Golden Lake
Stormwater Retrofit Assessment

Prepared by:

ANOKA CONSERVATION DISTRICT

for the

RICE CREEK WATERSHED DISTRICT

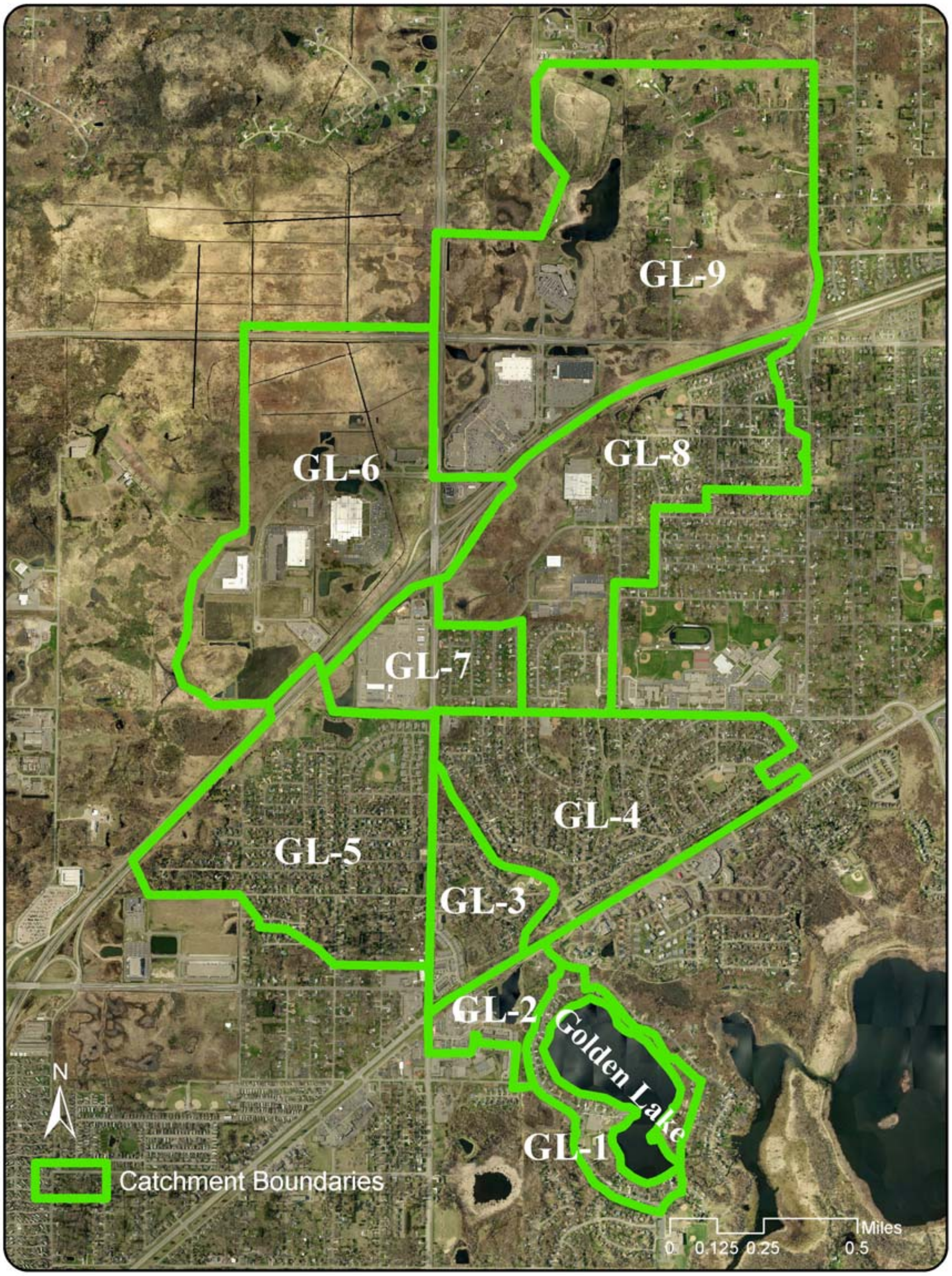
Partial funding provided by the Clean Water Fund (from the Clean Water, Land, and Legacy Amendment).

December 2011

Cover photo: The southern basin of Golden Lake, as seen from Golden Lake Park.

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 Golden Lake before it is discharged into the lake. Golden Lake is an important recreational lake in Circle Pines, Minnesota, but suffers from high nutrient levels, algae blooms, and poor water clarity. The lake is listed by the State of Minnesota as impaired for excess nutrients. These problems have serious negative effects on recreational use of the lake, the fishery, and property values. An in-depth TMDL study of phosphorus sources has been completed. One of the phosphorus sources identified was stormwater runoff. This stormwater assessment systematically examines these sources, investigates ways to improve stormwater treatment, and prioritizes opportunities by cost-effectiveness.

Golden Lake has a long history of water quality improvement efforts, and this project builds upon the successes of those past projects. No one effort will rehabilitate this lake (or most others), and therefore a suite of efforts is needed. Past efforts have included fish community manipulation, lake aeration, restricting motorized boat traffic, excavation of sediment at the primary stormwater discharge point into the lake, stormwater retrofits, new stormwater treatment basins, and others. This study takes these past efforts into account, especially by incorporating existing stormwater practices into modeling efforts.

This stormwater assessment focuses on “stormwater retrofitting” and cost effectiveness ranking. Stormwater retrofitting 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 to Golden Lake through stormwater conveyances. Then, we divided those areas into nine 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 1,070 acre area contributes an estimated 512 acre feet of runoff, 330 pounds of phosphorus and 97,243 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,
- Permeable asphalt, and

- Iron enhanced sand filters.

If all of these practices were installed, significant pollution reduction could be accomplished. 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.

It's noteworthy that any projects that benefit Golden Lake will also benefit important downstream waterbodies. Golden Lake discharges into Rice Creek, which has an impaired macroinvertebrate and fish community. Rice Creek discharges to the Mississippi River. Various reaches of the Mississippi River are impaired for E. coli bacteria, suspended solids, and phosphorus. Stormwater retrofitting in the Golden Lake watershed will include practices that help alleviate all of these problems.

The table on the next page 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 was installed alone with no other projects upstream of it in the same catchment. Installation of projects in series will result in lower total treatment than the simple sum of treatment across the individual projects due to treatment train effects. 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 on the next page.

Catchments GL-1 through GL-7: 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 ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Installation Cost	Estimated cost/ 1,000lb-TSS/year (30-year)	Estimated cost/ lb-TP/year (30-year)
1	GL-5*	Pond Modification - Iron Enhanced Sand Filter	1	17.6 - 23.9	0	0.0	$39,180 - $64,180	N/A	$145 - $177
2	GL-2	Pond Modification - Iron Enhanced Sand Filter	1	35.2	0	0.0	$89,180	N/A	$167
3	GL-4*	Residential Rain Gardens	5 - 15	5.4 - 13.5	865 - 2,281	4.1 - 10.8	$25,020 - $71,420	$1,398 - $1,537	$224 - $260
4	GL-3	Residential Rain Gardens	5	4.1	674	3.2	$25,020	$1,794	$295
5	GL-7	Residential Rain Gardens	5	3.9	676	3.2	$25,020	$1,788	$310
6	GL-5*	Residential Rain Gardens	5 - 10	3 - 5.6	687 - 1,354	4.1 - 7.6	$25,020 - $48,220	$1,741 - $1,760	$403 - $421
7	GL-4*	New Pond with Expanded Drainage Area and Iron Enhanced Sand Filter	1	27.1	3,679	0.0	$172,655 - $228,215	$3,129 - $4,135	$425 - $629
8	GL-4*	New Pond with Expanded Drainage Area	1	13.9	3,679	0.0	$120,780 - $176,340	$2,189 - $3,195	$579 - $845
9	GL-4*	New Pond	1	9.7	2,249	0.0	$95,630 - $151,190	$2,835 - $4,482	$657 - $1,039
10	GL-1*	Golden Lake Park Rain Garden	1	0.7	371	1.1	$19,960	$1,996	$1,139
11	GL-1*	Golden Lake Park Permeable Asphalt	1	0.7	432	1.2	$133,014	$10,752	$6,531

* Pollution reduction benefits and costs can not be summed with other projects in the same catchment because they are alternative options for treating the same source area.

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 Golden Lake subwatershed 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 to Golden Lake were chosen for study. Golden Lake is a high priority because of its potential recreational and fisheries value, known water quality impairments, and because improvements at Golden Lake will also benefit downstream waterbodies including Rice Creek and the Mississippi River, which are also impaired. In the Golden Lake TMDL study, stormwater was identified as a source of phosphorus that needs to be reduced to reach lake goals. The communities in the watershed, the Rice Creek Watershed District, and the Anoka Conservation District are committed and equipped to improve stormwater management.

Stormwater runoff from impervious surfaces like pavement and roofs can carry a variety of pollutants. While stormwater treatment to remove these pollutants is adequate in some areas, other areas were built before modern-day stormwater treatment technologies and requirements or have undersized treatment devices.

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 to Golden 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 9 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 and this nutrient fuels algae blooms. 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 stormwater drainage infrastructure (with invert elevations).

Desktop retrofit analysis features to look for and 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 filter systems before water 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 pass 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.**

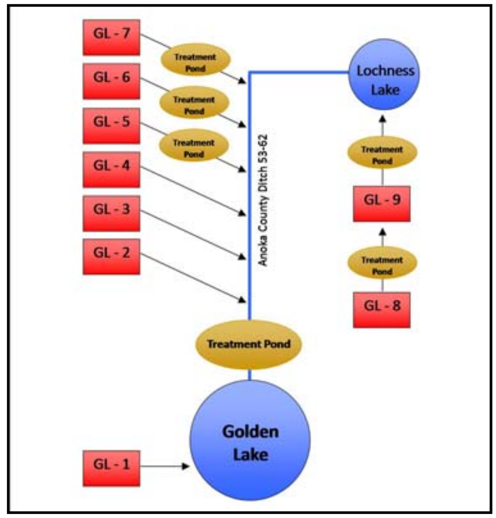
Step 4: Treatment Analysis/Cost Estimates

Sites most likely to be conducive to addressing the cities' and watershed district'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.

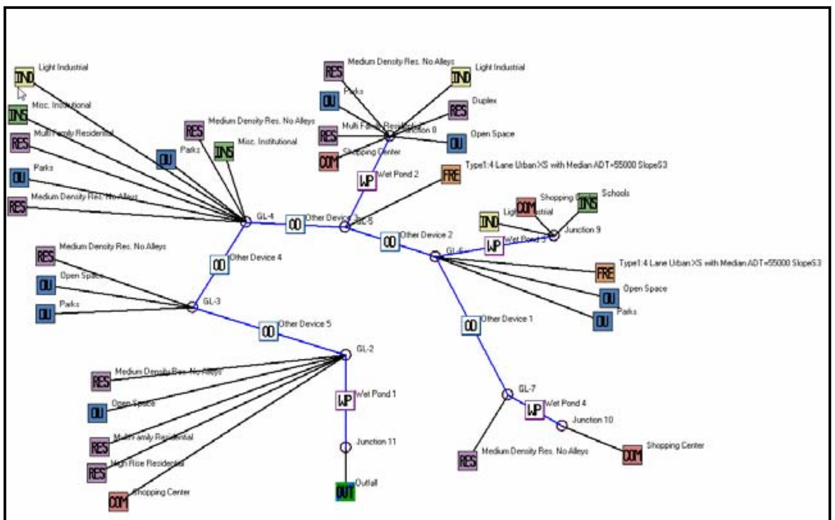
Treatment analysis

Each proposed project's pollutant removal estimates were estimated 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.

The image to the right displays a simplified flow network for all catchments analyzed in this assessment. Anoka County Ditch 53-62 flows throughout the Golden Lake subwatershed, and as a result the connectivity of the catchments to Golden Lake is greatly increased. With the exceptions of GL-8 and GL-9, which first pass through Lochness Lake prior to entering Anoka County Ditch 53-62, the catchments are highly connected to Golden Lake. Several stormwater treatment ponds exist throughout the subwatershed, and the effectiveness of each is further detailed within the catchment profiles section.



The newest version of WinSLAMM (version 10), which allows routing of multiple catchments and stormwater treatment practices, was used for this assessment because of the unique connectivity amongst the catchments identified in the focus area under investigation. Anoka County Ditch 53-62 connects many of the catchments in this assessment and routes them directly to a large stormwater treatment pond prior to entering Golden Lake. Therefore, volume and pollutant loads to Golden Lake from any given catchment must take into consideration the large stormwater treatment pond’s effectiveness. The screen shot to the right displays a network of catchments used in this assessment to accurately model the effectiveness of the large stormwater treatment pond directly upstream of Golden Lake (represented by “Wet Pond 1”).



WinSLAMM modeling network of the Golden Lake subwatershed that represents existing conditions. Each colored square connected to a junction circle via a line represents a land cover type within a catchment (e.g. RES = residential, OU = other urban, COM = commercial, INS = institutional, IND = industrial, and FRE = freeway). All land cover types that collectively meet at a junction represent all land covers within a particular catchment. Catchments are labeled at the junction circle (e.g. GL-2). All water from catchments GL-2 through GL-7 was routed through “Wet Pond 1” prior to discharge into Golden Lake at the “Outfall.” This pond is located southeast of Lake Drive between Golden Lake Road and Village Parkway.

The initial step was to create a “base” model which estimated pollutant loading from each catchment in its present-day state without taking into consideration any existing stormwater treatment. To accurately model the land uses in each catchment, we delineated each land use in each catchment using geographic information systems (specifically, ArcMap), and assigned each a WinSLAMM standard land use file. A site specific land use file was created by adjusting total acreage and accounting for local soil types. 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 ArcMap, and adjusting the model acreages if needed.

Once the "base" model was established, an "existing conditions" model was created by incorporating any existing stormwater treatment practices in the catchment. For example, street cleaning with mechanical or vacuum street sweepers, rain gardens, underground sumps, stormwater treatment ponds, and others were included in the "existing conditions" model if they were present in the catchment.

Finally, each proposed stormwater treatment practice was added to the "existing conditions" 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.

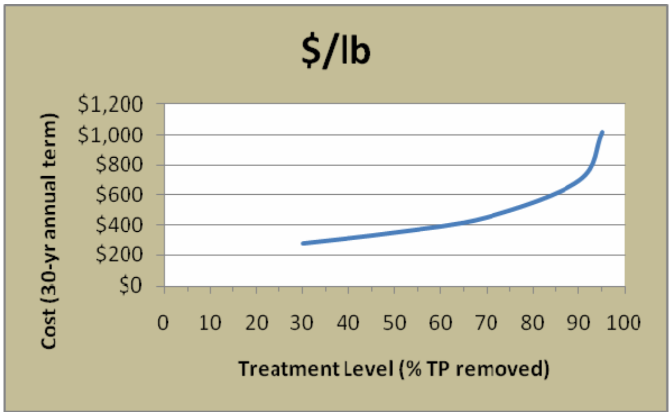
WinSLAMM stormwater computer model inputs

General WinSLAMM Model Inputs	
Parameter	**File/Method**
Land use acreage	ArcMap
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 cities 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 seemed 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 and How to Read Them

The following pages are the "Catchment Profiles." These profiles provide the most important details of this report, including:

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

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

To save space and avoid being repetitive, explanations of the catchment profiles are provided below. We strongly recommend reviewing this section before moving forward in the report.

The analyses of each catchment are broken into "base, existing, and proposed" conditions. They are defined as follows:

Base conditions -	Volume and pollutant loadings from the catchment landscape without any stormwater practices.
Existing conditions -	Volume and pollutant loadings after already-existing stormwater practices are taken into account.
Proposed conditions -	Volume and pollutant loadings after proposed stormwater retrofits.

Many analyses for this assessment were performed at two geographic scales, "catchment and network." They are defined as follows:

Catchment level analyses -	Volume and pollutant loads exiting the catchment at the catchment boundary. There may be other stormwater practices existing or proposed farther downstream, but this analysis ignores them.
Network level analyses -	Volume and pollutant loads that reach Golden Lake through the entire network. These will be much larger numbers than loadings from any one catchment because it is the sum of multiple catchments that discharge at the same point into the lake, and might receive treatment from the same practice. This analysis takes into account stormwater treatment ponds that are in-line with the ditch and upstream of Golden Lake. Most notably, there is a large network outfall pond that treats all water from most catchments just before it enters Golden Lake. The network level analysis includes catchments GL-2 through GL7. Catchment GL-1 is not included in the network level analyses because it is the area immediately around the lake, and does not drain through any network-level outfall ponds. Catchments GL-8 & GL-9 are excluded from network level analyses because they drain to Lochness Lake, where substantial water chemistry changes likely occur.

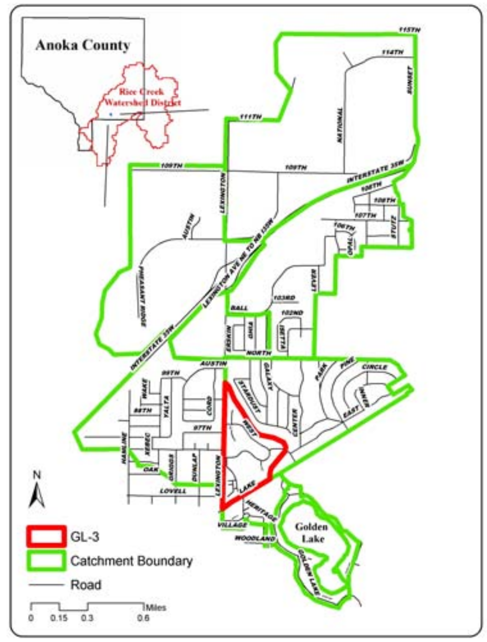
The pollutant load reduction for a proposed stormwater retrofit will often be greater at the catchment level than at the network level. This is because there is a large stormwater pond that treats water from most catchments just before it enters Golden Lake (network outfall pond). For example, a proposed project may capture 10 pounds of phosphorus at the catchment level, but that doesn't necessarily mean 10 fewer pounds of phosphorus will reach the lake because some of that phosphorus was already being removed by the network outfall pond. Benefits of a proposed project must be judged by their pollutant reductions and cost effectiveness at the network level.

The example catchment profile on the following pages explains important features of each profile.

HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Catchment A

Existing Catchment Summary	
Acres	58.90
Dominant Land Cover	Residential
Parcels	237
Volume (acre-feet/yr)	18.37
TP (lb/yr)	25.00
TSS (lb/yr)	6461.00



DESCRIPTION

Example Catchment is primarily comprised of medium-density, single-family residential development…

EXISTING STORMWATER TREATMENT

Existing stormwater treatment practices within Example Catchment consist of street cleaning with a mechanical sweeper in the spring and fall and a network of stormwater treatment ponds…

Catchment ID banner.

Volume and pollutants generated from this catchment under existing conditions.

Catchment locator map.

HOW TO READ THE CATCHMENT PROFILES

Catchment-level analysis of existing conditions.

Catchment Specific Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	25.2	0.2	1%	**25.0**
	TSS (lb/yr)	7,186	725.0	10%	**6,461**
	Volume (acre-feet/yr)	18.4	0.0	0%	**18.4**
	Number of BMP's	1			
	BMP Size/Description	Street cleaning, stormwater pond			

Volume of water and pounds of pollutants generated from the catchment without any stormwater management practices (base conditions).

Pollutants and volume removed by existing stormwater management practices (existing conditions).

Pollutants and volume exiting the catchment after existing practices.

Percent reductions by existing practices.

Network-level analysis of existing conditions.

Network-Wide Existing Conditions (GL-2 through GL-7)

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	623.7	313.0	50%	**310.7**
	TSS (lb/yr)	216,101	124,172.0	57%	**91,929**
	Volume (acre-feet/yr)	494.5	0.0	0%	**494.5**
	Number of BMP's	All BMPs in catchments GL-2 through GL-7			
	BMP Size/Description	Street cleaning and extended wet detention ponds just before outfall into Golden Lake			

Same definitions as above, except here the numbers refer to pollutants and volumes exiting catchments GL-2 through GL-7 in the network collectively. The existing practices include stormwater ponds that treat water from multiple catchments, including the network outfall pond just before water is discharged into Golden Lake.

HOW TO READ THE CATCHMENT PROFILES

Map shows catchment boundaries, stormwater infrastructure, and the locations of proposed stormwater retrofits.

Proposed stormwater retrofits. The project ID number (3 in this case) corresponds to this project's ranking study-wide. This project was the third most cost effective project at phosphorus removal identified in this study.

RETROFIT RECOMMENDATIONS

Project ID #3 – Curb-Cut Rain Garden Network
Drainage Area – 33.7 acres
Location – 5 locations throughout residential area
Property Ownership – Private
Description – The residential land cover within this catchment is best suited to residential, curb-cut rain gardens (see Appendix B for design options). Seven optimal rain garden locations were identified (see map below). Generally, ideal curb-cut rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical land owner participation rates we analyzed a scenario where 5 rain gardens were installed in catchment GL-3. Volume and pollutant reductions resulting from the rain garden installations are highlighted in the tables below.

EXAMPLE Conceptual and example images –


Before rain


During rain

HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Catchment Specific Cost/Benefit Analysis

Volume or pollutant removal this project will achieve.

The project's rank (3) is shown again and three "levels" of this project are compared: 6, 9, or 12 rain gardens, for example.

Cumulative pollutant removal achieved by this project and already-existing practices.

	Cost/Benefit Analysis	***Project ID***					
		3 6 Rain Gardens		**3 9 Rain Gardens**		**3 12 Rain Gardens**	
		New trtmt	**Net trtmt %**	**New trtmt**	**Net trtmt %**	**New trtmt**	**Net trtmt %**
Treatment	**TP (lb/yr)**	5.4	39%	6.8	43%	7.7	46%
	TSS (lb/yr)	1,684	41%	2,127	45%	2,408	48%
	Volume (acre-feet/yr)	4.2	33%	5.4	38%	6.1	41%
	Number of BMP's	6		9		12	
	BMP Size/Description	1,500 sq ft		2,250 sq ft		3,000 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	**Materials/Labor/Design**	$27,210		$40,710		$54,210	
	Promotion & Admin Costs	$2,450		$2,870		$3,290	
	Total Project Cost	$29,660		$43,580		$57,500	
	Annual O&M	$450		$675		$900	
	Term Cost/1,000lb-TSS/yr	$855		$1,000		$1,170	
	Term Cost/lb-TP/yr	**$266**		**$313**		**$364**	

Project installation cost estimation.

Cost effectiveness at suspended solids removal. The project cost is divided by suspended solids removal in pounds (30 yrs). Includes operations and maintenance over the project life (30 years unless otherwise noted).

Cost effectiveness at phosphorus removal. The project cost is divided by phosphorus removal in pounds (30 yrs). Includes operations and maintenance over the project life (30 years unless otherwise noted).

Compare cost effectiveness of various project "levels" in these rows for TSS (2nd row from bottom) or TP (bottom row) removal. Compare cost effectiveness numbers between projects to determine the best value.

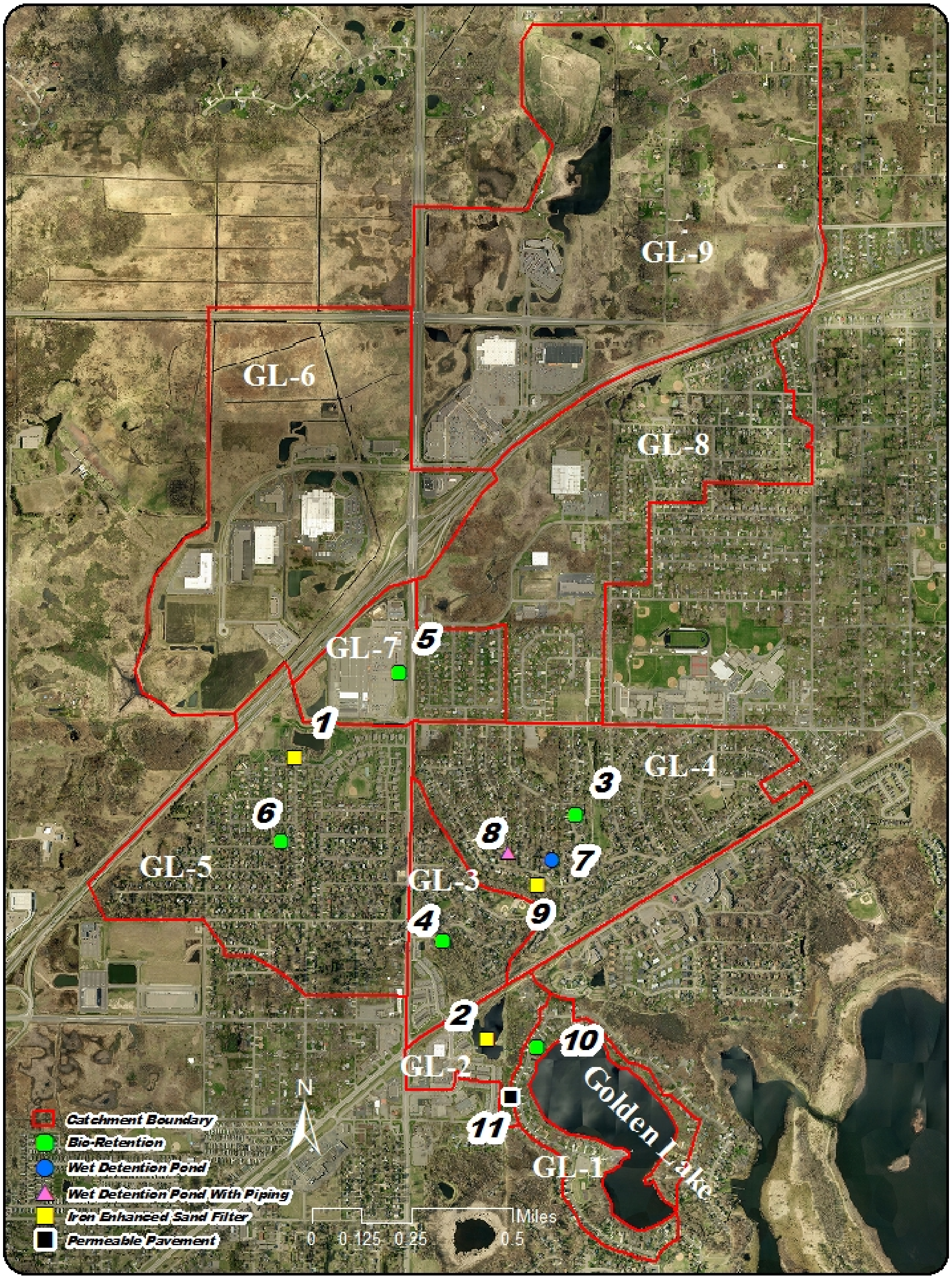
HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Network-Wide Cost/Benefit Analysis (GL-2 through GL-7)

	Cost/Benefit Analysis	Project ID					
		3 6 Rain Gardens		3 9 Rain Gardens		3 12 Rain Gardens	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	5.4	39%	6.8	43%	7.7	46%
	TSS (lb/yr)	1,684	41%	2,127	45%	2,408	48%
	Volume (acre-feet/yr)	4.2	33%	5.4	38%	6.1	41%
	Number of BMP's	6		9		12	
	BMP Size/Description	1,500 sq ft		2,250 sq ft		3,000 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$27,210		$40,710		$54,210	
	Promotion & Admin Costs	$2,450		$2,870		$3,290	
	Total Project Cost	$29,660		$43,580		$57,500	
	Annual O&M	$450		$675		$900	
	Term Cost/1,000lb-TSS/yr	$855		$1,000		$1,170	
	Term Cost/lb-TP/yr	**$266**		**$363**		**$414**	

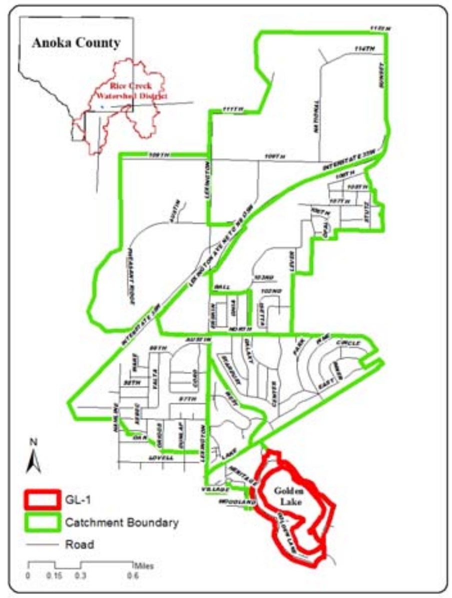
This table is the same as the previous catchment-level table, except it examines the costs and benefits of proposed stormwater retrofits at the network level. **This table should be used to compare projects in catchments GL-2 through GL-7 because it represents volume and pollutant removals at the point where the water enters Golden Lake.**

Map of stormwater catchment areas (GL-1 thru GL-9) 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 GL-1

Existing Catchment Summary	
Acres	56.20
Dominant Land Cover	Residential
Parcels	137
Volume (acre-feet/yr)	17.32
TP (lb/yr)	18.96
TSS (lb/yr)	5,314



CATCHMENT DESCRIPTION

Catchment GL-1 consists of the area surrounding Golden Lake that drains directly to the lake. Medium-density, single-family residential development is the primary land cover type within GL-1. Golden Lake Park is also included in this area.

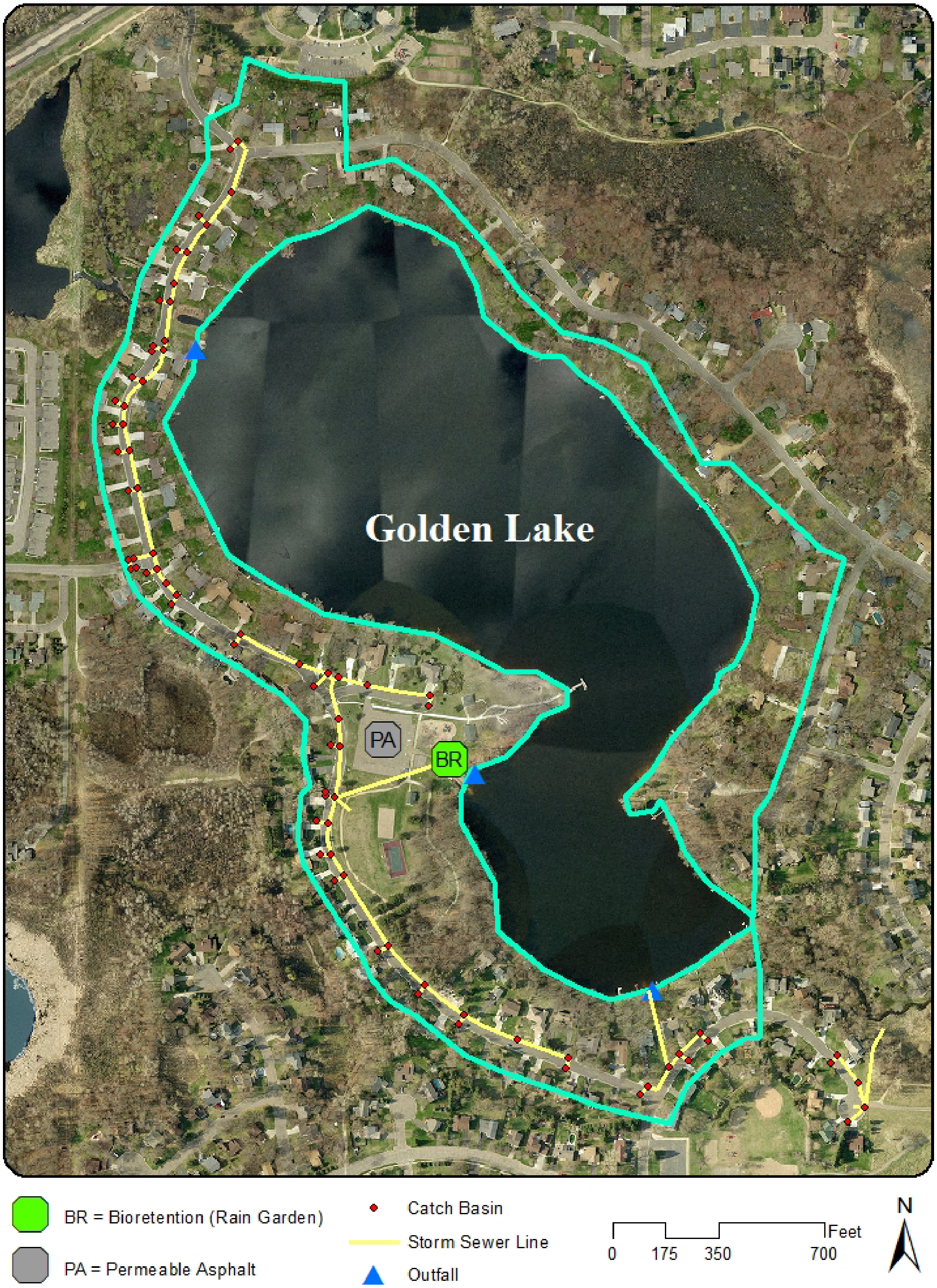
EXISTING STORMWATER TREATMENT

Catchment GL-1 has some of the most elaborate existing stormwater treatment of all the catchments identified in this study. A 2008 street and utility improvement project along West Golden Lake Road resulted in the installation of several stormwater treatment practices. In addition to the spring and fall street cleaning schedule, three curb-cut residential rain gardens, three sumps, and a 5,600 square foot underground infiltrating drain tile field were constructed.

The high density of catch basins that were installed as part of the 2008 street reconstruction project make GL-1 a poor candidate for curb-cut rain gardens because of the many small drainage areas (i.e. an optimally placed curb-cut rain garden would have a small drainage area). Yet, the three curb-cut rain gardens that were installed were placed in locations that have the largest drainage areas. However, the inlets and sediment accumulation (see images to right) within the basins likely require additional maintenance to ensure stormwater runoff is able to enter the gardens. Existing pollutant loads from this catchment to Golden Lake are shown in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	27.5	8.6	31%	**19.0**
	TSS (lb/yr)	8,647	3,333	39%	**5,314**
	Volume (acre-feet/yr)	21.1	3.8	18%	**17.3**
	Number of BMP's	8			
	BMP Size/Description	3 Rain Gardens, 3 Sumps, Street Cleaning, and Infiltrating Drain Tile Field			

RETROFIT RECOMMENDATIONS



Project ID #10 – Golden Lake Park - Parking Lot Rain Garden
Drainage Area - 0.86 acres
Location – Golden Lake Park on West side of Golden Lake
Property Ownership – City of Circle Pines
Description – Space is available within Golden Lake Park to treat runoff generated by the 0.86 acre parking lot that drains directly to Golden Lake. A rain garden placed to the side of the lake access ramp (BR in the map below) would collect run-off from the parking lot and provide stormwater treatment via infiltration. The rain garden was modeled as a single 1,000 square foot garden. See Appendix B for rain garden design options. Volume and pollutant reductions resulting from the rain garden installation are highlighted in the table below.
Proposed Site Images -

	Cost/Benefit Analysis	Project ID					
		10 Rain Garden					
		New trtmt	Net %			New trtmt	Net %
Treatment	TP (lb/yr)	0.7	33%				
	TSS (lb/yr)	371	43%				
	Volume (acre-feet/yr)	1.1	23%				
	Number of BMP's	1					
	BMP Size/Description	1,000 sq ft					
	BMP Type	Complex Bioretention					
Cost	Materials/Labor/Design	$18,210					
	Promotion & Admin Costs	$1,750					
	Total Project Cost	$19,960					
	Annual O&M	$75					
	Term Cost/1,000lb-TSS/yr	$1,996					
	Term Cost/lb-TP/yr	**$1,139**					

Project ID #11 – Golden Lake Park Parking Lot Permeable Asphalt

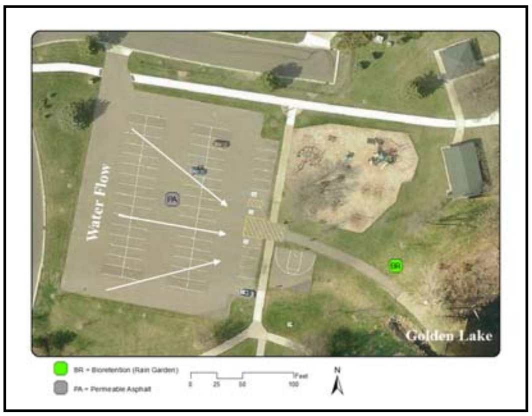
Drainage Area - 0.86 acres

Location – Golden Lake Park on West side of Golden Lake

Property Ownership – City of Circle Pines

Description – An alternative option to the rain garden described above would be permeable asphalt within the 0.86 acre parking lot (PA in the map below). Generally, permeable pavements can treat water from an area of impervious surface three times the size of the permeable pavement. Therefore, 0.22 acres (9,366 square feet) of permeable asphalt would be sufficient to treat the 0.86 acre parking lot. The model included maintenance, such as restorative vacuuming on an annual basis. See appendix A for more details on the design of permeable pavements. Catchment-wide volume and pollutant removal are shown in the table below.

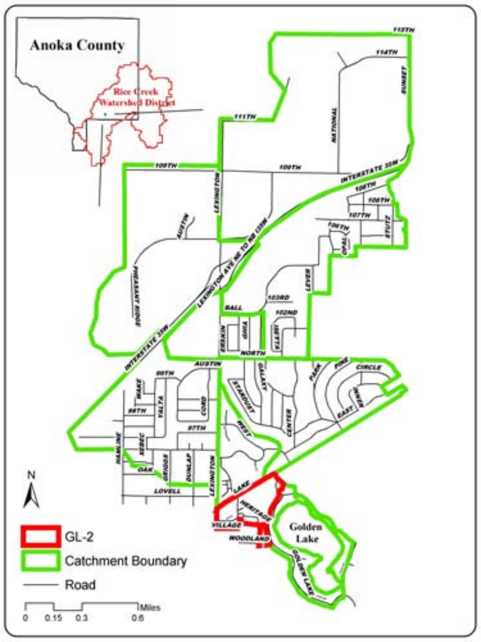
Proposed Site Images –



	Cost/Benefit Analysis	Project ID					
		11 Permeable Asphalt					
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	0.7	34%				
	TSS (lb/yr)	432	44%				
	Volume (acre-feet/yr)	1.2	24%				
	Number of BMP's	1					
	BMP Size/Description	9,366	sq ft				
	BMP Type	Permeable Asphalt					
Cost	Materials/Labor/Design	$131,334					
	Promotion & Admin Costs	$1,680					
	Total Project Cost	$133,014					
	Annual O&M	$215					
	Term Cost/1,000lb-TSS/yr	$10,752					
	Term Cost/lb-TP/yr	**$6,531**					

Catchment GL-2

Existing Catchment Summary	
Acres	40.80
Dominant Land Cover	Open Space
Parcels	132
Volume (acre-feet/yr)	26.40
TP (lb/yr)	23.90
TSS (lb/yr)	7,743



DESCRIPTION

Catchment GL-2 is located upstream of Golden Lake and consists primarily of open space with substantial areas of commercial and multi-family residential land cover. The large open space present in catchment GL-2 is dominated by the City of Circle Pines Wetland Mitigation Project (RCWD No. 97-149).

EXISTING STORMWATER TREATMENT

Street cleaning in the spring and fall is conducted by the City of Circle Pines. In addition, Anoka County Ditch 53-62 flows into the five acre wet pond located in catchment GL-2. The pond provides water quality treatment for the all drainage areas studied in this report, other than GL-1, which drains directly to Golden Lake.

Existing volume and pollutant loading from this catchment are displayed in the two tables below. The network-wide existing conditions table highlights the effects of the five acre wet pond located within GL-2 that treats all water from Ditch 53-62 prior to entering Golden Lake.

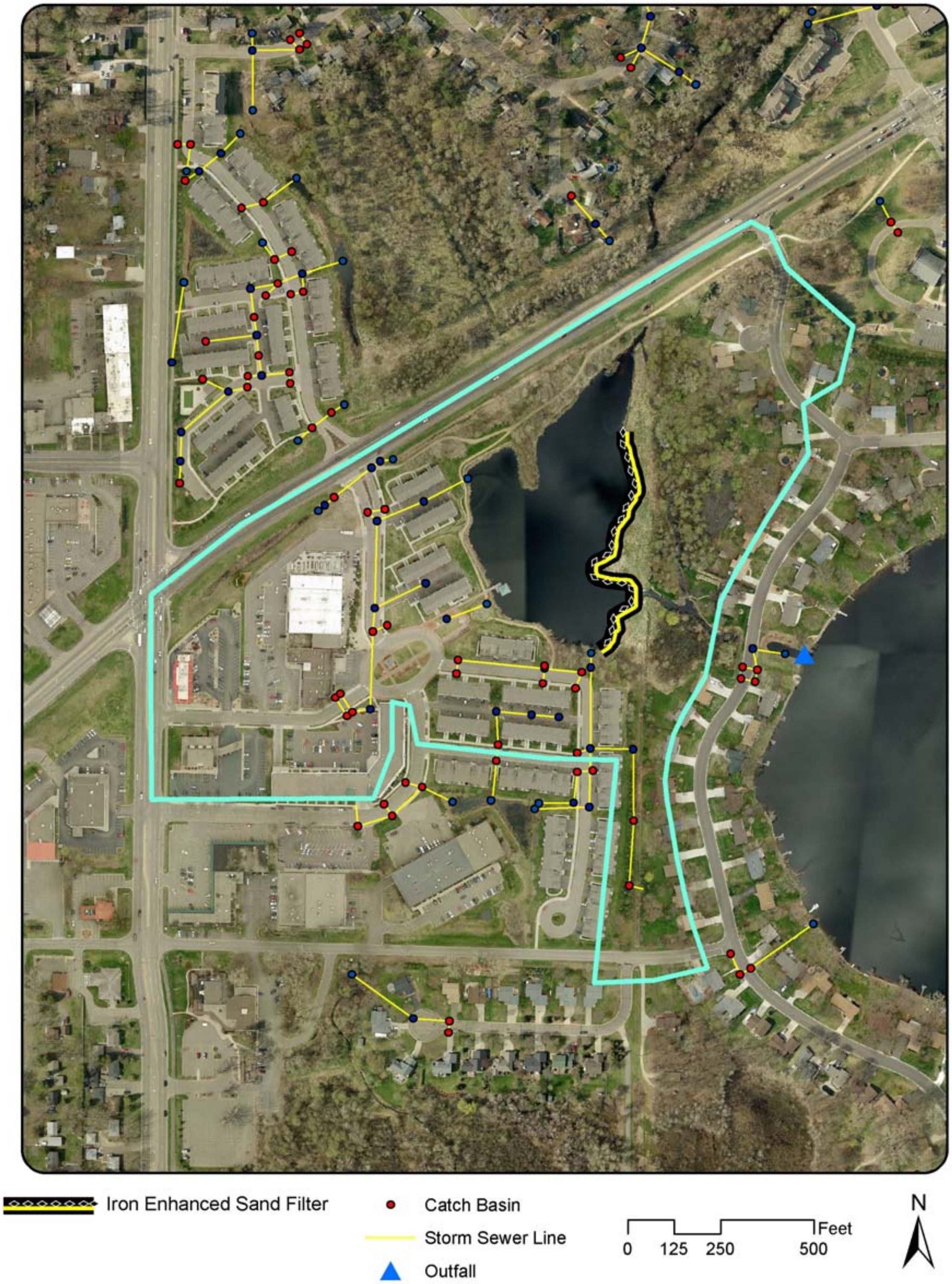
Catchment Specific Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	24.0	0.1	0%	**23.9**
	TSS (lb/yr)	8,281	538	6%	**7,743**
	Volume (acre-feet/yr)	26.4	0.0	0%	**26.4**
	Number of BMP's	1			
	BMP Size/Description	Street cleaning			

Network-Wide Existing Conditions (GL-2 through GL-7)

	Existing Conditions	**Base Loading**	**Treatment**	**Net Treatment %**	**Existing Loading**
Treatment	**TP (lb/yr)**	623.7	313.0	50%	**310.7**
	TSS (lb/yr)	216,101	124,172	57%	**91,929**
	Volume (acre-feet/yr)	494.5	0.0	0%	**494.5**
	Number of BMP's	All BMPs in catchments GL-2 through GL-7			
	BMP Size/Description	Street cleaning and extended wet detention ponds			

RETROFIT RECOMMENDATIONS

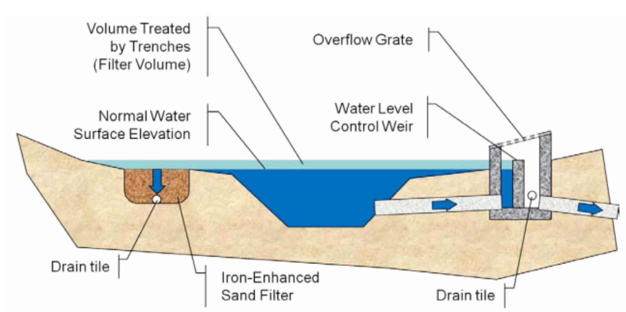


<u>Project ID #2 –</u> <u>Iron enhanced sand filter for existing pond</u>
Drainage Area – 1,013.3 acres
Location – East side of wet detention pond located Northeast of Golden Lake in catchment GL-2
Property Ownership – City of Circle Pines
Description – Retrofitting the existing wet pond with an iron enhanced sand filter along the eastern edge of the pond would significantly increase the pond's efficiency at removing dissolved phosphorus (Erickson & Gulliver 2010). A significant percentage of phosphorus in stormwater is dissolved (30%-45%).

The iron enhanced sand filter would be installed at an elevation slightly above the normal water level of the pond so that following a storm event the increase in depth of the pond would be first diverted to the iron enhanced sand filter. The filter would have drain tile installed along the base of the trench and would outlet downstream of the current pond outlet. Large storm events that overwhelm the iron enhanced sand filter's capacity would exit the pond via the existing outlet.

Based on available space and the large contributing drainage area, a 700 foot long by 10 foot wide by 2 foot deep filter with one foot of live storage above the iron enhanced sand filter was modeled. Network-wide volume and pollutant removal are shown in the table below. Please note that no estimates are included for modifications to the outlet structure of the existing pond, and the cost estimates assume the city would complete the installation. The iron enhanced sand filter would need to be an engineered project, and the existing pond outlet may be deemed unsuitable for this type of practice which would result in the additional expense of a new outlet. Nevertheless, the large drainage area treated by this pond (1,013.3 acres) combined with the effectiveness of the iron enhanced sand filter will likely make this one of the most cost effective options regardless of the need to replace the pond's outlet structure.

Conceptual and Proposed Site Images -



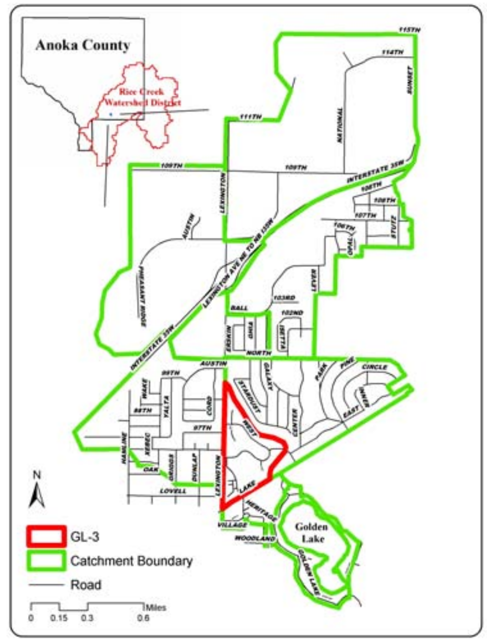
(Erickson & Gulliver 2010)

Network-Wide Cost/Benefit Analysis (GL-2 through GL-7)

	Cost/Benefit Analysis	**Project ID**					
		2 Iron Enhanced Sand Filter					
		New trtmt	**Net %**				
Treatment	**TP (lb/yr)**	35.2	56%				
	TSS (lb/yr)	0	57%				
	Volume (acre-feet/yr)	0.0	0%				
	Number of BMP's	1					
	BMP Size/Description	700	linear feet				
	BMP Type	Iron Enhanced Sand Filter					
Cost	**Materials/Labor/Design**	$87,500					
	Promotion & Admin Costs	$1,680					
	Total Project Cost	$89,180					
	Annual O&M	$2,917					
	Term Cost/1,000lb-TSS/yr	N/A					
	Term Cost/lb-TP/yr	**$167**					

Catchment GL-3

Existing Catchment Summary	
Acres	58.90
Dominant Land Cover	Residential
Parcels	237
Volume (acre-feet/yr)	18.37
TP (lb/yr)	25.00
TSS (lb/yr)	6,461



DESCRIPTION

Catchment GL-3 is primarily comprised of medium-density, single-family residential development with Carl Eck Park positioned on the east side. Ditch 53-62 forms the eastern boundary of catchment GL-3 and Lexington Avenue forms the western boundary. There is a 12.3 acre section of multi-family residential land cover in the southwest corner of the catchment, but this land cover was removed from the analysis because of the existing stormwater treatment described below.

EXISTING STORMWATER TREATMENT

Existing stormwater treatment practices within GL-3 consist of street cleaning with a mechanical sweeper in the spring and fall and a network of stormwater treatment ponds that treat the multi-family residential land cover in the southwest corner of the catchment. The stormwater ponds were determined to be isolated from Ditch 53-62, except under extreme conditions when overflow may cause them to reach the ditch. However, there is a large area of open space through which the overflow water would need to travel prior to entering the ditch. For these reasons, the 12.3 acre multi-family residential land cover was removed from this analysis. The tables below highlight existing volume and pollutant loads from catchment GL-3.

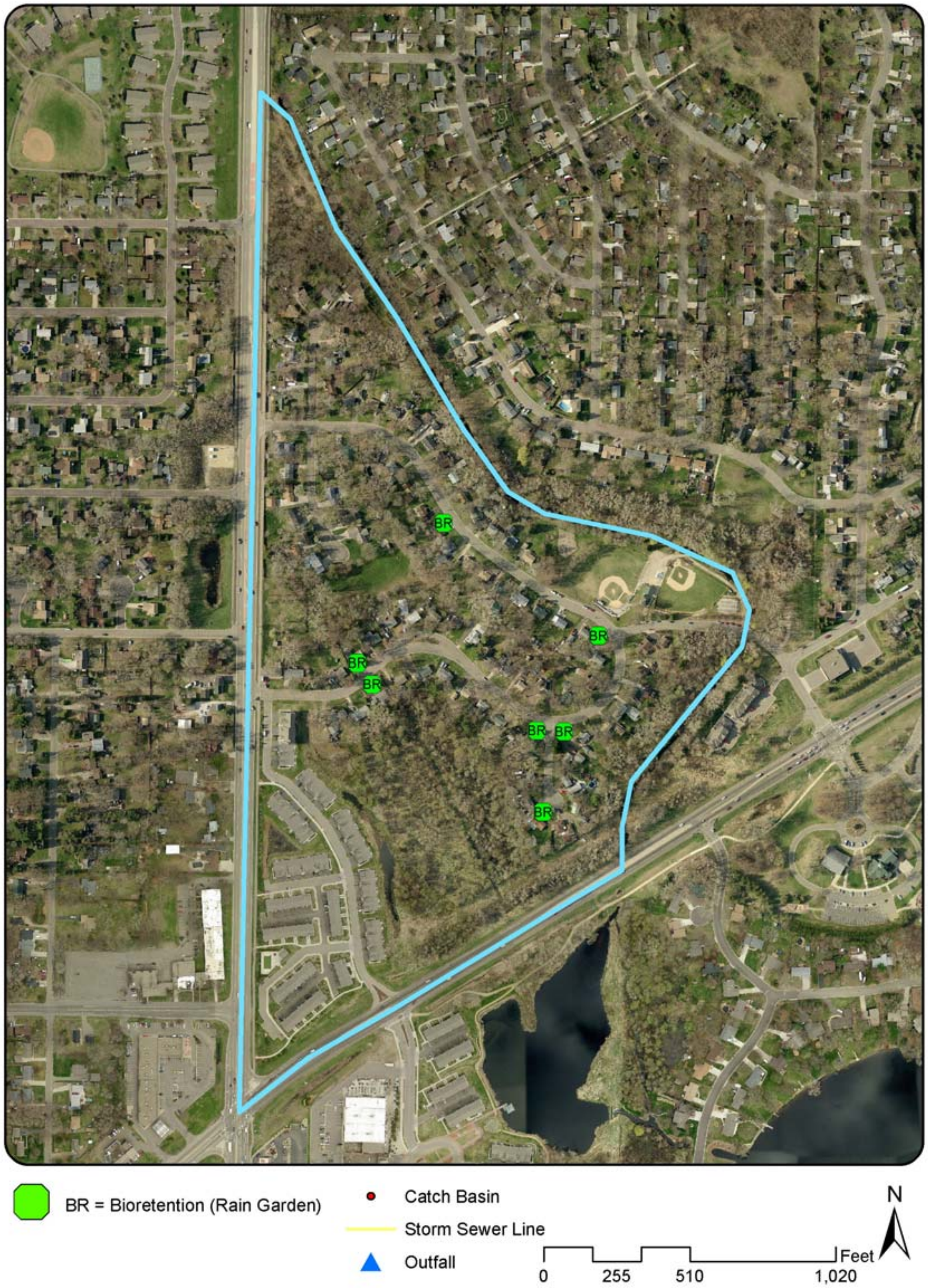
Catchment Specific Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	25.2	0.2	1%	**25.0**
	TSS (lb/yr)	7,186	725	10%	**6,461**
	Volume (acre-feet/yr)	18.4	0.0	0%	**18.4**
	Number of BMP's	1			
	BMP Size/Description	Street Cleaning			

Network-Wide Existing Conditions (GL-2 through GL-7)

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	623.7	313.0	50%	**310.7**
	TSS (lb/yr)	216,101	124,172	57%	**91,929**
	Volume (acre-feet/yr)	494.5	0.0	0%	**494.5**
	Number of BMP's	All BMPs in catchments GL-2 through GL-7			
	BMP Size/Description	Street cleaning and extended wet detention ponds			

RETROFIT RECOMMENDATIONS



Project ID #4 – Curb-Cut Rain Garden Network
Drainage Area – 33.7 acres
Location – 5 locations throughout medium-density residential land cover in catchment GL-3
Property Ownership – Private
Description – The residential land cover within this catchment is best suited for residential, curb-cut rain gardens (see Appendix B for design options). Seven optimal rain garden locations were identified (see map above). Generally, ideal curb-cut rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical land owner participation rates we analyzed a scenario where 5 rain gardens were installed in catchment GL-3. Volume and pollutant reductions resulting from the rain garden installations are highlighted in the tables below.
Conceptual images -

Before rain

During rain

Catchment Specific Cost/Benefit Analysis

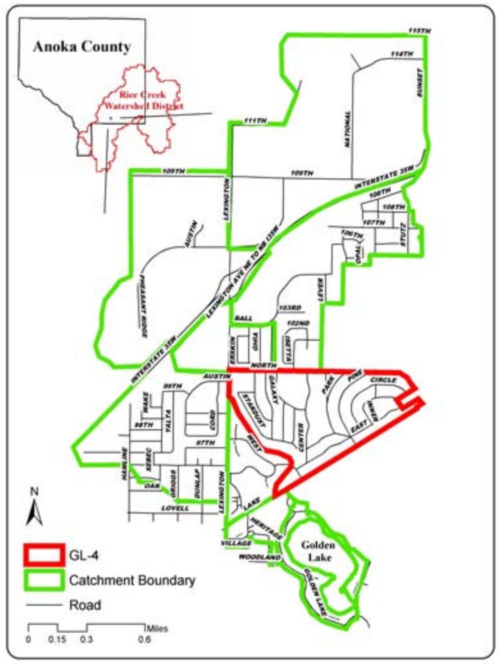
	Cost/Benefit Analysis	Project ID					
		4 5 Rain Gardens					
		New trtmt	Net %			New trtmt	Net %
Treatment	TP (lb/yr)	6.8	28%				
	TSS (lb/yr)	1,273	28%				
	Volume (acre-feet/yr)	3.2	18%				
	Number of BMP's	5					
	BMP Size/Description	1,250 sq ft					
	BMP Type	Complex Bioretention					
Cost	Materials/Labor/Design	$22,710					
	Promotion & Admin Costs	$2,310					
	Total Project Cost	$25,020					
	Annual O&M	$375					
	Term Cost/1,000lb-TSS/yr	$950					
	Term Cost/lb-TP/yr	**$178**					

Network-Wide Cost/Benefit Analysis (GL-2 through GL-7)

	Cost/Benefit Analysis	Project ID					
		4 5 Rain Gardens					
		New trtmt	Net %				
Treatment	TP (lb/yr)	4.1	51%				
	TSS (lb/yr)	674	58%				
	Volume (acre-feet/yr)	3.2	1%				
	Number of BMP's	5					
	BMP Size/Description	1,250 sq ft					
	BMP Type	Complex Bioretention					
Cost	Materials/Labor/Design	$22,710					
	Promotion & Admin Costs	$2,310					
	Total Project Cost	$25,020					
	Annual O&M	$375					
	Term Cost/1,000lb-TSS/yr	$1,794					
	Term Cost/lb-TP/yr	**$295**					

Catchment GL-4

Existing Catchment Summary	
Acres	233.30
Dominant Land Cover	Residential
Parcels	589
Volume (acre-feet/yr)	99.40
TP (lb/yr)	124.20
TSS (lb/yr)	36,595



DESCRIPTION

Catchment GL-4 is located directly north of Golden Lake and is part of the eastern boundary of the focus area for this assessment. Ditch 53-62 creates the western boundary of this catchment and all stormwater runoff flows into the ditch. Land cover within catchment GL-4 consists primarily of medium-density, single-family residential and three sizeable parks (North Star, Center, and Inner).

EXISTING STORMWATER TREATMENT

Existing stormwater treatment within catchment GL-4 consists of street cleaning with a mechanical street sweeper. However, the large areas of medium-density, single-family residential land cover drain untreated into Anoka County Ditch 53-62, which eventually enters Golden Lake. Several storm sewer outfalls outlet to an open area just north of Anoka County Ditch 53-62. The outfalls carry large sediment loads (see images to right) and have created channels directly to Anoka County Ditch 53-62 with significant erosion.

Catchment Specific Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	125.1	0.9	1%	**124.2**
	TSS (lb/yr)	40,441	3,846	10%	**36,595**
	Volume (acre-feet/yr)	99.4	0.0	0%	**99.4**
	Number of BMP's	1			
	BMP Size/Description	Street Cleaning			

Network-Wide Existing Conditions (GL-2 through GL-7)

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	623.7	313.0	50%	**310.7**
	TSS (lb/yr)	216,101	124,172	57%	**91,929**
	Volume (acre-feet/yr)	494.5	0.0	0%	**494.5**
	Number of BMP's	All BMPs in catchments GL-2 through GL-7			
	BMP Size/Description	Street cleaning and extended wet detention ponds			

RETROFIT RECOMMENDATIONS

Project ID #3 – Curb-Cut Rain Garden Network
Drainage Area – 187.3 acres
Location – 15 locations throughout medium-density residential land cover in catchment GL-4
Property Ownership – Private
Description – The residential land cover within this catchment is best suited for residential, curb-cut rain gardens (see Appendix B for design options). Sixty two optimal rain garden locations were identified (see map above). Generally, ideal curb-cut rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical land owner participation rates we analyzed scenarios where 5, 10, and 15 rain gardens were installed in catchment GL-4. Volume and pollutant reductions resulting from the rain garden installations are highlighted in the tables below.
Example Images -

Before

After

Catchment Specific Cost/Benefit Analysis

	Cost/Benefit Analysis	Project ID					
		3 5 Rain Gardens		3 10 Rain Gardens		3 15 Rain Gardens	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	9.1	8%	16.3	14%	22.5	19%
	TSS (lb/yr)	1,633	14%	3,025	17%	4,291	20%
	Volume (acre-feet/yr)	4.1	4%	7.6	8%	10.8	11%
	Number of BMP's	5		10		15	
	BMP Size/Description	1,250 sq ft		2,500 sq ft		3,750 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$22,710		$45,210		$67,710	
	Promotion & Admin Costs	$2,310		$3,010		$3,710	
	Total Project Cost	$25,020		$48,220		$71,420	
	Annual O&M	$375		$750		$1,125	
	Term Cost/1,000lb-TSS/yr	$740		$779		$817	
	Term Cost/lb-TP/yr	**$133**		**$145**		**$156**	

Network-Wide Cost/Benefit Analysis (GL-2 through GL-7)

	Cost/Benefit Analysis	Project ID					
		3 5 Rain Gardens		3 10 Rain Gardens		3 15 Rain Gardens	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	5.4	51%	9.7	52%	13.5	52%
	TSS (lb/yr)	865	58%	1,593	58%	2,281	59%
	Volume (acre-feet/yr)	4.1	1%	7.6	2%	10.8	2%
	Number of BMP's	5		10		15	
	BMP Size/Description	1,250 sq ft		2,500 sq ft		3,750 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$22,710		$45,210		$67,710	
	Promotion & Admin Costs	$2,310		$3,010		$3,710	
	Total Project Cost	$25,020		$48,220		$71,420	
	Annual O&M	$375		$750		$1,125	
	Term Cost/1,000lb-TSS/yr	$1,398		$1,480		$1,537	
	Term Cost/lb-TP/yr	**$224**		**$243**		**$260**	

***Project ID #'s 7, 8, and 9* – New Wet Pond (and additional options)**
Drainage Area – 233.3 acres
Location – Carl Eck Park north of Anoka County Ditch 53-62
Property Ownership – City of Circle Pines
Description – A large unused space north of Anoka County Ditch 53-62 within Carl Eck Park presents an opportunity for a new stormwater pond. The site is favorable because it is owned by the city (simpler project administration) and would treat a large area of residential land cover prior to draining into the ditch.

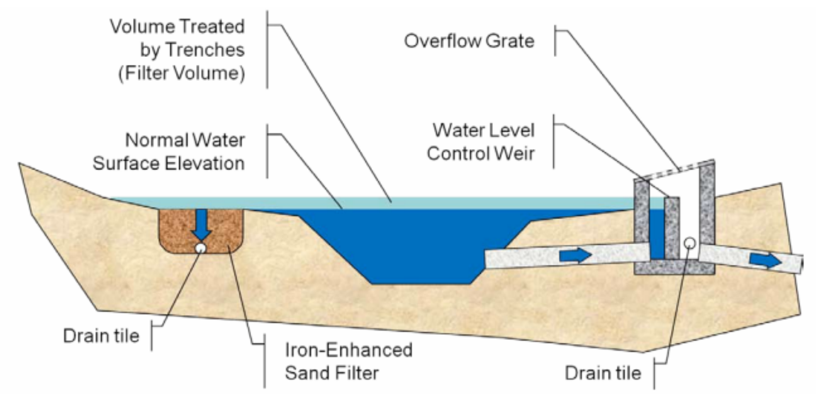
Several options were evaluated and represent Proposed Projects 7, 8, and 9. Proposed Project 7 is the most cost effective (with respect to phosphorus removal) and represents a new pond with additional piping to expand the drainage area treated as well as an iron enhanced sand filter around the perimeter of the pond. Proposed Project 8 is the pond with the additional piping to expand the drainage area but no iron enhanced sand filter. Proposed Project 9 is simply installing the pond without the additional piping or iron enhanced sand filter.

Installation of an iron enhanced sand filter along the eastern edge of the pond would significantly increase the pond's efficiency at removing dissolved phosphorus (Erickson & Gulliver 2010). A significant percentage of phosphorus in stormwater is dissolved (30%-45%).

The iron enhanced sand filter would be installed at an elevation slightly above the normal water level of the wet pond so that following a storm event the increase in depth of the pond would be first diverted to the iron enhanced sand filter. The filter would have drain tile installed along the base of the trench and would outlet downstream of the current pond outlet. Large storm events that overwhelm the iron enhanced sand filter's capacity would exit the pond using the existing outlet.

Based on available space, a 415 foot long by 10 foot wide by 2 foot deep filter with one foot of live storage above the iron enhanced sand filter was modeled. Network-wide volume and pollutant removal are shown in the table below. Please note that no estimates are included for modifications to the outlet structure of the existing pond, and the cost estimates assume the city would complete the installation. The iron enhanced sand filter would need to be an engineered project, and the existing pond outlet may be deemed unsuitable for this type of practice which would result in the additional expense of a new outlet. Nevertheless, the large drainage area treated by this pond (233.3 acres) combined with the effectiveness of the iron enhanced sand filter will likely make this one of the more cost effective options regardless of need to replace the pond's outlet structure. The proposed pond is 0.86 acres (2,750 cubic yard storage capacity). Volume and pollutant reductions for the three proposed projects are highlighted in the tables below.

Conceptual and Proposed Site Images -



(Erickson & Gulliver 2010)

Catchment Specific Cost/Benefit Analysis

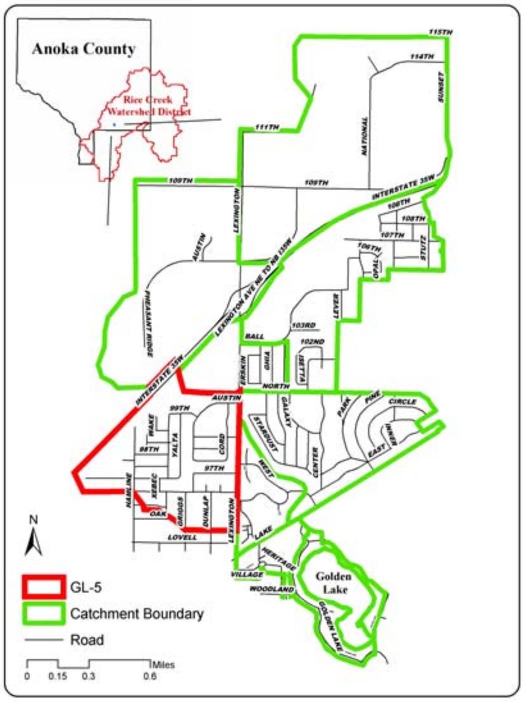
	Cost/Benefit Analysis	Network Treatment By BMP					
		9 Pond		8 Pond + Piping		7 Pond + Piping + IESF	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	46.2	38%	59.4	48%	72.6	59%
	TSS (lb/yr)	13,331	42%	17,625	53%	17,625	53%
	Volume (acre-feet/yr)	0.0	0%	0.0	0%	0.0	0%
	Number of BMP's	1-Pond excavated		1-Pond excavated + Additional Piping		1-Pond excavated + Additional Piping + Iron Enhanced Sand Filter	
	BMP Size/Description	2,750	cubic yards	2,750	cubic yards	2,750	cubic yards
	BMP Type	Wet Pond		Wet Pond		Wet Pond	
Cost	Materials/Labor/Design	$93,950		$119,100		$170,975	
	Promotion & Admin Costs	$1,680		$1,680		$1,680	
	Total Project Cost	$95,630		$120,780		$172,655	
	Annual O&M	$3,188		$4,026		$5,755	
	Term Cost/1,000lb-TSS/yr	$478		$457		$653	
	Term Cost/lb-TP/yr	**$138**		**$136**		**$158**	

Network-Wide Cost/Benefit Analysis (GL-2 through GL-7)

	Cost/Benefit Analysis	Network Treatment By BMP					
		9 Pond		8 Pond + Piping		7 Pond + Piping + IESF	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	9.7	52%	13.9	52%	27.1	55%
	TSS (lb/yr)	2,249	59%	3,679	59%	3,679	59%
	Volume (acre-feet/yr)	0.0	0%	0.0	0%	0.0	0%
	Number of BMP's	1-Pond excavated		1-Pond excavated + Additional Piping		1-Pond excavated + Additional Piping + Iron Enhanced Sand Filter	
	BMP Size/Description	2,750	cubic yards	2,750	cubic yards	2,750	cubic yards
	BMP Type	Wet Pond		Wet Pond		Wet Pond	
Cost	Materials/Labor/Design	$93,950		$119,100		$170,975	
	Promotion & Admin Costs	$1,680		$1,680		$1,680	
	Total Project Cost	$95,630		$120,780		$172,655	
	Annual O&M	$3,188		$4,026		$5,755	
	Term Cost/1,000lb-TSS/yr	$2,835		$2,189		$3,129	
	Term Cost/lb-TP/yr	**$657**		**$579**		**$425**	

Catchment GL-5

Existing Catchment Summary	
Acres	257.50
Dominant Land Cover	Residential
Parcels	564
Volume (acre-feet/yr)	114.55
TP (lb/yr)	82.50
TSS (lb/yr)	25,590



DESCRIPTION

Catchment GL-5 is bordered by Interstate 35 East on the eastern boundary and Lexington Avenue on the western boundary. Anoka County Ditch 53-62 forms the northern boundary and the southern boundary is approximately Lovell Road. Land cover in the catchment is comprised primarily of medium-density, single-family residential.

EXISTING STORMWATER TREATMENT

The 257.5 acres of land in catchment GL-5 drain north to an existing stormwater treatment pond that outlets to Anoka County Ditch 53-62. The pond is located in Centennial Green Park. In addition, street cleaning is conducted with a mechanical street sweeper once each in the spring and fall. The tables below highlight existing volume and pollutant loads from catchment GL-5.

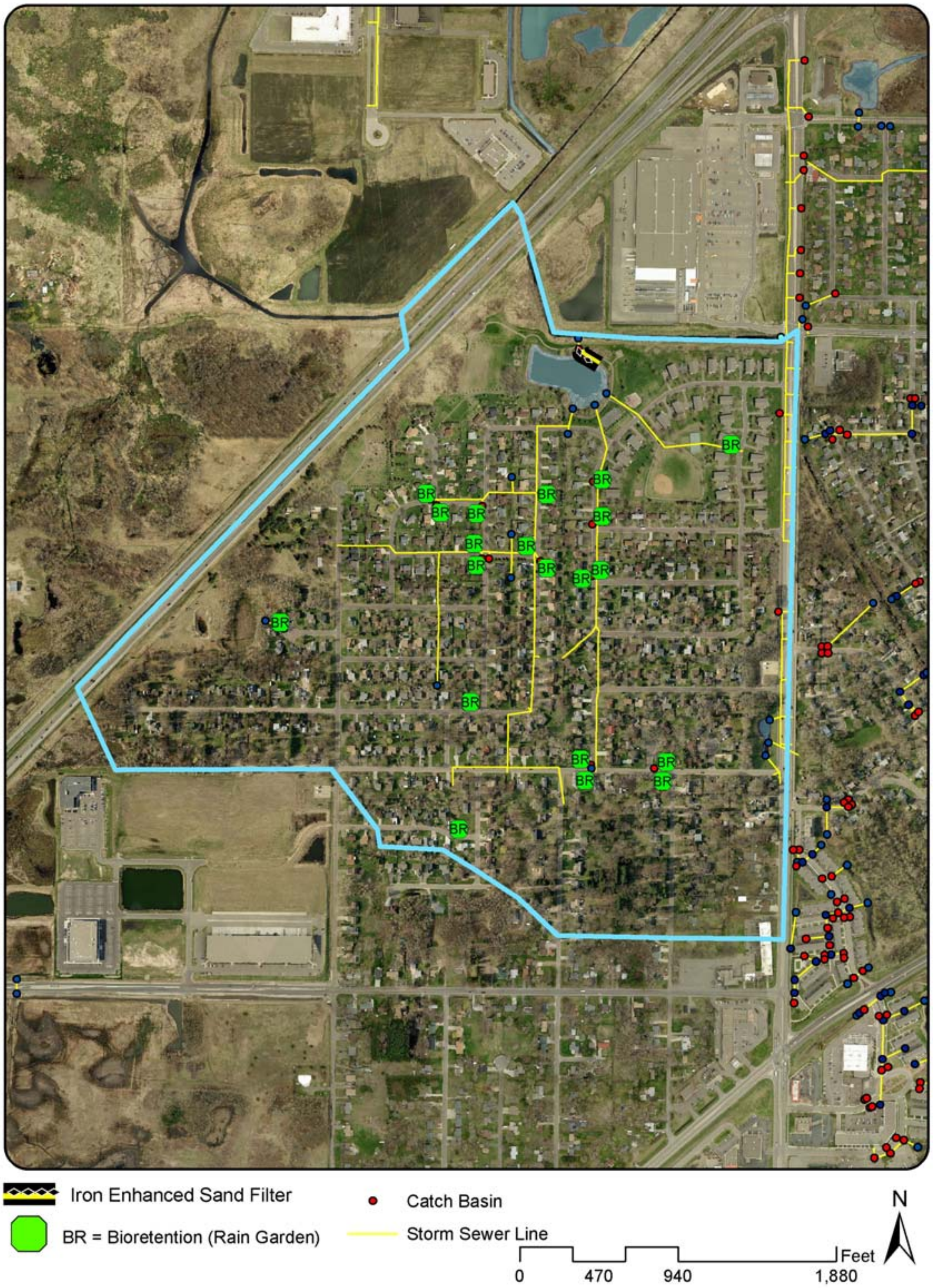
Catchment Specific Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	176.7	94.2	53%	**82.5**
	TSS (lb/yr)	54,253	28,663	53%	**25,590**
	Volume (acre-feet/yr)	114.6	0.0	0%	**114.6**
	Number of BMP's	2			
	BMP Size/Description	Street cleaning and pond			

Network-Wide Existing Conditions (GL-2 through GL-7)

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	623.7	313.0	50%	**310.7**
	TSS (lb/yr)	216,101	124,172	57%	**91,929**
	Volume (acre-feet/yr)	494.5	0.0	0%	**494.5**
	Number of BMP's	All BMPs in catchments GL-2 through GL-7			
	BMP Size/Description	Street cleaning and extended wet detention ponds			

RETROFIT RECOMMENDATIONS



Project ID #1 – Iron enhanced sand filter (IESF) for existing pond

Drainage Area – 257.5 acres

Location – East side of wet detention pond located within Centennial Green Park in catchment GL-5

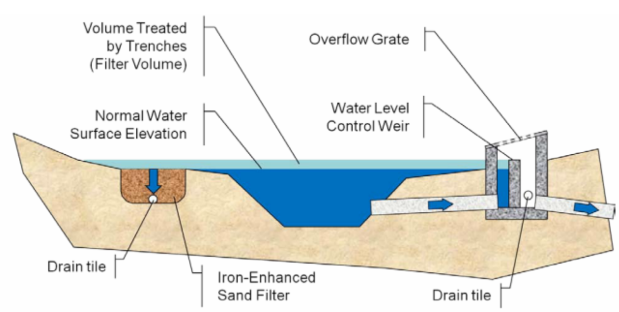
Property Ownership – City of Blaine

Description – Retrofitting the existing wet detention pond with an iron enhanced sand filter along the eastern edge of the pond would significantly increase the pond's efficiency at removing dissolved phosphorus (Erickson & Gulliver 2010). A significant percentage of phosphorus in stormwater is dissolved (30%-45%).

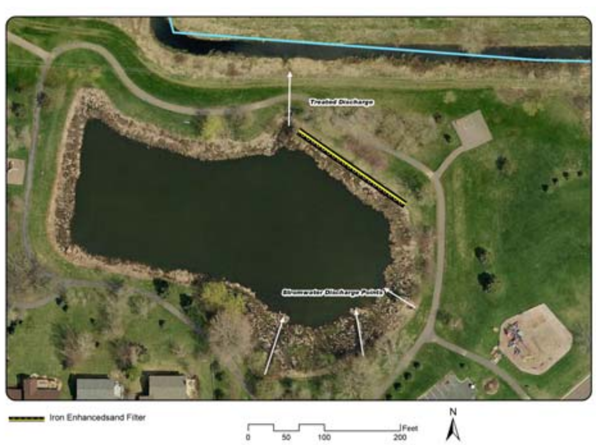
The iron enhanced sand filter would be installed at an elevation slightly above the normal water level of the detention pond so that following a storm event the increase in depth of the pond would be first diverted to the iron enhanced sand filter. The filter would have drain tile installed along the base of the trench and would outlet downstream of the current pond outlet. Large storm events that overwhelm the iron enhanced sand filter's capacity would exit the pond using the existing outlet.

Based on available space, two filter lengths, 300 and 500 feet long, by 10 feet wide by 2 feet deep with one foot of live storage above the iron enhanced sand filter were modeled. Volume and pollutant removal are shown in the tables below. Please note that no estimates are included for modifications to the outlet structure of the existing pond, and the cost estimates assume the city would complete the installation. The iron enhanced sand filter would need to be an engineered project, and the existing pond outlet may be deemed unsuitable for this type of practice which would result in the additional expense of a new outlet. Nevertheless, the large drainage area treated by this pond (257.5 acres) combined with the effectiveness of the iron enhanced sand filter will make this one of the more cost effective options.

Conceptual and Proposed Site Images -



(Erickson & Gulliver 2010)



Catchment Specific Cost/Benefit Analysis

	Cost/Benefit Analysis	***Project ID***					
		1 IESF		**1 IESF**			
		New trtmt	**Net %**	**New trtmt**	**Net %**		
Treatment	**TP (lb/yr)**	17.6	58%	23.9	67%		
	TSS (lb/yr)	0	53%	0	53%		
	Volume (acre-feet/yr)	0.0	0%	0.0	0%		
	Number of BMP's	1		1			
	BMP Size/Description	300	linear feet	500	linear feet		
	BMP Type	Iron Enhanced Sand Filter		Iron Enhanced Sand Filter			
Cost	**Materials/Labor/Design**	$37,500		$62,500			
	Promotion & Admin Costs	$1,680		$1,680			
	Total Project Cost	$39,180		$64,180			
	Annual O&M	$1,250		$2,083			
	Term Cost/1,000lb-TSS/yr	N/A		N/A			
	Term Cost/lb-TP/yr	**$145**		**$177**			

Network-Wide Cost/Benefit Analysis (GL-2 through GL-7)

	Cost/Benefit Analysis	Project ID					
		1 IESF		1 IESF			
		New trtmt	Net %	New trtmt	Net %		
Treatment	TP (lb/yr)	17.6	53%	23.9	54%		
	TSS (lb/yr)	0	57%	0	57%		
	Volume (acre-feet/yr)	0.0	0%	0.0	0%		
	Number of BMP's	1		1			
	BMP Size/Description	300	linear feet	500	linear feet		
	BMP Type	Underground Sand Filter		Underground Sand Filter			
Cost	Materials/Labor/Design	$37,500		$62,500			
	Promotion & Admin Costs	$1,680		$1,680			
	Total Project Cost	$39,180		$64,180			
	Annual O&M	$1,250		$2,083			
	Term Cost/1,000lb-TSS/yr	N/A		N/A			
	Term Cost/lb-TP/yr	**$145**		**$177**			

Project ID #6 – Curb-Cut Rain Garden Network
Drainage Area – 177.7 acres
Location – 10 locations throughout medium-density residential land cover in catchment GL-5
Property Ownership – Private
Description – The residential land cover within this catchment is best suited for residential, curb-cut rain gardens (see Appendix B for design options). Twenty optimal rain garden locations were identified (see map above). Generally, ideal curb-cut rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical land owner participation rates we analyzed scenarios where five and ten rain gardens were installed in catchment GL-5. Volume and pollutant reductions resulting from the rain garden installations are highlighted in the tables below.
Conceptual Images -

Before

After

Catchment Specific Cost/Benefit Analysis

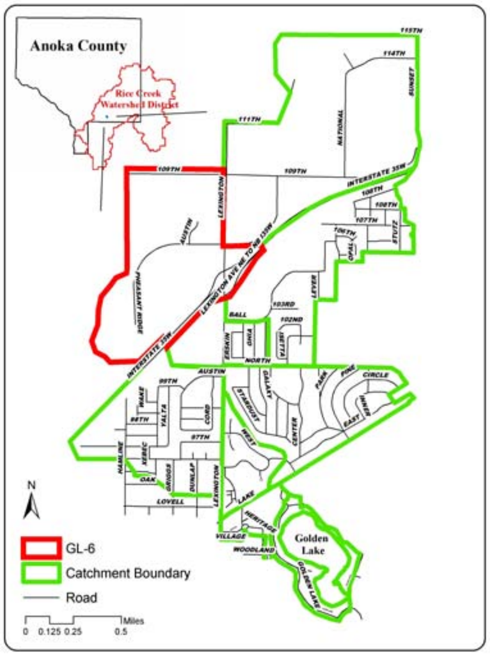
	Cost/Benefit Analysis	Project ID					
		6 5 Rain Gardens		6 10 Rain Gardens			
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	3.1	55%	5.7	57%		
	TSS (lb/yr)	615	54%	1,147	55%		
	Volume (acre-feet/yr)	4.1	4%	7.6	7%		
	Number of BMP's	5		10			
	BMP Size/Description	1,250 sq ft		2,500 sq ft			
	BMP Type	Complex Bioretention		Complex Bioretention			
Cost	Materials/Labor/Design	$22,710		$45,210			
	Promotion & Admin Costs	$2,310		$3,010			
	Total Project Cost	$25,020		$48,220			
	Annual O&M	$375		$750			
	Term Cost/1,000lb-TSS/yr	$1,966		$2,055			
	Term Cost/lb-TP/yr	**$390**		**$414**			

Network-Wide Cost/Benefit Analysis (GL-2 through GL-7)

	Cost/Benefit Analysis	Project ID					
		6 5 Rain Gardens		6 10 Rain Gardens			
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	3.0	51%	5.6	51%		
	TSS (lb/yr)	687	58%	1,354	58%		
	Volume (acre-feet/yr)	4.1	1%	7.6	2%		
	Number of BMP's	5		10			
	BMP Size/Description	1,250 sq ft		2,500 sq ft			
	BMP Type	Complex Bioretention		Complex Bioretention			
Cost	Materials/Labor/Design	$22,710		$45,210			
	Promotion & Admin Costs	$2,310		$3,010			
	Total Project Cost	$25,020		$48,220			
	Annual O&M	$375		$750			
	Term Cost/1,000lb-TSS/yr	$1,760		$1,741			
	Term Cost/lb-TP/yr	**$403**		**$421**			

Catchment GL-6

Existing Catchment Summary	
Acres	340.60
Dominant Land Cover	Open Space
Parcels	41
Volume (acre-feet/yr)	157.07
TP (lb/yr)	143.00
TSS (lb/yr)	40,989



DESCRIPTION

Catchment GL-6 is primarily open space with approximately 75 acres of light industrial land cover, most notably Globe University and Aveda. Anoka County Ditch 53-62 bisects this catchment. The northern boundary is 109th Avenue, the southern boundary is Interstate 35 East, the eastern boundary is Lexington Avenue, and the western boundary was determined based on a combination of topographical data and the focus area of this assessment.

EXISTING STORMWATER TREATMENT

In addition to street cleaning with a vacuum assisted street sweeper once each in the spring and fall, a number of stormwater treatment ponds exist throughout this catchment. The ponds were constructed as part of requirements from the Rice Creek Watershed District for new developments. Therefore, treatment of the stormwater runoff within this catchment is better than many of the other catchments within the assessment focus area. The tables below highlight the existing volume and pollutant loading from catchment GL-6

Catchment Specific Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	212.5	69.5	33%	**143.0**
	TSS (lb/yr)	80,672	39,683	49%	**40,989**
	Volume (acre-feet/yr)	157.1	0.0	0%	**157.1**
	Number of BMP's	2			
	BMP Size/Description	Street cleaning and existing ponds			

Network-Wide Existing Conditions (GL-2 through GL-7)

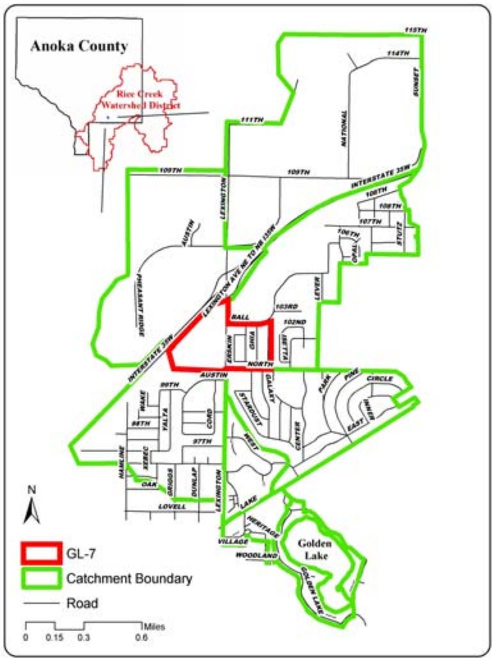
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	623.7	313.0	50%	**310.7**
	TSS (lb/yr)	216,101	124,172	57%	**91,929**
	Volume (acre-feet/yr)	494.5	0.0	0%	**494.5**
	Number of BMP's	All BMPs in catchments GL-2 through GL-7			
	BMP Size/Description	Street cleaning and extended wet detention ponds			

RETROFIT RECOMMENDATIONS

No retrofit recommendations were made for catchment GL-6. The existing stormwater treatment pond network is providing substantial treatment and appears to be functioning well based on model results and observations by maintenance staff within GL-6. More specifically, Aveda maintenance staff members have rarely observed the stormwater treatment pond network outlet to Anoka County Ditch 53-62. Therefore, the volume and pollutant loads in the above table are likely over-estimating the loads to Golden Lake. The WinSLAMM model assumes the ponds are at capacity and any additional water input results in overflow to the ditch. The existing treatment and large areas of open space within this catchment resulted in no recommended retrofits.

Catchment GL-7

Existing Catchment Summary	
Acres	82.20
Dominant Land Cover	Commercial
Parcels	117
Volume (acre-feet/yr)	78.70
TP (lb/yr)	33.80
TSS (lb/yr)	12,191



DESCRIPTION

Catchment GL-7 is a relatively small catchment that consists of similar acreages of commercial and medium-density, single-family residential land cover. Fleet Farm represents the majority of the commercial land cover, located near the west side of the catchment, and Anoka County Ditch 53-62 flows along the southwest side of the catchment.

EXISTING STORMWATER TREATMENT

Existing stormwater treatment practices within catchment GL-7 consist of street cleaning with a vacuum assisted street sweeper once each in the spring and fall and a stormwater treatment pond located to the west of the Fleet Farm building that provides treatment for that property. In addition, multiple parking lot rain gardens are located throughout the Fleet Farm parking lot. Visual inspection suggested that most of the gardens are functioning well, but the large garden between the main parking lot and the car wash may require maintenance. The medium-density, single-family residential area in the eastern portion of the catchment has no additional stormwater treatment. The volume and pollutant loads from this catchment are highlighted in the tables below.

Catchment Specific Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	60.2	26.4	44%	**33.8**
	TSS (lb/yr)	25,268	13,077	52%	**12,191**
	Volume (acre-feet/yr)	78.7	0.0	0%	**78.7**
	Number of BMP's	2			
	BMP Size/Description	Street Cleaning and Ponds			

Network-Wide Existing Conditions (GL-2 through GL-7)

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	623.7	313.0	50%	**310.7**
	TSS (lb/yr)	216,101	124,172	57%	**91,929**
	Volume (acre-feet/yr)	494.5	0.0	0%	**494.5**
	Number of BMP's	All BMPs in catchments GL-2 through GL-7			
	BMP Size/Description	Street cleaning and extended wet detention ponds			

RETROFIT RECOMMENDATIONS

Project ID #5 – Curb-Cut Rain Garden Network
Drainage Area – 34.7 acres
Location – 5 locations throughout medium-density residential land cover in catchment GL-7
Property Ownership – Private
Description – The residential land cover within this catchment is best suited for residential, curb-cut rain gardens (see Appendix B for design options). Eight optimal rain garden locations were identified (see map above). Generally, ideal curb-cut rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical land owner participation rates we analyzed a scenario where five rain gardens were installed in catchment GL-7. Volume and pollutant reductions resulting from the rain garden installations are highlighted in the tables below.
Conceptual images -

Before

After

Catchment Specific Cost/Benefit Analysis

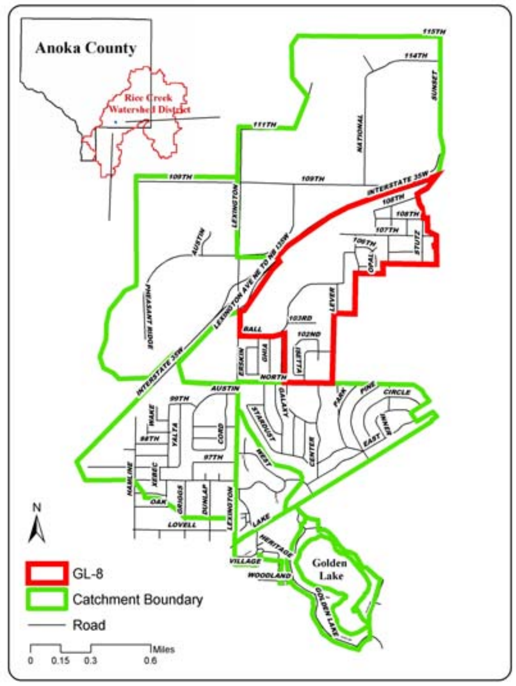
	Cost/Benefit Analysis	Project ID					
		5 5 Rain Gardens					
		New trtmt	Net %			New trtmt	Net %
Treatment	TP (lb/yr)	6.4	54%				
	TSS (lb/yr)	1,266	57%				
	Volume (acre-feet/yr)	3.2	4%				
	Number of BMP's	5					
	BMP Size/Description	1,250 sq ft					
	BMP Type	Complex Bioretention					
Cost	Materials/Labor/Design	$22,710					
	Promotion & Admin Costs	$2,310					
	Total Project Cost	$25,020					
	Annual O&M	$375					
	Term Cost/1,000lb-TSS/yr	$955					
	Term Cost/lb-TP/yr	**$189**					

Network-Wide Cost/Benefit Analysis (GL-2 through GL-7)

	Cost/Benefit Analysis	***Project ID***					
		5 5 Rain Gardens					
		New trtmt	**Net %**			**New trtmt**	**Net %**
Treatment	**TP (lb/yr)**	3.9	51%				
	TSS (lb/yr)	676	58%				
	Volume (acre-feet/yr)	3.2	1%				
	Number of BMP's	5					
	BMP Size/Description	1,250 sq ft					
	BMP Type	Complex Bioretention					
Cost	**Materials/Labor/Design**	$22,710					
	Promotion & Admin Costs	$2,310					
	Total Project Cost	$25,020					
	Annual O&M	$375					
	Term Cost/1,000lb-TSS/yr	$1,788					
	Term Cost/lb-TP/yr	**$310**					

Catchment GL-8

Existing Catchment Summary	
Acres	283.30
Dominant Land Cover	Residential
Parcels	403
Volume (acre-feet/yr)	129.71
TP (lb/yr)	107.10
TSS (lb/yr)	34,744



DESCRIPTION

Catchment GL-8 is located in the north eastern part of the focus area for this assessment. As a result, stormwater runoff from catchment GL-8 flows to the north into GL-9, then into Lochness Lake, and finally into Ditch 53-62 before ultimately entering Golden Lake. Therefore, any proposed retrofits in either GL-8 or GL-9 should be viewed first for their benefits to Lochness Lake and secondarily for their benefits to water quality in Golden Lake.

Catchment GL-8 is primarily comprised of medium-density, single-family residential development with a large portion of open space also present.

EXISTING STORMWATER TREATMENT

Existing stormwater treatment practices within GL-8 consist of street cleaning with a vacuum assisted sweeper in the spring and fall and a network of stormwater treatment ponds that treat a large portion of the commercial, institutional, and residential land cover types. Again, catchment GL-8 is not as directly connected to Golden Lake as catchments GL-1 through GL-7 because it passes through Lochness Lake prior to entering Anoka County Ditch 53-62. Catchment GL-8 was not modeled as part of the GL-2 through GL-7 network.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	179.3	72.2	40%	**107.1**
	TSS (lb/yr)	62,331	27,587	44%	**34,744**
	Volume (acre-feet/yr)	129.7	0.0	0%	**129.7**
	Number of BMP's	2			
	BMP Size/Description	Street cleaning and existing ponds			

RETROFIT RECOMMENDATIONS

Project A – Curb-Cut Rain Garden Network
Drainage Area – 132.5 acres
Location – 10 locations throughout medium-density residential land cover in catchment GL-8
Property Ownership – Private
Description – The residential land cover within this catchment is best suited for residential, curb-cut rain gardens (see Appendix B for design options). Nineteen optimal rain garden locations were identified (see map above). Generally, ideal curb-cut rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical land owner participation rates we analyzed scenarios where five and ten rain gardens were installed in catchment GL-8. Volume and pollutant reductions resulting from the rain garden installations are highlighted in the table below.
Example Curb-Cut Rain Garden Images -

Before rain

During rain

	Cost/Benefit Analysis	Project ID					
		A 5 Rain Gardens		A 10 Rain Gardens			
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	2.8	42%	4.5	43%		
	TSS (lb/yr)	581	45%	1,003	46%		
	Volume (acre-feet/yr)	3.7	3%	6.2	5%		
	Number of BMP's	5		10			
	BMP Size/Description	1,250 sq ft		2,500 sq ft			
	BMP Type	Complex Bioretention		Complex Bioretention			
Cost	Materials/Labor/Design	$22,710		$45,210			
	Promotion & Admin Costs	$2,310		$3,010			
	Total Project Cost	$25,020		$48,220			
	Annual O&M	$375		$750			
	Term Cost/1,000lb-TSS/yr	$2,081		$2,350			
	Term Cost/lb-TP/yr	**$432**		**$524**			

Project B – Permeable Asphalt at 4501 Ball Rd. NE in Blaine

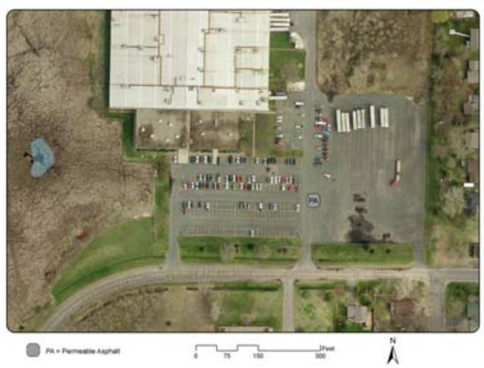
Drainage Area – 4.7 acres

Location – 4501 Ball Rd. NE, Blaine

Property Ownership – Private

Description – The large parking lot located at 4501 Ball Rd. NE in Blaine generates large volumes of runoff and high pollutant loads (see map below). At the same time, the parking and loading space is a necessity for the business located on that property. Therefore, permeable pavement was considered as a replacement for some of the traditional pavement to reduce stormwater volumes and provide water quality treatment. Permeable pavements can treat water from an area of impervious surface approximately three times the size of the permeable pavement. Therefore, 1.17 acres (51,048 square feet) of permeable asphalt would be sufficient to treat the 4.7 acre parking lot. The model included maintenance, such as restorative vacuuming on an annual basis. See appendix A for more details on the design of permeable pavements. Catchment-wide volume and pollutant removal are shown in the table below.

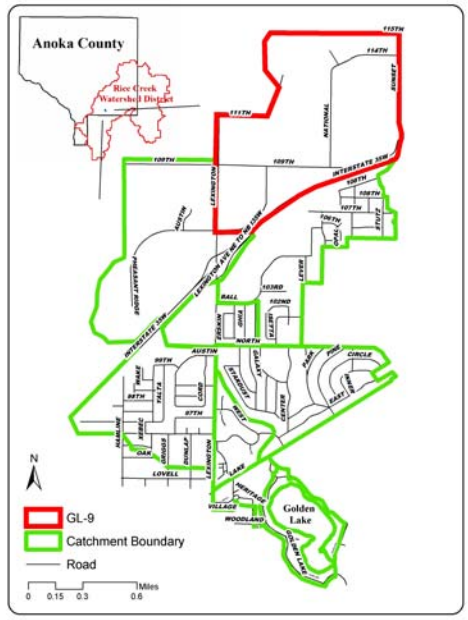
Proposed Site Image -



	Cost/Benefit Analysis	***Project ID***					
		B Permeable Asphalt					
		New trtmt	**Net %**	**New trtmt**	**Net %**	**New trtmt**	**Net %**
Treatment	**TP (lb/yr)**	6.9	44%				
	TSS (lb/yr)	3,409	50%				
	Volume (acre-feet/yr)	6.7	5%				
	Number of BMP's	1					
	BMP Size/Description	51,048 sq ft					
	BMP Type	Permeable Asphalt					
Cost	**Materials/Labor/Design**	$714,882					
	Promotion & Admin Costs	$1,680					
	Total Project Cost	$716,562					
	Annual O&M	$1,174					
	Term Cost/1,000lb-TSS/yr	$7,351					
	Term Cost/lb-TP/yr	**$3,644**					

Catchment GL-9

Existing Catchment Summary	
Acres	503.40
Dominant Land Cover	Open Space
Parcels	86
Volume (acre-feet/yr)	192.61
TP (lb/yr)	192.20
TSS (lb/yr)	45,867



DESCRIPTION

Catchment GL-9 is primarily comprised of open space, but there are significant areas of commercial (55 acres) and medium-density, single-family residential (80 acres) land cover.

Catchment GL-9 is the farthest from Golden Lake within the focus area of this assessment. Stormwater runoff from catchment GL-9 flows to the north into Lochness Lake, and finally into Ditch 53-62 before ultimately entering Golden Lake. Therefore, any proposed retrofits in GL-9 should be viewed first for their benefits to Lochness Lake and secondarily for their benefits to water quality in Golden Lake.

EXISTING STORMWATER TREATMENT

Existing stormwater treatment practices within GL-9 consist of street cleaning with a vacuum assisted sweeper in the spring and fall and a network of stormwater treatment ponds that treat a large portion of the commercial and school land cover types. Again, catchment GL-9 is not as directly connected to Golden Lake as catchments GL-1 through GL-7 because it passes through Lochness Lake prior to entering Ditch 53-62. Catchment GL-9 was not modeled as part of the GL-2 through GL-7 network.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	244.3	52.1	21%	**192.2**
	TSS (lb/yr)	72,311	26,444	37%	**45,867**
	Volume (acre-feet/yr)	192.6	0.0	0%	**192.6**
	Number of BMP's	2			
	BMP Size/Description	Street cleaning and existing ponds			

RETROFIT RECOMMENDATIONS

The large areas of open space, the existing treatment by the network of stormwater ponds surrounding the commercial land cover, and the treatment presumably provided by Lochness Lake resulted in no recommended retrofits within catchment GL-9.

Retrofit Ranking

The tables on the next page summarize 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 on the next page.

Please note that retrofits from GL-8 (residential rain gardens and permeable asphalt) are included in a separate table. Catchments GL-8 and GL-9 are presented separately because they drain to Lochness Lake, where substantial water chemistry changes likely occur, upstream of Golden Lake. Catchments GL-8 and GL-9 were not modeled as part of the GL-2 through GL-7 network. Therefore, any benefits the proposed retrofits within GL-8 provide should be first viewed from the standpoint of Lochness Lake and secondarily from the standpoint of benefits to Golden Lake.

Catchments GL-1 through GL-7: 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 ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Installation Cost	Estimated cost/ 1,000lb-TSS/year (30-year)	Estimated cost/ lb-TP/year (30-year)
1	GL-5*	Pond Modification - Iron Enhanced Sand Filter	1	17.6 - 23.9	0	0.0	$39,180 - $64,180	N/A	$145 - $177
2	GL-2	Pond Modification - Iron Enhanced Sand Filter	1	35.2	0	0.0	$89,180	N/A	$167
3	GL-4*	Residential Rain Gardens	5 - 15	5.4 - 13.5	865 - 2,281	4.1 - 10.8	$25,020 - $71,420	$1,398 - $1,537	$224 - $260
4	GL-3	Residential Rain Gardens	5	4.1	674	3.2	$25,020	$1,794	$295
5	GL-7	Residential Rain Gardens	5	3.9	676	3.2	$25,020	$1,788	$310
6	GL-5*	Residential Rain Gardens	5 - 10	3 - 5.6	687 - 1,354	4.1 - 7.6	$25,020 - $48,220	$1,741 - $1,760	$403 - $421
7	GL-4*	New Pond with Expanded Drainage Area and Iron Enhanced Sand Filter	1	27.1	3,679	0.0	$172,655 - $228,215	$3,129 - $4,135	$425 - $629
8	GL-4*	New Pond with Expanded Drainage Area	1	13.9	3,679	0.0	$120,780 - $176,340	$2,189 - $3,195	$579 - $845
9	GL-4*	New Pond	1	9.7	2,249	0.0	$95,630 - $151,190	$2,835 - $4,482	$657 - $1,039
10	GL-1*	Golden Lake Park Rain Garden	1	0.7	371	1.1	$19,960	$1,996	$1,139
11	GL-1*	Golden Lake Park Permeable Asphalt	1	0.7	432	1.2	$133,014	$10,752	$6,531

* Pollution reduction benefits and costs can not be summed with other projects in the same catchment because they are alternative options for treating the same source area.

Catchments GL-8 and GL-9: 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 ID	Retrofit Type	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Cost	Estimated cost/ 1,000lb-TSS/year (30-year)	Estimated cost/ lb-TP/year (30-year)
A	GL-8	Residential Rain Gardens	5 - 10	2.8 - 4.5	581 - 1,003	3.7 - 6.2	$25,020 - $48,220	$2,081 - $2,350	$432 - $524
B	GL-8	Parking Lot Permeable Asphalt	1	6.9	3,409	6.7	$716,562	$7,351	$3,644

References

Erickson, A.J. and J.S. Gulliver. 2010. Performance Assessment of an Iron-Enhanced Sand Filtration Trench for Capturing Dissolved Phosphorus. University of Minnesota St. Anthony Falls Laboratory Engineering, Environmental and Geophysical Fluid Dynamics Project Report No. 549. Prepared for the City of Prior Lake, Prior Lake, MN.

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

Appendix A – Retrofit Concept Designs

- Perimeter Sand Filters
- Tree Pit Filters
- Porous Pavement
- Flow Splitters
- Hydrodynamic Separators

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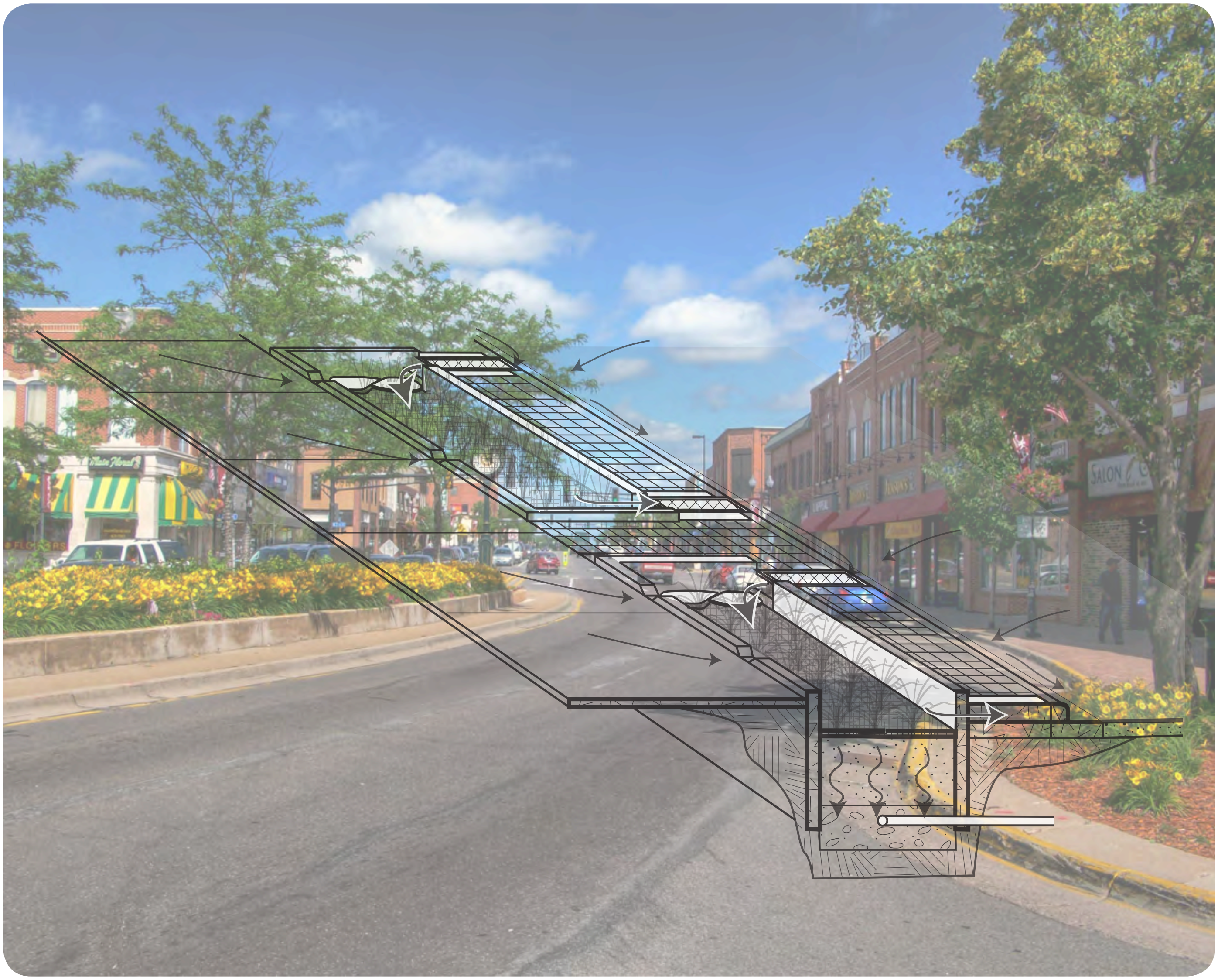
Urban Stormwater Best Management Practices / Retrofit Concepts



ANOKA CONSERVATION DISTRICT

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

Retrofit Concepts: *Perimeter Sand Filter*

Perimeter sand filters (Delaware filters) consist of two parallel trench-like chambers that are typically installed along the perimeter of a parking lot. Parking lot runoff enters the first chamber, which has a shallow permanent pool of water. The first trench captures heavy solids before the runoff spills into the second trench, which consists of a sand layer (typically 18" deep). Water infiltrates through the sand and is collected by an under-drain and delivered, ideally, to another stormwater BMP or existing stormsewer network. If both chambers fill up to capacity, excess parking lot runoff is routed to a bypass drop inlet. The sand may have iron filings added to improve dissolved phosphorus removal.

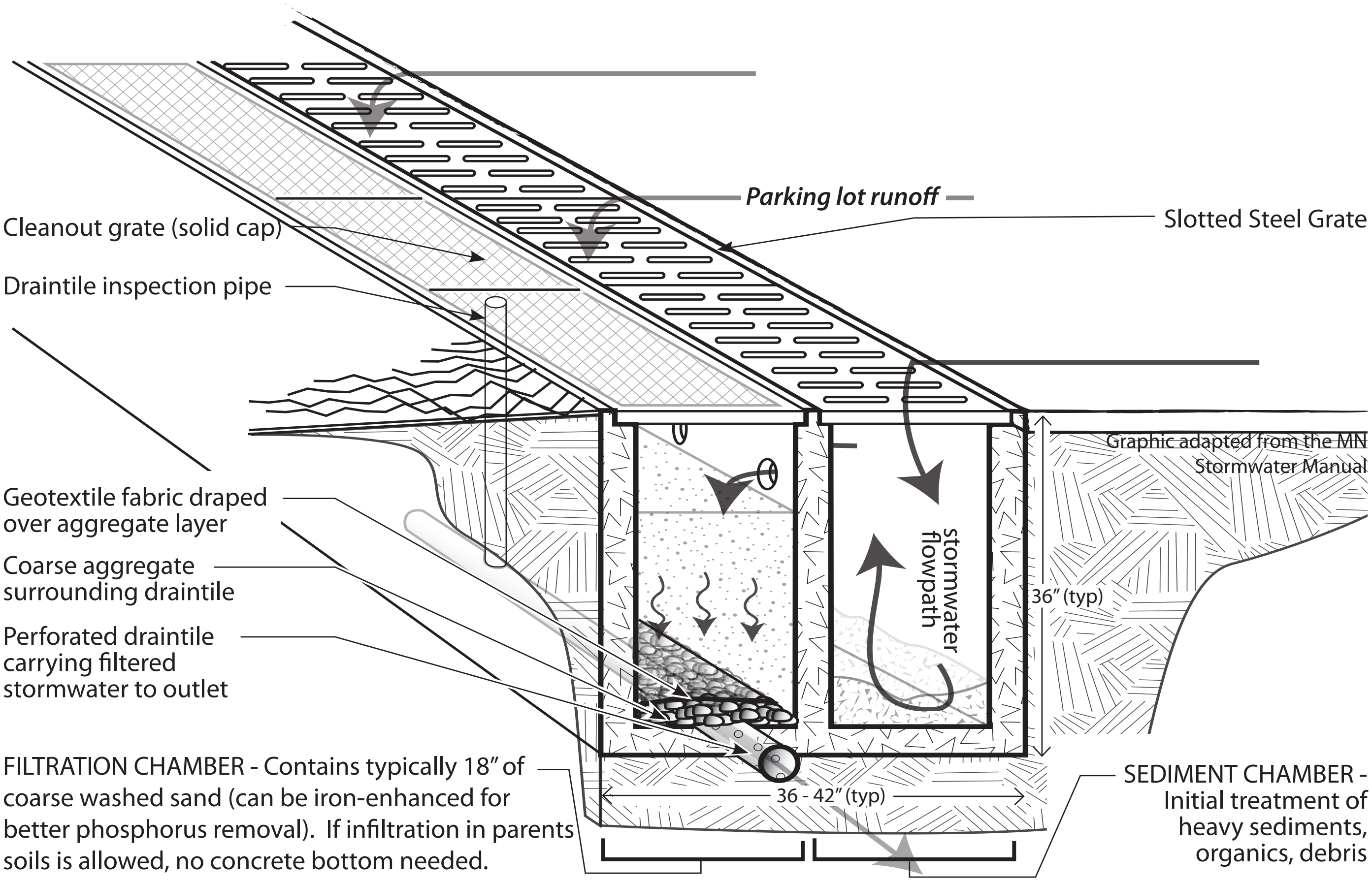

Sand filter inspection, Iowa Stormwater Partnership

BENEFITS:
- Great for adjacent to large impervious areas like parking lots
- Remove up to 90 percent of total suspended solids, 55 percent of total phosphorous, and 35 percent of total nitrogen
- Can effectively treat hot-spot runoff
- Consume small amounts of land

COST:
- Approximately $21.50 per cu ft of storage

CONCERNS:
- High maintenance burden (regular inspections for clogging, sand replacement, and removal of captured sediment)
- Not recommended for areas with high sediment content in stormwater or areas receiving significant clay/silt runoff
- Relatively costly

RECOMMENDED DRAINAGE AREA:
- Highly impervious sites up to 2 acres
- Approximately 100 linear feet treats 1 acre of impervious area



Retrofit Concepts: *Tree Pit Filter*

Stormwater tree pits consist of an underground structure and above ground plantings which collect and treat stormwater using bioretention. Although their structures differ, stormwater tree pits closely resemble traditional street trees and are perfect for urban streets where space is limited.


Tree pit filter, nyc.org

BENEFITS:

- Reduces runoff volume, flow rate and temperature
- Increases groundwater infiltration and recharge
- Improves aesthetic appeal of streets and neighborhoods
- Provides shade to nearby buildings to reduce energy costs
- Requires limited space
- Simple to install
- Available in multiple sizes
- Eliminates watering and fertilizing needed by traditional street trees

CONCERNS:

- Tree species will be limited to those that have salt tolerance and limited root aggression
- Regular inspections to prevent clogging & maintain function

RECOMMENDED DRAINAGE AREA:

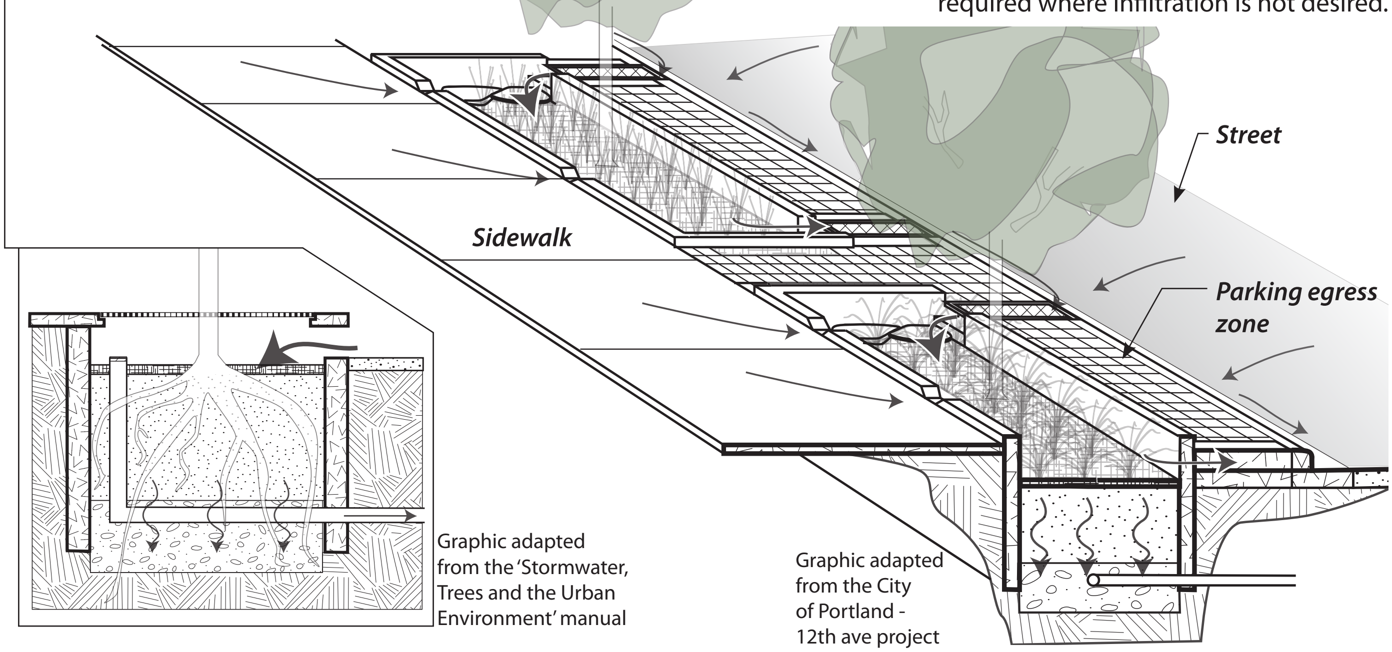
- Optimum ratio at highy impervious sites is one 6' x 6' tree pit per .25 acres

COST:

- Approximately $98.75 per cu ft of storage

Single Tree Pit Filter -
Stormwater enters pit via street curb cut (and sidewalk runoff through tree grate), filters through porous soil media and infiltrates into ground and/or enters a perforated draintile leading to a controlled outlet (i.e. stormsewer). Note: A concrete bottom may be required where infiltration is not desired.

Connected Boulevard Stormwater Planters-
Stormwater enters recessed planters via multiple street curb cuts (and sidewalk runoff through cuts in short wall), filters through porous soil media and infiltrates into ground and/or enters a perforated draintile leading to a controlled outlet (i.e. stormsewer); entire planter can be vegetated with perennials, shrubs and trees. Splash stones are located at curb cut inlets to lessen stormwater energy and allow for easy cleanout of debris/heavy sediment. Note: A concrete bottom may be required where infiltration is not desired.



Graphic adapted from the 'Stormwater, Trees and the Urban Environment' manual

Graphic adapted from the City of Portland - 12th ave project

Retrofit Concepts: *Porous Pavement*

Porous pavements come in a wide array of materials - ***concrete, asphalt, pavers, and grid*** - with void spaces that allow water to percolate through the surface and reach a subsurface layer of coarse aggregate allowing stormwater to quickly drain into the ground. Porous pavements are ideally situated in areas where soil type, seasonal water table and frost line levels allow for groundwater recharge. Porous pavements are typically used in low traffic areas and are well suited for use in parking lots, overflow areas, low traffic roads, residential driveways and pedestrian walkways. They can also be installed surrounding other stormwater management systems to provide overflow collection and infiltration.

BENEFITS:

- Reduces runoff volume, flow rate and temperature
- Increases groundwater infiltration and recharge
- Reduces the need for traditional stormwater infrastructure
- Can improve aesthetic appeal of paved areas (pavers)
- Flexible for use in areas of various shapes and sizes
- Remove up to 80 percent of total phosphorous and total nitrogen
- Reduced Ice buildup on street

CONCERNS:

- Typically not suited for slopes greater than 5%
- Cost
- At minimum 2 vacuum sweepings per year
- Periodic replacement of fill material in joint spacing (pavers)
- Not suitable for areas generating a lot of sediment

RECOMMENDED DRAINAGE AREA:

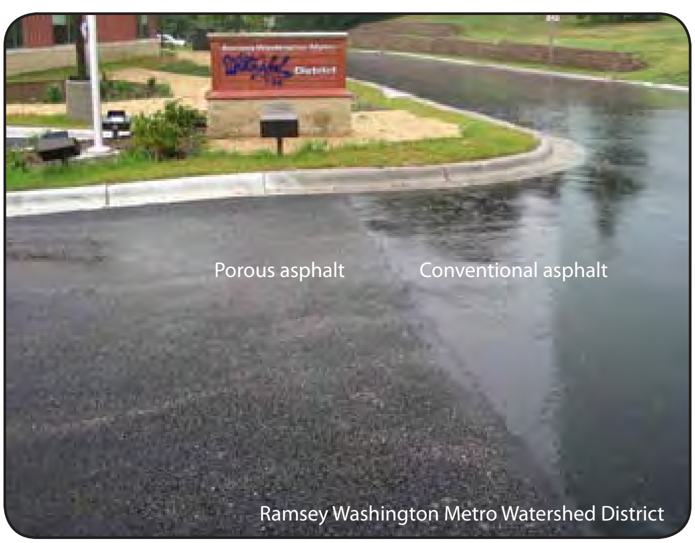
- Typically 3:1 (drainage area to porous pavement area) or less

COST:

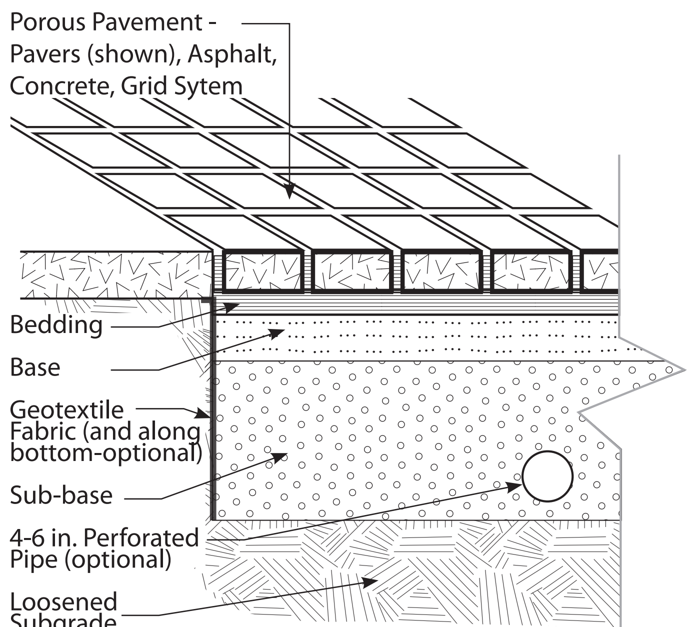
- Approximately $14 - $35 per cu ft storage depending on underlayment

Permeable pavement in parking aisle, City of Portland

Permeable pavers, Minneapolis



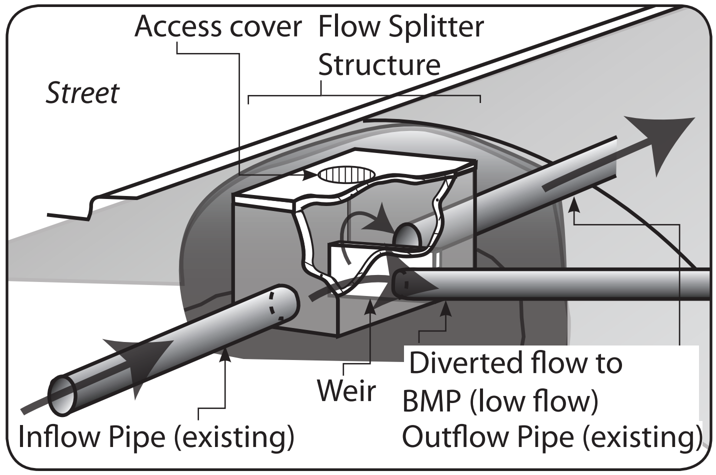
Ramsey Washington Metro Watershed District



Graphic adapted from the Charles River Watershed Association - Information Sheet

Retrofit Concepts: Flow Splitters

Flow splitters are stormsewer structures used to divert initial flows from stormsewer network out into a stormwater BMP such as constructed wetlands, detention ponds, infiltration basins, swales and various other filtration practices. During intense rain events excess stormwater travels over a weir, located in the flow splitter, and continues down pipe. Flow splitters are often designed to divert at least the 'first flush' into a BMP.



BENEFITS:

- Provides the ability to capture and treat otherwise untreated stormwater
- Allows high flows to bypass the connected stormwater BMPs thus reducing opportunities for erosion and re-suspension of sediment captured in the BMP systems
- Only periodic inspections are needed, with annual debris / sediment cleanout being sufficient

CONCERNS:

- Alone this practice does not reduce pollutants. It is a tool to divert appropriate flows into a water quality practice

RECOMMENDED DRAINAGE AREA:

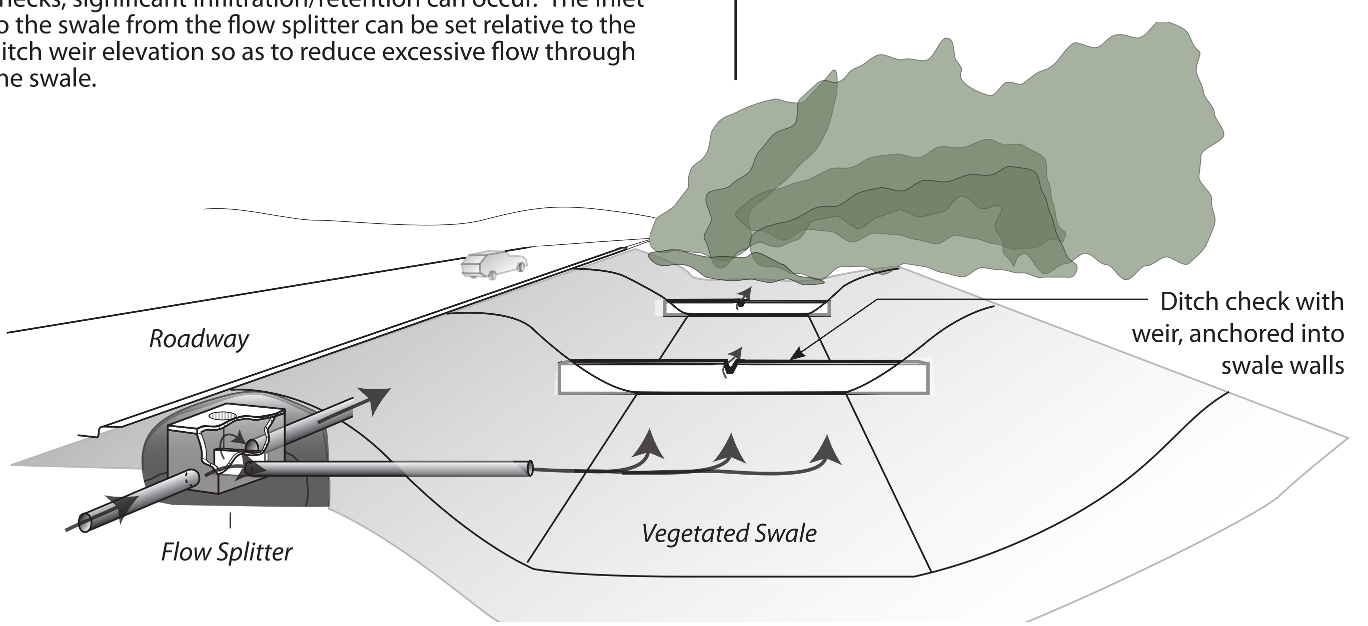
- Varies, pipe sizing can be scaled according to drainage area and capacity of Stormwater BMP that flow is diverted to

COST:

- Varies, the smallest typical structure to fit a weir is 48" diameter.
- Individual component costs of a 48" diameter structure*:
  1. Base slab ~ $250,
  2. Weir ~ $200 per vertical foot,
  3. Riser (side walls) ~ $130 per vertical foot,
  4. Cover slab (with opening) ~ $300,
  5. Metal casting (top grate, option) ~ $400
  6. Diverted flow pipe ~ $2 - $10 per linear foot (depends on material and diameter)

**Based on local sourcing, 2010*

Flow Splitter to Stormwater BMP -
Flow splitters can be used to divert runoff to a suite of stormwater Best Management Practices including a vegetated swale (shown) where filtration and, with ditch checks, significant infiltration/retention can occur. The inlet to the swale from the flow splitter can be set relative to the ditch weir elevation so as to reduce excessive flow through the swale.



Retrofit Concepts: Hydrodynamic Separators

Hydrodynamic Separator devices are structural BMPs vary in size and function, but all use some form of filtration, settling, or hydrodynamic separation to remove particulate pollutants from overland or piped flow. They often replace traditional catch basins and look much the same from the surface. Below the surface is a series of baffles, chambers, and devices designed to capture pollutants. They generally remove coarse sediment, oil and grease, litter, and debris and are often employed in areas with high concentrations of pollutants in runoff (ultra urban and retrofit situations). They may serve as pre-treatment of stormwater runoff before it reaches other BMPs, such as infiltration systems. Manufacturers of the devices provide the internal design specifications and installation instructions.


Southeast Michigan Stormwater LID case study

BENEFITS:

- Can be used in a variety of applications including retrofitting existing stormwater systems
- Subsurface device, consumes little to no land
- Removal of sediment, oils and other floatables

CONCERNS:

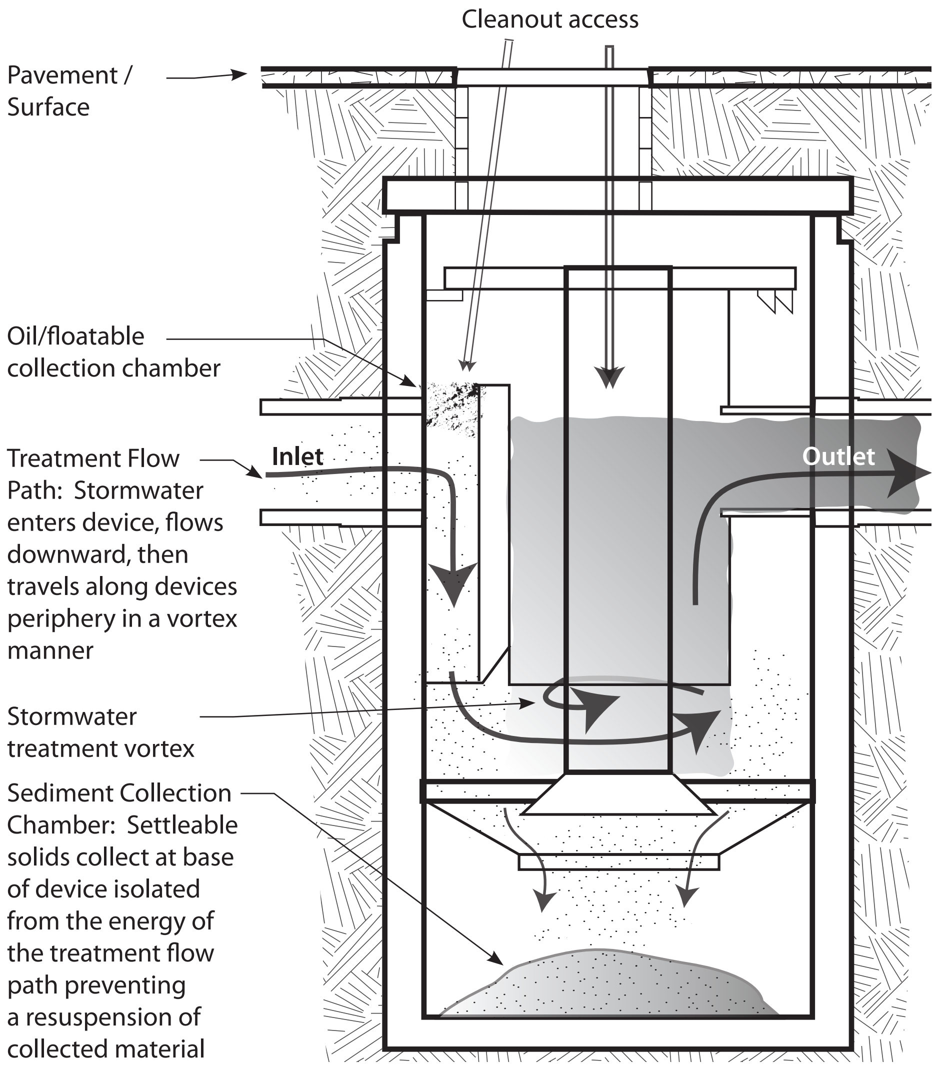
- A minimum annual vacuum removal of captured pollutants; however, required inspections every 6 months for the first year observing sedimentation and oil accumulation rates may determine more frequent visits are necessary
- High initial installation costs

RECOMMENDED DRAINAGE AREA:

- With a suite of scalable devices, drainage areas can range from a single parking lot up to 7 acres of predominently impervious surfaces (based on a standard 80% removal rate of total suspended solids on Stormceptor products**)

COST:

- Varies widely, from $2,300 to $40,000 depending on site characteristics including the amount of runoff (in cfs) required to be treated, the amount of land available, and any other treatment technologies that are presently being used. Often costs break down to approximately $9,000 per acre runoff treated*



Base design source: *Dowstream Defender***

**EPA Technology Fact Sheet*
***This mention does not constitute an endorsement of product*

Appendix B – Rain Garden Concept Designs

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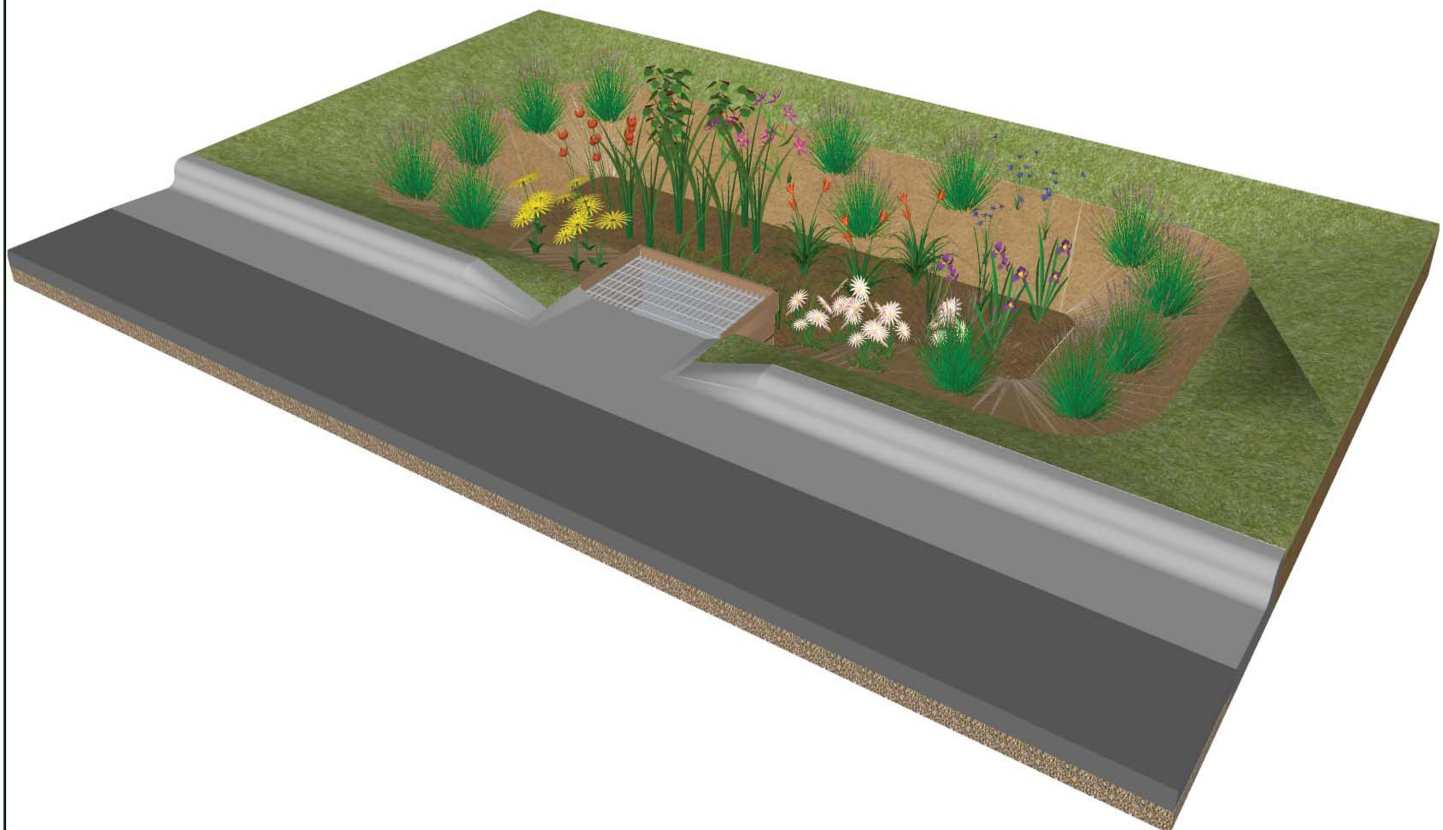
ANOKA COUNTY CURB-CUT RAINGARDENS



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

Property rises greater than 1 foot above the curb height within 16 feet of the curb
→ Retaining wall needed

2

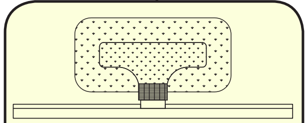
Retaining not needed:

- Garden site recieves greater than 4 hours of full sun between 10 am and 4 pm → Sun garden
- Garden site recieves less than 4 hours of full sun between 10 am and 4 pm → Shade garden

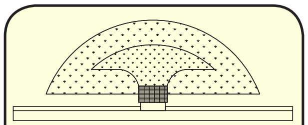
Retaining wall needed:

- Garden site recieves greater than 4 hours of full sun between 10 am and 4 pm → Sun garden
- Garden site recieves less than 4 hours of full sun between 10 am and 4 pm → Shade garden

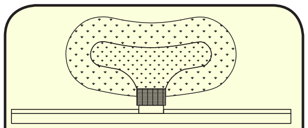
3



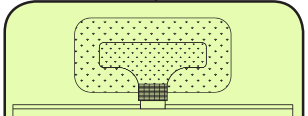
I. Rectangle
Sun, No Wall
pg. 8



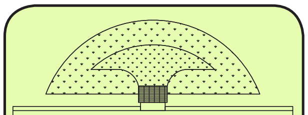
II. Arc
Sun, No Wall
pg. 9



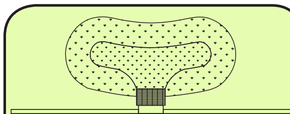
III. Curvilinear
Sun, No Wall
pg. 10



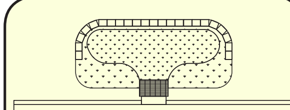
IV. Rectangle
Shade, No Wall
pg. 11



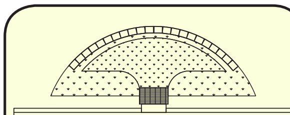
V. Arc
Shade, No Wall
pg. 12



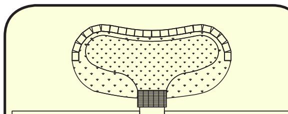
VI. Curvilinear
Shade, No Wall
pg. 13



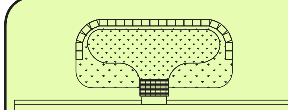
VII. Rectangle
Sun, with Wall
pg. 14



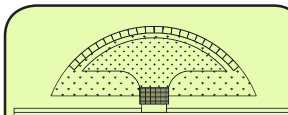
VIII. Arc
Sun, with Wall
pg. 15



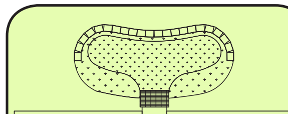
IX. Curvilinear
Sun, with Wall
pg. 16



X. Rectangle
Shade, with Wall
pg. 17

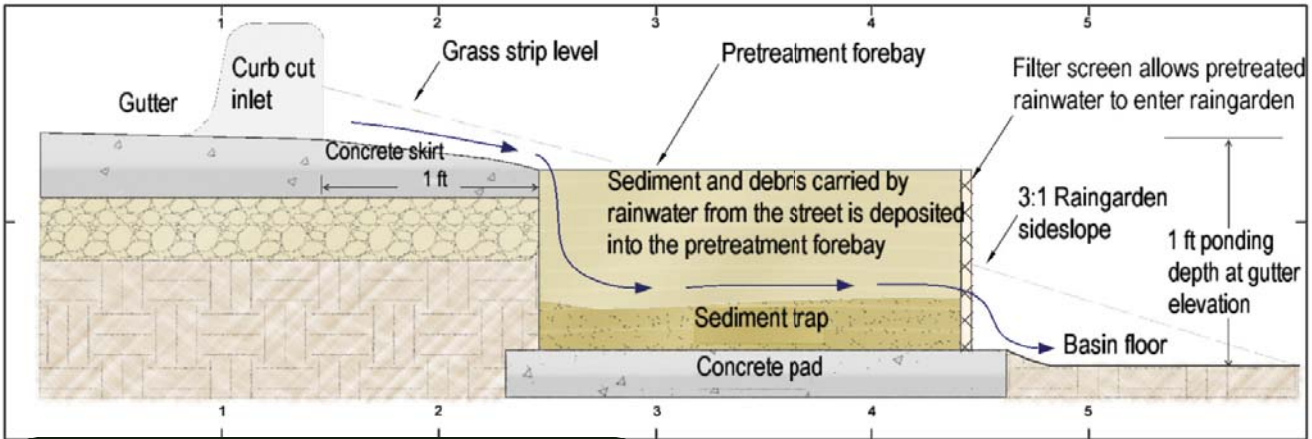


XI. Arc
Shade, with Wall
pg. 18

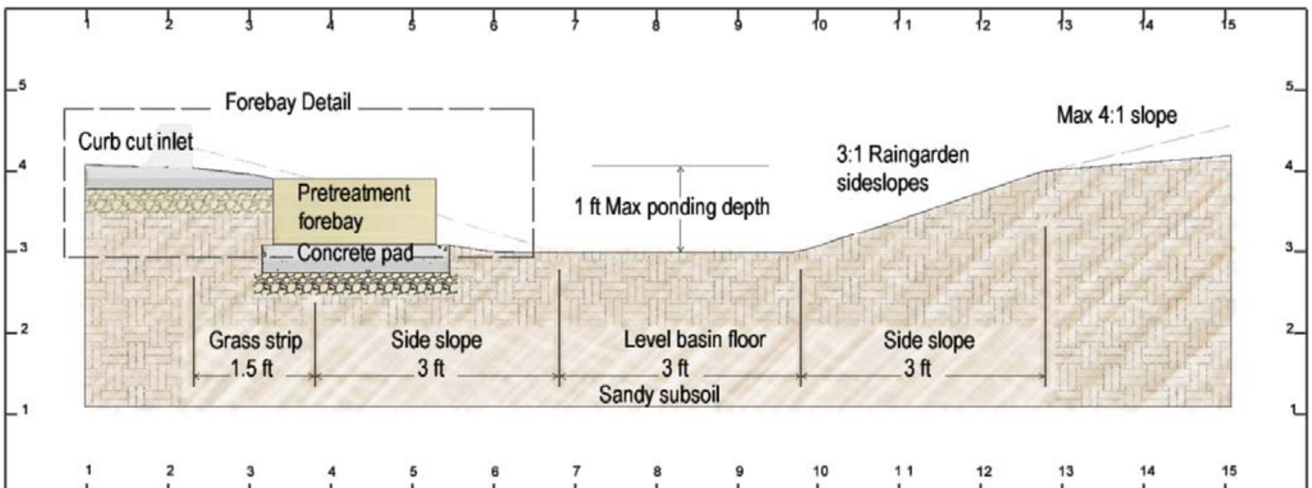


XII. Curvilinear
Shade, With Wall
pg. 19

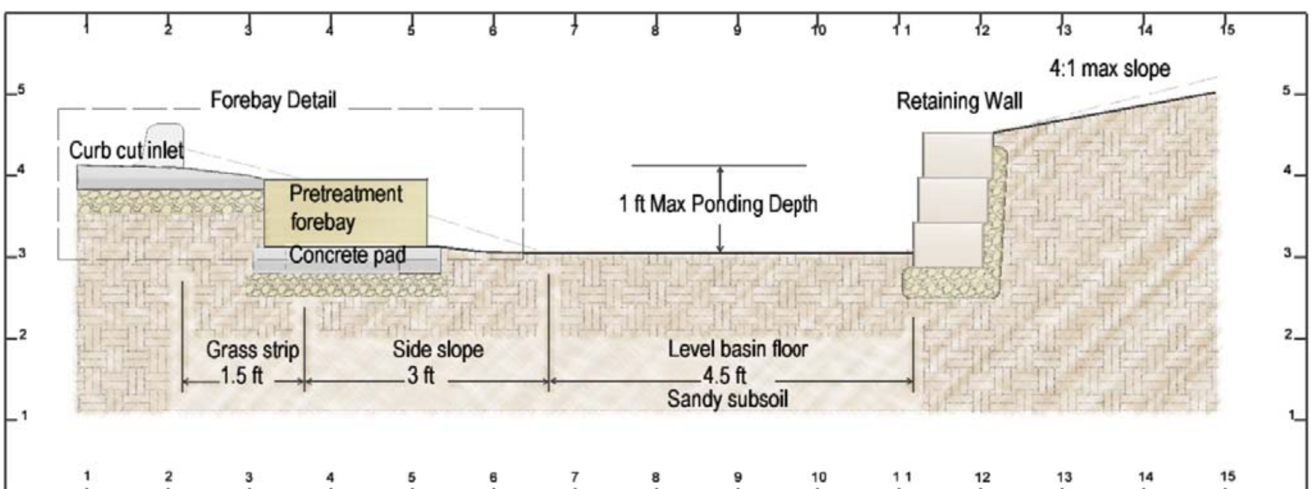
ANATOMY OF A CURB-CUT RAINGARDEN



PRETREATMENT FOREBAY

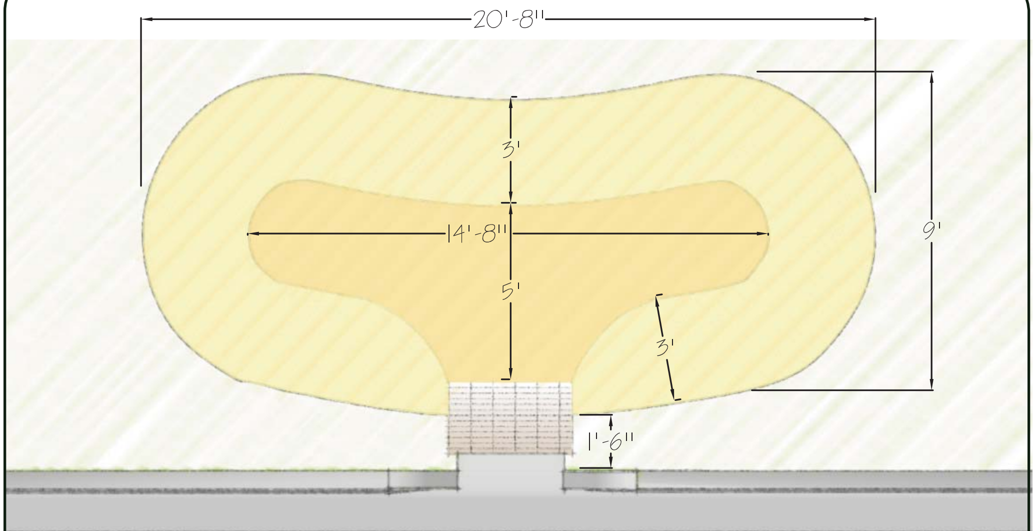


RAINGARDEN WITHOUT RETAINMENT

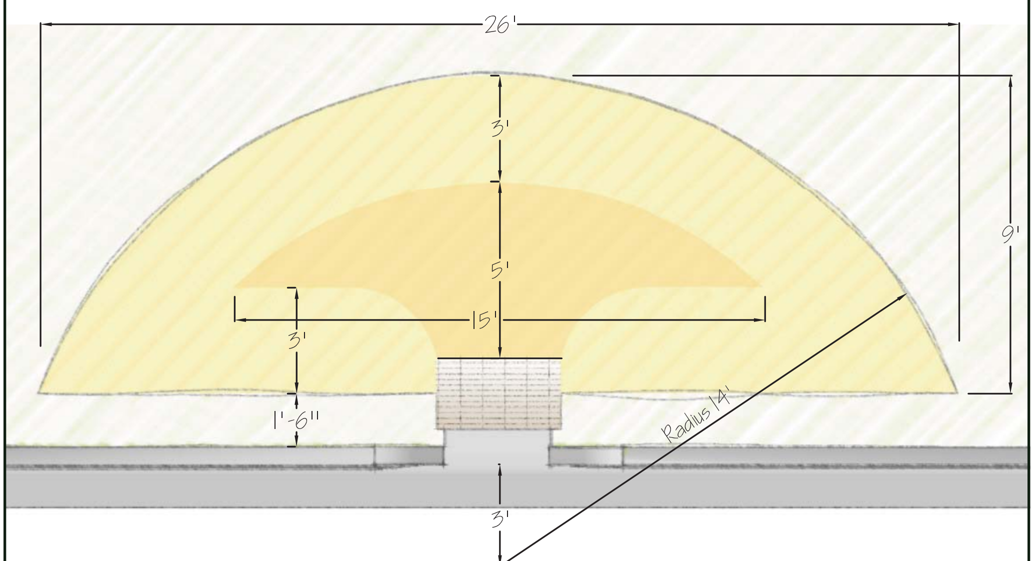


RAINGARDEN WITH RETAINING WALL

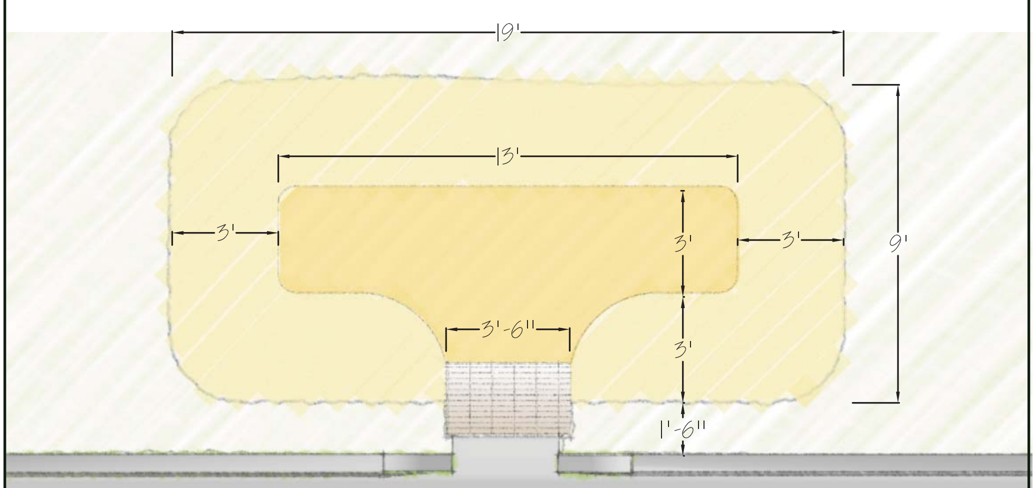
Raingarden Dimensions without a Retaining Wall



Curvilinear Garden



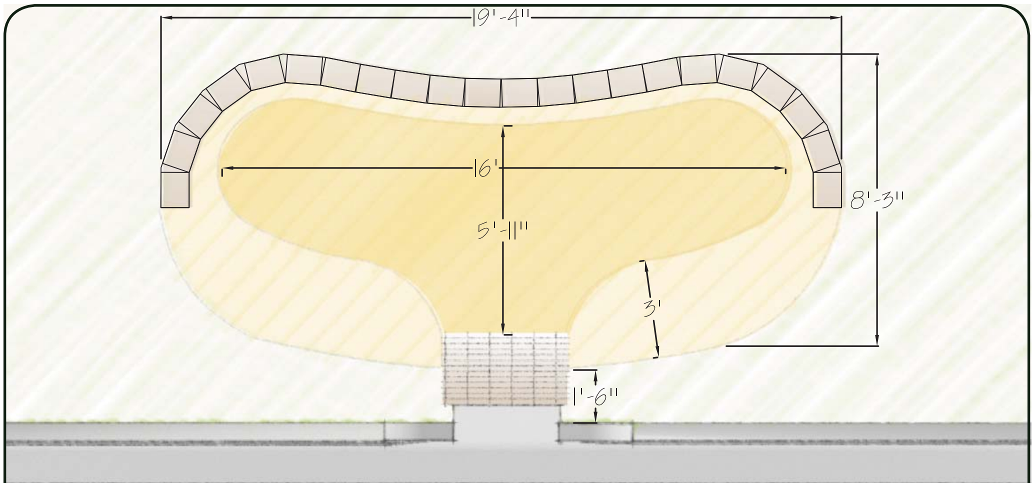
Arc Garden

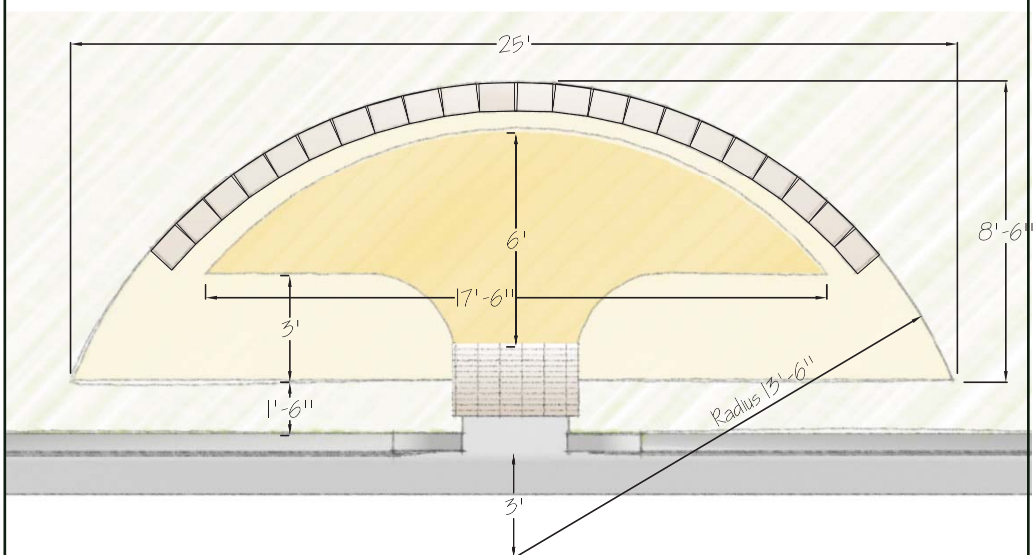


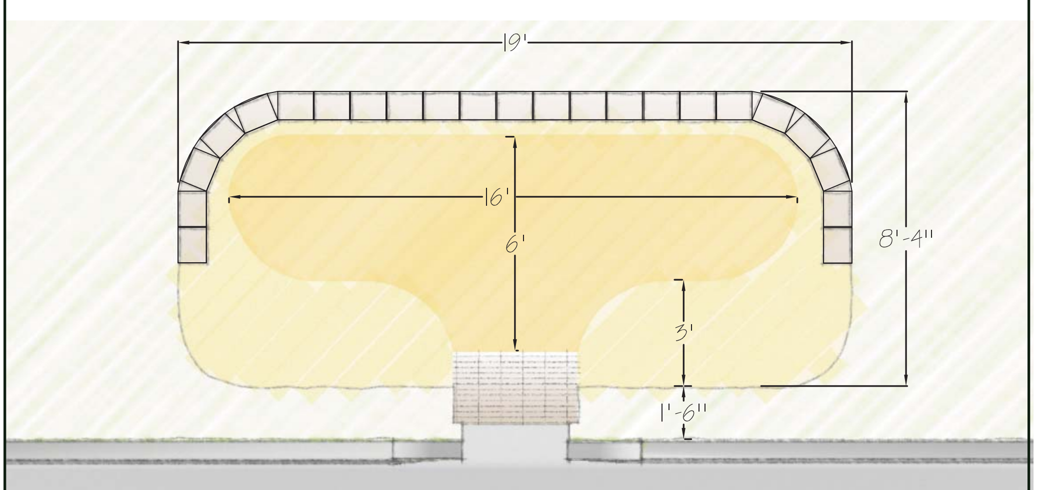
Rectangle Garden

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

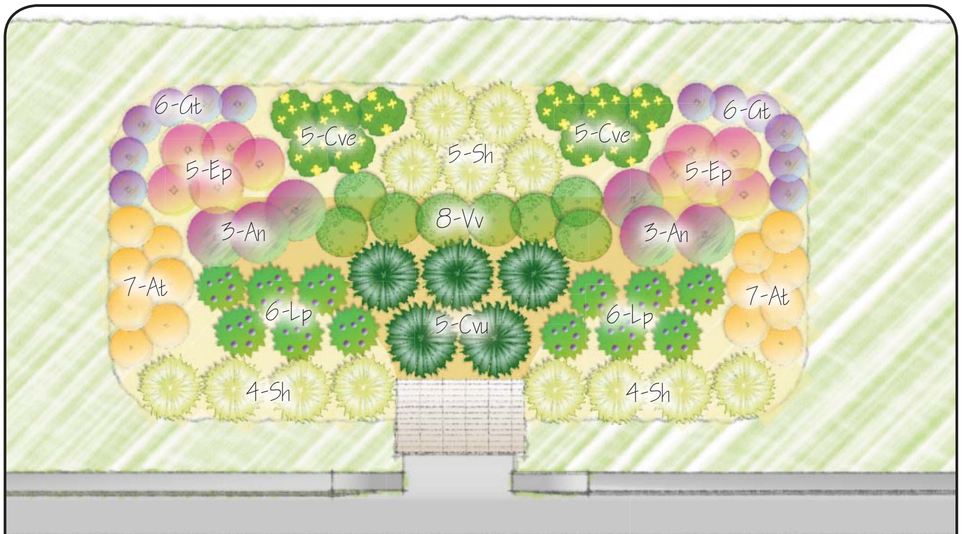




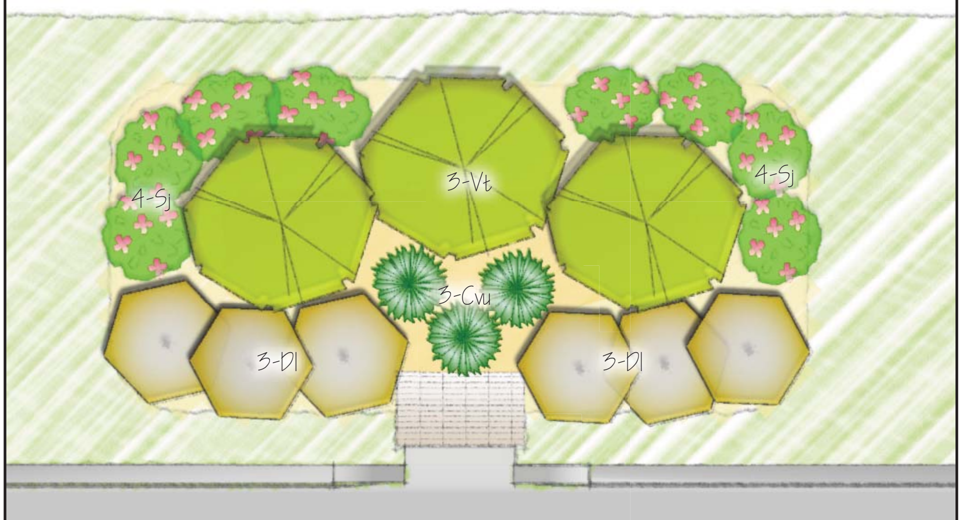


The dimensions given are the minimum dimensions needed to achieve the storage volume required by this stormwater retrofit program. The level basin floor needs to be set 1 foot below the gutter elevation. The entire planting area should be covered with 3 inches of shredded hardwood mulch.

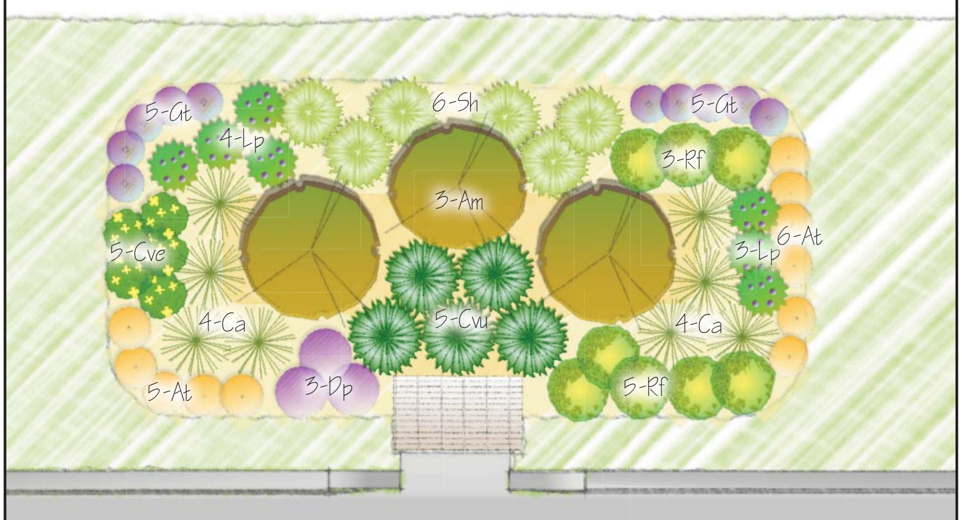
I. Rectangle Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

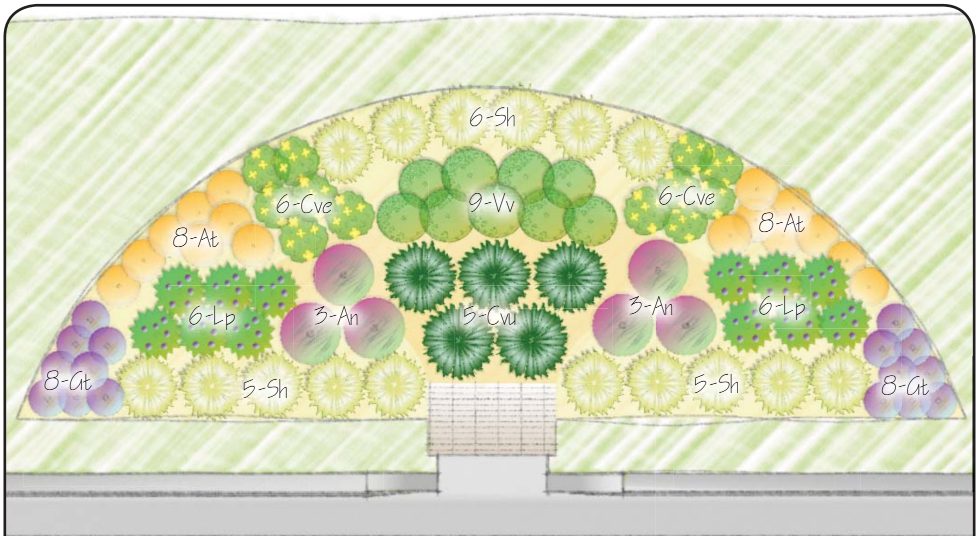


Mixed Shrub/Flower Garden

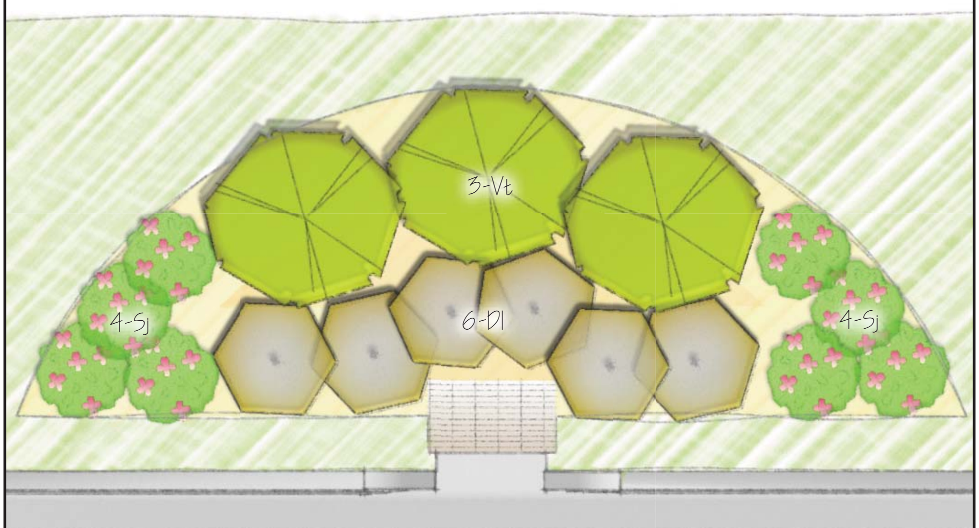
Plant Key

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'*

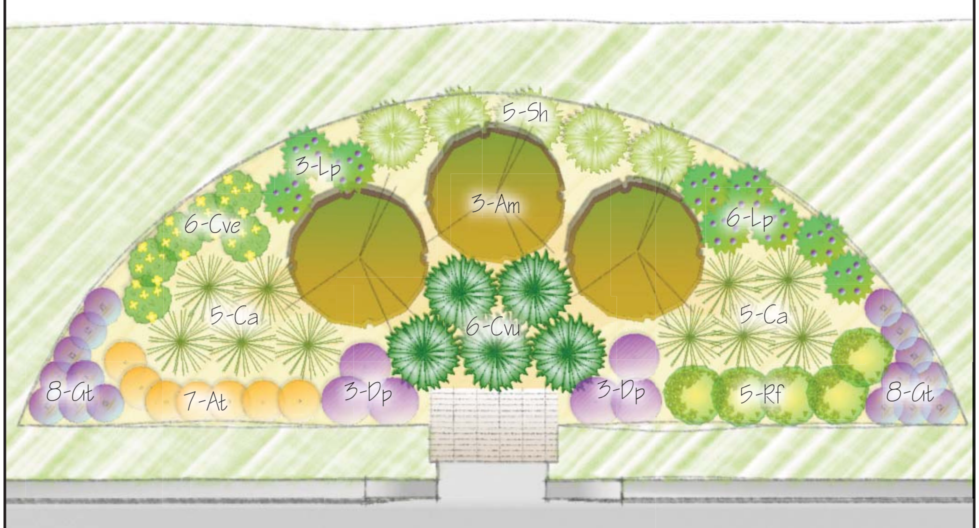
II. Arc Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

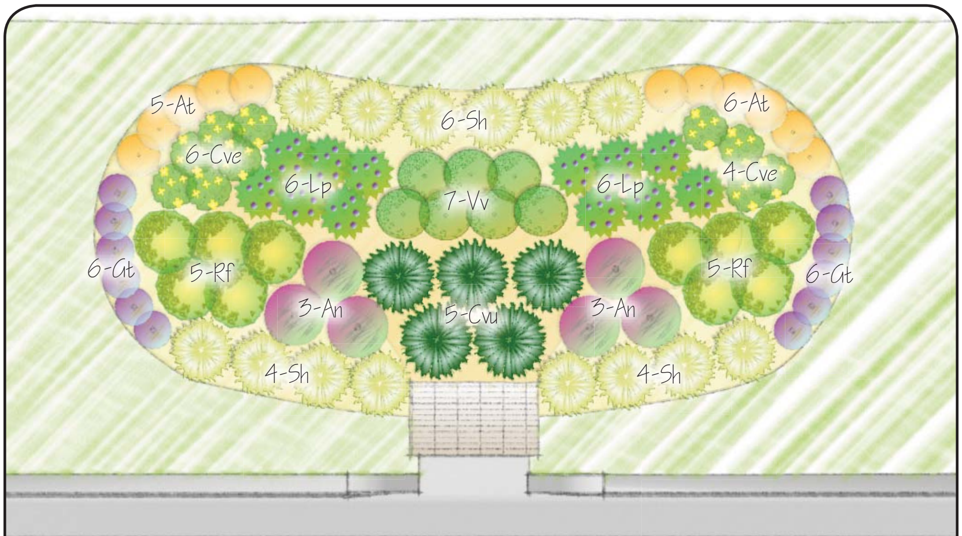


Mixed Shrub/Flower Garden

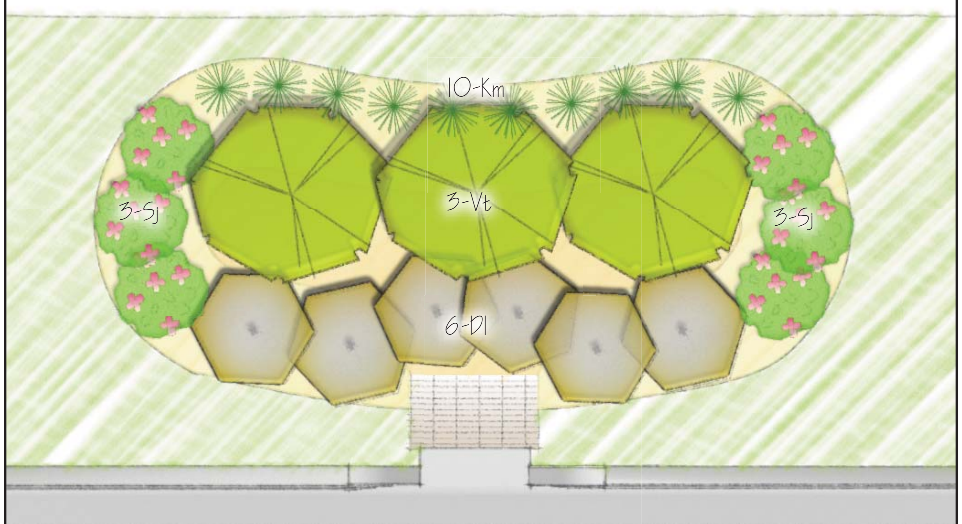
Plant Key

- **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



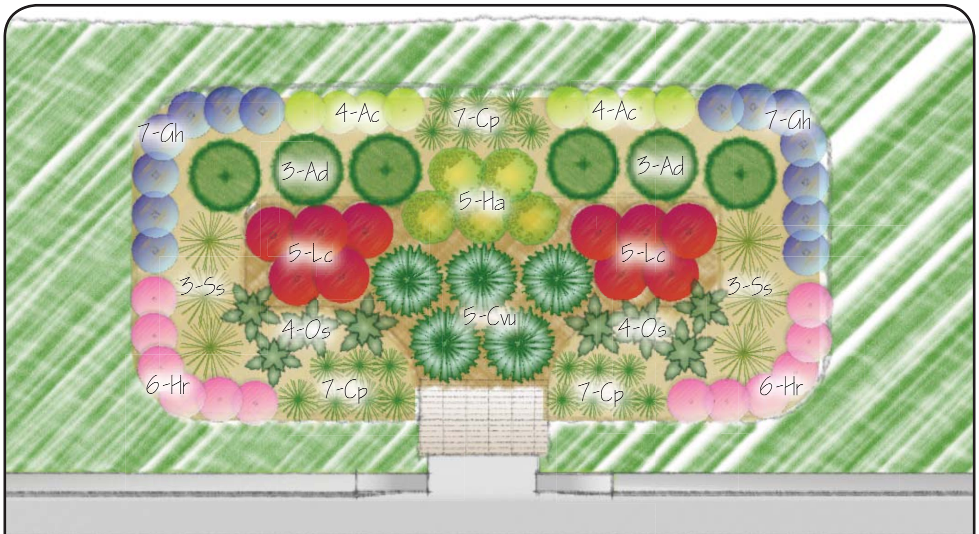
Shrub Garden

Mixed Shrub/Flower Garden

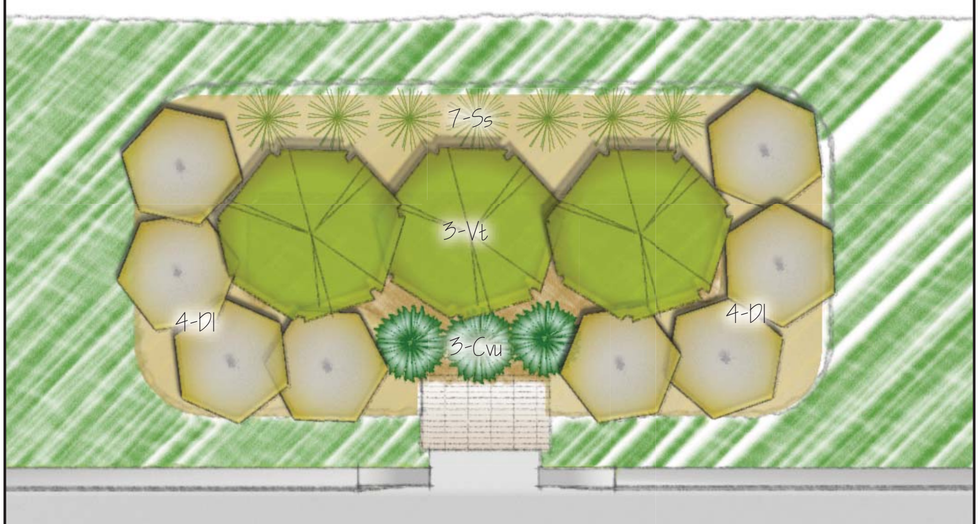
Plant Key

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*
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'*

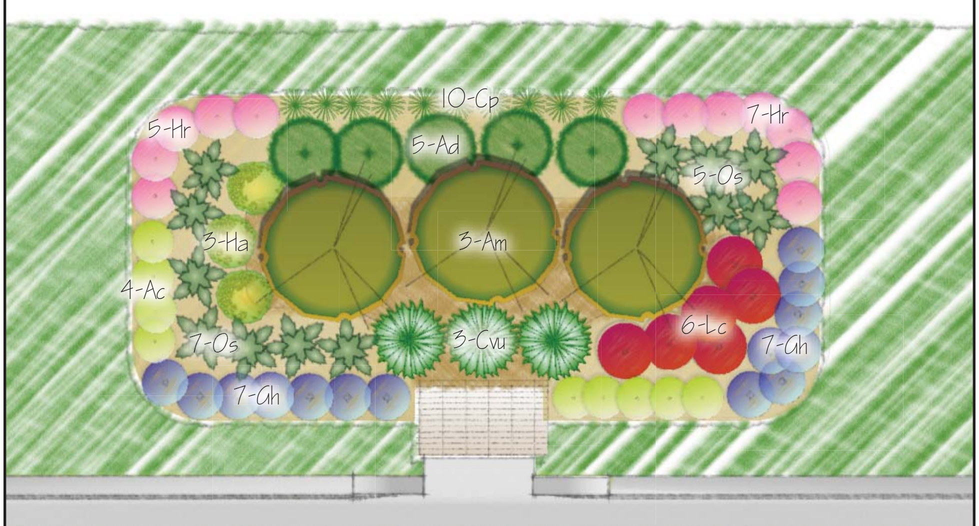
IV. Rectangle Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

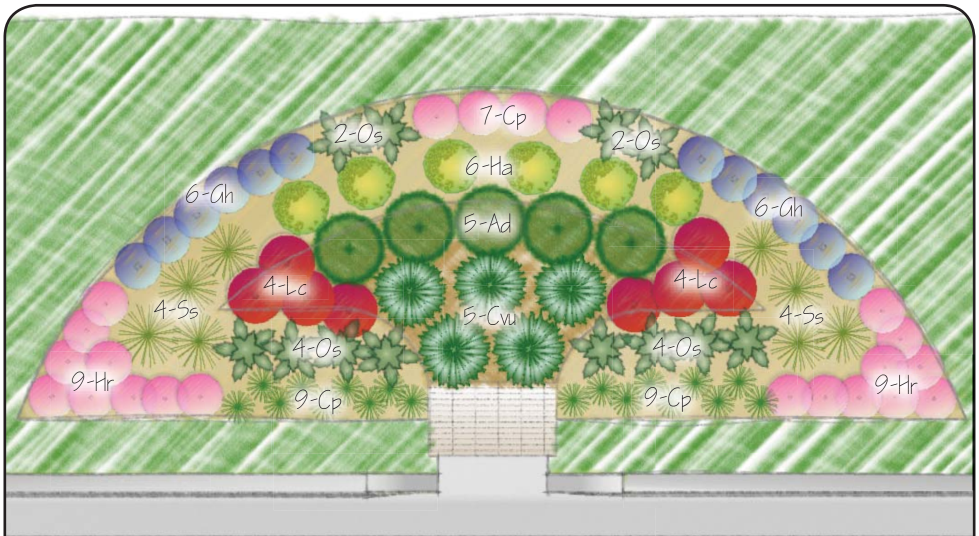


Mixed Shrub/Flower Garden

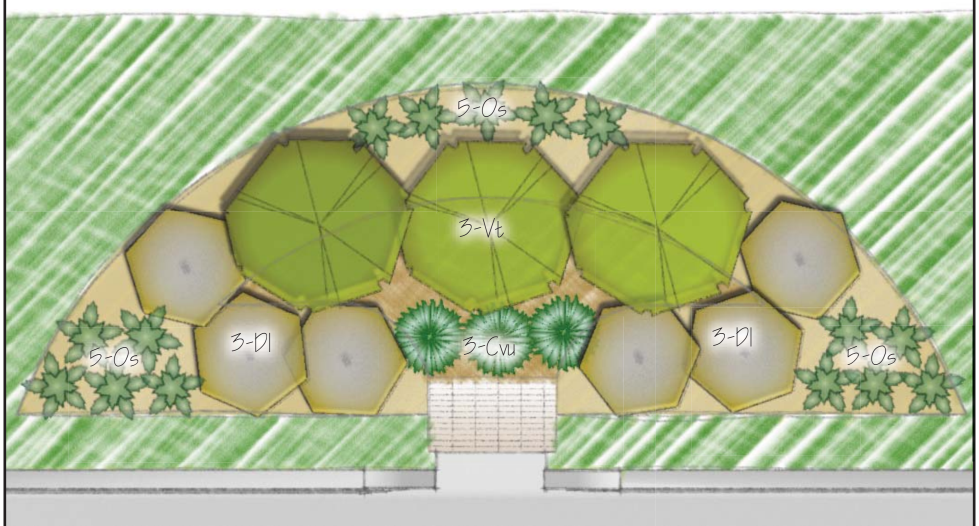
Plant Key

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



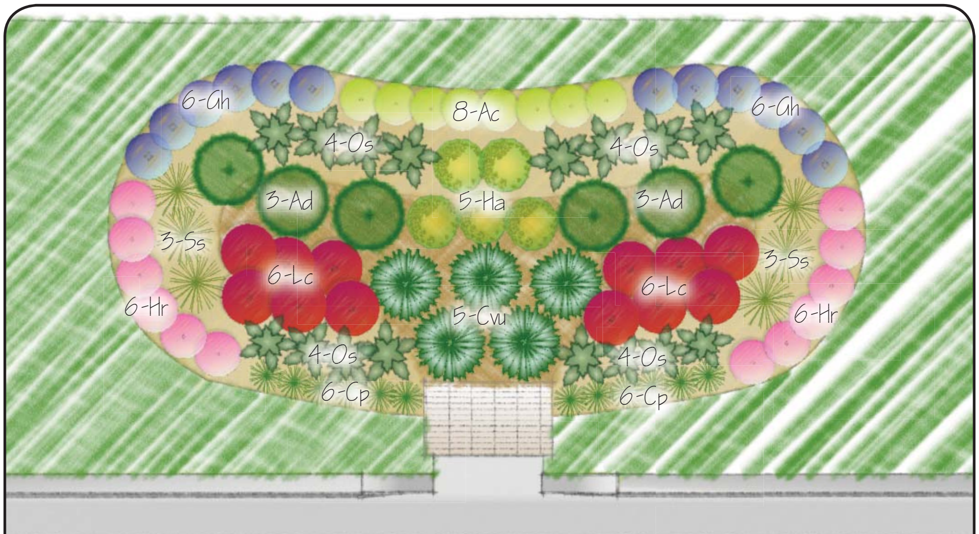
Shrub Garden

Mixed Shrub/Flower Garden

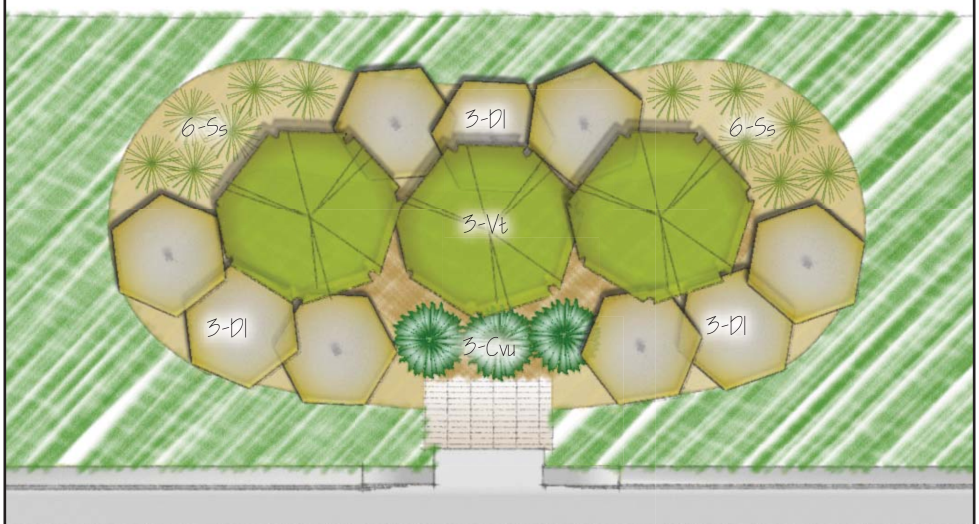
Plant Key

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*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
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'*

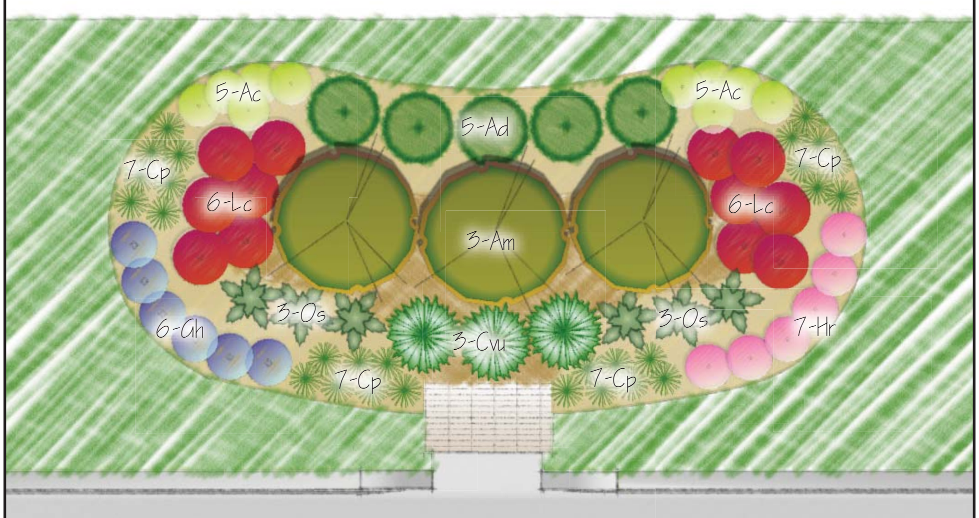
VI. Curvilinear Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

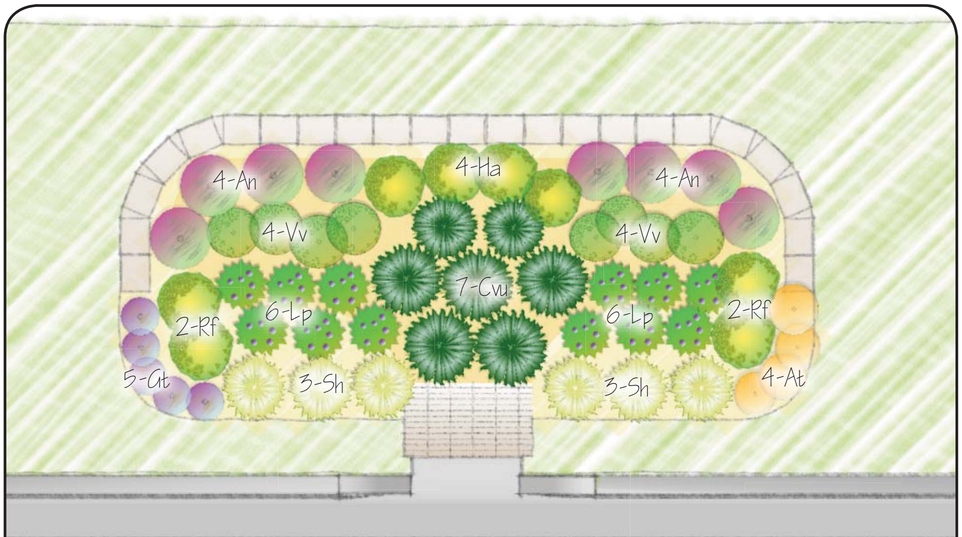


Mixed Shrub/Flower Garden

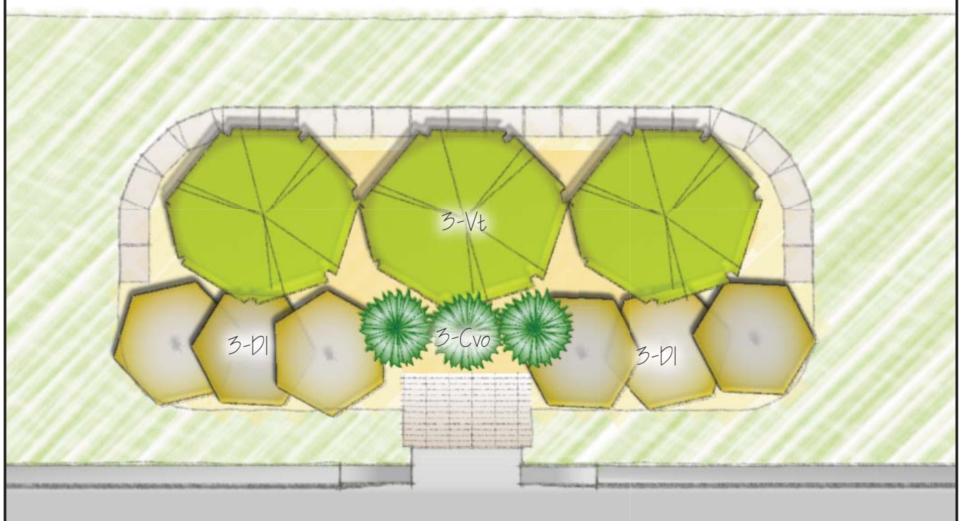
Plant Key

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'*

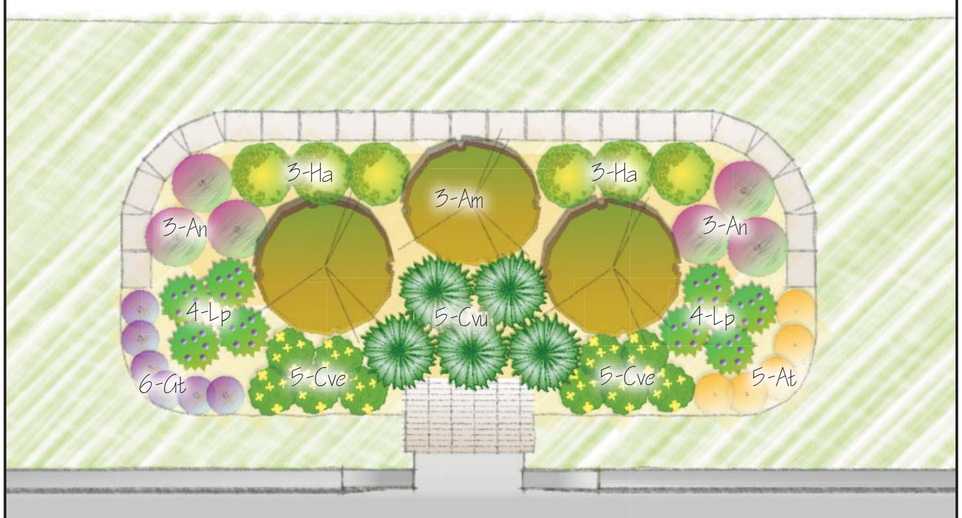
VII. Rectangle Garden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

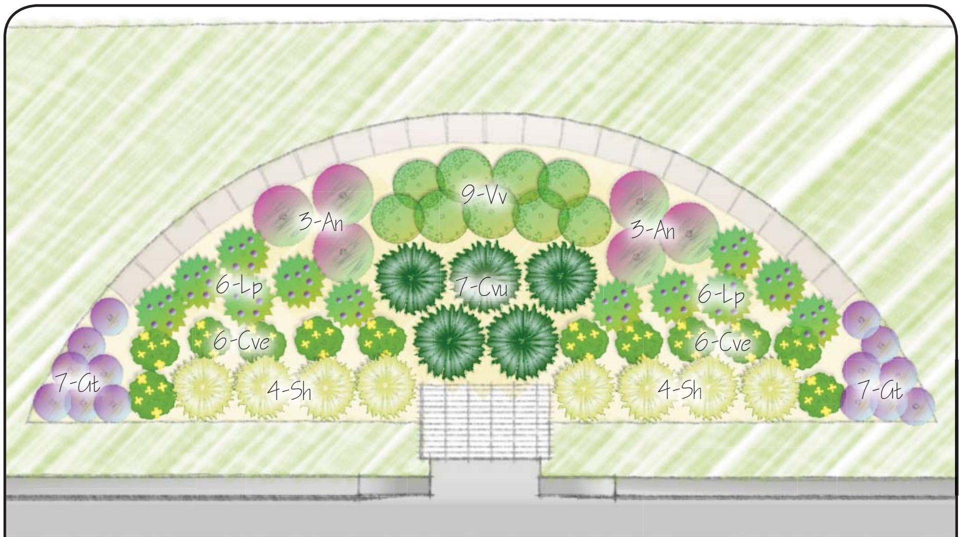


Mixed Shrub/Flower Garden

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 Garden - Sunny Site - Retaining Wall



Flowering Perennial Garden

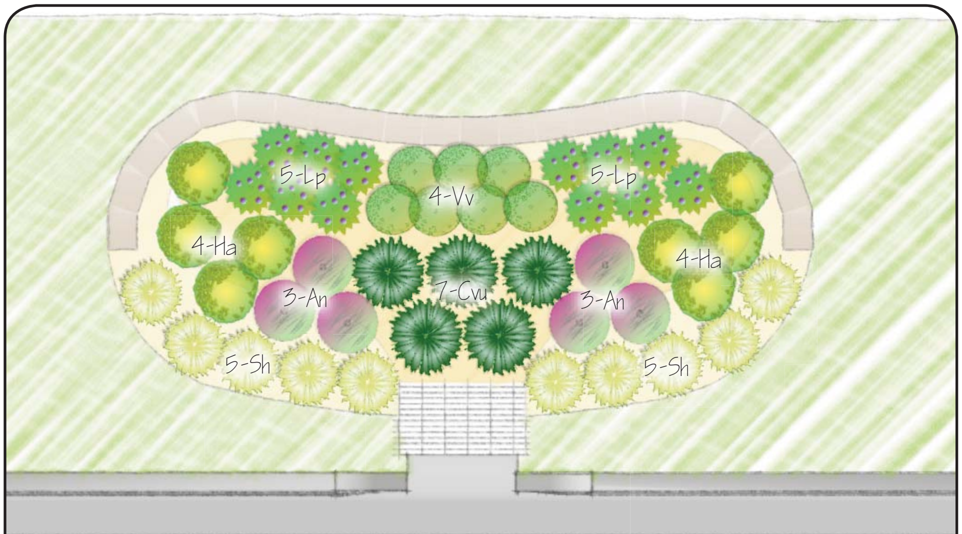
Shrub Garden

Mixed Shrub/Flower Garden

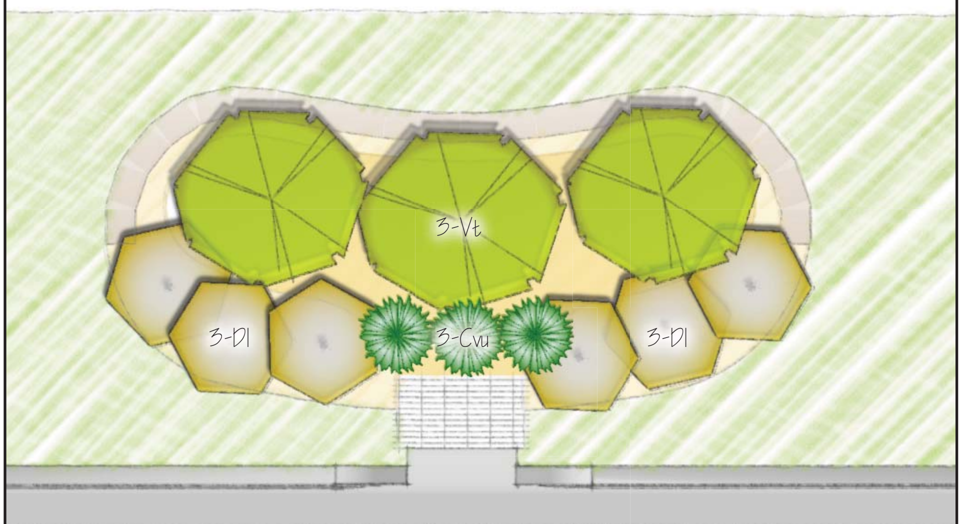
Plant Key

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'*

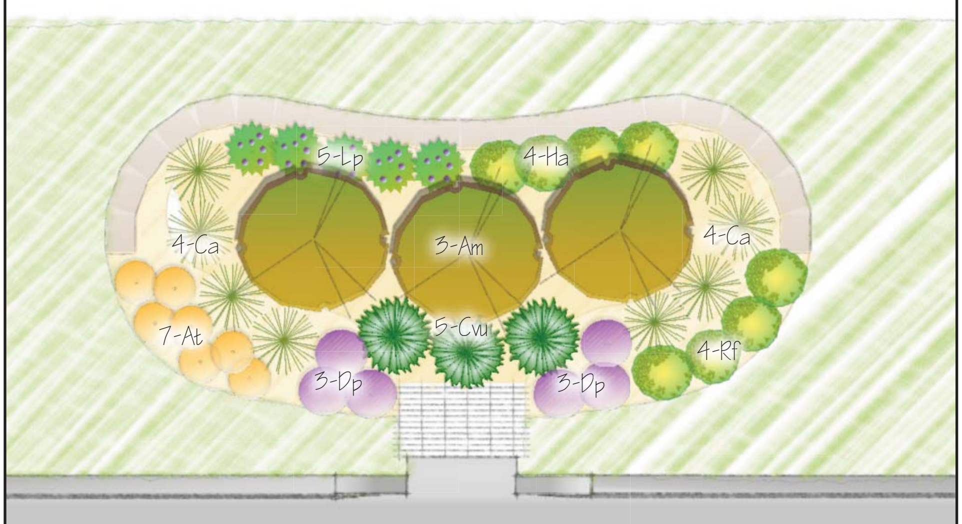
IX. Curvilinear Garden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden



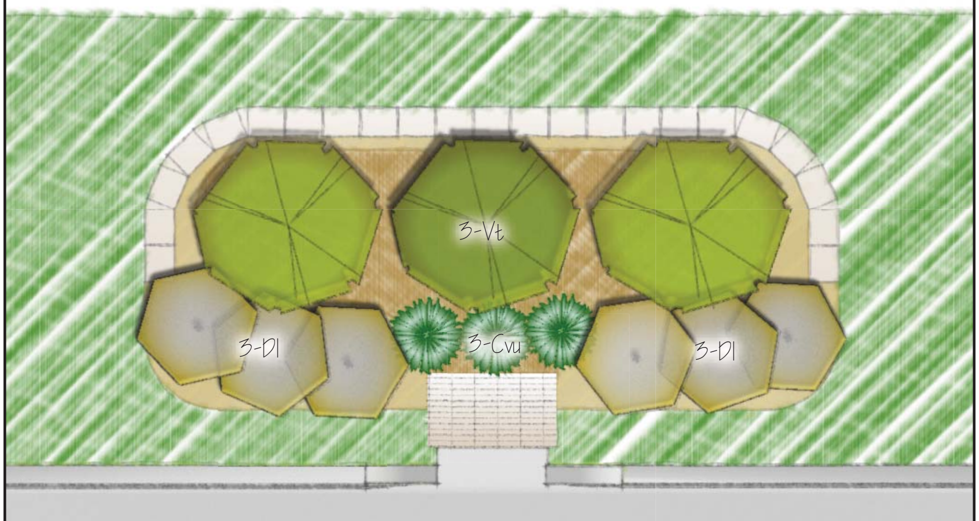
Mixed Shrub/Flower Garden

Plant Key

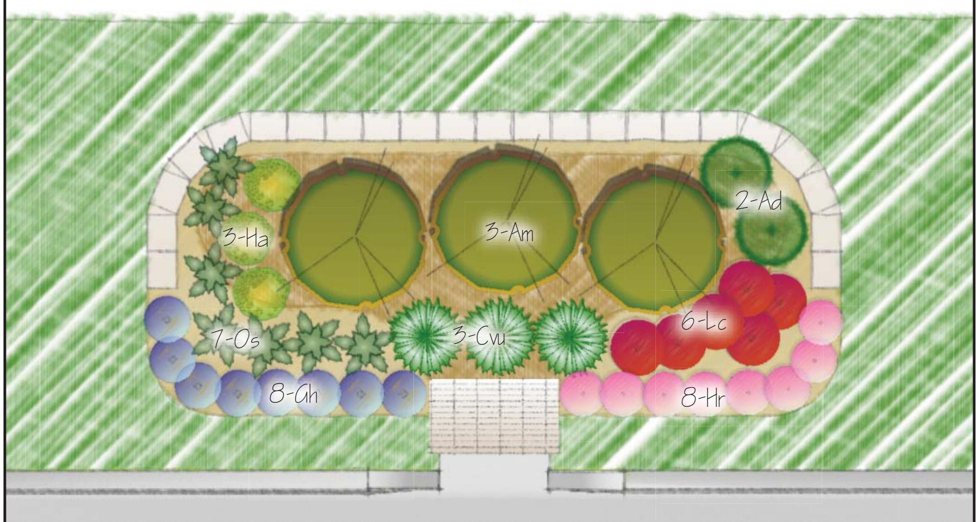
Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ha	SNEEZEWEED *Helenium autumnale*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

X. Rectangle Garden - Shady Site - Retaining Wall

Flowering Perennial Garden



Shrub Garden

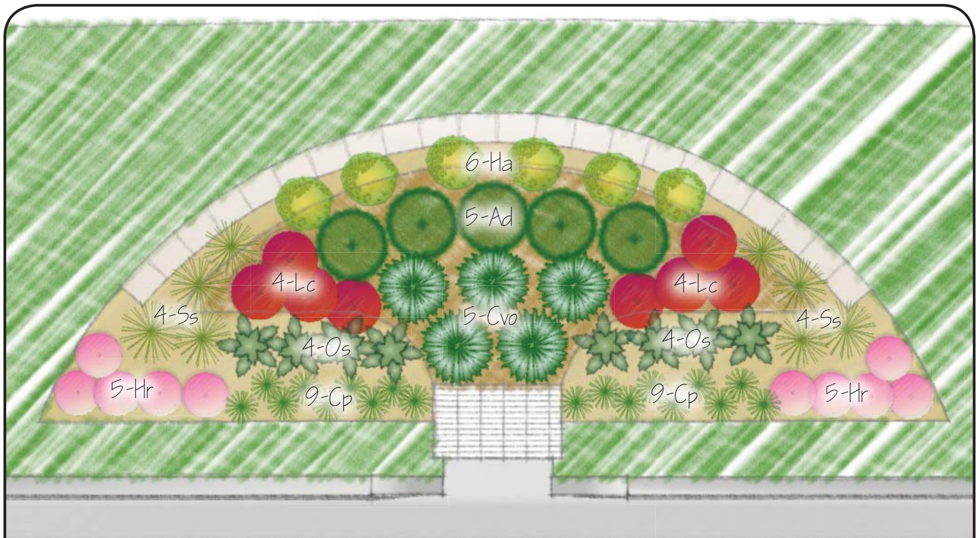


Mixed Shrub/Flower Garden

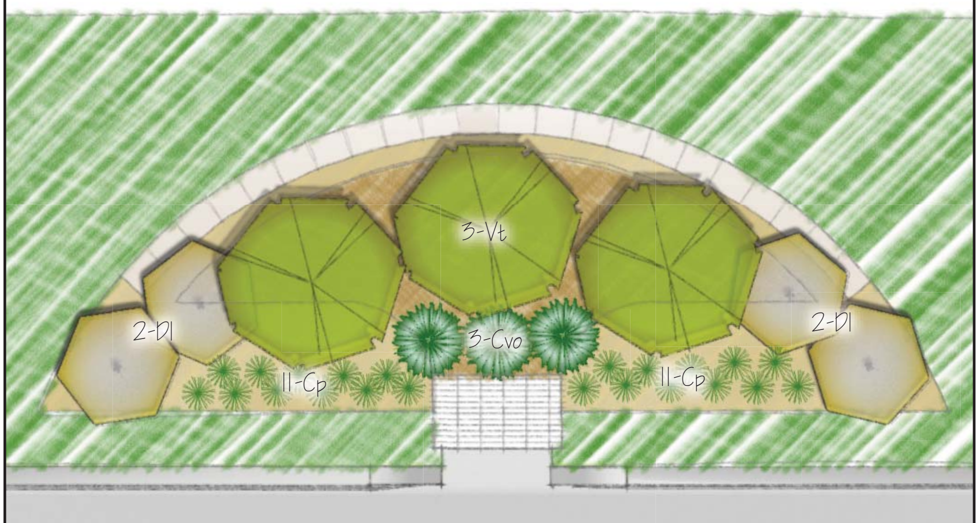
Plant Key

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'*

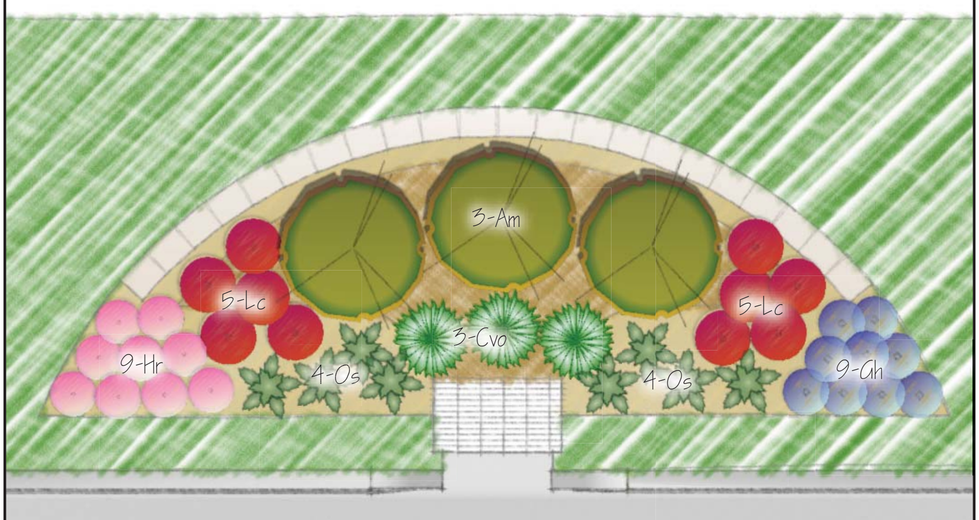
XI. Arc Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

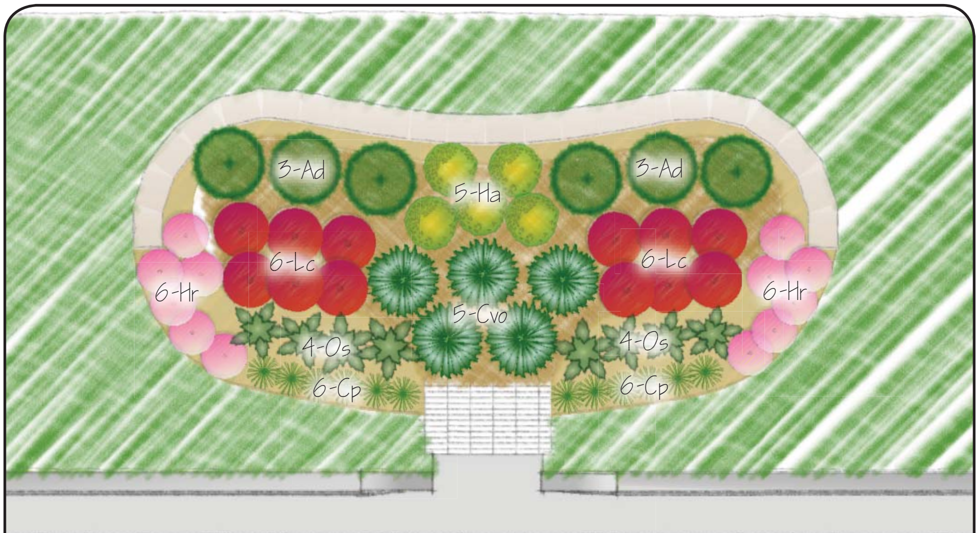


Mixed Shrub/Flower Garden

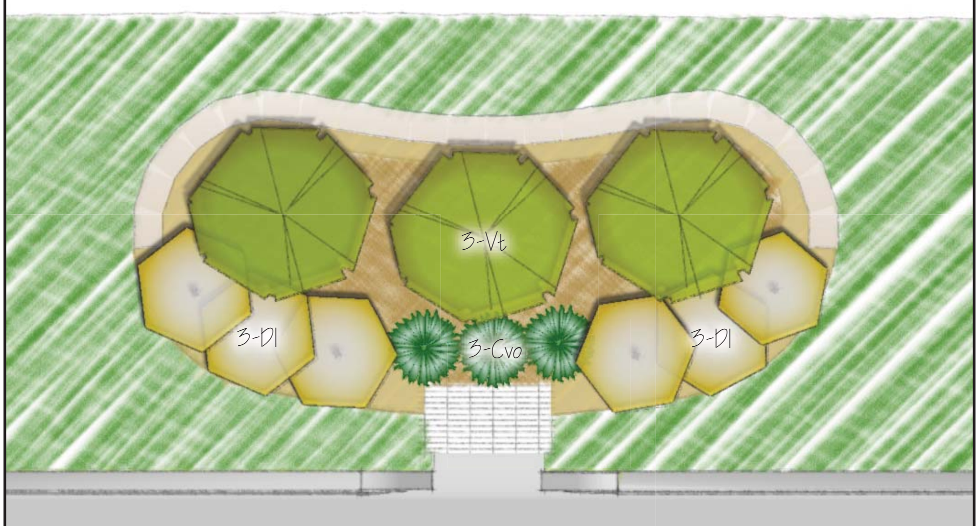
Plant Key

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