Martin Lake
Stormwater Retrofit Assessment

Prepared by:

ANOKA CONSERVATION DISTRICT

for the

SUNRISE RIVER WATERSHED MANAGEMENT ORGANIZATION, MARTIN LAKERS ASSOCIATION, AND LINWOOD TOWNSHIP

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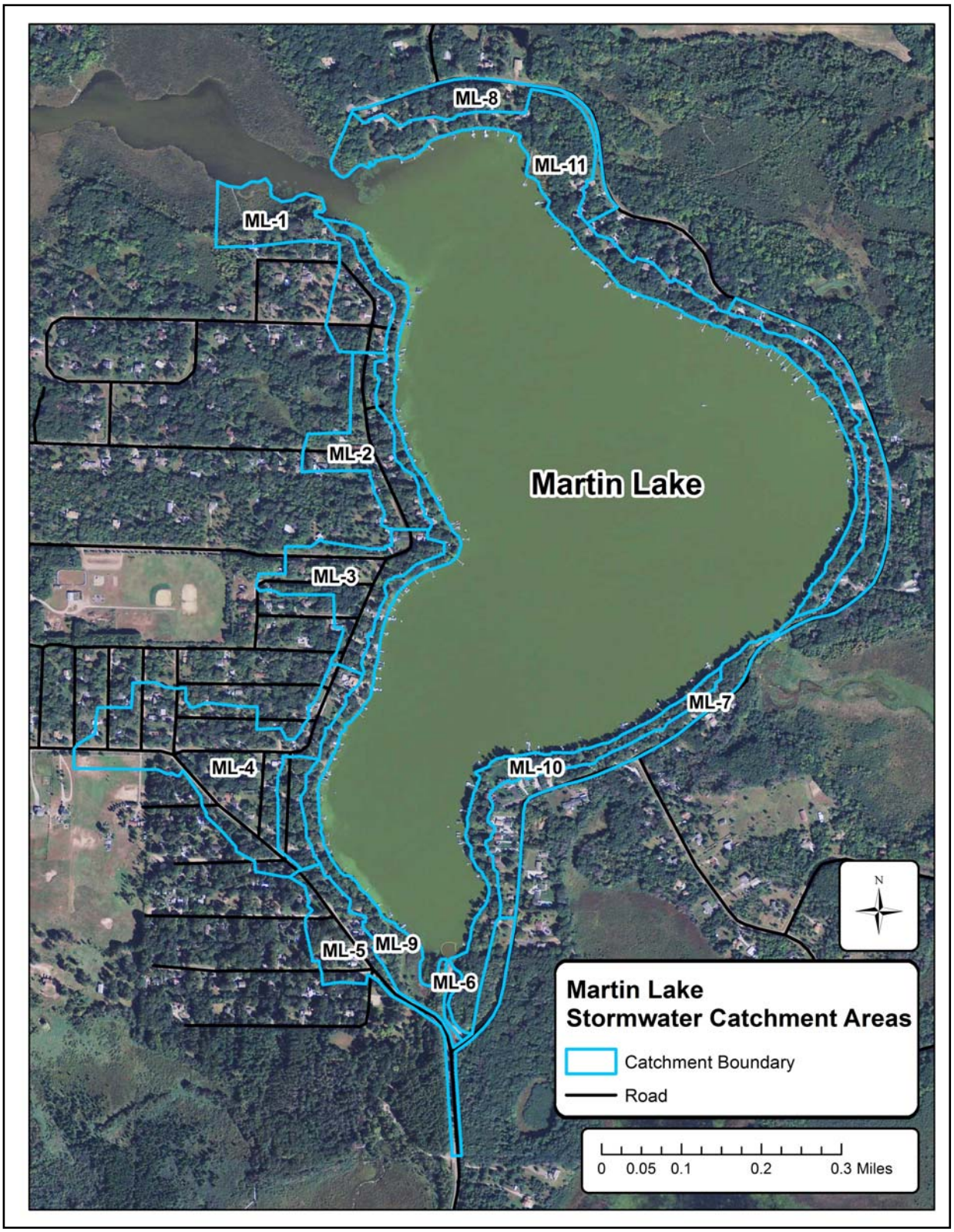
August 2011

Cover photos: A storm basin which drains into Martin Lake. Martin Lake is shown in the background.

Contents

Map of stormwater catchment areas referred to in this report.



Executive Summary

This study provides recommendations for cost effectively improving treatment of stormwater from neighborhoods surrounding Martin Lake before it is discharged into the lake. Martin Lake is an important recreational lake in Linwood Township, Minnesota, but suffers from algae blooms throughout most of each summer. These algae blooms, fueled by excessive amounts of the nutrient phosphorus, have serious negative effects on recreational use of the lake, the fishery, and property values. The Minnesota Pollution Control Agency has listed the lake as "impaired" for failing to meet state water quality standards. An in-depth study of phosphorus sources has been completed. One of the phosphorus sources identified was stormwater from neighborhoods surrounding the lake. Many of these neighborhoods were developed before modern-day stormwater treatment requirements. This stormwater assessment systematically examined these neighborhoods, investigated ways to improve stormwater treatment, and prioritized opportunities by cost-effectiveness.

The approaches in this report are often termed "stormwater retrofitting." This refers to adding stormwater treatment to an already built-up area, where little open land exists. This process is investigative and creative. Stormwater retrofitting success is sometimes improperly judged by the number of projects installed or by comparing costs alone. Those approaches neglect to consider how much pollution is removed per dollar spent. In this stormwater assessment we estimated both costs and pollutant reductions, and used them to calculate cost effectiveness of each possible project.

We delineated the areas that drain directly to Martin Lake, either through surface flows or stormwater conveyances. Then, we divided those areas into 11 smaller stormwater drainage areas, or "catchments." For each catchment, we modeled stormwater volume and pollutants using the software WinSLAMM. First, we modeled existing conditions, including existing stormwater treatment practices. Currently, the 112 acre area contributes an estimated 24.5 acre feet of runoff, 30.4 pounds of phosphorus and 8,533 pounds of total suspended solids to the lake each year. Then we modeled possible stormwater retrofits to estimate reductions in volume, total phosphorus (TP), and total suspended solids (TSS). Finally, we estimated the cost of each retrofit project, including 30-year lifespan operations and maintenance. Projects were ranked by cost effectiveness with respect to total phosphorus reduction.

A variety of stormwater retrofit approaches were identified. They included:

- Maintenance of, or alterations to, existing stormwater treatment practices.
- Residential curb-cut rain gardens,
- Swales with check dams,
- Street sweeping, and
- Lakeshore restorations.

Because stormwater catchments around Martin Lake are all small, the recommended practices are all relatively small and a single large project in any one location would be overkill. Each practice would need to be strategically placed for maximum effectiveness. A practice was considered only if an appropriate place existed and we felt it would be effective.

If all of these practices were installed, significant pollution reduction could be accomplished. Across all catchments, the annual potential pollution reduction is 3.6 acre feet of runoff (15%), 8.7 pounds of phosphorus (29%), and 2,963 pounds of total suspended solids (35%). Admittedly, not all projects will be installed. Rather, they could be installed in order of cost effectiveness (pounds of pollution reduced per dollar spent). Other, larger sources of these pollutants to the lake exist too, and the community will need to balance the effectiveness of all project types.

This report provides conceptual sketches or photos of recommended stormwater retrofitting projects. The intent is to provide an understanding of the approach. If a project is selected, site-specific designs must be prepared. This typically occurs after committed partnerships are formed to install the project. Committed partnerships must include willing landowners when installed on private property.

The table below summarizes potential projects. Potential projects are organized from most cost effective to least, based on cost per pound of total phosphorus removed. The benefits of each project were estimated as if that project were installed alone with no other projects upstream of it in the same catchment. Reported treatment levels are dependent upon optimal siting and sizing. More detail about each project can be found in the catchment profile pages of this report. Projects that were deemed unfeasible due to prohibitive size, number, or were too expensive to justify installation are not included in the table below.

Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Total suspended solids (TSS) reduction is also shown. For more information on each project refer to the catchment profile pages later in this report.

Project ID	Catchment	Description (refer to catchment profile pages for more detail)	Location	Drainage Area (acres)	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Cost	Estimated cost/lb TP/year (30-year)
1	ML-3	Pond maintenance - excavate 1.5 ft.	East of 228th Pl. NE and W Martin Lake Dr. intersection	10.08	1.1	435	0.0	$3,930 - $5,990	$245 - $374
2	ML-2	Pond maintenance - excavate 1 ft.	East of 230th Ave. and W Martin Lake Dr. intersection	8.44	0.5	187	0.0	$2,696 - $3,940	$385 - $563
3	ML-5	Curb-cut rain garden	22529 W Martin Lake Dr.	1.29	0.7	225	0.4	$6,460	$437
4	ML-5	Curb-cut rain garden	22514 W Martin Lake Dr.	1.19	0.6	215	0.4	$6,460	$458
5	ML-2	Curb-cut rain garden	23003 W Martin Lake Dr.	1.86	0.5	156	0.4	$6,460	$570
6	ML-3	Curb-cut rain garden	22908 W Martin Lake Dr.	1.84	0.8	235	0.6	$10,960	$577
7	ML-2	Curb-cut rain garden	22964 W Martin Lake Dr.	1.61	0.5	144	0.4	$6,460	$616
8	ML-3	Curb-cut rain garden	Public parcel between 228th Pl. NE and 229th Ave. NE	1.32	0.5	141	0.4	$6,460	$638
9	ML-7	Curb-cut rain garden	23154 E Martin Lake Dr.	0.67	0.3	103	0.2	$6,460	$882
10	ML-7	Curb-cut rain garden	23136 E Martin Lake Dr.	0.48	0.3	78	0.2	$6,460	$1,159
11	ML-1	Curb-cut rain garden	23140 W Martin Lake Dr.	0.58	0.2	75	0.2	$6,460	$1,200
12	ML-1	Biofiltration swale	Public parcel N of 23131 W Martin Lake Dr.	0.50	0.2	67	0.2	$6,460	$1,358
13	ML-1-6	Vacuum assisted street sweeping (1 spring/1 fall)	Catchments ML-1, ML-2, ML-3, ML-4, ML-5, and ML-6	N/A	1.8	803	0.0	$2570/year	$1,390
14	ML-4	Biofiltration swale	Feather St. NE	3.91	0.1	22	0.1	$4,787	$6,127
15	ML-9,10,11	Lakeshore restorations	Catchments ML-9, ML-10, and ML-11	2.5 - 7.5	0.2 - 0.6	26 - 77	0.05 - 0.14	$63,710 - $186,510	$13,992 - $14,271
Totals				**36.3 - 41.3**	**8.3 - 8.7**	**2,912 - 2,963**	**3.55 - 3.64**	**$146,793 - $272,897**	

About this Document

This 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.

Document Organization

This document is organized into three major sections, plus references and appendices. Each section is briefly described below.

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.

Catchment Profiles

The area surrounding Martin Lake was divided into stormwater catchments for the purpose of this assessment. Each catchment was given a unique ID number. For each catchment, the following information is detailed:

Catchment Description

Within each catchment profile is a table that summarizes basic catchment information including acres, land cover, parcels, and estimated annual pollutant and volume loads. A brief description of the land cover, stormwater infrastructure, and any other important general information is also described here. Existing stormwater practices are noted, and their estimated effectiveness presented.

Retrofit Recommendations

The recommendation section describes the conceptual retrofit(s) that were scrutinized. It includes tables outlining the estimated pollutant removals by each, as well as costs. A map provides promising locations for each retrofit approach.

Retrofit Ranking

This section ranks stormwater retrofit projects across all catchments to create a prioritized project list. The list is sorted by cost per pound of phosphorus removed for each project over a duration of 30 years. The final cost per pound treatment value includes installation and maintenance costs.

There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point. Other considerations for prioritizing installation may include:

- Non-target pollutant reductions
- Timing projects to occur with other road or utility work
- Project visibility
- Availability of funding
- Total project costs
- Educational value

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 during the assessment.

Methods

Selection of Subwatershed

Many factors are considered when choosing which subwatershed to assess for stormwater retrofits. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Assessments supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the assessment also rank highly. For some communities a stormwater assessment complements their MS4 stormwater permit. The focus is always on a high priority waterbody.

For this assessment, neighborhoods which drain directly to Martin Lake were chosen for study. This work was outlined in the Sunrise River Watershed Management Plan. It is also consistent with the Total Maximum Daily Load (TMDL) study for Martin Lake. Martin Lake is a high priority because of its potential recreational and fisheries value, serious water quality impairments, and because improvements at Martin Lake will also benefit downstream waterbodies including the Sunrise River and St. Croix River, which are also impaired.

This study recognizes that while stormwater is an important contributor of pollutants to Martin Lake, it is not the only one, nor anywhere close to being the largest. Other sources, as identified in the TMDL study, actually contribute much more phosphorus and solids to Martin Lake. Sadly, we cannot expect to make Martin Lake compliant with state water quality standards by addressing the biggest pollutant sources alone; the TMDL study figures a very large (41%) reduction in phosphorus is needed. Some of the sources are difficult to address. We must do our best to attack every pollutant source in order to make meaningful improvement. Therefore, improvements to stormwater treatment should be pursued. Many stormwater retrofits are “low hanging fruit” - relatively easy projects that will collectively improve the lake in small but measurable ways.

Areas draining directly to Martin Lake – Because many of these areas were built before modern-day stormwater treatment technologies and requirements, treatment before discharge into Martin Lake is limited. Sediment loading to the lake is high (left) and existing practices can quickly become overwhelmed (right).

Subwatershed Assessment Methods

The process used for this assessment is outlined below and was modified from the Center for Watershed Protection's *Urban Stormwater Retrofit Practices,* Manuals 2 and 3 (Schueler, 2005, 2007). Locally relevant design considerations were also incorporated 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 management organization members 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 focus area may be determined.

In this assessment, the focus area was all areas that drain directly to Martin Lake through stormwater conveyances. This restricts the study area to neighborhoods immediately surrounding the lake, and encompasses the areas of highest density development in the lake's watershed. We divided this area into 11 catchments using a combination of stormwater infrastructure maps and observed topography. In areas where topography seemed flat, catchments were delineated by observing the direction of water flow during rainfall. Later in the study, some of these catchments were combined because they were adjacent and did not drain to the lake through stormwater conveyances and therefore few, if any, stormwater retrofits would be recommended.

Targeted pollutants for this study were total phosphorus and total suspended solids. Total phosphorus was chosen because the lake exceeds state water quality standards for phosphorus. This nutrient fuels algae blooms that plague Martin Lake. Total suspended solids was also chosen as a target pollutant because it contributes to lake turbidity and many other pollutants, such as heavy metals, are transported by these particles. Volume of stormwater was tracked throughout this study because it is necessary for pollutant loading calculations and potential retrofit project considerations.

Step 2: Desktop Retrofit Analysis

The desktop analysis involves computer-based scanning of the subwatershed for potential retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure. Accurate GIS data are 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 the storm drainage infrastructure (with invert elevations).

For this assessment, paper records of stormwater infrastructure were obtained from Linwood Township, and much of this was digitized into GIS. These files will be provided to the Township, and will help them meet stormwater mapping requirements of the state and watershed management organization. High-resolution aerial photography and parcel boundaries were available from Anoka County. Unfortunately, fine topography data was not available.

Desktop retrofit analysis features to look for and associated potential stormwater retrofit projects.

Feature	Potential Retrofit Project
Existing Ponds	Add storage and/or improve water quality by excavating pond bottom, modifying riser, raising embankment, and/or modifying flow routing.
Open Space	New regional treatment (pond, bioretention).
Roadway Culverts	Add wetland or extended detention water quality treatment upstream.
Outfalls	Split flows or add storage below outfalls if open space is available.
Conveyance system	Add or improve performance of existing swales, ditches and non-perennial streams.
Large Impervious Areas (campuses, commercial, parking)	Stormwater treatment on site or in nearby open spaces.
Neighborhoods	Utilize right of way, roadside ditches, curb-cut rain gardens, 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 and identify additional opportunities. During the investigation, the drainage area and stormwater infrastructure mapping data were verified. Site constraints were assessed to determine the most feasible retrofit options as well as eliminate sites from consideration. The field investigation may have also revealed additional retrofit opportunities that could have gone unnoticed during the desktop search.

General list of stormwater BMPs considered for each catchment/site.

Stormwater Treatment Options for Retrofitting		
Area Treated	Best Management Practice	Potential Retrofit Project
5-500 acres	Extended Detention	12-24 hr detention of stormwater with portions drying out between events (preferred over wet ponds). May include multiple cell design, infiltration benches, sand/peat/iron filter outlets and modified choker outlet features.
	Wet Ponds	Permanent pool of standing water with new water displacing pooled water from previous event.
	Wetlands	Depression less than 1-meter deep and designed to emulate wetland ecological functions. Residence times of several days to weeks. Best constructed off-line with low-flow bypass.
0.1-5 acres	Bioretention	Use of native sol, soil microbe and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.

	Filtering	**Filter runoff through engineered media and passing it through an under-drain. May consist of a combination of sand, soil, compost, peat, and iron.**
	Infiltration	**A trench or sump that is rock-filled with no outlet that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering infiltration area.**
	Swales	**A series of vegetated, open channel practices that can be designed to filter and/or infiltrate runoff.**
	Other	**On-site, source-disconnect practices such as rain-leader disconnect rain gardens, rain barrels, green roofs, cisterns, stormwater planters, dry wells, or permeable pavements.**

Step 4: Treatment Analysis/Cost Estimates

Sites most likely to be conducive to addressing the Township and Sunrise River WMO's goals and appear to have simple-to-moderate design, installation, and maintenance were chosen for a cost/benefit analysis. Estimated costs included design, installation, and maintenance annualized across a 30-year period. Estimated benefits included are pounds of phosphorus and total suspended solids removed, though projects were ranked only by cost per pound of phosphorus removed annually.

Treatment analysis

Each proposed project's pollutant removal estimates were obtained using the stormwater model WinSLAMM. WinSLAMM uses an abundance of stormwater data from the upper Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It is useful for determining the effectiveness of proposed stormwater control practices. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model "landscape" that reflects the actual landscape being considered. The user is allowed to place a variety of stormwater treatment practices that treat water from various parts of this landscape. It uses rainfall and temperature data from a typical year, routing stormwater through the user's model for each storm.

A "base" model was created which estimated pollutant loading from each catchment in its present-day state. To accurately model the land uses in each catchment, we delineated each land use in each catchment using ArcGIS, and assigned each a WinSLAMM standard land use file. A site specific land use file was created by adjusting total acreage and converting to "sand" soils to account for the sandy soils in Linwood Township. For catchments with multiple standard land use files, these were combined using the software's batch processing capability. This process resulted in a model that included estimates of the acreage of each type of source area (roof, road, lawn, etc.) in each catchment. For certain source areas critical to our models we verified that model estimates were accurate by calculating actual acreages in ArcGIS, and adjusting the model acreages if needed.

Once the "base" model was created, each proposed stormwater treatment practice was added to the model and pollutant reductions were generated. Because neither a detailed design of each practice nor in-depth site investigation was completed, a generalized design for each practice was used. Whenever possible, site-specific parameters were included. Design parameters were modified to obtain various levels of treatment. It is worth noting that we modeled each practice individually, and the benefits of projects may not be additive, especially if serving the same area. Reported treatment levels are dependent upon optimal site selection and sizing.

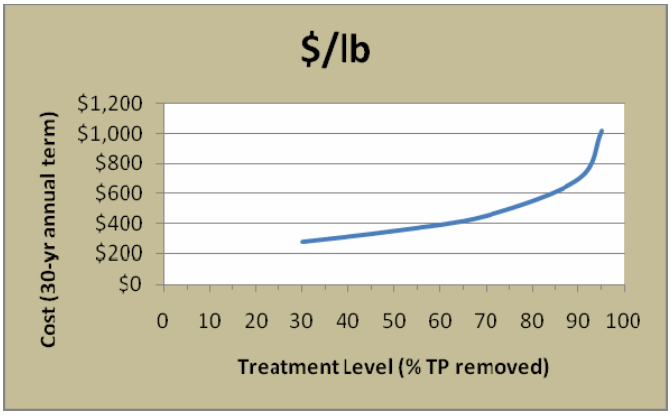
WinSLAMM stormwater computer model inputs

General WinSLAMM Model Inputs	
Parameter	**File/Method**
Land use acreage	ArcGIS
Precipitation/Temperature Data	Minneapolis 1959 – the rainfall year that best approximates a typical year.
Winter season	Included in model. Winter dates are 11-4 to 3-13.
Pollutant probability distribution	WI_GEO01.ppd
Runoff coefficient file	WI_SL06 Dec06.rsv
Particulate solids concentration file	WI_AVG01.psc
Particle residue delivery file	WI_DLV01.prr
Street delivery files	WI files for each land use.

Cost Estimates

Cost estimates were annualized costs that incorporated design, installation, installation oversight, and maintenance over a 30-year period. In cases where promotion to landowners is important, such as rain gardens, those costs were included as well. In cases where multiple, similar projects are proposed in the same locality, promotion and administration costs were estimated using a non-linear relationship that accounted for savings with scale. Design assistance from an engineer is assumed for practices in-line with the stormwater conveyance system, involving complex stormwater treatment interactions, or posing a risk for upstream flooding. It should be understood that no site-specific construction investigations were done as part of this stormwater assessment, and therefore cost estimates account for only general site considerations.

The costs associated with several different pollution reduction levels were calculated. Generally, more or larger practices result in greater pollution removal. However the costs of obtaining the highest levels of treatment are often prohibitively expensive (see figure). By comparing costs of different treatment levels, the township and watershed organization can best choose the project sizing that meets their goals.



Step 5: Evaluation and Ranking

The cost per pound of phosphorus treated was calculated for each potential retrofit project. Only projects that seem realistic and feasible were considered. The recommended level was the level of treatment that would yield the greatest benefit per dollar spent while being considered feasible and not falling below a minimal amount needed to justify crew mobilization and outreach efforts. Local officials may wish to revise the recommended level based on water quality goals, finances, or public opinion.

Catchment Profiles

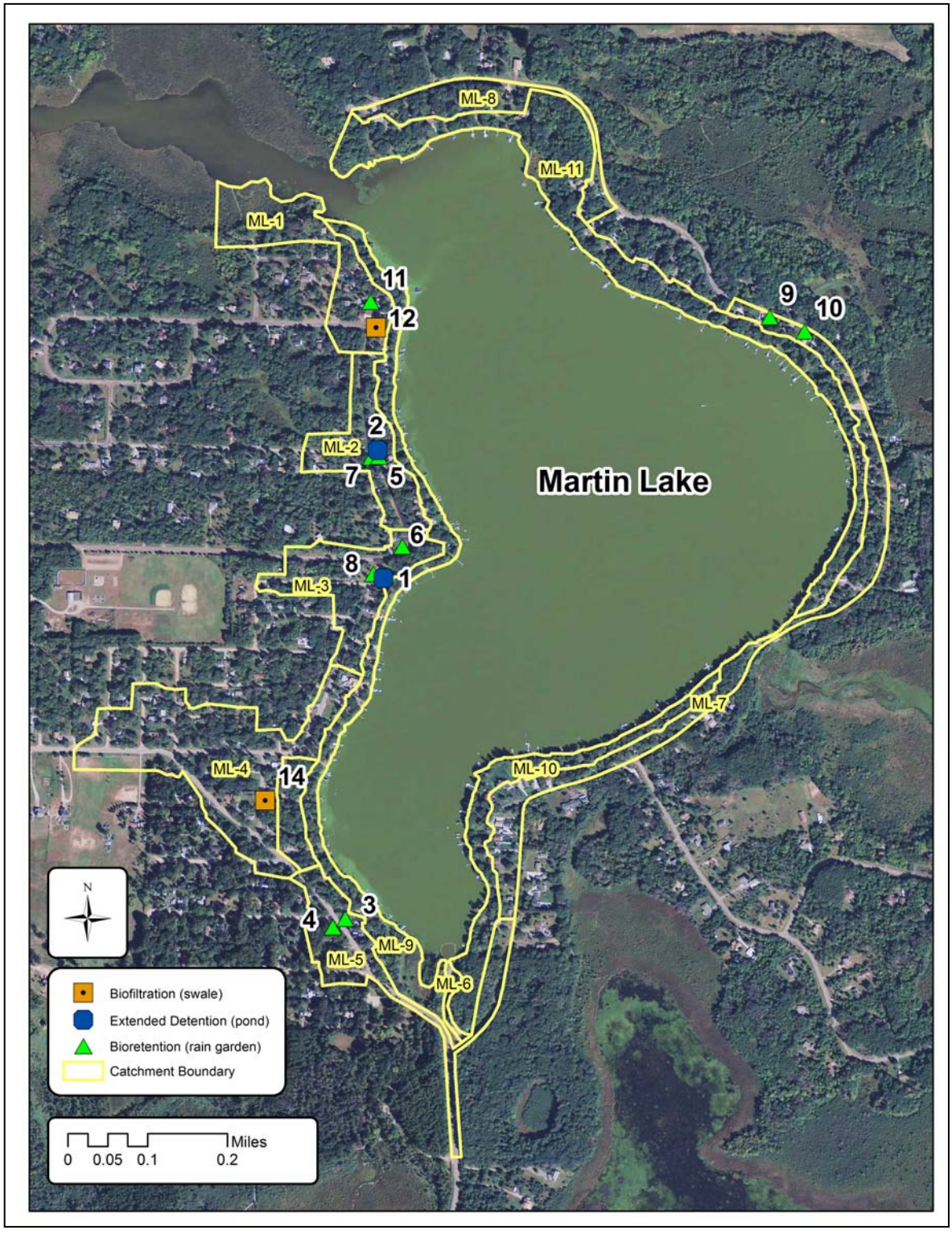
The following pages provide information for each stormwater catchment area analyzed. Each catchment profile includes:

- Summary of existing conditions, including existing stormwater infrastructure, and estimated pollutant export to Martin Lake
- Map of the catchment
- Recommended stormwater retrofits, pollutant reductions, and costs.

Catchment profiles are provided for the eleven catchments analyzed. Please refer to the catchment summary map on the following page.

Following all of the catchment profiles is a summary table that ranks all projects in all catchments by cost effectiveness.

Map of stormwater catchment areas (ML-1 thru ML-11) and potential retrofit projects referred to in this report. The numbers next to each potential project represent ranking with respect to the cost per pound of total phosphorus removed per year. Catchment profiles on the following pages provide additional detail.



Catchment ML-1

Existing Catchment Summary	
Acres	10.95
Dominant Land Cover	Residential
Parcels	27
Volume (acre-feet/yr)	2.33
TP (lb/yr)	3.30
TSS (lb/yr)	985.87

CATCHMENT DESCRIPTION

Catchment ML-1 is primarily comprised of medium density, single-family residential development. It also includes a few acres of open space.

EXISTING STORMWATER TREATMENT

There are no existing stormwater treatment practices within ML-1. The series of five catch basins and associated storm sewer pipes channel stormwater runoff directly to Martin Lake. Existing pollutant loads from this catchment to Martin Lake are shown in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	3.3	0.0	0%	**3.3**
	TSS (lb/yr)	986	0.0	0%	**986**
	Volume (acre-feet/yr)	2.3	0.0	0%	**2.3**
	Number of BMP's	0			
	BMP Size/Description	Not Applicable			

RETROFIT RECOMMENDATIONS

***Proposed Project 11* -** Curb-cut Rain Garden
Drainage Area - 0.58 acres
***Location* -** 23140 West Martin lake Drive
***Property Ownership* –** Private
***Description* –** Curb-cut rain garden immediately up-gradient of the catch basin. The rain garden will collect and infiltrate all curbside flows until it fills. When the rain garden is full, water will bypass to the catch basin. A project at this site would require removal of an existing chain link fence. See Appendix A for rain garden design options.
***Conceptual images* -**


Before


After

***Proposed Project 12* -** Biofiltration Swale
Drainage Area - 0.50 acres
***Location* -** Public parcel north of 23131 West Martin Lake Drive
***Property Ownership* –** Linwood Township
***Description* –** The curb would be cut to allow curbside flows to travel down the length of the existing township easement toward the lake, rather than piped through the storm sewer into the lake with no treatment. Along the flow path there could be two or more small earthen berms to allow settling and infiltration, while preventing erosion.
***Conceptual images* -**


Before


After

***Proposed Projects 11* & 12-** Curb-cut Rain Gardens
Drainage Area - 1.08 acres
Description - Installation of both projects simultaneously results in the lowest cost per pound of total phosphorus removed (see table below). In addition, efficiency of the construction process will be maximized because of the close proximity of the two rain gardens to one another. Different areas drain to each of the projects, so volume reduction and pollutant treatment are not redundant.

	Cost/Benefit Analysis	Project ID					
		12		11		11 & 12	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	0.2	6%	0.2	7%	0.5	14%
	TSS (lb/yr)	67	7%	75	8%	142	14%
	Volume (acre-feet/yr)	0.2	6%	0.2	7%	0.3	14%
	Number of BMP's	1		1		2	
	BMP Size/Description	250 sq ft		250 sq ft		500 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$4,710		$4,710		$9,210	
	Promotion & Admin Costs	$1,750		$1,750		$1,890	
	Total Project Cost	$6,460		$6,460		$11,100	
	Annual O&M	$75		$75		$150	
	Term Cost/1,000lb-TSS/yr	$4,361		$3,847		$3,660	
	Term Cost/lb-TP/yr	**$1,358**		**$1,200**		**$1,141**	

Catchment ML-2

Existing Catchment Summary	
Acres	8.44
Dominant Land Cover	Residential
Parcels	41
Volume (acre-feet/yr)	3.27
TP (lb/yr)	3.69
TSS (lb/yr)	1082.71

DESCRIPTION

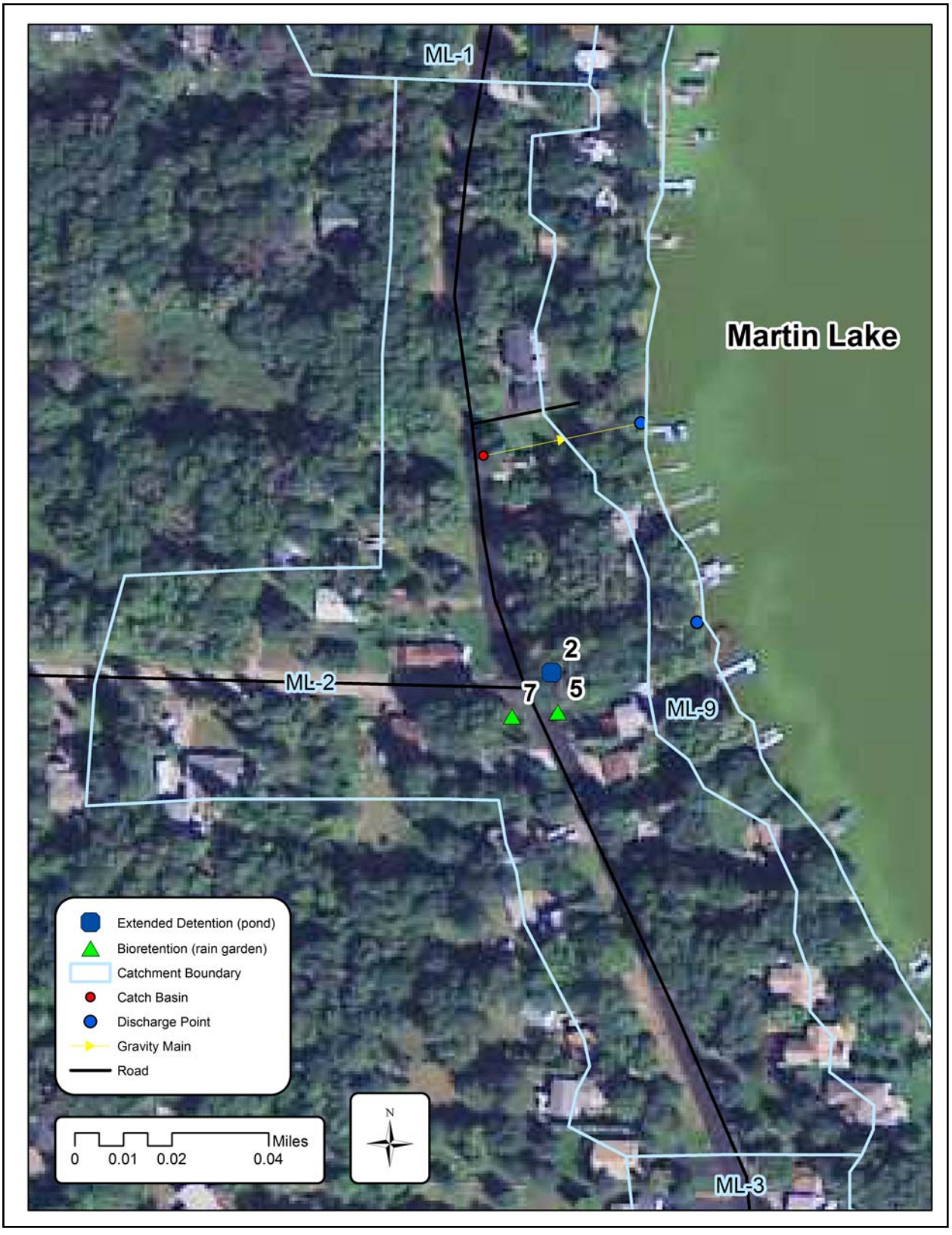
Catchment ML-2 is primarily comprised of medium density, single-family residential development.

EXISTING STORMWATER TREATMENT

One existing stormwater pond is located in ML-2 (photo to right), within a township easement. It was recently renovated and is located directly east of the intersection of 230th Avenue and Martin Lake Drive West. It has a concrete swale inlet. When the small basin fills, water overflows across a cable concrete berm and then travels less than 100 feet through a narrow channel into the lake. An average one foot water depth was measured across the small basin, and significant accumulation of sediment within the pond was observed. This basin is well sited and uses the small available space well. However, it is overwhelmed by sediment and flows. Pre-treatment or additional treatment upstream is advised, along with more frequent sediment removal to maintain the basin's performance.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	4.3	0.6	15%	**3.7**
	TSS (lb/yr)	1,335	252.8	19%	**1,083**
	Volume (acre-feet/yr)	3.3	0.0	0%	**3.3**
	Number of BMP's	1			
	BMP Size/Description	Outfall Pond			

RETROFIT RECOMMENDATIONS



Proposed Project 5 **-** Curb-cut Rain Garden
Drainage Area - 1.86 acres
Location **-** 23003 West Martin Lake Drive
Property Ownership – Private
Description – Curb-cut rain garden immediately up-gradient of the existing stormwater basin. When the rain garden is full, water will bypass to the catch basin. This rain garden will reduce the load on the existing outfall basin, boosting its performance. The rain garden itself will also provide pollutant reduction through infiltration. There are concerns that the home's septic system drainfield may extend into the proposed rain garden area, which would make this project unfeasible. See Appendix A for rain garden design options.
Conceptual images **-**

Before

After

Proposed Project 7 **-** Curb-cut Rain Garden
Drainage Area - 1.61 acres
Location **-** 22964 West Martin Lake Drive
Property Ownership – Private
Description – Curb-cut rain garden immediately up-gradient of the existing stormwater basin. When the rain garden is full, water will bypass to the catch basin. This rain garden will reduce the load on the existing outfall basin, boosting its performance. The rain garden itself will also provide pollutant reduction through infiltration. See Appendix A for rain garden design options.
Conceptual images **-**

Before

After

Proposed Projects 5 & 7- Curb-cut Rain Gardens
Drainage Area - 3.47 acres
Description - Installation of both projects simultaneously results in the lowest cost per pound of total phosphorus removed (see table below). In addition, efficiency of the construction process will be maximized because of the close proximity of the two rain gardens to one another. Different areas drain to each of the projects, so volume reduction and pollutant treatment are not redundant.

	Cost/Benefit Analysis	Project ID					
		7		5		7 & 5	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	0.5	26%	0.5	26%	1.0	37%
	TSS (lb/yr)	144	30%	156	31%	300	41%
	Volume (acre-feet/yr)	0.4	12%	0.4	13%	0.8	25%
	Number of BMP's	1		1		2	
	BMP Size/Description	250 sq ft		250 sq ft		500 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$4,710		$4,710		$9,210	
	Promotion & Admin Costs	$1,750		$1,750		$1,890	
	Total Project Cost	$6,460		$6,460		$11,100	
	Annual O&M	$75		$75		$150	
	Term Cost/1,000lb-TSS/yr	$2,013		$1,858		$1,736	
	Term Cost/lb-TP/yr	**$616**		**$570**		**$531**	

Proposed Project 2 - Pond Maintenance
Drainage Area - 8.44 acres
Location - East of 230th Ave. and West Martin Lake Drive intersection
Property Ownership – Linwood Township
Description – The existing stormwater pond treating ML-2 has accumulated significant amounts of sediment. This has reduced the stormwater treatment volume within the basin. Even when new, this basin was never deep enough to offer significant pollutant settling. Settling that does occur is mostly scoured out and into the lake by high flows during intense storms. This basin can only serve a useful purpose if accumulated sediment is regularly removed from it. Deep excavation is not possible because it would create steep side slopes on such a small pond. However, dredging one foot of accumulated sediment is feasible, and would probably return the pond to a like-new condition. It would increase the effectiveness of the pond.

Part of the costs of a one foot excavation will be determined by the allowable uses of the dredged material. Contamination tests will determine allowable uses. The table on the following page analyzes the project under three different scenarios for dredged material disposal, including:

Level 1 Material Disposal - Dredged material suitable for fill or reuse on residential or recreational sites.

Level 2 Material Disposal - Dredged material suitable for fill or reuse on industrial properties.

Level 3 Material Disposal - Dredged material significantly contaminated and must be managed for specific contaminants present.

	Cost/Benefit Analysis	Project ID					
		2		2		2	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	0.5	25%	0.5	25%	0.5	25%
	TSS (lb/yr)	187	33%	187	33%	187	33%
	Volume (acre-feet/yr)	0.0	0%	0.0	0%	0.0	0%
	Number of BMP's	1 - Pond excavated 1 ft. (Level 1 Material)		1 - Pond excavated 1 ft. (Level 2 Material)		1 - Pond excavated 1 ft. (Level 3 Material)	
	BMP Size/Description	34 cubic yards		34 cubic yards		34 cubic yards	
	BMP Type	Wet Pond		Wet Pond		Wet Pond	
Cost	Materials/Labor/Design	$1,016		$1,360		$1,700	
	Promotion & Admin Costs	$1,680		$1,960		$2,240	
	Total Project Cost	$2,696		$3,320		$3,940	
	Annual O&M	$90		$111		$131	
	Term Cost/1,000lb-TSS/yr	$962		$1,185		$1,406	
	Term Cost/lb-TP/yr	**$385**		**$474**		**$563**	

Catchment ML-3

Existing Catchment Summary	
Acres	10.08
Dominant Land Cover	Residential
Parcels	36
Volume (acre-feet/yr)	4.02
TP (lb/yr)	4.89
TSS (lb/yr)	1457.40

DESCRIPTION

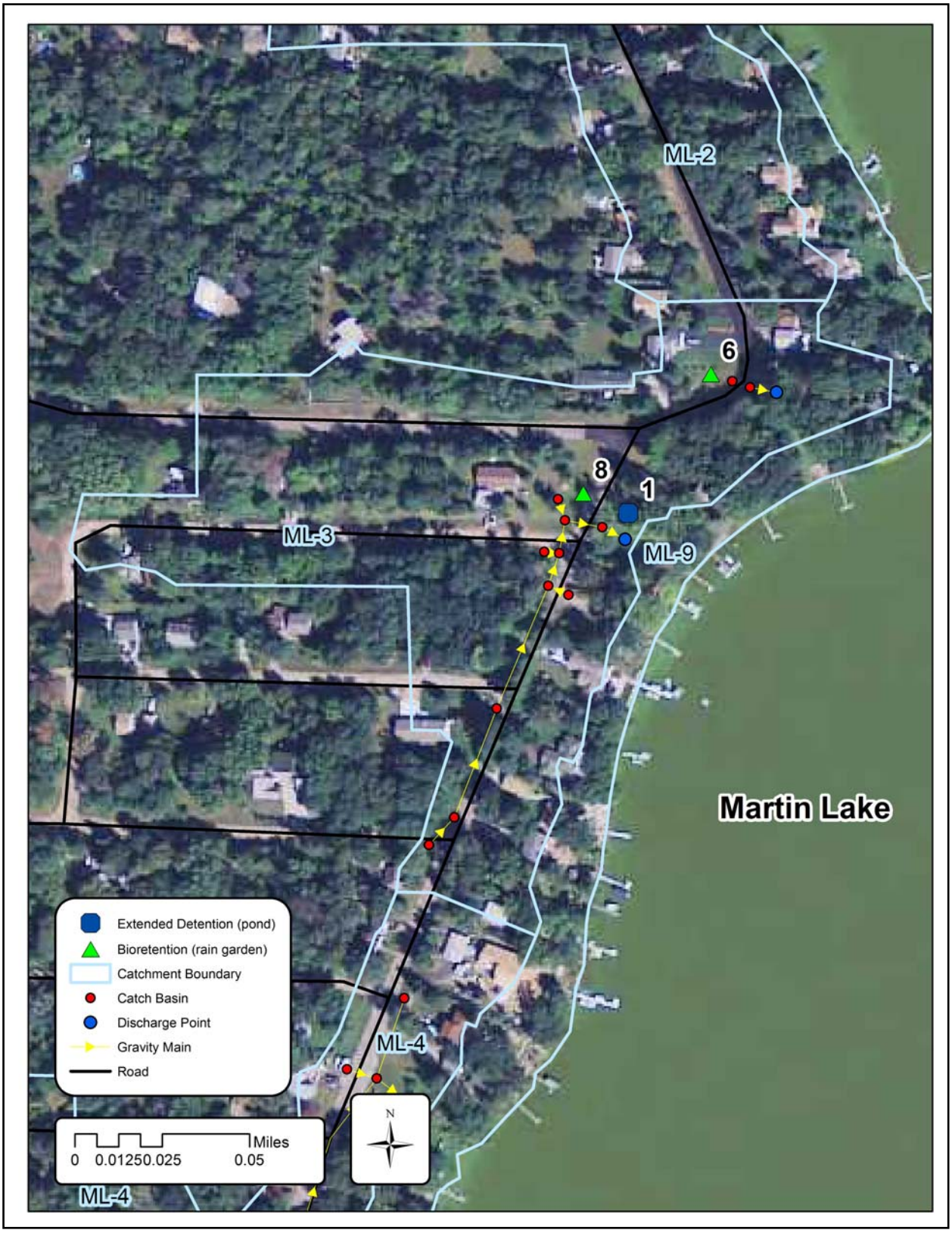
Catchment ML-3 is primarily comprised of medium density, single-family residential development.

EXISTING STORMWATER TREATMENT

One existing stormwater pond is within ML-3 (right) and included in the modeling. The pond is located east of the intersection between 228th Place NE and Martin Lake Dr. W. Water enters the pond through a flared end section pipe, and a narrow channel downstream of the overflow allows water to enter the lake following storm events. An average one foot water depth was measured across the small pond, and significant accumulation of sediment within the pond was observed. The pond is heavily vegetated, primarily with cattails, and it was therefore modeled as a "wet pond."

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	5.8	1.0	16%	**4.9**
	TSS (lb/yr)	1,848	390.1	21%	**1,457**
	Volume (acre-feet/yr)	4.0	0.0	0%	**4.0**
	Number of BMP's	1			
	BMP Size/Description	Outfall Pond			

RETROFIT RECOMMENDATIONS



Proposed Project 6 **-** Curb-cut Rain Garden
Drainage Area - 1.84 acres
Location **-** 22908 West Martin Lake Drive
Property Ownership **–** Private
Description **–** Curb-cut rain garden immediately up-gradient of the existing stormwater basin. The large space available at this particular site allowed for a rain garden twice the typical size (500 sq. ft. rather than 250 sq. ft.). A riser would need to be added to the existing culvert on the upstream side of the road. The top of that riser would serve as the emergency overflow. The rain garden will provide pollutant reduction through infiltration. See Appendix A for rain garden design options.
Conceptual images **-**

Before

After

Proposed Project 8 **-** Curb-cut Rain Garden
Drainage Area - 1.32 acres
Location **-** Public parcel between 228th Place NE and 229th Ave. NE
Property Ownership **–** Linwood Township
Description **–** Curb-cut rain garden immediately up-gradient of the existing stormwater basin. When the rain garden is full, water will bypass to the catch basin. This rain garden will reduce the load on the existing outfall basin, boosting its performance. The rain garden itself will also provide pollutant reduction through infiltration. See Appendix A for rain garden design options.
Conceptual images **-**

Before

After

Proposed Projects 6 **& 8-** Curb-cut Rain Gardens
Drainage Area - 3.16 acres
Description - Installation of both projects simultaneously results in the lowest cost per pound of total phosphorus removed (see table below). In addition, efficiency of the construction process will be maximized because of the close proximity of the two rain gardens to one another. Different areas drain to each of the projects, so volume reduction and pollutant treatment are not redundant.

	Cost/Benefit Analysis	Project ID					
		6		8		6 & 8	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	0.8	29%	0.5	24%	1.2	37%
	TSS (lb/yr)	235	34%	141	29%	378	42%
	Volume (acre-feet/yr)	0.6	15%	0.4	9%	0.9	24%
	Number of BMP's	1		1		2	
	BMP Size/Description	500 sq ft		250 sq ft		750 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$9,210		$4,710		$13,710	
	Promotion & Admin Costs	$1,750		$1,750		$1,890	
	Total Project Cost	$10,960		$6,460		$15,600	
	Annual O&M	$75		$75		$150	
	Term Cost/1,000lb-TSS/yr	$1,872		$2,058		$1,774	
	Term Cost/lb-TP/yr	**$577**		**$638**		**$547**	

Proposed Project 1 - Pond Maintenance
Drainage Area - 10.08 acres
Location - East of 228th Place NE and West Martin Lake Drive intersection
Property Ownership – Linwood Township
Description – The existing stormwater pond treating ML-3 has accumulated significant amounts of sediment. This has reduced the stormwater treatment volume within the basin. Even when new, this basin was never deep enough to offer significant pollutant settling. Settling that does occur is mostly scoured out and into the lake by high flows during intense storms. This basin can only serve a useful purpose if accumulated sediment is regularly removed from it. Deep excavation is not possible because it would create steep side slopes on such a small pond. However, dredging 1.5 feet of accumulated sediment is feasible, and would probably return the pond to a like-new condition. It would increase the effectiveness of the pond.

Part of the costs of a 1.5 foot excavation will be determined by the allowable uses of the dredged material. Contamination tests will determine allowable uses. The table on the following page analyzes the project under three different scenarios for dredged material disposal, including:

Level 1 Material Disposal - Dredged material suitable for fill or reuse on residential or recreational sites.

Level 2 Material Disposal - Dredged material suitable for fill or reuse on industrial properties.

Level 3 Material Disposal - Dredged material significantly contaminated and must be managed for specific contaminants present.

	Cost/Benefit Analysis	Project ID					
		1		1		1	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	1.1	35%	1.1	35%	1.1	35%
	TSS (lb/yr)	435	45%	435	45%	435	45%
	Volume (acre-feet/yr)	0.0	0%	0.0	0%	0.0	0%
	Number of BMP's	1 - Pond excavated 1.5 ft. (Level 1 Material)		1 - Pond excavated 1.5 ft. (Level 2 Material)		1 - Pond excavated 1.5 ft. (Level 3 Material)	
	BMP Size/Description	75 cubic yards		75 cubic yards		75 cubic yards	
	BMP Type	Wet Pond		Wet Pond		Wet Pond	
Cost	Materials/Labor/Design	$2,250		$3,000		$3,750	
	Promotion & Admin Costs	$1,680		$1,960		$2,240	
	Total Project Cost	$3,930		$4,960		$5,990	
	Annual O&M	$131		$165		$200	
	Term Cost/1,000lb-TSS/yr	$602		$760		$918	
	Term Cost/lb-TP/yr	**$245**		**$309**		**$374**	

Catchment ML-4

Existing Catchment Summary	
Acres	22.78
Dominant Land Cover	Residential
Parcels	82
Volume (acre-feet/yr)	8.43
TP (lb/yr)	7.27
TSS (lb/yr)	1858.28

DESCRIPTION

Catchment ML-4 is the largest individual catchment within the assessment. It also contains the most elaborate stormwater infrastructure. It is primarily medium density, single-family residential.

EXISTING STORMWATER TREATMENT

One existing stormwater pond exists (left image) and was included in the modeling. The pond is located between 227th Lane and Martin Lake Dr. W. Water enters the pond through a flared end section pipe, and a cable concrete berm serves as the overflow. Discharge is into Martin Lake.

Measured water depths in the pond averaged approximately two feet, and accumulation of sediment near the inlet was observed. However, the overall pond volume today is similar to when the pond was originally constructed. The lack of significant sediment accumulation reflects the poor pollutant removal and retention by the pond. Additional excavation is not practical in such a small basin, as it would result in steep side slopes.

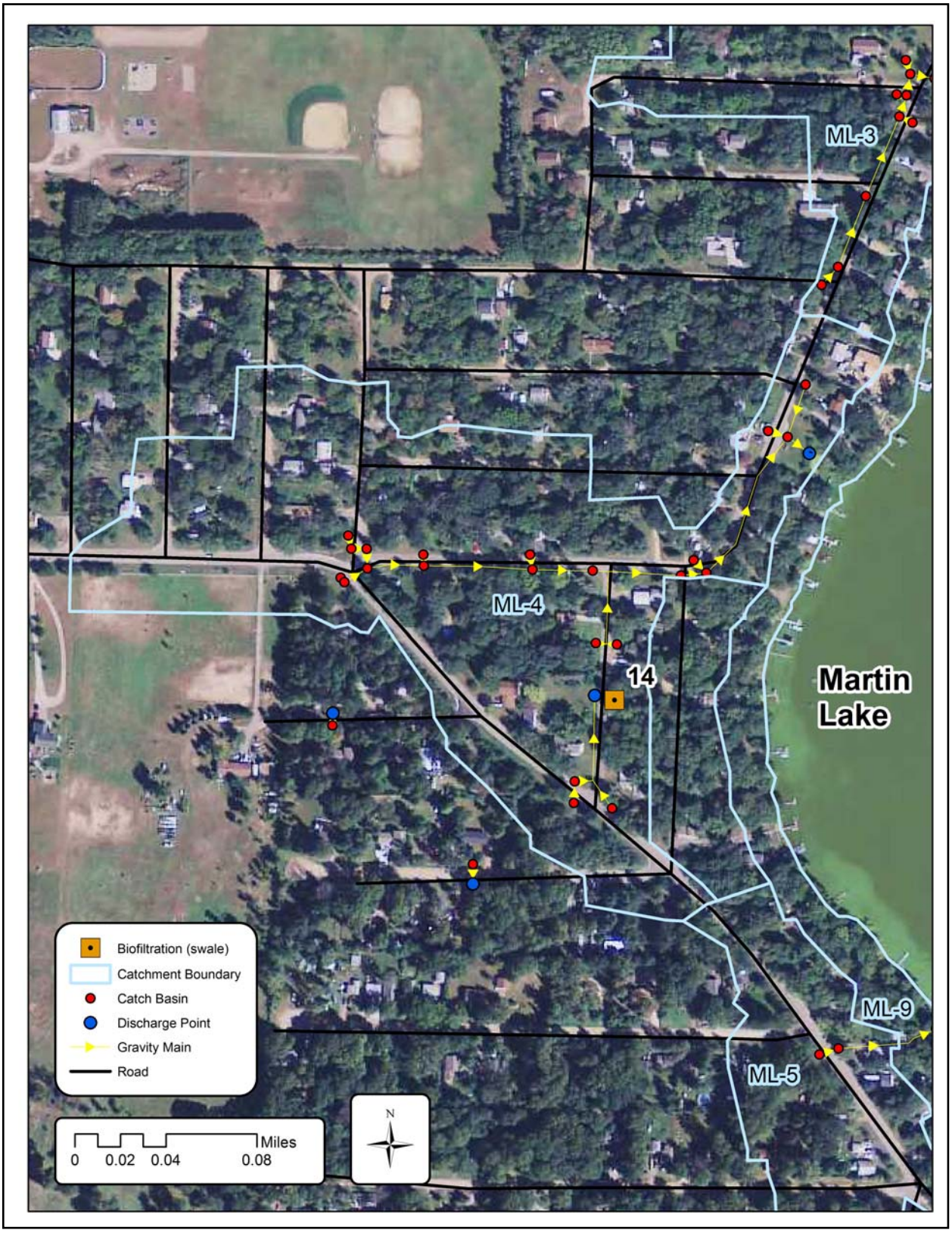
Additionally, two vegetated swales (right image) exist along Feather St. NE. The two swales were modeled as “grass swale drainage controls”.

WinSLAMM model results suggest 2,218 pounds of total suspended solids (TSS) are removed annually by the existing stormwater pond and vegetated swales. However, no evidence of this large volume of sediment was document during field observations. Therefore, the existing practices are not likely functioning as well as the model predicts. One possible explanation for this discrepancy is that the shallow profile of the small stormwater pond results in scouring and sediment resuspension during large rainfall events. While sediment and pollutants may settle out in the pond during smaller storms, during larger storms the accumulated sediment may enter the lake.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	13.0	5.7	44%	**7.3**
	TSS (lb/yr)	4,076	2,218.0*	54%	**1,858**
	Volume (acre-feet/yr)	9.3	0.9	10%	**8.4**
	Number of BMP's	3			
	BMP Size/Description	Outfall Pond, Vegetated Swales			

*Modeled treatment of total suspended solids (TSS) may be greater than actual conditions based upon field observations. See potential explanation in previous section of text.

RETROFIT RECOMMENDATIONS



Proposed Project 14 - Biofiltration Swale
Drainage Area - 3.91 acres
Location - Feather St. NE
Property Ownership – Linwood Township
Description – The existing biofiltration swale would be enhanced by installing check dams and vegetation that will slow water as it travels through the swale. This will allow sedimentation and pollutant removal, as well as the opportunity for some infiltration. Aesthetically, the appearance of the roadside ditch could be improved by the planting of low-maintenance, native shrubs within the swale. These shrubs would increase infiltration.
Conceptual images -

Before

After

	Cost/Benefit Analysis	Project ID					
		14					
		New trtmt	Net trtmt %				
Treatment	TP (lb/yr)	0.1	45%				
	TSS (lb/yr)	22	55%				
	Volume (acre-feet/yr)	0.1	10%				
	Number of BMP's	4					
	BMP Size/Description	213 sq ft					
	BMP Type	Simple Bioretention					
Cost	Materials/Labor/Design	$2,617					
	Promotion & Admin Costs	$2,170					
	Total Project Cost	$4,787					
	Annual O&M	$300					
	Term Cost/1,000lb-TSS/yr	$20,652					
	Term Cost/lb-TP/yr	**$6,127**					

Catchment ML-5

Existing Catchment Summary	
Acres	10.02
Dominant Land Cover	Residential
Parcels	30
Volume (acre-feet/yr)	4.52
TP (lb/yr)	7.02
TSS (lb/yr)	2298.63

DESCRIPTION

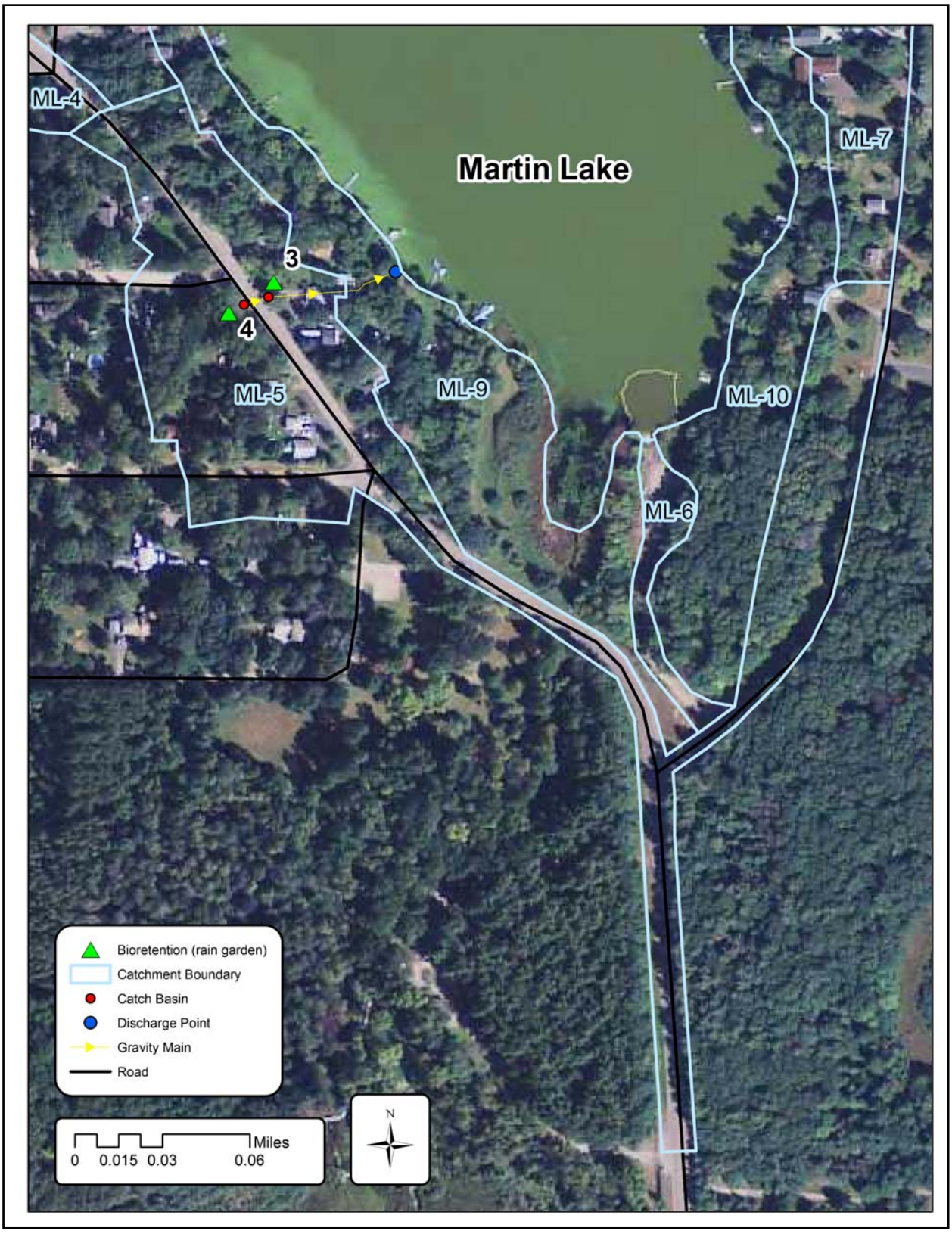
Catchment ML-5 is positioned along the south west side of Martin Lake. The catchment is primarily comprised of medium density, single-family residential development.

EXISTING STORMWATER TREATMENT

There are no existing stormwater treatment practices within ML-5. The two existing catch basins and associated storm sewer pipes channel stormwater runoff directly to Martin Lake. There is also a concrete swale that redirects a portion of the catchment's runoff toward a small wetland that borders the lake. Existing pollutant loads from this catchment to Martin Lake are shown in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	7.0	0.0	0%	**7.0**
	TSS (lb/yr)	2,299	0.0	0%	**2,299**
	Volume (acre-feet/yr)	4.5	0.0	0%	**4.5**
	Number of BMP's	0			
	BMP Size/Description	Not Applicable			

RETROFIT RECOMMENDATIONS



Proposed Project 3- Curb-cut Rain Garden
Drainage Area - 1.29 acres
Location - 22529 West Martin Lake Drive
Property Ownership – Private
Description – Curb-cut rain garden immediately up-gradient of the existing stormwater basin. When the rain garden is full, water will bypass to the catch basin. The rain garden will provide pollutant reduction through infiltration. See Appendix A for rain garden design options.
Conceptual images -

Before

After

Proposed Project 4 - Curb-cut Rain Garden
Drainage Area - 1.19 acres
Location - 22514 West Martin Lake Drive
Property Ownership – Private
Description – Curb-cut rain garden immediately up-gradient of the existing stormwater basin. Inlets on both sides of the catch basin are possible, and would result in the rain garden treating a larger drainage area. When the rain garden is full, water will bypass to the catch basin. The rain garden will provide pollutant reduction through infiltration. See Appendix A for rain garden design options.
Conceptual images -

Before

After

Proposed Projects 3 & 4- Curb-cut Rain Gardens
Drainage Area - 2.48 acres
Description - Installation of both projects simultaneously results in the lowest cost per pound of total phosphorus removed (see table below). In addition, efficiency of the construction process will be maximized because of the close proximity of the two rain gardens to one another. Different areas drain to each of the projects, so volume reduction and pollutant treatment are not redundant.

	Cost/Benefit Analysis	Project ID					
		4		3		4 & 3	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	0.6	9%	0.7	9%	1.3	18%
	TSS (lb/yr)	215	9%	225	10%	440	19%
	Volume (acre-feet/yr)	0.4	8%	0.4	9%	0.8	17%
	Number of BMP's	1		1		2	
	BMP Size/Description	250 sq ft		250 sq ft		500 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$4,710		$4,710		$9,210	
	Promotion & Admin Costs	$1,750		$1,750		$1,890	
	Total Project Cost	$6,460		$6,460		$11,100	
	Annual O&M	$75		$75		$150	
	Term Cost/1,000lb-TSS/yr	$1,350		$1,289		$1,181	
	Term Cost/lb-TP/yr	**$458**		**$437**		**$400**	

Catchment ML-6

Existing Catchment Summary	
Acres	0.67
Dominant Land Cover	Institutional
Parcels	1
Volume (acre-feet/yr)	0.33
TP (lb/yr)	0.32
TSS (lb/yr)	178.53

DESCRIPTION

This catchment includes the Martin Lake boat launch that provides public access to the lake. The boat launch and associated parking lot were newly constructed in 2010.

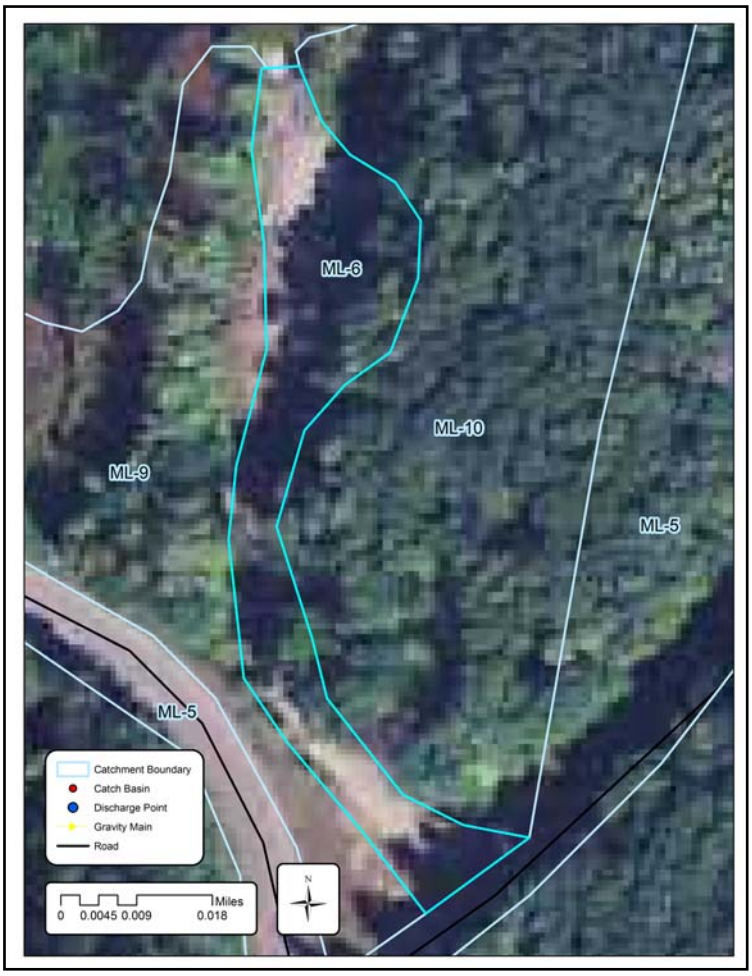
EXISTING STORMWATER TREATMENT

The wet detention pond located on the west side of the boat launch parking lot is the only existing stormwater treatment in this small catchment. However, it captures runoff from the entire parking lot and incoming road, providing substantial treatment as is highlighted in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	1.1	0.8	70%	**0.3**
	TSS (lb/yr)	458	279.4	61%	**179**
	Volume (acre-feet/yr)	0.8	0.5	59%	**0.3**
	Number of BMP's	1			
	BMP Size/Description	Outfall Pond			

RETROFIT RECOMMENDATIONS

No retrofit recommendations were made for catchment ML-6. The existing wet detention pond is providing substantial treatment and appears to be functioning well based on the model results (see existing conditions table). The pond was also hypothetically modeled with accumulation of one foot of sediment, and the pond continued to achieve respectable volume and pollutant reductions. Therefore, annual inspection of the pond and a future maintenance schedule are sufficient for this catchment.



Catchment ML-7

Existing Catchment Summary	
Acres	1.71
Dominant Land Cover	Residential
Parcels	8
Volume (acre-feet/yr)	0.72
TP (lb/yr)	0.95
TSS (lb/yr)	292.69

DESCRIPTION

Catchment ML-7 is positioned along the east side of Martin Lake. The catchment is primarily comprised of medium density, single-family residential development.

EXISTING STORMWATER TREATMENT

There are no existing stormwater treatment practices within ML-7. The majority of this catchment does not drain directly to the lake. However, 1.71 acres of the catchment does drain directly to the lake via an aqueduct (see map on next page). The volume and pollutant loads to the lake from this area are highlighted in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	0.9	0.0	0%	**0.9**
	TSS (lb/yr)	293	0.0	0%	**293**
	Volume (acre-feet/yr)	0.7	0.0	0%	**0.7**
	Number of BMP's	0			
	BMP Size/Description	Not Applicable			

RETROFIT RECOMMENDATIONS

Proposed Project 9- Curb-cut Rain Garden
Drainage Area - 0.67 acres
Location - 23154 East Martin Lake Drive
Property Ownership – Private
Description – Curb-cut rain garden immediately up-gradient of the existing aqueduct. When the rain garden is full, water will bypass to the aqueduct that drains directly to the lake. The rain garden will provide pollutant reduction through infiltration. See Appendix A for rain garden design options.
Conceptual images -

Before

After

Proposed Project 10 - Curb-cut Rain Garden
Drainage Area - 0.48 acres
Location - 23136 East Martin Lake Drive
Property Ownership – Private
Description – Curb-cut rain garden immediately up-gradient of the existing aqueduct. When the rain garden is full, water will bypass to the aqueduct that drains directly to the lake. The rain garden will provide pollutant reduction through infiltration. See Appendix A for rain garden design options.
Conceptual images -

Before

After

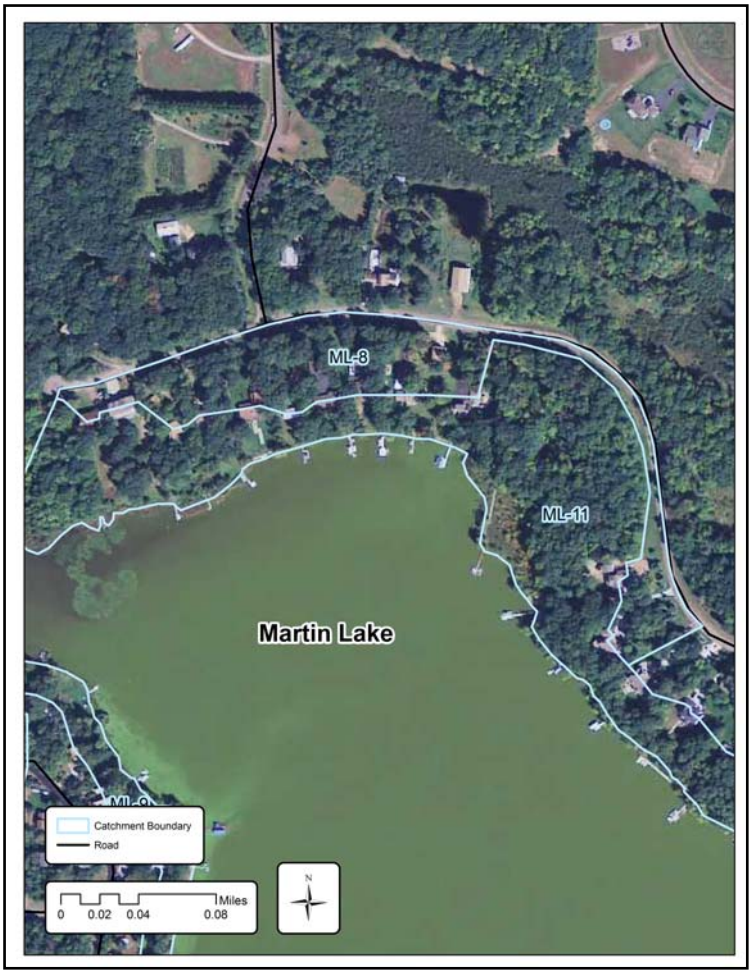
Proposed Projects 9 & 10- Curb-cut Rain Gardens
Drainage Area - 1.15 acres
Description - Installation of both projects simultaneously does not result in the lowest cost per pound of total phosphorus removed (see table below). This is due to the large difference in cost effectiveness between the two projects. Proposed project 10 is substantially less cost effective and therefore the cost effectiveness of the two projects combined is slightly higher than if only proposed project 9 is installed. However, different areas drain to each of the projects, so volume reduction and pollutant treatment are not redundant.

	Cost/Benefit Analysis	Project ID					
		10		9		10 & 9	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	0.3	26%	0.3	35%	0.6	62%
	TSS (lb/yr)	78	27%	103	35%	184	63%
	Volume (acre-feet/yr)	0.2	26%	0.2	34%	0.4	61%
	Number of BMP's	1		1		2	
	BMP Size/Description	250 sq ft		250 sq ft		500 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$4,710		$4,710		$9,210	
	Promotion & Admin Costs	$1,750		$1,750		$1,890	
	Total Project Cost	$6,460		$6,460		$11,100	
	Annual O&M	$75		$75		$150	
	Term Cost/1,000lb-TSS/yr	$3,709		$2,807		$2,831	
	Term Cost/lb-TP/yr	**$1,159**		**$882**		**$887**	

Catchment ML-8

DESCRIPTION

Catchment ML-8 is positioned along the northeast side of Martin Lake. The catchment is primarily comprised of medium density, single-family residential development. Volume and pollutant loads from this catchment were not modeled because it does not drain directly to Martin Lake. All stormwater from this catchment is diverted away from the lake and infiltrated in undeveloped areas.



Catchments ML-9, 10, & 11

Existing Catchment Summary	
Acres	47.59
Dominant Land Cover	Residential
Parcels	163
Volume (acre-feet/yr)	0.86
TP (lb/yr)	3.00
TSS (lb/yr)	378.53

DESCRIPTION

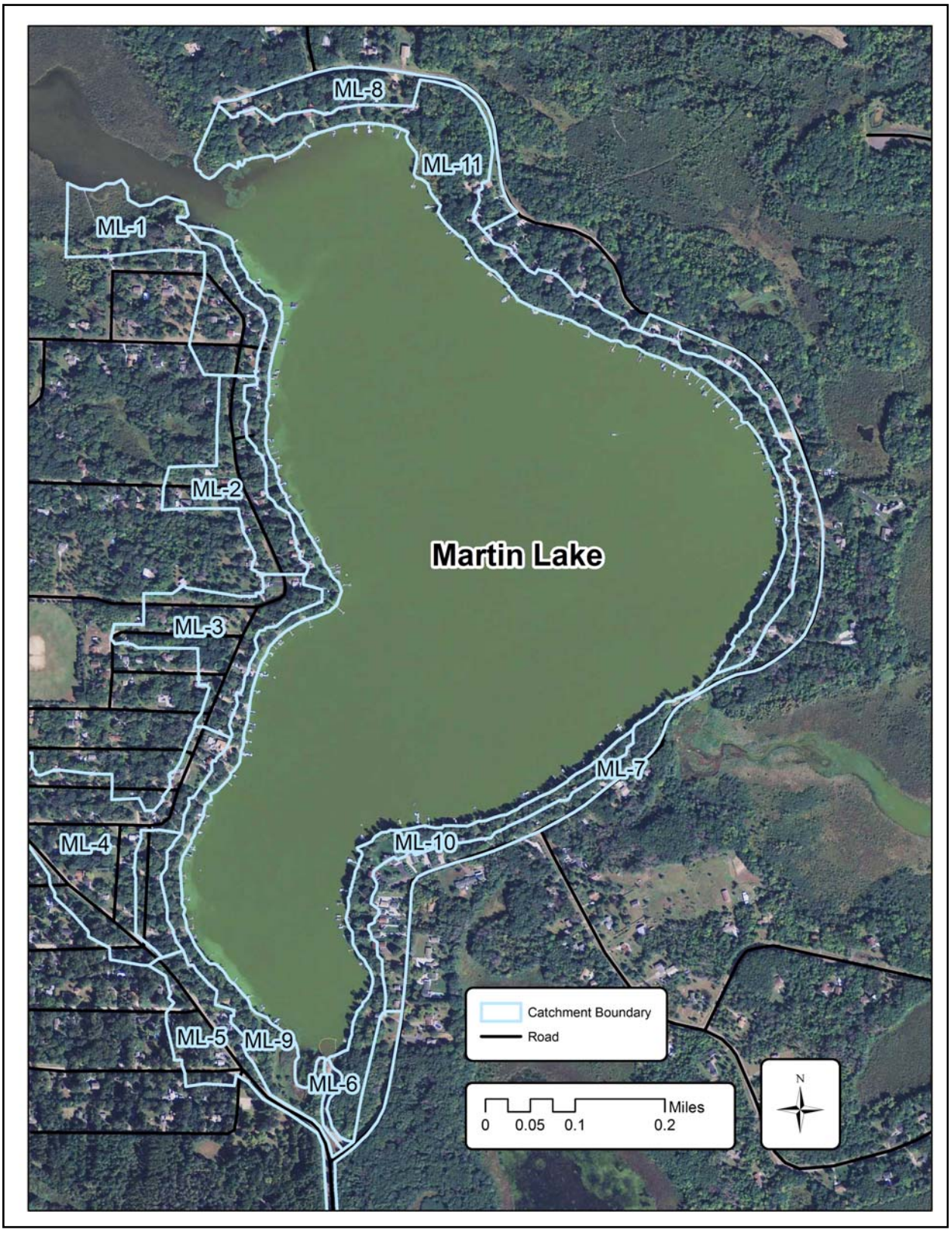
Catchments ML-9, 10, and 11 consist of backyard lakeshore areas immediately surrounding Martin Lake. The catchments are primarily comprised of medium density, single-family residential development.

EXISTING STORMWATER TREATMENT

There are no existing stormwater treatment practices within the catchment. Runoff from these catchments drains directly to the lake by flowing across backyards. Much of this flow is infiltrated. The volume and pollutant loads to the lake from this area are in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	3.0	0.0	0%	**3.0**
	TSS (lb/yr)	379	0.0	0%	**379**
	Volume (acre-feet/yr)	0.9	0.0	0%	**0.9**
	Number of BMP's	0			
	BMP Size/Description	Not Applicable			

RETROFIT RECOMMENDATIONS



Proposed Project 15 - Lakeshore Restorations

Location - Any lakefront property on Martin Lake

Property Ownership – Private

Description – The shoreline is critical for fisheries, water quality, and overall ecology. Lakeshore restorations provide a practical and functional approach for landscaping in these unique areas. They are protective against erosion, filter backyard runoff before it reaches the lake, and provide fish and wildlife habitat. The three scenarios in the table below outline the volume and pollutant reductions associated with 10, 20, and 30 lakeshore restorations around Martin Lake. Each lakeshore restoration was assumed to treat 0.25 acres and be 75 feet wide (75% of the average 100 foot lakeshore property) and 20 feet long (a 20 foot wide buffer).

While the pollutant reductions from lakeshore restorations are not great, the approach still deserves serious consideration. These projects do provide substantial benefit to lake ecology. Pollutant removal alone underestimates the benefit.

Conceptual images -

Before

After

	Cost/Benefit Analysis	Project ID					
		15		15		15	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	0.2	6%	0.4	12%	0.6	18%
	TSS (lb/yr)	26	7%	52	14%	77	20%
	Volume (acre-feet/yr)	0.0	5%	0.1	10%	0.1	16%
	Number of BMP's	10		20		30	
	BMP Size/Description	15,000 sq ft		30,000 sq ft		45,000 sq ft	
	BMP Type	Lakeshore Restoration		Lakeshore Restoration		Lakeshore Restoration	
Cost	Materials/Labor/Design	$60,700		$120,700		$180,700	
	Promotion & Admin Costs	$3,010		$4,410		$5,810	
	Total Project Cost	$63,710		$125,110		$186,510	
	Annual O&M	$500		$1,000		$1,500	
	Term Cost/1,000lb-TSS/yr	$101,638		$100,146		$99,649	
	Term Cost/lb-TP/yr	**$14,271**		**$14,061**		**$13,992**	

Retrofit Ranking

The table below summarizes the assessment results. The benefits of each project were estimated if that project were installed alone, with no other projects upstream of it in the same catchment. Reported treatment levels are dependent upon optimal siting and sizing. More detail about each project can be found in the catchment profile pages of this report. Projects that were deemed unfeasible due to prohibitive size, number, or were too expensive to justify installation are not included in the table below.

An additional recommendation included in the table below, but not included in the separate catchment profiles is the implementation of street sweeping. Currently, street sweeping is not conducted within any of the catchments. We modeled street sweeping using a vacuum assisted sweeper twice a year (spring and fall) in catchments 1-6. The cost and associated pollutant removals are highlighted in the table below. While it is not particularly cost effective for phosphorus removal (the basis of project rankings in the table), it will reduce suspended solids more than any other retrofit. It is also required by the Sunrise River Watershed Management Organization. It should be done.

Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Total suspended solids (TSS) reduction is also shown. For more information on each project refer to the catchment profile pages earlier in this report.

Project ID	Catchment	Description (refer to catchment profile pages for more detail)	Location	Drainage Area (acres)	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Cost	Estimated cost/lb TP/year (30-year)
1	ML-3	Pond maintenance - excavate 1.5 ft.	East of 228th Pl. NE and W Martin Lake Dr. intersection	10.08	1.1	435	0.0	$3,930 - $5,990	$245 - $374
2	ML-2	Pond maintenance - excavate 1 ft.	East of 230th Ave. and W Martin Lake Dr. intersection	8.44	0.5	187	0.0	$2,696 - $3,940	$385 - $563
3	ML-5	Curb-cut rain garden	22529 W Martin Lake Dr.	1.29	0.7	225	0.4	$6,460	$437
4	ML-5	Curb-cut rain garden	22514 W Martin Lake Dr.	1.19	0.6	215	0.4	$6,460	$458
5	ML-2	Curb-cut rain garden	23003 W Martin Lake Dr.	1.86	0.5	156	0.4	$6,460	$570
6	ML-3	Curb-cut rain garden	22908 W Martin Lake Dr.	1.84	0.8	235	0.6	$10,960	$577
7	ML-2	Curb-cut rain garden	22964 W Martin Lake Dr.	1.61	0.5	144	0.4	$6,460	$616
8	ML-3	Curb-cut rain garden	Public parcel between 228th Pl. NE and 229th Ave. NE	1.32	0.5	141	0.4	$6,460	$638
9	ML-7	Curb-cut rain garden	23154 E Martin Lake Dr.	0.67	0.3	103	0.2	$6,460	$882
10	ML-7	Curb-cut rain garden	23136 E Martin Lake Dr.	0.48	0.3	78	0.2	$6,460	$1,159
11	ML-1	Curb-cut rain garden	23140 W Martin Lake Dr.	0.58	0.2	75	0.2	$6,460	$1,200
12	ML-1	Biofiltration swale	Public parcel N of 23131 W Martin Lake Dr.	0.50	0.2	67	0.2	$6,460	$1,358
13	ML-1-6	Vacuum assisted street sweeping (1 spring/1 fall)	Catchments ML-1, ML-2, ML-3, ML-4, ML-5, and ML-6	N/A	1.8	803	0.0	$2570/year	$1,390
14	ML-4	Biofiltration swale	Feather St. NE	3.91	0.1	22	0.1	$4,787	$6,127
15	ML-9,10,11	Lakeshore restorations	Catchments ML-9, ML-10, and ML-11	2.5 - 7.5	0.2 - 0.6	26 - 77	0.05 - 0.14	$63,710 - $186,510	$13,992 - $14,271
Totals				**36.3 - 41.3**	**8.3 - 8.7**	**2,912 - 2,963**	**3.55 - 3.64**	**$146,793 - $272,897**	

References

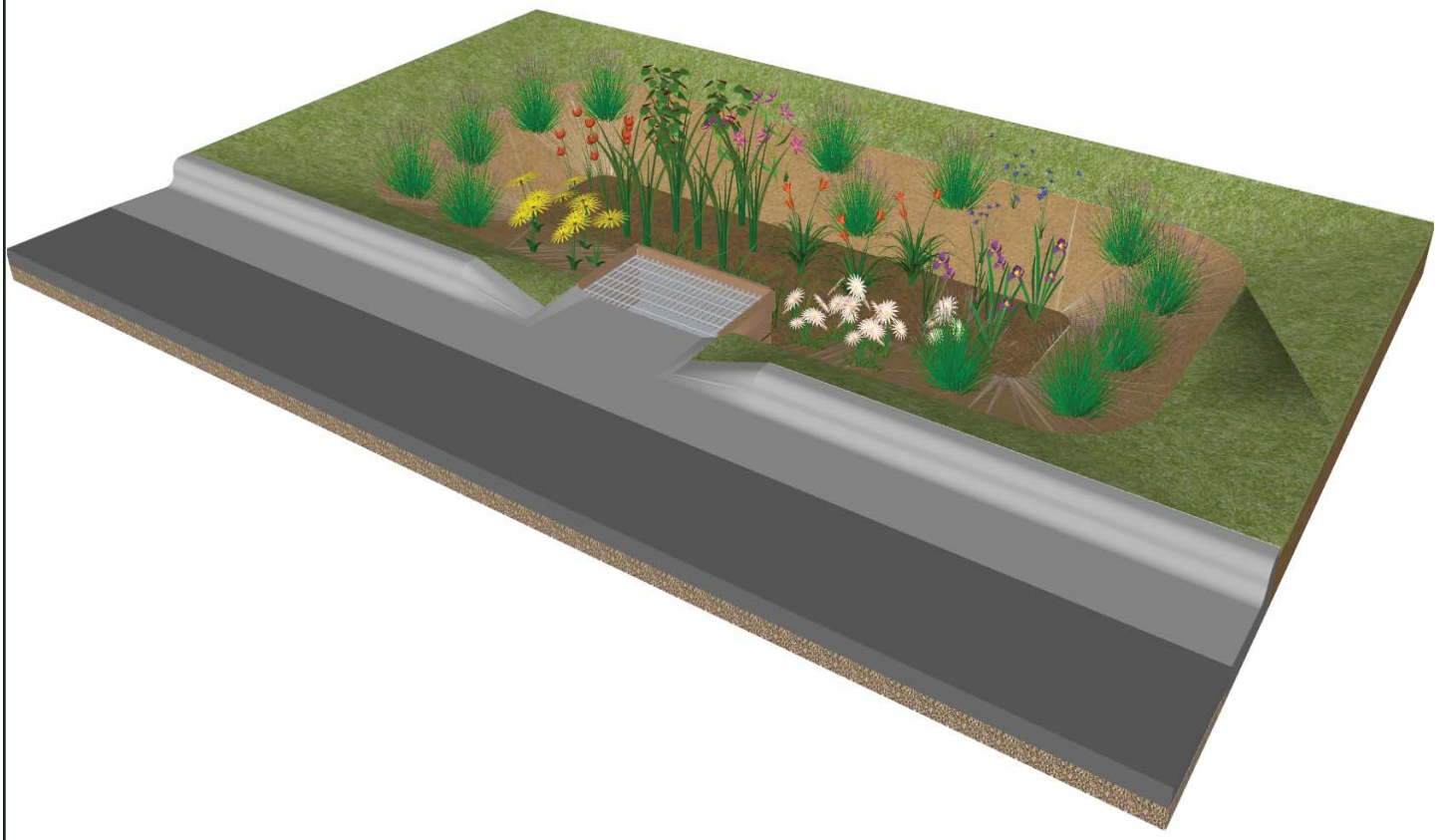
Minnesota Stormwater Steering Committee. 2005. *Minnesota Stormwater Manual.* Minnesota Pollution Control Agency. St. Paul, MN.

Schueler et. al. 2005. *Methods to Develop Restoration Plans for Small Urban Watersheds. Manual 2, Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection. Ellicott City, MD.

Schueler et. al. 2007. *Urban Stormwater Retrofit Practices. Manual 3, Urban Subwatershed Restoration Manual Series. Center for Watershed Protection*. Ellicott City, MD.

Appendix A – Rain Garden Concept Designs

ANOKA COUNTY CURB-CUT RAINGARDENS



Drawing rainwater from the street gutter reduces runoff and pollutants to local water bodies

Prepared by the Anoka Conservation District in association with
the Metropolitan Conservation Districts

URBAN RAINWATER: SLOW IT DOWN AND SOAK IT UP

Under natural conditions the majority of rainwater falling on Anoka County would infiltrate the soil surface to be absorbed by plants or percolate more deeply into the soil to feed groundwater recharge and provide steady base-flow to streams and rivers. As land development has expanded more and more land is covered with impervious surfaces such as roads, parking lots and buildings. This conversion from native vegetation to impervious structure has greatly altered the hydrologic cycle and surface water ecology by greatly increasing runoff rates and effectively washing nutrient laden sediments and other pollutants into local surface waters. Treating and infiltrating urban rainwater as close to the point where it falls as possible is recognized as a vital and effective method for augmenting groundwater resources and reducing surface water quality impacts.

In dense residential ***sub-watersheds*** there is limited suitable public land on which to treat and infiltrate rainwater. In these situations utilizing private land and easements along roadways for treatment becomes an important tool for improving water quality. The curb and gutter system that channels rainwater quickly from your neighborhood can be disconnected with a ***curb-cut*** that directs rainwater from the street into a depressed ***raingarden***. This allows rainwater falling within the catchment area of the raingarden to return to the natural hydrologic cycle of ***infiltration*** and ***evapotranspiration***, effectively reducing downstream flooding, erosion and ***non-point source pollution***. An individual curb-cut raingarden may only mitigate for a small portion of urban runoff, however the treating the rainwater runoff close to its source is an essential strategy in hydrologic restoration and cumulatively curb-cut gardens can actualize significant benefits within an urbanized ***sub-watershed***.

The Anoka Conservation District has designed a set of curb-cut raingardens that can be applied to the physical conditions of your property and to your preference of garden shapes and plant selections. Each garden is designed to provide a water storage capacity of 100 cubic feet. Anoka Conservation

Photo by Rusty Schmidt

District has also designed a modular pretreatment box to be placed at the raingarden inlet to capture sediment and debris prior to water entering the garden. This pretreatment box is a vital component to the longevity and functionality of your raingarden.

Please utilize the key on page 4 to determine the basic design needs of your property and continue to the designated page to select your choice of plant palettes. Plant images are shown of pages 20 and 21.

curb-cut: A section of curb and gutter that has been reconstructed to convey stormwater into a filter strip, rain garden, or other stormwater management strategy.

evapotranspiration: The transfer of liquid water from the earth's surface to atmospheric water vapor as result of transpiration by plants and evaporation by solar energy and diffusion. Evapotranspiration can constitute a significant water "loss" from a watershed.

infiltration: Water moving through a permeable soil surface by the force of gravity and soil capillary action. The rate of infiltration is highly dependent on soil type. Infiltration rates within the Anoka Sand Plain are generally very high.

non-point source pollution: Rainwater runoff that has accumulated pollutant loads (nutrients, sediments, petrochemicals etc.) over a large dispersed area. As opposed to point source pollution that has a defined single source.

raingarden: A landscaped garden in a shallow depression that receives rainwater runoff from nearby impervious surfaces such as roofs, parking lots or streets. The purpose of a raingarden is to reduce peak runoff flows, increase groundwater recharge and improve water quality in our lakes, streams and wetlands. Peak flow reduction is achieved by temporarily staging runoff within the raingarden basin until it infiltrates into the soil surface or evaporates (typically within 24 hours). This process also increases the quantity and movement of soil water that may feed groundwater recharge. Infiltrated water quality is improved by reducing sediment, nutrient and other chemical pollutant loads through chemical and biological processes in the soil. Downstream water quality is improved in kind by offsetting erosive peak flows and by capturing and treating pollutants higher in the watershed.

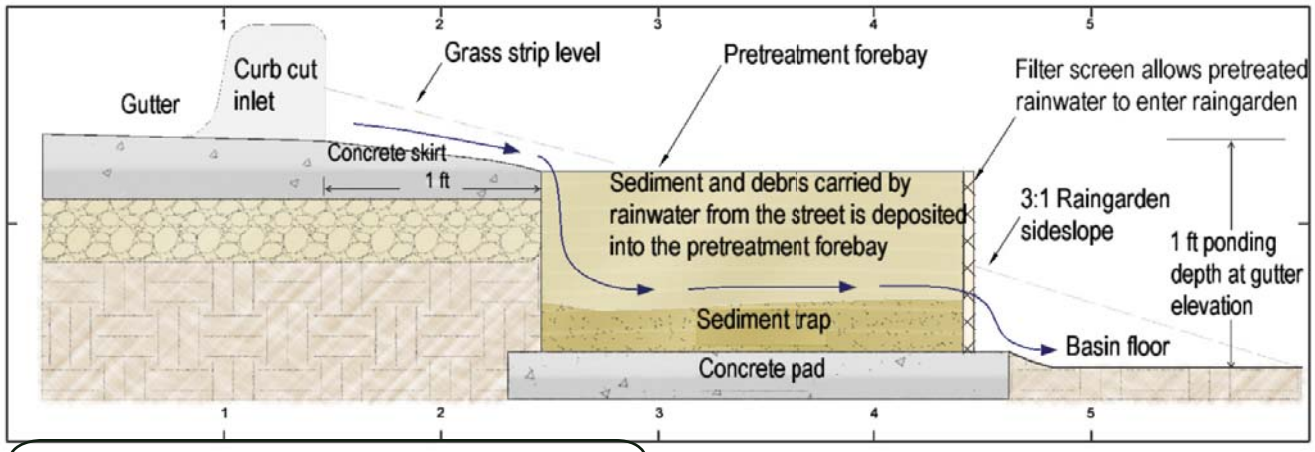
sub-watersheds: A discreet portion of a larger watershed, typically less than 2500 acres. Sub-watersheds can be more effectively analyzed and managed for water quality with site scale treatments.

CHOOSE YOUR RAINGARDEN DESIGN

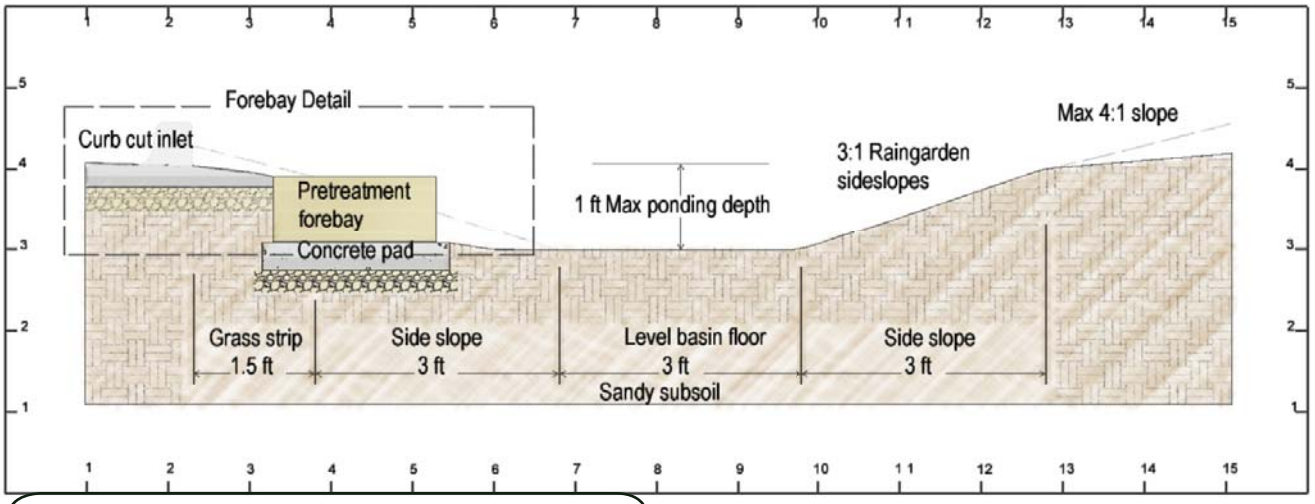
1

- Property rises less than 1 foot above the top of curb height within 16 feet of the curb
  - Retaining not needed
    - **2** Garden site recieves greater than 4 hours of full sun between 10 am and 4 pm
      - Sun garden
        - **3** I. Rectangle Sun, No Wall pg. 8
        - II. Arc Sun, No Wall pg. 9
        - III. Curvilinear Sun, No Wall pg. 10
    - **2** Garden site recieves less than 4 hours of full sun between 10 am and 4 pm
      - Shade garden
        - **3** IV. Rectangle Shade, No Wall pg. 11
        - V. Arc Shade, No Wall pg. 12
        - VI. Curvilinear Shade, No Wall pg. 13
- Property rises greater than 1 foot above the curb height within 16 feet of the curb
  - Retaining wall needed
    - **2** Garden site recieves greater than 4 hours of full sun between 10 am and 4 pm
      - Sun garden
        - **3** VII. Rectangle Sun, with Wall pg. 14
        - VIII. Arc Sun, with Wall pg. 15
        - IX. Curvilinear Sun, with Wall pg. 16
    - **2** Garden site recieves less than 4 hours of full sun between 10 am and 4 pm
      - Shade garden
        - **3** X. Rectangle Shade, with Wall pg. 17
        - XI. Arc Shade, with Wall pg. 18
        - XII. Curvilinear Shade, With Wall pg. 19

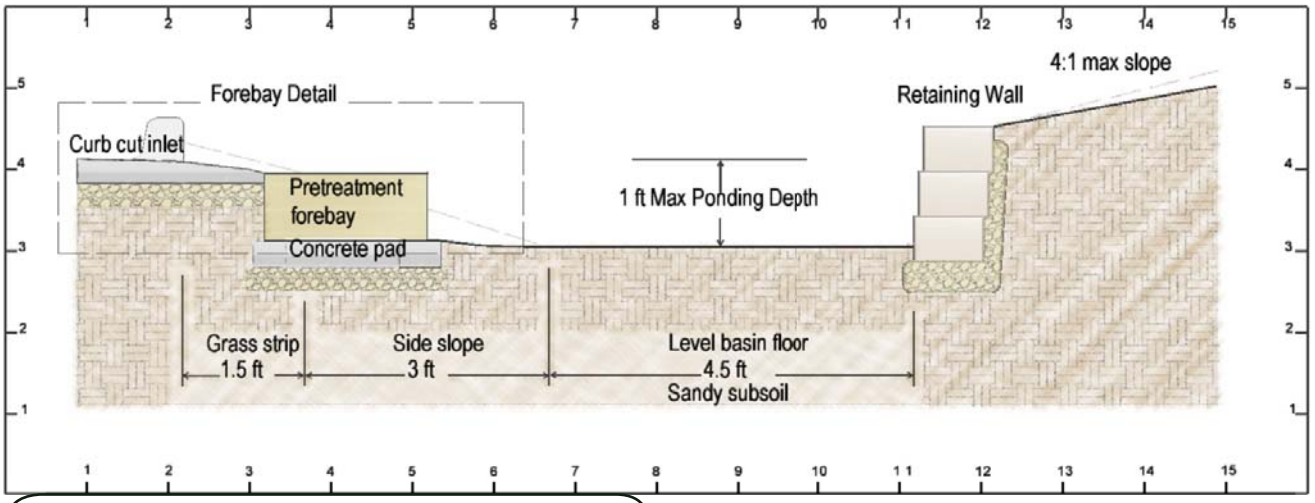
ANATOMY OF A CURB-CUT RAINGARDEN



PRETREATMENT FOREBAY

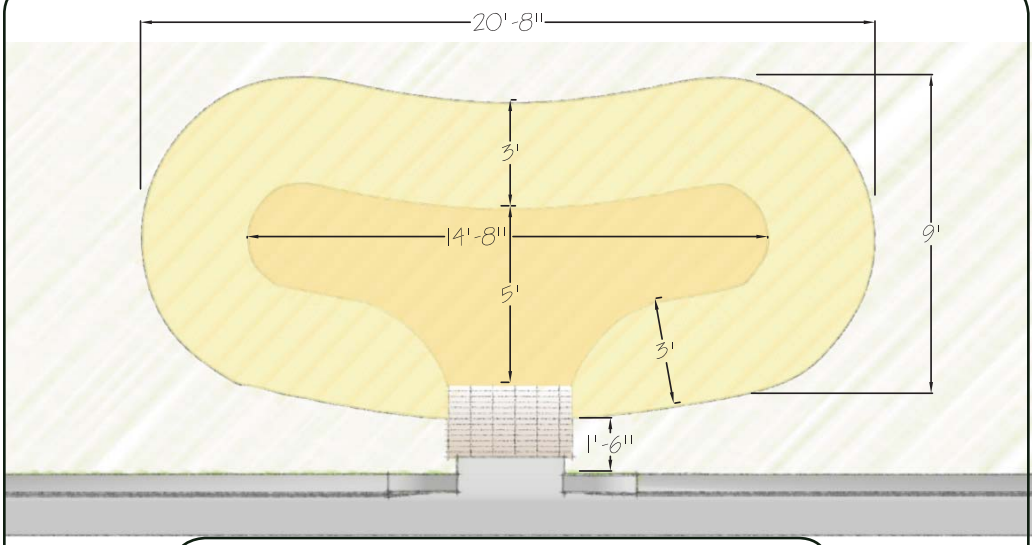


RAINGARDEN WITHOUT RETAINMENT

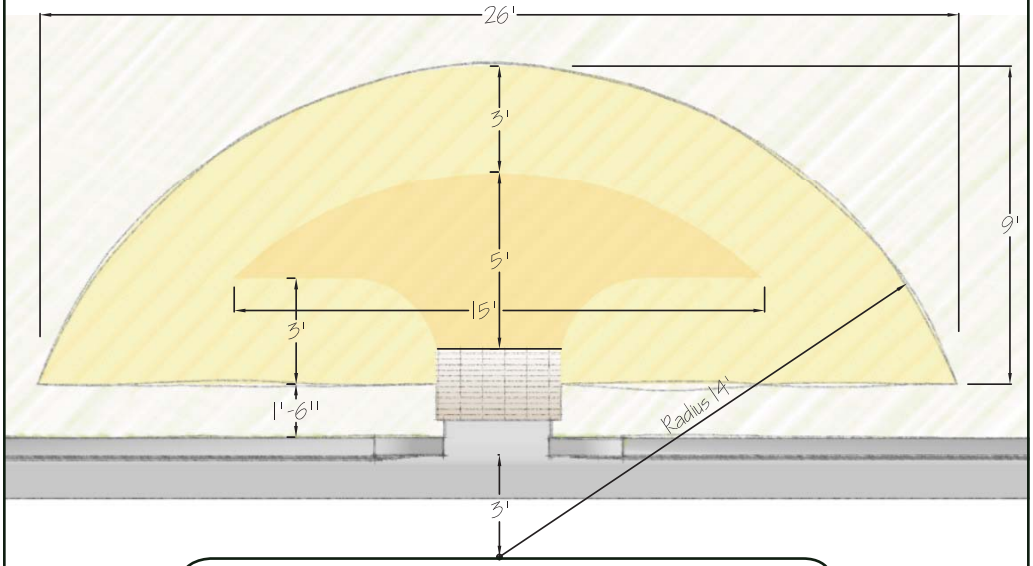


RAINGARDEN WITH RETAINING WALL

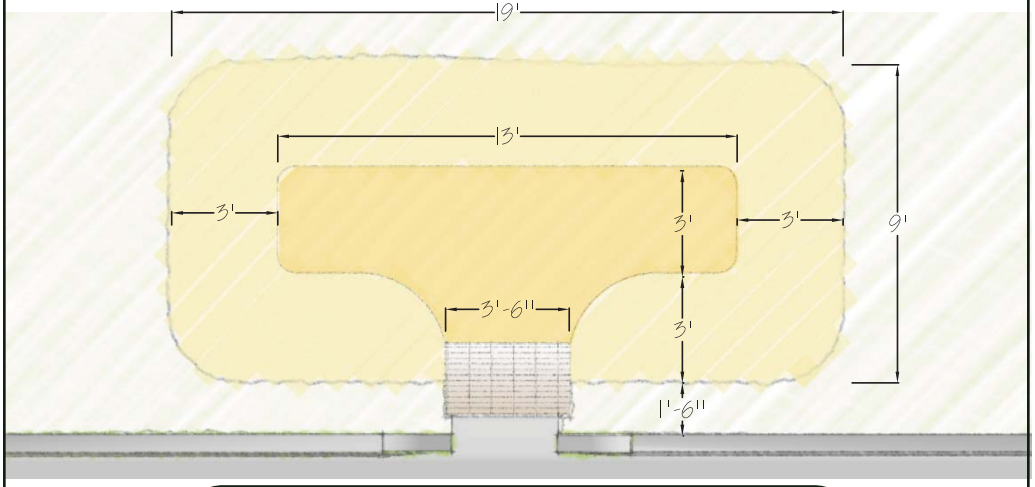
Raingarden Dimensions without a Retaining Wall



Curvilinear Garden



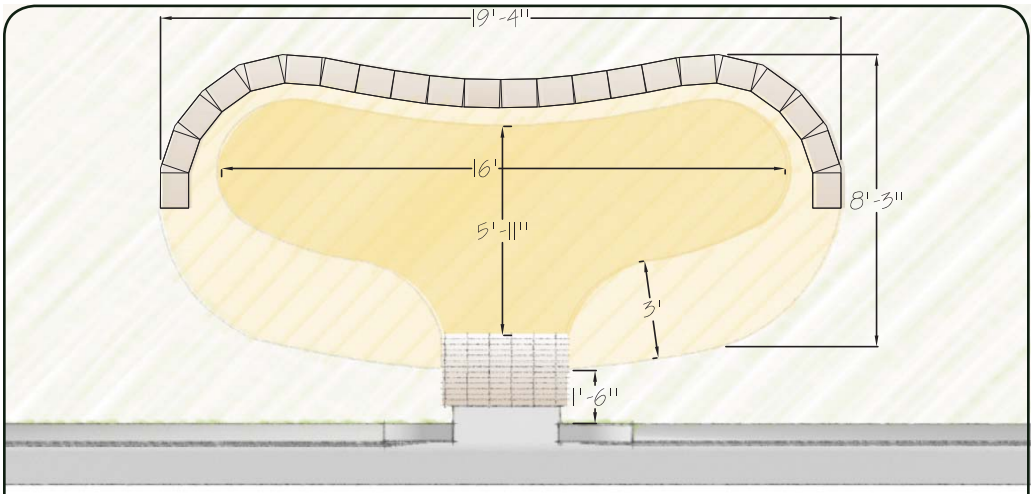
Arc Garden

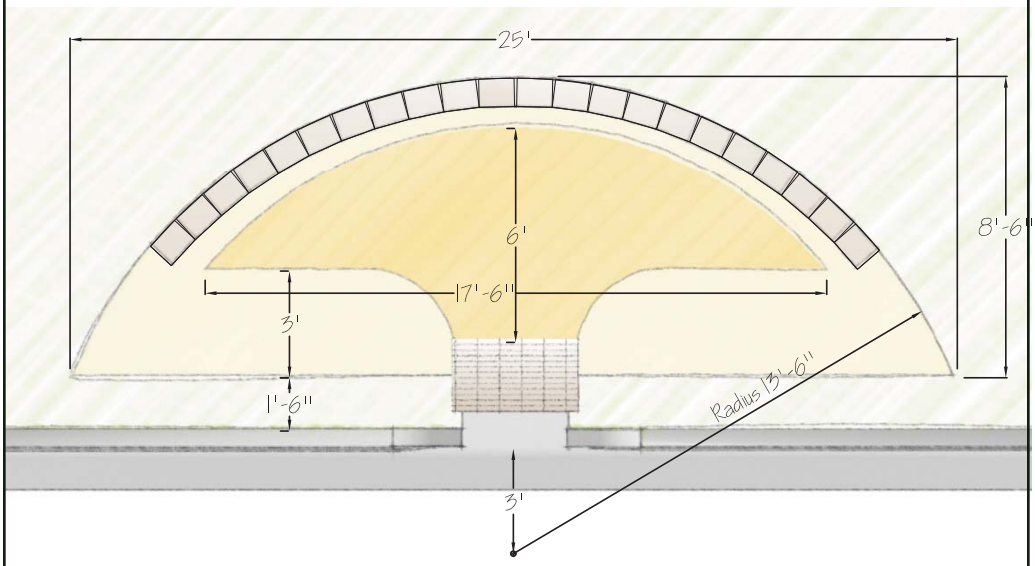


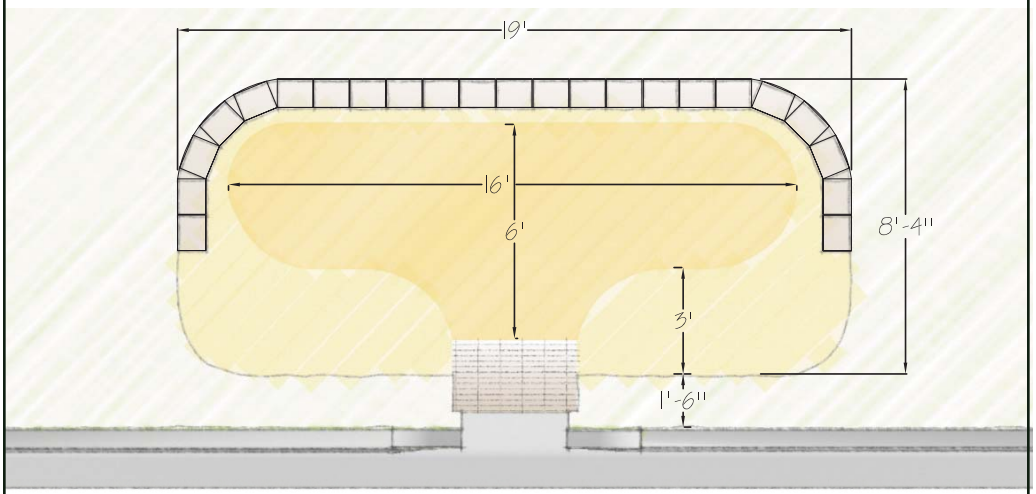
Rectangle Garden

The dimensions given are the minimum dimensions needed to achieve the storage volume required by this stormwater retrofit program. The level basin floor needs to be set 1 foot below the gutter elevation. The entire planting area should be covered with 3 inches of shredded hardwood mulch.

Raingarden Dimensions with a Retaining Wall

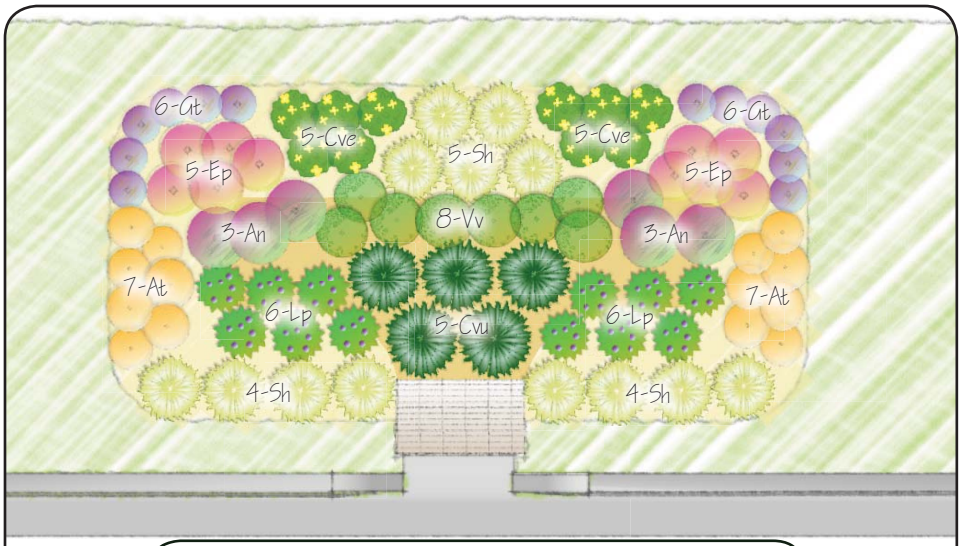




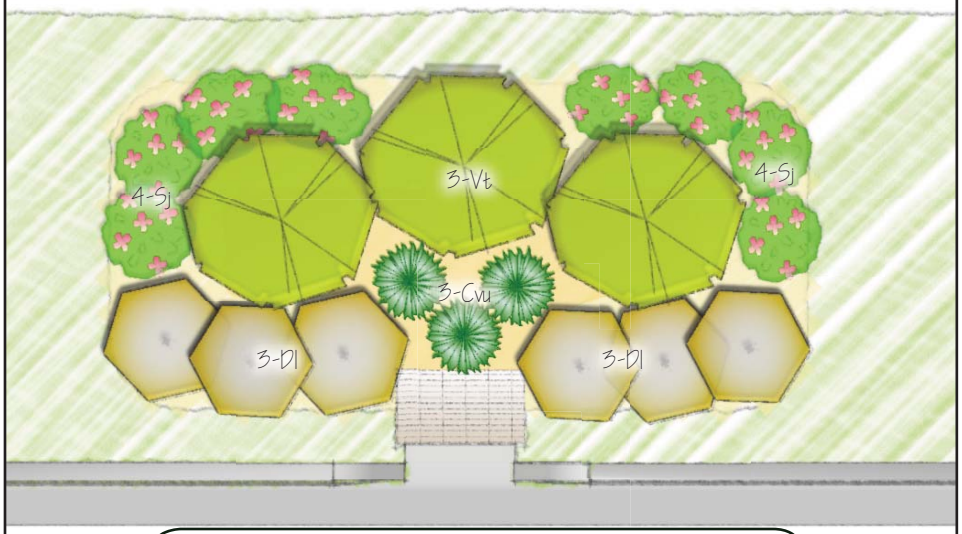


The dimensions given are the minimum dimensions needed to achieve the storage volume required by this stormwater retrofit program. The level basin floor needs to be set 1 foot below the gutter elevation. The entire planting area should be covered with 3 inches of shredded hardwood mulch.

I. Rectangle Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



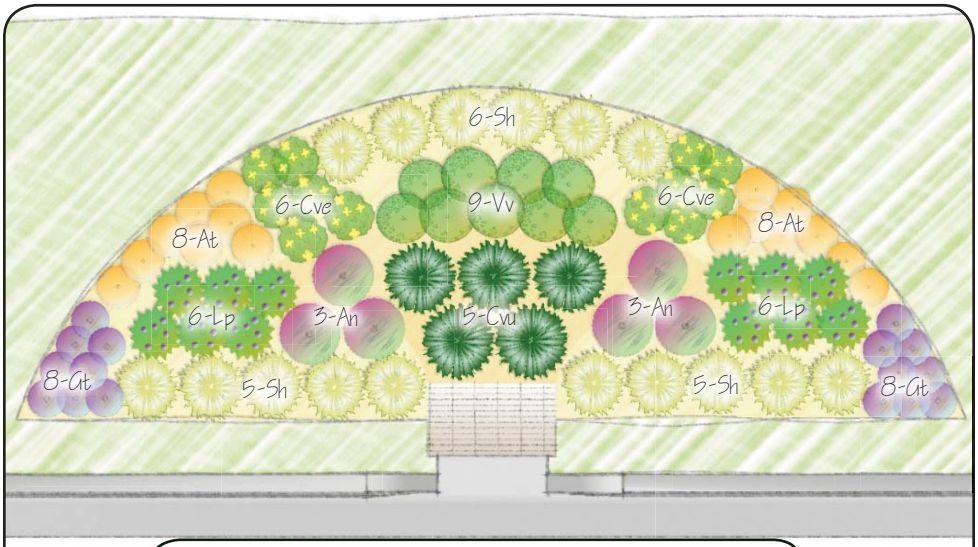
Shrub Garden

Mixed Shrub/Flower Garden

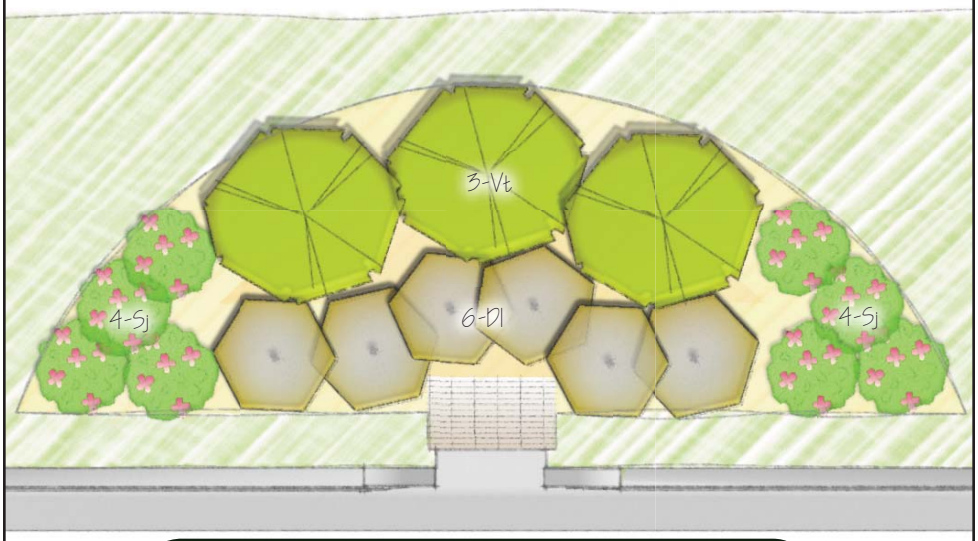
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dp	PURPLE PRARIE CLOVER *Dalea purpurea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ep	PURPLE CONEFLOWER *Echinacea purpurea*
Gt	PRAIRIE SMOKE *Geum trifolium*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sj	DART'S RED SPIRAEA *Spiraea japonica*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Veronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

II. Arc Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



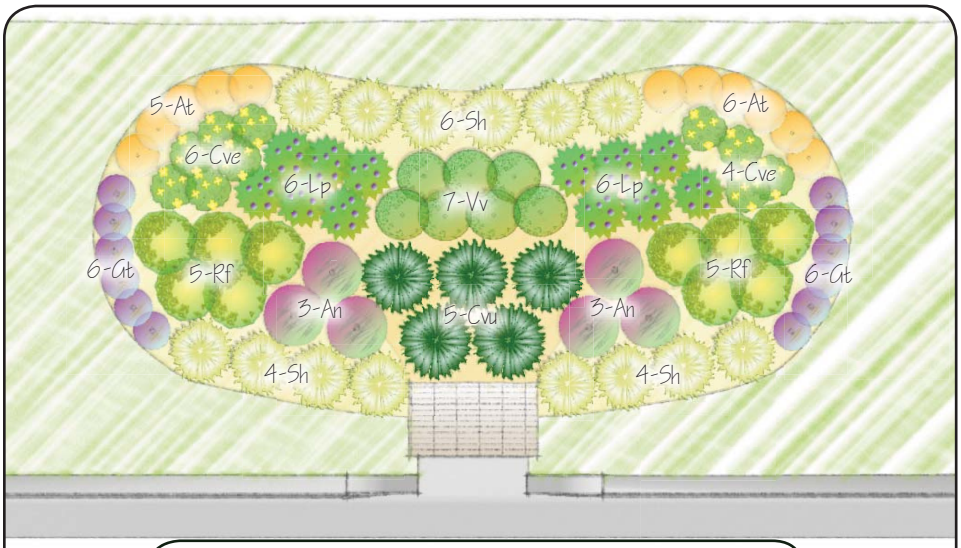
Shrub Garden

Mixed Shrub/Flower Garden

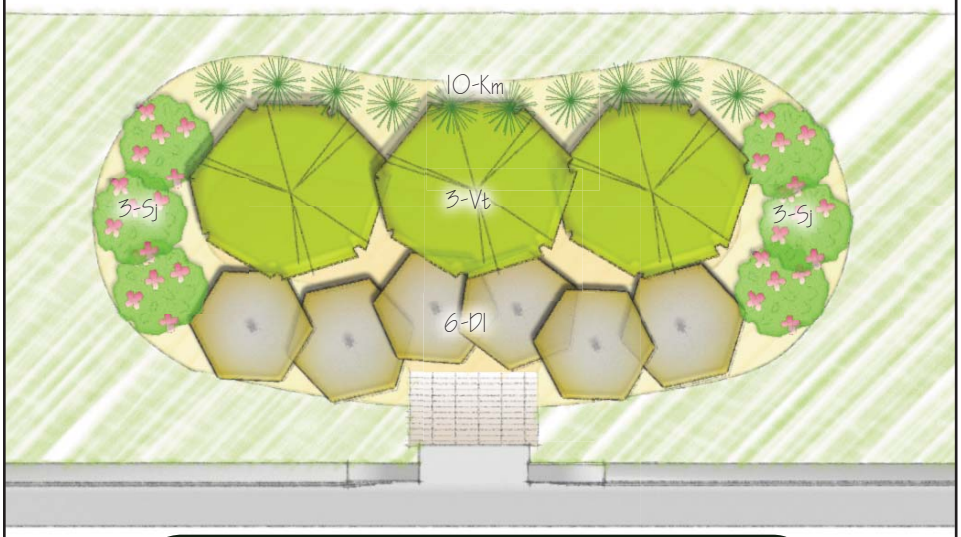
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dp	PURPLE PRARIE CLOVER *Dalea purpurea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ep	PURPLE CONEFLOWER *Echinacea purpurea*
Gt	PRAIRIE SMOKE *Geum trifolium*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sj	DART'S RED SPIRAEA *Spiraea japonica*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Veronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

III. Curvilinear Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

Mixed Shrub/Flower Garden

Plant Key

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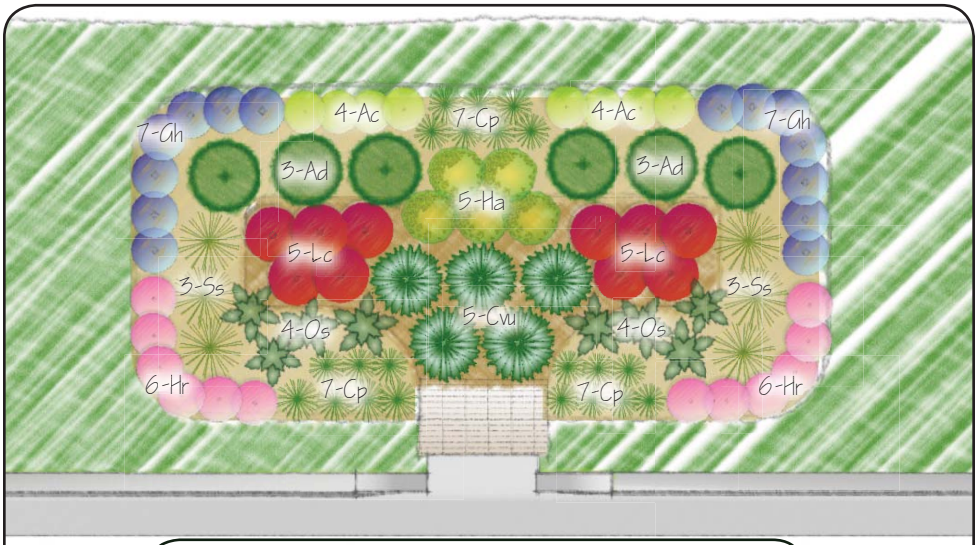
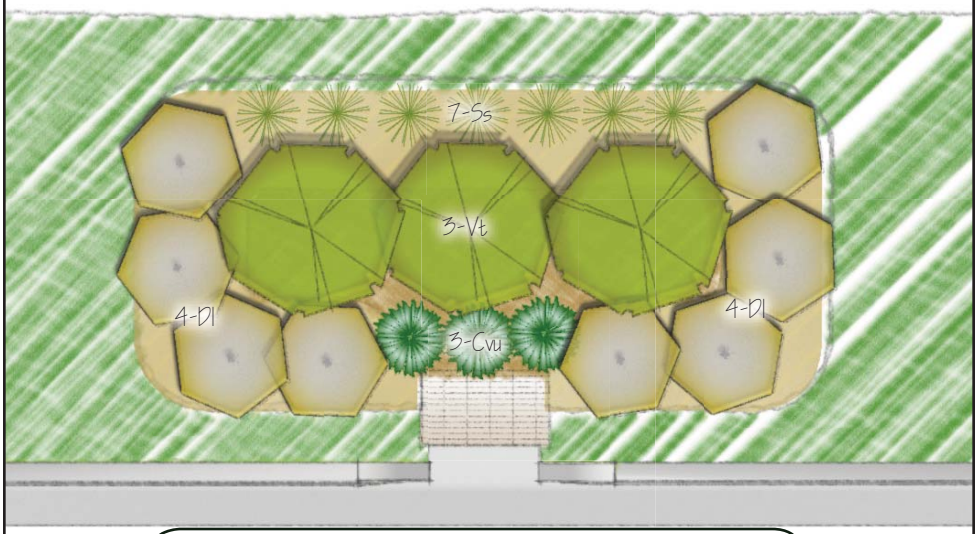
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cvu	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dp	PURPLE PRARIE CLOVER *Dalea purpurea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gt	PRAIRIE SMOKE *Geum trifolium*
Km	JUNE GRASS *Koeleria macrantha*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sj	DART'S RED SPIRAEA *Spiraea japonica*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Veronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

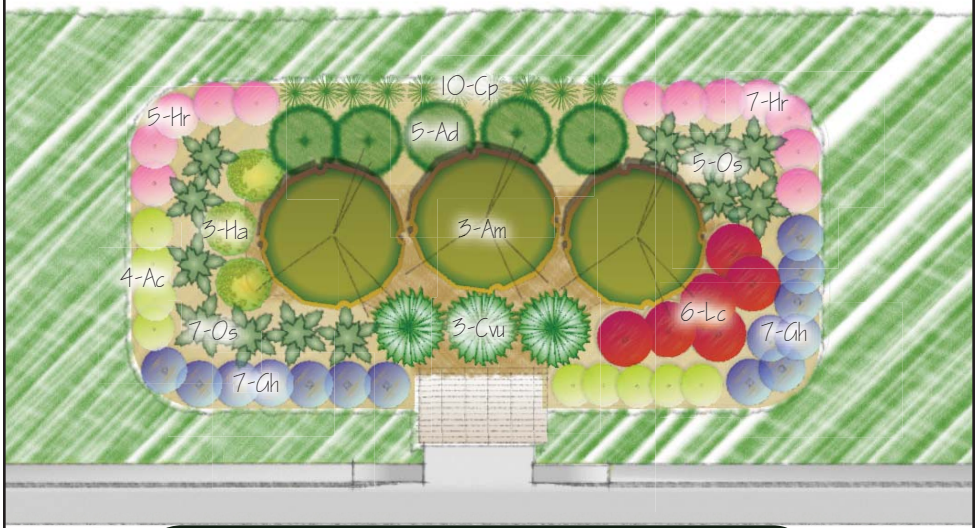
IV. Rectangle Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

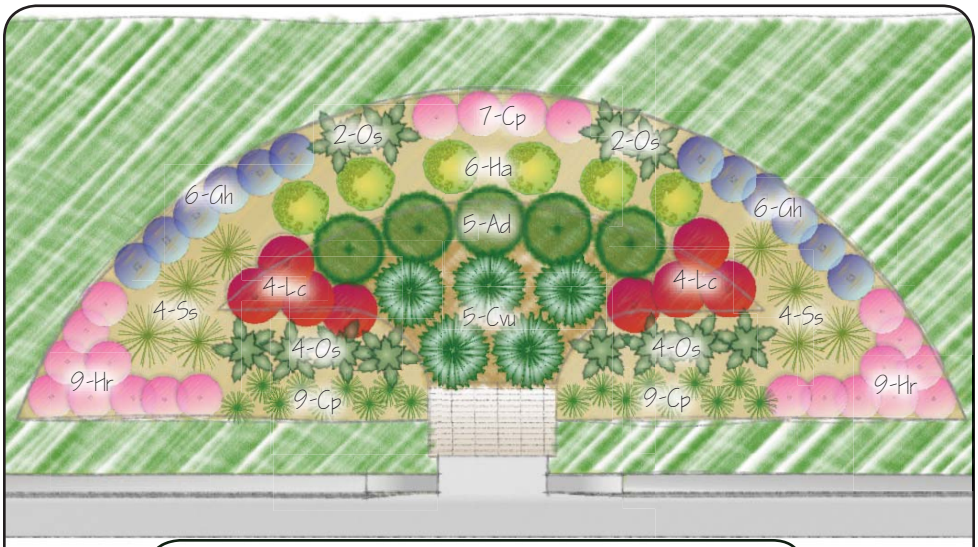


Mixed Shrub/Flower Garden

Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ac	CANADA ANEMONE *Anemone canadensis*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

V. Arc Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden

Shrub Garden

Mixed Shrub/Flower Garden

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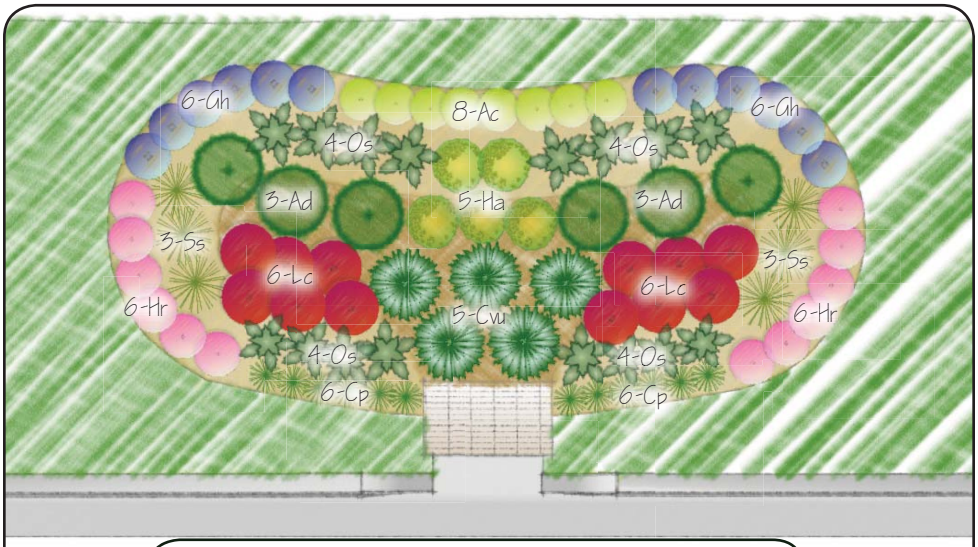
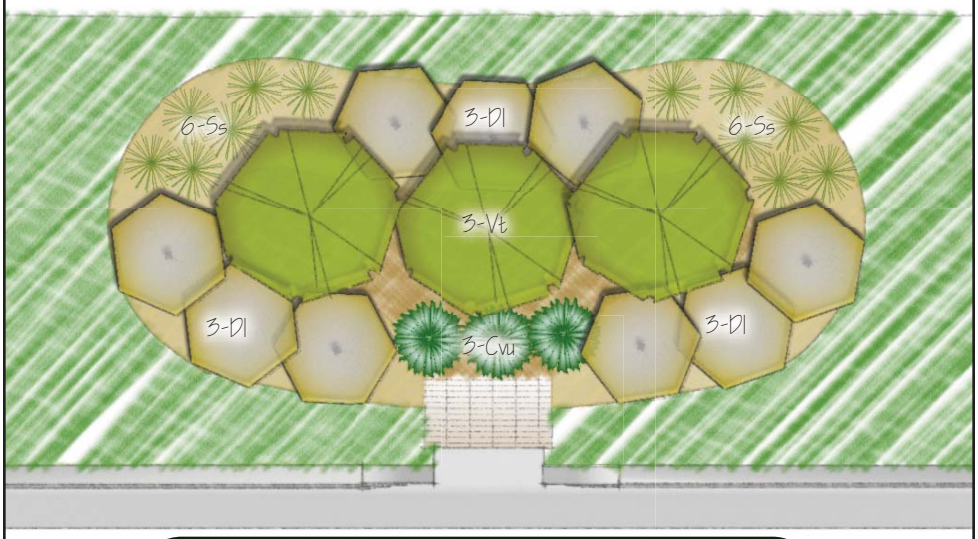
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

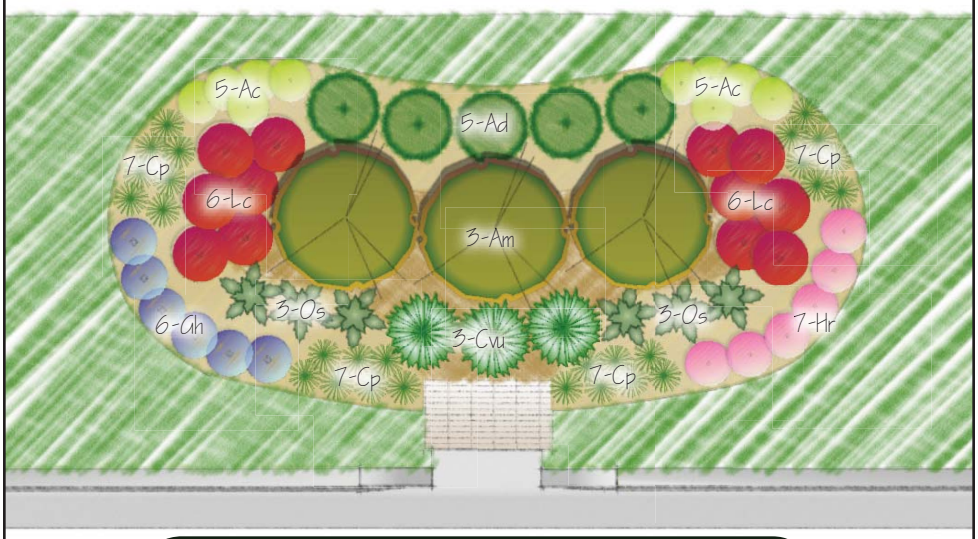
VI. Curvilinear Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden



Mixed Shrub/Flower Garden

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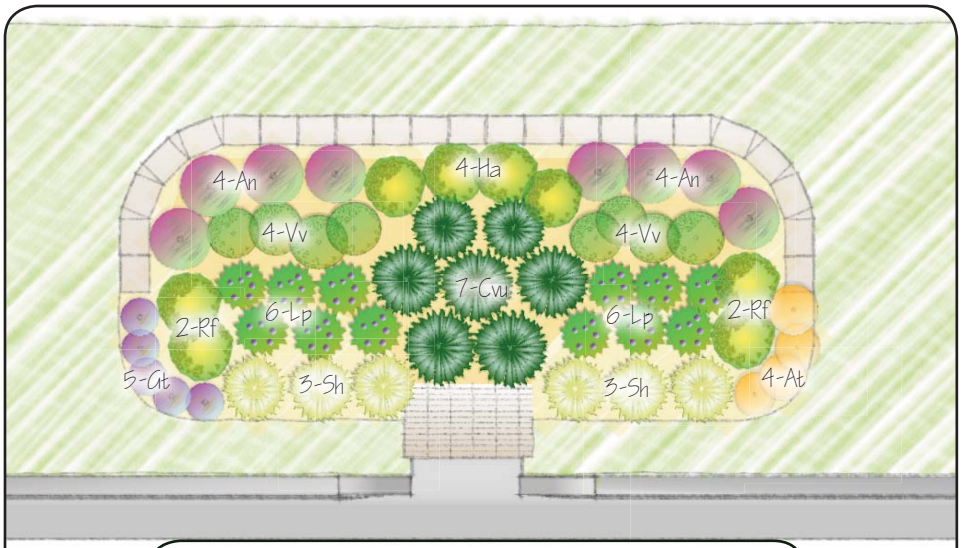
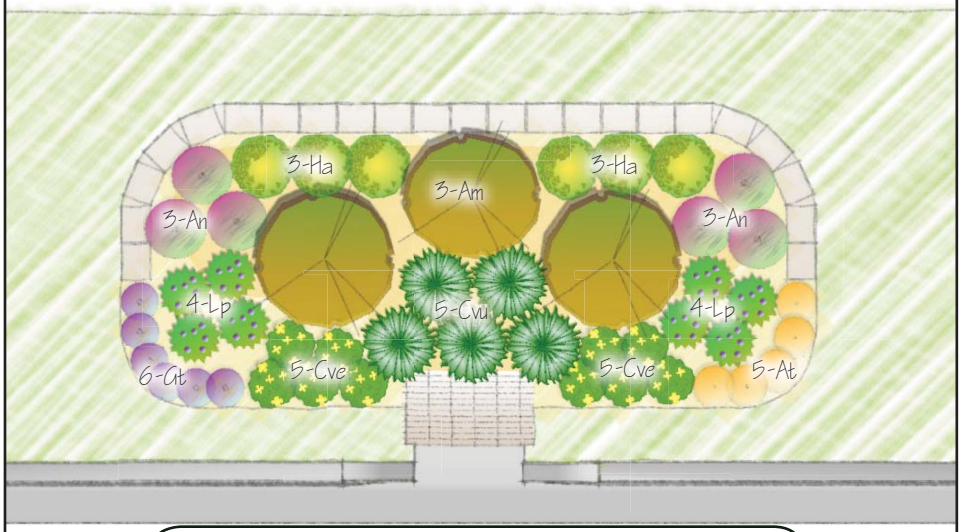
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

VII. Rectangle Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden

Shrub Garden

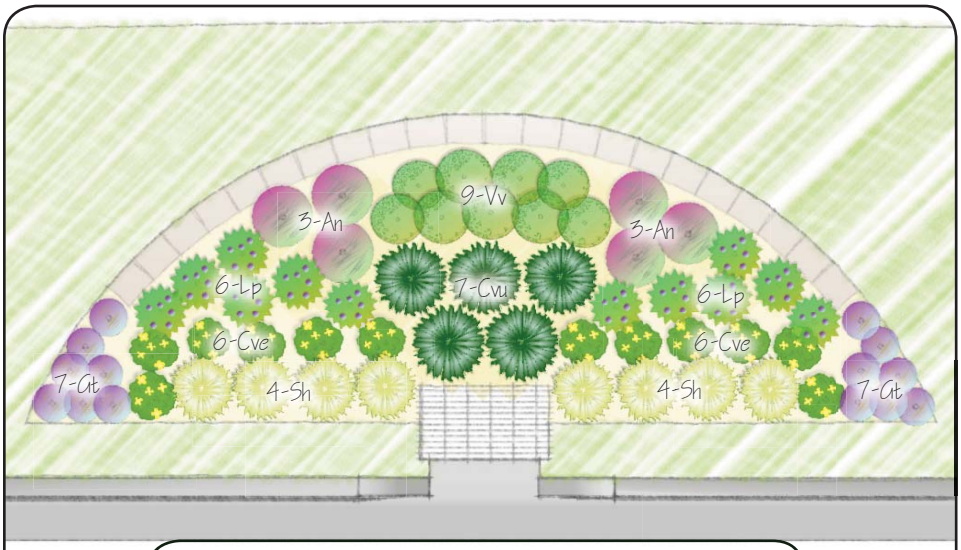


Mixed Shrub/Flower Garden

Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gt	PRAIRIE SMOKE *Geum trifolium*
Ha	SNEEZEWEED *Helenium autumnale*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Vronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

VIII. Arc Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden

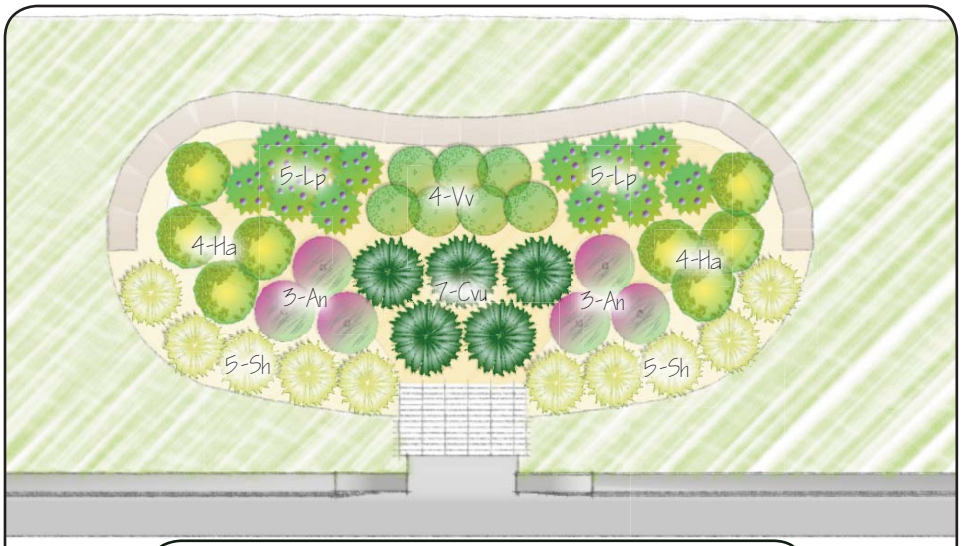
Shrub Garden

Mixed Shrub/Flower Garden

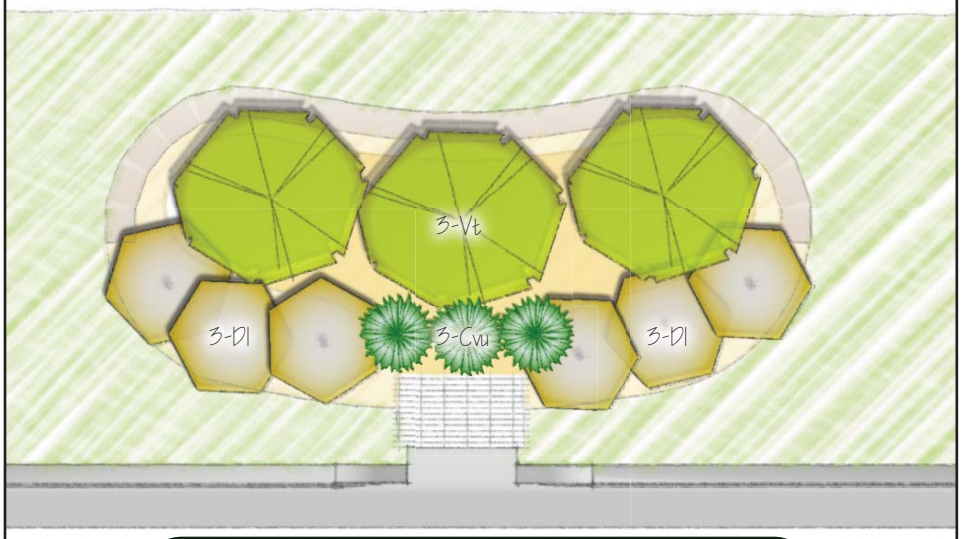
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gt	PRAIRIE SMOKE *Geum trifolium*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Sj	DART'S RED SPIRAEA *Spiraea japonica*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Veronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

IX. Curvilinear Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

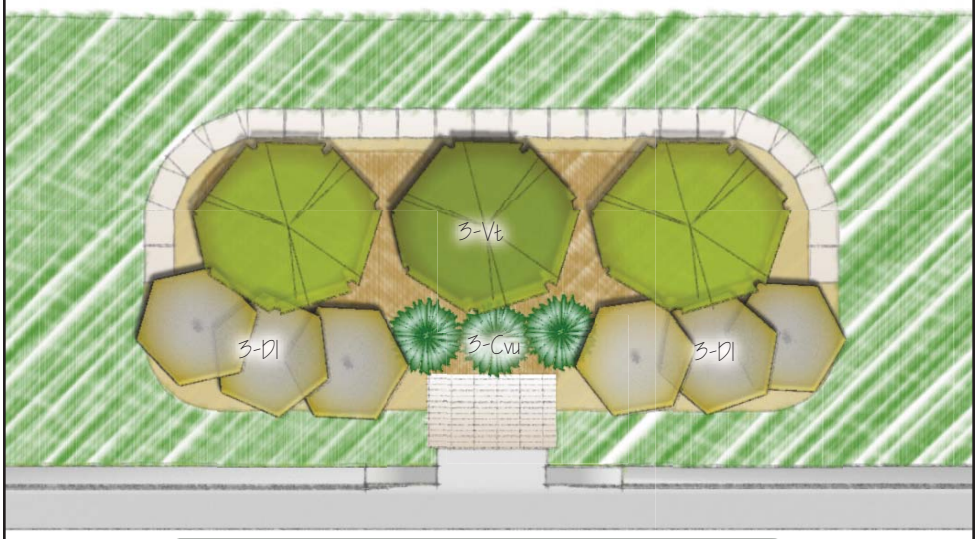
Mixed Shrub/Flower Garden

Plant Key

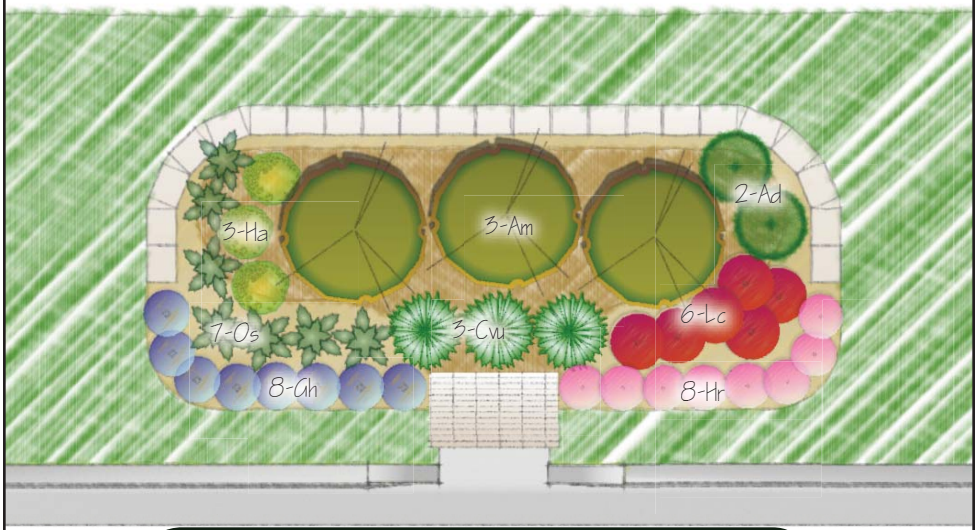
Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ha	SNEEZEWEED *Helenium autumnale*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT V*ronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

X. Rectangle Garden - Shady Site - Retaining Wall

Flowering Perennial Garden



Shrub Garden

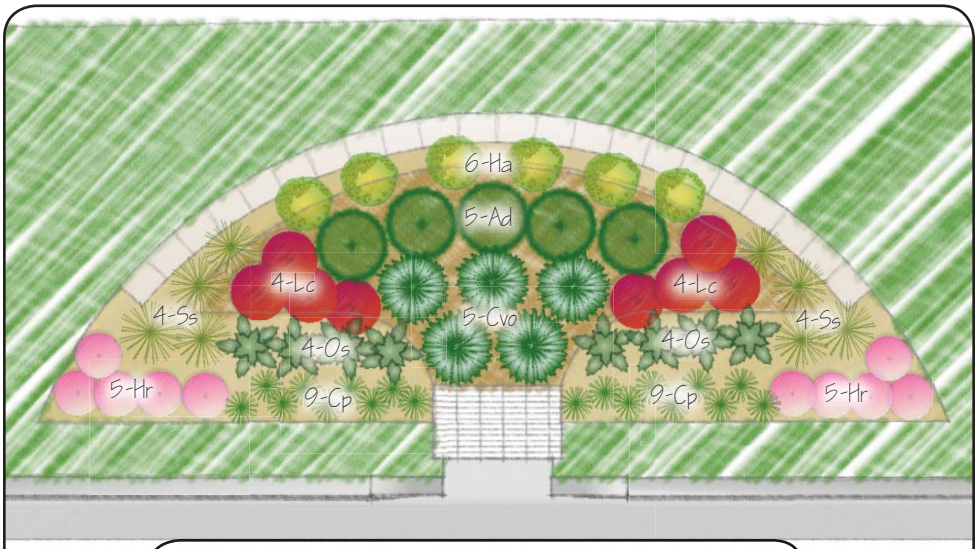


Mixed Shrub/Flower Garden

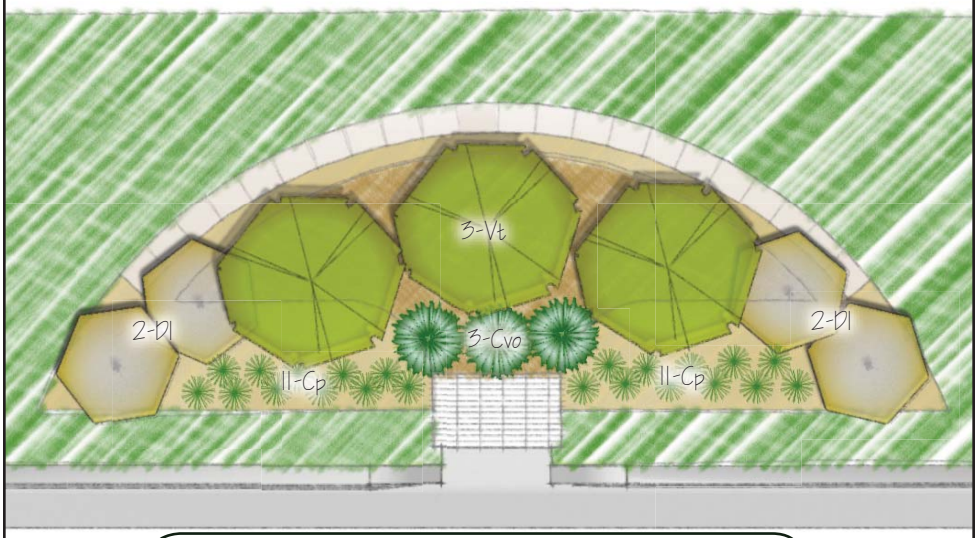
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

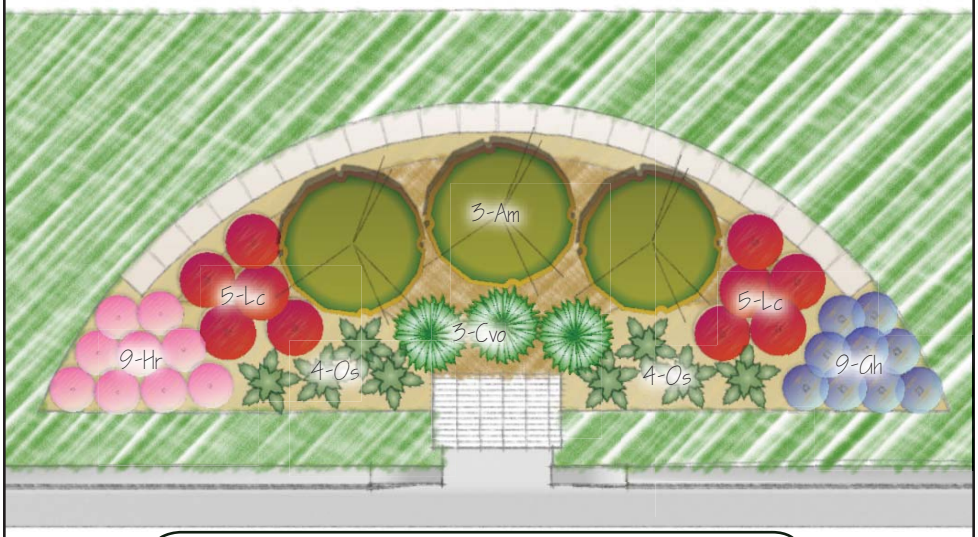
XI. Arc Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

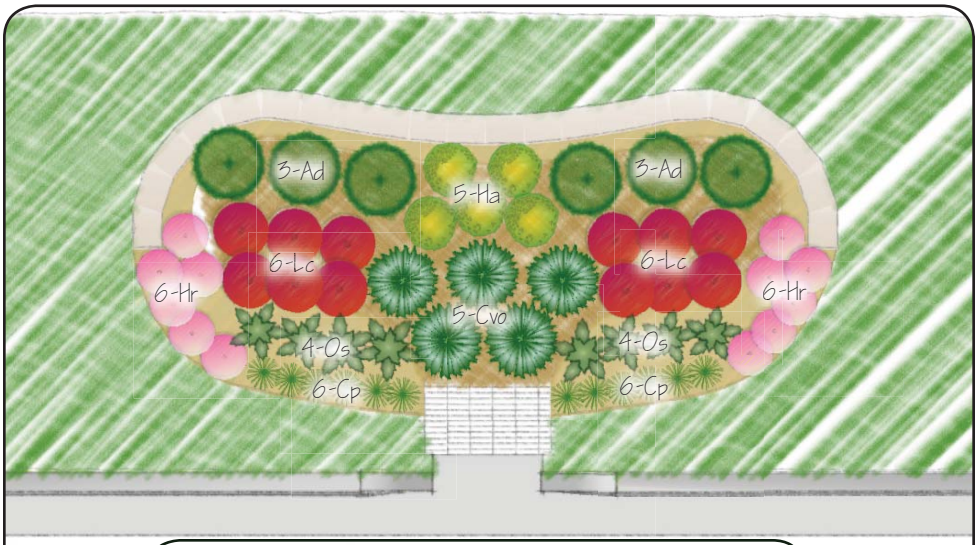


Mixed Shrub/Flower Garden

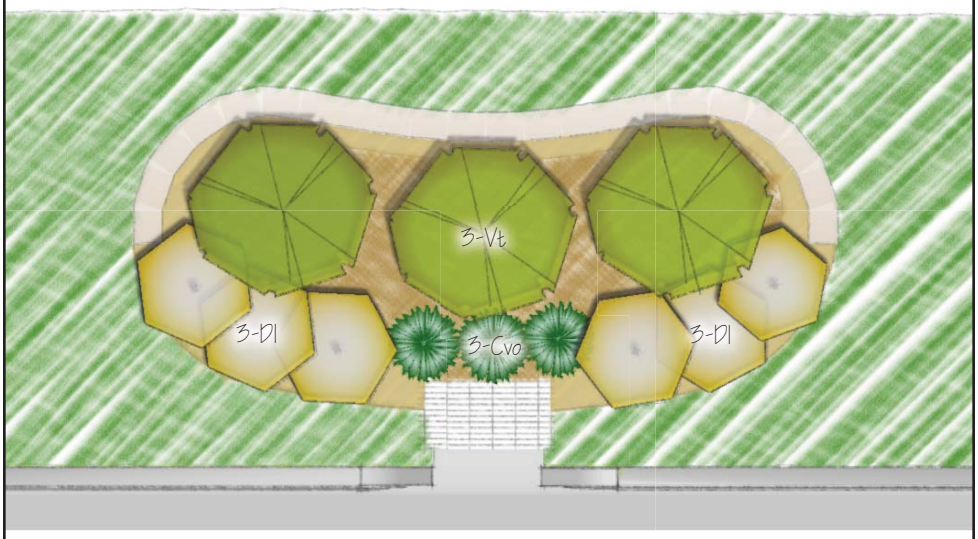
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvo	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

XII. Curvilinear Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

Mixed Shrub/Flower Garden

Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvo	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

FLOWERING PERENNIAL
Plant pallette

CANADA ANEMONE
Anemone canadensis

GOAT'S BEARD
Aruncus diocius

BUTTERFLY MILKWEED
Asclepias tuberosa

ASTER 'PURPLE DOME'
Aster novae-angliae 'Purple Dome'

COREOPSIS 'MOONBEAM'
Coreopsis verticillata 'Moonbeam'

PURPLE PRARIE CLOVER
Dalea purpurea

PURPLE CONEFLOWER
Echinacea purpurea

GERANIUM 'JOHNSON BLUE'
Geranium himalayense x pratense

PRAIRIE SMOKE
Geum trifolium

SNEEZEWEED
Helenium autumnale

ALUMROOT
Heuchera richardsonii

PRAIRIE BLAZING STAR
Liatris pycnostachya

CARDINAL FLOWER
Lobelia cardinalis

SENSITIVE FERN
Onoclea sensibilis

GOLDSTRUM BLACK-EYED SUSAN
Rudbeckia fulgida

CULVERS ROOT
Veronicastrum virginicum

SHRUB
Plant pallette

BLACK CHOKEBERRY
Aronia melonocarpa

DWARF BUSH HONEYSUCKLE
Diervilla lonicera

DART'S RED SPIRAEA
Spiraea japonica

CRANBERRYBUSH VIBURNUM
Viburnum trilobum 'compactum'

GRASSES
Plant pallette

KARL FORESTER GRASS
Calamagrostis acutifolia

PENNSYLVANIA SEDGE
Carex pennsylvanica

FOX SEDGE
Carex vulpinoidea

JUNE GRASS
Koeleria macrantha

LITTLE BLUESTEM
Schizachyrium scoparium

PRAIRIE DROPSEED
Sporobolis heterolepsis