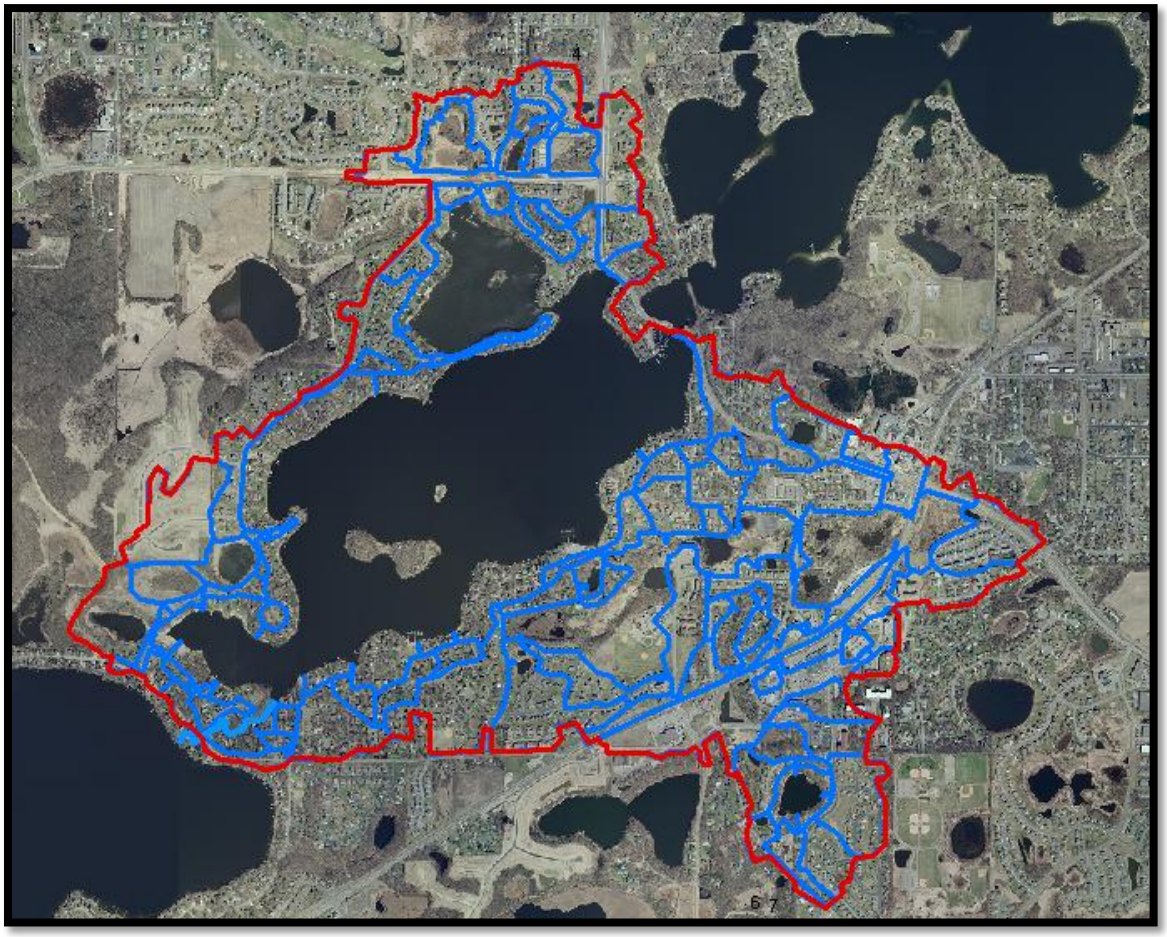
Upper Prior Lake Subwatershed Stormwater Retrofit Assessment: Phase I



Prepared by:

the SCOTT SOIL AND WATER CONSERVATION DISTRICT

with assistance from:

the METRO CONSERVATION DISTRICTS

and the CITY OF PRIOR LAKE

for the PRIOR LAKE SPRING LAKE WATERSHED DISTRICT

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Background

This report was completed as a result of grant funding through the Clean Water Legacy Fund. The grant allocated money to the eleven-county metro area to be used on studying high priority watersheds, identifying stormwater retrofit projects that could be constructed in areas where stormwater treatment does not exist, or could be enhanced. The overall goal of the program is to improve water quality throughout the eleven county metro area.

This report details the results of a study completed to identify stormwater retrofit opportunities located within the Upper Prior Lake subwatershed. This document should be considered as *one part* of an overall watershed restoration plan that would include additional items such as:

- Educational Outreach,
- Stream Repair,
- Lakeshore Riparian Zone Management,
- Discharge Prevention,
- Upland Native Plant Community Restoration, and
- Pollutant Source Control.

The methods and analysis behind this document attempt to provide a sufficient level of detail to rapidly assess sub-watersheds of variable scales and land-uses to identify optimal locations for stormwater treatment. The time commitment required for this methodology 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 best management practices that either supplement existing stormwater infrastructure or provide quality and volume treatment where none currently exists. Relative comparisons are then made between catchments to determine where best to initialize final retrofit design efforts. Final, site-specific design sets (driven by existing limitations of the landscape and its effect on design element selections) will need to be developed to determine a more refined estimate of the reported pollutant removal amounts reported here-in. This typically occurs after the procurement of committed partnerships relative to each specific target parcel slated for the placement of BMPs.

Executive Summary

The 1600-acre Upper Prior Lake subwatershed has been divided into 92 smaller catchments, ranging in size from 0.7 acres to 46.3 acres. Of these 92 catchments, 16 were considered high priority and were analyzed for annual pollutant loading. Stormwater practice options were compared, for each catchment, given their specific site constraints and characteristics. A stormwater practice was selected by weighing cost, ease of installation and maintenance and ability to serve multiple functions identified by the City and Watershed Management Organization.

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 siting and sizing. The recommended treatment levels/amounts summarized here are based on a subjective assessment of what can realistically be expected to be installed considering expected public participation and site constraints.

Retrofit Ranking

Catchment or Pond ID	Retro Type	Qty of 100 ft^3 BMPs	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/yr
Pond 2	PM, F		55	5.7		$19,325	10*	$166
Pond 3B	PM, F		34	4.1		$12,000	10*	$394
Pond 3A	PM, F		16	3.9		$15,225	10*	$492
UP-108	B	8	56	1.7	1.24	$10,089	30	$579
Pond 4	PM, F		24	2.1		$12,748	10*	$613
UP-178	B	5	15	1	0.11	$7,557	30	$630
UP-139	B	5	15	1	0.11	$7,557	30	$643
UP-97	B	10	10	1.7	0.31	$14,363	30	$772
UP-93	B	3	12	0.5	0.09	$4,992	30	$846
Pond 5	PM, F		26	1.9		$24,000	10*	$849
UP-90	B	3	12	0.5	0.09	$4,992	30	$852
Pond 13	PM, F		24	2.4		$18,000	10*	$1,117
UP-95	PS	2	18	0.3	0.06	$4,804	30	$1,145
Pond 11	PM, F		31	5.3		$19,900	10*	$1,371
Pond 15AB	PM, F		24	9.5		$154,910	10*	$1,631
Pond 6	PM, F		34	0.9		$14,150	10*	$2,275

*Operation and Maintenance costs were not calculated for the 10-year period.

B = Bioretention (infiltration and/or filtration, usually a curb cut rain garden)
F = Filtration (sand curtain, surface sand filter, sump, outlet filtration system, etc)
PM = Pond Modification (increased area/depth, additional cells, forebay, and/or outlet modification, etc.)
PS = Permeable Surface (pervious pavement, etc)

[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.

About this Document

Document Overview

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

This document is organized into four major sections that describe the general methods used, individual catchment profiles, a resulting retrofit ranking for the subwatershed and references used in this assessment protocol. In some cases, and 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 general procedures used when assessing the subwatershed. It overviews the processes of retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis and project ranking. Project-specific details of each process are defined if different from the general, standard procedures.

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.

Retrofit Profiles

When applicable, each retrofit profile is labeled with a unique ID to coincide with the subwatershed name (e.g., SC-001 for Sand Creek catchment 001). This ID is referenced when comparing projects across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

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

Retrofit Recommendation

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

Cost/Treatment Analysis

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

Site Selection

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

Retrofit Ranking

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

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

References

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

Appendices

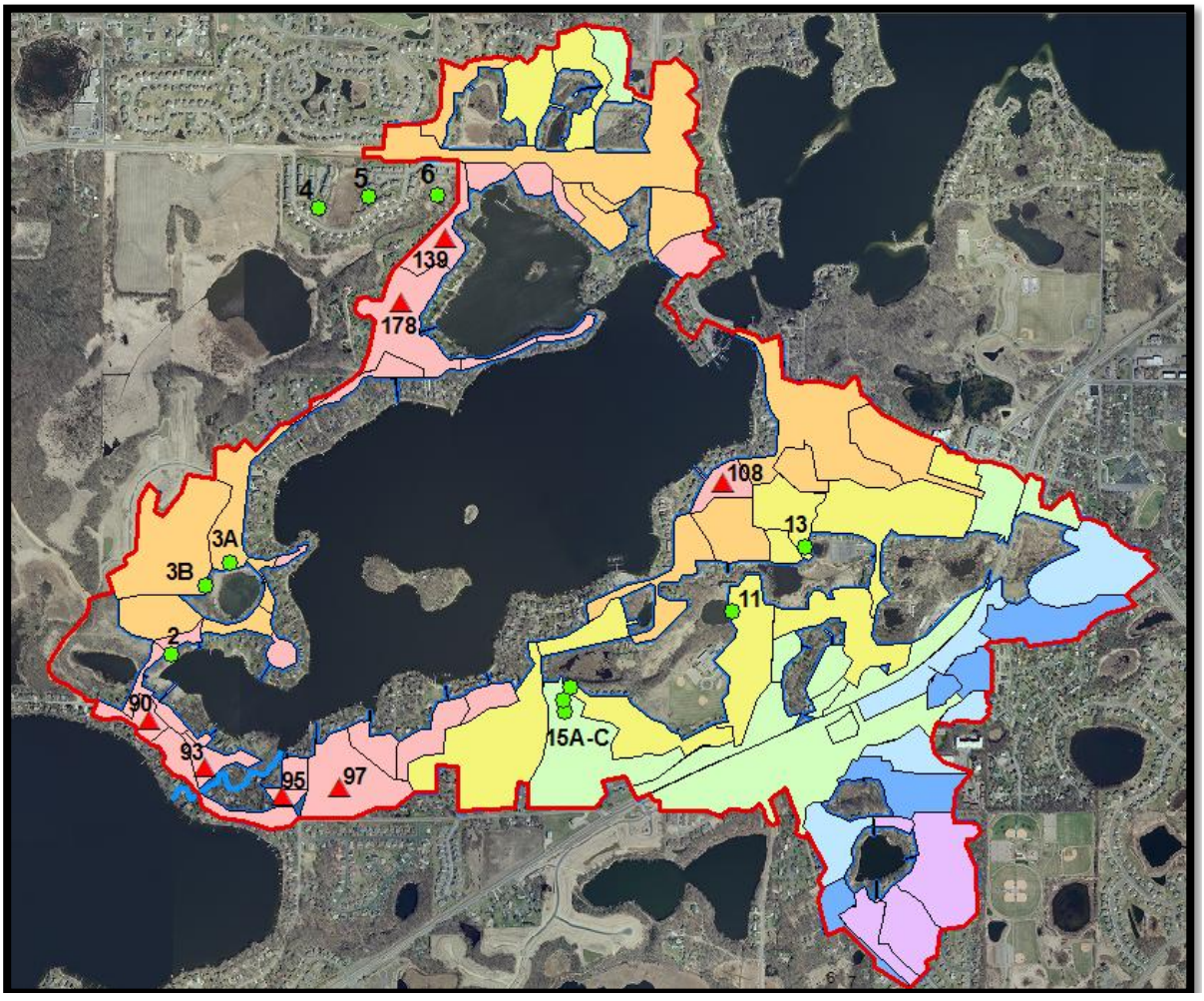
This section provides supplemental information and/or data used at various points along the assessment protocol.

Methods

Selection of a Subwatershed and Focus Areas (Catchments)

The Prior Lake Spring Lake Watershed District (PLSLWD), along with the City of Prior Lake, and the Scott Soil and Water Conservation District (SWCD) selected the subwatershed of Upper Prior Lake for their first stormwater retrofit assessment because this lake is currently listed as impaired for nutrients and the current land use is almost exclusively residential areas. Many of these neighborhoods were built prior to stormwater regulations and in many cases, stormwater runoff passes directly to the lake without pre-treatment.

This subwatershed is made up of 92 previously delineated catchments. In order to best utilize time and resources, not all of the catchments were studied. It was decided to do a more thorough study on smaller targeted areas. First, the catchments with a direct discharge through a pipe to the lake were studied. These are the pink areas on the map as shown below. Second, the catchments where planned stormwater improvements were planned were studied. Some of these planned projects had opportunities for greater water quality improvements if additional money was available. These project locations are shown on the map below with a green dot and associated project numbers.



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.

Upper Prior Lake Catchment Profiles

For development of the Upper Prior Lake catchment profiles section, xx out of xx catchments were selected as the phase one areas for stormwater retrofit efforts. Those catchments receiving modern stormwater pond treatment, or in some cases 2 levels of treatment, were not modeled or further analyzed in this assessment. It is recommended that after these initial catchments are built out to satisfactory reduction levels that the remaining pond networks be modeled. These additional catchments should then be analyzed by first considering pond modification, then uphill, distributed retrofits.

Each Catchment Profile includes a table showing the data relevant to various levels of treatment. The recommended treatment level (or expected success in establishing a certain amount of practices in the catchment) is highlighted. The table below is an example of such a table recommending the 10% treatment level, or, in other words, establishing enough BMP's to equal 1,100 ft^3 of live storage.

	Cost/Benefit Analysis	*Existing*	*Estimated Reductions and Costs*					
Treatment	**TP (lb/yr)**	3.9	0.3	9%	0.5	12%	0.6	15%
	TSS (lb/yr)	1469	125	9%	176	12%	223	15%
	Volume (acre-feet/yr)	2.34	0.06	3%	0.09	4%	0.12	5%
	Live Storage Volume (cu. ft.)	--	214		321		428	
	BMP Type	--	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Costs	**Materials/Labor/Design**	--	$2,808		$4,212		$5,615	
	Promotion & Admin Costs	--	$1,049		$780		$633	
	Total Project Cost	--	$3,856		$4,992		$6,248	
	Annual O&M	--	$161		$241		$321	
	Term Cost/lb/yr (30 yr)	--	$838		$852		$882	

UPPER PRIOR 90

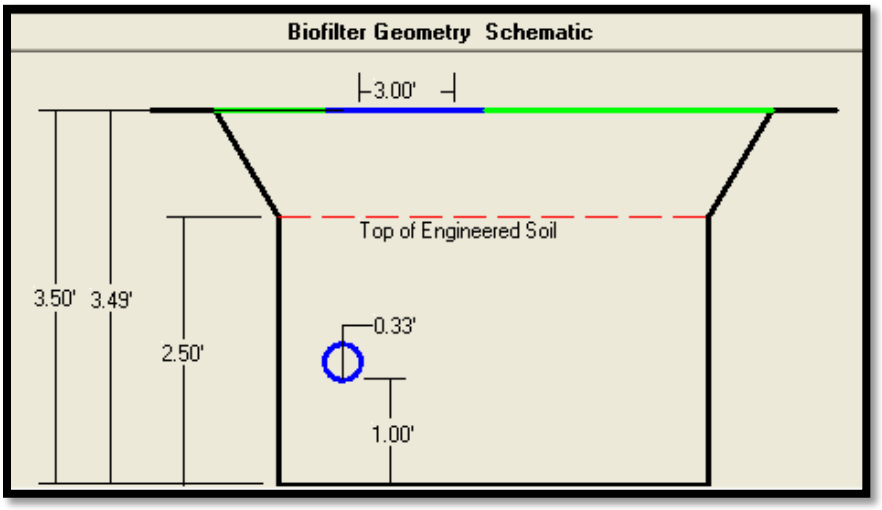
Catchment Summary of Current Conditions	
Hydraulic Conductivity (in/hr)	0.10
Runoff Volume (acre-feet/yr)	2.3
Total Phosphorus, TP (lb/yr)	3.9
Total Suspended Solids, TSS (lb/yr)	1469

WinSLAMM Model Input Parameters	
Dominant Land Cover	Residential
Area (acres)	4.7
Limiting Soil Type	Clay Loam
Composite Curve Number	69

DESCRIPTION and RETROFIT RECOMMENDATION

This 4.7 acre catchment discharges directly to the lake through a public storm pipe, without treatment, and is comprised primarily of medium density, single-family residential development with one municipally owned park (1.0-acre). The catchment is located between Spring and Upper Prior Lakes, centered near the intersection of Spring Lake Road and Northwood Road. The soils are mainly Hayden loams (HaB), 0-6% slopes, with a confining, underlying layer consisting of clay loam. The best opportunity to treat stormwater in this catchment would be to utilize the public space to incorporate several smaller bioretention basins or one or two larger ones in the municipal park, capturing sediment and phosphorus prior to release into Upper Prior Lake.

TREATMENT ANALYSIS AND COST ESTIMATE



The bioretention system modeled in WinSLAMM is shown to the left.

The total cost to install 3 curb cut rain gardens is estimated to be $4,992. When including operation and maintenance costs over a 30 year period, the cost per pound of phosphorus removed is $852.

	Cost/Benefit Analysis	*Existing*	*Estimated Reductions and Costs*					
Treatment	**TP (lb/yr)**	3.9	0.3	9%	0.5	12%	0.6	15%
	TSS (lb/yr)	1469	125	9%	176	12%	223	15%
	Volume (acre-feet/yr)	2.34	0.06	3%	0.09	4%	0.12	5%
	Live Storage Volume (cu. ft.)	--	214		321		428	
	BMP Type	--	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Costs	**Materials/Labor/Design**	--	$2,808		$4,212		$5,615	
	Promotion & Admin Costs	--	$1,049		$780		$633	
	Total Project Cost	--	$3,856		$4,992		$6,248	
	Annual O&M	--	$161		$241		$321	
	Term Cost/lb P/yr (30 yr)	--	$838		$852		$882	

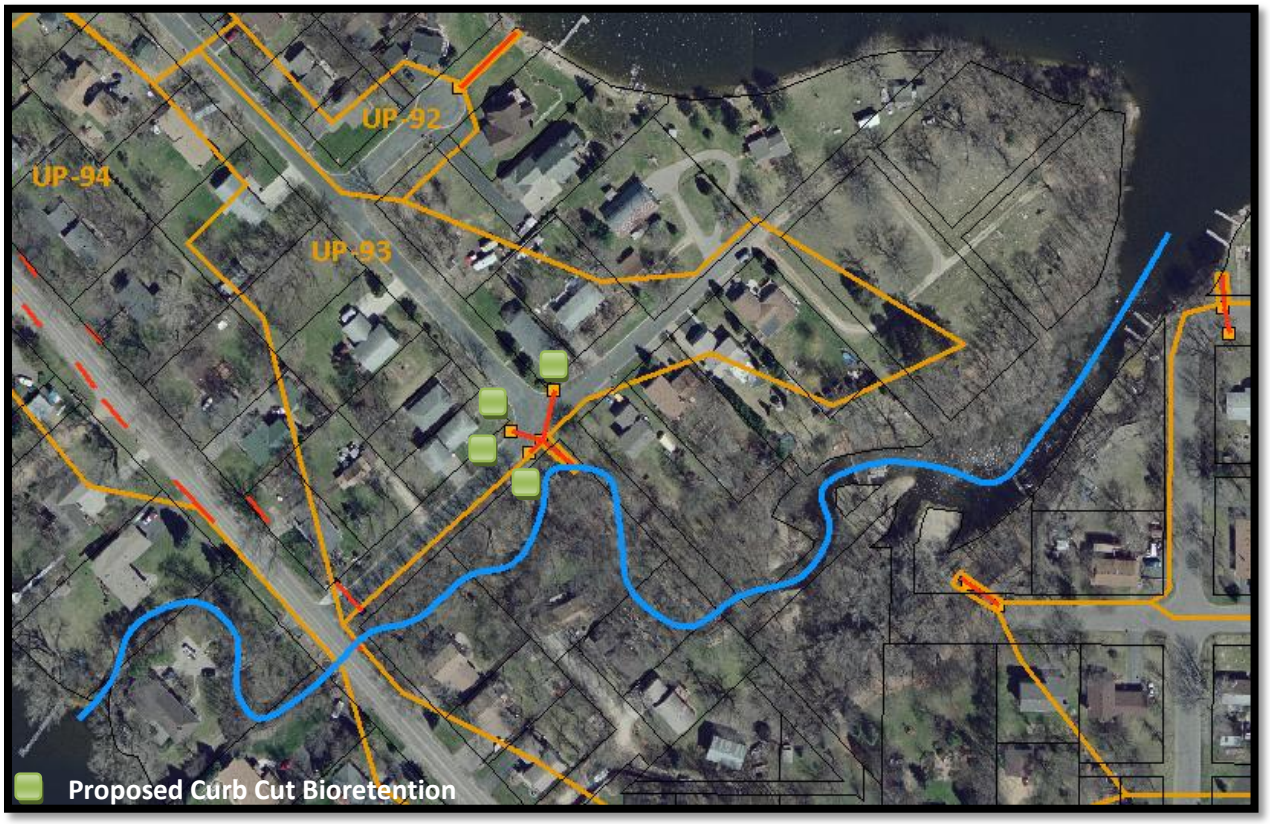
UPPER PRIOR 93

Catchment Summary of Current Conditions	
Hydraulic Conductivity (in/hr)	0.10
Runoff Volume (acre-feet/yr)	2.41
Total Phosphorus, TP (lb/yr)	4.02
Total Suspended Solids, TSS (lb/yr)	1516

WinSLAMM Model Input Parameters	
Dominant Land Cover	Residential
Area (acres)	4.84
Limiting Soil Type	Clay Loam
Composite Curve Number	69

DESCRIPTION and RETROFIT RECOMMENDATION

This 4.84 acre catchment discharges directly to the lake through a public storm pipe, without treatment, and is comprised primarily of medium density, single-family residential development. The catchment is located immediately west of the small channel that connects Spring and Upper Prior Lakes. The soils are Hayden loams (HaB), 0-6% slopes, with a confining, underlying layer consisting of clay loam. The best opportunity to treat stormwater would be to install up to four curb-cut rain gardens, located just upstream of the catchbasins in this catchment, at the Lime Rd SW and Center Rd SW intersection.



	Cost/Benefit Analysis	Existing	Estimated Reductions and Costs					
Treatment	TP (lb/yr)	4.0	0.3	9%	0.5	12%	0.6	15%
	TSS (lb/yr)	1516	126	8%	177	12%	224	15%
	Volume (acre-feet/yr)	2.41	0.06	3%	0.09	4%	0.12	5%
	Live Storage Volume (cu. ft.)		214		321		428	
	BMP Type		Complex Bioretention		Complex Bioretention		Complex Bioretention	
Costs	Materials/Labor/Design		$2,808		$4,212		$5,615	
	Promotion & Admin Costs		$1,049		$780		$633	
	Total Project Cost		$3,856		$4,992		$6,248	
	Annual O&M		$161		$241		$321	
	Term Cost/lb/yr (30 yr)		$833		$846		$876	

The total cost to install 3 curb cut rain gardens is estimated to be $4,993. When including operation and maintenance costs over a 30 year period, the cost per pound of phosphorus removed is $846.

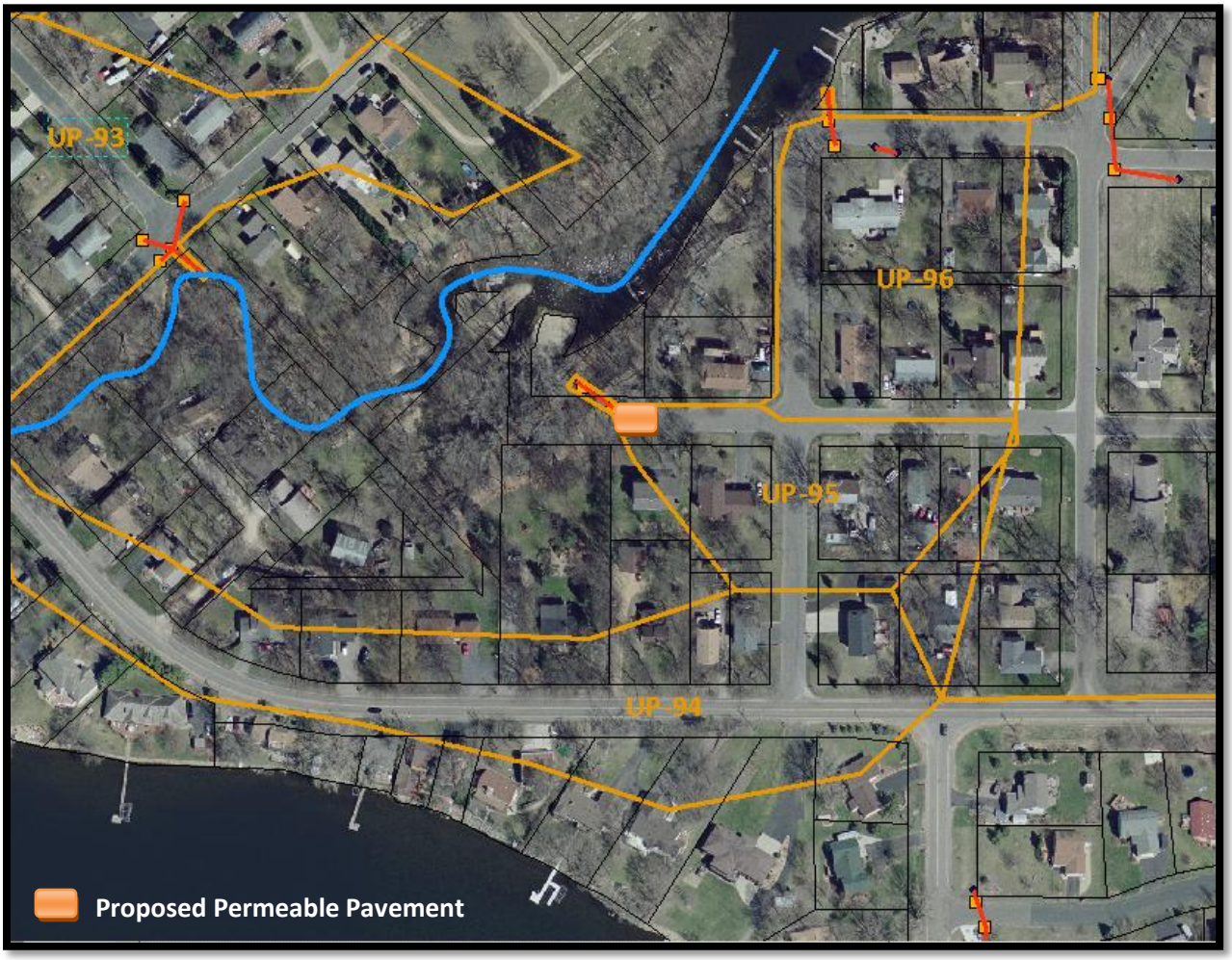
UPPER PRIOR 95

Catchment Summary of Current Conditions	
Hydraulic Conductivity (in/hr)	0.10
Runoff Volume (acre-feet/yr)	0.93
Total Phosphorus, TP (lb/yr)	1.55
Total Suspended Solids, TSS (lb/yr)	586

WinSLAMM Model Input Parameters	
Dominant Land Cover	Residential
Area (acres)	1.87
Limiting Soil Type	Clay Loam
Composite Curve Number	69

DESCRIPTION and RETROFIT RECOMMENDATION

This 1.87 acre catchment discharges directly to the lake through a public storm pipe, without treatment, and is comprised primarily of medium density, single-family residential development. The catchment is located immediately east of the small channel that connects Spring and Upper Prior Lakes. The soils are mainly Hayden loams (HaB), 0-6% slopes, with a confining, underlying layer consisting of clay loam. The best opportunity to treat stormwater in this catchment would be to construct a permeable pavement section at the end of Vale Circle SW and treat the stormwater before it enters the channel.



	Cost/Benefit Analysis	Existing	Annual Marginal Treatment Enhancement (amt/%)					
			Min		Optimal		Max	
Treatment	TP (lb/yr)	1.6	0.2	10%	0.3	18%	0.4	24%
	TSS (lb/yr)	586	60	10%	105	18%	140	24%
	Volume (acre-feet/yr)	0.93	0.04	4%	0.06	6%	0.08	9%
	Live Storage Volume (cubic feet)		107		214		321	
	BMP Type		Grass/Gravel Permeable Pavement		Grass/Gravel Permeable Pavement		Grass/Gravel Permeable Pavement	
Costs	Materials/Labor/Design		$1,878		$3,756		$5,634	
	Promotion & Admin Costs		$1,738		$1,049		$780	
	Total Project Cost		$3,616		$4,804		$6,414	
	Annual O&M		$80		$161		$241	
	Term Cost/lb/yr (30 yr)		$1,255		$1,145		$1,228	

The total cost to install 200 square feet of permeable pavement is estimated to be $4,904. When including operation and maintenance costs over a 30 year period, the cost per pound of phosphorus removed is $1,145.

UPPER PRIOR 97

Catchment Summary of Current Conditions	
Hydraulic Conductivity (in/hr)	2.31
Runoff Volume (acre-feet/yr)	9.77
Total Phosphorus, TP (lb/yr)	16.28
Total Suspended Solids, TSS (lb/yr)	6137

WinSLAMM Model Input Parameters	
Dominant Land Cover	Residential
Area (acres)	19.59
Limiting Soil Type(s)	Sand, Clay Loam
Composite Curve Number	69.7

DESCRIPTION and RETROFIT RECOMMENDATION

This 19.59 acre catchment discharges directly to the lake through a public storm pipe, without treatment, and is comprised primarily of medium density, single-family residential development. The catchment is located south of Upper Prior Lake. The soils are a mixture Hayden loams (HaB) with 0-6% slopes, Estherville loam (LaC) with 6-12% slopes, Estherville-Burnsville complex (LbC2), moderately eroded with 6-12% slopes, Estherville loam (LaB2) with 2-6% slopes and moderately eroded, Webster Glencoe silty clay loam (Wb), and Terrill loam (TbB) with 2-6% slopes. The Estherville loams have underlying material of gravel and/or sand and will offer excellent infiltration opportunities. The other soil types have a confining underlying layer consisting of clay loam. The best opportunity to treat stormwater in this catchment would be to incorporate curb cut rain gardens in the areas where slopes are gentle and the soils have maximum infiltration capacities.

	Cost/Benefit Analysis	Existing	Annual Marginal Treatment Enhancement (amt/%)					
			Min		Optimal		Max	
Treatment	TP (lb/yr)	16.3	0.9	6%	1.7	10%	2.3	14%
	TSS (lb/yr)	6137	330	5%	608	10%	854	14%
	Volume (acre-feet/yr)	9.77	0.16	2%	0.31	3%	0.46	5%
	Live Storage Volume (cubic feet)		535		1070		1,605	
Costs	BMP Type		Complex Bioretention		Complex Bioretention		Complex Bioretention	
	Materials/Labor/Design		$7,019		$14,038		$21,058	
	Promotion & Admin Costs		$538		$324		$241	
	Total Project Cost		$7,557		$14,363		$21,299	
	Annual O&M		$401		$803		$1,204	
	Term Cost/lb/yr (30 yr)		$695		$772		$832	

The total cost to install 10 curb cut rain gardens is estimated to be $14,363. When including operation and maintenance costs over a 30 year period, the cost per pound of phosphorus removed is $772.

UPPER PRIOR 108

Catchment Summary of Current Conditions	
Hydraulic Conductivity (in/hr)	5.38
Runoff Volume (acre-feet/yr)	2.31
Total Phosphorus, TP (lb/yr)	3.02
Total Suspended Solids, TSS (lb/yr)	1376

WinSLAMM Model Input Parameters	
Dominant Land Cover	Residential
Area (acres)	5.46
Limiting Soil Type	Loose Gravel
Composite Curve Number	69

DESCRIPTION and RETROFIT RECOMMENDATION

This 5.36 acre catchment discharges directly to the lake through a public storm pipe, without treatment, and is comprised primarily of medium density, single-family residential development. The catchment is located east of Upper Prior Lake. The soils are mainly Hayden loams (HaB), 0-6% slopes, with a confining, underlying layer consisting of clay loam. The best opportunity to treat stormwater in this catchment would be to install several smaller bioretention basins throughout the neighborhood, capturing sediment and phosphorus prior to release into Upper Prior Lake. The highest priority locations are the ones located immediately upstream of the catch basins.

	Cost/Benefit Analysis	Existing	Annual Marginal Treatment Enhancement (amt/%)					
			Min		Optimal		Max	
Treatment	TP (lb/yr)	3.0	1.0	33%	1.7	56%	2.1	70%
	TSS (lb/yr)	1376	494	36%	791	57%	970	70%
	Volume (acre-feet/yr)	2.31	0.78	34%	1.24	54%	1.54	67%
	Live Storage Volume (cubic feet)		428		856		1,284	
Costs	BMP Type		Simple Bioretention		Simple Bioretention		Simple Bioretention	
	Materials/Labor/Design		$4,854		$9,707		$14,561	
	Promotion & Admin Costs		$633		$382		$284	
	Total Project Cost		$5,486		$10,089		$14,845	
	Annual O&M		$321		$642		$963	
	Term Cost/lb/yr (30 yr)		$499		$579		$694	

The total cost to install 8 curb cut rain gardens is estimated to be $10,089. When including operation and maintenance costs over a 30 year period, the cost per pound of phosphorus removed is $579.

UPPER PRIOR 139

Catchment Summary of Current Conditions	
Hydraulic Conductivity (in/hr)	0.10
Runoff Volume (acre-feet/yr)	4.03
Total Phosphorus, TP (lb/yr)	6.72
Total Suspended Solids, TSS (lb/yr)	2531

WinSLAMM Model Input Parameters	
Dominant Land Cover	Residential
Area (acres)	8.08
Limiting Soil Type	Clay Loam
Composite Curve Number	69

DESCRIPTION and RETROFIT RECOMMENDATION

This 8.08 acre catchment discharges directly to the lake through a public storm pipe, without treatment, and is comprised primarily of medium density, single-family residential development. with one municipally owned park (1.0-acre). The catchment is located on the northwest corner of Upper Prior Lake. The soils are Hayden loams (HaB2, BcB3, HcD3), with varying slopes and varying degrees of erodibility. The underlying, confining layer consists of clay loam. The best opportunity to treat stormwater in this catchment would be to utilize the public space to install several curb cut rain gardens that will capture sediment and phosphorus prior to release into Upper Prior Lake.

	Cost/Benefit Analysis	Existing	Annual Marginal Treatment Enhancement (amt/%)					
			Min		Optimal		Max	
Treatment	TP (lb/yr)	6.7	0.8	12%	1.0	15%	1.6	24%
	TSS (lb/yr)	2531	278	11%	374	15%	473	19%
	Volume (acre-feet/yr)	4.00	0.05	1%	0.11	3%	0.17	4%
	Live Storage Volume (cubic feet)		321		535		856	
Costs	BMP Type		Complex Bioretention		Complex Bioretention		Complex Bioretention	
	Materials/Labor/Design		$4,212		$7,019		$11,231	
	Promotion & Admin Costs		$780		$538		$382	
	Total Project Cost		$4,992		$7,557		$11,612	
	Annual O&M		$241		$401		$642	
	Term Cost/lb/yr (30 yr)		$518		$630		$643	

The total cost to install 5 curb cut rain gardens is estimated to be $7,557. When including operation and maintenance costs over a 30 year period, the cost per pound of phosphorus removed is $630.

UPPER PRIOR 178

Catchment Summary of Current Conditions	
Hydraulic Conductivity (in/hr)	0.10
Runoff Volume (acre-feet/yr)	10.03
Total Phosphorus, TP (lb/yr)	16.72
Total Suspended Solids, TSS (lb/yr)	6303

WinSLAMM Model Input Parameters	
Dominant Land Cover	Residential
Area (acres)	22.59
Limiting Soil Type	Clay Loam
Composite Curve Number	70.2

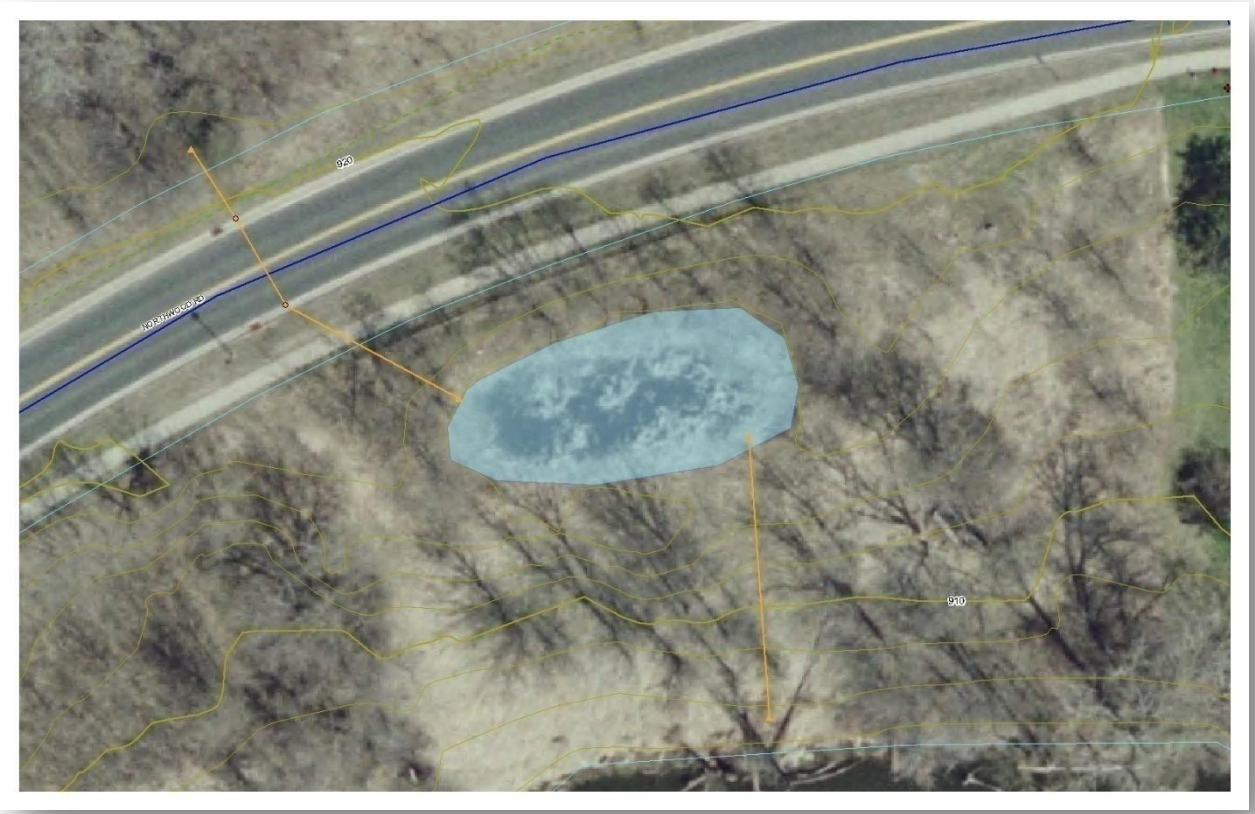
DESCRIPTION and RETROFIT RECOMMENDATION

This 22.59 acre catchment discharges directly to the lake through a public storm pipe, without treatment, and is comprised primarily of medium density, single-family residential development. The catchment is located on the northwest side of Upper Prior Lake. The soils are mostly Hayden loams (HaC2, HcD3, HcC2, HaB2), with varying slopes and levels of erodibility. The underlying layer consists of a confining layer of clay loam. The best opportunity to treat stormwater in this catchment would be to install several smaller bioretention basins that will capture sediment and phosphorus prior to release into Upper Prior Lake.

	Cost/Benefit Analysis	Existing	Annual Marginal Treatment Enhancement (amt/%)					
			Min		Optimal		Max	
Treatment	TP (lb/yr)	6.7	0.8	12%	1.0	15%	1.6	24%
	TSS (lb/yr)	2531	278	11%	374	15%	473	19%
	Volume (acre-feet/yr)	4.00	0.05	1%	0.11	3%	0.17	4%
	Live Storage Volume (cubic feet)		321		535		856	
Costs	BMP Type		Complex Bioretention		Complex Bioretention		Complex Bioretention	
	Materials/Labor/Design		$4,212		$7,019		$11,231	
	Promotion & Admin Costs		$780		$538		$382	
	Total Project Cost		$4,992		$7,557		$11,612	
	Annual O&M		$241		$401		$642	
	Term Cost/lb/yr (30 yr)		$518		$630		$643	

The total cost to install 5 curb cut rain gardens is estimated to be $7,557. When including operation and maintenance costs over a 30 year period, the cost per pound of phosphorus removed is $630.

Pond 2



Catchment Summary – Site 2	
Acres	11.63
Watershed TP (lb/yr) load	10.47
Existing treatment (lb/yr)	3.48
Treatment after modification (lb/yr)	9.22
New treatment (lb/yr)	**5.74**
Cost for new treatment (cost/lb/yr over 10 years)	**$165.80**

The maintenance and retrofit work to be done at site 2 includes a drainage alteration to restore a drained wetland and correct ravine erosion, a hydraulic modification of a pond outlet structure and a 500 square foot outlet filtration system.

The total cost of this project, is $9,515. Over ten years, the cost per pound of phosphorus removed is $165.80.

Pond 3A and 3B

Catchment Summary – Site 3A	
Acres	12.80
Watershed TP (lb/yr) load	11.52
Existing treatment (lb/yr)	4.03
Treatment after modification (lb/yr)	7.91
New treatment (lb/yr)	**3.88**
Cost for new treatment (cost/lb/yr over 10 years)	**$492.00**

The maintenance and retrofit at site 3A includes maintenance of existing water quality pond volume, hydraulic modification of the pond outlet structure and a 500 square foot outlet filtration system. The total cost of this project is $19,105.25. Therefore, the cost per pound of phosphorus removed after 10 years is $492.00

Catchment Summary – Site 3B	
Acres	29.07
Watershed TP (lb/yr) load	26.16
Existing treatment (lb/yr)	13.23
Treatment after modification (lb/yr)	17.37
New treatment (lb/yr)	**4.14**
Cost for new treatment (cost/lb/yr over 10 years)	**$394.30**

The maintenance and retrofit at site 3B includes modification of an existing outlet control structure and creation of a 1600 square foot outlet filtration system. The total cost of this project is $16,325.00. Therefore, the cost per pound of phosphorus removed after 10 years is $394.30.

Pond 4

Catchment Summary – Site 4	
Acres	9.79
Parcels	R4
Watershed TP (lb/yr) load	8.81
Existing treatment (lb/yr)	4.85
Treatment after modification (lb/yr)	6.93
New treatment (lb/yr)	**2.08**
Cost for new treatment (cost/lb/yr over 10 years)	**$612.90**

The maintenance and retrofit at site 4 includes expanded water quality volume, a new outlet control structure, and a 550 square foot outlet filtration system.

The total cost of the project is $12,747.75. Therefore the cost per pound of phosphorus removed over a ten year period is $612.90.

Pond 5

Catchment Summary – Site 5	
Acres	8.08
Watershed TP (lb/yr) load	7.27
Existing treatment (lb/yr)	3.96
Treatment after modification (lb/yr)	5.82
New treatment (lb/yr)	**1.86**
Cost for new treatment (cost/lb/yr over 10 years)	**$849.00**

The maintenance and retrofit at site 5 includes expanded water quality volume, a new outlet control structure and a 450 square foot outlet filtration system.

The total cost of the project is $15,791.50. Therefore, the cost per pound of phosphorus removed over a ten year period is $849.00

Pond 6

Catchment Summary – Site 6	
Acres	3.03
Watershed TP (lb/yr) load	2.73
Existing treatment (lb/yr)	1.45
Treatment after modification (lb/yr)	2.39
New treatment (lb/yr)	**0.94**
Cost for new treatment (cost/lb/yr over 10 years)	**$2275**

The maintenance and retrofit at site 6 includes maintenance of existing water quality pond volume, a new outlet control structure and a 360 square foot outlet filtration system.

The total cost for this project $21,392.25. Therefore, the total cost per pound of phosphorus removed over a ten year period is $2275.

Pond 11

Catchment Summary – Site 11	
Acres	19.10
Watershed TP (lb/yr) load	17.19
Existing treatment (lb/yr)	6.25
Treatment after modification (lb/yr)	11.50
New treatment (lb/yr)	**5.25**
Cost for new treatment (cost/lb/yr over 10 years)	**$1371**

The maintenance and retrofit at Site 11 includes maintenance and expansion of existing water quality pond volume, a new outlet control structure and a 750 square foot outlet filtration system.

The total cost of this project is $72,002. Therefore, the cost per pound of phosphorus removed over a ten year period is $1371.

Pond 13

Catchment Summary – Site 13	
Acres	10.89
Watershed TP (lb/yr) load	9.80
Existing treatment (lb/yr)	4.32
Treatment after modification (lb/yr)	6.69
New treatment (lb/yr)	**2.37**
Cost for new treatment (cost/lb/yr over 10 years)	**$1117**

The maintenance and retrofit at site 13 includes maintenance and expansion of existing water quality pond volume, a new outlet control structure, and a 500 square foot outlet filtration system.

The total cost of this project is $26,481.50. Therefore, the cost per pound of phosphorus removed after ten years is $1117.

Pond 15A-B

Catchment Summary – Site 15A	
Acres	29.49
Watershed TP (lb/yr) load	26.54
Existing treatment (lb/yr)	13.53
Treatment after modification (lb/yr)	19.83
New treatment (lb/yr)	**6.30**
Catchment Summary – Site 15B	
Acres	14.8
Watershed TP (lb/yr) load	13.32
Existing treatment (lb/yr)	4.50
Treatment after modification (lb/yr)	7.66
New treatment (lb/yr)	**3.16**
TOTAL New Treatment (lb/yr)	**9.46**
Cost for new treatment (cost/lb/yr over 10 years)	**$1631**

The maintenance and retrofit at site 15A and 15B includes maintenance and expansion of existing water quality pond volume on two ponds, expansion and enhancement of a small wetland, new outlet structure for 2 ponds and the expanded wetland and a 4500 square foot outlet filtration system.

The total cost of these projects is $154,910. Therefore, the cost per pound of phosphorus removed over a ten year period is $1631.

Retrofit Ranking

Based on the information previously presented, the projects are ranked, below, based solely on cost per pound of phosphorus removed, from lowest to highest.

Catchment or Pond ID	Retro Type	Qty of 100 ft^3 BMPs	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/yr
Pond 2	PM, F		55	5.7	--	$19,325	10*	$166
Pond 3B	PM, F		34	4.1	--	$12,000	10*	$394
Pond 3A	PM, F		16	3.9	--	$15,225	10*	$492
UP-108	B	8	56	1.7	1.24	$10,089	30	$579
Pond 4	PM, F		24	2.1	--	$12,748	10*	$613
UP-178	B	5	15	1	0.11	$7,557	30	$630
UP-139	B	5	15	1	0.11	$7,557	30	$643
UP-97	B	10	10	1.7	0.31	$14,363	30	$772
UP-93	B	3	12	0.5	0.09	$4,992	30	$846
Pond 5	PM, F		26	1.9	--	$24,000	10*	$849
UP-90	B	3	12	0.5	0.09	$4,992	30	$852
Pond 13	PM, F		24	2.4	--	$18,000	10*	$1,117
UP-95	PS	2	18	0.3	0.06	$4,804	30	$1,145
Pond 11	PM, F		31	5.3	--	$19,900	10*	$1,371
Pond 15AB	PM, F		24	9.5	--	$154,910	10*	$1,631
Pond 6	PM, F		34	0.9	--	$14,150	10*	$2,275

*Operation and Maintenance costs were not calculated for the 10-year period.

B = Bioretention (infiltration and/or filtration, usually a curb cut rain garden)
F = Filtration (sand curtain, surface sand filter, sump, outlet filtration system, etc)
PM = Pond Modification (increased area/depth, additional cells, forebay, and/or outlet modification, etc.)
PS = Permeable Surface (pervious pavement, etc)

[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.