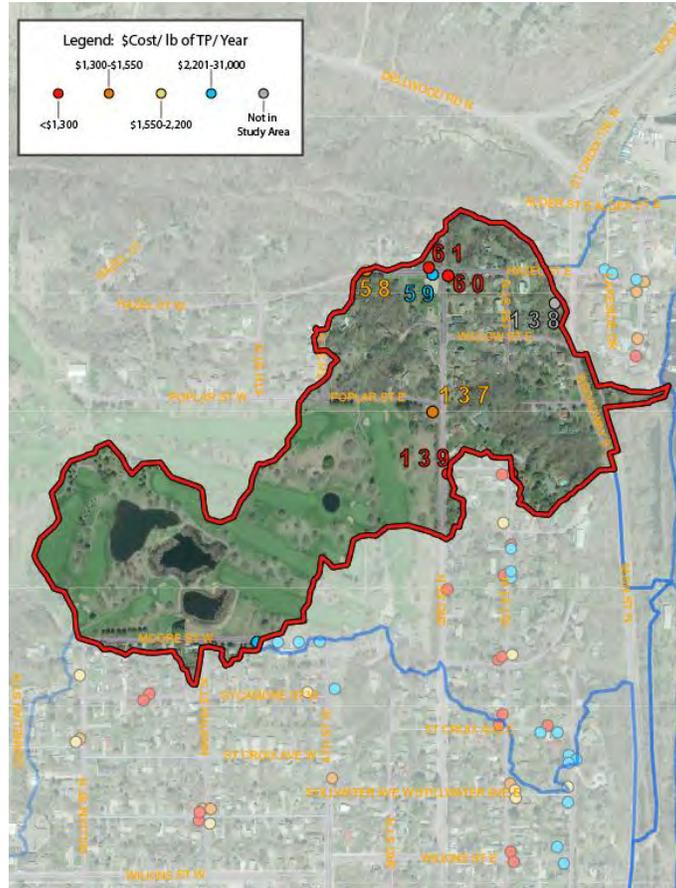
### RETROFIT RECOMMENDATION

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.

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

### 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

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

<b>WinSLAMM Input Summary</b> <i>Catchment SD-36</i>			
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		
<b>TOTAL</b>			<b>94.9</b>

### 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 through overland flow and open drainage systems. The majority of Lakeside Drive and 2<sup>nd</sup> Avenue South and the surrounding areas drain to the City of Bayport's Park locating in the center of this catchment area.

### RETROFIT RECOMMENDATION

Bioinfiltration 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.

<b>BMP Treatment Summary</b> <i>Catchment SD-36</i>			<i>INSTALLED/DESIGNED</i>		
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
<b>TOTAL</b>	<b>11</b>				<b>\$75,400.00</b>

### Catchment # SD-36

Term Cost Rank = #4



		COST/BENEFIT ANALYSIS		REDUCTIONS	
		Unit	Baseline	Load with 9.6% TP Reduction	Load Reduction
<b>TREATMENT</b>	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	
<b>COST</b>	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

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

<b>WinSLAMM Input Summary</b> <i>Catchment SD-14</i>			
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
<b>TOTAL</b>			<b>150.6</b>

### DESCRIPTION

This catchment is comprised primarily of medium-density residential properties without alleys. Stormwater runoff discharges directly to Lake St. Croix through 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.

<b>BMP Treatment Summary</b> <i>Catchment SD-14</i>			<i>INSTALLED/DESIGNED</i>		
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
<b>TOTAL</b>	<b>43</b>				<b>\$329,750.00</b>

## Catchment # SD-14

### Term Cost Rank #5



		<b>COST/BENEFIT ANALYSIS</b>		<b>REDUCTIONS</b>	
		<i>Unit</i>	<i>Baseline</i>	Load with 19.3% TP Reduction	Load Reduction
<b>TREATMENT</b>	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	
<b>COST</b>	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

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

<b>WinSLAMM Input Summary</b> <i>Catchment SD-30</i>	
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
<b>TOTAL</b>	<b>253.12</b>

### DESCRIPTION

This catchment is comprised of primarily wooded bluff land, prison and medium density residential properties. Runoff is conveyed to Lake St. Croix through 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.

<b>BMP Treatment Summary</b> <i>Catchment SD-30</i>	# of BMP	SF per BMP	INSTALLED/DESIGNED		
			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
<b>TOTAL</b>	<b>2</b>				<b>\$12,625.00</b>

## Catchment # SD-30

Term Cost Rank = #6



		<b>COST/BENEFIT ANALYSIS</b>		<b>REDUCTIONS</b>	
		<i>Unit</i>	<i>Baseline</i>	Load with 0.56% TP Reduction	Load Reduction
<b>TREATMENT</b>	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		
<b>COST</b>	Design and Installation	-	\$15,325		
	Promotion & Admin Costs	-	\$900		
	Total Project Cost	-	\$16,225		
	Annual O&M	-	\$800		
	Term Cost/lb/yr (10 yr)	-	<b>\$2,720</b>		

## Catchment # SD-2

Term Cost Rank = #7

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

<b>WinSLAMM Input Summary</b> <i>Catchment SD-2</i>	
Standard Land Use Code	Acres
FREE	0.48
MDRNA	9.74
OPEN	1.94
STRIPCOM	1.10
<b>TOTAL</b>	<b>13.25</b>

### DESCRIPTION

This catchment is comprised of primarily medium-density residential properties. Runoff is conveyed to Lake St. Croix through 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.

<b>BMP Treatment Summary</b> <i>Catchment SD-2</i>			<i>INSTALLED/DESIGNED</i>		
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 BioFILTER 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
<b>TOTAL</b>	<b>8</b>				<b>\$47,500.00</b>

## Catchment # SD-2

Term Cost Rank = #7



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

## Catchment # SD-6

Term Cost Rank = #8

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

<b>WinSLAMM Input Summary</b> <i>Catchment SD-6</i>	
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
<b>TOTAL</b>	<b>200.95</b>

### DESCRIPTION

This catchment is comprised of primarily medium-density residential properties. Runoff is conveyed to Lake St. Croix through 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.

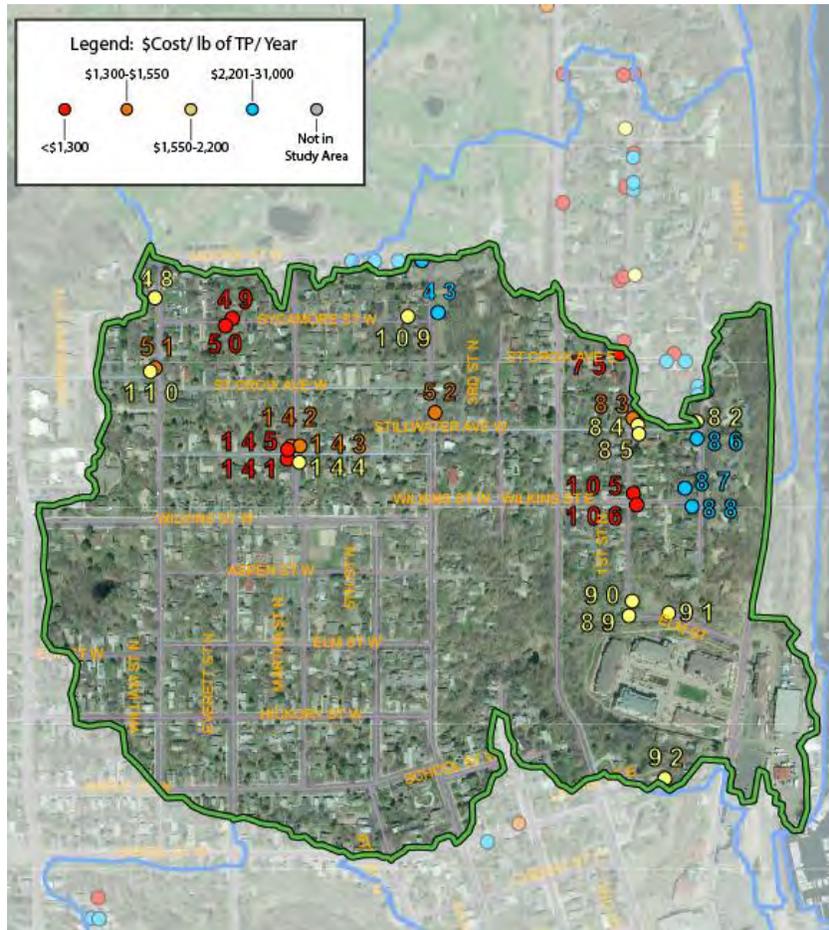
### RETROFIT RECOMMENDATION

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.

<b>BMP Treatment Summary</b> <i>Catchment SD-6</i>			<i>INSTALLED/DESIGNED</i>		
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
<b>TOTAL</b>	<b>28</b>				<b>\$166,900.00</b>

### Catchment # SD-6

Term Cost Rank = #8



		COST/BENEFIT ANALYSIS		REDUCTIONS	
		Unit	Baseline	Load with 6.6% TP Reduction	Load Reduction
<b>TREATMENT</b>	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		
<b>COST</b>	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

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

<b>WinSLAMM Input Summary</b> <i>Catchment SD-10</i>	
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
<b>TOTAL</b>	<b>280.94</b>

### DESCRIPTION

This catchment is comprised of primarily medium-density residential properties. Runoff is conveyed to Lake St. Croix through 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.

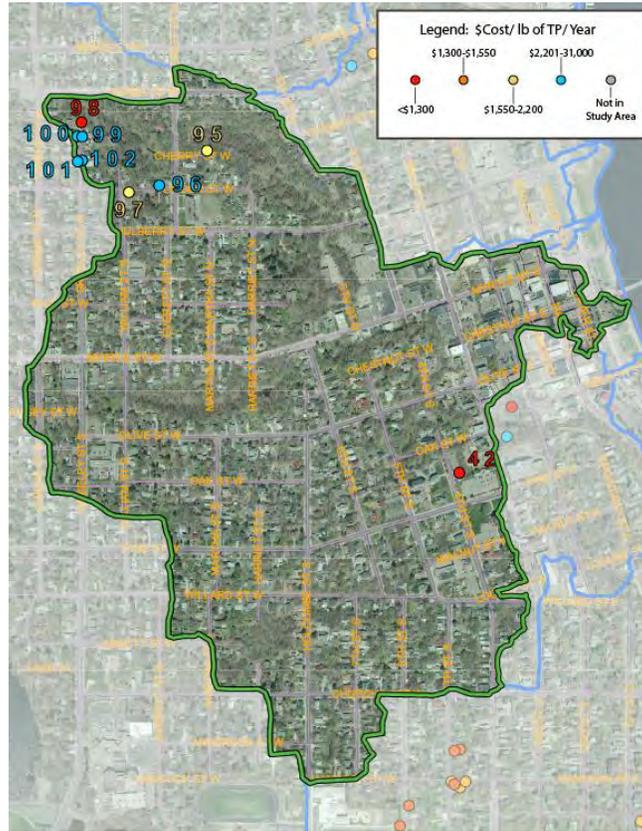
### RETROFIT RECOMMENDATION

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.

<b>BMP Treatment Summary</b> <i>Catchment SD-10</i>			<i>INSTALLED/DESIGNED</i>		
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
<b>TOTAL</b>	<b>9</b>				<b>\$61,450.00</b>

### Catchment # SD-10

Term Cost Rank = #9



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

## Catchment # SD-5

Term Cost Rank = #10

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

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

### 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 through the storm sewer system with contributions from open drainage on the west side of the catchment.

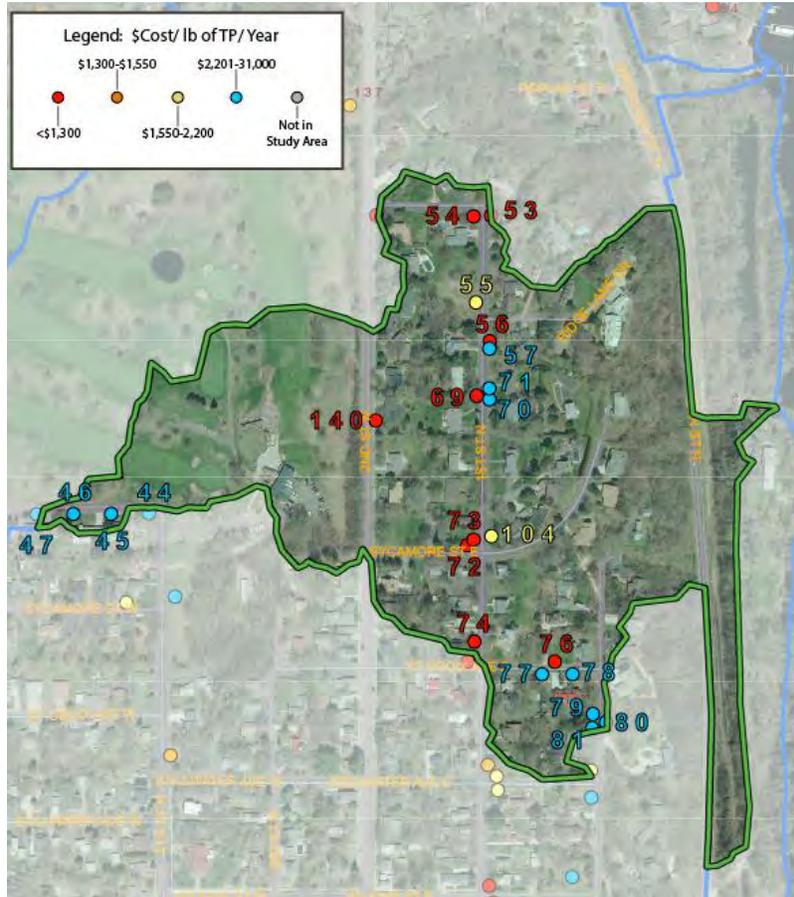
### RETROFIT RECOMMENDATION

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.

<b>BMP Treatment Summary</b> <i>Catchment SD-5</i>	<i>INSTALLED/DESIGNED</i>				
	<b># of BMP</b>	<b>SF per BMP</b>	<b>Cost per SF</b>	<b>Cost Per BMP</b>	<b>Total Cost</b>
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
<b>TOTAL</b>	<b>22</b>				<b>120,500.00</b>

### Catchment # SD-5

Term Cost Rank = #10



		COST/BENEFIT ANALYSIS		REDUCTIONS	
		Unit	Baseline	Load with 21.1% TP Reduction	Load Reduction
<b>TREATMENT</b>	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	
<b>COST</b>	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

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

<b>WinSLAMM Input Summary</b> <i>Catchment SD-8</i>	
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
<b>TOTAL</b>	<b>55.47</b>

### DESCRIPTION

This catchment is comprised of primarily medium-density residential properties. Runoff is conveyed to Lake St. Croix through 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.

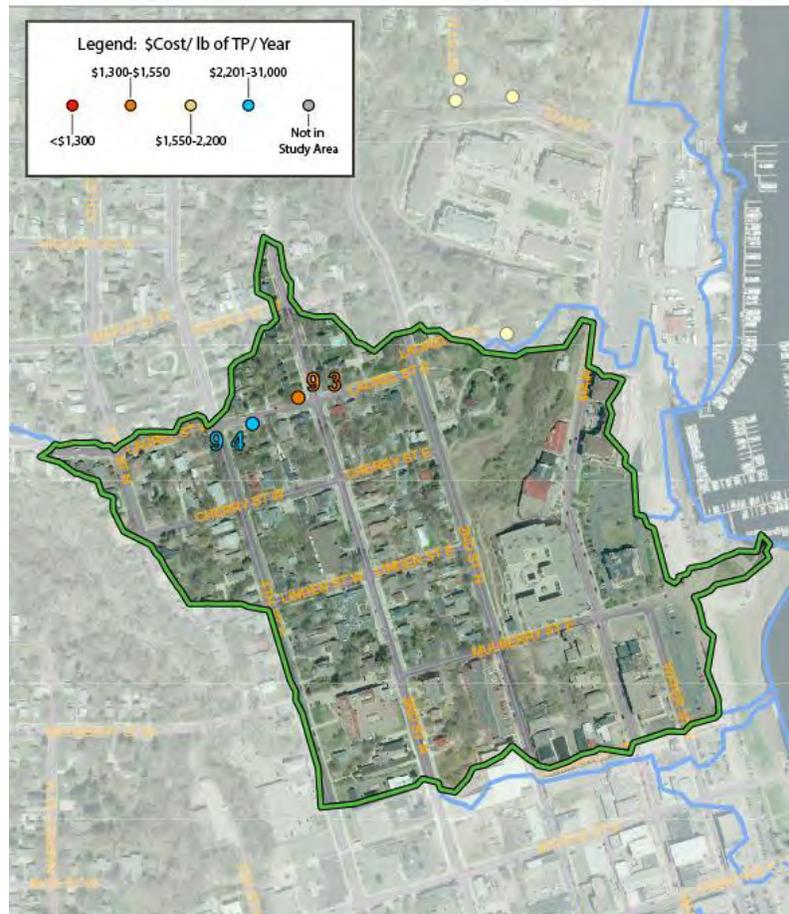
### RETROFIT RECOMMENDATION

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.

<b>BMP Treatment Summary</b> <i>Catchment SD-8</i>	# of BMP	SF per BMP	INSTALLED/DESIGNED		
			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
<b>TOTAL</b>	<b>2</b>				<b>\$26,000.00</b>

## Catchment # SD-8

Term Cost Rank = #11



		COST/BENEFIT ANALYSIS		REDUCTIONS	
		Unit	Baseline	Load with 1.4% TP Reduction	Load Reduction
<b>TREATMENT</b>	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		
<b>COST</b>	Design and Installation	-	\$16,450		
	Promotion & Admin Costs	-	\$900		
	Total Project Cost	-	\$17,350		
	Annual O&M	-	\$800		
	Term Cost/lb/yr (10 yr)	-	<b>\$3,895</b>		

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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.