Woodcrest Creek
Stormwater Retrofit Assessment

Prepared by:

With assistance from:

THE METRO CONSERVATION DISTRICTS

for the

COON CREEK WATERSHED DISTRICT

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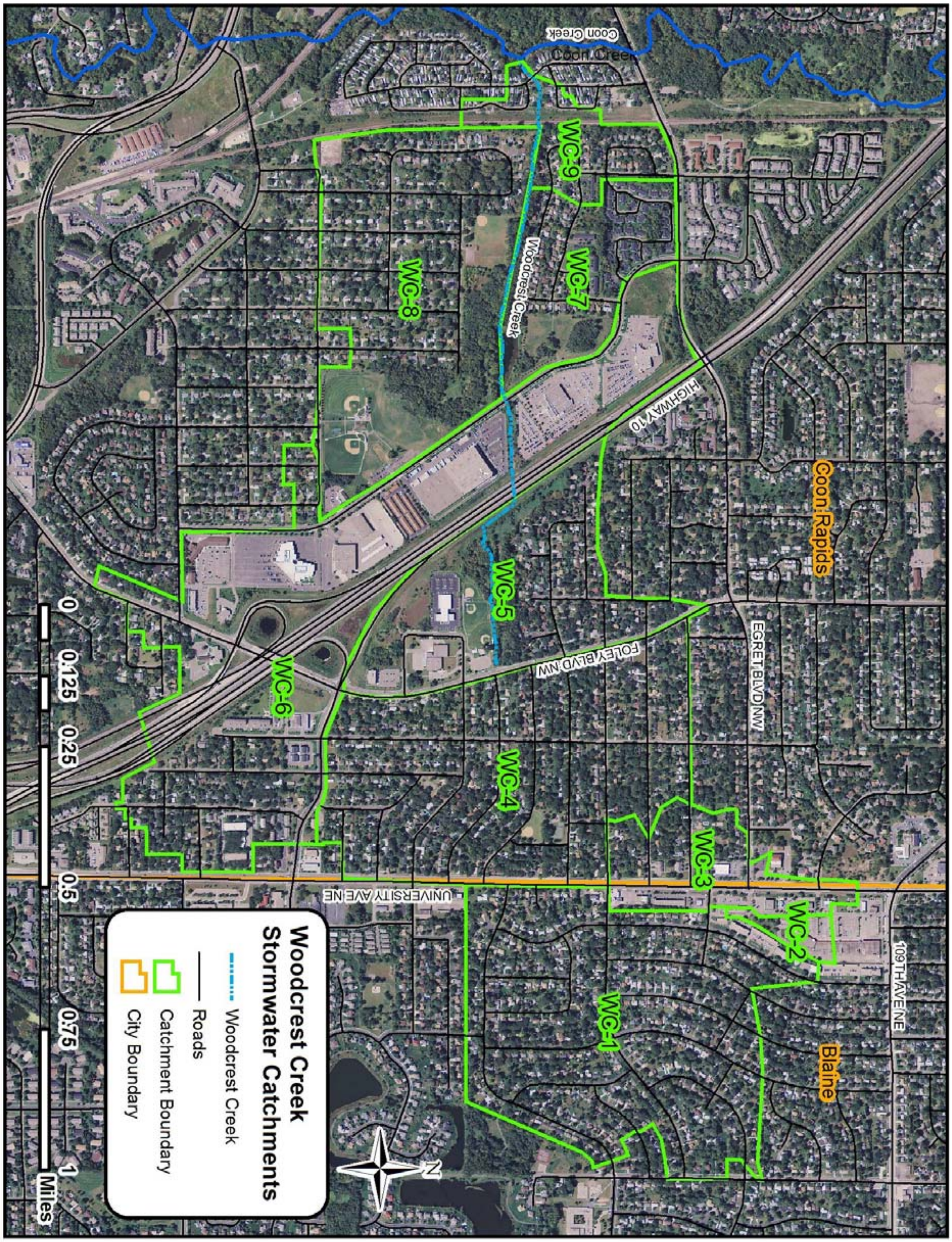
Cover photo: Outfall from a large stormwater pond west of Woodcrest Drive. The photo shows flows leaving the pond while it was near capacity during a rain event.

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 the Woodcrest Creek subwatershed. Woodcrest Creek was identified as a high priority due to the deterioration of the stream channel resulting from excessive water during storms, noticeably poor water quality, and the lack of stormwater treatment. Most of the Woodcrest Creek subwatershed is older neighborhoods and commercial areas built before modern-day stormwater treatment requirements. Woodcrest Creek is one of the main tributaries of Coon Creek. Coon Creek is a major drainage way through central Anoka County and serves as stormwater conveyance for the Cities of Ham Lake, Andover, Blaine, Columbus, and Coon Rapids. The Coon Creek's confluence with the Mississippi River in Coon Rapids is just upstream from drinking water intakes for the Twin Cities. The stormwater retrofits in this report will help alleviate existing water quality and hydrology problems in Woodcrest Creek, provide benefits to impaired waterbodies including Coon Creek and the Mississippi River, and improve the quality of a drinking water source that serves a large metropolitan population.

This stormwater assessment systematically examined areas of the subwatershed draining to Woodcrest Creek, investigated ways to improve stormwater treatment, and prioritized the opportunities by cost-effectiveness. The approaches in this report are often termed "stormwater retrofitting." This refers to adding stormwater treatment to an already built-up area. This process is investigative and creative. Stormwater retrofitting success is sometimes improperly judged by the number of projects installed or by comparing costs alone. That approach neglects 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 dissected the subwatershed into nine stormwater drainage areas, or "catchments." One catchment was excluded from in-depth analysis due to adequate existing treatment practices. The remaining eight catchments are comprised of large residential neighborhoods, parks, and commercial business areas that lack sufficient stormwater treatment. Each catchment was modeled for stormwater volume and pollutants using the software WinSLAMM. The model included both existing conditions and possible stormwater retrofits to estimate reductions in volume, total phosphorus (TP), and total suspended solids (TSS). Finally, costs were estimated for each retrofit project. Projects were ranked by cost effectiveness based on dollars per pound pollutant removed.

A variety of stormwater retrofit approaches were identified. In residential areas, networks of strategically-placed rain gardens that accept road runoff are often favored. In some commercial and park areas, existing pipe alignments and land availability lent themselves to larger infiltration basins. In other places practices such as ponds were already in place but under-utilized. Small modifications to these practices can yield substantially improved stormwater treatment. In some commercial areas where parking space is at a premium, more expensive retrofits were considered that would provide stormwater treatment without reducing available parking.

This report provides conceptual sketches or photos of stormwater retrofitting projects that are recommended. 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.

The table below summarizes the assessment results. Stormwater retrofit projects are grouped into tiers from most cost effective to least, using cost per pound of phosphorus removed. 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 ranges are dependent upon optimal siting and sizing. More detail about each project can be found in the catchment profile pages of this report.

Summary of stormwater retrofit opportunities ranked by cost-effectiveness

Tier 1 Retrofit Recommendations ($0-$500/lb TP/yr)

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)
In-Stream	New Pond	1	39.0 - 64.0	12,345 - 19,478	0.0	$105,000 - $136,500	$275 - $348	$84 - $110
WC-9*	Infiltration/Retention	1	7.9	3,594	6.7	$4,620	$240	$109
WC-1	Residential Rain Gardens	10 - 18	18.4 - 24.5	8,548 - 11,341	14.5 - 19.1	$43,720 - $77,240	$258 - $346	$120 - $160
WC-4	Residential Rain Gardens	10 - 18	16.2 - 24.1	7,503 - 11,137	12.6 - 18.8	$43,720 - $77,240	$294 - $352	$136 - $163
WC-8	Residential Rain Gardens	6 - 12	8.3 - 13.0	3,833 - 5,963	6.6 - 10.4	$26,960 - $52,100	$352 - $442	$162 - $203
WC-5	Pond Modification	1	9.4	3,821	0.0	$24,320 - $35,490	$423 - $619	$172 - $252
WC-7	Residential Rain Gardens	4 - 6	4.9 - 6.1	2,278 - 2,808	4.0 - 5.0	$18,580 - $26,960	$396 - $480	$188 - $221
WC-5	Stormwater Disconnects	4	1.3	982	2.3	$1,900	$278	$204
WC-9*	Residential Rain Gardens	3 - 5	4.4 - 5.8	2,048 - 2,701	3.5 - 4.6	$26,540 - $38,970	$542 - $620	$252 - $289
In-Stream	Pond Modification	2 - 3	11.0 - 31.0	1,972 - 7,272	0.0	$71,400 - $210,000	$1,393 - $2,746	$327 - $450

Tier 2 Retrofit Recommendations ($501-$1,500/lb TP/yr)

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)
WC-1	Apt. Rain Garden	1 - 2	2.1 - 2.9	1,462 - 1,974	2.1 - 5.2	$15,230 - $29,130	$758 - $1,100	$527 - $759
WC-3	Apt./Office Rain Gardens	2	2.3	1,078	2.3	$22,180	$1,521	$701
WC-6*	Bioretention	2 - 14	2.4 - 3.6	1,903 - 2,769	4.0 - 5.8	$33,635 - $329,690	$1,196 - $6,887	$948 - $5,297
WC-6*	Biofiltration	2 - 14	2.0 - 3.0	1,522 - 2,215	0.0	$40,758 - $404,430	$1,277 - $7,304	$1,277 - $7,304
In-Stream	Channel Stabilization	1	5.7	538,650	0.0	$210,000	$14	$1,368

Tier 3 Retrofit Recommendations (>$1,500/lb TP/yr)

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)
WC-7	Pond Modification	1	2.0	730	0.0	$45,030 - $67,930	$4,112 - $6,204	$1,501 - $2,264
WC-5	Sand Filter	1	0.4	252	0.0	$15,800	$4,947	$2,899
WC-6*	Sand Filter	1	2.4	1,607	0.0	$97,680	$5,013	$3,315
WC-3	Sand Filter	1	0.5 - 1.5	350 - 1,054	0.0	$22,280 - $65,680	$5,105 - $5,060	$3,463 - $3,503
WC-6*	Permeable Asphalt	1	3.8	2,769	5.8	$611,520	$7,723	$5,628

*Pollution reduction benefits and costs cannot be summed with other projects in the same catchment because they are alternative options for treating the

(yellow highlight) Project concept that can be applied to commercial properties in other catchments.

Special Considerations

Two pond projects identified in the assessment are in-line with the Woodcrest Creek channel and provide water quality treatment to multiple catchments. This means that BMPs installed in catchments up-gradient could improve the performance of the in-line ponds by reducing the volume or pollutant load that reaches them. It is not practical to assess the impact of each individual BMP on the in-line ponds for the purpose of this study. However, several general scenarios were developed to demonstrate how the benefits of installing BMPs within catchments will also improve the performance of the in-line ponds.

Five scenarios were analyzed to illustrate how different levels of catchment BMP installation affect the overall pollutant load in Woodcrest Creek. The following tables show pollutants produced at a variety of locations throughout the subwatershed. The pollutant load is separated by that which is produced by runoff within catchments and erosion within the creek channel. Pollutant removal is listed in tables to show where reductions can be achieved. The remaining pollutant load, taking into account upstream contributions as well as treatment, is listed for the outlet of several locations. For scenarios where BMPs are implemented, estimated total project cost and cost/lb TP/yr (30-year term) are included.

The first table shows the conditions in 2010 prior to the stabilization of upper Woodcrest Creek. These are the baseline conditions used as a comparison for other scenarios. In this situation, erosion of the upper (WC-5) and lower (WC-8) creek channels are contributing the majority of TSS loading in the subwatershed. The only existing BMP is the Woodcrest Drive pond (WC Pond), which is operating at capacity.

SUMMER 2010 - NO BMPS INSTALLED

	TSS (lb/yr)				TP (lb/yr)			
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet
WC1	39,044				126			
University				39,044				126
WC3	14,431				46			
WC4	37,511				121			
Foley				90,986				293
WC5	22,868	459,000			74	5		
Hwy 10				572,854				372
WC6	78,745				253			
WC Pond			123,597	528,002			198	427
WC7	12,374				40			
WC8	21,587	567,000			70	6		
WC9	7,123				23			
Railroad				1,136,086				565

The next two tables show the benefits achieved by stabilizing upper and lower Woodcrest Creek. Even though TSS is reduced by over 436,000 lbs/yr, the Woodcrest Drive pond is still removing the same amount of sediment as in the base conditions. This illustrates that the overall load is still more than the pond can effectively treat. The lower Woodcrest Creek stabilization project is located downstream of the Woodcrest pond, so it does not affect the pond function. However, it does significantly decrease the overall estimated TSS load at the downstream outlet (Railroad).

SPRING 2011 - AFTER UPPER WOODCREST CREEK CHANNEL STABILIZATION (WC5)

	TSS (lb/yr)				TP (lb/yr)				Estimated Total	$/lb TP
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet		
WC1	39,044				126					
University				39,044				126		
WC3	14,431				46					
WC4	37,511				121					
Foley				90,986				293		
WC5	22,868	22,950			74	0.2			$137,218	$994
Hwy 10				136,804				367		
WC6	78,745				253					
WC Pond			123,597	91,952			198	422		
WC7	12,374				40					
WC8	21,587	567,000			70	6				
WC9	7,123				23					
Railroad				700,036				561		
								TOTAL COST	$137,218	$994

SPRING 2012 - AFTER LOWER WOODCREST CREEK CHANNEL STABILIZATION (WC8)

	TSS (lb/yr)				TP (lb/yr)				Estimated	$/lb TP
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet	Total	
WC1	39,044				126					
University				39,044				126		
WC3	14,431				46					
WC4	37,511				121					
Foley				90,986				293		
WC5	22,868	22,950			74	0.2				
Hwy 10				136,804				367		
WC6	78,745				253					
WC Pond			123,597	91,952			198	422		
WC7	12,374				40					
WC8	21,587	28,350			70	0.3			$172,500	$1,009
WC9	7,123				23					
Railroad				161,386				556		
								TOTAL COST	$172,500	$1,009

The final two tables illustrate the reductions achieved by a combination of the two streambank stabilization projects and installing low or high cost BMPs identified in each catchment profile. Low cost removal BMPs are the tier 1 retrofit recommendations ($0-$500/lb-TP/yr) and the high cost removal is if all projects were installed (Tiers 1-3). These scenarios also include modifications to the Woodcrest Drive pond and the creation of a new pond east of Highway 10. The low cost removal options provide a tremendous value for TP reduction at $93/lb and will further reduce TSS loading by over 44,000 lbs/yr. The combination of the streambank stabilization, new pond east of Highway 10, and BMPs installed within the catchments significantly reduces the TSS load to the Woodcrest Drive Pond to the point where it is operating at or below capacity. The high cost removal options further reduce TSS and TP loading, but are less cost effective at $315/lb. At a cost of over a million dollars more than the low cost removal scenario, the high cost removal scenario is not a reasonable goal to pursue.

ULTIMATE CONDITION - LOW COST REMOVAL

	TSS				TP				Estimated	$/lb TP
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet	Total	
WC1	39,044		8,548		126		18		$43,720	$120
University				30,496				108		
WC3	14,431				46					
WC4	37,511		7,503		121		16		$43,720	$136
Foley				74,935				258		
WC5	22,868	22,950	4,803		74	0.2	11		$37,390	$456
Hwy 10			62,547	53,403			85	237	$100,000	$85
WC6	78,745				253					
WC Pond			73,395	58,753			152	338	$15,000	$750
WC7	12,374		2,278		40		5		$18,580	$188
WC8	21,587	28,350	5,158		70	0.3	11		$39,530	$178
WC9	7,123		3,594		23		8		$4,620	$109
Railroad				117,157				447		
								TOTAL COST	$302,560	$93

(Additional table on following page)

ULTIMATE CONDITION - HIGH COST REMOVAL

	TSS				TP				Estimated Total	$/lb TP
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet		
WC1	39,044		10,010		126		21		$58,950	$647
University				29,034				106		
WC3	14,431		1,782		46		3		$66,280	$4,167
WC4	37,511		7,503		121		16		$43,720	$136
Foley				71,691				253		
WC5	22,868	0	5,055		74	0.2	11		$53,190	$3,355
Hwy 10			64,037	25,467			91	225	$125,000	$65
WC6	78,745		7,801		253		11		$783,573	$11,168
WC Pond			79,038	17,373			171	297	$170,000	$210
WC7	12,374		3,008		40		7		$86,510	$2,452
WC8	21,587	28,350	5,158		70	0.3	11		$39,530	$178
WC9	7,123		3,594		23		8		$4,620	$109
Railroad				75,047				404		
								TOTAL COST	$1,431,373	$315

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 four major sections, plus appendices. Each section is 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 Woodcrest Creek 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 the catchment profiles 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.

Retrofits Considered but Rejected

Retrofits that were examined, but deemed unfeasible or impractical.

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 treated for each project for the duration of one maintenance term (conservative estimate of BMP effective life). The final cost per pound treatment value includes installation and maintenance costs.

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

- Reductions of other pollutants
- 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 at various points along the assessment protocol.

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, impairment status of the waterbody, and TMDL studies are just a few of the resources available to help determine which waterbodies 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.

Woodcrest Creek, which drains directly to Coon Creek, was chosen for study. Coon Creek is a high priority waterbody locally due to the fact that it serves as a main stormwater conveyance for central Anoka County, and because it is a major tributary to the Mississippi River upstream of drinking water supply intakes. Both Coon Creek and the Mississippi are designated as impaired by the State of Minnesota. Poor quality of stormwater and deterioration of the Woodcrest Creek channel due to high volumes of stormwater runoff played a major role in selecting the subwatershed for assessment. Most of the subwatershed was developed before modern-day stormwater treatment requirements. Many areas have a high percentage of land surface that is impervious, with pavement or rooftops that generate large volumes of runoff that is sent to Woodcrest Creek with little or no treatment. Any stormwater treatment within the subwatershed will not only benefit Woodcrest Creek, but Coon Creek and the Mississippi River as well.

Impervious Surfaces – A high percentage of surfaces in Woodcrest Creek are both impervious (pavement, roofs) and within land uses that generate high pollutant loads. These areas were built in the 1960's-1980's before modern-day stormwater treatment technologies and requirements resulting in limited treatment before discharging to Coon Creek.

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 district staff to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to assess in large subwatersheds, a focus area may be determined.

In this assessment, the focus area was the entire Woodcrest Creek subwatershed. We divided this area into nine catchments using a combination of stormwater infrastructure maps, GIS land use and elevation data, and field verified drainage boundaries. In areas where topography seemed flat, catchments were delineated by observing the direction of water flow during rainfall events.

Step 2: Desktop Retrofit Analysis

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

For this assessment, GIS layers of stormwater infrastructure were obtained from the Cities of Blaine and Coon Rapids. The boundaries of the Woodcrest Creek subwatershed were available from the Coon Creek Watershed district and were further refined throughout the assessment process. High-resolution aerial photography and parcel boundaries were available from Anoka County.

Desktop retrofit analysis features and associated potential stormwater retrofit projects.

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

Step 3: Retrofit Reconnaissance Investigation

After identifying potential retrofit sites through this desktop search, a field investigation was conducted to evaluate each site 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 often reveals additional retrofit opportunities that could have gone unnoticed during the desktop search.

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

Stormwater Treatment Options for Retrofitting		
Area Treated	**Best Management Practice**	**Potential Retrofit Project**
5-500 acres	Extended Detention	**12-24 hr detention of stormwater with portions drying out between events (preferred over wet ponds). May include multiple cell design, infiltration benches, sand/peat/iron filter outlets and modified choker outlet features.**
	Wet Ponds	**Permanent pool of standing water with new water displacing pooled water from previous event.**
	Wetlands	**Depression less than 1-meter deep and designed to emulate wetland ecological functions. Residence times of several days to weeks. Best constructed off-line with low-flow bypass.**
0.1-5 acres	Bioretention	**Use of native sol, soil microbe and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof**
	Filtering	**Filter runoff through engineered media and passing it through an under-drain. May consist of a combination of sand, soil, compost, peat, compost 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 or curb-cut raingardens, 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 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. This period may include multiple life cycles for a given project. Estimated benefits included are pounds of phosphorus and suspended solids removed, though projects were ranked only by cost per pound of phosphorus removed annually.

Treatment analysis

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

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

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

WinSLAMM stormwater computer model inputs

General WinSLAMM Model Inputs	
Parameter	**File/Method**
Land use acreage	**ArcGIS**
Precipitation/Temperature Data	**Minneapolis 1959 – the rainfall year that best approximates a typical year.**
Winter season	**Included in model. Winter dates are Nov 4 – March 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.**

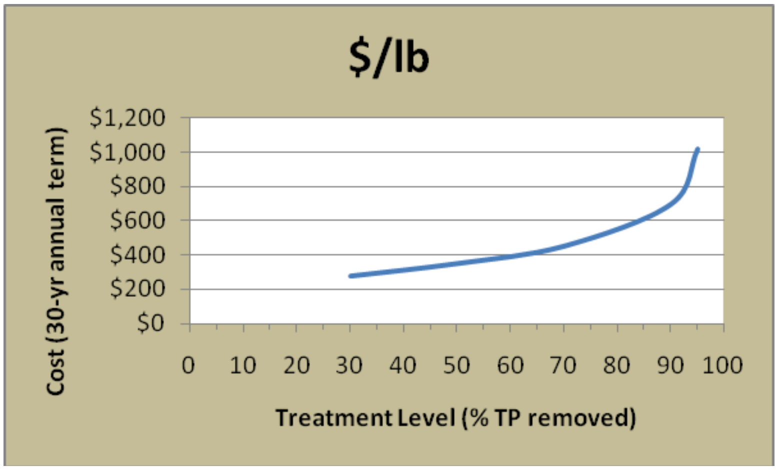
Cost Estimates

Cost estimates were annualized costs that incorporated design, installation, installation oversight, and maintenance over the expected lifespan of the practice. In cases such as rain gardens, where promotion to landowners is important, 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 on-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.

Several items relating to project costs are listed in the cost/benefit analysis table for each retrofit option. All costs are in 2010 dollars. Below is a brief description of each item:

Item	**Description**
Materials/Labor/Design	Total estimated cost for project design and construction.
Promotion & Admin Costs	Estimated cost of project promotion and administration. This cost assumes that each landowner approached is willing to cooperate with the project. In some cases, additional promotion will be needed to identify enough willing landowners. This is especially true in the case of residential rain gardens. Promotion costs could be significantly higher depending on the level of willing participation.
Total Project Cost	Total of materials/labor/design and promotion & admin costs.
Annual O&M	Estimated annual operation and maintenance costs over a 30-year "term". In some cases, such as stormwater pond maintenance, expenses will occur every 10 or 30 years instead of annually. The purpose of this line is to provide an average annual cost.
O&M Present Worth (or Present Value)	This is the amount of money that would need to be invested in year one of a project in order to withdraw annual O&M over a 30-year period. It assumes 3% annual growth on the investment above the cost of money (including inflation), so that at the end of the 30-year term the investment would be zeroed out. This is calculated by multiplying the estimated annual O&M by a present worth factor of 19.6.
Term Cost/1,000lb-TSS/yr	Estimated cost per 1,000 pound of TSS reduced per year over a 30-year term. Costs include total project cost and annual O&M.
Term Cost/lb-TP/yr	Estimated cost per pound of TP reduced per year over a 30-year term. Costs include total project cost and annual O&M.

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 Watershed District 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. Projects were grouped into tiers from most to least cost effective. Only projects that seem 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. The watershed district may wish to revise the recommended level based on water quality goals, finances, or public opinion.

Water Quality Sampling

Background

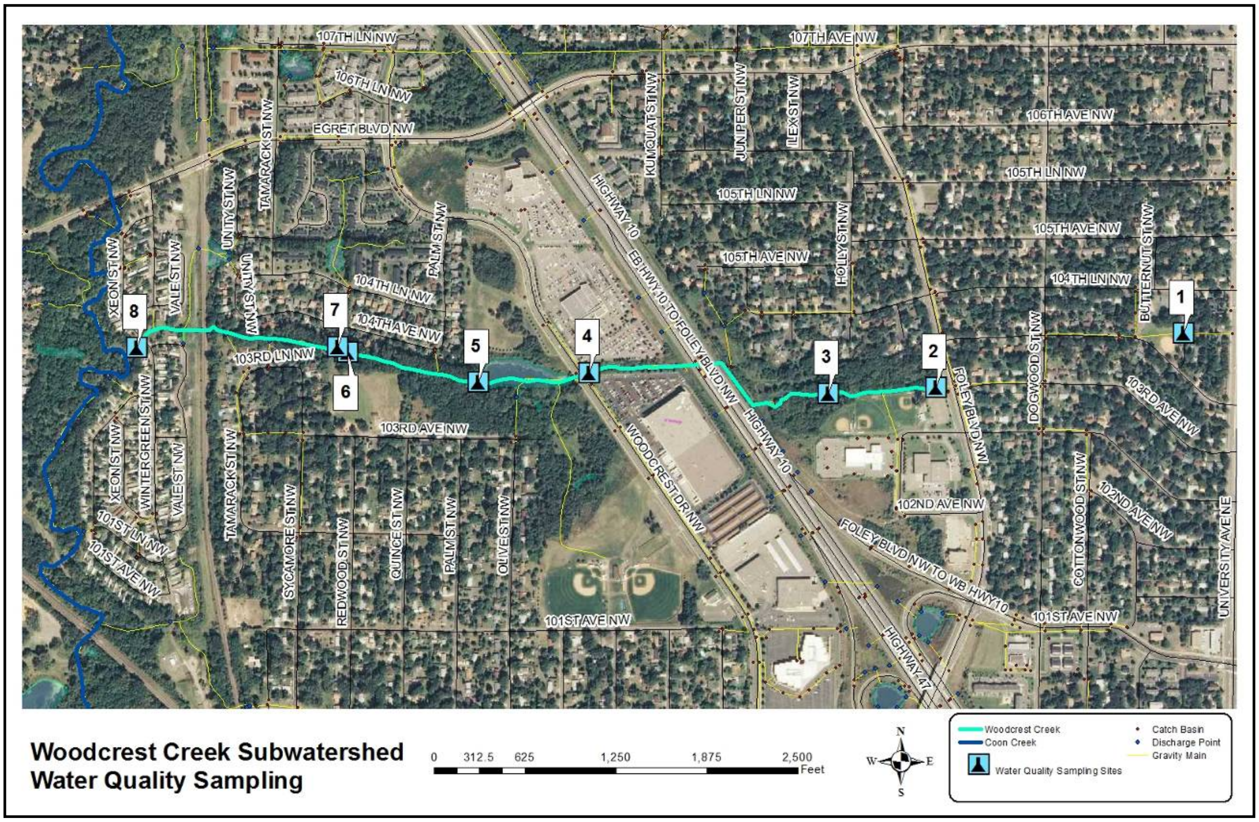
The Anoka Conservation District conducted stream water quality sampling within Woodcrest Creek as part of the 2010 Woodcrest Creek Subwatershed Stormwater Retrofit Assessment. The goals of this additional sampling were to document changes in water quality from upstream to downstream and identify areas of poor water quality within Woodcrest Creek for targeted remediation. The results of these efforts initiated a foundation for understanding the impacts Woodcrest Creek has on its receiving water body, Coon Creek.

Methods

Samples were collected at eight locations along Woodcrest Creek during two storms as part of this stormwater assessment (see map on following page). On September 15th, 2010 sampling followed 0.53 inches of rainfall. On September 23rd, 2010 sampling followed 0.89 inches of rainfall. Not all sites were monitored during each storm. Some sites were within stormwater pipes; others in open channel portions of the creek. Sampling sites were strategically located to be at catchment divides or to sasses the effectiveness of a particular stormwater treatment BMP. Water quality data was also being collected during the study period in Coon Creek such that water quality in Coon and Woodcrest Creeks can be compared.

A Horiba multi-probe was used to measure water temperature, pH, conductivity, turbidity, and salinity at each sampling location. Water samples were collected for analysis of total phosphorus and total suspended solids at only select locations because of budget limitations. Water sample analysis was performed by a state-approved laboratory.

The number of samples collected does not allow for a comprehensive water quality assessment because extrapolating the data from two storm events does not provide an adequate representation of the functioning of Woodcrest Creek. However, these data provide some general insights and provide assurances that stormwater modeling done for this study is accurate.



Results and Discussion

Total Phosphorus, Total Suspended Solids, and Turbidity

Suspended solids were higher during the larger rainfall event. The best data is available from the Foley Boulevard stream crossing, where all parameters were measured during both storms. TSS at this site was double during the 0.89-inch rainfall when compared to the 0.53-inch rainfall, with readings of 19 and 41 mg/L. Reasons may include greater loading from impervious surfaces, more within-stream sediment movement in higher flows, and perhaps that the larger rainfall exceed the treatment capacity of existing stormwater BMPs.

It is interesting to note that turbidity at Foley Boulevard was actually lower during the larger storm event. One potential explanation for this phenomenon could be driven by the size of the suspended particles present in the samples at the time of data collection. The large grass and leaf particles observed potentially bypassed the turbidity meter because of the protective case around the probe. The total suspended solids parameter is more rigorous and provides a better representation of the suspended material present in the creek.

Total phosphorus showed little change during the two storms monitored. The Foley Boulevard stream crossing was the only site with phosphorus data from both storms. Phosphorus levels were 132 and 105 µg/L for the smaller and larger storm, respectively. This is a negligible difference.

Conductivity increased dramatically from upstream to downstream. Conductivity is a broad measure of dissolved pollutants including salts, metals, and others. During the smaller storm conductivity readings were taken at every site. Farthest upstream, conductivity was low, at 0.029 mS/cm. Farthest downstream it was 1.47 mS/cm, a more than 50-fold increase. It is also one of the higher conductivity readings ever observed by Anoka Conservation District staff county-wide.

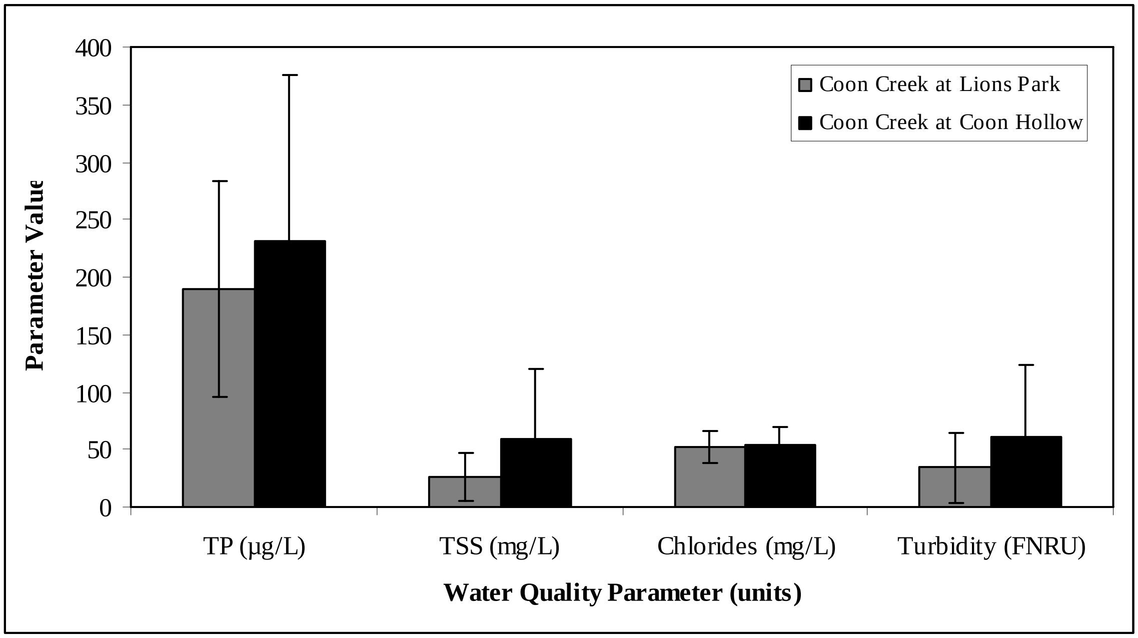
The largest stormwater pond in the subwatershed, just west of Woodcrest Drive, seems to have some effectiveness despite being largely filled with sediment. Water was monitored as it entered and left the pond. Turbidity was reduced from 25 NTU to six NTU during the smaller storm. During the larger storm turbidity was reduced from 39 to 36, TSS was reduced from 46 to 19 mg/L, and TP was reduced from 0.116 to 0.075 mg/L. These reductions, particularly during the smaller storm, are encouraging. However it is clear that the pond is inefficient in larger storms. Given that the pond is full of sediment, it is likely that larger storms scour out any pollutants that accumulated during smaller storms. Given this pond's position in-line with the stream and near the bottom of the subwatershed, its performance is critical. It should be examined for retrofitting or maintenance.

Site Number	Site Location	Date	Time	TSS (mg/L)	TP (µg/L)	pH	Cond. (mS/cm)	Turb. (NTU)	Temp. (°C)	Sal. (%)	Appearance
1	@ Alder St. NW	9/15/2010	13:30			6.43	0.029	40	16.9	0.00	Clear; Large suspended particles (mostly grass clippings and leaves)
2	@ Foley Blvd. NW	9/15/2010	13:45	19	132	6.75	0.03	41	16.7	0.00	Clear; Large suspended particles (mostly grass clippings and leaves)
3	@ Approx. Hwy. 10 N of Baseball Fields	9/15/2010	15:05			7.55	0.088	30	16.3	0.00	Slightly brown
4	@ Woodcrest Dr. NW	9/15/2010	14:45			7.65	0.238	25	16.2	0.00	Medium brown
6	@ Woodcrest Park	9/15/2010	14:30			7.84	1.49	18	16.7	0.06	Clear; Large suspended particles (mostly grass clippings and leaves)
7	@ Woodcrest Park Outfall	9/15/2010	14:35			8.04	0.291	6	15.7	0.01	Clear
8	@ Xeon St. NW	9/15/2010	14:10	8	89	7.8	1.47	17	16.4	0.06	Clear; Large suspended particles (mostly grass clippings and leaves)
2	@ Foley Blvd. NW	9/23/2010	13:30	41	105	6.45	0.09	30	17.6	0.00	Large suspended particles (mostly grass clippings and leaves)
4	@ Woodcrest Dr. NW	9/23/2010	13:45	46	116	7.1	0.022	39	17.5	0.00	Brown; Large suspended particles (mostly grass clippings and leaves)
5	@ Downstream of Woodcrest Dr. Pond	9/23/2010	14:30	19	75	6.84	0.093	36	17.4	0.00	Sparse large suspended particles

Impacts to Coon Creek

Water quality data from Coon Creek allows us to gain insight into the impact of Woodcrest Creek on Coon Creek. Admittedly, data from Woodcrest Creek is too sparse to generate firm conclusions, but some general observations are possible. Analysis of two Coon Creek sites, one upstream and one downstream of Woodcrest Creek, displays the deterioration of common measures of stream water quality at downstream sites within Coon Creek (see figure below). Total phosphorus, TSS, and turbidity are higher at Coon Creek at Coon Hollow, the downstream site. Therefore, significant contributions of pollutants within the stretch of Coon Creek between Lions Park and Coon Hollow are responsible for the increases in these parameters and subsequent decrease in overall water quality.

Woodcrest Creek is one of the significant tributaries to Coon Creek between Lions Park and Coon Hollow. The qualitative observations made throughout this subwatershed assessment in conjunction with the limited water quality data suggest that Woodcrest Creek is contributing to the decrease in Coon Creek water quality between Lions Park and Coon Hollow.



Average values (± one standard deviation) of common stream water quality parameters between 2007 and 2010 for two Coon Creek sampling sites. Coon Creek at Lions Park is located 1.9 miles upstream of Woodcrest Creek's confluence with Coon Creek, and Coon Creek at Coon Hollow is located 0.8 miles downstream.

Management Implications

The existing stormwater treatment pond located downstream of Woodcrest Dr. NW appears to be decreasing in-stream concentrations of both total phosphorus and total suspended solids based on the two storm samples collected. Modifications to this control structure may provide increased water quality benefits to Woodcrest Creek and subsequently Coon Creek. The water samples collected at Foley Dr. NW indicate that the upstream catchments, dominated by medium density residential land cover, are contributing total phosphorus and total suspended solids. Therefore, best management practices installed within those neighborhoods may improve the water quality prior to the creek entering the treatment pond, thereby potentially reducing the maintenance costs of the pond and improving water quality in a larger stretch of the creek.

Because of the limited number of samples collected these data should not be used alone to determine future management actions within the Woodcrest Creek subwatershed. The conclusions presented above are broad generalizations. Confidence in the determinations must be low because the data is sparse. Nevertheless, the patterns observed are intriguing, provide preliminary data that can serve as a basis for the development of future data collection efforts, and serve as a "field check" of other conclusions in this report.

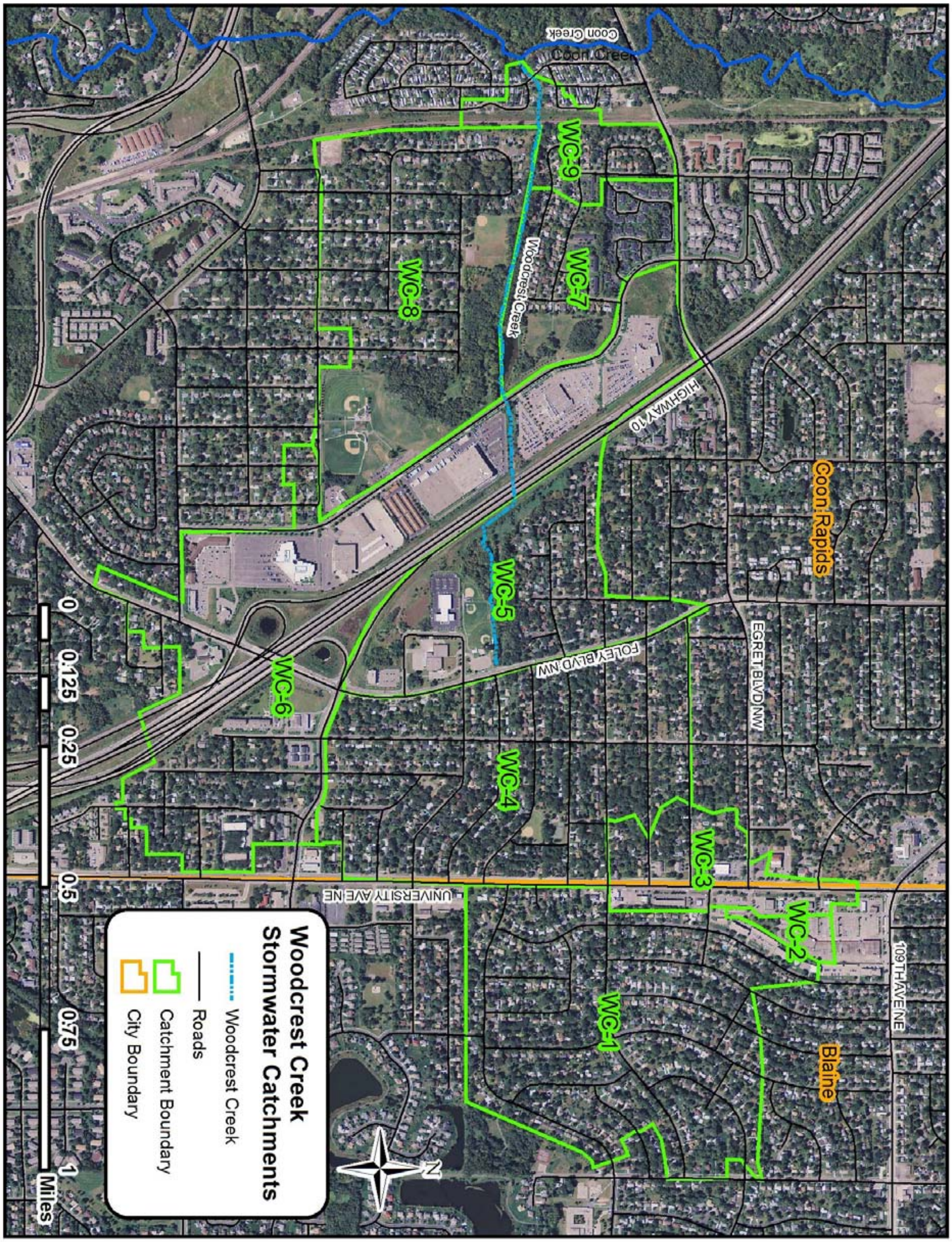
Catchment Profiles

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

- Summary of existing conditions, including estimated pollutant export to Woodcrest Creek.
- Map of the catchment.
- Recommended stormwater retrofits, pollutant reductions, and costs.
- Retrofits considered but rejected.

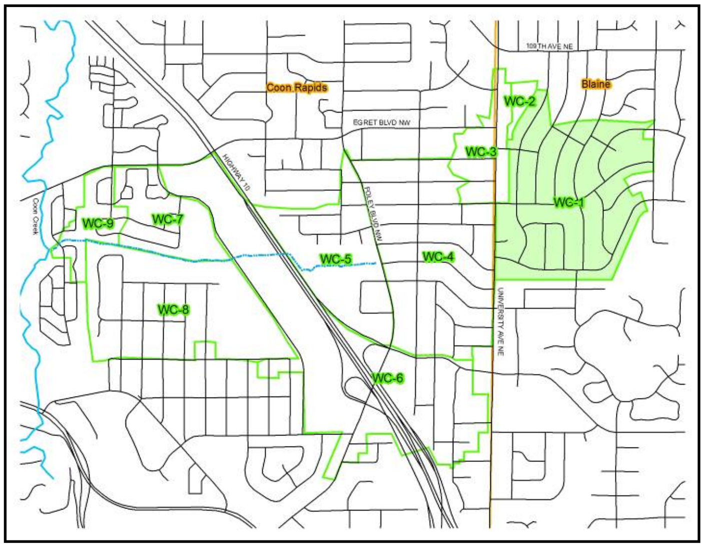
Catchment profiles are provided for each of the nine catchments. Following the final catchment profile is a summary ranking table that outlines all projects from all catchments based upon cost effectiveness. The summary ranking table is arguably the most important component of this report because it provides detailed information for each project from each catchment that may be used to prioritize future management efforts.

Map of stormwater catchment areas referred to in this report. A detailed profile for each catchment is on the following pages.



Catchment 1

Catchment Summary	
Acres	150.2
Dominant Land Cover	Residential
Parcels	472
Volume (acre-feet/yr)	66.9
TP (lb/yr)	78.6
TSS (lb/yr)	36,804



CATCHMENT DESCRIPTION

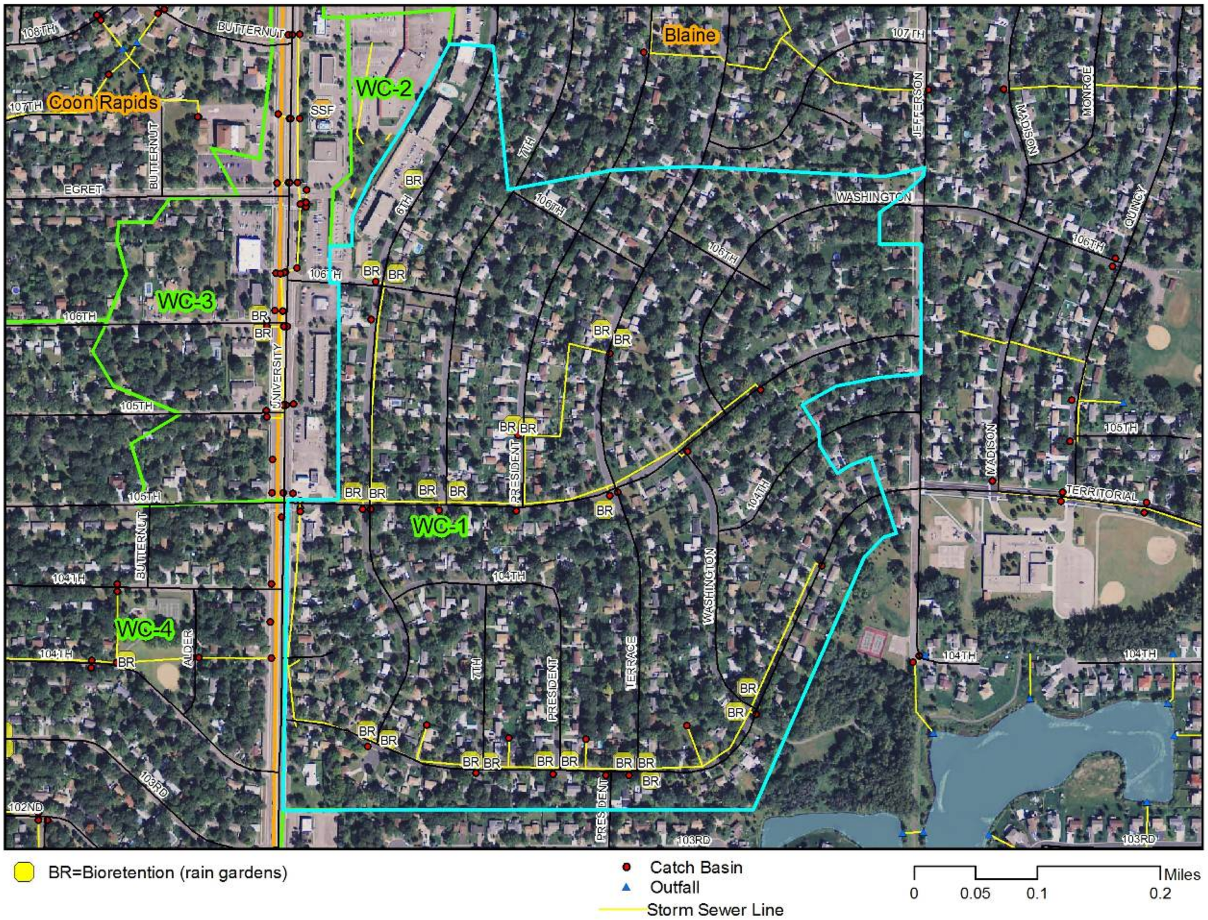
This catchment is one of three catchments located in Blaine. It is comprised of primarily medium density, single-family residential development. It also includes an apartment complex on the northwest side of the catchment.

EXISTING STORMWATER TREATMENT

There are no existing stormwater treatment practices in this catchment other than street sweeping. All stormwater runoff is captured in catch basins and discharged to Woodcrest Creek. Existing pollutant loading from this catchment to Woodcrest Creek is shown in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	83.9	5.3	6%	**78.6**
	TSS (lb/yr)	39,123	2,319	6%	**36,804**
	Volume (acre-feet/yr)	66.9	0.0	0%	**66.9**
	Number of BMP's	1			
	BMP Size/Description	Street Sweeping			

RETROFIT RECOMMENDATIONS



Curb-Cut Rain Garden Network - The residential nature of this catchment makes it best suited to residential, curb-cut rain gardens (see appendix B for design options). Twenty three ideal rain garden locations were identified (see map). Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large area. Considering typical landowner participation rates we analyzed scenarios where 10, 14, and 18 rain gardens were installed (levels 1, 2, and 3 in the table below). At these three levels of treatment, catchment-wide removal of TSS and TP could be increased to the levels shown in the table on the following page. The cost per pound of phosphorus removed is lowest if 10 rain gardens are installed. However, costs for all levels of treatment are relatively low so a higher level of treatment could be pursued if funding allows.

Curb-Cut Rain Garden Network

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	18.4	28%	19.8	30%	24.5	36%
	TSS (lb/yr)	8,548	28%	9,182	29%	11,341	35%
	Volume (acre-feet/yr)	14.5	22%	15.5	23%	19.1	29%
	Number of BMP's	10		14		18	
	BMP Size/Description	2,500 sq ft		3,500 sq ft		4,500 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$40,710		$56,910		$73,110	
	Promotion & Admin Costs	$3,010		$3,570		$4,130	
	Total Project Cost	$43,720		$60,480		$77,240	
	Annual O&M	$750		$1,050		$1,350	
	O&M Present Worth	$14,700		$20,580		$26,460	
	Term Cost/1,000lb-TSS/yr	$258		$334		$346	
	Term Cost/lb-TP/yr	**$120**		**$155**		**$160**	

Complex Bioretention – Assumes engineered soils, curb cuts, forebays, and partial retaining wall

Apartment Rain Gardens – Space is available for infiltration practices at the Stonegate Apartments complex. Two ideal locations were identified (see map right). There is enough room for a 1,000 square foot rain garden at the south end of the property (labeled 1) and a larger 2,000 square foot garden located adjacent to the main parking area (labeled 2). The practices were modeled for treating runoff from rooftops and parking areas. The two practices could reduce catchment wide TSS and TP loading by the amounts shown in the table on the following page. Though the overall cost per pound of treatment is higher than the residential rain gardens described above, these two rain gardens are also favorable since project coordination with a single landowner is often easier to manage. Also, single large projects are less expensive to install and maintain than multiple smaller projects.

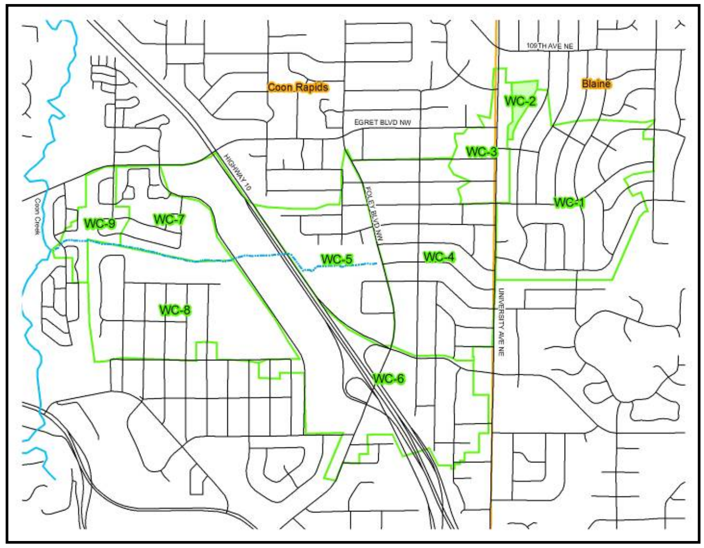
Stonegate Apartments Rain Gardens

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	2.1	9%	2.9	10%		
	TSS (lb/yr)	1,462	10%	1,974	11%		
	Volume (acre-feet/yr)	2.1	3%	5.2	8%		
	Number of BMP's	1		1			
	BMP Size/Description	1,000 sq ft		2,000 sq ft			
	BMP Type	Moderately Complex Bioretention		Moderately Complex Bioretention			
Cost	Materials/Labor/Design	$14,110		$28,010			
	Promotion & Admin Costs	$1,120		$1,120			
	Total Project Cost	$15,230		$29,130			
	Annual O&M	$600		$1,200			
	O&M Present Worth	$11,760		$23,520			
	Term Cost/1,000lb-TSS/yr	$758		$1,100			
	Term Cost/lb-TP/yr	**$527**		**$759**			

Moderately Complex Bioretention – Assumes engineered soils, curb cuts, and forebays.

Catchment 2

Catchment Summary	
Acres	5.5
Dominant Land Cover	Commercial
Parcels	3
Volume (acre-feet/yr)	0.0
TP (lb/yr)	0.0
TSS (lb/yr)	0



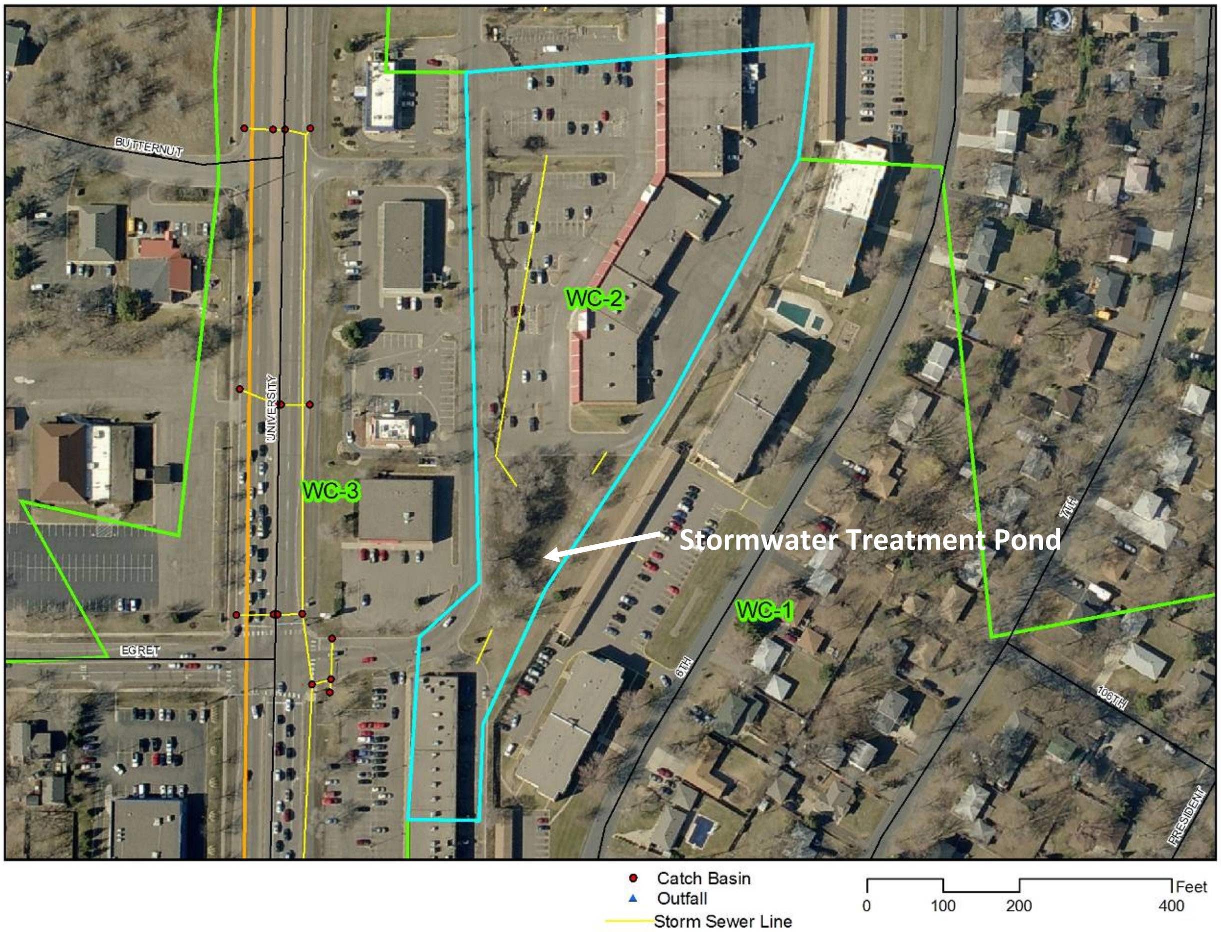
DESCRIPTION

This small catchment is comprised of a shopping center and parking areas on the east side of University Ave in Blaine. Stormwater runoff is captured in catch basins and discharged to a dry pond.

EXISTING STORMWATER TREATMENT

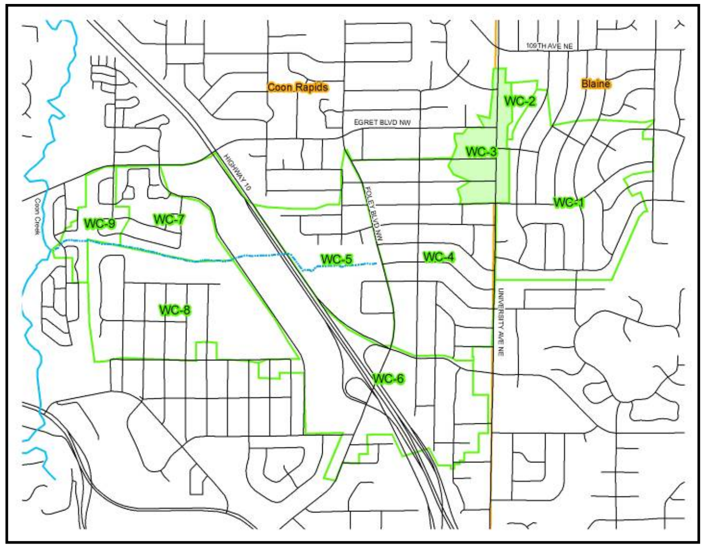
The dry pond has three inlets and no outlet resulting in 100% treatment for the catchment (map on following page). Turf grass growing in the bottom of the pond is evidence that water is rapidly infiltrated by the sandy soils. Due to the amount of existing stormwater treatment, no retrofits are recommended.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	5.3	5.3	100%	**0.0**
	TSS (lb/yr)	3,752	3,752	100%	**0**
	Volume (acre-feet/yr)	6.7	6.7	100%	**0.0**
	Number of BMP's	1			
	BMP Size/Description	Dry pond with no outlet			


BUTTERNUT
UNIVERSITY
EGRET
WC-1
WC-2
WC-3
Stormwater Treatment Pond
6TH
7TH
105TH
PRESIDENT
Catch Basin
Outfall
Storm Sewer Line
Feet
0
100
200
400

Catchment 3

Catchment Summary	
Acres	34.9
Dominant Land Cover	Residential, Commercial
Parcels	64
Volume (acre-feet/yr)	35.5
TP (lb/yr)	25.5
TSS (lb/yr)	16,378



DESCRIPTION

Catchment 3 consists of commercial development and medium density residential development in the cities of Coon Rapids and Blaine. Stormwater is captured in catch basins throughout the catchment and piped south where it joins a main stormwater line that eventually daylights as Woodcrest Creek.

EXISTING STORMWATER TREATMENT

The only functioning stormwater treatment practice in this catchment is street sweeping. Existing pollutant loading from this catchment to Woodcrest Creek, after street sweeping, is shown in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	26.6	1.1	4%	**25.5**
	TSS (lb/yr)	16,982	604	4%	**16,378**
	Volume (acre-feet/yr)	35.5	0.0	0%	**35.5**
	Number of BMP's	1			
	BMP Size/Description	Street Sweeping			

RETROFIT RECOMMENDATIONS

Townhome & Office Rain Gardens – Space is available for a bioretention facility on each side of 106th Avenue at University Avenue in front of the Liberty Park townhomes and a small office complex. The area is flat, which would make construction easier. It would treat runoff from the townhomes, office building and the residential area on 106th Avenue. The rain gardens were modeled as one 1,500 ft^2 garden (750 ft^2 each). They would be treating a little over five acres and approximately 30% of the residential development in the catchment. Pollutant reductions resulting from installing both rain gardens are highlighted in the table below.

Townhome & Office Rain Gardens at 106th Avenue and University Avenue.

Townhome & Office Rain Gardens

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	2.3	13%				
	TSS (lb/yr)	1,078	10%				
	Volume (acre-feet/yr)	2.3	6%				
	Number of BMP's	2					
	BMP Size/Description	1,500 sq ft					
	BMP Type	Moderately Complex Bioretention					
Cost	Materials/Labor/Design	$21,060					
	Promotion & Admin Costs	$1,120					
	Total Project Cost	$22,180					
	Annual O&M	$900					
	O&M Present Worth	$17,640					
	Term Cost/1,000lb-TSS/yr	$1,521					
	Term Cost/lb-TP/yr	**$701**					

Moderately Complex Bioretention – Assumes engineered soils, curb cuts, and forebays.

Perimeter Sand Filters in Commercial Parking Lots –
A challenge in commercial areas and parking lots is to install practices that address stormwater without consuming parking spaces. Permeable pavement and sand filters are two options (see Catchment 6 profile for details on permeable asphalt). Sand filters have the advantage of being installed without disturbing large areas of a parking lot. Their weakness is that they do not reduce volume. See appendix A for more details on the design of perimeter sand filters.

The pollutant removal numbers presented below assume the sand filters are enhanced by addition of iron filings to the filter media. Iron filings substantially improve removal of dissolved phosphorus. A significant portion of phosphorus in stormwater is dissolved.

We modeled scenarios where 0.87 acres (approx 10%), 1.75 acres (20%), and 2.62 acres (30%) of commercial parking lots were treated by perimeter sand filters. Generally, 100 linear feet of perimeter sand filter (as designed in appendix A) can treat water from 1 acre of impervious surfaces. Catchment-wide removal of pollutants could be increased to the levels shown in the table on the following page.

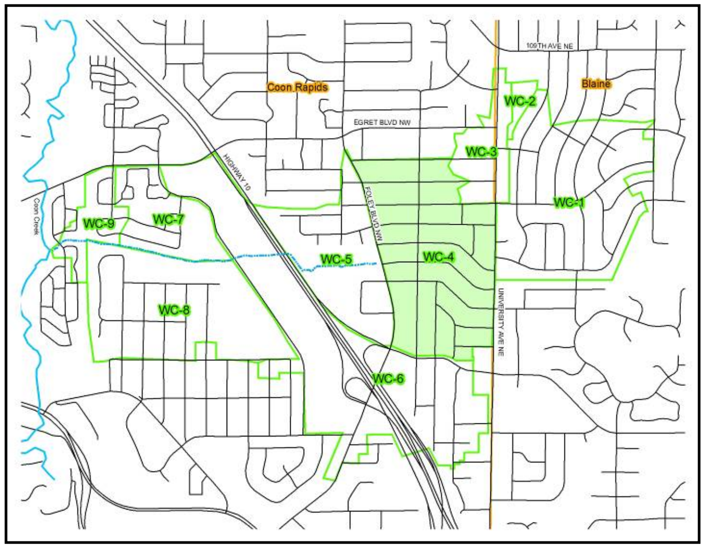
Perimeter Sand Filters in Commercial Parking Lots

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	0.5	6%	1.0	8%	1.5	10%
	TSS (lb/yr)	350	6%	704	8%	1,054	10%
	Volume (acre-feet/yr)	0.0	0%	0.0	0%	0.0	0%
	Number of BMP's	Treating 0.87 acres parking (10%)		Treating 1.75 acres parking (20%)		Treating 2.62 acres parking (30%)	
	BMP Size/Description	87	linear feet	175	linear feet	262	linear feet
	BMP Type	Perimeter Sand Filter		Perimeter Sand Filter		Perimeter Sand Filter	
Cost	Materials/Labor/Design	$20,880		$42,000		$62,880	
	Promotion & Admin Costs	$1,400		$2,100		$2,800	
	Total Project Cost	$22,280		$44,100		$65,680	
	Annual O&M	$1,044		$2,100		$3,144	
	O&M Present Worth	$20,462		$41,160		$61,622	
	Term Cost/1,000lb-TSS/yr	$5,105		$5,071		$5,060	
	Term Cost/lb-TP/yr	**$3,503**		**$3,466**		**$3,463**	

Retrofits Considered but Rejected –
Stormwater Disconnects - Stormwater disconnecting is the practice of routing stormwater onto permeable surfaces, such as lawn or other unused open space, instead of into catch basins. Though there is some space between parking lots and roads where stormwater disconnects would normally be located, numerous factors prevent them from being feasible. Stormwater flow direction, existing landscaping, signs, and utilities prevented disconnects from being considered as a reasonable alternative.

Catchment 4

Catchment Summary	
Acres	144.3
Dominant Land Cover	Residential
Parcels	377
Volume (acre-feet/yr)	59.9
TP (lb/yr)	73.5
TSS (lb/yr)	33,675



CATCHMENT DESCRIPTION

This catchment is comprised of medium density, single-family residential development. There are also two city parks in the catchment.

EXISTING STORMWATER TREATMENT

There are no existing stormwater treatment practices in this catchment other than street sweeping. All stormwater runoff is captured in catch basins and discharged to Woodcrest Creek. Existing pollutant loading from this catchment to Woodcrest Creek is shown in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	78.4	5.0	6%	**73.5**
	TSS (lb/yr)	35,830	2,155	6%	**33,675**
	Volume (acre-feet/yr)	59.9	0.0	0%	**59.9**
	Number of BMP's	1			
	BMP Size/Description	Street Sweeping			

RETROFIT RECOMMENDATIONS

Curb-Cut Rain Garden Network - The residential nature of this catchment makes it best suited to residential, curb-cut rain gardens (see appendix B for design options). Twenty six ideal rain garden locations were identified, including sites at Alder and Acorn city parks where a larger rain garden would be appropriate (see map). Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large area. Considering typical landowner participation rates we analyzed scenarios where 10, 14, and 18 rain gardens were installed (levels 1, 2, and 3 in the table below). At these three levels of treatment, catchment-wide removal of TSS and TP could be increased to the levels shown on the following page. The cost per pound of phosphorus removed is lowest if 10 rain gardens are installed. However, costs for all levels of treatment are relatively low so a higher level of treatment could be pursued if funding allows.

Curb-Cut Rain Garden Network

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	16.2	27%	19.5	31%	24.1	37%
	TSS (lb/yr)	7,503	27%	9,060	31%	11,137	37%
	Volume (acre-feet/yr)	12.6	21%	15.3	26%	18.8	31%
	Number of BMP's	10		14		18	
	BMP Size/Description	2,500 sq ft		3,500 sq ft		4,500 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$40,710		$56,910		$73,110	
	Promotion & Admin Costs	$3,010		$3,570		$4,130	
	Total Project Cost	$43,720		$60,480		$77,240	
	Annual O&M	$750		$1,050		$1,350	
	O&M Present Worth	$14,700		$20,580		$26,460	
	Term Cost/1,000lb-TSS/yr	$294		$338		$352	
	Term Cost/lb-TP/yr	**$136**		**$157**		**$163**	

Complex Bioretention – Assumes engineered soils, curb cuts, forebays, and partial retaining wall

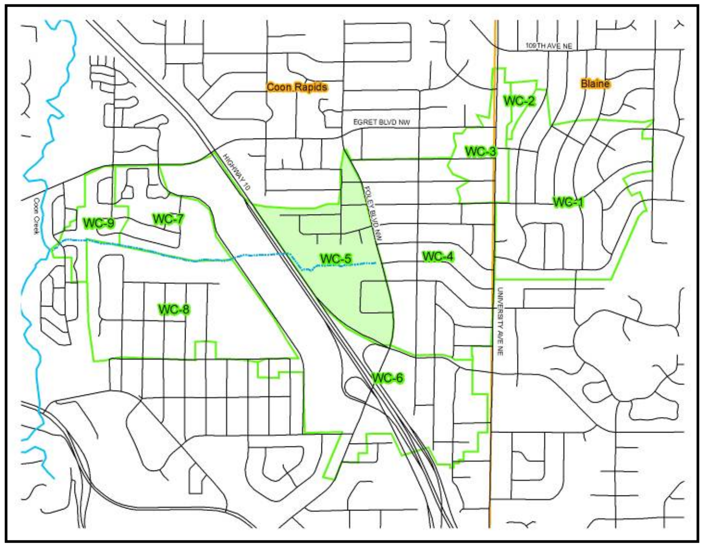
Alder and Acorn parks (pictured above) provide opportunities for larger bioretention cells on public property.

Retrofits Considered but Rejected –
Permeable Asphalt or Bioretention at Intersections – Several intersections in the catchment are fairly large and could provide opportunity for installation of BMPs. Permeable asphalt was considered but rejected due to the cost and clogging that may result from street runoff. Bioretention was rejected

because intersections would need to be re-graded to get water to flow into a roundabout style cell. Similar treatment could be achieved for much less cost by installing curb-cut style gardens.

Catchment 5

Catchment Summary	
Acres	73.5
Dominant Land Cover	Residential, Park, Freeway, Commercial
Parcels	120
Volume (acre-feet/yr)	34.0
TP (lb/yr)	78.9
TSS (lb/yr)	39,233



DESCRIPTION

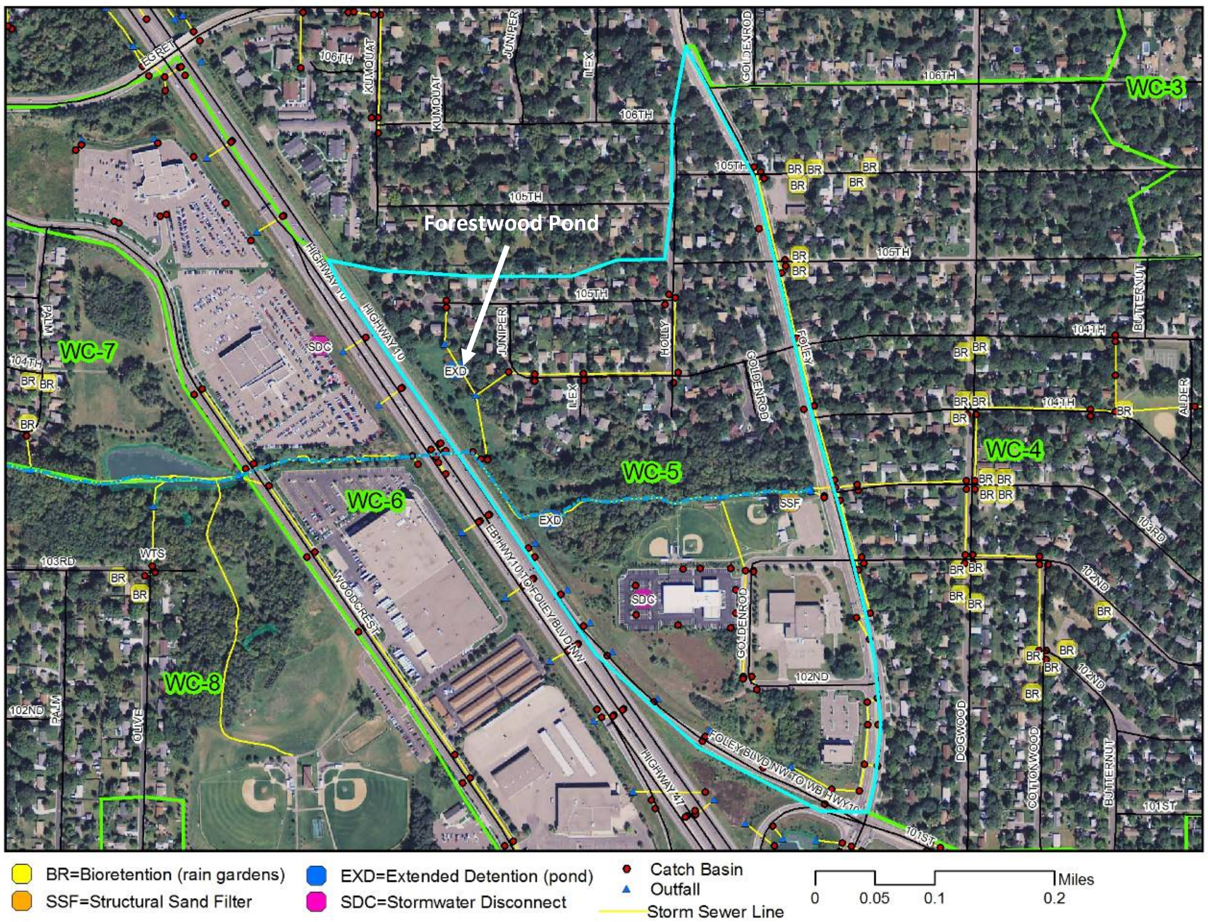
Catchment five is located between Foley Boulevard and Highway 10 in Coon Rapids. The catchment consists of a residential neighborhood, post office, and Progressive Insurance office. Aspen park and baseball fields separate the residential and commercial areas. Woodcrest Creek is daylighted from the underground stormwater pipe system under Foley Boulevard on the east side of this catchment, and flows west before going under Highway 10. A stream channel realignment and stabilization project for the section of Woodcrest Creek in Catchment 5 was completed in 2010.

EXISTING STORMWATER TREATMENT

Three stormwater treatment practices were identified in the catchment and included in the modeling; street sweeping, Forestwood pond treating the residential area, and a pond on the post office property. The Forestwood pond showed signs of being filled with sediment. There was little or no standing water, and vegetation was growing throughout the pond area. There is currently little or no storage capacity. For this reason, the pond was modeled as a swale, as there is currently little or no storage capacity. The pond at the south west corner of the post office property will likely need to be maintained in the coming years, but seems to have enough capacity to provide treatment for the property. Progressive Insurance's property was assumed to be connected to Woodcrest Creek, as there was limited information available on their stormwater infrastructure. The sum of benefits from the existing stormwater treatment is in the table on the following page.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	82.4	3.5	4%	**78.9**
	TSS (lb/yr)	40,853	1,620	4%	**39,233**
	Volume (acre-feet/yr)	34.3	0.3	1%	**34.0**
	Number of BMP's	3			
	BMP Size/Description	Street Sweeping, Forestwood Pond (modeled as swale), Post Office Pond			

RETROFIT RECOMMENDATIONS



Forestwood Pond Excavation/Modification – The pond treating the residential area is not currently functioning as a pond due to the amount of sediment that has been collected in the basin. Dredging one foot out of the pond and raising the outlet elevation by two feet with a broad crested weir would provide a substantial increase in pollutant removal over the existing conditions. Cost estimates were

prepared to address the three potential management levels based on pollutants found in the pond dredge materials. Costs also include testing the material for contamination, and modifying the pond outlet. The three dredge material management categories are as follows:

Management Level 1 – Dredged material suitable for fill or reuse on residential or recreational sites.

Management Level 2 – Dredged material suitable for fill or reuse on industrial properties.

Management Level 3 – Dredged material significantly contaminated and must be managed for specific contaminants present.

Forestwood Pond Excavation/Modification

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	9.4	16%	9.4	16%	9.4	16%
	TSS (lb/yr)	3,821	13%	3,821	13%	3,821	13%
	Volume (acre-feet/yr)	0.0	1%	0.0	1%	0.0	1%
	Number of BMP's	1-Pond excavated 1ft (Level 1 Material), raised outlet		1-Pond excavated 1ft (Level 2 Material), raised outlet		1-Pond excavated 1ft (Level 3 material), raised outlet	
	BMP Size/Description	535	cubic yards	535	cubic yards	535	cubic yards
	BMP Type	Wet Pond		Wet Pond		Wet Pond	
Cost	Materials/Labor/Design	$22,550		$27,900		$33,250	
	Promotion & Admin Costs	$1,680		$1,960		$2,240	
	Total Project Cost	$24,230		$29,860		$35,490	
	Annual O&M	$808		$995		$1,183	
	O&M Present Worth	$15,830		$19,509		$23,187	
	Term Cost/1,000lb-TSS/yr	$423		$521		$619	
	Term Cost/lb-TP/yr	**$172**		**$212**		**$252**	

Progressive Insurance Stormwater Disconnects – Before going forward with this retrofit, the parking lot will need to be surveyed, and stormwater routing should be verified. Available stormwater mapping was insufficient to determine where stormwater goes once it enters a catch basin, so it was assumed to be connected to Woodcrest Creek. If other treatment practices are in place, this retrofit may be unnecessary.

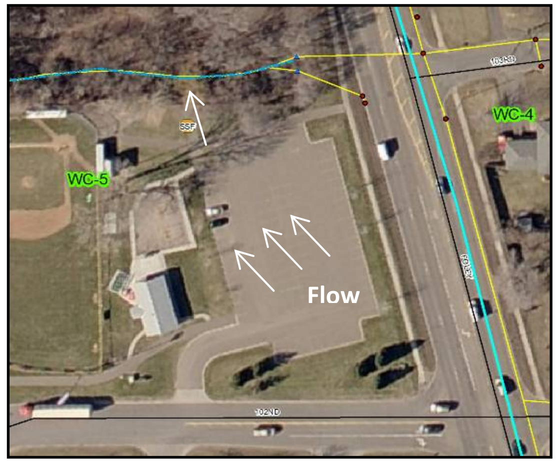

Example stormwater disconnect site.

Stormwater disconnecting is the practice of routing stormwater onto permeable surfaces, such as lawn, instead of into catch basins. There are at least two promising locations for stormwater disconnects at the Progressive Insurance office building, but given the size of the parking lot, it is likely there are more. Each would be accomplished by installing a curb-cut immediately up-gradient of an existing catch basin and doing some minor re-grading with erosion protection. In each case the water would be directed to unused open space. This is similar to a curb-cut rain garden approach except that it would utilize the large areas of available space on the south and west side of the property and the sandy soils on-site. The added cost of creating a basin to contain and infiltrate the water would outweigh the additional benefit gained. We analyzed a scenario where four disconnects were installed and assumed 50% of impervious surface from the property could be disconnected. Catchment-wide removal of TSS and TP could be increased to the levels shown in the table below.

Progressive Insurance Stormwater Disconnects

	Cost/Benefit Analysis	*Network Treatment By BMP*					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	1.3	6%				
	TSS (lb/yr)	982	6%				
	Volume (acre-feet/yr)	2.3	8%				
	Number of BMP's	4					
	BMP Size/Description	40 linear feet					
	BMP Type	Curb-Cut					
Cost	Materials/Labor/Design	$1,200					
	Promotion & Admin Costs	$700					
	Total Project Cost	$1,900					
	Annual O&M	$210					
	O&M Present Worth	$4,116					
	Term Cost/1,000lb-TSS/yr	$278					
	Term Cost/lb-TP/yr	$204					

Little League Parking Lot Sand Filter – A challenge in commercial areas and parking lots is to install practices that address stormwater without consuming parking spaces. Permeable pavement and sand filters are two options (see Catchment 6 profile for details on permeable asphalt). Sand filters have the advantage of being installed without disturbing large areas of a parking lot. Their weakness is that they do not reduce volume. See appendix A for more details on the design of perimeter sand filters.



One scenario was modeled where the entire 0.6 acre parking lot would be treated by perimeter sand filters (pictured right). Additional surveying is needed to determine if a perimeter or Austin style sand filter is most appropriate for the site based on water flow direction. For a conservative estimate, the more expensive perimeter sand filters were used in the cost benefit analysis. Generally, 100 linear feet of perimeter sand filter (as designed in appendix A) can treat water from 1 acre of impervious surfaces.

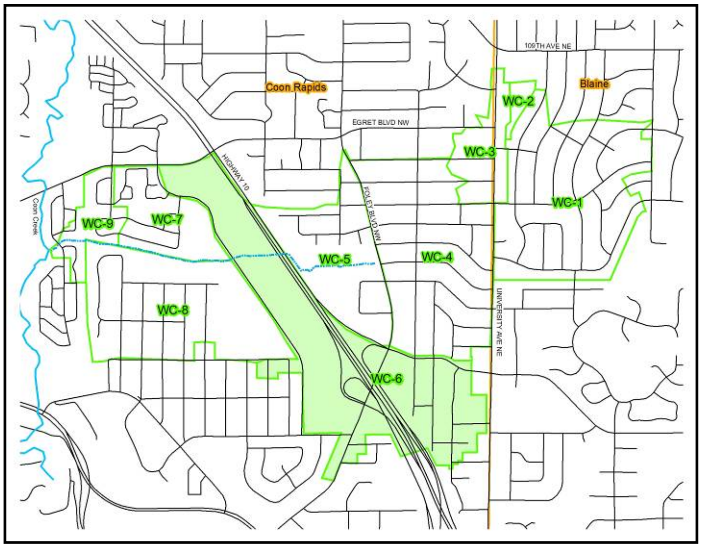
The pollutant removal numbers presented below assume the sand filters are enhanced by addition of iron filings to the filter media. Iron filings substantially improve removal of dissolved phosphorus. A significant portion of phosphorus in stormwater is dissolved. Installing a perimeter sand filter would increase catchment-wide removal of pollutants to the levels shown in the table below.

Little League Parking Lot Sand Filter

	Cost/Benefit Analysis	*Network Treatment By BMP*					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	0.4	5%				
	TSS (lb/yr)	252	5%				
	Volume (acre-feet/yr)	0.0	1%				
	Number of BMP's	Treating Ball Field Parking (0.6 acres)					
	BMP Size/Description	60	linear feet				
	BMP Type	Perimeter Sand Filter					
Cost	Materials/Labor/Design	$14,400					
	Promotion & Admin Costs	$1,400					
	Total Project Cost	$15,800					
	Annual O&M	$720					
	O&M Present Worth	$14,112					
	Term Cost/1,000lb-TSS/yr	$4,947					
	Term Cost/lb-TP/yr	**$2,899**					

Catchment 6

Catchment Summary	
Acres	203.0
Dominant Land Cover	Commercial, Freeway, Residential
Parcels	156
Volume (acre-feet/yr)	157.2
TP (lb/yr)	47.4
TSS (lb/yr)	41,864



DESCRIPTION

Catchment 6 includes a large commercial area between Woodcrest Drive and Highway 10, the intersection of Highway 10 and Foley Boulevard, and a small residential development northeast of Highway 10. The commercial area has a movie theatre, furniture store, lumber yard, storage garages, and a car dealership. Stormwater runoff from these areas are captured in catch basins and directed to Woodcrest Creek through pipes or swales. The creek itself is only about 720 feet long in this catchment. It flows from the east under Highway 10 and leaves the catchment on the west side as it enters a large retention pond. The area of this catchment located south of the creek is within Coon Rapid's Drinking Water Supply Management Area (DWSMA), and a portion is within a Wellhead Protection Area (WPA) for well #5 (see map in Appendix D).

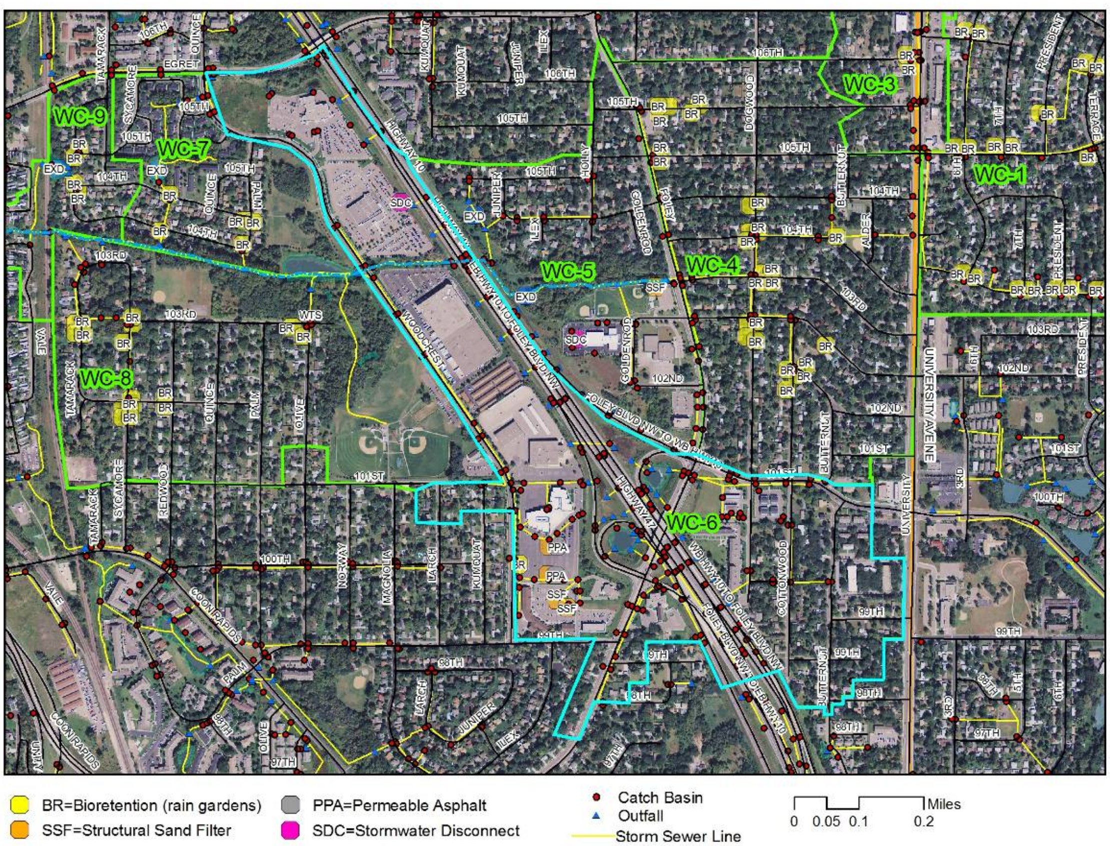
EXISTING STORMWATER TREATMENT

Several existing stormwater treatment practices in addition to street sweeping were taken into account in the analysis of catchment 6. Two treatment ponds located in the interchange of Highway 10 and Foley Boulevard were designed to treat runoff from the highway and some surrounding residential and commercial areas. Since they are already receiving a significant amount of treatment, areas receiving treatment from these ponds were not assessed for retrofit potential. Swales running along Highway 10 also provide treatment to the overflow from the highway ponds, runoff from the highway, and parking lots. The car dealership at the north end of the catchment has a small pond on-site that is treating runoff from the property. Base loading (no BMPs) and existing loading (with existing BMPs) are summarized in the table on the following page.

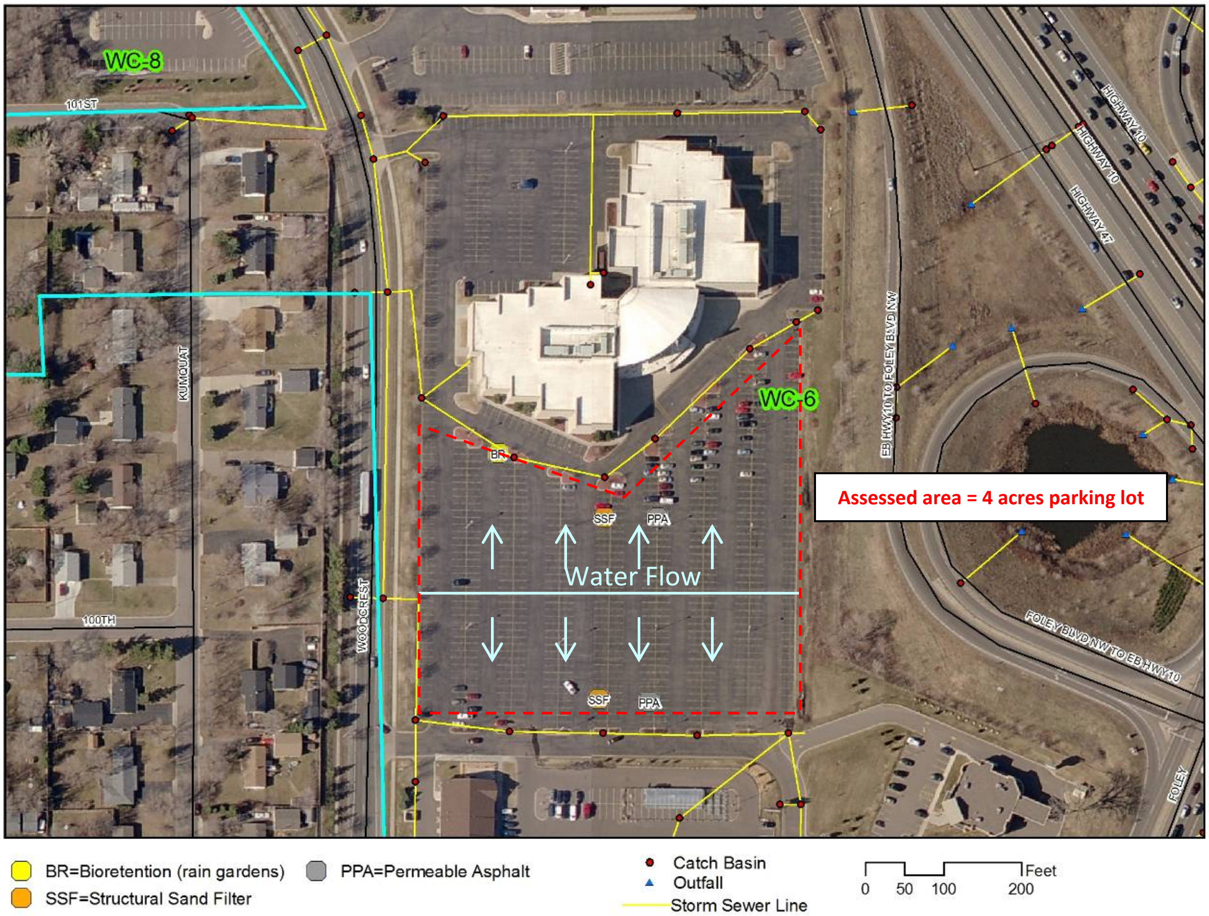
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	153.9	106.5	69%	**47.4**
	TSS (lb/yr)	96,634	54,770	57%	**41,864**
	Volume (acre-feet/yr)	199.5	42.3	21%	**157.2**
	Number of BMP's	4			
	BMP Size/Description	Street Sweeping, Hwy 10 Ponds, Car Dealership Pond, Swales			

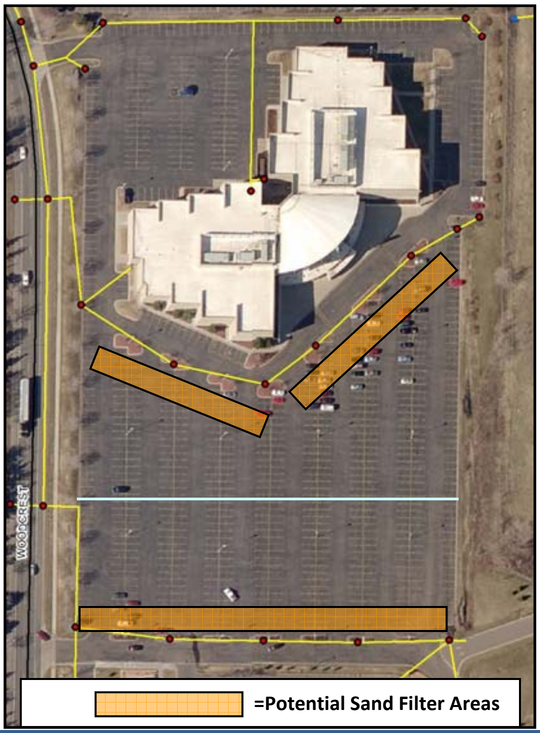
RETROFIT RECOMMENDATIONS

The portion of this catchment receiving no treatment is mainly within the commercial areas. Due to the similar nature of each commercial property, only one was assessed for retrofits. The findings from the assessed property can be extrapolated to the other properties, as pollutant loading and treatment amounts will be similar across the land cover type. The assessed property is the AMC Movie Theatre, located on Woodcrest Drive north of 99th Avenue. Options for treating four acres of parking lot are summarized below.



Commercial Property Retrofit Example – AMC Movie Theatre Parking Lot





Parking Lot Perimeter Sand Filter – A challenge in commercial areas and parking lots is to install practices that address stormwater without consuming parking spaces. Permeable pavement and sand filters are two options. Sand filters have the advantage of being installed without disturbing large areas of a parking lot. Because they do not infiltrate water, they are ideal for use in drinking water protection areas. Since this area is within one of Coon Rapids' DWSMAs, sand filters might be the best choice for treating runoff because they do not infiltrate water. See appendix A for more details on the design of perimeter sand filters.

We modeled a scenario where 4 acres of parking lot would be treated by perimeter sand filters (see map right). Generally, 100 linear feet of perimeter sand filter (as designed in appendix A) can treat water from 1 acre of impervious surfaces. Installing a perimeter sand filter would increase catchment-wide removal of pollutants to the levels shown in the table below (Level 1). The pollutant removal numbers presented below assume the sand filters are enhanced by addition of iron filings to the filter media. Iron filings substantially improve removal of dissolved phosphorus. A significant portion of phosphorus in stormwater is dissolved.

Parking Lot Permeable Asphalt – Large parking lots generate large volumes of runoff and contribute to pollutant loading in Woodcrest Creek. At the same time, local businesses prefer not to convert existing parking into a stormwater treatment device. Therefore, permeable pavement was considered as a replacement for some of the traditional pavement to reduce stormwater volumes and provide water quality treatment. **However, potential risks of infiltrating runoff from commercial areas within a DWSMA should be assessed before any infiltration practices are installed.**

A scenario where four acres of parking lot was treated by permeable asphalt was modeled. Generally, permeable pavements can treat water from an area of impervious surface three times the size of the permeable pavement. Therefore, the area of permeable pavement needed to treat the acreages mentioned above is one acre (one acre pervious + 3 acres impervious = 4 acres total). The model did include maintenance, such as restorative vacuuming of the pavement annually. See appendix A for more details on the design of permeable pavements. Catchment-wide removal of volume and pollutants could be increased to the levels shown in the table below (Level 2).

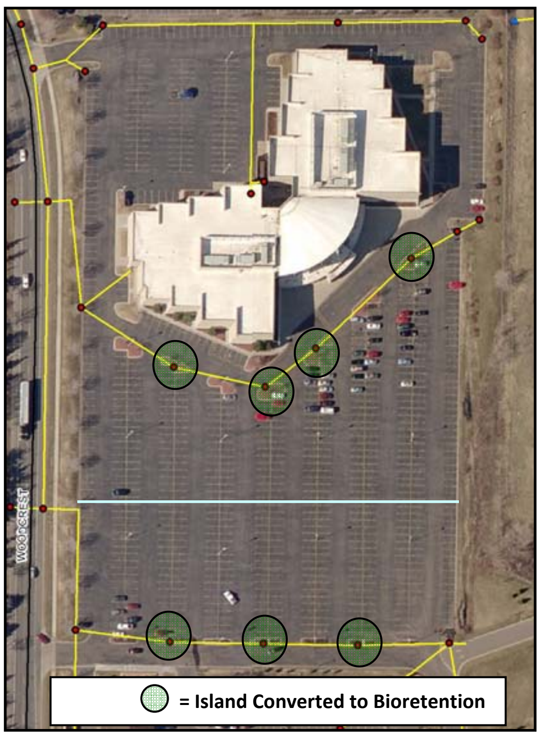
Parking Lot Sand Filters & Permeable Asphalt

	Cost/Benefit Analysis	*Network Treatment By BMP*					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	2.4	71%	3.8	72%		
	TSS (lb/yr)	1,607	58%	2,769	60%		
	Volume (acre-feet/yr)	0.0	21%	5.8	24%		
	Number of BMP's	Treating 4.0 acres		Treating 4.0 acres			
	BMP Size/Description	400 linear ft		43,560 sq ft			
	BMP Type	Perimeter Sand Filter		Permeable Asphalt			
Cost	Materials/Labor/Design	$96,000		$609,840			
	Promotion & Admin Costs	$1,680		$1,680			
	Total Project Cost	$97,680		$611,520			
	Annual O&M	$4,800		$1,002			
	O&M Present Worth	$94,080		$19,637			
	Term Cost/1,000lb-TSS/yr	$5,013		$7,723			
	Term Cost/lb-TP/yr	**$3,315**		**$5,628**			

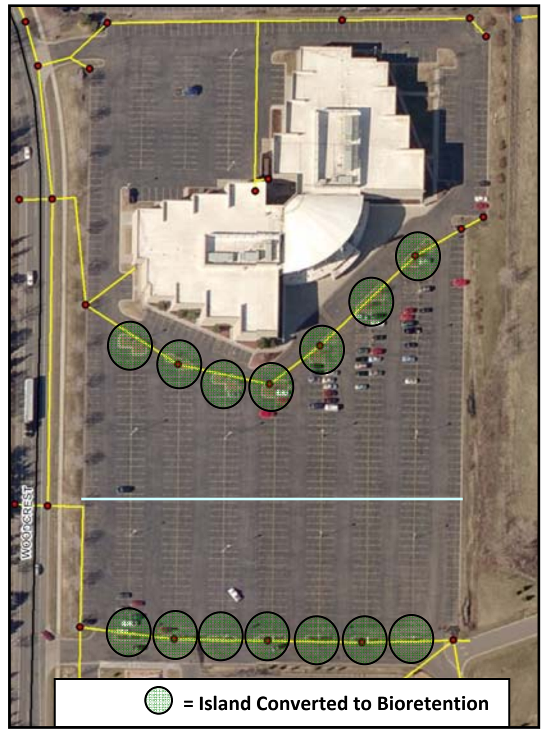
Parking Lot Bioretention – A competitive alternative to sand filters and permeable asphalt is to install bioretention practices (rain gardens) within the parking lot. This method uses existing stormwater infrastructure as emergency overflows, and often converts existing raised parking lot islands into sunken basins designed for infiltration. In some cases, parking spaces are eliminated, which is not desirable in a commercial setting. **Since this area is within a DWSMA, potential risks of infiltrating runoff from commercial areas should be assessed before any infiltration practices are installed.**

Three bioretention scenarios were analyzed for the four acre movie theatre parking lot. The findings could also be applied to other commercial properties in the subwatershed with similar parking lot arrangements.

Scenario 1 – Convert raised islands with adjacent catch basins to sunken bioretention cells (Level 1 in cost/benefit analysis table below): Currently seven of the 14 parking lot islands have adjacent stormwater catch basins. The parking lot is graded to direct stormwater runoff to those catch basins where it is sent untreated via pipe to Woodcrest Creek. Modifying the islands to function essentially as curb-cut rain gardens, will achieve a significant amount of stormwater treatment without the need to modify existing stormwater infrastructure. In addition, the existing catch basins will serve as the emergency overflow for the gardens. Pollutant reductions for this option are outlined in Level 1 of the table below.



Scenario 2 – Convert all raised islands to sunken bioretention cells (Level 2 in cost/benefit analysis table below): Converting all of the 14 raised islands to rain gardens provides additional treatment beyond scenario 1 levels, but it also doubles the construction cost. The islands without catch basins would be modified the same as the islands with catch basins. When they are full, water will bypass the garden and continue on its normal path. Pollutant reductions for this option are outlined in Level 2 of the table below.



Project area not to scale

Scenario 3 – Create single long linear sunken island at each end of the parking lot (Level 3 in cost/benefit analysis table below): This approach expands the existing parking lot islands to create two long, narrow bioretention cells; one at each end of the parking lot (adjacent to the existing catch basins). The northern and southern cells would be approximately 490 and 390 feet long, respectively. Each cell would be an average of 23 feet wide, which is about the same width as the existing islands. The benefit of this approach is that it provides more treatment than the previously described scenarios. However, it poses some potential limitations. The cells are significantly more expensive and do not fit within the existing landscape footprints. Therefore, installation would require substantial modifications to the existing parking lot. The increased size of the bioretention cells will require the elimination of some parking spaces, and driving lanes may be impeded. Pollutant reductions for this option are highlighted in Level 3 of the table below.

Parking Lot Bioretention

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	2.4	71%	3.1	71%	3.6	72%
	TSS (lb/yr)	1,903	59%	2,426	59%	2,769	60%
	Volume (acre-feet/yr)	4.0	23%	5.1	24%	5.8	24%
	Number of BMP's	7		14		2	
	BMP Size/Description	1,925 sq ft		3,878 sq ft		20,200 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$31,395		$63,034		$327,450	
	Promotion & Admin Costs	$2,240		$2,240		$2,240	
	Total Project Cost	$33,635		$65,274		$329,690	
	Annual O&M	$1,155		$2,327		$8,080	
	O&M Present Worth	$22,638		$45,605		$158,368	
	Term Cost/1,000lb-TSS/yr	$1,196		$1,856		$6,887	
	Term Cost/lb-TP/yr	**$948**		**$1,452**		**$5,297**	

Complex Bioretention – Assumes engineered soils, curb cuts, forebays, and partial retaining wall

Parking Lot Biofiltration – Because stormwater runoff infiltration from commercial sites is not recommended within a DWSMA, modifications can be made to the bioretention practices outlined above to prevent infiltration while still providing water quality improvement. Lining the bioretention cells with an impervious layer and adding an underdrain connected to the existing stormwater sewer system will effectively convert the bioretention cells to biofiltration and eliminate infiltration. The addition of iron-enhanced sand will further improve the efficacy of the practice and increase the removal of TP to 82% for the volume passing through the system. Pollutant reduction estimates for converting islands with adjacent catch basins to biofiltration (Level 1), converting all islands to biofiltration (Level 2), and converting the long linear islands to biofiltration (Level3) are highlighted in the table below.

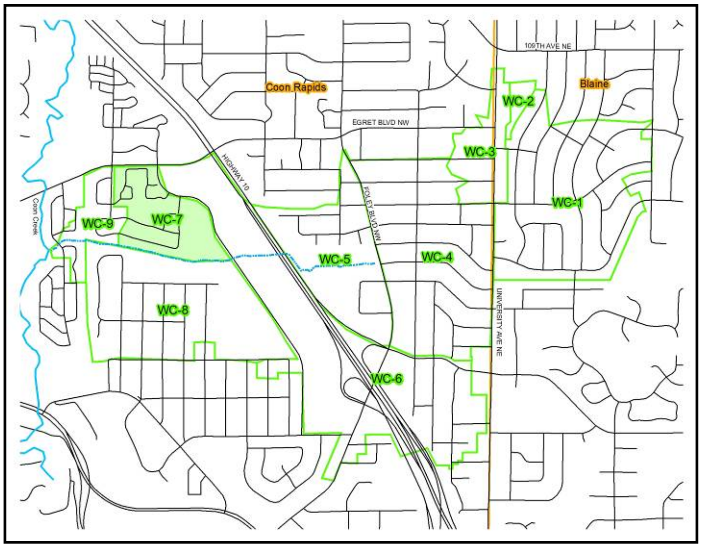
Parking Lot Biofiltration

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	2.0	70%	2.5	71%	3.0	71%
	TSS (lb/yr)	1,522	58%	1,941	59%	2,215	59%
	Volume (acre-feet/yr)	0.0	21%	0.0	21%	0.0	21%
	Number of BMP's	7		14		2	
	BMP Size/Description	1,925 sq ft		3,878 sq ft		20,200 sq ft	
	BMP Type	Highly Complex Bioretention		Highly Complex Bioretention		Highly Complex Bioretention	
Cost	Materials/Labor/Design	$38,518		$77,382		$402,190	
	Promotion & Admin Costs	$2,240		$2,240		$2,240	
	Total Project Cost	$40,758		$79,622		$404,430	
	Annual O&M	$1,155		$2,327		$8,080	
	O&M Present Worth	$22,638		$45,605		$158,368	
	Term Cost/1,000lb-TSS/yr	$1,651		$2,566		$9,733	
	Term Cost/lb-TP/yr	**$1,277**		**$1,959**		**$7,304**	

Highly Complex Bioretention – Assumes engineered soils including iron-enhancement, curb cuts, forebays, partial retaining wall, and underdrains connected to existing storm sewer system.

Catchment 7

Catchment Summary	
Acres	47.6
Dominant Land Cover	Residential
Parcels	195
Volume (acre-feet/yr)	13.5
TP (lb/yr)	15.9
TSS (lb/yr)	7,222



DESCRIPTION

Catchment 7 is located on the north side of Woodcrest Creek west of Woodcrest Drive, and it is bordered by Egret Boulevard on the north. The catchment is comprised of single family homes and a townhome development. Stormwater runoff is captured in catch basins and sent to the creek via swales and pipes.

EXISTING STORMWATER TREATMENT

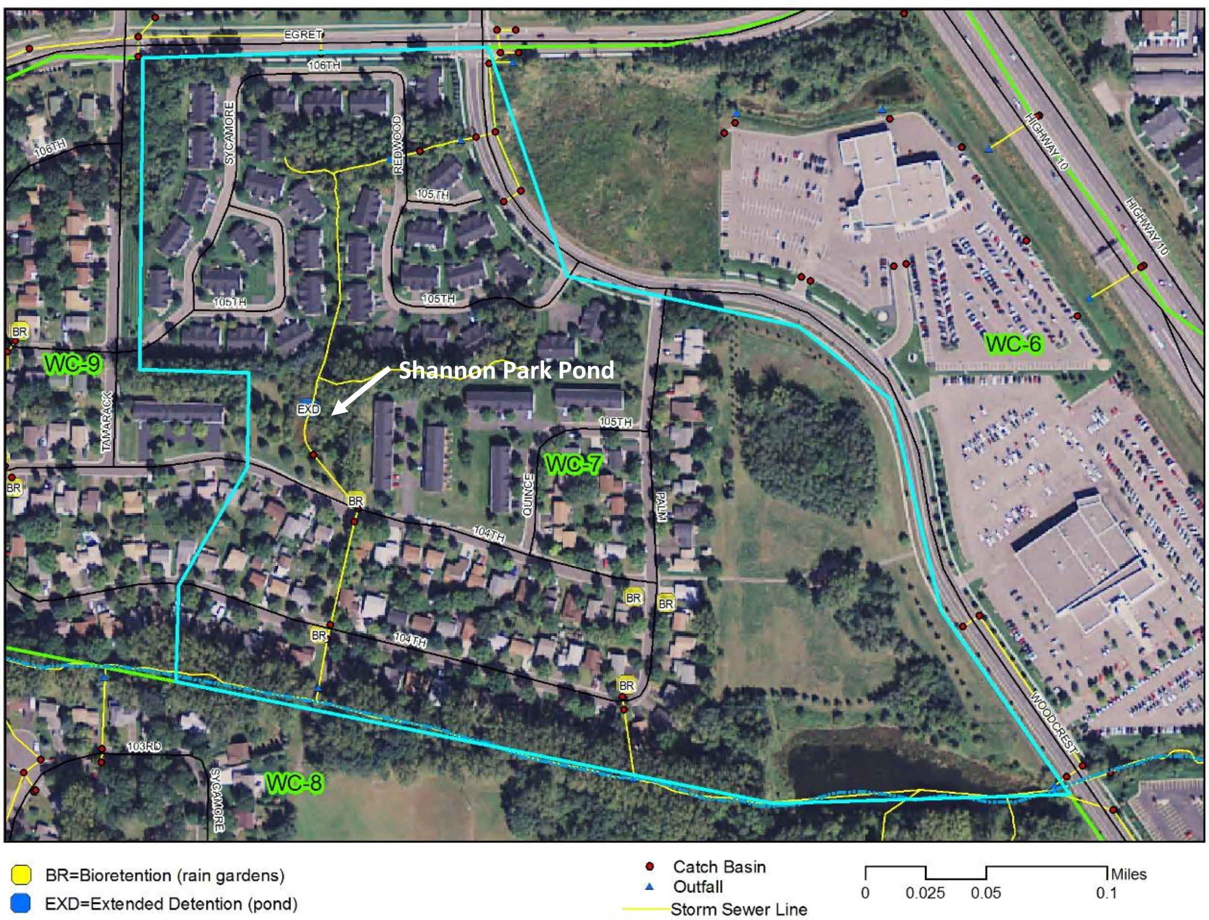
All stormwater upstream of Catchment 7 goes through a large sediment/rate control pond on the east side of the catchment. The pond is currently filled to the outlet elevation with sediment, and the canal gate is left open year round. The large volume of water that goes to this pond during a rain event is more than the canal gate can discharge, so ponding can occur to the elevation of the internal weir within the outlet structure. However, the periodic ponding is likely only providing temporary benefit. Once the pond returns to a lower level, the velocity of the remaining water flow will likely re-suspend any previously deposited sediment. More information on this pond including retrofit options is located in the "in-stream treatment" section of this report.

A second pond within the catchment is located within the townhome development on the north side of the catchment. Stormwater runoff from the townhomes and roads is sent to a swale/ditch that empties into a small retention pond. Currently the pond is full of sediment and is overgrown with cattails. The outlet elevation of the pond is the same as the elevation of the bottom of the pond, resulting in very little potential of ponding and water quality improvement.

The pond along Woodcrest Drive was not included in the modeling for this catchment because the catchment discharges downstream of the pond. The townhome pond was included, but was modeled as a swale. Most stormwater runoff is likely going straight through the pond to the outlet with very little treatment. Street sweeping was included for the catchment. Base loading and existing loading, taking into account existing treatment, are summarized in the table on the following page.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	20.5	4.6	22%	**15.9**
	TSS (lb/yr)	9,242	2,020	22%	**7,222**
	Volume (acre-feet/yr)	15.5	2.0	13%	**13.5**
	Number of BMP's	2			
	BMP Size/Description	Street Sweeping, Townhome Pond (modeled as swale)			

RETROFIT RECOMMENDATIONS



Shannon Park Pond Excavation/Modification – The pond treating the townhome development is not currently functioning as a pond due to the amount of sediment that has collected in the basin. Dredging approximately 1.8 feet out of the pond and raising the outlet elevation by 1.2 feet would provide a substantial increase in pollutant removal over the existing conditions. Cost estimates were prepared to address the three potential management levels based on pollutants found in the pond dredge materials.

Costs also include testing the material for contamination and modifying the pond outlet. The three dredge material management categories are as follows:

Management Level 1 – Dredged material suitable for use or reuse on residential or recreational sites.

Management Level 2 – Dredged material suitable for use or reuse on industrial properties.

Management Level 3 – Dredged material significantly contaminated and must be managed for specific contaminants present.

Shannon Park Pond Excavation/Modification

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	2.0	32%	2.0	32%	2.0	32%
	TSS (lb/yr)	730	30%	730	30%	730	30%
	Volume (acre-feet/yr)	0.0	13%	0.0	13%	0.0	13%
	Number of BMP's	1-Pond excavated 1.8 ft (Level 1 Material)		1-Pond excavated 1.8 ft (Level 2 Material)		1-Pond excavated 1.8 ft (Level 3 material)	
	BMP Size/Description	1,145	cubic yards	1,145	cubic yards	1,145	cubic yards
	BMP Type	Wet Pond		Wet Pond		Wet Pond	
Cost	Materials/Labor/Design	$43,350		$54,800		$66,250	
	Promotion & Admin Costs	$1,680		$1,680		$1,680	
	Total Project Cost	$45,030		$56,480		$67,930	
	Annual O&M	$1,501		$1,883		$2,264	
	O&M Present Worth	$29,420		$36,900		$44,381	
	Term Cost/1,000lb-TSS/yr	$4,112		$5,158		$6,204	
	Term Cost/lb-TP/yr	**$1,501**		**$1,883**		**$2,264**	

Curb-Cut Rain Garden Network – Rain gardens are a good retrofit option for residential areas (see appendix B for design options). Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large area. In this catchment, the single family residential lots are on average 0.14 acres. This makes finding space for rain gardens a challenge. For this reason, we analyzed scenarios where only a small number of gardens would be installed. Based on the number of properties and likelihood of finding properties suited for a garden, we analyzed pollutant removal if two, four, and six rain gardens were installed (levels 1, 2, and 3 in the table below). At these three levels of treatment, catchment-wide removal of TSS and TP could be increased to the levels shown in the table below. The cost per pound of phosphorus removed is lowest if two rain gardens are installed. However, costs for all levels of treatment are relatively low so a higher level of treatment could be pursued if funding allows and willing landowners can be found.

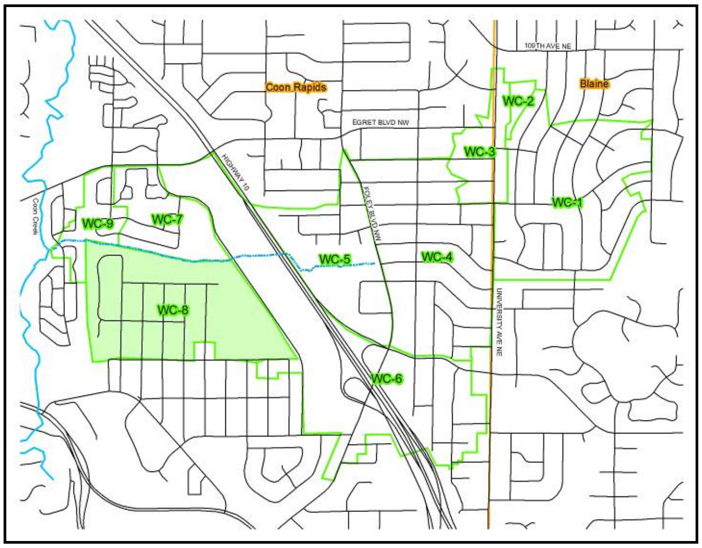
Curb-Cut Rain Garden Network

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	2.7	35%	4.9	46%	6.1	52%
	TSS (lb/yr)	1,238	35%	2,278	47%	2,808	52%
	Volume (acre-feet/yr)	2.2	27%	4.0	39%	5.0	45%
	Number of BMP's	2		4		6	
	BMP Size/Description	500 sq ft		1,000 sq ft		1,500 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$8,310		$16,410		$24,510	
	Promotion & Admin Costs	$1,890		$2,170		$2,450	
	Total Project Cost	$10,200		$18,580		$26,960	
	Annual O&M	$150		$300		$450	
	O&M Present Worth	$2,940		$5,880		$8,820	
	Term Cost/1,000lb-TSS/yr	$396		$404		$480	
	Term Cost/lb-TP/yr	**$181**		**$188**		**$221**	

Complex Bioretention – Assumes engineered soils, curb cuts, forebays, and partial retaining wall

Catchment 8

Catchment Summary	
Acres	126.7
Dominant Land Cover	Residential, Park
Parcels	204
Volume (acre-feet/yr)	35.9
TP (lb/yr)	44.0
TSS (lb/yr)	19,990



DESCRIPTION

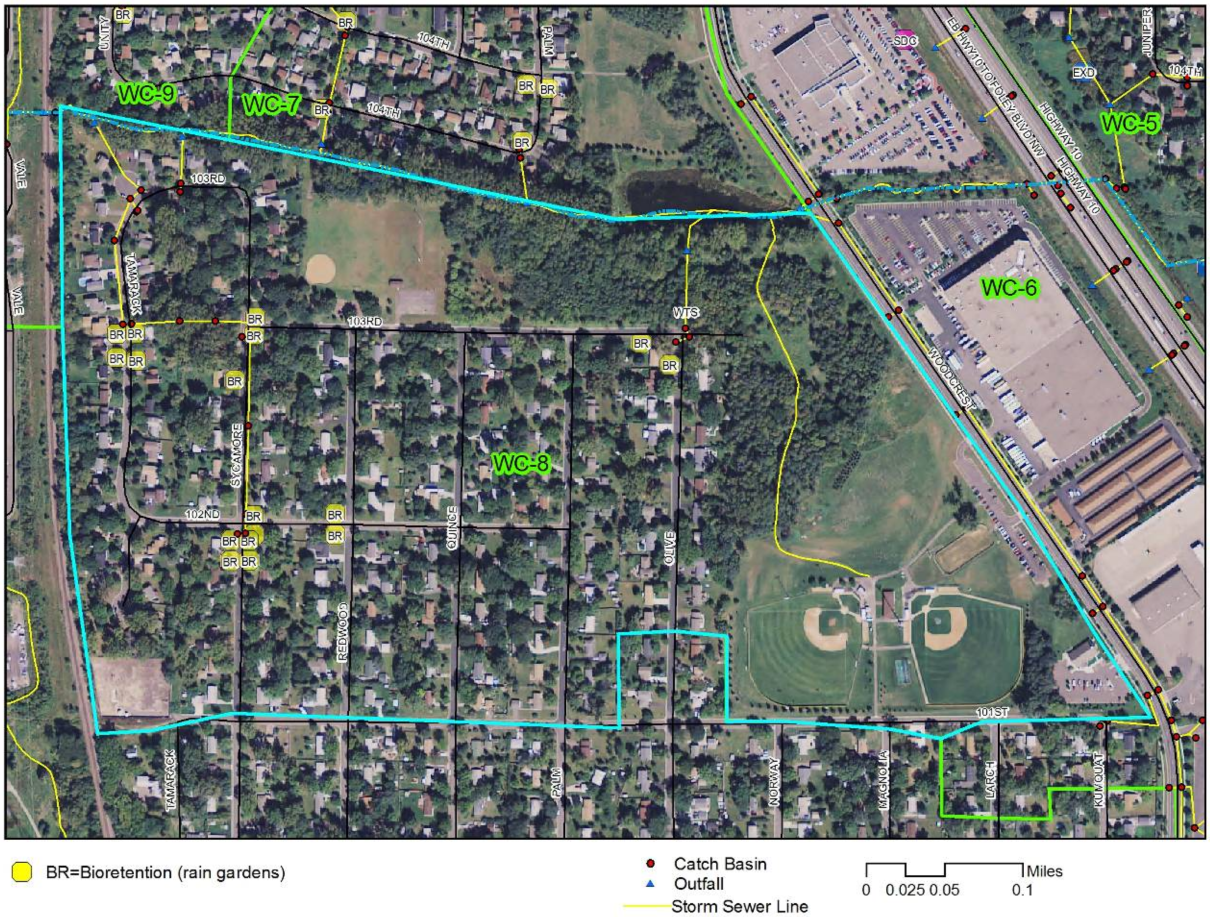
Catchment 8 is located on the south side of Woodcrest Creek and is bordered by Woodcrest Drive to the west and railroad tracks to the east. The catchment is made up of residential single family homes as well as Woodcrest and Wintercrest parks. Stormwater runoff is captured in catch basins and piped to the creek.

EXISTING STORMWATER TREATMENT

There is currently no stormwater treatment in this catchment other than street sweeping. A small portion of the catchment drains to the large rate control/sedimentation pond highlighted in the profile for Catchment 7, but little treatment is achieved by this pond. Base loading and existing loading, taking into account existing street sweeping, is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	46.7	2.7	6%	**44.0**
	TSS (lb/yr)	21,152	1,162	5%	**19,990**
	Volume (acre-feet/yr)	35.9	0.0	0%	**35.9**
	Number of BMP's	1			
	BMP Size/Description	Street Sweeping			

RETROFIT RECOMMENDATIONS



Curb-Cut Rain Garden Network - The residential nature of this catchment makes it best suited to residential, curb-cut rain gardens (see appendix B for design options). Seventeen ideal rain garden locations were identified (see map). Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large area. Considering typical landowner participation rates we analyzed scenarios where six, nine, and twelve rain gardens were installed (levels 1, 2, and 3 in the table below). At these three levels of treatment, catchment-wide removal of TSS and TP could be increased to the levels shown in the table below. The cost per pound of phosphorus removed is lowest if six rain gardens are installed. However, costs for all levels of treatment are relatively low so a higher level of treatment could be pursued if funding allows and willing landowners can be found.

Curb-Cut Rain Garden Network

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	8.3	24%	11.2	30%	13.0	34%
	TSS (lb/yr)	3,833	24%	5,158	30%	5,963	34%
	Volume (acre-feet/yr)	6.6	18%	8.9	25%	10.4	29%
	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	$24,510		$36,660		$48,810	
	Promotion & Admin Costs	$2,450		$2,870		$3,290	
	Total Project Cost	$26,960		$39,530		$52,100	
	Annual O&M	$450		$675		$900	
	O&M Present Worth	$8,820		$13,230		$17,640	
	Term Cost/1,000lb-TSS/yr	$352		$386		$442	
	Term Cost/lb-TP/yr	**$162**		**$178**		**$203**	

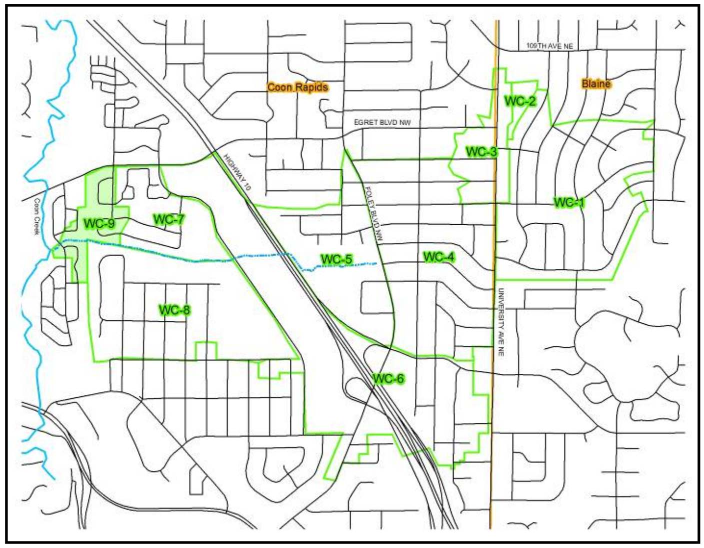
Complex Bioretention – Assumes engineered soils, curb cuts, forebays, and partial retaining wall

Retrofits Considered but Rejected –

New small pond – There is available space in Woodcrest Park on the south side of the existing large retention pond for a new small pond to treat stormwater exiting the outfall in that area. However, the concept was rejected because the pipe and corresponding outfall only capture a small area of residential neighborhood. Similar treatment could be achieved with the installation of a few rain gardens for a much lower cost.

Catchment 9

Catchment Summary	
Acres	27.4
Dominant Land Cover	Residential
Parcels	86
Volume (acre-feet/yr)	11.6
TP (lb/yr)	14.2
TSS (lb/yr)	6,489



DESCRIPTION

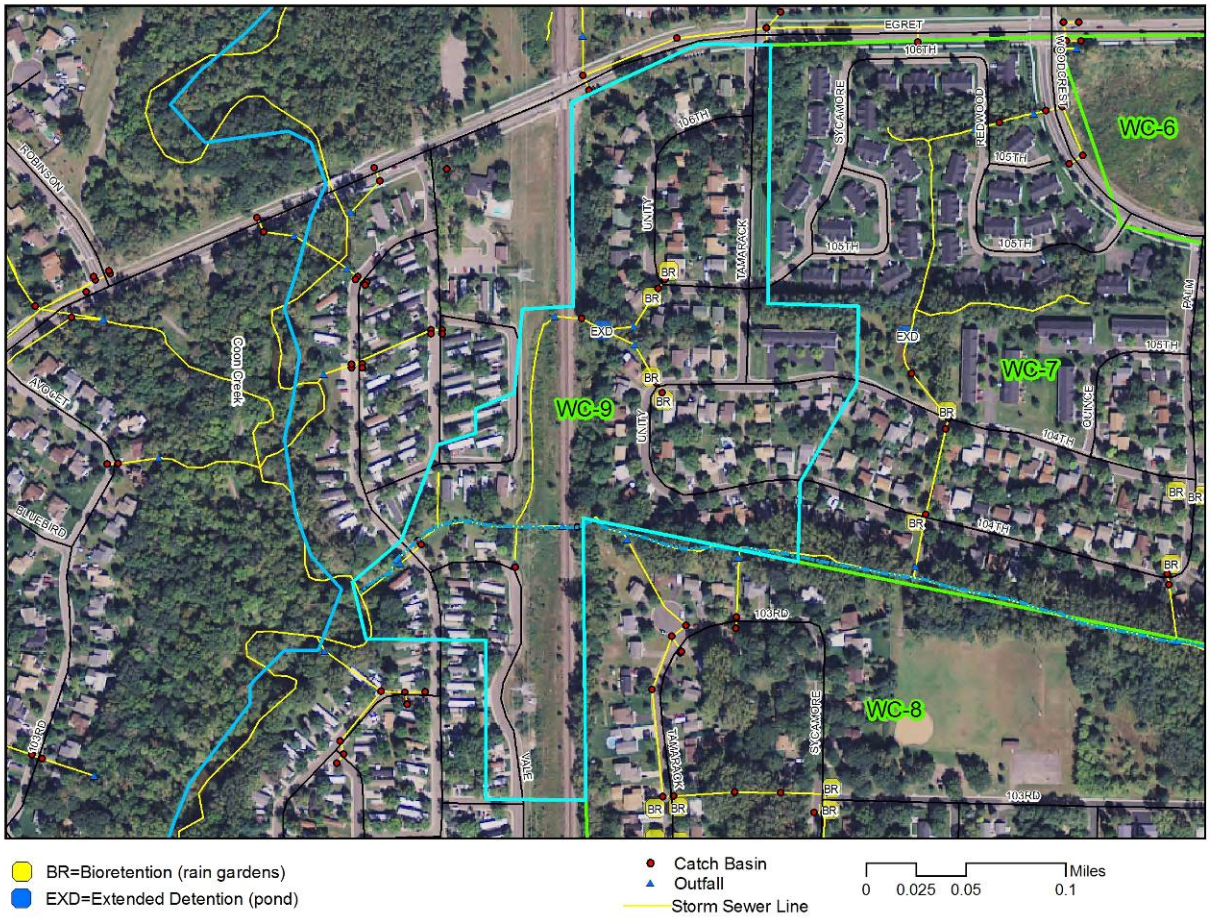
Catchment 9 contains the final stretch of Woodcrest Creek before it's confluence with Coon Creek. It is made up of single family residential development, and a small portion of the Creekside Estates trailer park. Woodcrest Creek enters Catchment 9 under the railroad tracks and goes through the trailer park before connecting with Coon Creek.

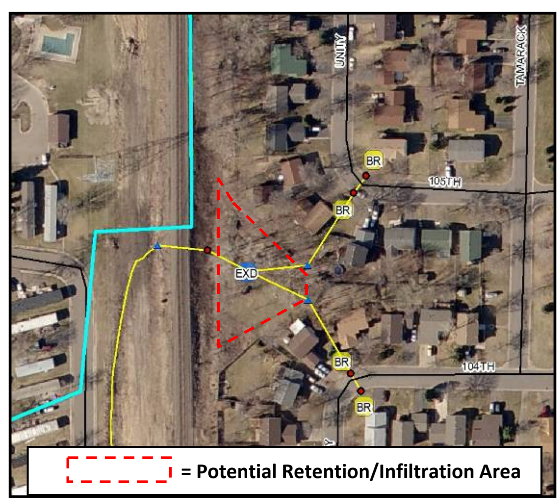
EXISTING STORMWATER TREATMENT

There is currently no stormwater treatment in this catchment other than street sweeping. Base loading and existing loading, taking into account existing street sweeping, is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	15.1	0.9	6%	**14.2**
	TSS (lb/yr)	6,901	412	6%	**6,489**
	Volume (acre-feet/yr)	11.6	0.0	0%	**11.6**
	Number of BMP's	1			
	BMP Size/Description	Street Sweeping			

RETROFIT RECOMMENDATIONS





New Infiltration/Retention - The open area on the west side of the residential development is ideally situated to provide stormwater runoff treatment. The surrounding homes and outfalls from the development are higher in elevation than the culvert that directs the water under the railroad tracks. This scenario provides an opportunity to raise the invert elevation of the culvert to create ponding and promote infiltration. This could simply be achieved by installing a one foot broad crested weir or similar structure in front of the culvert to temporarily restrict water flow. The sandy soils will provide sufficient infiltration, and the temporary ponding will increase sedimentation. Periodic sediment removal will be necessary maintenance. Pollutant reductions for this option are highlighted in Level 1 of the table on the following page.

Curb-Cut Rain Garden Network – Rain gardens were considered as an alternative to the above option for the single family residential area of this catchment (see appendix B for design options). Four ideal rain garden locations were identified (see map), but additional sites might be found up-gradient. Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large area. Considering typical landowner participation rates we analyzed scenarios where three or five rain gardens were installed (levels 2 and 3 in the table below). At these levels of treatment, catchment-wide removal of TSS and TP could be increased to the levels shown in the table below. The cost per pound of phosphorus removed is lowest if three rain gardens are installed.

Retention Area/ Curb-Cut Rain Garden Network

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	7.9	58%	4.4	35%	5.8	44%
	TSS (lb/yr)	3,594	58%	2,048	36%	2,701	45%
	Volume (acre-feet/yr)	6.7	58%	3.5	30%	4.6	40%
	Number of BMP's	1		3		5	
	BMP Size/Description	Outlet under RR raised 1 ft		1,500 sq ft		2,250 sq ft	
	BMP Type	Simple Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$3,500		$24,510		$36,660	
	Promotion & Admin Costs	$1,120		$2,030		$2,310	
	Total Project Cost	$4,620		$26,540		$38,970	
	Annual O&M	$710		$225		$375	
	O&M Present Worth	$13,916		$4,410		$7,350	
	Term Cost/1,000lb-TSS/yr	$240		$542		$620	
	Term Cost/lb-TP/yr	**$109**		**$252**		**$289**	

Simple Bioretention – No engineered soils
Complex Bioretention – Assumes engineered soils, curb cuts, forebays, and partial retaining wall

In-Stream Treatment

PROJECTS

Four potential water quality improvement projects were identified within the Woodcrest Creek channel. One project was completed in 2010. These projects were not included in a specific catchment profile because they provide treatment to multiple catchments, or their benefit cannot be attributed to a specific catchment. The four in-stream treatment projects identified are:

1. Woodcrest Drive Pond Modification
2. New Stormwater Pond East of Highway 10
3. Upper Woodcrest Creek Stabilization (completed in 2010)
4. Lower Woodcrest Creek Stabilization

1. WOODCREST DRIVE POND MODIFICATION

DESCRIPTION

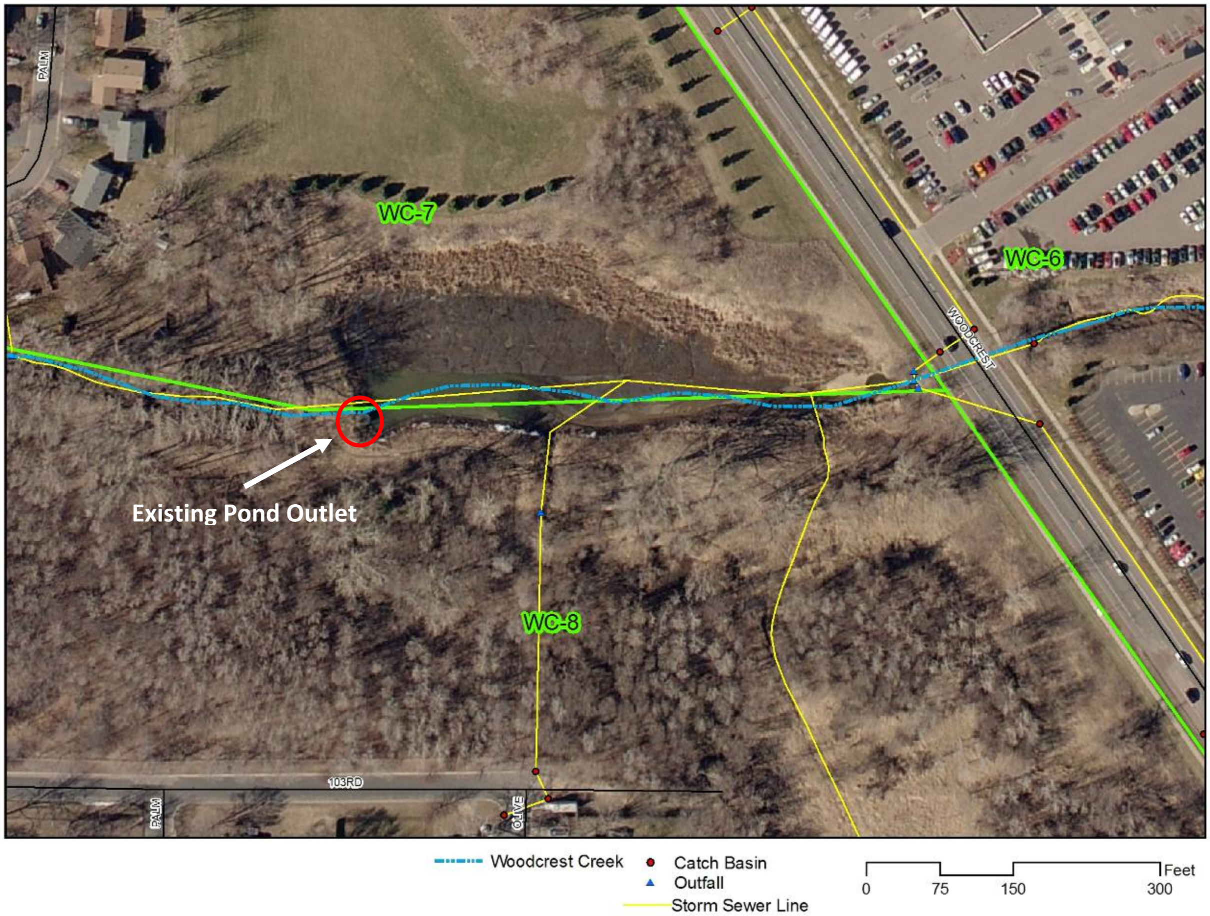
The pond west of Woodcrest Drive acts as a sedimentation/rate control feature serving catchments one to six and a small portion of catchment eight. There are four inlets, one of which is the main Woodcrest channel. The pond elevation is controlled by a weir structure with a small canal gate. The main creek channel continues below the pond outlet, making the pond a flow-through system.

EXISTING STORMWATER TREATMENT

The pond is currently filled with sediment close to the canal gate outlet elevation. The rate of water inflow to this pond during a rain event is more than the canal gate can discharge, so ponding does occur up to the elevation of the internal weir within the outlet structure. However, the periodic ponding is likely only providing temporary benefit. Once the pond returns to a lower level, the velocity of the remaining water flow re-suspends some of the previously deposited sediment. Base loading (excluding stormwater treatment practices) and existing loading, taking into account existing pond performance, is summarized in the table below. CCWD staff observed a crack in the outlet structure that reduces the removal efficiency of the pond. For this report, it was assumed the crack would be fixed as a routine maintenance activity, and the as-designed condition is considered the "existing condition."

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	487.0	166.0	34%	**321.0**
	TSS (lb/yr)	150,771	99,509	66%	**51,262**
	Volume (acre-feet/yr)	0.0	0.0	0%	**0.0**
	Number of BMP's	1			
	BMP Size/Description	Pond West of Woodcrest Drive			

RETROFIT RECOMMENDATIONS



Numerous options were evaluated to increase water quality treatment in the Woodcrest Pond. Options included raising the outlet elevation, excavating to increase the permanent pool depth, excavating to expand the permanent pool area, installing an iron-enhanced filtration bench, and combining these options. The least-costly option is to excavate the pond bottom to an elevation of 855.0 and raise the outlet elevation from 862.3 to 863.3. This results in an annual TP reduction of 11 pounds and an annual TSS reduction of nearly 2,000 pounds. The most costly option is to excavate the pond to a bottom elevation of 852.0 and expand the pond to the northeast. While most costly (assuming Management Level 3 for dredged material disposal), it provides the greatest water quality treatment (31.0 pounds TP/yr, 7,272 pounds TSS/yr) making it the most cost-effective option.

An alternative for any selected option is to add an iron-enhanced filtration bench to the pond. This is a new practice for stormwater treatment and consists of creating a filter media (sand and iron filings) that completely or partially surrounds the pond. Up to a certain rainfall depth, all runoff must pass through the filter media and drain into a perforated pipe that is connected to the pond outlet structure. For larger rainfall events, water overflows into the outlet structure, and the pond operates as it does without the filtration bench.

Woodcrest Drive Pond Modification

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	11.0	36%	15.0	37%	31.0	40%
	TSS (lb/yr)	1,972	67%	2,050	67%	7,272	71%
	Volume (acre-feet/yr)	0.0	0%	0.0	0%	0.0	0%
	Number of BMP's	2		3		3	
	BMP Size/Description	Raise existing pond outlet + excavate to 855		Level 1 + add iron/sand filtration		Level 2 + Expand pond	
	BMP Type	Wet Pond		Wet Pond		Wet Pond	
Cost	Materials/Labor/Design	$68,000		$78,000		$200,000	
	Promotion & Admin Costs	$3,400		$3,900		$10,000	
	Total Project Cost	$71,400		$81,900		$210,000	
	Annual O&M	$2,567		$2,900		$3,133	
	O&M Present Worth	$50,307		$56,840		$61,413	
	Term Cost/1,000lb-TSS/yr	$2,508		$2,746		$1,393	
	Term Cost/lb-TP/yr	**$450**		**$375**		**$327**	

2. NEW POND EAST OF HIGHWAY 10

DESCRIPTION

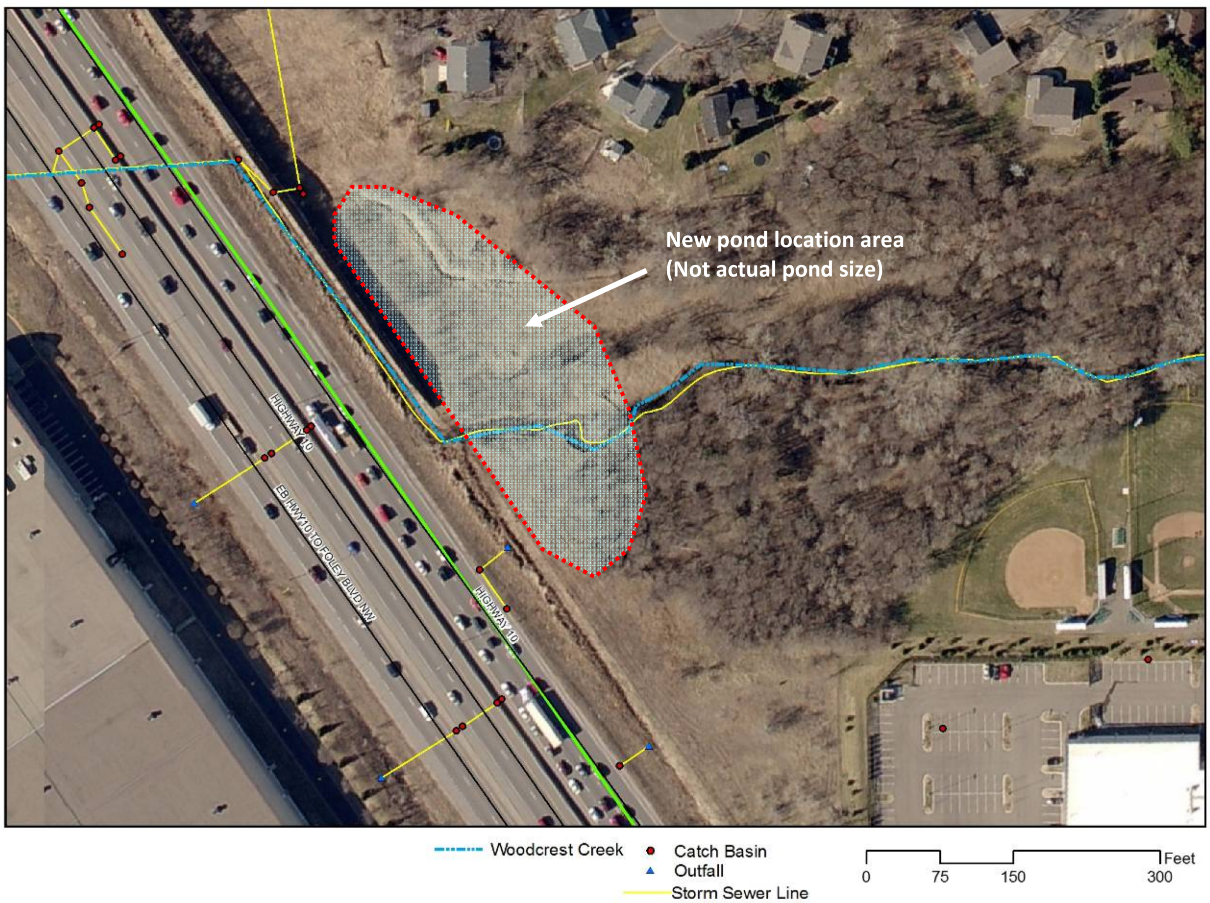
There is a large unused space east of Highway 10 and just downstream of the Woodcrest stabilization project completed in 2010. The property is within a park owned by Coon Rapids, and the area is classified as an M3 (manage 3) wetland by the city (ID# 24-8). This category is reserved for areas that provide the highest functions of water quality protection and flood attenuation. Woodcrest Creek flows through the wetland area before entering the culvert under Highway 10.

EXISTING STORMWATER TREATMENT

Currently there are no stormwater treatment practices at this location. Existing pollutant load estimates are highlighted in the table below. This includes loading from all upstream catchments.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	367.0	0.0	0%	**367.0**
	TSS (lb/yr)	113,854	0	0%	**113,854**
	Volume (acre-feet/yr)	0.0	0.0	0%	**0.0**
	Number of BMP's	0			
	BMP Size/Description	NA			

RETROFIT RECOMMENDATIONS



Open space exists to the east of Highway 10 for a new stormwater retention pond. The site is attractive because it is near the bottom of the watershed, is owned by the city (easier project administration), and it would reduce the demand on the already overwhelmed Woodcrest Drive pond. The new pond would be in-line with Woodcrest Creek since the pond inlet and outlet are direct from/to the creek. Two options were evaluated to provide water quality treatment at this location: a pond with four-foot maximum depth and a pond with ten-foot maximum depth. For both options, the outlet elevation (normal water level) was assumed to be the Highway 10 culvert invert elevation.

New Pond East of Highway 10

	Cost/Benefit Analysis	*Network Treatment By BMP*					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	39.0	11%	64.0	17%		
	TSS (lb/yr)	12,345	11%	19,478	17%		
	Volume (acre-feet/yr)	0.0	0%	0.0	0%		
	Number of BMP's	1		1			
	BMP Size/Description	New Pond (87,120 cubic foot perm pool)		New Pond (115,000 cubic foot perm pool)			
	BMP Type	Wet Pond		Wet Pond			
Cost	Materials/Labor/Design	$100,000		$130,000			
	Promotion & Admin Costs	$5,000		$6,500			
	Total Project Cost	$105,000		$136,500			
	Annual O&M	$800		$800			
	O&M Present Worth	$15,680		$15,680			
	Term Cost/1,000lb-TSS/yr	$348		$275			
	Term Cost/lb-TP/yr	**$110**		**$84**			

3. UPPER WOODCREST CREEK STABILIZATION (COMPLETED IN 2010)

DESCRIPTION

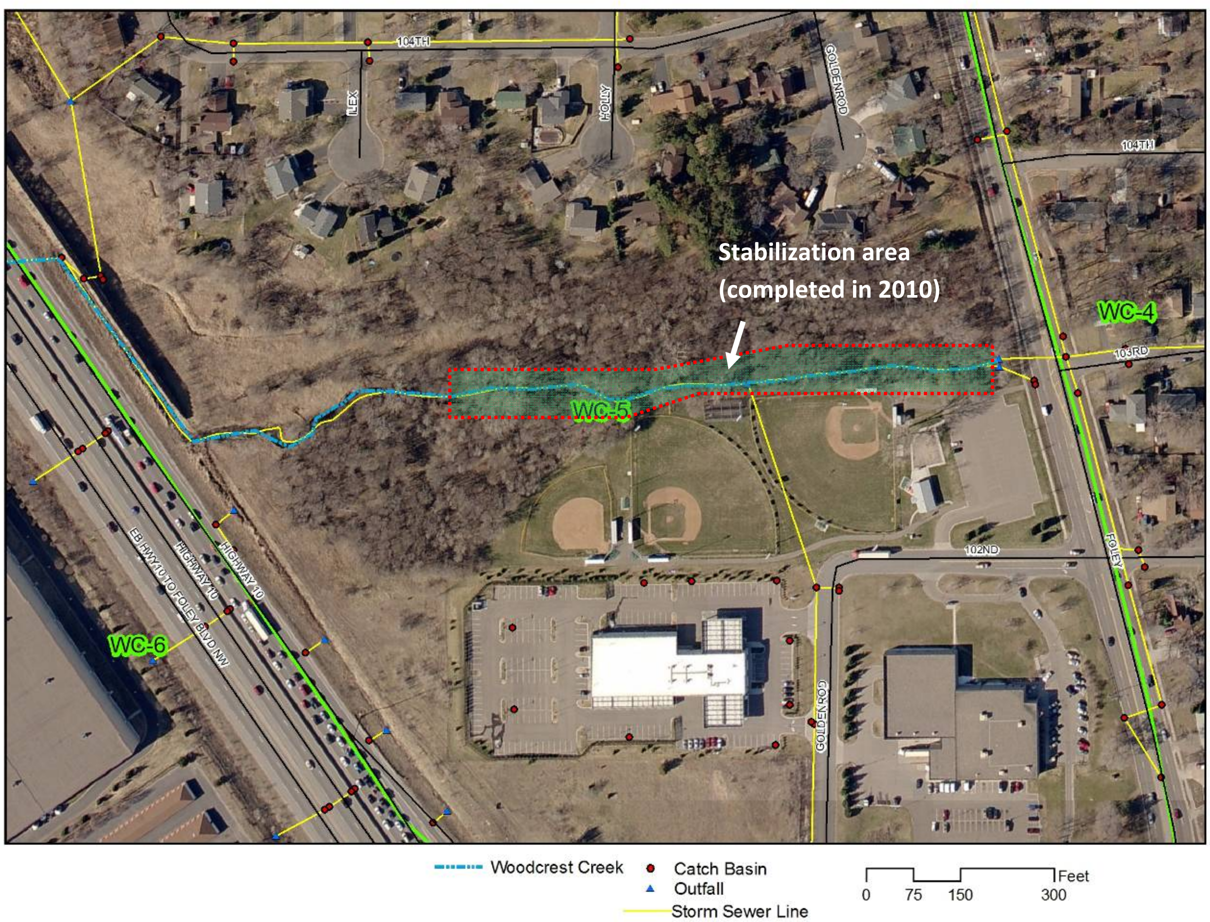
The portion of Woodcrest Creek from Foley Boulevard to Highway 10 had been experiencing significant erosion due to high volumes of stormwater flow and a lack of stabilizing vegetation. The erosion resulted in sediment being transported downstream, and caused safety concerns because this portion of the creek is bordered by the Little League baseball fields.

EXISTING STORMWATER TREATMENT

Prior to correction, there were no stormwater treatment practices at this location. Pre-construction pollutant load estimates are highlighted in the table below. The estimates only reflect what was generated in this section of the creek due to erosion.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	5.0	0.0	0%	**5.0**
	TSS (lb/yr)	459,000	0	0%	**459,000**
	Volume (acre-feet/yr)	0.0	0.0	0%	**0.0**
	Number of BMP's	0			
	BMP Size/Description	NA			

RETROFIT RECOMMENDATIONS



Stream flows in this section of the creek range from 0 to 535 cfs (100-year) with resultant velocities up to 4 fps. The channel banks were being undercut as a result, leading to slope instability, safety concerns on adjacent properties, and significant sediment loading to Coon Creek.

Alternatives considered in the feasibility study included piping, hard armoring of the entire channel, and soil bioengineering. Constructed in the fall of 2010, the City of Coon Rapids and CCWD opted for the soil bioengineering alternative. The soil bioengineering approach thinned shade trees, removed exotic species, and installed vegetated riprap and rock grade control structures throughout the channel reach.

Upper Woodcrest Creek Stabilization

	Cost/Benefit Analysis	*Network Treatment By BMP*					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	4.8	95%				
	TSS (lb/yr)	436,050	95%				
	Volume (acre-feet/yr)	0.0	0%				
	Number of BMP's	1					
	BMP Size/Description	900 Linear Feet					
	BMP Type	Channel Stabilization					
Cost	Materials/Labor/Design	$150,000					
	Promotion & Admin Costs	$7,500					
	Total Project Cost	$157,500					
	Annual O&M	$800					
	O&M Present Worth	$15,680					
	Term Cost/1,000lb-TSS/yr	$14					
	Term Cost/lb-TP/yr	**$1,274**					

4. LOWER WOODCREST CREEK STABILIZATION

DESCRIPTION

The portion of Woodcrest Creek from the Woodcrest Drive Pond west to the railroad tracks is experiencing significant erosion due to high volumes of stormwater flow and a lack of stabilizing vegetation. The erosion is resulting in high sediment loads transported downstream. A more detailed assessment of the streambank erosion can be found in Appendix C.

EXISTING STORMWATER TREATMENT

There are no stormwater treatment practices at this location. Pollutant load estimates are highlighted in the table below. The estimates only reflect what is generated in this section of the creek due to erosion of the creek channel.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	6.0	0.0	0%	**6.0**
	TSS (lb/yr)	567,000	0	0%	**567,000**
	Volume (acre-feet/yr)	0.0	0.0	0%	**0.0**
	Number of BMP's	0			
	BMP Size/Description	NA			

RETROFIT RECOMMENDATIONS

Stream flows in the lower section of the creek range from 0 to 1,000 cfs (100-year) with resultant velocities up to 25 fps. The channel banks have been undercut as a result, leading to slope instability, safety concerns on the part of adjacent property owners, and a significant source of sediment to Coon Creek.

Alternatives to stabilize the channel include piping, hard armoring of the entire channel, and soil bioengineering. The CCWD expects to work with the City of Coon Rapids and residents to develop a stabilization plan similar to that designed and constructed for the Upper Woodcrest Creek channel that includes tree thinning, removing noxious vegetation, installing a stable channel toe and establishing deep rooted vegetation on the banks.

Hard armoring of the channel and grade controls could be installed during the winter months. Plantings would be installed immediately in the spring in order to minimize turf reconstruction and limit the exposure of the channel to erosion and bank failure.

Lower Woodcrest Creek Stabilization

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	5.7	95%				
	TSS (lb/yr)	538,650	95%				
	Volume (acre-feet/yr)	0.0	0%				
	Number of BMP's	1					
	BMP Size/Description	1,500 Linear Feet					
	BMP Type	Channel Stabilization					
Cost	Materials/Labor/Design	$200,000					
	Promotion & Admin Costs	$10,000					
	Total Project Cost	$210,000					
	Annual O&M	$800					
	O&M Present Worth	$15,680					
	Term Cost/1,000lb-TSS/yr	$14					
	Term Cost/lb-TP/yr	**$1,368**					

Special Considerations

The Woodcrest Drive pond and new pond east of Highway 10 are in-line with the Woodcrest Creek channel and provide water quality treatment to multiple catchments. This means that BMPs installed in catchments up-gradient could improve the performance of the in-line ponds by reducing the volume or pollutant load that reaches them. It is not practical to assess the impact of each individual BMP on the in-line ponds for the purpose of this study. However, several general scenarios were developed to demonstrate how the benefits of installing BMPs within catchments will also improve the performance of the in-line ponds.

Five scenarios were analyzed to illustrate how different levels of catchment BMP installation affect the overall pollutant load in Woodcrest Creek. The following tables show pollutants produced at a variety of locations throughout the subwatershed. The pollutant load is separated by that which is produced by runoff within catchments and erosion within the creek channel. Pollutant removal is listed in tables to show where reductions can be achieved. The remaining pollutant load, taking into account upstream contributions as well as treatment, is listed for the outlet of several locations. For scenarios where BMPs are implemented, estimated total project cost and cost/lb TP/yr (30-year term) are included.

The first table shows the conditions in 2010 prior to the stabilization of upper Woodcrest Creek. These are the baseline conditions used as a comparison for other scenarios. In this situation, erosion of the upper (WC-5) and lower (WC-8) creek channels are contributing the majority of TSS loading in the subwatershed. The only existing BMP is the Woodcrest Drive pond (WC Pond), which is overwhelmed.

SUMMER 2010 - NO BMPS INSTALLED

	TSS (lb/yr)				TP (lb/yr)			
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet
WC1	39,044				126			
University				39,044				126
WC3	14,431				46			
WC4	37,511				121			
Foley				90,986				293
WC5	22,868	459,000			74	5		
Hwy 10				572,854				372
WC6	78,745				253			
WC Pond			123,597	528,002			198	427
WC7	12,374				40			
WC8	21,587	567,000			70	6		
WC9	7,123				23			
Railroad				1,136,086				565

The next two tables show the benefits achieved by stabilizing upper and lower Woodcrest Creek. Even though TSS is reduced by over 436,000 lbs/yr, the Woodcrest Drive pond is still removing the same amount of sediment as in the base conditions. This illustrates that the overall load is still more than the pond can effectively treat. The lower Woodcrest Creek stabilization project is located downstream of the Woodcrest pond, so it does not affect the pond function. However, it does significantly decrease the overall estimated TSS load at the downstream outlet (Railroad).

SPRING 2011 - AFTER UPPER WOODCREST CREEK CHANNEL STABILIZATION (WC5)

	TSS (lb/yr)				TP (lb/yr)				Estimated Total	$/lb TP
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet		
WC1	39,044				126					
University				39,044				126		
WC3	14,431				46					
WC4	37,511				121					
Foley				90,986				293		
WC5	22,868	22,950			74	0.2			$137,218	$994
Hwy 10				136,804				367		
WC6	78,745				253					
WC Pond			123,597	91,952			198	422		
WC7	12,374				40					
WC8	21,587	567,000			70	6				
WC9	7,123				23					
Railroad				700,036				561		
								TOTAL COST	$137,218	$994

SPRING 2012 - AFTER LOWER WOODCREST CREEK CHANNEL STABILIZATION (WC8)

	TSS (lb/yr)				TP (lb/yr)				Estimated Total	$/lb TP
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet		
WC1	39,044				126					
University				39,044				126		
WC3	14,431				46					
WC4	37,511				121					
Foley				90,986				293		
WC5	22,868	22,950			74	0.2				
Hwy 10				136,804				367		
WC6	78,745				253					
WC Pond			123,597	91,952			198	422		
WC7	12,374				40					
WC8	21,587	28,350			70	0.3			$172,500	$1,009
WC9	7,123				23					
Railroad				161,386				556		
								TOTAL COST	$172,500	$1,009

The final two tables illustrate the reductions achieved by a combination of the two streambank stabilization projects and installing low or high cost BMPs identified in each catchment profile. Low cost removal BMPs are the tier 1 retrofit recommendations ($0-$500/lb-TP/yr) and the high cost removal is if all projects were installed (Tiers 1-3). These scenarios also include modifications to the Woodcrest Drive pond and the creation of a new pond east of Highway 10. The low cost removal options provide a tremendous value for TP reduction at $93/lb and will further reduce TSS loading by over 44,000 lbs/yr. The combination of the streambank stabilization, new pond east of Highway 10, and BMPs installed within the catchments significantly reduces the TSS load to the Woodcrest Drive Pond to the point where it is operating at or below capacity. The high cost removal options further reduce TSS and TP loading, but are less cost effective at $315/lb. At a cost of over a million dollars more than the low cost removal scenario, the high cost removal scenario is not a reasonable goal to pursue.

ULTIMATE CONDITION - LOW COST REMOVAL

	TSS				TP				Estimated Total	$/lb TP
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet		
WC1	39,044		8,548		126		18		$43,720	$120
University				30,496				108		
WC3	14,431				46					
WC4	37,511		7,503		121		16		$43,720	$136
Foley				74,935				258		
WC5	22,868	22,950	4,803		74	0.2	11		$37,390	$456
Hwy 10			62,547	53,403			85	237	$100,000	$85
WC6	78,745				253					
WC Pond			73,395	58,753			152	338	$15,000	$750
WC7	12,374		2,278		40		5		$18,580	$188
WC8	21,587	28,350	5,158		70	0.3	11		$39,530	$178
WC9	7,123		3,594		23		8		$4,620	$109
Railroad				117,157				447		
								TOTAL COST	$302,560	$93

ULTIMATE CONDITION - HIGH COST REMOVAL

	TSS				TP				Estimated Total	$/lb TP
Location	Runoff	Channel	Removal	Outlet	Runoff	Channel	Removal	Outlet		
WC1	39,044		10,010		126		21		$58,950	$647
University				29,034				106		
WC3	14,431		1,782		46		3		$66,280	$4,167
WC4	37,511		7,503		121		16		$43,720	$136
Foley				71,691				253		
WC5	22,868	0	5,055		74	0.2	11		$53,190	$3,355
Hwy 10			64,037	25,467			91	225	$125,000	$65
WC6	78,745		7,801		253		11		$783,573	$11,168
WC Pond			79,038	17,373			171	297	$170,000	$210
WC7	12,374		3,008		40		7		$86,510	$2,452
WC8	21,587	28,350	5,158		70	0.3	11		$39,530	$178
WC9	7,123		3,594		23		8		$4,620	$109
Railroad				75,047				404		
								TOTAL COST	$1,431,373	$315

Retrofit Ranking

The table below summarizes the assessment results. Stormwater retrofit projects are grouped into tiers from most cost effective to least, using cost per pound of phosphorus removed. 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 ranges are dependent upon optimal siting and sizing. More detail about each project can be found in the catchment profile pages of this report.

Summary of stormwater retrofit opportunities ranked by cost-effectiveness

Tier 1 Retrofit Recommendations ($0-$500/lb TP/yr)

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)
In-Stream	New Pond	1	39.0 - 64.0	12,345 - 19,478	0.0	$105,000 - $136,500	$275 - $348	$84 - $110
WC-9*	Infiltration/Retention	1	7.9	3,594	6.7	$4,620	$240	$109
WC-1	Residential Rain Gardens	10 - 18	18.4 - 24.5	8,548 - 11,341	14.5 - 19.1	$43,720 - $77,240	$258 - $346	$120 - $160
WC-4	Residential Rain Gardens	10 - 18	16.2 - 24.1	7,503 - 11,137	12.6 - 18.8	$43,720 - $77,240	$294 - $352	$136 - $163
WC-8	Residential Rain Gardens	6 - 12	8.3 - 13.0	3,833 - 5,963	6.6 - 10.4	$26,960 - $52,100	$352 - $442	$162 - $203
WC-5	Pond Modification	1	9.4	3,821	0.0	$24,320 - $35,490	$423 - $619	$172 - $252
WC-7	Residential Rain Gardens	4 - 6	4.9 - 6.1	2,278 - 2,808	4.0 - 5.0	$18,580 - $26,960	$396 - $480	$188 - $221
WC-5	Stormwater Disconnects	4	1.3	982	2.3	$1,900	$278	$204
WC-9*	Residential Rain Gardens	3 - 5	4.4 - 5.8	2,048 - 2,701	3.5 - 4.6	$26,540 - $38,970	$542 - $620	$252 - $289
In-Stream	Pond Modification	2 - 3	11.0 - 31.0	1,972 - 7,272	0.0	$71,400 - $210,000	$1,393 - $2,746	$327 - $450

Tier 2 Retrofit Recommendations ($501-$1,500/lb TP/yr)

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)
WC-1	Apt. Rain Garden	1 - 2	2.1 - 2.9	1,462 - 1,974	2.1 - 5.2	$15,230 - $29,130	$758 - $1,100	$527 - $759
WC-3	Apt./Office Rain Gardens	2	2.3	1,078	2.3	$22,180	$1,521	$701
WC-6*	Bioretention	2 - 14	2.4 - 3.6	1,903 - 2,769	4.0 - 5.8	$33,635 - $329,690	$1,196 - $6,887	$948 - $5,297
WC-6*	Biofiltration	2 - 14	2.0 - 3.0	1,522 - 2,215	0.0	$40,758 - $404,430	$1,277 - $7,304	$1,277 - $7,304
In-Stream	Channel Stabilization	1	5.7	538,650	0.0	$210,000	$14	$1,368

Tier 3 Retrofit Recommendations (>$1,500/lb TP/yr)

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)
WC-7	Pond Modification	1	2.0	730	0.0	$45,030 - $67,930	$4,112 - $6,204	$1,501 - $2,264
WC-5	Sand Filter	1	0.4	252	0.0	$15,800	$4,947	$2,899
WC-6*	Sand Filter	1	2.4	1,607	0.0	$97,680	$5,013	$3,315
WC-3	Sand Filter	1	0.5 - 1.5	350 - 1,054	0.0	$22,280 - $65,680	$5,105 - $5,060	$3,463 - $3,503
WC-6*	Permeable Asphalt	1	3.8	2,769	5.8	$611,520	$7,723	$5,628

*Pollution reduction benefits and costs cannot be summed with other projects in the same catchment because they are alternative options for treating the

(Yellow highlight) Project concept that can be applied to commercial properties in other catchments.

References

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

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

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

Appendix A – Retrofit Concept Designs

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

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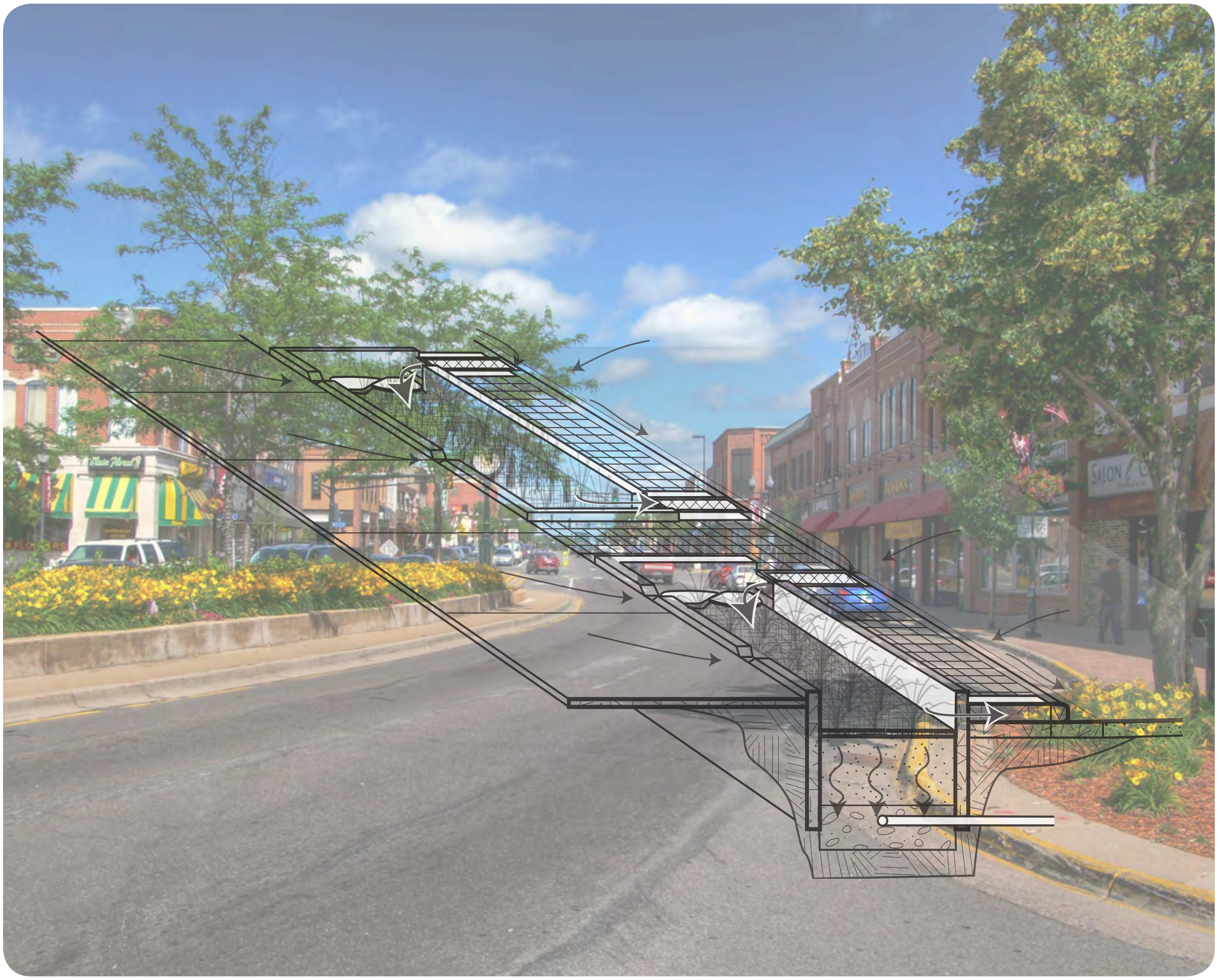
Urban Stormwater Best Management Practices

Retrofit Concepts



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.

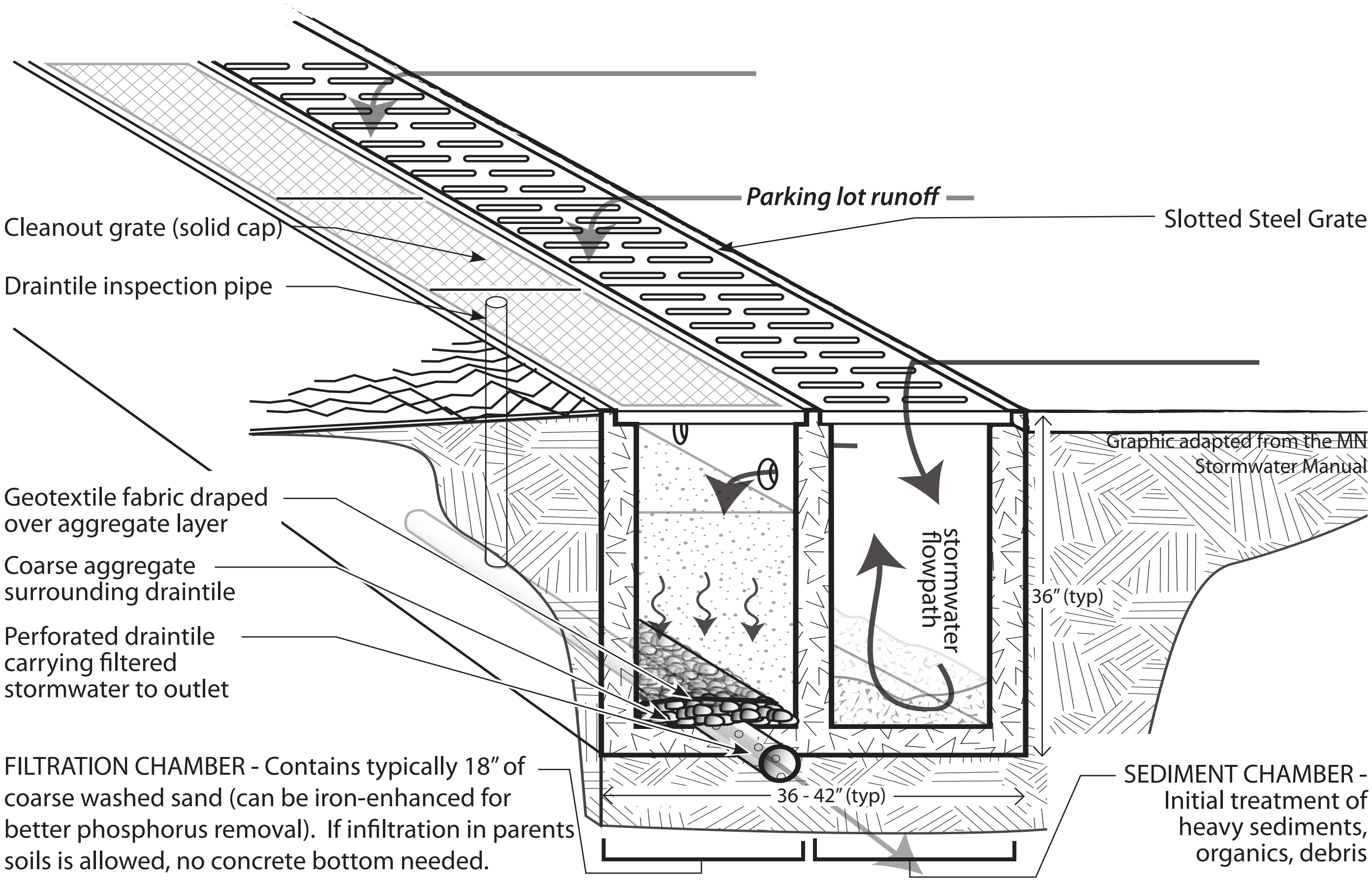

Sand filter inspection, Iowa Stormwater Partnership

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:

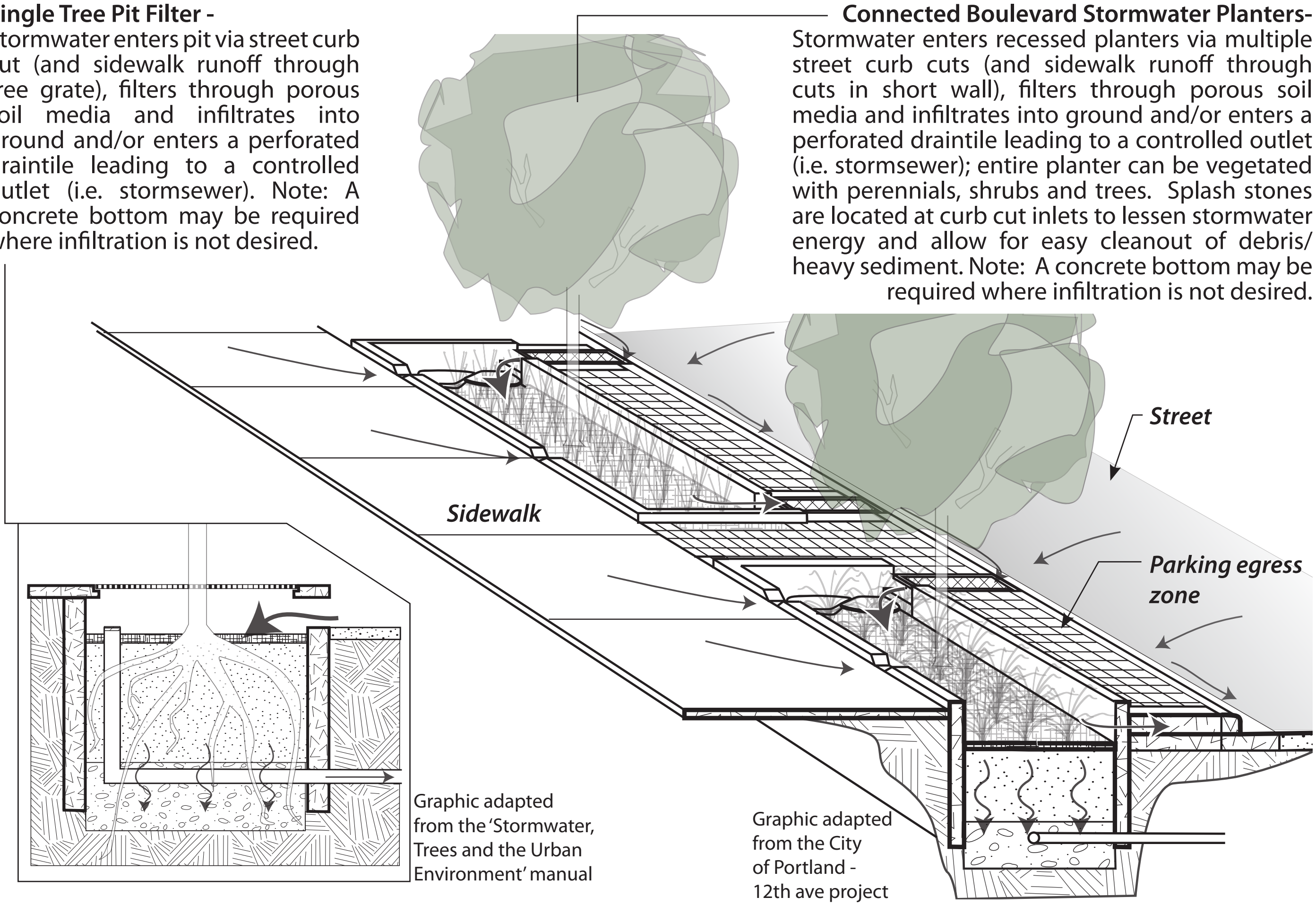
- Optimum ratio at highy impervious sites is one 6' x 6' tree pit per .25 acres

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:

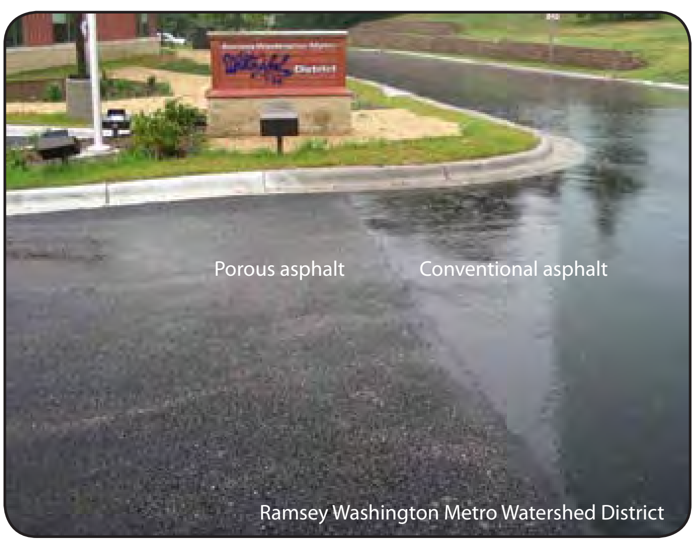
- Typically 3:1 (drainage area to porous pavement area) or less

COST:

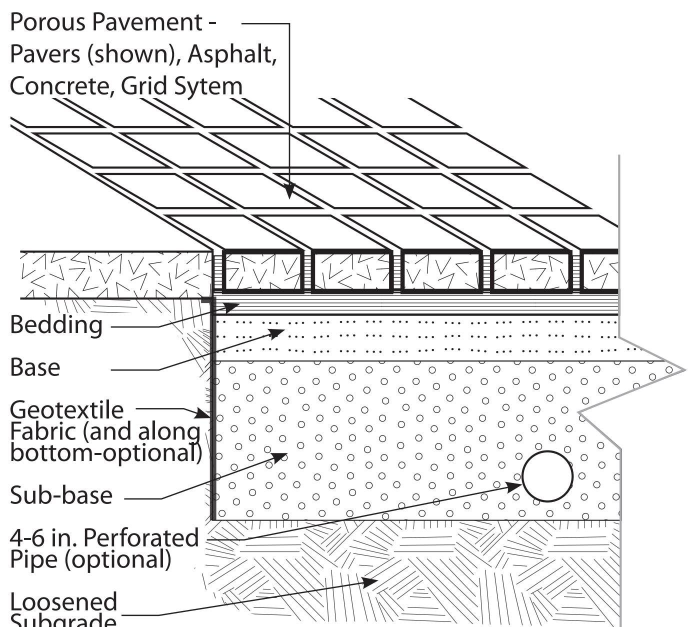
- Approximately $14 - $35 per cu ft storage depending on underlayment

Permeable pavement in parking aisle, City of Portland

Permeable pavers, Minneapolis



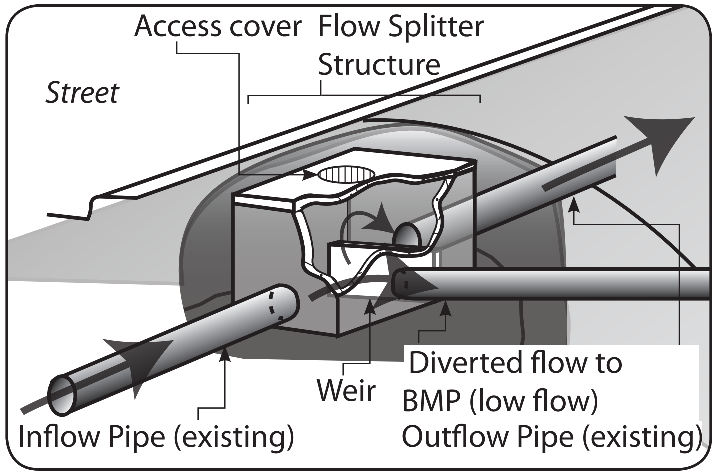
Ramsey Washington Metro Watershed District



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

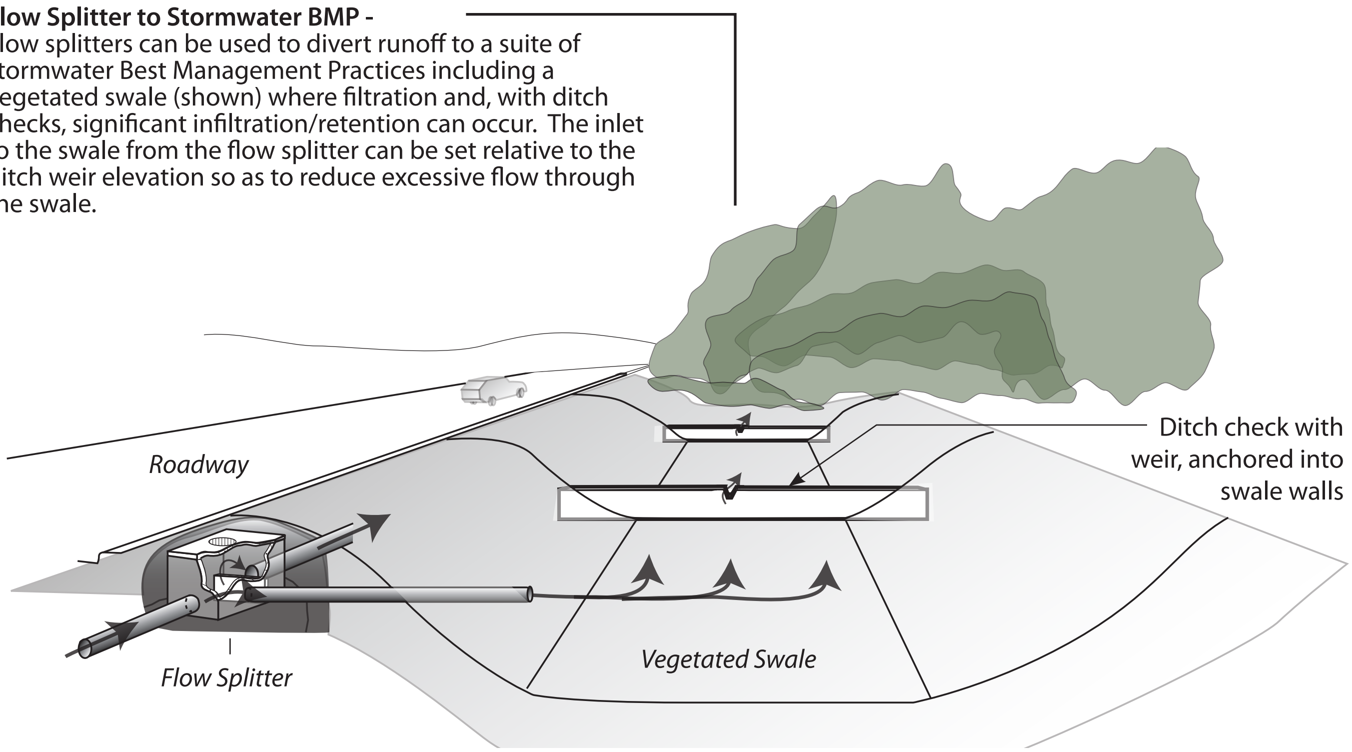
RECOMMENDED DRAINAGE AREA:
- Varies, pipe sizing can be scaled according to drainage area and capacity of Stormwater BMP that flow is diverted to

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

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:

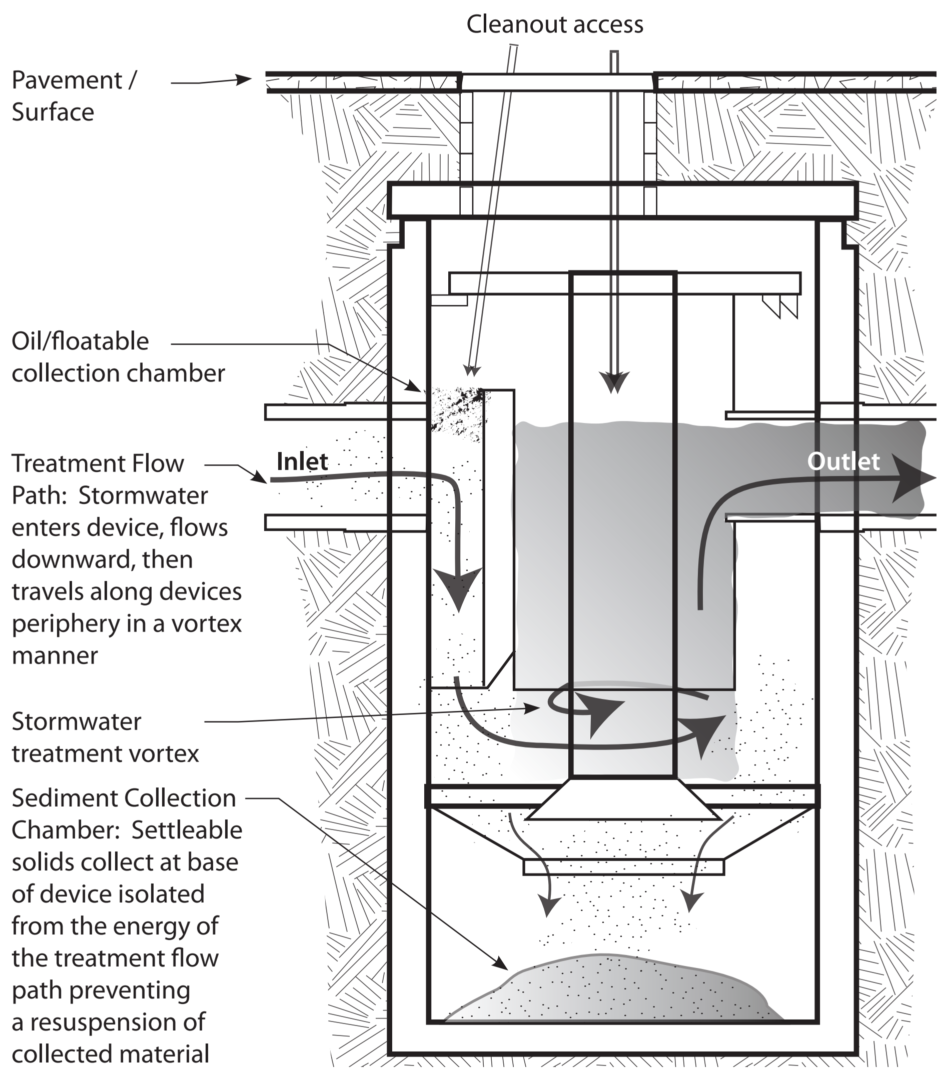
- A minimum annual vacuum removal of captured pollutants; however, required inspections every 6 months for the first year observing sedimentation and oil accumulation rates may determine more frequent visits are necessary
- High initial installation costs

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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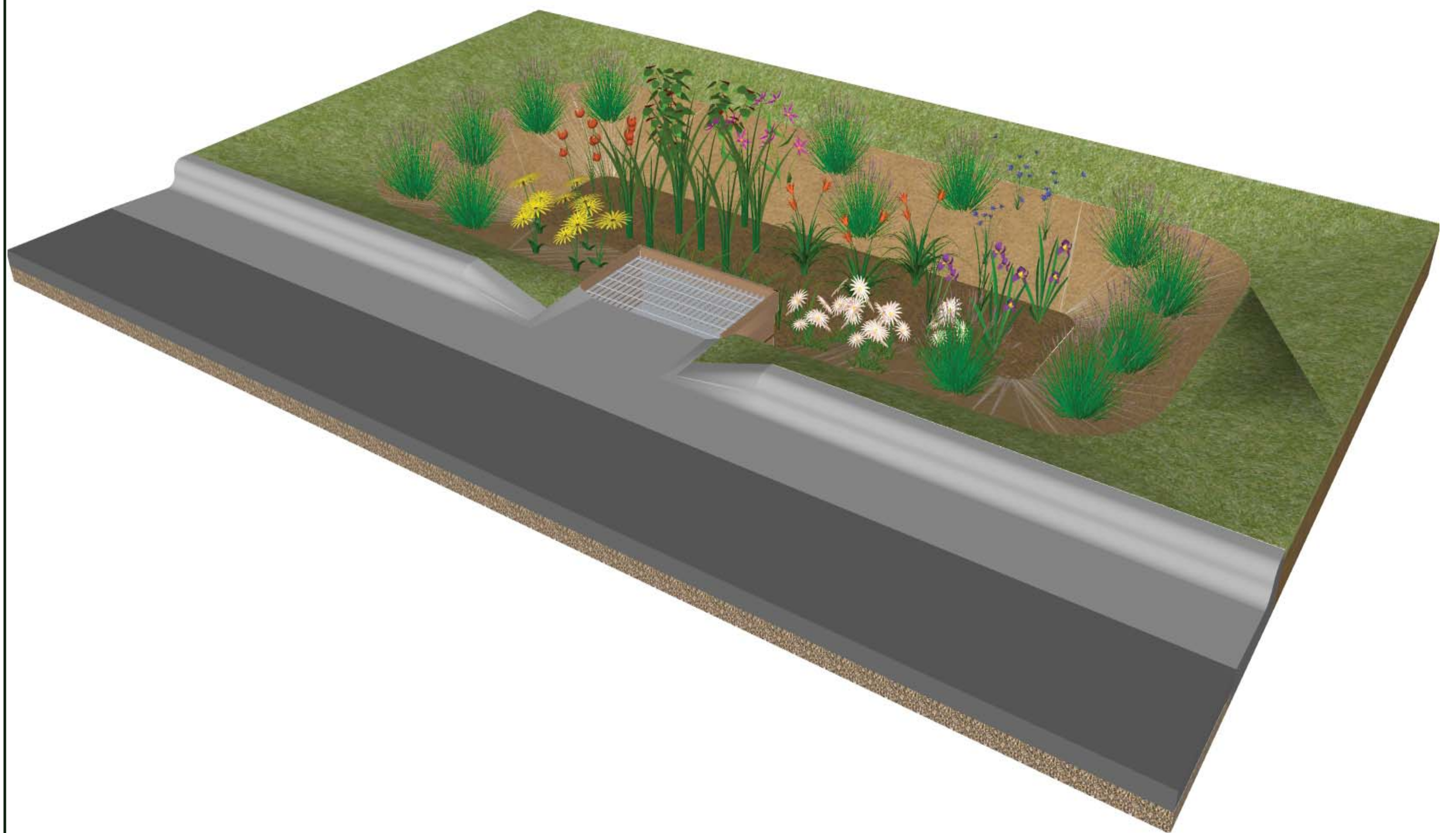
ANOKA COUNTY CURB-CUT RAINGARDENS



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.

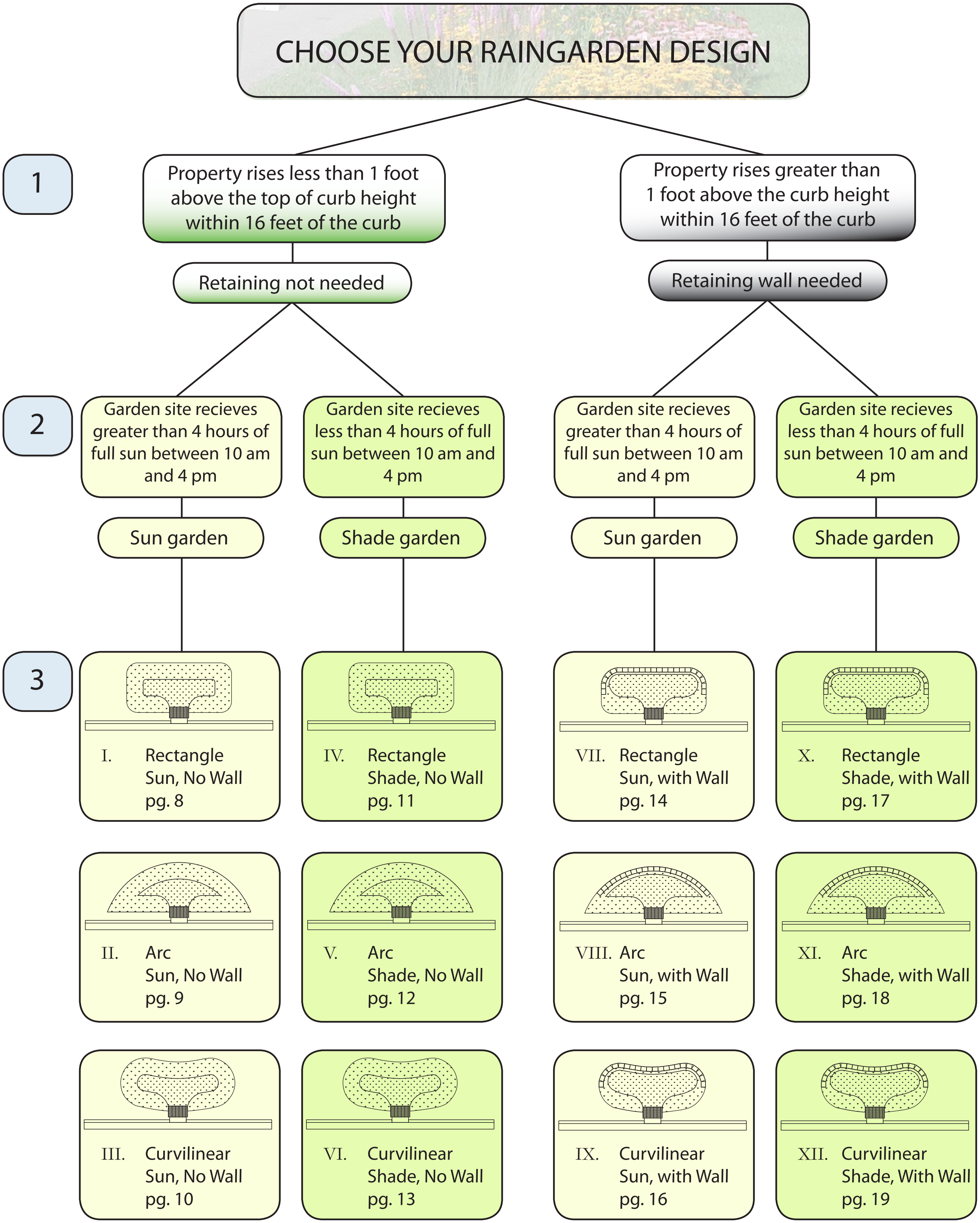
evapotranspiration: The transfer of liquid water from the earth's surface to atmospheric water vapor as result of transpiration by plants and evaporation by solar energy and diffusion. Evapotranspiration can constitute a significant water "loss" from a watershed.

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.

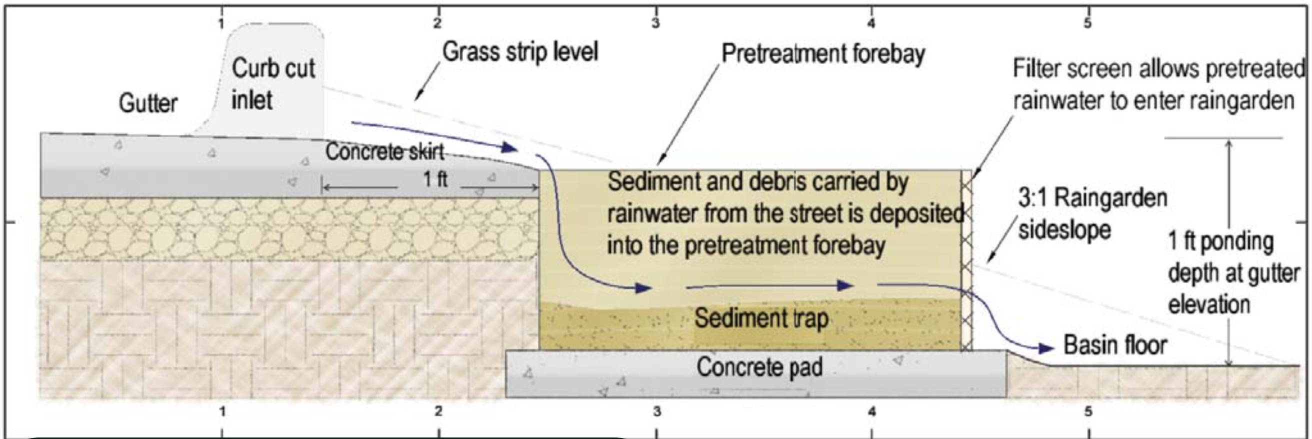
non-point source pollution: Rainwater runoff that has accumulated pollutant loads (nutrients, sediments, petrochemicals etc.) over a large dispersed area. As opposed to point source pollution that has a defined single source.

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.

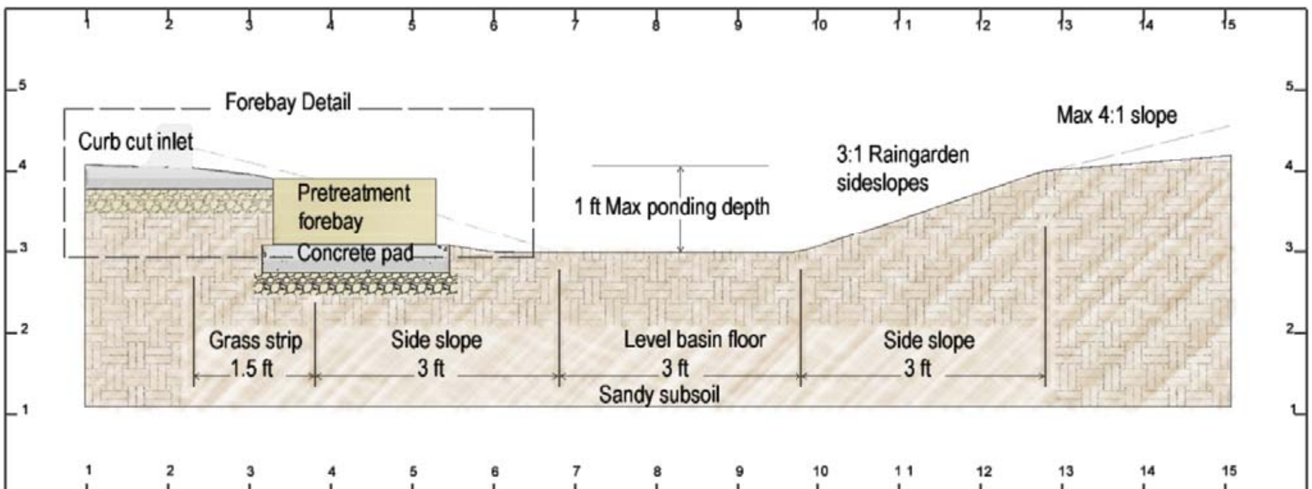
sub-watersheds: A discreet portion of a larger watershed, typically less than 2500 acres. Sub-watersheds can be more effectively analyzed and managed for water quality with site scale treatments.


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
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
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

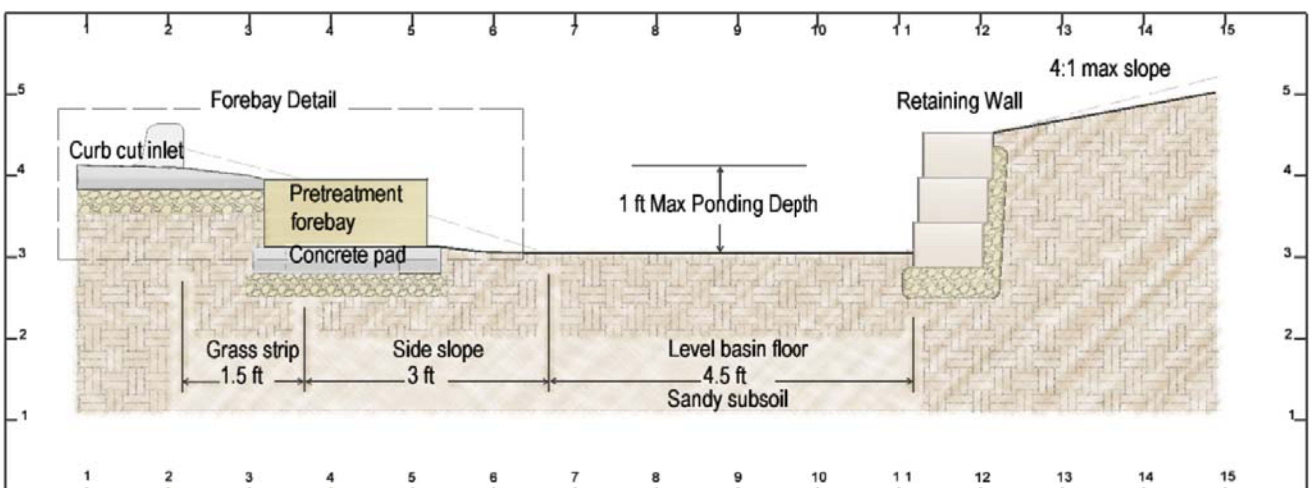
ANATOMY OF A CURB-CUT RAINGARDEN



PRETREATMENT FOREBAY

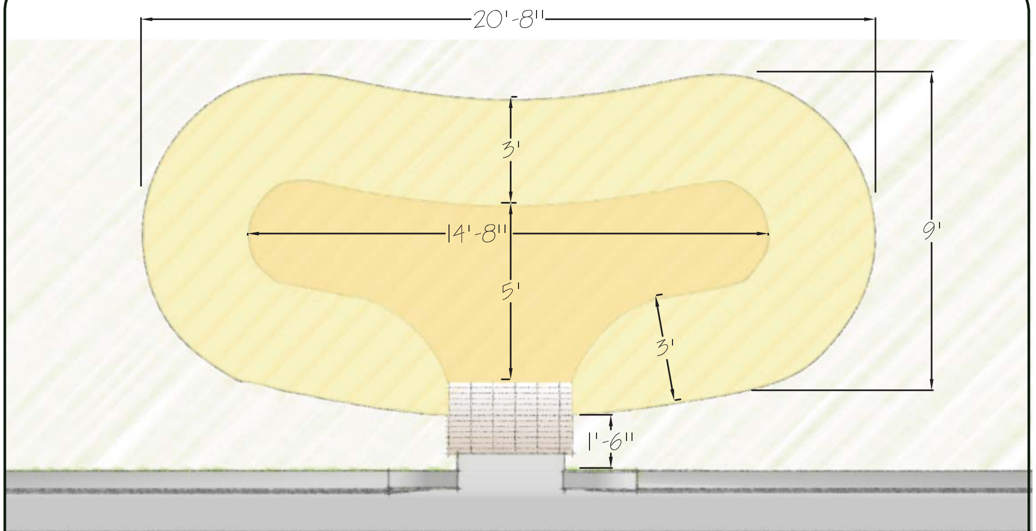


RAINGARDEN WITHOUT RETAINMENT

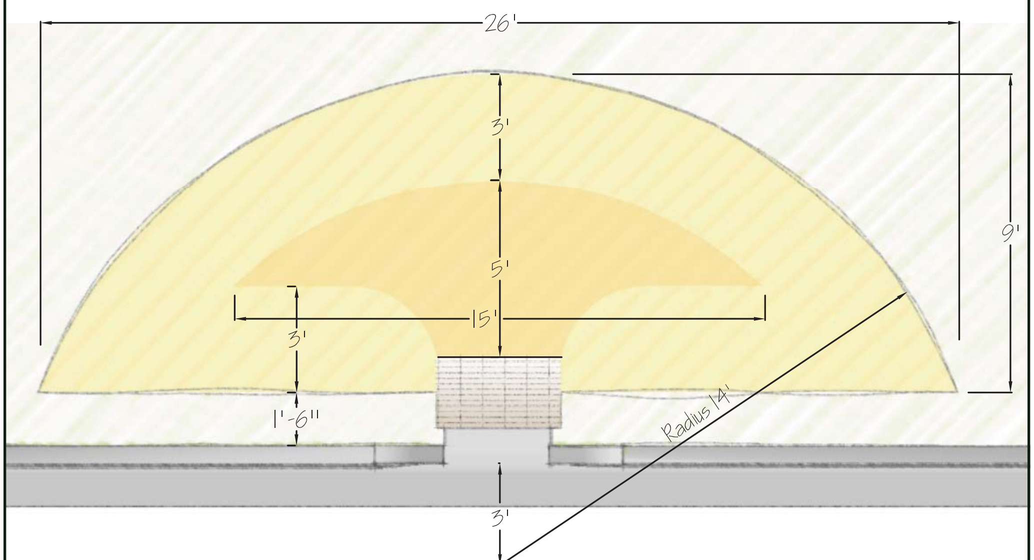


RAINGARDEN WITH RETAINING WALL

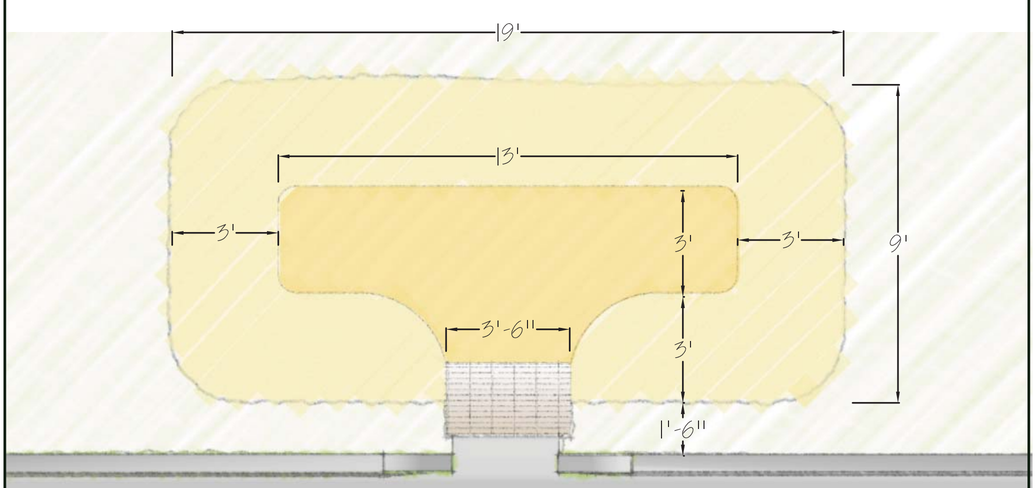
Raingarden Dimensions without a Retaining Wall



Curvilinear Garden



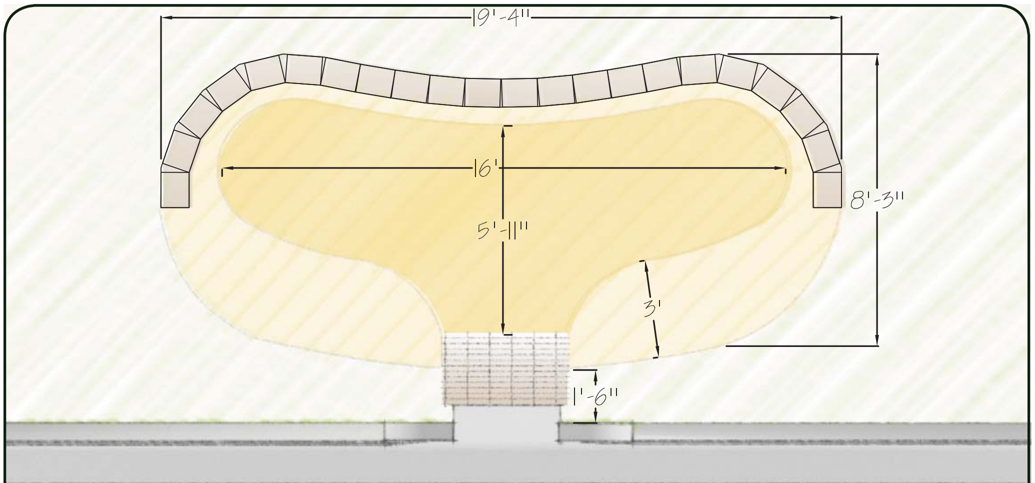
Arc Garden

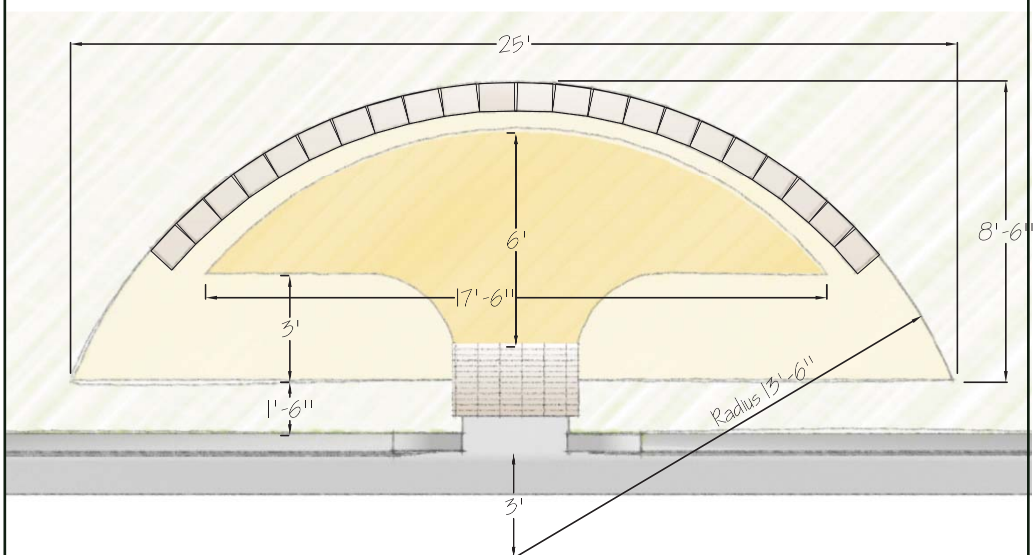


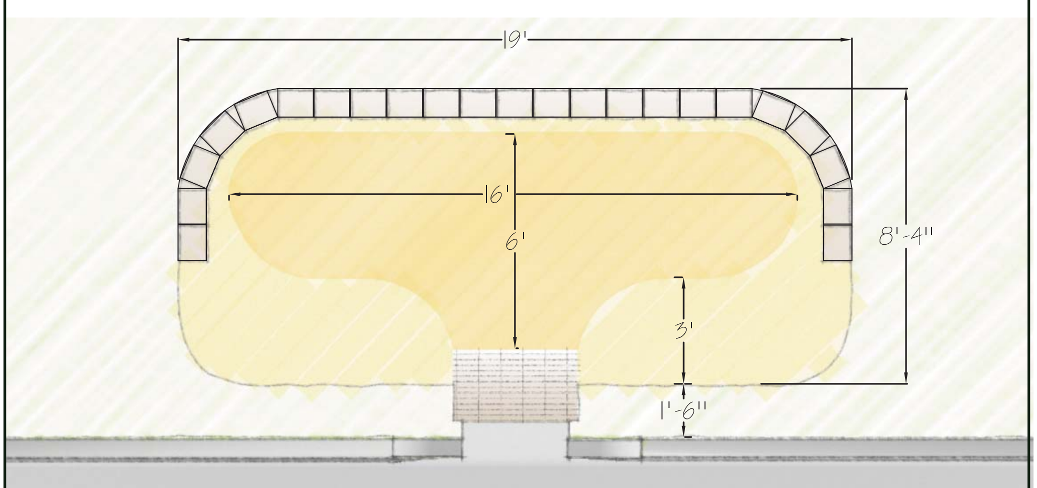
Rectangle Garden

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

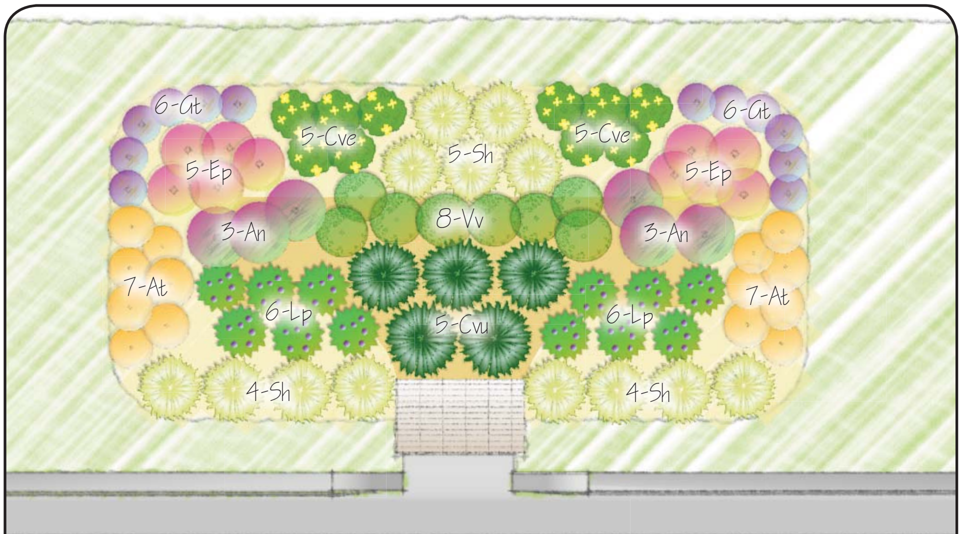




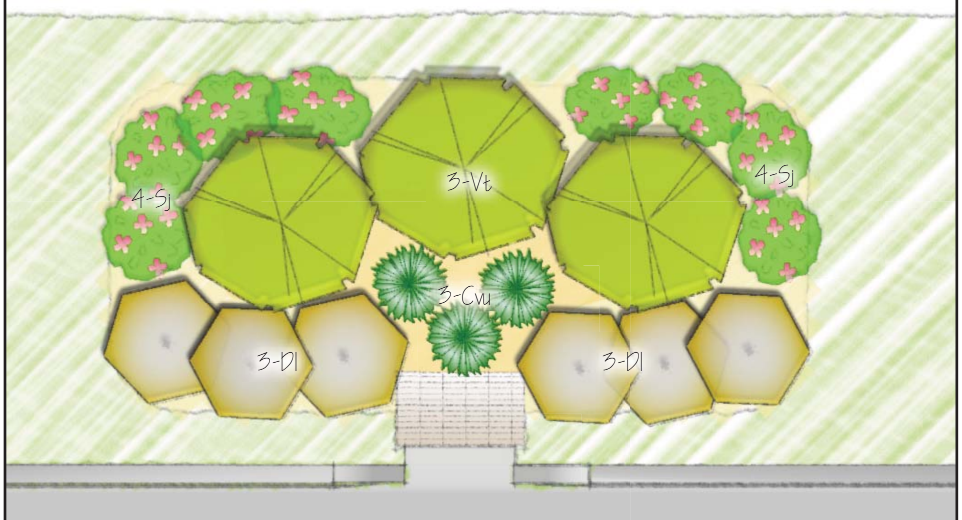


The dimensions given are the minimum dimensions needed to achieve the storage volume required by this stormwater retrofit program. The level basin floor needs to be set 1 foot below the gutter elevation. The entire planting area should be covered with 3 inches of shredded hardwood mulch.

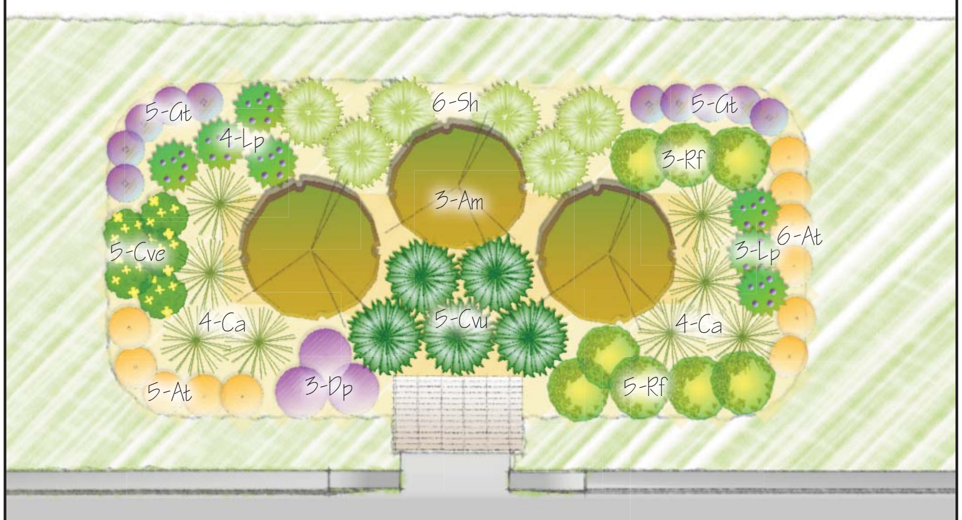
I. Rectangle Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

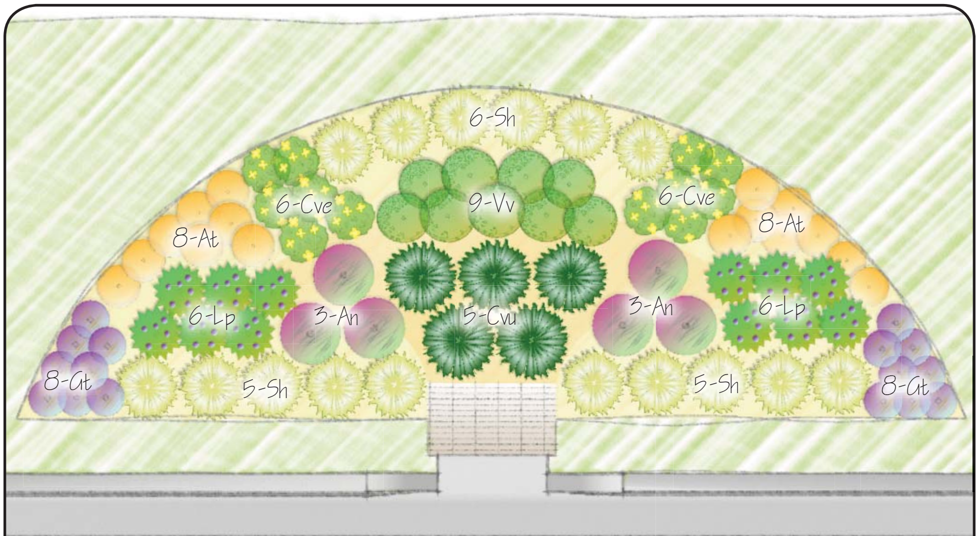


Mixed Shrub/Flower Garden

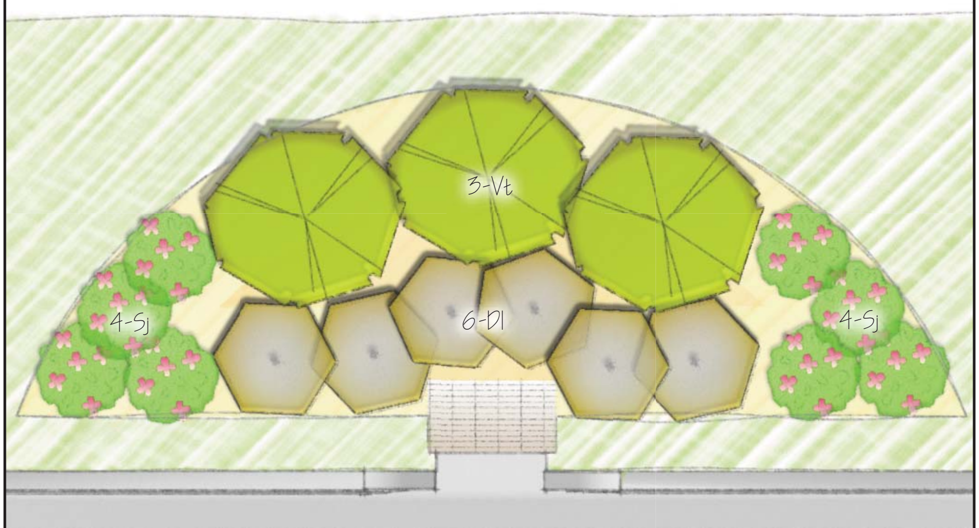
Plant Key

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'*

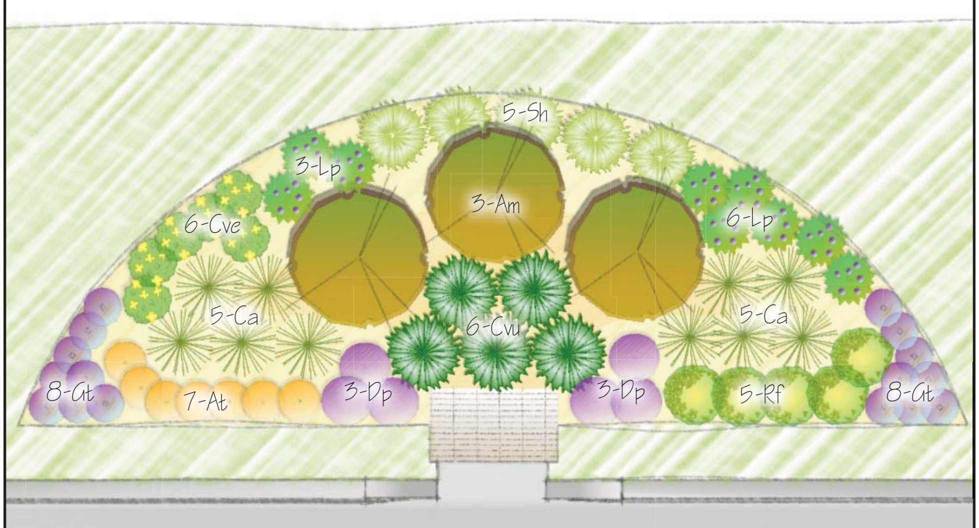
II. Arc Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

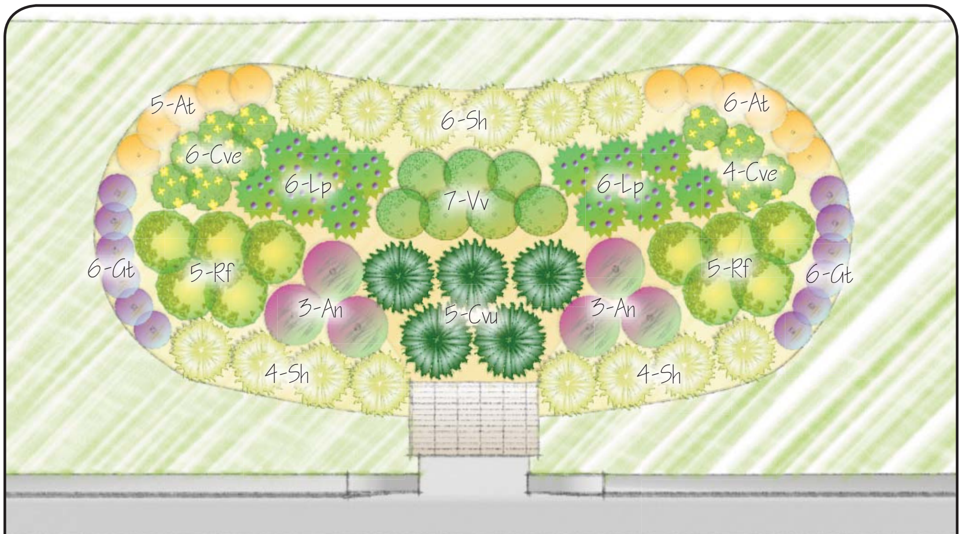


Mixed Shrub/Flower Garden

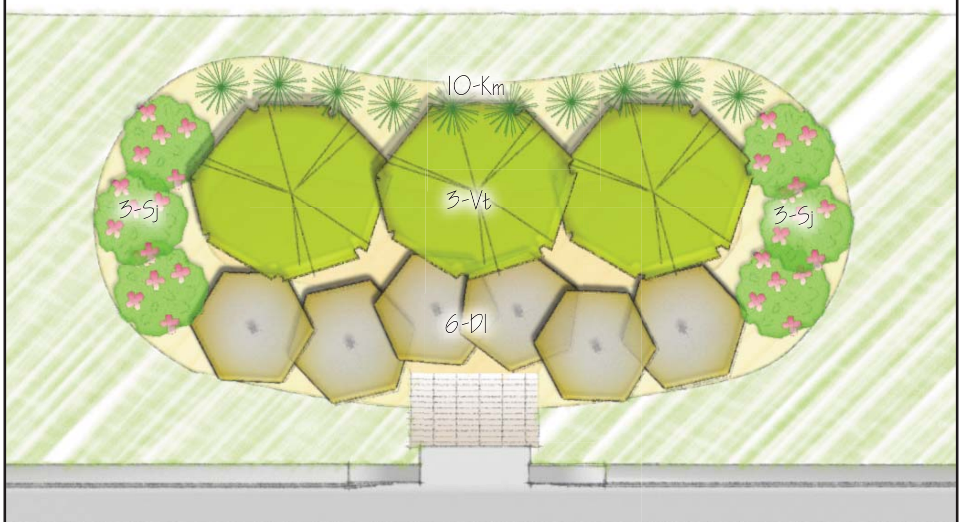
Plant Key

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



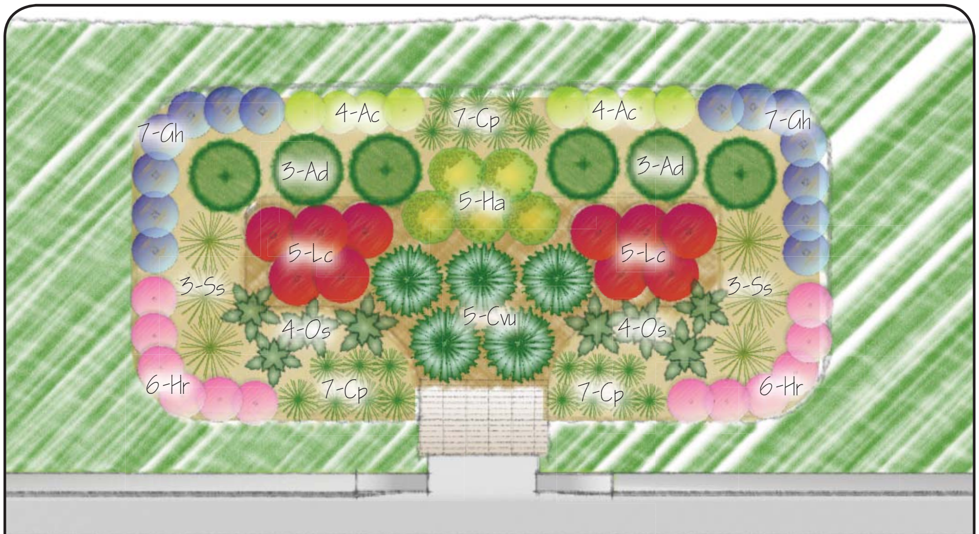
Shrub Garden

Mixed Shrub/Flower Garden

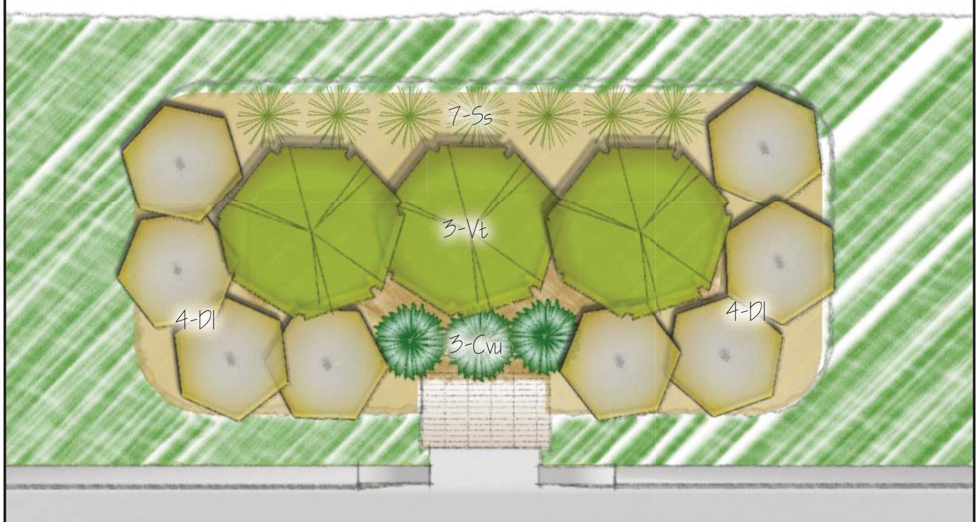
Plant Key

- **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'*

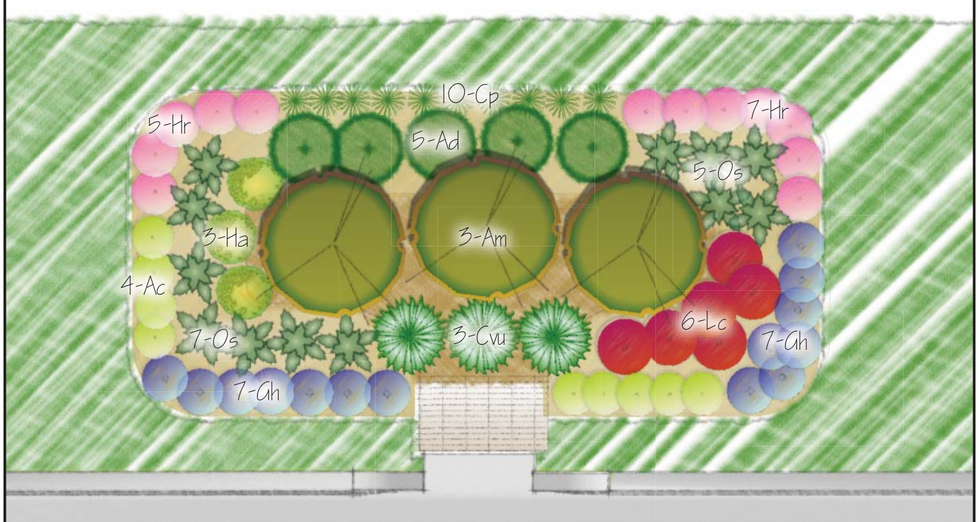
IV. Rectangle Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

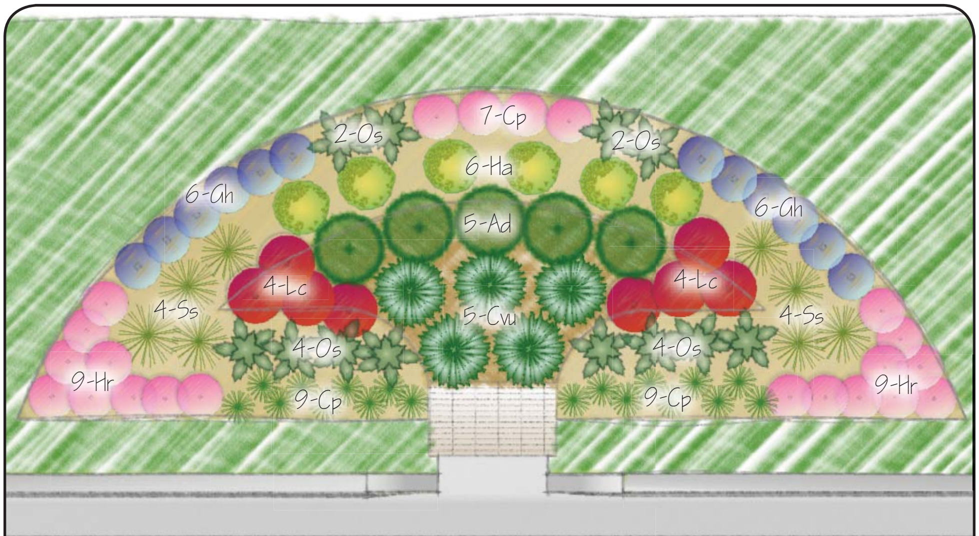


Mixed Shrub/Flower Garden

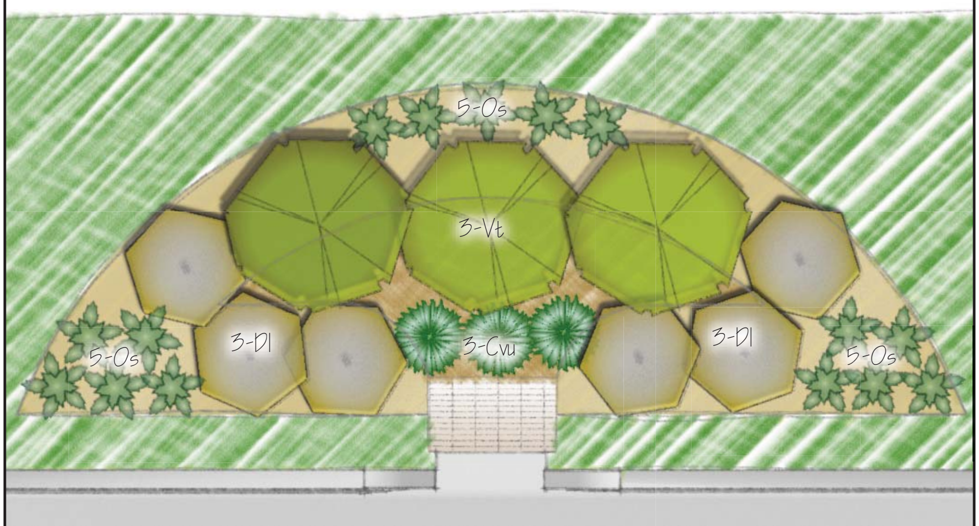
Plant Key

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



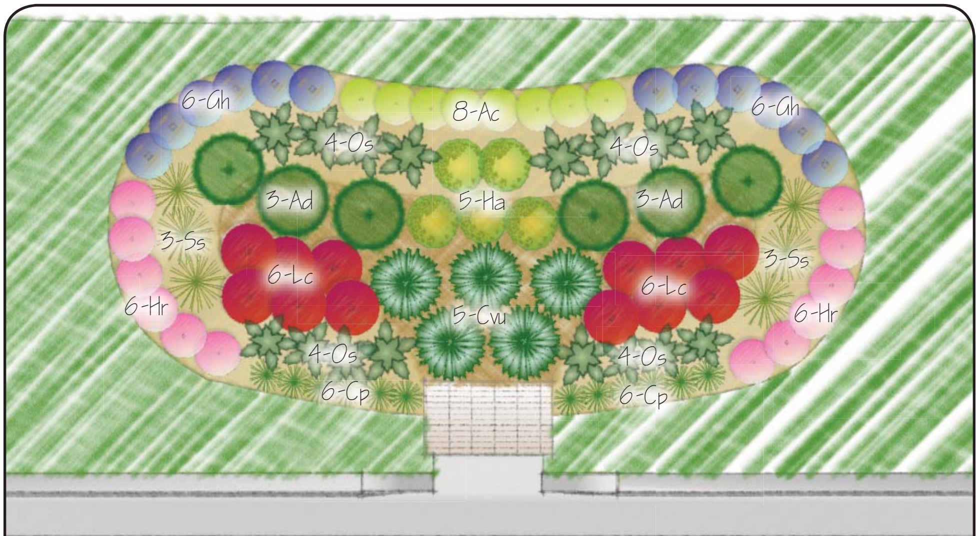
Shrub Garden

Mixed Shrub/Flower Garden

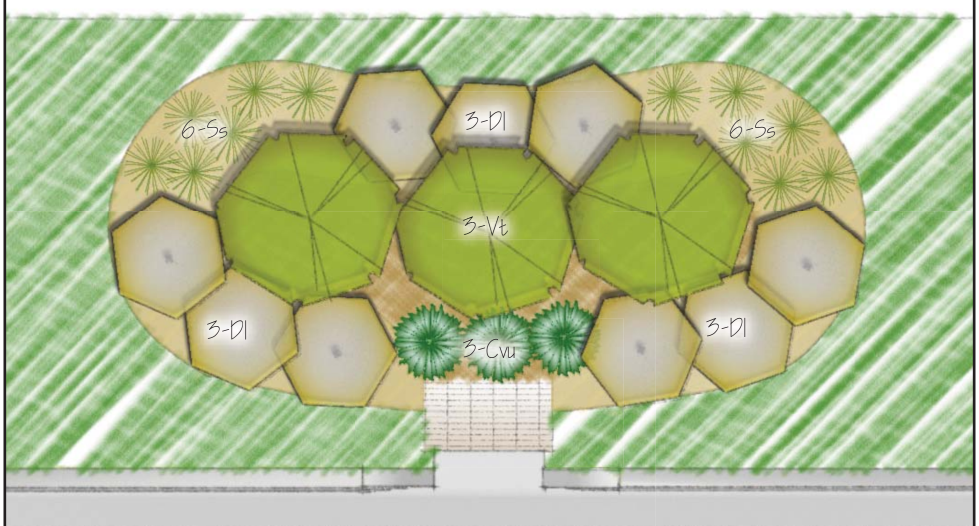
Plant Key

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'*

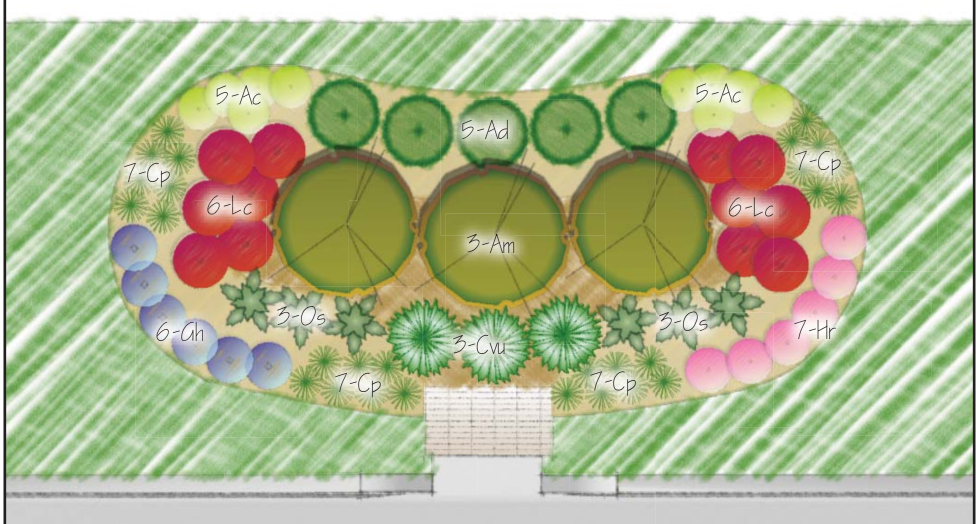
VI. Curvilinear Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

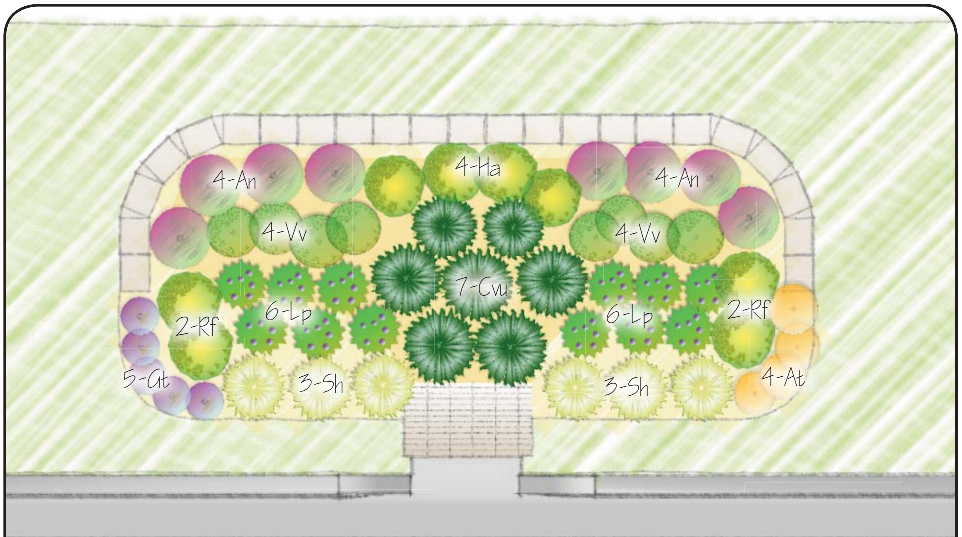


Mixed Shrub/Flower Garden

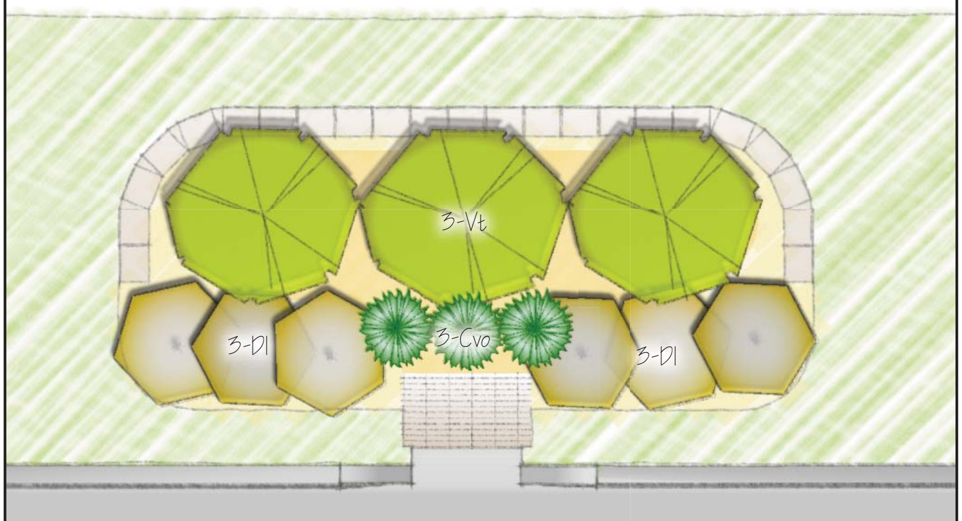
Plant Key

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'*

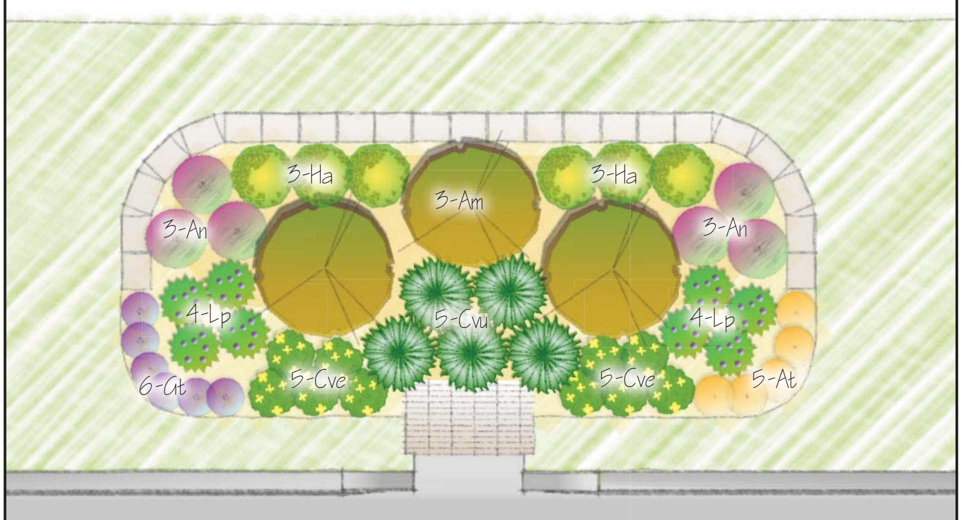
VII. Rectangle Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

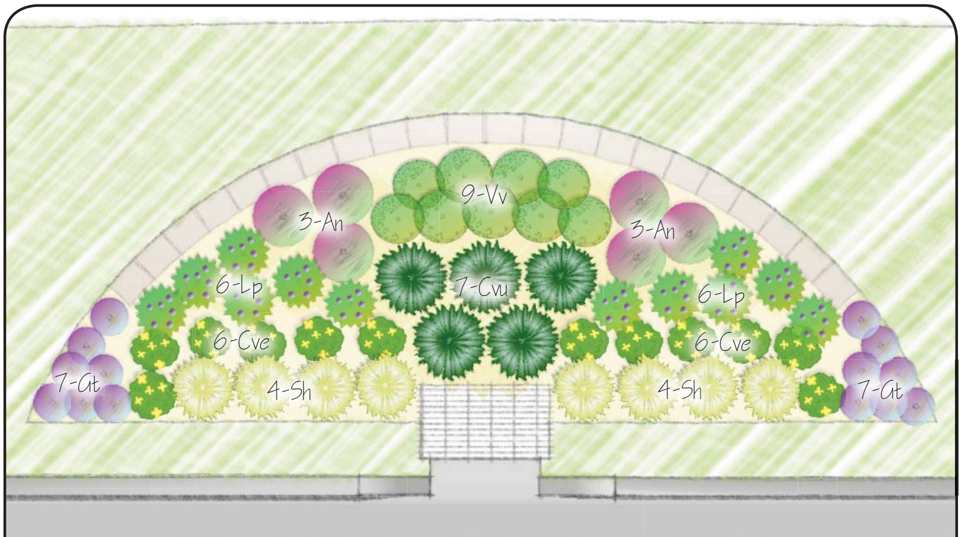


Mixed Shrub/Flower Garden

Plant Key

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

VIII. Arc Garden - Sunny Site - Retaining Wall



Flowering Perennial Garden

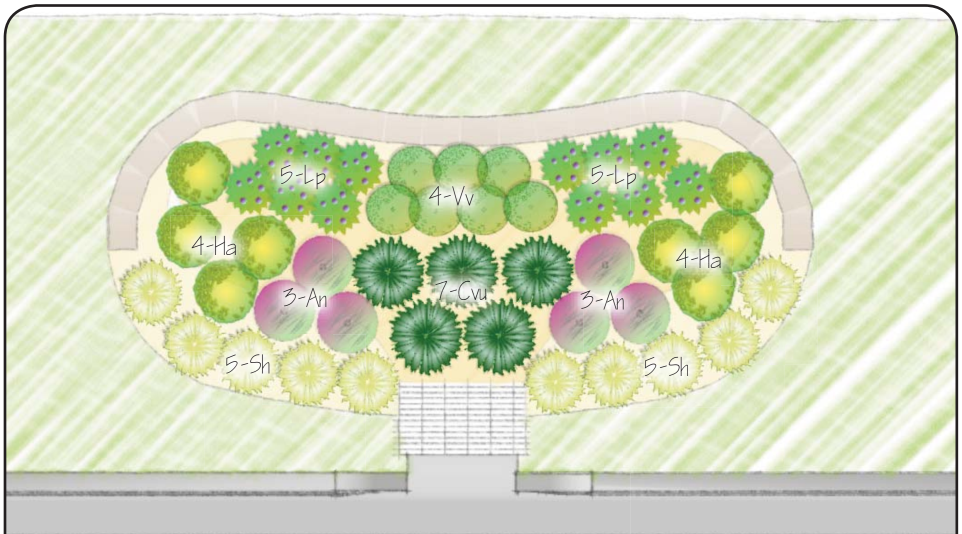
Shrub Garden

Mixed Shrub/Flower Garden

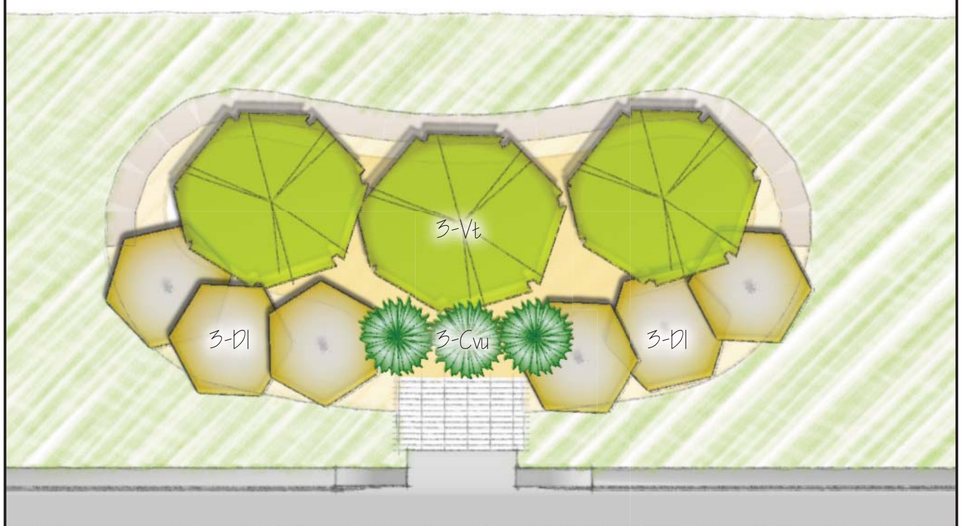
Plant Key

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'*

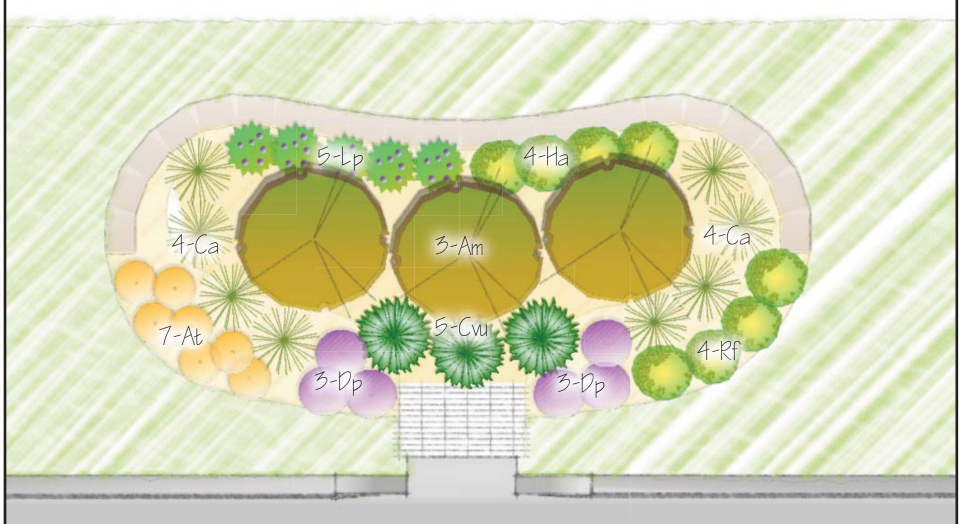
IX. Curvilinear Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden



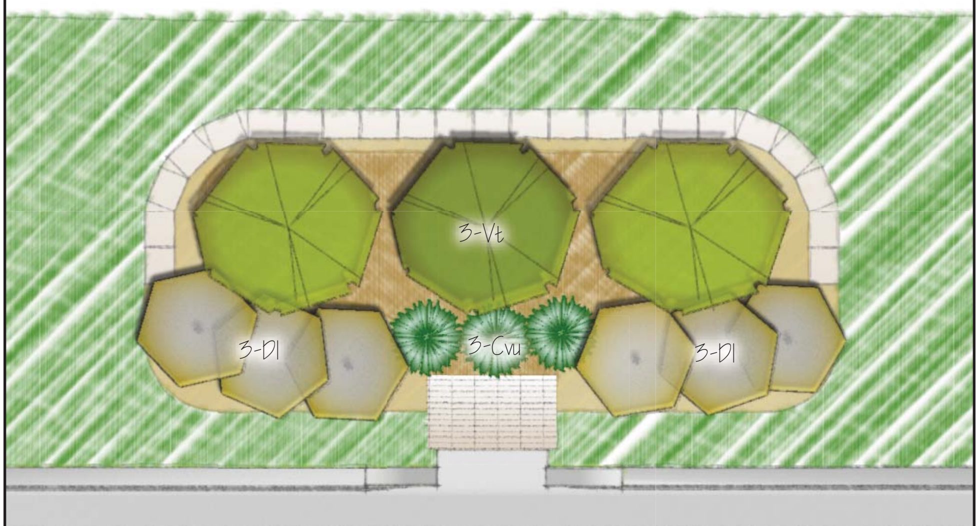
Mixed Shrub/Flower Garden

Plant Key

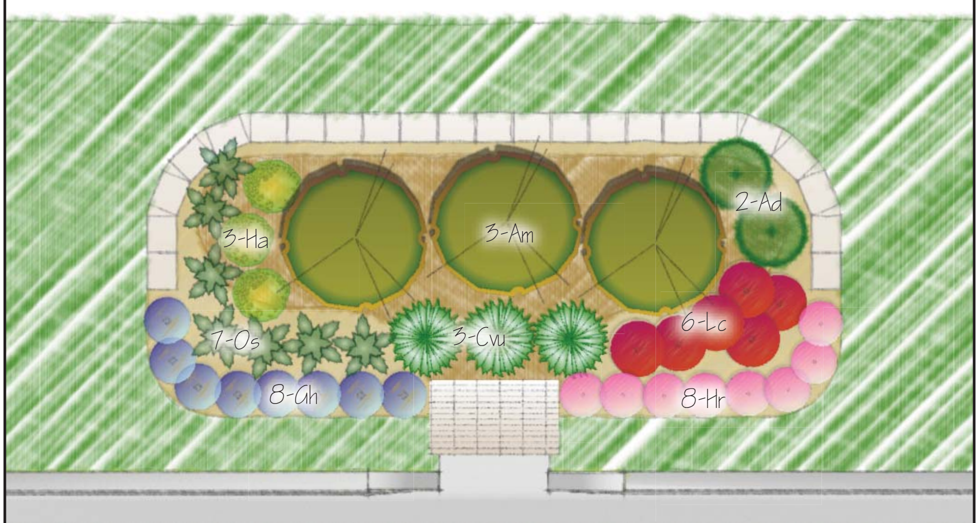
Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ha	SNEEZEWEED *Helenium autumnale*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

X. Rectangle Garden - Shady Site - Retaining Wall

Flowering Perennial Garden



Shrub Garden

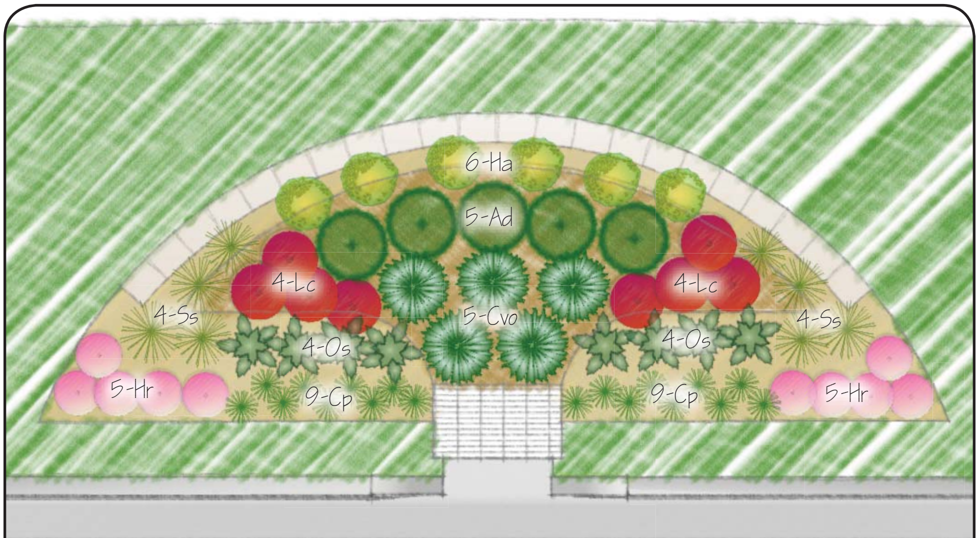


Mixed Shrub/Flower Garden

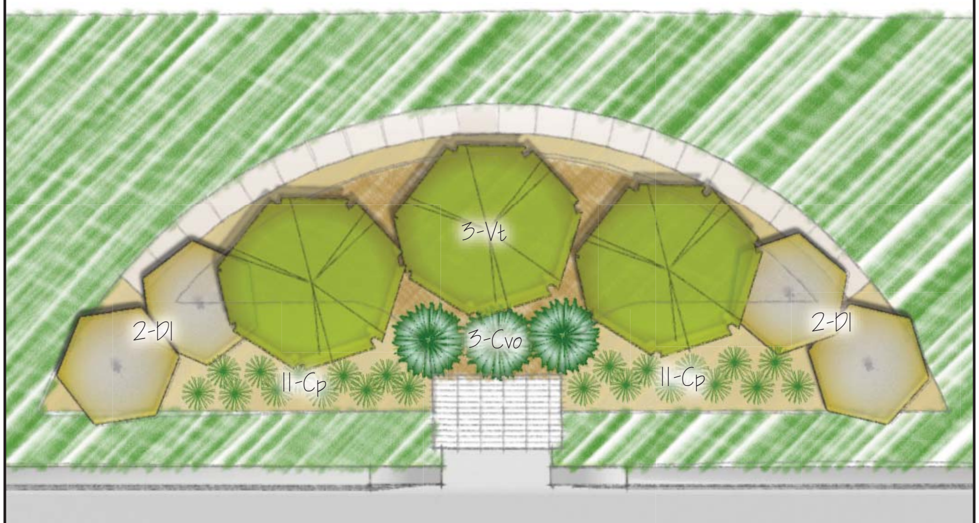
Plant Key

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'*

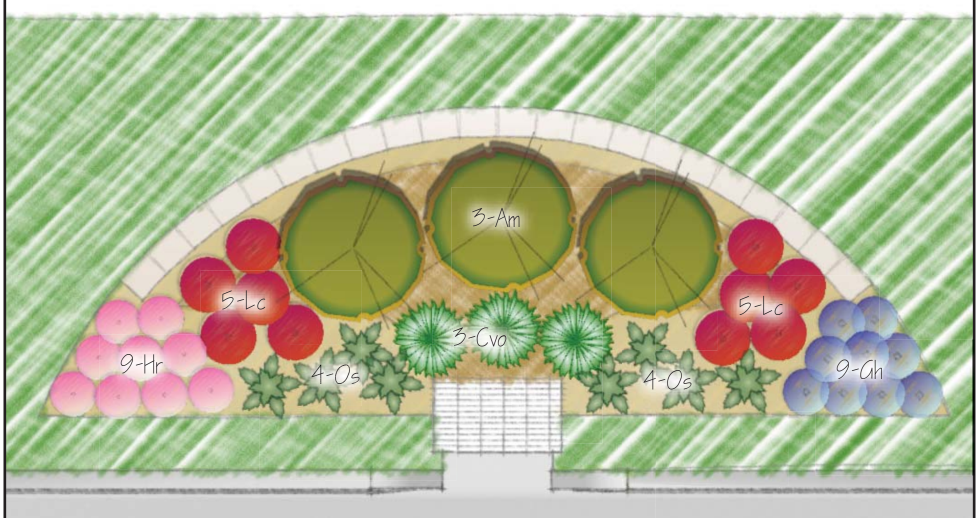
XI. Arc Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

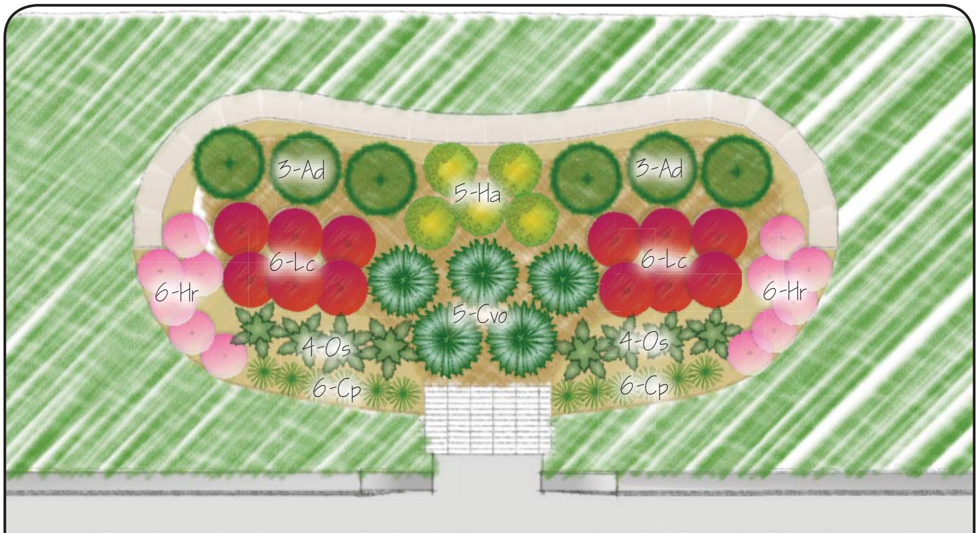


Mixed Shrub/Flower Garden

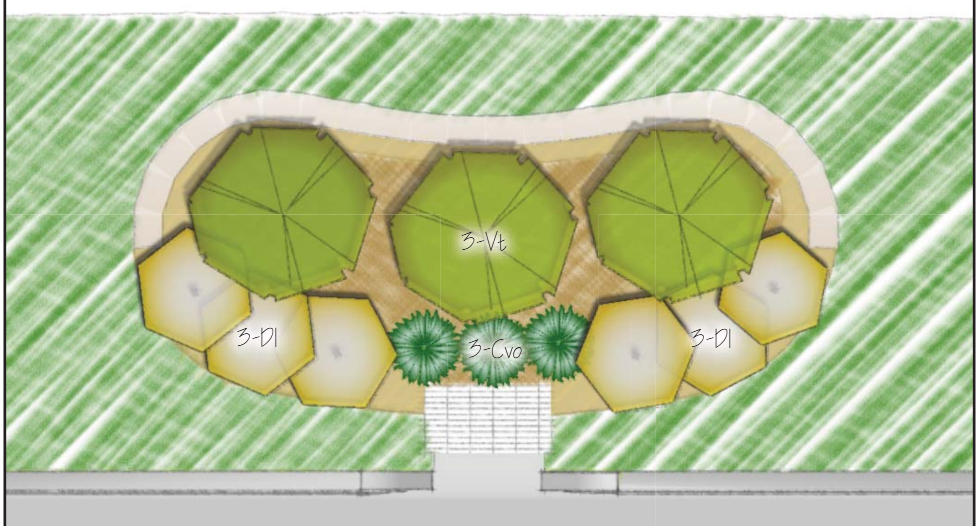
Plant Key

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

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Appendix C – Woodcrest Creek Rapid Bank Erosion Assessment

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Ham Lake, Minnesota 55304
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Woodcrest Creek Subwatershed
Rapid Bank Erosion Assessment

Description:
A bank erosion assessment along Woodcrest Creek downstream of Woodcrest Drive was requested by the Coon Creek Watershed District as part of the Woodcrest Creek subwatershed assessment conducted by the Anoka Conservation District (ACD). The bank erosion assessment was conducted in December 2010 and consisted of two primary components.

A rapid erosion assessment was conducted on the stretch of creek located between the pedestrian bridge in Woodcrest Park and the treatment pond west of Woodcrest Drive (Figure 1). This stretch of creek was identified as problematic with respect to erosion and bank stability during water sample collections as part of the subwatershed assessment. The degree of erosion and bank instability noted during the summer of 2010 warranted more detailed assessments of the creek and buffer conditions. The results of the assessment include erosion and undercutting severity for specific reaches of stream and corresponding banks (Figure 1), along with photo documentation of the problematic areas (Figures 2 - 12).

In addition, a ditch maintenance inspection form was completed from five vantage points evenly spaced along Woodcrest Creek where a detailed assessment was restricted because of access limitations related to private property. These inspections provided an overall assessment of the creek as seen from each vantage point and cover the majority of the creek located between Woodcrest Drive and the confluence of Woodcrest Creek with Coon Creek (Figure 13). The resulting scores from the ditch maintenance inspections can be found in Tables 1 - 5 and correspond to the sites identified in Figure 13.

The ditch maintenance inspection form was obtained from the Coon Creek Watershed District, and ACD staff slightly modified the form to better assess this stretch of Woodcrest Creek. The scoring system, values ranging from 0 to 3 representing increasing severity, was used for the categories listed in Tables 1-5. Of particular note was the modification made by ACD staff for the highest severity category of 3. The Coon Creek Watershed District has generally reserved this categorization for areas that pose an immediate threat to public safety. Rather, this categorization was modified to address areas with significant active erosion that pose a potential threat to private property. Values for all categories were then averaged in an attempt to provide an overall assessment of the particular stretch of creek under investigation.

Recommendation:

Based on the results of the rapid bank erosion assessment (Figure 1), several stretches of creek were identified as requiring immediate repair with respect to obstructions and erosion and undercutting severity.

The ditch maintenance inspections each identified stretches of creek that required immediate repair concerning at least one of the categories on the inspection form (Tables 1 - 5). Averaging the scores of the ditch maintenance inspections highlighted two stretches of creek that are in need of more immediate attention based on their relatively high scores in several categories. More specifically, Station 2 (Table 2) and Station 5 (Table 5) had the highest average score of 2.375.

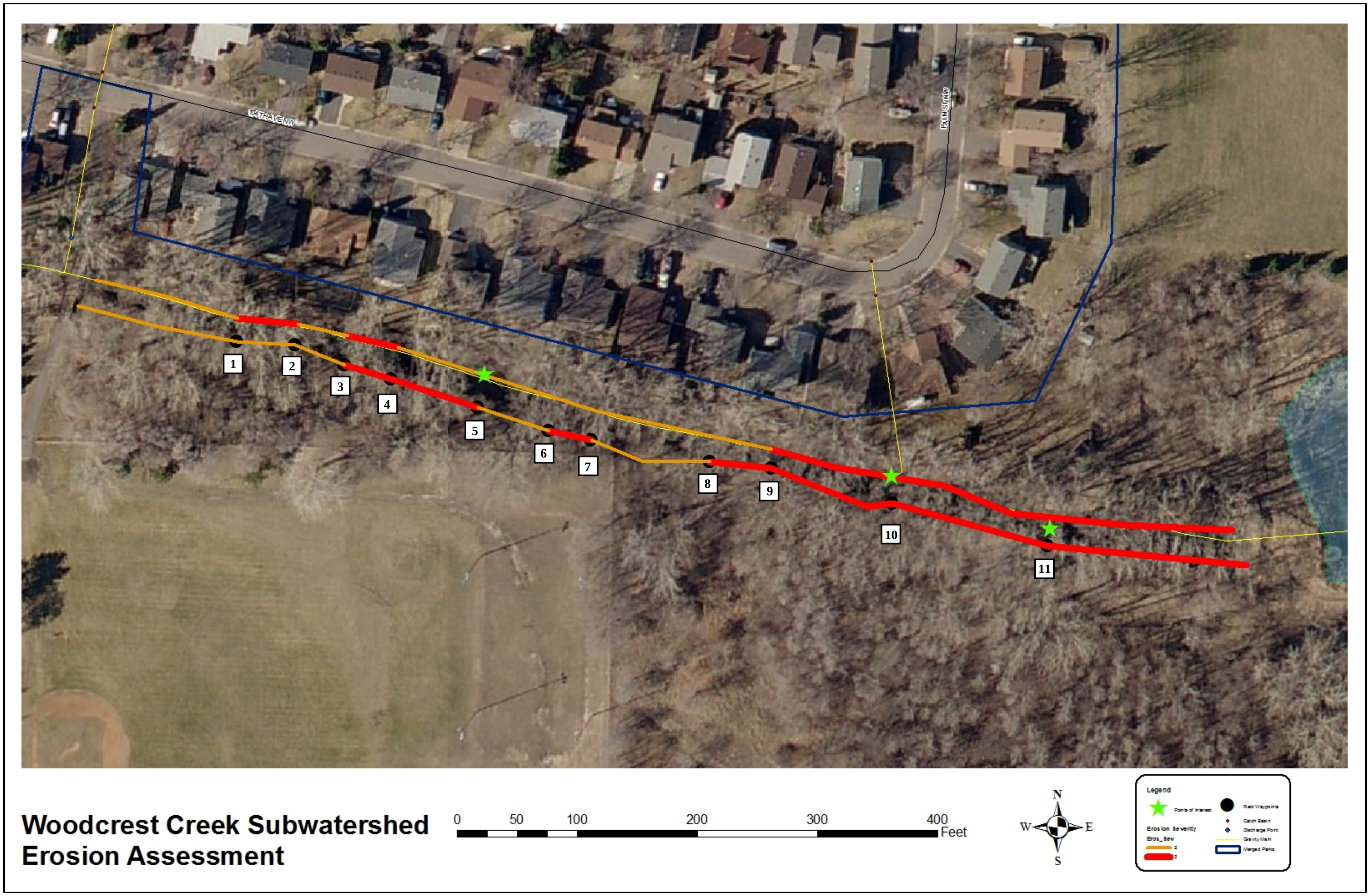

Figure 1. Bank erosion severity along Woodcrest Creek downstream of Woodcrest Drive as assessed by the Anoka Conservation District in December 2010. Numbers on the map correspond to photo documentation (Figures 2 - 12).

Figure 2. Photo taken at number 1 in Figure 1. Displays an erosion and undercutting severity of 3.

Figure 3. Photo taken at number 2 in Figure 1. Displays an erosion and undercutting severity of 3.

Figure 4. Photo taken at number 3 in Figure 1. Displays an erosion and undercutting severity of 3.

Figure 5. Photo taken at number 4 in Figure 1. Displays an erosion and undercutting severity of 3.

Figure 6. Photo taken at number 5 in Figure 1. Displays an erosion and undercutting severity of 3.

Figure 7. Photo taken at number 6 in Figure 1. Displays an erosion and undercutting severity of 3.

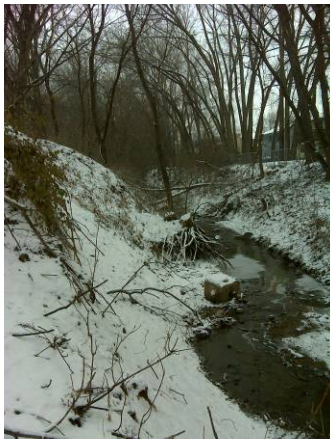

Figure 8. Photo taken at number 7 in Figure 1. Displays an erosion and undercutting severity of 3.

Figure 9. Photo taken at number 8 in Figure 1. Displays an erosion and undercutting severity of 3.

Figure 10. Photo taken at number 9 in Figure 1. Displays an erosion and undercutting severity of 3.

Figure 11. Photo taken at number 10 in Figure 1. Displays an erosion and undercutting severity of 3.

Figure 12. Photo taken at number 11 in Figure 1. Displays an erosion and undercutting severity of 3.

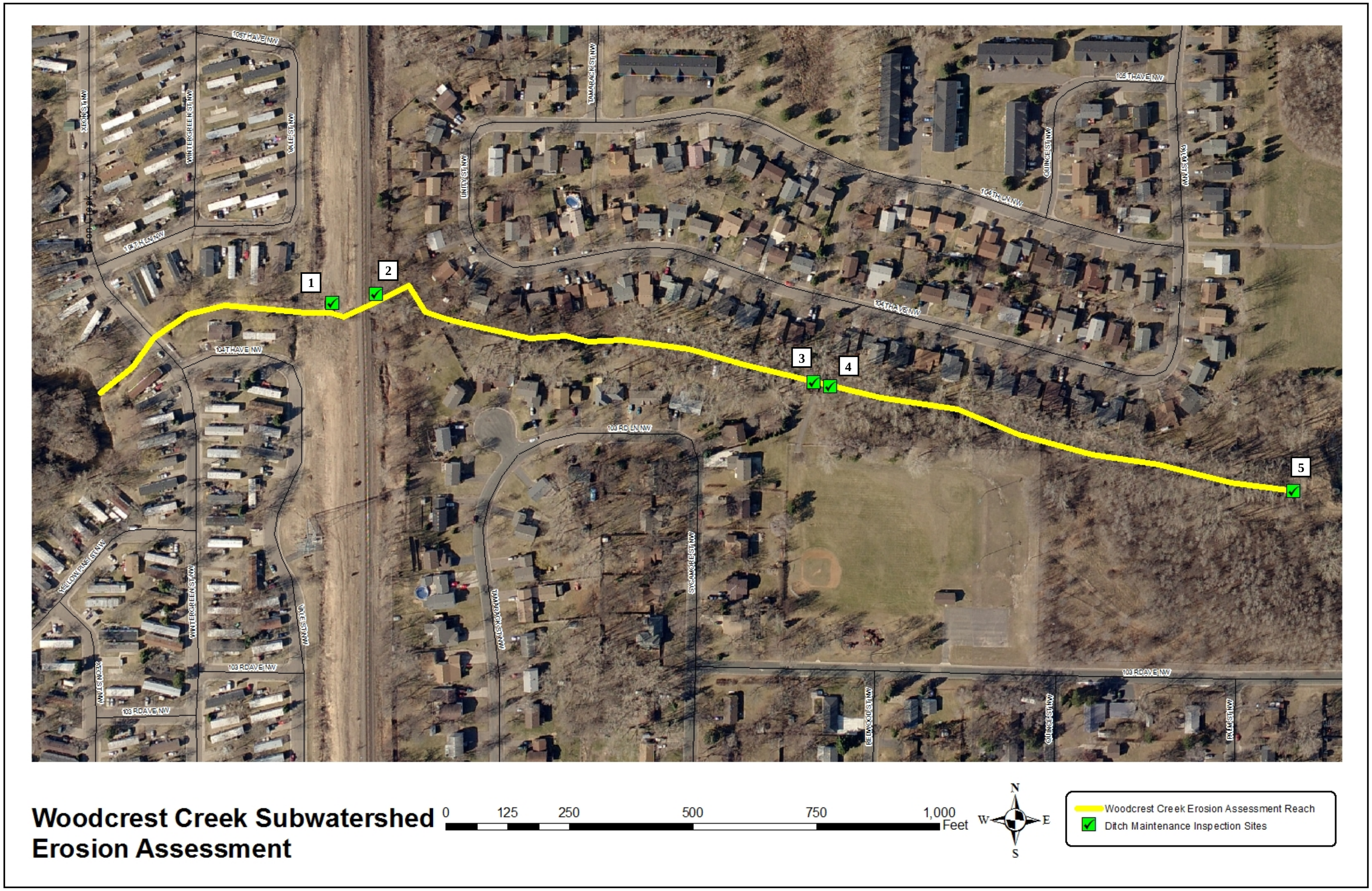

Figure 13. Reach of Woodcrest Creek assessed by the Anoka Conservation District in December 2010 using the Coon Creek Watershed District ditch maintenance inspection form. Numbers correspond to sites where ditch maintenance forms were completed. Results are presented in Tables 1 - 5.

Table 1. Ditch maintenance inspection form data for site 1 in Figure 13.

Ditch: Woodcrest Creek
Station: 1
Direction Facing: Downstream

Category	Score	Notes
Presence of 16.5' grass buffer	3	
Stabilization of spoil banks	0	
Presence of obstructions	0	
Variation from approved plans	N/A	
Channel cross section shape	1	
Channel vegetation	N/A	
Channel sinuosity	2	
Ditch bank vegetation	3	
Hydraulic capacity	2	
Erosion and undercutting	2	
Average	1.625	

Table 2. Ditch maintenance inspection form data for site 2 in Figure 13.

Ditch: Woodcrest Creek
Station: 2
Direction Facing: Upstream

Category	Score	Notes
Presence of 16.5' grass buffer	3	
Stabilization of spoil banks	0	
Presence of obstructions	2	
Variation from approved plans	N/A	
Channel cross section shape	2	
Channel vegetation	N/A	
Channel sinuosity	3	
Ditch bank vegetation	3	
Hydraulic capacity	3	
Erosion and undercutting	3	
Average	2.375	

Table 3. Ditch maintenance inspection form data for site 3 in Figure 13.

Ditch: Woodcrest Creek
Station: 3
Direction Facing: Downstream

Category	Score	Notes
Presence of 16.5' grass buffer	3	
Stabilization of spoil banks	2	Spots of 3
Presence of obstructions	2	
Variation from approved plans	N/A	
Channel cross section shape	2	Spots of 3
Channel vegetation	N/A	
Channel sinuosity	2	Spots of 3
Ditch bank vegetation	2	Spots of 3
Hydraulic capacity	1	
Erosion and undercutting	2	Spots of 3
Average	2	

Table 4. Ditch maintenance inspection form data for site 4 in Figure 13.

Ditch: Woodcrest Creek **Station: 4** **Direction Facing: Upstream**		
Category	Score	Notes
Presence of 16.5' grass buffer	1	
Stabilization of spoil banks	0	
Presence of obstructions	3	
Variation from approved plans	N/A	
Channel cross section shape	2	Spots of 3
Channel vegetation	N/A	
Channel sinuosity	1	
Ditch bank vegetation	3	
Hydraulic capacity	1	
Erosion and undercutting	2	
Average	1.625	

Table 5. Ditch maintenance inspection form data for site 5 in Figure 13.

Ditch: Woodcrest Creek **Station: 5** **Direction Facing: Downstream**		
Category	Score	Notes
Presence of 16.5' grass buffer	0	
Stabilization of spoil banks	3	
Presence of obstructions	3	
Variation from approved plans	N/A	
Channel cross section shape	3	
Channel vegetation	N/A	
Channel sinuosity	3	
Ditch bank vegetation	3	
Hydraulic capacity	1	
Erosion and undercutting	3	
Average	2.375	

Appendix D – Coon Rapids Wellhead Protection Areas (WPAs) and Drinking Water Supply Management Areas (DWSMAs)

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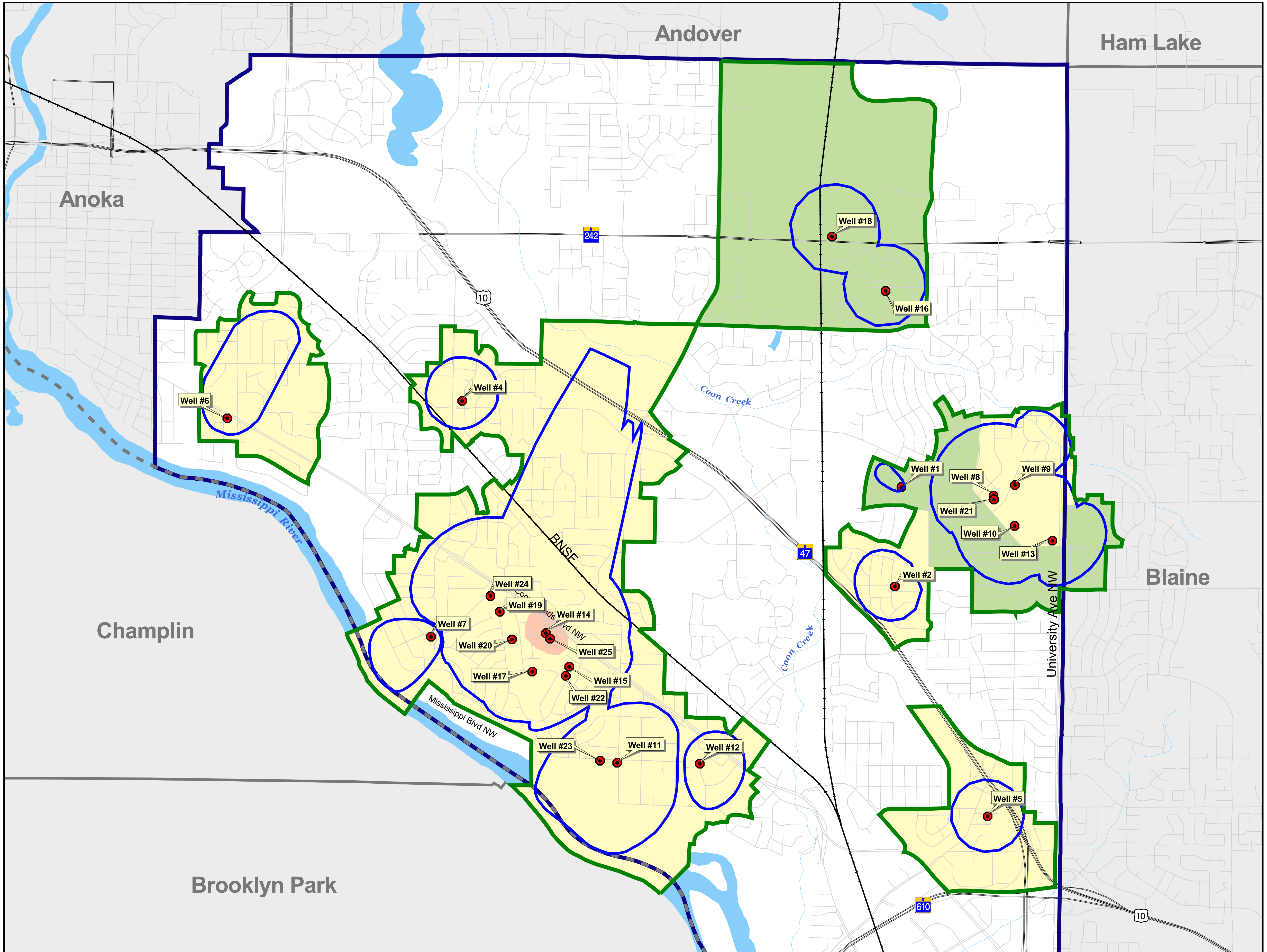

City of Coon Rapids

Wellhead Protection Plan

Wellhead Protection Areas and Drinking Water Supply Management Areas

Figure 1

- Public Supply Well
- Wellhead Protection Area
- Drinking Water Supply Management Area
- High Vulnerability
- Moderate Vulnerability
- Low Vulnerability
- Municipal Boundary
- Water
- Road
- Railroad
- County Boundary

July 2007

Feet
3000 0 3000

Bonestroo

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