Wilmes Lake Subwatershed Retrofit Analysis

Prepared for the South Washington Watershed District

By the Washington Conservation District

10/15/2014

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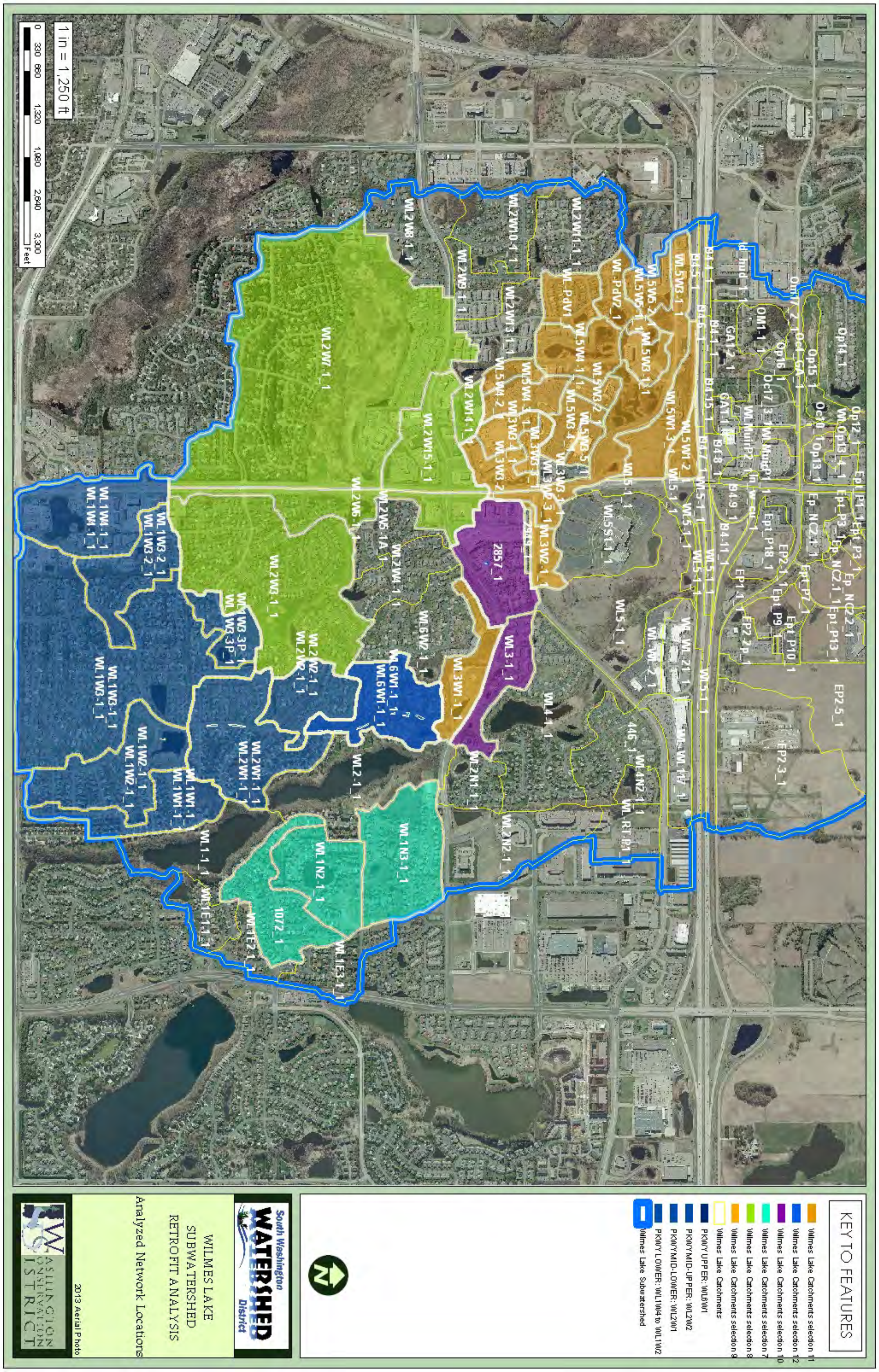
Selected Catchment Networks - Reference Map



Executive Summary

This analysis provides recommendations for cost effective treatment of stormwater runoff from the Wilmes Lake Subwatershed (herein described as Wilmes Lake Subwatershed Retrofit Analysis). This area is entirely located within the South Washington Watershed District (SWWD) and within the cities of Woodbury and Oakdale.

Wilmes Lake consists of two basins (north and south) with a footprint of 36 acres and a subwatershed of 2,986 acres. Wilmes Lake is part of a system of lakes that drain SWWD's Northern Watershed (NWS). There are additional subwatersheds that flow into Wilmes Lake (Armstrong and Markgrafs lakes); however, for the purpose of this analysis, only the Wilmes Lake subwatershed was considered. Through water quality data and analysis it is determined Wilmes Lake is impaired for excess nutrients.

The following load reduction goals for Wilmes Lake were identified during initial scoping meetings – load reductions amounts calculated based on the growing season (June – Sept):

Wilmes North Basin - 47% reduction; 71 lbs (32 kg)
Wilmes South Basin - 32% reduction; 27 lbs (12 kg)

Existing treatments were accounted for in the modeling process. The entire subwatershed, consisting of 123 catchments, was investigated via desktop analysis. Final catchment networks selected for retrofitablity were influenced by information provided in the 2012 Water Quality Report for Armstrong, Markgrafs and Wilmes Lakes, completed by Houston Engineering for the SWWD, by Capital Improvement Projects timeline within the subwatershed for the city of Woodbury, and by retrofit feasibility.

WinSLAMM was used for the water quality modeling of 8 separate catchment networks to establish base loading, existing loading – accounting for existing stormwater management practices, and were analyzed for seasonal pollutant loading - total phosphorus, total suspended solids and runoff volume specifically.

Stormwater retrofit practice options were compared, for each catchment network, given their specific site constraints and characteristics. A stormwater practice was selected by weighing cost, ease of installation and maintenance and ability to serve multiple functions. Concept designs were drafted for individual projects identified through the cost/benefit analysis and ranking.

A variety of stormwater retrofit approaches were identified totaling between 65 - 70 lbs of total phosphorus reduction (TP) per growing season. An additional 40 lbs TP/yr load reduction was identified by the installation of the Wilmes Ravine Stabilization in 2011.

Stormwater BMPs identified in this analysis:

- Biofiltration raingardens
- Stormwater reuse systems
- Iron-enhanced sand filters (IESFs)
- Bioswales

Retrofit Ranking

The table on the next page summarizes potential projects. Potential projects are organized from the most cost effective to the least, based on cost per pound of total phosphorus removed. Installation of projects with overlapping drainage areas will result in lower total treatment than the simple sum of treatment across the individual projects due to treatment train effects. Reported treatment levels of identified projects are dependent upon optimal siting and sizing. More detail about each project can be found in the 'Catchment Profile' pages of this report. Projects that were deemed unfeasible due to prohibitive size, number, or were too expensive to justify installation are not included in the table.

Wilmes Stormwater Retrofit Opportunities: Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Volume and total suspended solids (TSS) reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Catchment ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/growing season)	TSS Reduction (lb/growing season)	Volume Reduction (acft/growing season)	Total Project Cost	Estimated Annual Operations & Maintenance	Estimated cost/ lb-TP/growing season (30-seasons)	Estimated cost/ 1,000lb-TSS/season (30-seasons)	NETWORK TP reduction	NETWORK Estimated cost/ lb-TP/growing season (30-seasons)
1	WL1-1 (WL1N3-1_1 thru 1072_1)	IESF (180 LN FT)	1	16	n/a	n/a	$99,600	$1,500.00	$310.00	N/A	LIMITED NETWORK TREATMENT	
2	Tamarack SE Pond (WL3W2)	IESF (350 LN FT)	1	9.5	n/a	n/a	$66,000	$1,460	$430.00	N/A	5.7	$647
3	Lower (WL1W2-1_1)	Reuse System - pump and 3 acre irrigation distribution	1	9.6	5184	21.1	$303,000	$1,000	$1,150	$4,282	LIMITED NETWORK TREATMENT	
4*	Mid-Lower (WL2W1-1_1)	2,000 sqft Bioretention w/underdrain	1	1.9	755	0.3	$37,000	$1,000	$1,151	$5,916	LIMITED NETWORK TREATMENT	
5*	WL2857	500 sqft Bioretention w/underdrain	4	1.7	811	0.1	$44,000	$2,000	$1,341	$5,754	1.615	1445
6*	Upper (WL6W1-1_1)	2,000 sqft Bioretention w/underdrain	2	3.3	1,262	0.5	$74,500	$2,000	$1,350	$7,105	LIMITED NETWORK TREATMENT	
7*	Mid-Lower (WL2W1-1_1)	2,000 sqft Bioretention w/underdrain	2	3.0	1,150	0.4	$65,500	$2,000	$1,381	$7,275	LIMITED NETWORK TREATMENT	
8*	WL2857	500 sqft Bioretention w/underdrain	8	3.1	1,375	0.2	$83,000	$2,000	$1,462	$6,594	2.95	15.37
9*	Mid-Lower (WL2W1-1_1)	2,000 sqft Bioretention w/underdrain	4	4.3	1,603	0.7	$114,000	$3,000	$1,570	$8,484	4.085	$1,579
10*	WL2857	500 sqft Bioretention w/underdrain	2	0.8	450	0.1	$23,000	$1,000	$1,600	$5,333	0.76	$1,579.00
11	WL2W6-1	5,400 sqft Bioswale	1	1.1	550	n/a	$45,200	$300	$1,642	$2,796	1.045	$1,537
12*	Upper (WL6W1-1_1)	2,000 sqft Bioretention w/underdrain	4	4.9	1,830	0.8	$130,500	$4,000	$1,693	$9,125	LIMITED NETWORK TREATMENT	
13	Tamarack S Pond (WL2W14-1)	IESF (375 LN FT)	1	2.3	n/a	n/a	$91,000	$1,500	$1,971	N/A	1.15	$3,942
14	Tamarack North Pond(WL5W3)	Reuse System	1	12.5	n/a	17.8	$725,000	$1,000	$2,013	N/A	10	$2,517
15*	Upper (WL6W1-1_1)	2,000 sqft Bioretention w/underdrain	8	6.4	2308	1.0	$226,500	$8,000	$2,433	$13,474	LIMITED NETWORK TREATMENT	
16	Tamarack West Pond (WL5W4)	Reuse System	1	4.3	n/a	6.1	$399,000	$1,000	$3,326	N/A	3.8	$3,763
17	Mid-Upper (WL2W2-1_1)	2,000 sqft Bioretention w/underdrain	1	0.7	233	0.1	$37,000	$1,000	$3,436	$19,170	LIMITED NETWORK TREATMENT	

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

Interlachen Parkway Subsection Memo

Interlachen Parkway is included as a subsection to the Wilmes Lake Subwatershed Retrofit Analysis (SWA). This analysis provides recommendations for cost effectively improving treatment of stormwater from areas that drain to or are intersected by Interlachen Parkway before reaching Wilmes Lake. The portion of Interlachen Parkway included in this analysis is between Tamarack Road and Valley Creek Road. All references to BMP opportunities along Interlachen Parkway pertain only to this portion.

Seven catchments intersect Interlachen Parkway; all of which are part of larger catchment drainage networks. These catchments are described by their unique ID as well as their relationship to Interlachen Parkway.

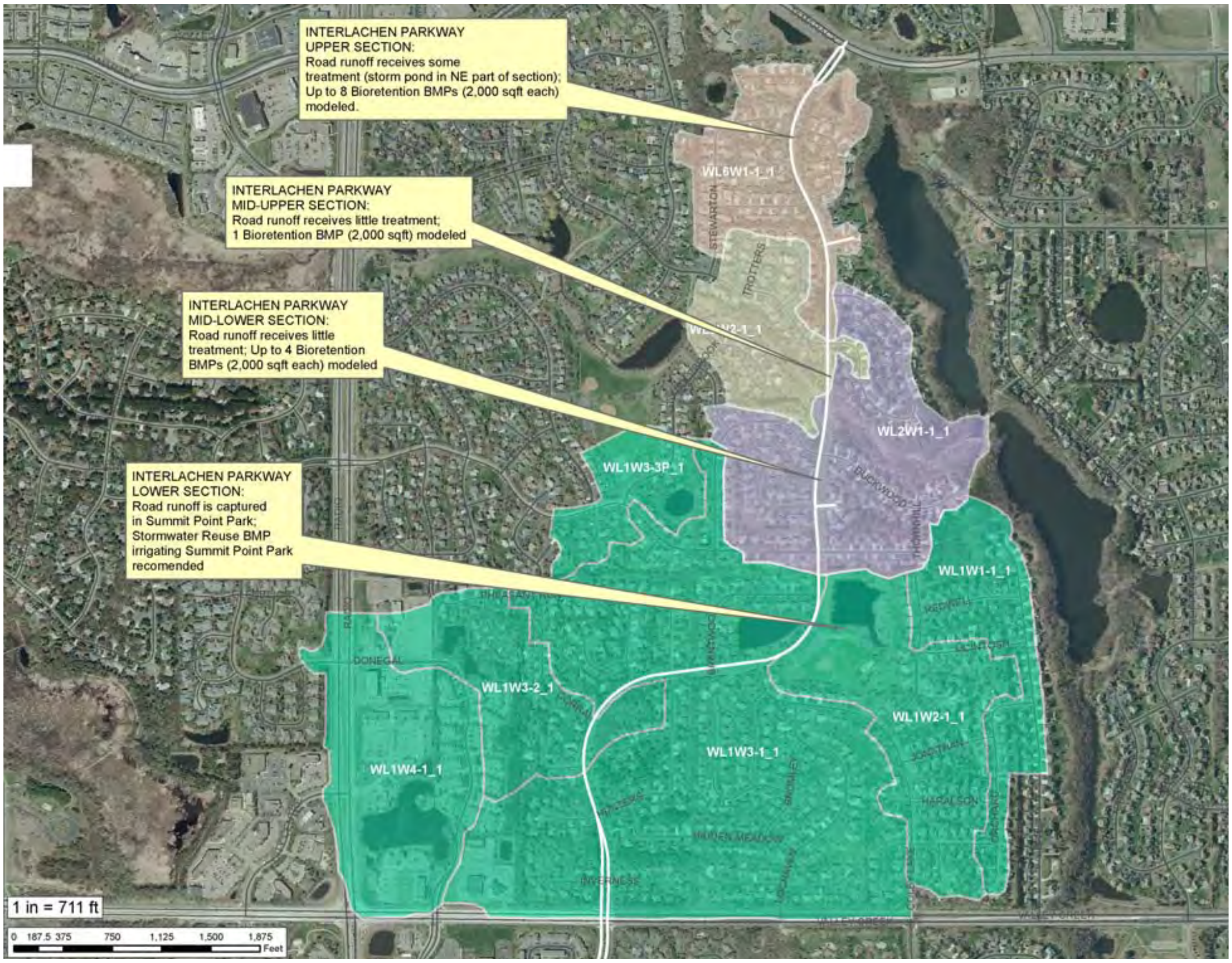
CATCHMENT	UNIQUE ID	DESRIPTION
UPPER SECTION	WL6W1_1	Drains thru 0.9 ac wet pond
MID-UPPER SECTION	WL2W2_1	Drains to Wilmes via ravine
MID-LOWER SECTION	WL2W1_1	Drains to Wilmes via ravine
LOWER SECTION	WL1W4-1_1 to WL1W1-1_1	Drains thru wet ponds

Bioretention best management practices (BMPs) were selected as most appropriate for the Upper, Mid-Upper, and Mid-Lower catchments due to the available greenspace along Interlachen Parkway and presence of stormsewer infrastructure – allowing potential split flows into bioretention BMPs. Bioretention BMPs were not considered feasible for the Lower Section catchments due to limited greenspace and steeper topography. Stormwater reuse is considered the most appropriate BMP for this section. The stormwater reuse BMP would consist of pumping stormwater from WL1W2_1P stormwater pond and distributing throughout adjacent Summit Point Park grounds.

Water quality Model Parameters: WinSLAMM, pollutant loading/reduction based on growing season (June – Sept)

A cost/benefit table and catchment profiles are included.

RETROFIT RECOMMENDATIONS



NETWORK WL6Wx (INTERLACHEN PKWY UPPER SECTION -WL6W1-1-1)

CATCHMENT DESCRIPTION

Catchment WL6W1-1_1 is part of a catchment network receiving outflows from catchment WL6W2-1_1. Network drainage area is 78.8 acres.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/ season)	48.3	8.0	16.5%	**40.3**
	TSS (lb/ season)	17,495	2,859.0	16.3%	**14,636**
	Volume (acre-feet/ season)	26.8	0.5	1.9%	**26.3**
	Number of BMP's	2			
	BMP Size/Description	1 qty - .91 AC Stormwater Pond WL6W1-1 , 1 qty- 1.7 AC Stormwater Wetland in WL6W2-1			

RETROFIT RECOMMENDATIONS

Bioretention BMPs optimally located along Interlachen Parkway could capture up to 29.19 acres of catchment WL6W1-1_1 (Upper Section). The following table considers up to 8 – 2,000 sqft bioretention cells with underdrains. The costs of these cells estimate installing split-flow structures in the existing stormsewer network. *See concept plan in appendix D*

	Cost/Removal Analysis	***Project ID***					
		Bioretention-2		Bioretention-4		Bioretention-8	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/ season)	3.3	28.2%	4.9	41.8%	6.4	54.2%
	TSS (lb/ season)	1262.0	29.5%	1830.0	42.8%	2308.0	88.6%
	Volume (acre-feet/ season)	0.5	5.6%	0.8	8.5%	1.0	16.9%
	Number of BMP's	2		4		8	
	BMP Size/Description	4,000	sqft	8,000	sqft	16,000	sqft
	BMP Type	Moderately Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention	
Cost	Materials/Labor/Design	$72,000		$128,000		$224,000	
	Promotion & Admin Costs	$2,500		$2,500		$2,500	
	Probable Project Cost	**$74,500**		**$130,500**		**$226,500**	
	Annual O&M	$2,000		$4,000		$8,000	
	30-yr Cost/lb-TP/ season	**$1,350**		**$1,694**		**$2,433**	
	30-yr Cost/2,000lb-TSS/ season	**$7,105**		**$9,126**		**$13,475**	

NETWORK WL2Wx (INTERLACHEN PKWY MID-UPPER SECTION (WL2W2-1_1)

CATCHMENT DESCRIPTION

Catchment WL2W2-1_1 is part of a large catchment network. Catchment runoff receives little to no treatment before reaching Wilmes Lake. The values included in the Existing Conditions table below only include the drainage area contributing to the BMP opportunity. Total drainage area is 2.88 acres.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/ season)	1.8	0.0	0.0%	**1.8**
	TSS (lb/ season)	635.6	0.0	0.0%	**636**
	Volume (acre-feet/ season)	0.9	0.0	0.0%	**0.9**
	Number of BMP's	0			
	BMP Size/Description	0			

RETROFIT RECOMMENDATIONS

Bioretention BMPs optimally located along Interlachen Parkway could capture up to 2.88 acres of catchment WL2W2-1_1 (Mid-Upper Section). The following table considers up to 1 – 2,000 sqft bioretention cell with underdrains. The costs of this cell estimates installing a split-flow structure in the existing stormsewer network. See concept plan in appendix D.

	Cost/Removal Analysis	*Project ID*	
		parkway bioretention	
		New trtmt	Net %
Treatment	TP (lb/ season)	0.7	37%
	TSS (lb/ season)	233.0	37%
	Volume (acre-feet/ season)	0.1	13%
	Number of BMP's	1	
	BMP Size/Description	2,000	sqft
	BMP Type	Moderately Complex Bioretention	
Cost	Materials/Labor/Design	$36,000	
	Promotion & Admin Costs	$1,000	
	Probable Project Cost	**$37,000**	
	Annual O&M	$1,000	
	30-yr Cost/lb-TP/ season	**$3,436**	
	30-yr Cost/2,000lb-TSS/ season	**$19,170**	

NETWORK WL2Wx INTERLACHEN PKWY MID-LOWER SECTION (WL2W1-1_1)

CATCHMENT DESCRIPTION

Catchment WL2W1-1_1 is part of a large catchment network. Catchment runoff receives little to no treatment before reaching Wilmes Lake. The values included in the Existing Conditions table below only include the drainage area contributing to the BMP opportunity. Total drainage area is 24.41 acres.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/ season)	15.0	0.0	0.0%	**15.0**
	TSS (lb/ season)	3847.0	0.0	0.0%	**3,847**
	Volume (acre-feet/yr)	8.0	0.0	0.0%	**8.0**
	Number of BMP's	0			
	BMP Size/Description				

RETROFIT RECOMMENDATIONS

Bioretention BMPs optimally located along Interlachen Parkway could capture up to 24.41 acres of catchment WL2W1-1_1 (Mid-Lower Section). The following table considers up to 4 – 2,000 sqft bioretention cells with underdrains. The costs of this cell estimates installing split-flow structures in the existing stormsewer network. See concept plan in appendix D.

	Cost/Removal Analysis	*Project ID*					
		1 Bioretention		2 Bioretention		4 Bioretention	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/ season)	1.9	12.9%	3.0	20.2%	4.3	28.8%
	TSS (lb/ season)	755.0	19.6%	1150.0	39.3%	1603.0	41.7%
	Volume (acre-feet/ season)	0.3	3.4%	0.4	6.8%	0.7	8.1%
	Number of BMP's	1		2		4	
	BMP Size/Description	2,000	sqft	4,000	sqft	8,000	Sqft
	BMP Type	Moderately Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention	
Cost	Materials/Labor/Design	$36,000		$64,000		$112,000	
	Promotion & Admin Costs	$1,000		$1,500		$2,000	
	Probable Project Cost	**$37,000**		**$65,500**		**$114,000**	
	Annual O&M	$1,000		$2,000		$3,000	
	30-yr Cost/lb-TP/ season	**$1,151**		**$1,381**		**$1,570**	
	30-yr Cost/2,000lb-TSS/season	**$5,916**		**$7,275**		**$8,484**	

NETWORK WL1Wx (INTERLACHEN PKWY LOWER SECTION (WL1W2-1_1)

CATCHMENT DESCRIPTION

Catchment WL1W2-1_1 is part of a large catchment network. Catchment runoff is captured in Summit Point Park stormwater pond before reaching Wilmes Lake. The values included in the Existing Conditions table are for the entire catchment that drains to Summit Point Park stormwater pond (including Interlachen Parkway). The total drainage area captured is 300 acres.

	Existing Conditions	Base Loading	Existing Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/season)	198.0	108.9	55.0%	**89.1**
	TSS (lb/season)	80,858	41,402.0	51.2%	**39,456**
	Volume (acre-feet/season)	126.8	2.9	2.3%	**123.9**
	Number of BMP's	5			
	BMP Size/Description	5 qty - Stormwater Wet Ponds			

RETROFIT RECOMMENDATIONS

Bioretention BMPs were not considered feasible for the Lower Section catchments due to limited greenspace and steeper topography. Stormwater reuse is considered the most appropriate BMP for this section. The stormwater reuse BMP would consist of pumping stormwater from Summit Point Park and distributing throughout Summit Point Park (~3 acres) via a variable demand irrigation system. As modeled the system would achieve 99% of irrigation demand. The reuse system was modeled using WinSLAMM's water withdrawal rate table and Met Council's stormwater reuse guide – variable demand irrigation calculator. An estimated installation cost used for this reuse system is coarse due to limited information. See concept plan in appendix D.

	Cost/Removal Analysis	*Project ID*	
		Stormwater Reuse	
		New trtmt	Net %
Treatment	TP (lb/season)	9.6	11%
	TSS (lb/season)	5,184	13%
	Volume (acre-feet/season)	21.1	17%
	Number of BMP's	1	
	BMP Size/Description	133,150	sqft
	BMP Type	Stormwater Reuse	
Cost	Materials/Labor/Design	$200,000	
	Promotion & Admin Costs	$3,000	
	Probable Project Cost	**$203,000**	
	Annual O&M	$1,000	
	30-yr Cost/lb-TP/season	**$809**	
	30-yr Cost/2,000lb-TSS/season	**$2,996**	

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Tamarack Village Mall Subsection Memo

Tamarack Village Mall is included as a section to the Wilmes Lake Subwatershed Retrofit Analysis (SWA). This analysis provides recommendations for cost effectively improving treatment of stormwater runoff on the 95 acre Tamarack Village Mall site, identified in the SWWD's 2012 Water Quality Monitoring Report as a significant source area of phosphorus loading (.75 - .95 lbs/ac TP yield). The identified projects, cost estimates and load reductions (for reuse projects) within the this subsection were included in 2014 Technical Memo prepared by HR Green for SWWD in January, 2014 titled 'Tamarack Village Mall Stormwater Improvements: Stormwater Re-use & Iron-Enhanced Sand Filters – City of Woodbury, MN'. This report can be found in Appendix C.

CATCHMENT NETWORK	UNIQUE ID	DESRIPTION
NORTH	WL5W3-1_1 *of WL5Wx Network*	Stormwater Pond receiving runoff from north portion of site
WEST	WL5W4-1_1 *of WL5Wx Network*	Stormwater Pond receiving runoff from west portion of site
SOUTH	WL2W14-1_1 *of WL2Wx Network*	Stormwater Pond receiving runoff from south portion of site
SOUTHEAST	WL3W3-2_1 *of WL3Wx Network*	Stormwater Pond receiving runoff from southeast portion of site

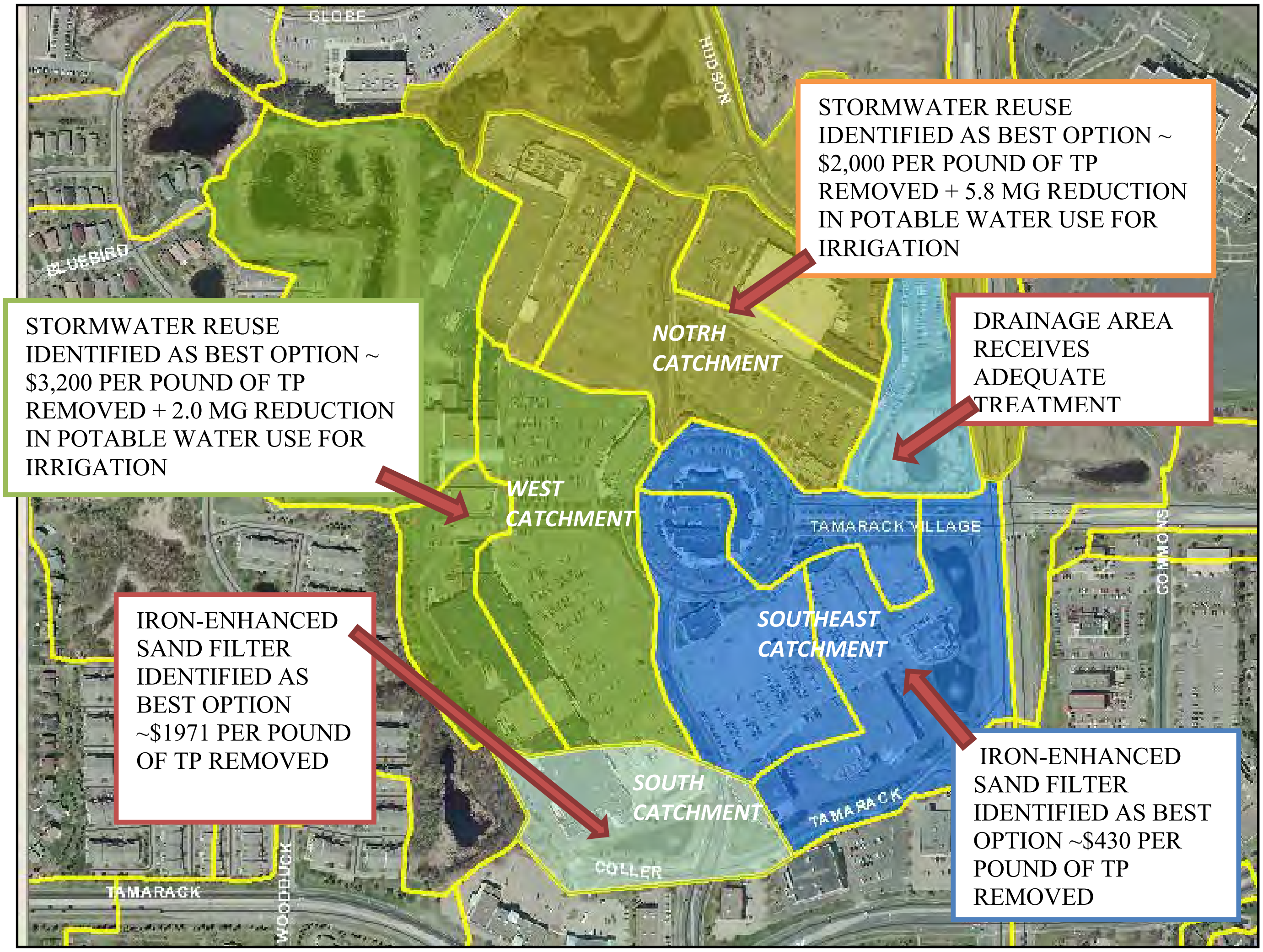
Note: The stormwater pond on the northeast portion of the site (WL3W3-1_1) was not considered for retrofit as the drainage area is too small to support stormwater reuse options and the stormwater pond area is too limited for pond retrofits.

Water quality Model Parameters:

Stormwater Reuse Projects – XPSWMM and Minnesota Stormwater Manual
IESF – WinSLAMM and Minnesota Stormwater Manual
All pollutant loading/reduction based on growing season (June – Sept)

A cost/benefit table and catchment profiles are included.

RETROFIT RECOMMENDATIONS



NETWORK WL5Wx (TAMARACK MALL NORTH & WEST SECTION)

Catchment Network Summary - Existing	
Acres	161.1
Dominant Land Cover	Commercial/Duplex
Volume (acre-feet/ season)	62.2
TP (lb/ season)	37.7
TSS (lb/ season)	22,610

CATCHMENT NETWORK DESCRIPTION

WL5Wx catchment network is comprised primarily of the commercial land use for Tamarack Village Mall and duplexes to the west.

EXISTING STORMWATER TREATMENT

Catchment network runoff flows into a complex treatment system of stormwater wetlands and ponds. The 2012 Water Quality Monitoring Report load reduction percentages were used for all wetlands and ponds in treatment system.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	88.5	50.6	57.4%	**37.7**
	TSS (lb/yr)	47564	24954	52.5%	**22,610**
	Volume (acre-feet/yr)	88.4	26.2	29.5%	**62.2**
	Number of BMP's	8			
	BMP Size/Description	5 stormwater ponds and 3 stormwater wetlands			

WL5W3-1_1 Pond Reuse System (North Pond)

Drainage Area – 117.3 acres (30.6 acres on site, 86.7 acres off site)
Location – North side of Tamarack Village Mall, along Hudson Rd.
Property Ownership – Public
Description – Opportunity to retrofit existing pond with a pump and connect to existing irrigation distribution systems for the north, northwest and central portions of Tamarack Village Mall. See Appendix C for more information.

	Cost/Removal Analysis	***Project ID***	
		Stormwater Reuse	
		New trtmt	**Net %**
Treatment	**TP (lb/season)**	12.5	33%
	TSS (lb/season)	N/A	N/A
	Volume (acre-feet/season)	17.8	29%
	Number of BMP's	1	
	BMP Size/Description	5.8	volume provided (millon gal)
	BMP Type	Stormwater Reuse System, connected to existing distribution system	
Cost	**Materials/Labor/Design**	$715000	
	Promotion & Admin Costs	$10,000	
	Probable Project Cost	**$725,000**	
	Annual O&M	$1,000	
	30-yr Cost/lb-TP/ season	**$2,013**	
	30-yr Cost/2,000lb-TSS/season	**N/A**	

WL5W4-1 1 Pond Reuse System (West Pond)

Drainage Area – 43.8 acres (24.6 acres on site, 19.2 acres off site)
Location – Directly west of Tamarack Village Mall
Property Ownership – Public
Description – Opportunity to retrofit existing pond with a pump and connect to existing irrigation distribution system for west portion of Tamarack Village Mall. See Appendix C for more information.

<table>
<tr><td rowspan="3"></td><td rowspan="3">Cost/Removal Analysis</td><td colspan="2">Project ID</td></tr>
<tr><td colspan="2">Stormwater Reuse</td></tr>
<tr><td>New trtmt</td><td>Net %</td></tr>
<tr><td rowspan="6">Treatment</td><td>TP (lb/season)</td><td>4.3</td><td>11%</td></tr>
<tr><td>TSS (lb/season)</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Volume (acre-feet/season)</td><td>6.1</td><td>10%</td></tr>
<tr><td>Number of BMP's</td><td colspan="2">1</td></tr>
<tr><td>BMP Size/Description</td><td>2.0</td><td>volume provided (million gal)</td></tr>
<tr><td>BMP Type</td><td colspan="2">Stormwater Reuse System, connects to existing distribution system</td></tr>
<tr><td rowspan="6">Cost</td><td>Materials/Labor/Design</td><td colspan="2">$389,000</td></tr>
<tr><td>Promotion & Admin Costs</td><td colspan="2">$10,000</td></tr>
<tr><td>Probable Project Cost</td><td colspan="2">$399,000</td></tr>
<tr><td>Annual O&M</td><td colspan="2">$1,000</td></tr>
<tr><td>30-yr Cost/lb-TP/season</td><td colspan="2">$3,326</td></tr>
<tr><td>30-yr Cost/2,000lb-TSS/season</td><td colspan="2">N/A</td></tr>
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Network WL3Wx (TAMARACK MALL SOUTHEAST SECTION)

Catchment Network Summary - Existing	
Acres	45.68
Dominant Land Use	Commercial
Volume (acre-feet/season)	25.9
TP (lb/ season)	11.9
TSS (lb/ season)	6,976

CATCHMENT NETWORK DESCRIPTION

WL3Wx catchment network is comprised primarily of the commercial land use for Tamarack Village Mall and of the Tamarack Mall – southeast section and direct runoff from Radio Drive and Hudson Road.

EXISTING STORMWATER TREATMENT

Catchment network runoff begins in a the Tamarack Village Mall receiving treatment from the on-site stormwater pond (WL3W3-2_1) then flows through a series of small stormwater ponds and stormwater wetlands before reaching Wilmes Lake. The 2012 Water Quality Monitoring Report load reduction percentages were used for all wetlands and ponds in treatment system.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/season)	25.9	14.0	54.1%	**11.9**
	TSS (lb/season)	16,126	9,150.0	56.7%	**6,976**
	Volume (acre-feet/season)	32.4	6.5	20.1%	**25.9**
	Number of BMP's	7			
	BMP Size/Description	5 stormwater ponds, 2 stormwater wetlands			

WL3W3-2_1 Pond Iron-Enhanced Sand Filter (Southeast Pond)

Drainage Area – 28.7 acres (26.9 acres on site, 1.9 acres off site)
Location – Southeast side of Tamarack Village Mall, adjacent to Radio Drive
Property Ownership – Private (easement)
Description – Opportunity to retrofit existing pond with an iron-enhanced sand filter with associated pond outlet modifications (weir). See Appendix C for more information.

	Cost/Removal Analysis	*Tamarack SE*	
		Iron-enhanced Sand Filter	
		New trtmt	Net %
Treatment	TP (lb/season)	9.5	90%
	TSS (lb/season)	N/A	N/A
	Volume (acre-feet/season)	N/A	N/A
	Number of BMP's	1	
	BMP Size/Description	3,500	sqft
	BMP Type	Structural Iron-Enhanced Sand Filter – 350' x 10'	
Cost	Materials/Labor/Design	$64,000	
	Promotion & Admin Costs	$2,000	
	Probable Project Cost	**$66,000**	
	Annual O&M	$1,460	
	30-yr Cost/lb-TP/season	**$430**	
	30-yr Cost/2,000lb-TSS/season	**N/A**	

Network WL2Wx (TAMARACK MALL SOUTH SECTION)

WL2W14-1 1 Pond Iron-Enhanced Sand Filter (South Pond)

Drainage Area – 8.0 acres
Location – South side of Tamarack Village Mall adjacent to Coller Way
Property Ownership – Private (easement)
Description – Opportunity to retrofit existing pond with an iron-enhanced sand filter with associated pond outlet modifications (weir). See Appendix B for more information.

	Cost/Removal Analysis	***Project ID***	
		Iron-enhanced Sand Filter	
		New trtmt	**Net %**
Treatment	**TP (lb/season)**	2.3	2%
	TSS (lb/ season)	500	0.1%
	Volume (acre-feet/ season)	0.0	0%
	Number of BMP's	1	
	BMP Size/Description	3,750	sqft
	BMP Type	Structural Iron-Enhanced Sand Filter (375' x 10')	
Cost	**Materials/Labor/Design**	$89,000	
	Promotion & Admin Costs	$2,000	
	Probable Project Cost	**$91,000**	
	Annual O&M	$1,500	
	30-yr Cost/lb-TP/ season	**$1,971**	
	30-yr Cost/2,000lb-TSS/ season	**$18,133**	

NETWORK WL2Wx

Catchment Network Summary - Existing	
Acres	729
Dominant Land Use	Residential
Volume (acre-feet/yr)	173.6
TP (lb/yr)	145.3
TSS (lb/yr)	59,974

CATCHMENT NETWORK DESCRIPTION

The WL2Wx catchment network comprises approximately 25% of the 2900 acre drainage area for Wilmes Lake. Though predominantly residential, WL2Wx contains significant commercial and multifamily residential areas; however, they are buffered by a 64 acre stormwater wetland (Evergreen Park). The main conveyance to Wilmes Lake is stabilized open channel and parkland.

EXISTING STORMWATER TREATMENT

WL2Wx contains a 64 acre stormwater wetland (Evergreen Park) in series with 3 large stormwater ponds (Seasons Park), connected by an open channel leading through wilmes lake ravine to wilmes lake north basin. The 2010 Wilmes Ravine Stabilization project resulted in significant TP and TSS load reductions (40 lbs/yr, 190.9 tons/yr respectively per BWSR Gully spreadsheet). From a subwatershed perspective, the WL2Wx catchment network is a low priority for additional retrofits as it already has significant treatment built in; however, the size of the network makes finding additional load reduction opportunities relevant, though less so than maintaining existing stormwater treatment systems.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	407.5	237.3	58.2%	**170.2**
	TSS (lb/yr)	545,691	459,882	84.3%	**85,809**
	Volume (acre-feet/yr)	256.8	83.2	32.4%	**173.6**
	Number of BMP's	10			
	BMP Size/Description	1 – Stormwater Wetland, 8 Stormwater Ponds, 1 Ravine Stabilization (Wilmes)			

RETROFIT RECOMMENDATIONS

WL2W14-1P Pond Iron-Enhanced Sand Filter

Drainage Area – 7.5 acres
Location – South side of Tamarack Mall
Property Ownership – Private
Description – Details of this project are located within the Tamarack Mall Section.

WL2W6-1_1 Radio Drive Bioswales

Drainage Area – 9.32 acres
Location – Radio Drive between Pinehurst Road and Seasons Parkway
Property Ownership – Public (ROW)
Description – There are expansive mowed ROW with rural ditch sections and wide medians along this section of Radio Drive. There are several opportunities for bioswale BMPs with multiple possible configurations identified throughout this catchment. The pollution reduction estimates assume 300 total lineal feet of ditch/median converted to bioswale with an average width of 18 feet (6 ft bottom, 6 ft sides). Biowswale inputs also factor a dense vegetative cover of 24 inches in height. The most beneficial bioswale location is within the median of Radio Drive buffering a catchbasin outletting into WL2W6-1_1 stormwater pond.

	Cost/Removal Analysis	*Project ID*	
		Bioswales	
		New trtmt	Net %
Treatment	TP (lb/yr)	1.1	1%
	TSS (lb/yr)	26,481	31%
	Volume (acre-feet/yr)	n/a	0%
	Number of BMP's	1	
	BMP Size/Description	5,400	sqft
	BMP Type	Water Quality Swale	
Cost	Materials/Labor/Design	$43,200	
	Promotion & Admin Costs	$2,000	
	Probable Project Cost	**$45,200**	
	Annual O&M	$300	
	30-yr Cost/lb-TP/yr	**$1,642**	
	30-yr Cost/2,000lb-TSS/yr	**$65,591.98**	

NETWORK 2857-1 & WL3-1

Catchment Network Summary – Existing	
Acres	62
Dominant Land Use	Duplex / Commercial
Volume (acre-feet/season)	27.2
TP (lb/ season)	34.3
TSS (lb/ season)	15,660

CATCHMENT NETWORK DESCRIPTION

This catchment network contains relatively high density and, therefore, high ratios of impervious surfaces to open space with minimal treatment. Catchment 2857-1 contains over 13 acres of strip commercial land use and over 18 acres of duplex land use. Catchment WL3-1 contains over 9 acres of duplex land use.

EXISTING STORMWATER TREATMENT

Catchment 2857-1 does not contain any stormwater BMPs. Catchment 2857-1 flows into catchment WL3-1 stormwater pond. Pollution reductions for WL3-1 pond are set at 9% TP reduction according to the 2012 Water Quality Report. This figure was used in the network modeling.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/season)	40.4	6.1	15.1%	**34.3**
	TSS (lb/season)	18,410	2,750.0	14.9%	**15,660**
	Volume (acre-feet/ season)	29.9	2.7	9.0%	**27.2**
	Number of BMP's	1			
	BMP Size/Description	stormwater pond			

RETROFIT RECOMMENDATIONS

2857-1 Biofiltration Raingardens

Drainage Area – 32.1 acres
Location – Multiple locations along Commons Drive and/or Spring View Way
Property Ownership – Private (ROW)
Description – Biofiltration Raingardens were identified as the most appropriate BMP type within the 2857-1 catchment. Practice locations must be adjacent to existing stormsewer structures in order to receive maximum drainage area and allow for underdrain connection. Cost estimates include 500 sqft average facility size with 1.5' – 2.5' retaining walls.

	Cost/Removal Analysis	***Project ID***					
		Bioretention-2		**Bioretention-4**		**Bioretention-8**	
		New trtmt	**Net %**	**New trtmt**	**Net %**	**New trtmt**	**Net %**
Treatment	**TP (lb/season)**	0.8	2.9%	1.7	6.8%	3.1	12.1%
	TSS (lb/ season)	450.0	3.5%	811.0	6.4%	1375.0	10.8%
	Volume (acre-feet/ season)	0.1	0.2%	0.1	0.4%	0.2	0.7%
	Number of BMP's	2		4		8	
	BMP Size/Description	1,000	sqft	2,000	sqft	4,000	sqft
	BMP Type	Moderately Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention	
Cost	**Materials/Labor/Design**	$18,000		$36,000		$70,000	
	Promotion & Admin Costs	$3,000		$4,000		$6,000	
	Probable Project Cost	**$21,000**		**$40,000**		**$76,000**	
	Annual O&M	$500		$1,000		$2,000	
	30-yr Cost/lb-TP/ season	**$1,600**		**$1,341**		**$1,462**	
	30-yr Cost/2,000lb-TSS/ season	**$5,333**		**$5,754**		**$6,594**	

NETWORK WL1Nx + 1072_1

Catchment Network Summary – Existing	
Acres	120
Dominant Land Use	MDRNA
Volume (acre-feet/yr)	24.5
TP (lb/yr)	32.8
TSS (lb/yr)	13,335

CATCHMENT NETWORK DESCRIPTION

Catchment network WL1Nx (including 1072_1) is the only network in this analysis identified draining to Wilmes Lake from the east side of the subwatershed. This land use within this network is almost entirely MDRNA

EXISTING STORMWATER TREATMENT

There are 3 stormwater wetlands and 2 stormwater ponds within the drainage network. The last stormwater pond in the network is located just inside of the WL1-1 catchment (South Wilmes Lake) and provides the best opportunity for retrofitting in this network.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/season)	55.3	22.5	40.7%	**32.8**
	TSS (lb/season)	21,847	8,512.0	39.0%	**13,335**
	Volume (acre-feet/season)	33.7	9.2	27.3%	**24.5**
	Number of BMP's	5			
	BMP Size/Description	3 - Stormwater wetlands, 2 Stormwater Ponds			

RETROFIT RECOMMENDATIONS

1072-1 Outlet Pond Iron-Enhanced Sand Filter

Drainage Area – 120 acres
Location – Near Intersection of Wynstone Way and Schooner Drive
Property Ownership – Public
Description – The iron-enhanced sand filter would be retrofitted onto a small stormwater pond at the outlet of catchment 1072_1 outlet adjacent to South Wilmes Lake. Costs include significant retaining walls (2' – 3' are needed to provide a 10' wide bench at 180' in length, a new outlet structure to accommodate IESF underdrains and weir.

	Cost/Removal Analysis	***Project ID***	
		Iron-enhanced Sand Filter	
		New trtmt	**Net %**
Treatment	**TP (lb/yr)**	16.0	49%
	TSS (lb/yr)	n/a	0%
	Volume (acre-feet/yr)	n/a	0%
	Number of BMP's	1	
	BMP Size/Description	1,800	sqft
	BMP Type	Structural Iron-Enhanced Sand Filter	
Cost	**Materials/Labor/Design**	$99,600	
	Promotion & Admin Costs	$4,000	
	Probable Project Cost	**$103,600**	
	Annual O&M	$1,500	
	30-yr Cost/lb-TP/yr	**$310**	
	30-yr Cost/2,000lb-TSS/yr	**N/A**	

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Appendix A: Methods

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Methods

Selection of Subwatershed

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

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

Stormwater Retrofit Analysis Methods

The process used for this analysis is outlined in the following pages and was modified from the Center for Watershed Protection's *Urban Stormwater Retrofit Practices,* Manuals 2 and 3 (Schueler, 2005, 2007). Locally relevant design considerations were also incorporated into the process (*Minnesota Stormwater Manual*).

Step 1: Retrofit Scoping

Retrofit scoping includes determining the objectives of the retrofits (volume reduction, target pollutant, etc.) and the level of treatment desired. It involves meeting with local stormwater managers, city staff and watershed management organization members to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to analyze in large subwatersheds, a focus area may be determined.

In this analysis, the focus area was all areas that drain to Wilmes Lake. Included are areas of residential, commercial, industrial, and institutional land uses. The subwatershed was divided into 10 catchments using a combination of existing subwatershed mapping data, stormwater infrastructure maps, and observed topography.

The targeted pollutant for this study was total phosphorus, though total suspended solids and volume were also modeled and reported. Total phosphorus (TP) was chosen as the primary target pollutant because long term water quality monitoring has identified elevated levels Wilmes Lake. Total suspended solids (TSS) was also reported because many other pollutants, such as heavy metals, are transported by these particles. Volume of stormwater was tracked throughout this study because it is necessary for pollutant loading calculations and potential retrofit project considerations.

Step 2: Desktop Retrofit Analysis

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

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

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

Step 3: Retrofit Reconnaissance Investigation

After identifying potential retrofit sites through this desktop search, a field investigation was conducted to evaluate each site and identify additional opportunities. During the investigation, the drainage area and stormwater infrastructure mapping data were verified. Site constraints were assessed to determine the most feasible retrofit options as well as eliminate sites from consideration. The field investigation may have also revealed additional retrofit opportunities that could have gone unnoticed during the desktop search.

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

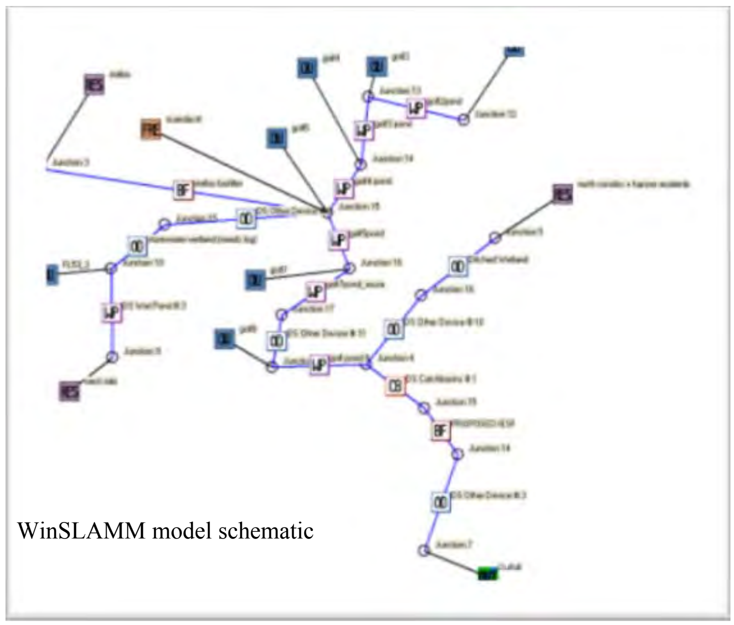
Stormwater Treatment Options for Retrofitting		
Area Treated	**Best Management Practice**	**Potential Retrofit Project**
5-500 acres	Extended Detention	**12-24 hr detention of stormwater with portions drying out between events (preferred over wet ponds). May include multiple cell design, infiltration benches, sand/peat/iron filter outlets and modified choker outlet features.**
	Wet Ponds	**Permanent pool of standing water with new water displacing pooled water from previous event.**
	Wetlands	**Depression less than 1-meter deep and designed to emulate wetland ecological functions. Residence times of several days to weeks. Best constructed off-line with low-flow bypass.**
0.1-5 acres	Bioretention	**Use of native soil, soil microbe and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.**
	Filtering	**Filter runoff through engineered media and pass it through an under-drain. May consist of a combination of sand, soil, compost, peat, and iron.**
	Infiltration	**A trench or sump that is rock-filled with no outlet that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering infiltration area.**
	Swales	**A series of vegetated, open channel practices that can be designed to filter and/or infiltrate runoff.**
	Other	**On-site, source-disconnect practices such as rain-leader Disconnect rain gardens, rain barrels, green roofs, cisterns, stormwater planters, dry wells, or permeable pavements.**

Step 4: Treatment Analysis/Cost Estimates

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

Treatment analysis

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



WinSLAMM model schematic

The newest version of WinSLAMM (version 10), which allows routing of multiple catchments and stormwater treatment practices, was used for this analysis because of the unique connectivity amongst the catchments identified in the focus area under investigation.

The initial step was to create a "base" model which estimated pollutant loading from each catchment in its present-day state without taking into consideration any existing stormwater treatment. To accurately model the land uses in each catchment, we delineated each land use in each catchment using geographic information systems (specifically, ArcMap), and assigned each a WinSLAMM standard land use file. A site specific land use file was created by adjusting total acreage and accounting for local soil types (all soils were modeled as silt in this analysis). This process resulted in a model that included estimates of the acreage of each type of source area (roof, road, lawn, etc.) in each catchment. For certain source areas critical to our models we verified that model estimates were accurate by calculating actual acreages in ArcMap, and adjusting the model acreages if needed.

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

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

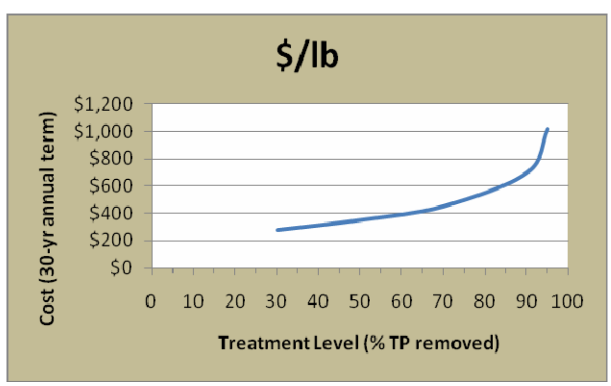
WinSLAMM stormwater computer model inputs

General WinSLAMM Model Inputs	
Parameter	**File/Method**
Land use acreage	ArcMap
Flow/Routing	Municipal Stormsewer data
Precipitation/Temperature Data	Minneapolis 1959 – the rainfall year that best approximates a typical year, only used seasonal dates – 6.1 – 9.30
Winter season	Included in model. Winter dates are 11-4 to 3-13.
Pollutant probability distribution	WI_GEO01.ppd
Runoff coefficient file	WI_SL06 Dec06.rsv
Particulate solids concentration file	WI_AVG01.psc
Particle residue delivery file	WI_DLV01.prr
Street delivery files	WI files for each land use.

Cost Estimates

All estimates were developed using 2013 dollars. Cost estimates were annualized costs that incorporated design, installation, installation oversight, and maintenance over a 10-year period. In cases where promotion to landowners is important, such as rain gardens, those costs were included as well. In cases where multiple, similar projects are proposed in the same locality, promotion and administration costs were estimated using a non-linear relationship that accounted for savings with scale. Design assistance from an engineer is assumed for practices in-line with the stormwater conveyance system, involving complex stormwater treatment interactions, or posing a risk for upstream flooding. It should be understood that no site-specific construction investigations were done as part of this stormwater retrofit analysis, and therefore cost estimates account for only general site considerations.

The costs associated with several different pollution reduction levels were calculated. Generally, more or larger practices result in greater pollution removal. However the costs of obtaining the highest levels of treatment are often prohibitively expensive (see figure). By comparing costs of different treatment levels, the cities and watershed 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. Only projects that seemed realistic and feasible were considered. The recommended level was the level of treatment that would yield the greatest benefit per dollar spent while being considered feasible and not falling below a minimal amount needed to justify crew mobilization and outreach efforts. Local officials may wish to revise the recommended level based on water quality goals, finances, or public opinion.

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Appendix B:
How to Read Catchment Profiles

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Catchment Profiles and How to Read Them

The analysis contains pages referred to as "Catchment Profiles." These profiles provide the most important details of this report, including:

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

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

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

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

Base conditions - Volume and pollutant loadings from the catchment landscape without any stormwater practices.

Existing conditions -Volume and pollutant loadings after already-existing stormwater practices are taken into account.

Proposed conditions - Volume and pollutant loadings after proposed stormwater retrofits.

Analyses were performed at one of two geographic scales, "catchment or network." They are defined as follows:

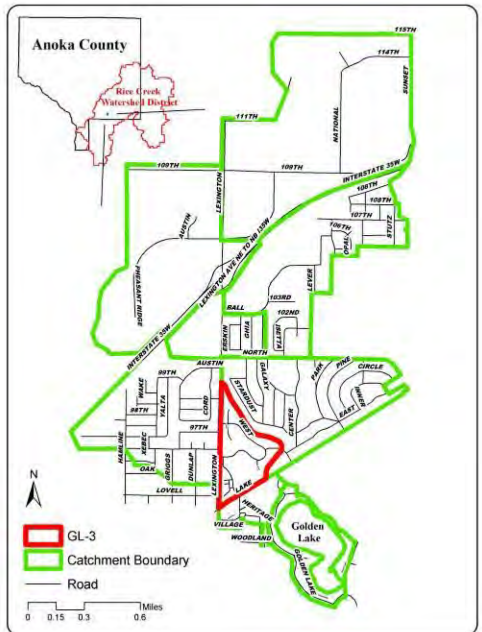
Catchment level analyses - Volume and pollutant loads exiting the catchment at the catchment boundary. There may be other stormwater practices existing or proposed farther downstream, but this analysis ignores them.

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

HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Catchment A

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



DESCRIPTION

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

EXISTING STORMWATER TREATMENT

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

Catchment ID banner.

Volume and pollutants generated from this catchment under existing conditions, and excludes existing network-wide treatment practices

Catchment locator map.

HOW TO READ THE CATCHMENT PROFILES

Catchment-level analysis of existing conditions.

Catchment Specific Existing Conditions

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

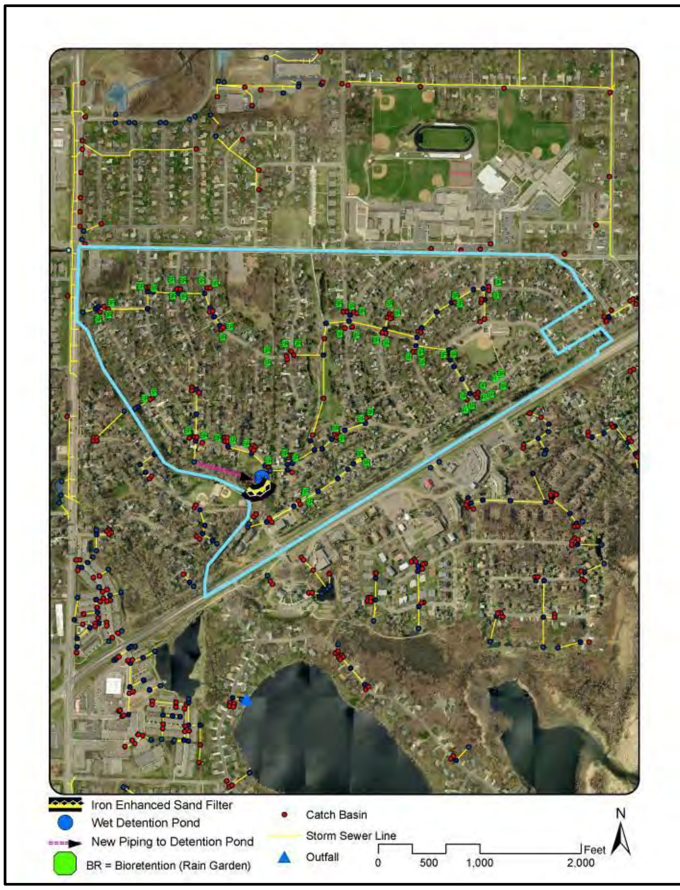
Volume of water and pounds of pollutants generated from the catchment without any stormwater management practices (base conditions).

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

Pollutants and volume exitsing the catchment after existing practices.

Percent reductions by existing practices.

HOW TO READ THE CATCHMENT PROFILES



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

Proposed stormwater retrofits. The project ID number corresponds to this project's catchment and project type.

RETROFIT RECOMMENDATIONS

Project ID LCC-1 Residentia l RG's – Curb-Cut Rain Garden Network

Drainage Area – 33.7 acres
Location – 5 locations throughout residential area
Property Ownership – Private
Description – The residential land cover within this catchment is best suited to residential, curb-cut rain gardens (see Appendix B for design options). Seven optimal rain garden locations were identified (see map below). Generally, ideal curb-cut rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical land owner participation rates we analyzed multiple quantity sets of raingardens (and shoreline restorations) within our study. Volume and pollutant reductions resulting from the rain garden installations are highlighted in the tables below.

HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Catchment Specific Cost/Benefit Analysis

Volume or pollutant removal this project will achieve.

Three "levels" of this project are compared: 6, 9, or 12 rain gardens, for example.

Pollutant removal achieved by this project.

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

Project installation cost estimation.

Cost effectiveness at suspended solids removal. The project cost is divided by suspended solids removal in tons (10 yrs). Includes operations and maintenance over the project contract life (10 years).

Cost effectiveness at phosphorus removal. The project cost is divided by phosphorus removal in pounds (10 yrs). Includes operations and maintenance over the project life (10 years unless otherwise noted).

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

HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Network-Wide Cost/Benefit Analysis

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

This table is the same as the previous catchment-level table, except it examines the costs and benefits of proposed stormwater retrofits at the network level.

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Appendix C:

Technical Memorandum

Tamarack Village Mall Stormwater Improvements: Stormwater Re-use & Iron Enhanced Sand Filters City of Woodbury, MN

January 24, 2014

HRG Project No: 20130066

Prepared For:

South Washington Watershed District

Washington County Conservation District

Prepared By:

HRGreen

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Introduction

The Tamarack Village Mall is an outdoor shopping center located west of the intersection of Radio Drive and Hudson Road in the City of Woodbury, MN. The approximately 95-acre complex is mostly built out, resulting in approximately 83 acres of impervious surface conveying stormwater to Wilmes Lake and the subsequent surface water features within the Colby Lake watershed. Based on previous water quality models, Tamarack Village was identified as a major source of total phosphorous, contributing approximately 0.85 lbs/acre/year to the Colby Lake system, which is considered impaired based on synthetic nutrient loads. To improve water quality discharging from the site, either stormwater re-use for on-site irrigation purposes or iron enhanced sand filter benches within the existing ponds are being proposed. Annual irrigation records for the shopping center from 2010 through 2012 indicate a high demand for potable water used for irrigation (approximately 10.2 million gallons per year), so an opportunity exists to both offset potable water demands with stormwater harvesting measures. Both re-use and iron enhanced sand filter benches will improve water quality and reduce the impacts of stormwater discharge to downstream systems by either infiltrating stormwater on-site or reducing discharges rates through a filtering media for larger probability events

The primary focus of this report is to provide a feasibility analysis for stormwater re-use, charting the stormwater volume that can be used for irrigation demand and subsequently infiltrated on-site. A secondary analysis consisted of deterring the feasibility of retrofitting selected stormwater ponds with an iron enhanced sand filters capable of reducing total phosphorous loads. .

I. Storm Water Re-Use

Irrigation Demand

Approximately 12 acres of planted boulevards and green space are irrigated via five separate irrigation systems within mall property. Based on water meter records from 2010 through 2012, the owners of the mall are paying approximately $23,000 annually for irrigation of their property. Throughout the growing season (April through October), approximately 10.2 million gallons (31 ac-ft) of the City’s potable water are distributed over these 12 acres. Over the 214 growing days, this translates to an average daily usage rate of approximately 0.17 acre-feet per day. The five distribution systems as well as the approximate water meter locations are shown in Figure 1 (included in the Appendix).

Based on the high demand and associated costs for irrigation needs, five existing stormwater ponds, shown in Figure 1, were investigated for the feasibility of sourcing irrigation volumes. Because use of stormwater as the irrigation source is dependent on recharge from rainfall events and the associated runoff generated, the critical growing season period used in the subsequent analysis was reduced from 214 days (April through October) to 122 days (June through September). This was done for two reasons: 1) recharge feasibility must focus on the peak demand period and 2) the monthly water meter records indicate a monthly variance and a peak demand season. Chart 1 below illustrates the greatest demand for irrigation volumes from June through September.

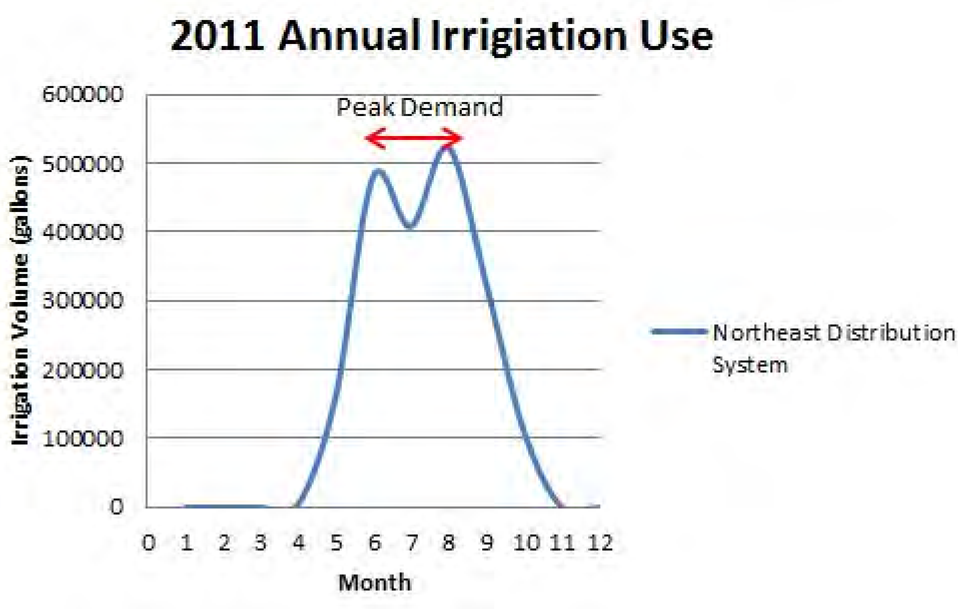


Chart 1: Determined Peak Demand Period

Using this peak demand season, the average daily irrigation volume increases to 0.22 acre-feet per day. Table 1 below identifies the average daily irrigation demand compiled over three years of records for each distribution system. The volumes shown were increased by 10% for design purposes.

Table 01: Average Irrigation Demand for each Distribution System

Distribution System	Average Design Daily Demand (ac-ft)
Northeast	0.06
Northwest	0.05
Southwest	0.04
Southeast	0.06
Central	0.03
Total	**0.24**

Re-Use Ponds and Drawdown Volumes

Five constructed stormwater ponds within the Tamarack Mall parcel were identified as potential stormwater re-use storage locations. Existing wetlands and constructed wetlands were deemed unacceptable due to anticipated regulatory hurdles. Of the five ponds shown in Figure 1, only the southernmost (S) pond is not adjacent to nor hydraulically connected to a wetland system. Since this study did not include the analysis of the groundwater surface water interaction for each pond system or a review of the records indicating the presence of a pond liner, it was assumed that each stormwater pond would be lined and that drawdown would only occur below the normal water level (NWL) of each stormwater pond, not directly affecting abutting wetland systems. For further studies, it is recommended that the groundwater interaction be reviewed in particularly for the west (W) and north (N) ponds.

Based on the review of the design plans for each stormwater pond, the dead pool volume from the NWL to a depth 2-foot below the NWL was calculated. A maximum depth of 2-feet was used as a boundary condition to reduce aesthetic impacts of drawdown to the ponds. Re-use calculations included available dead pool volume in the ponds between rainfall events rather than the live pool storage that comes into play only during storm events. Table 2 identifies incremental drawdown depths and associated drawdown volumes for each storm water pond.

Table 02: Available Stormwater Pond Drawdown Volumes

Stormwater Pond	Available Drawdown Volume (ac-ft)	
	1-ft	2-ft
N	0.85	1.55
W	0.92	1.73
S	0.36	0.63
SE	0.82	1.45
NE	0.16	0.28
Total	**3.12**	**5.65**

Since many of the ponds are connected to wetland systems through an overflow berm, constructing pond modifications to the raise the NWL would be invasive to the wetland system and most likely result in many permitting challenges. For this reason and since drawdown volume is not the limiting design factor for this re-use system, outlet modifications were not investigated and are not recommended.

Recharge Volumes

Although it is critical to having enough dead pool storage at one time to meet irrigation demands, it is also critical to have a continual source of inflow runoff that meets this daily demand throughout the peak season. The hydrologic conditions for each of the potential re-use ponds are somewhat unique, as a site and individually, as several of the ponds are routed to a downstream system and many of the ponds receive inflow from off-site areas. Figure 2, included in the Appendix, and Table 3 below illustrate the contributing on-site (direct inflow) and off-site (indirect inflow) subwatershed area for each pond and the interconnectivity between each system.

Table 03: Subwatershed Areas

Routed to Stormwater Pond	On-site Inflow Area (ac)	Off-site Inflow Area (ac)	% Off-site Inflow Area	Total Area (ac)
N	30.6	86.7	74%	117.3
W	24.6	19.2	44%	43.8
S	8.0	0.0	0%	8.0
SE	26.9	1.9	7%	28.7
NE	2.2	3.0	57%	5.2
Total	**92.3**	**110.8**	**53%**	**203.1**

Since many of the wetland systems are controlled via low flow berm, it was assumed that increases in inflow and bounce above the NWL happen relatively uniform within and through these systems. Therefore, when determining the inflow volumes (recharge amounts), the total watershed area draining to each pond system was used. Inflow volumes were calculated in XPSWMM based on the South Washington Watershed District's (SWWD) comprehensive H&H model. Inflow volumes were determined for a series of common, higher probability rainfall events more critical for recharging dwindling reserves at a higher frequency. Table 4 shows the calculated inflow volumes for the 0.25, 0.50 and 1.0-inch 24-hour storm events with a Type II rainfall distribution.

Table 04: Available Design Recharge Volume

Routed to Stormwater Pond	Available Design Inflow Volume (ac-ft) (24hr Type II Storm)		
	0.25-inch	**0.5-inch**	**1.0-inch**
N	0.58	2.09	6.42
W	0.09	0.56	1.62
S	0.02	0.12	0.33
SE	0.03	0.21	0.61
NE	0.01	0.06	0.17
Total	**0.73**	**3.04**	**9.15**

To understand the frequency in which a targeted rainfall depth occurs, historical rain gage information collected in the immediate area was analyzed. Rain gage data from the University of Minnesota's Climatology Department provided daily precipitation amounts from 2008 through 2012. The data was condensed to review only daily precipitation records within the determined peak irrigation period explained above. Statistics were completed to determine the inter-event duration (i.e. dry period) between storms resulting in rainfall depths greater than or equal to a 0.25, 0.5 and 1.0-inch event.

Table 05: Rainfall Statistics

Minimum Rainfall Event Depth	Inter-Event Duration (Days)
0.25-inch	7
0.5-inch	12
1.0-inch	29

Based on the inter-event durations shown in Table 5, the total irrigation demand within the dry period was determined for the entire site and for each irrigation (distribution) system. Since the design inflow volumes presented in Table 4 showed minimal on-site volumes produced for the 0.25-inch rainfall event and Table 5 showed a drastically longer inter-event duration for the 1.0-inch event, the analysis of the total irrigation demand volume was condensed to only review the demand between a 0.5-inch or greater rainfall event. Table 6 illustrates the estimated demand of irrigation volume between 0.5-inch or greater rainfall events. An example calculation follows.

Total Demand Volume between rainfall events for the Northeast distribution system =

0.055 ac-ft (Table 1 - Average Design Daily Demand) x 12 (Table 5 - Inter-Event Duration) = 0.66 ac-ft

Table 06: Total Demand Volume During Dry Periods

Distribution System	Estimated Irrigation Volume Demand (ac-ft) Between Rainfall Events
Northeast	0.66
Northwest	0.56
Southwest	0.50
Southeast	0.73
Central	0.37
Total	**2.82**

Sourcing Stormwater to Distribution Systems

With the spatial spread of the stormwater ponds, variable NWLs, dead pool storage volumes, inflow volumes, irrigation demands and the presence of separate irrigation systems, the feasibility of harvesting dead pool pond volumes on a global site basis (i.e all ponds would feed all distribution systems equally and simultaneously) would be a major challenge and cost. Therefore, this analysis included sourcing stormwater from an onsite pond to a distribution system in close proximity. The most effective option for each pond and distribution system based on matching the following elements together was analyzed:

1) Nearest stormwater pond location to closest location of distribution system

2) Dead pool drawdown volumes (Table 2) is greater than or equal to estimated irrigation demand volume (Table 6)

3) Available design inflow volume (Table 4) is greater than or equal to estimated irrigation demand volume (Table 6),

Since the NE pond illustrates the smallest dead pool drawdown and recharge volumes, harvesting stormwater from this pond was eliminated from consideration. Tables 7 and 8 identify proposed combinations and illustrate where the available recharge and drawdown volumes meet the demand volumes.

Table 07: Option 1 – Proposed Re-Use System

Stormwater Pond Drawing From	Routed to Distribution System(s)	Irrigation Demand Volume (ac-ft)	Available Combined Runoff Recharge Volume (ac-ft)	Available Combined Drawdown Volume (ac-ft)	Maximum Drawdown Depth (ft)
N	Northwest, Northeast & Central	1.59	2.09	1.55	2
W	Southwest	0.50	0.56	0.92	1
SE & S	Southeast	0.73	0.33	1.18	1

Table 08: Option 2 – Proposed Re-Use System

Stormwater Pond Drawing From	Distribution System	Irrigation Demand Volume (ac-ft)	Available Combined Runoff Recharge Volume (ac-ft)	Available Combined Drawdown Volume (ac-ft)	Drawdown Depth (ft)
N	Northwest, Northeast & Central	1.59	2.09	1.55	2
W	Southwest	0.50	0.56	0.92	1
SE	Southeast	0.73	0.21	0.82	1

Both options identify the limiting factor in red, and calculations were based on a 0.5-inch or greater storm event and the inter-event period associated. For example, Option 2 includes drawing stormwater from the SE pond to supply water to the Southeast irrigation system, but the available runoff would not meet the total demand volume. For this option, potable water would need to supplement harvested rainwater during dry periods when the estimated recharge volume is not available.

Table 9 below identifies the percentage of total demand provided by the limiting factor (either the available recharge or drawdown volume) for the mall as a whole. For example, in Option 2, a total of 2.26 ac-ft (1.55 + 0.50 + 0.21) of volume is available while 2.82 ac-ft of irrigation demand is needed.

Table 09: Available Volume versus Total Demand

Option	% of Total Demand
1	84%
2	80%

Since Option 1 has minimal increases in the percentage of the total demand being met but would require additional infrastructure to tie the SE and S stormwater ponds together, Option 2 is recommended.

Water Quality Improvements

For a commercial and residential area the Minnesota Storm Manual estimates an event mean concentration for total phosphorous (TP) to be 0.22 mg/L and 0.3 mg/L, respectively. Based on the results of Option 2 , 80% of the average annual use of 10.2 million gallons (equating to 8.2 million gallons) of potable water for irrigation purposes would be substituted with stormwater volumes. Assuming the application of watering of the green space incorporates conservation practices (excess runoff is minimized), it's valid to assume all stormwater volumes used of irrigating will infiltrate. Considering the source volumes are comprised mainly of commercial and residential land uses, an annual TP load reduction of 15 to 20 pounds is anticipated. This total TP removal is based on all re-use systems for Option 2 to be implemented. A breakdown of estimated removals for each re-use system is presented in Table 10 below. As seen the N pond results in the greatest removal estimates since the supplied volume is nearly 60% of the total demand throughout the mall area.

Table 10: Estimated Annual TP Removal

Stormwater Pond Drawing From	Distribution System	Average Annual Demand (Million Gallons)	% of Demand Per Distribution System(s)	Provided Average Annual Volume (Million Gallons)	Estimated TP Removal Per Year (lbs)
N	Northeast, Northwest, Central	5.9	97%	5.8	12.5
W	Southwest	2.0	100%	2.0	4.3
SE	Southeast	2.6	29%	0.75	0.7
Total	All	10.2	80%	8.2	17.5

Regulatory Issues

Installation of any structures, including pump stations and pipes, within the project area will likely require wetland-related permitting. Additionally, any drawdown or added water that may cause a change in wetland type (e.g. drawdown changing a Type 4 Deep Marsh into a Type 3 Shallow Marsh) may also require permitting and investigation. As discussed earlier, it's proposed that groundwater interaction and consequent drawdown effects could be minimalized if the stormwater ponds (specifically the N and W pond) adjacent to native or constructed wetland features would be lined with an impermeable layer below the NWL. Potential permit agencies would include SWWD for Minnesota Wetland Conservation Act Permits, Minnesota DNR for impacts to Public Waters, the Minnesota Board of Soil and Water Resources for impacts to replacement/mitigation wetlands (if present), and the St. Paul District of the U.S. Army Corps of Engineers for potential impacts to Waters of the U.S.

The regulatory nature of wet basins in the project area will not be clear without further investigation. A wetland delineation using methods described in the 1987 Corps of Engineers Wetlands Delineation Manual and Northeast and Northcentral Supplement will determine wetland extents in the area. Submittal of Minnesota Local/State/Federal Application Form for Water/Wetland Projects (Form 03B) would begin the wetland permit review process, although early agency coordination may help identify issues prior to submittal of the permit application.

Design Concepts

Pumps Stations

The proposed stormwater irrigation system upgrades consist of three pump stations, each pump station will be located at a stormwater pond which will serve as water source for irrigation. Each pump station consists of a wet well containing a single pump, control valve, and check valve. The pumps will be designed to provide the same pressure (approximated at 60 psi) at the connection to the watermain that is currently provided by the city water supply. The design flows for each pump assumed the total daily flow is distributed during a 1 hour period per day. For systems where the pump would distribute flows to multiple irrigation systems, it was assumed flows would not be drawn simultaneously to each irrigation system but each system would be on a separate schedule. Stormwater will be conveyed from the stormwater ponds to the irrigation system connection point via a PVC force main pipe. When stormwater volume is sufficient within the ponds, the proposed pump stations will supply the irrigation water. During periods of low water levels in the stormwater ponds, automatic control valves will allow city water to supply the irrigation system.

Based on the design for Option 2 presented in Table 8 and illustrated in Figure 3 (included in the appendix), the north pond pump station equipped with a 25HP pump would serve the northwest, northeast and central irrigation systems. The west pond pump station equipped with a 15HP pump would serve the southwest irrigation system and the southeast pond equipped with a 22 HP pump would serve will supply the southeast irrigation system. Varying pump horsepower is a result different static head and demand flows per system. The basis of the design is included in the appendix.

Pond Lining

Since the W and N pond are both situated next to wetland complexes, it's proposed that pond liners be included for both ponds. This is based on the assumption that a pond liner does not currently exist. The placement of a pond liner from the NWL down to the bottom elevation of the pond would create an impermeable layer prohibiting or restricting groundwater interaction between the ponds and wetlands. This would result in making sure the drawdown volumes are being sourced directly from the stormwater ponds rather from the connected pond and wetland system. To minimize any disturbance to regulated wetlands during a liner install, it's proposed that a 1-inch depth of AquaBlok product be used. This being AquaBlok can be installed without the need to drain the ponds/wetlands and would alleviate or minimize regulatory challenges.

Aesthetic Improvements

Due to the substantial grade difference between the road and the NWL and the presence of tall vegetation around the ponds aesthetic issues for the N and W pond is not a major concern. However, aesthetic issues due to a drawdown are a concern for the SE pond. This being the SE pond lies in highly visible area, grade difference is minimal and the pond edge is manicured and mowed. To mask the fluctuating NWLs for this pond, it's proposed that river rock be placed around the edge of the pond at an elevation 1-ft above and below the NWL. Aesthetic improvements for this pond perimeter do not include native seeding or plantings as this is dependent on the owners input.

II. Iron Enhanced Sand Filter

As an alternative to re-use, HR Green also investigated the possibility of installing iron enhanced sand filter benches within select existing stormwater ponds. The S and SE ponds were analyzed for their potential of housing a sand filter bench based on 1) the presence of a near 10:1 (H:V) slope just above the NWL as shown in the two figures below and 2) the fact that iron enhanced sand filter benches are designed to be above the NWL. Since a bench already exists, it's reasoned that minimum grading or disturbance would be necessary effectively reducing retro-fitting costs.

Figure A: Northern Portion of SE Pond

Figure B: South Pond Bench

The design included analyzing the existing pond hydraulics based on the SWWD's XPSWMM model and developing a proposed option that maintains or nearly maintains existing conditions related to flood control.

Using pond dimensions from the XPSWMM model, HR Green determined the maximum live storage volume that could be routed through each filter to both limit the drawdown time to meet design criteria values and allow for proposed peak water elevations to be at or below existing elevations. In order to maximize the life of the iron filings (i.e. prevent clogging or iron loss), the filings need to be in an aerobic environment where, based on the MN Stormwater Manual, stormwater needs to drawdown in 48 hours or less. The sand filter bench, set above the NWL, was designed with a 3:1 rip rap toe to prevent erosion and hold the enhanced media in place. Behind the rip rap, a 10-foot wide sand filter bench with a 10:1 slope and a 5% by weight mixture of sand and iron filings is proposed. Design calculations utilized an average infiltration rate from the MN Stormwater Manual and St. Anthony Falls Laboratory field results. With these two parameters and a set criterion of a maximum drawdown period of 48-hours, the bench length for each pond was determined. Results for the minimum bench lengths are presented in Table 11 below.

To force high probability stormwater volumes through the iron enhanced sand media and into the proposed perforated pipes rather than through the existing outlet, the design includes a weir structure at the pond outlet. The weir is situated downstream of the existing culvert opening. The perforated pipes surrounded in coarse aggregate material connect into the outlet structure on the downstream side of the weir. The height of the weir was designed to both maximize the amount of stormwater volume that would be conveyed and treated through the enhanced sand filter, refereed as Water Quality Volume in Table 11, and allow for proposed and existing peak elevations to match. Since the S pond has 8-feet of available bounce before overtopping, the weir was set at a higher elevation than the SE pond, effectively maximizing the water quality volume.

Table 11: Sand Filter Treatment Parameters

Pond	NWL	Water Quality Volume	Minimum Bench Length	Weir Height Above NWL	Weir Height Above NWL
		(ac-ft)	(ft)	(ft)	(ft)
SE	1010	1.35	350	1.2	1011.2
S	1012	1.57	375	2.5	1014.5

The sand filter inflow rates and pond outlet adjustments were incorporated into a proposed model based off the SWWD's existing XPSWMM model. One discrepancy was noticed in the SWWD's existing model for the SE pond. In the existing model, the SE pond outlet includes a 21-inch pipe under Hudson Road to the north. Based on a field visit, the pond outlet should also include a 48-inch grate located approximately 2-feet above the invert of the 21-inch pipe. By including the existing grate in the model, peak elevations decrease compared to the submitted SWWD existing model. This grate was incorporated into the Existing with Grate and Proposed conditions model. Proposed and existing conditions for each pond are listed in Table 12 below.

Table 12: Pond - Existing and Proposed Conditions

Pond	Event	Existing		Existing with Grate		Proposed	
		WSE	Discharge Rate	WSE	Discharge Rate	WSE	Discharge Rate
		(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)
SE	2-yr	1011.84	8.7	1011.84	8.7	1012.01	8.7
	10-yr	1012.87	12.6	1012.55	26.1	1013.10	19.6
	100-yr	1014.29	78.9	1013.71	95.8	1014.34	104.0
S	2-yr	1012.89	7.0	1012.89	7.0	1013.48	0.4
	10-yr	1013.28	12.7	1013.28	12.7	1014.54	0.5
	100-yr	1014.32	19.5	1014.32	19.5	1015.40	15.2

When comparing the Proposed conditions model to the Existing with Grate conditions model for the SE pond, WSE's increase by approximately 0.2-feet, 0.6-feet, and 0.6-feet for the 2-, 10- and 100-year storms, respectively. For the S pond, WSE's increased by 0.6-feet, 1.3-feet and 1.1-feet for the 2-, 10- and 100-year storms, respectively. The difference in the peak WSE's is less severe and almost identical for certain conditions when comparing the Proposed conditions model to the Existing (SWWD) conditions model. This analysis did not review freeboard requirements, effects to upstream hydraulics (I,e. upstream storm sewer network) or include a review of the accepted stormwater permits for these ponds (i.e. does the proposed hydraulics, peak flow and elevation meet permitted regulations). For future studies/designs, it's recommended that these items be fully investigated and the outlets be refined further. If additional hydraulic constraints are determined effectively limiting a rise in the proposed peak elevations, or discharge rates, a potential solution for SE pond would be to add additional live storage volume to the system. This could be done by grading the eastern end of the pond nearest the grove of trees and the connection point between the northern and southern portions of the pond.

III. Opinion of Probable Costs

The total schematic engineer's opinion probable cost for the complete reuse system is approximately $1.5 million, and costs for the proposed iron enhanced sand filters are approximately $150,000. Costs include construction, engineering, permitting and construction management services as well as a 20% contingency. Costs for the re-use systems do not include any water treatment that may be requested or required. A simplified breakdown of total costs for each re-use system and sand filter is shown in Table 13 below. A full overview of costs can be found in the appendix.

Table 13: Estimated Costs

System	Location	Total Estimated Cost
Re-Use	North	$ 725,000.00
Re-Use	West	$ 399,000.00
Re-Use	Southeast	$ 345,000.00
Sand Filter	Southeast	$ 64,000.00
Sand Filter	South	$ 89,000.00
All Improvements		$ 1,622,000.00

The total cost of the re-use systems could potentially be reduced if piping connections to the irrigation systems could be made at locations closer to the pump stations than at the existing city water connections. In addition the cost for the North and West Re-use systems could be reduced by approximately $60,000 a piece if the stormwater ponds are already lined.

IV. Recommendations

Based on applying the total estimated cost per re-use system and the estimated removal rates, a cost per pound of TP is shown in Table 14. No estimated annual TP removal rates were completed for the proposed iron enhanced sand filter outlets, however based on the Minnesota Stormwater Manual sand filters can remove 45% of total phosphorous loads and 85% of particulate phosphorous loads.

Table 14: Total Cost and Water Quality Improvement

System	Location	Cost per lbs TP Removed
Re-Use	North	$ 58,000
Re-Use	West	$ 92,000
Re-Use	Southeast	$ 502,000

It is recommended that a more detailed economic analysis be completed for the re-use systems to determine the expected return on investment and factor in items like annual maintenance and replacement costs. It should be noted, although this study only reviewed irrigation demand and supply generated by runoff volumes and captured in the surrounding stormwater ponds, the commercial setting may provide an additional source and use for different forms of “waste” water (including stormwater) water. Sources of additional supply water may include harvesting AC condensation and gray water and additional demands to consider may include water for toilet flushing or assisting with HVAC cooling requirements. If additional sources and demands are considered, it’s likely the configuration of the re-use system would change from a pond storing source to an underground system.

Although the re-use systems for this site may lend to be cost prohibitive, the pond retro-fitting option may be an affordable option to consider. Based on the watershed size, land use, public visibility and findings shown, it’s recommended that the iron enhanced sand filter for the SE pond be analyzed further and be considered for grant funding opportunities.

Appendix A

Tamarack Village Mall

Fig 1: Exist. Irrigation Areas and Distribution System

Legend

Irrigation Main Lines

- Central
- Northeast
- Northwest
- Southeast
- Southwest
- Potential Re-Use Ponds
- Parcels
- Irrigation Areas

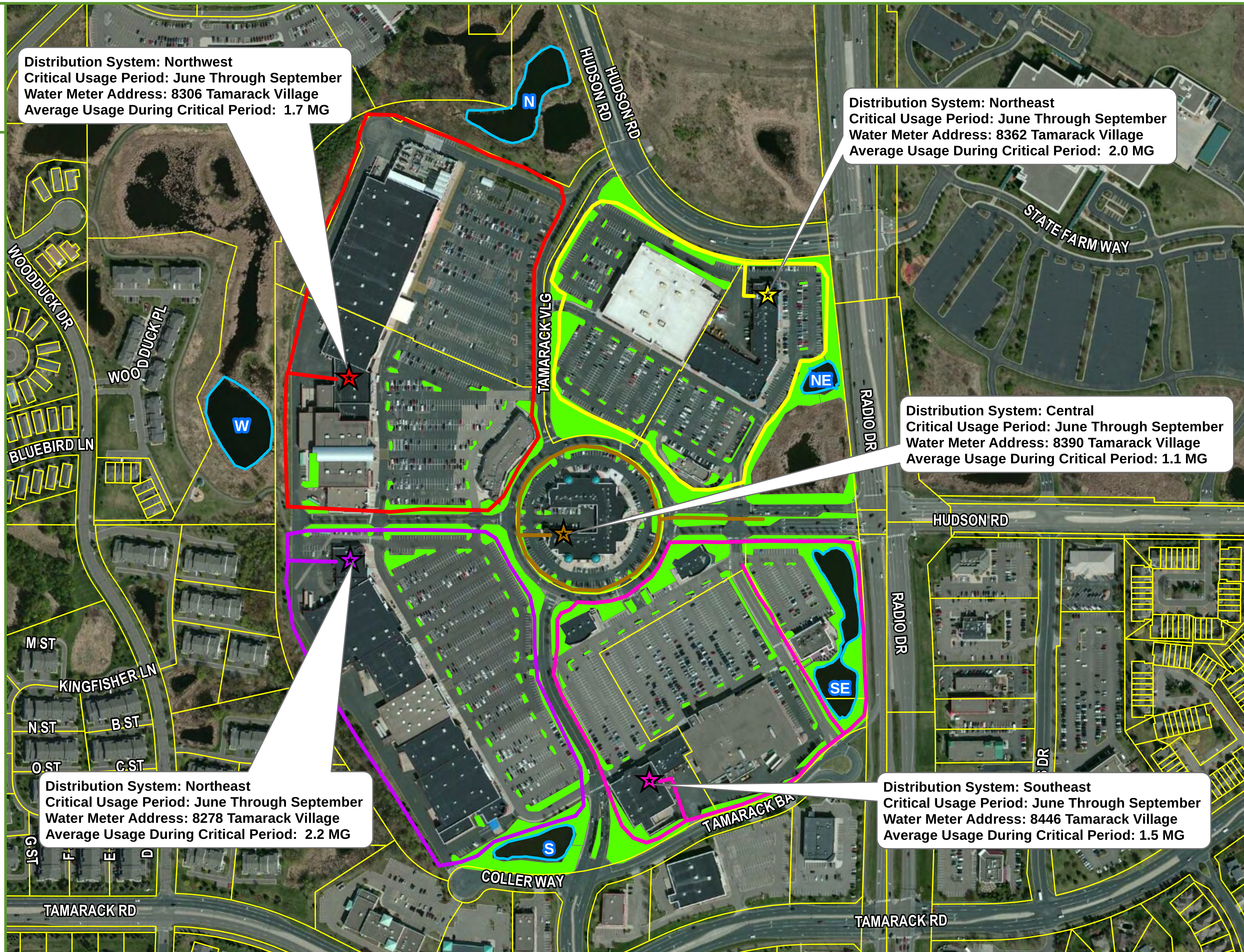
N W E S

0 75 150 300 Feet

1 inch = 300 feet

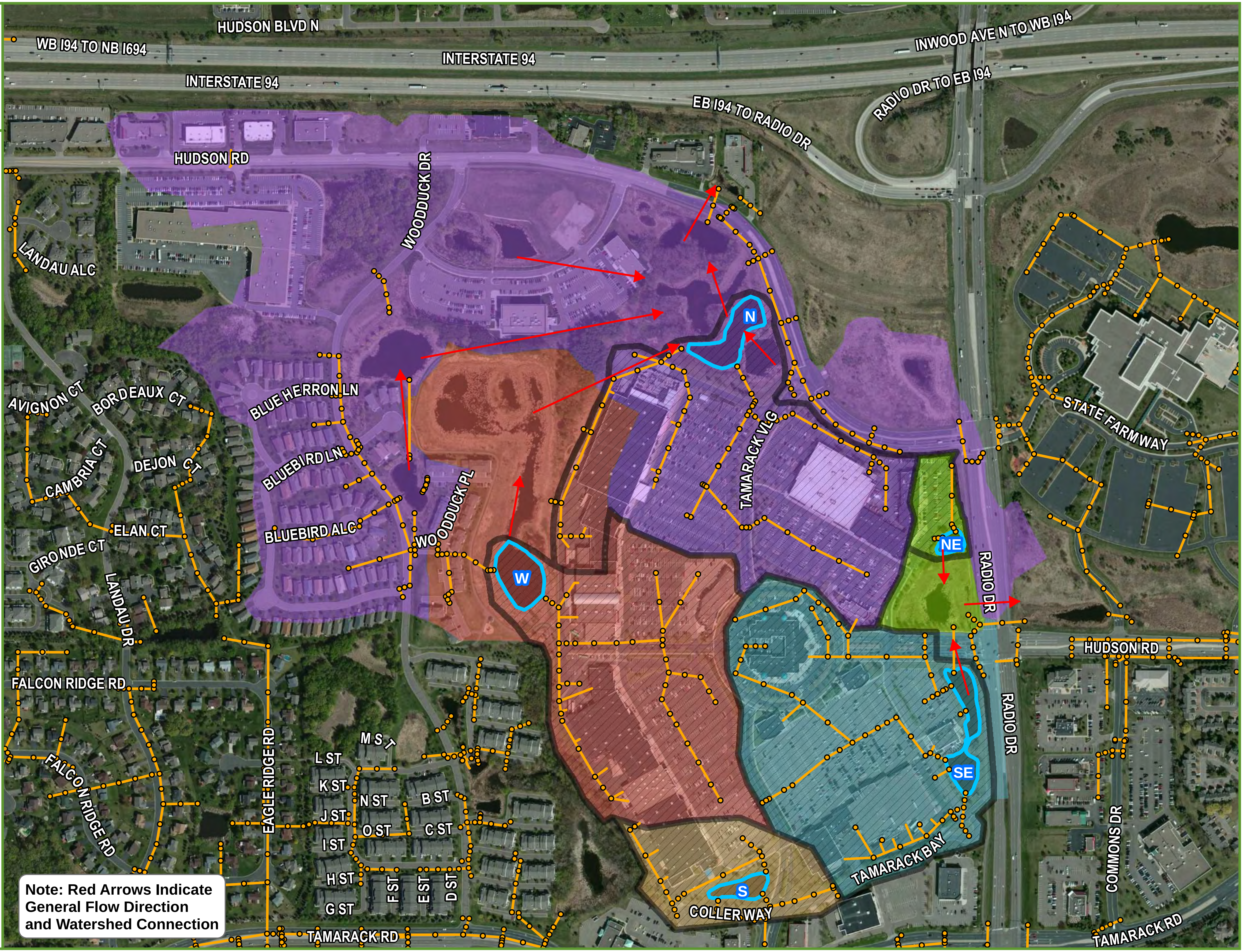
Data Source: SWWD
Projection: MN Washington Co.
Map Published: 09-29-2013
Author: DWM

HRGreen



Tamarack Village Mall

Fig 2: Subwatersheds



Legend

- Storm Sewer Structures
- Storm Sewer
- Potential Re-Use Ponds
- Subwatershed On-Site

Subwatershed Off-site & On-site

- Northeast
- Northwest
- South
- Southeast
- West

N, W, E, S

0 100 200 400 Feet

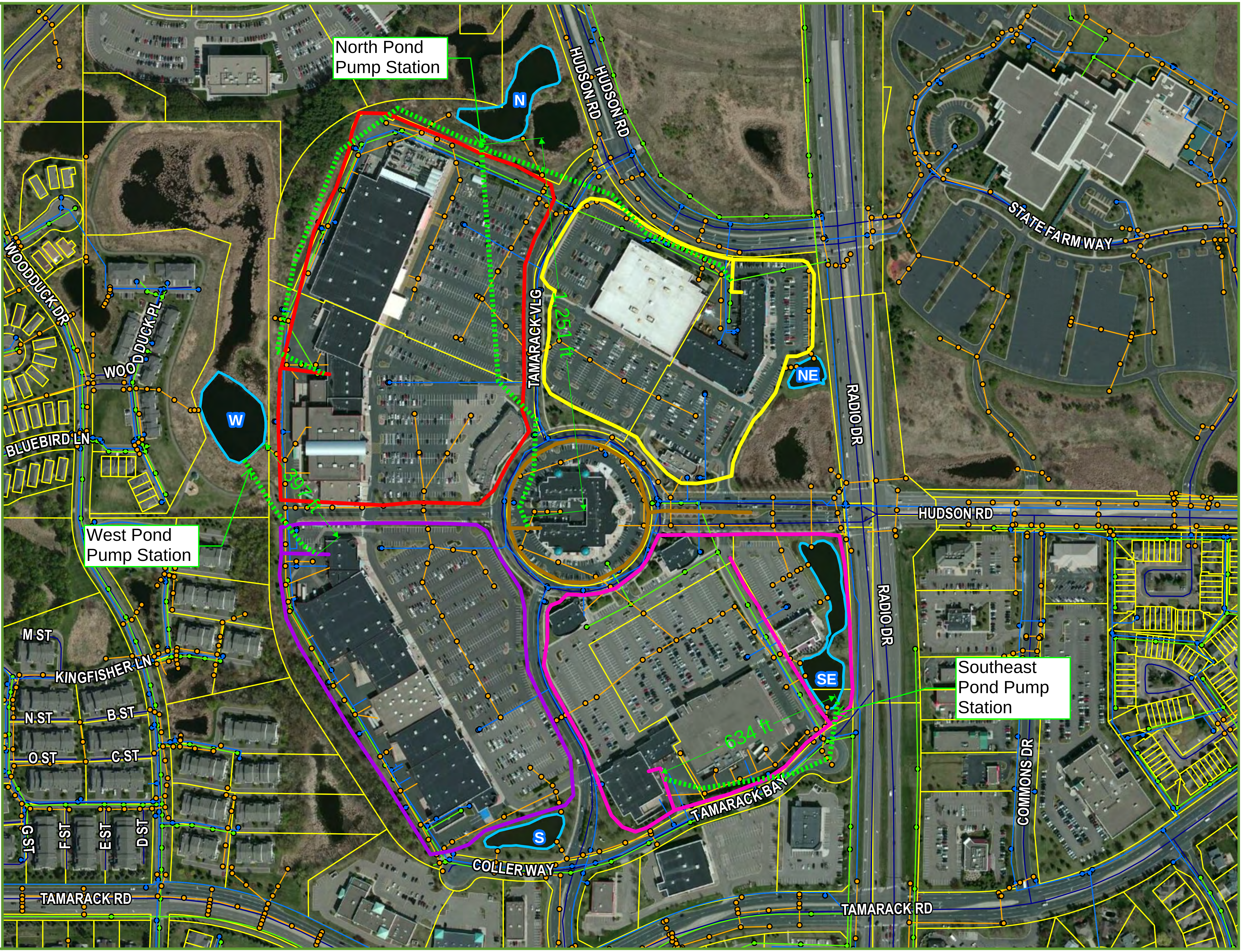
1 inch = 400 feet

Data Source: SWWD
Projection: MN Washington Co.
Map Published: 09-29-2013
Author: DWM

HRGreen

Tamarack Village Mall

Fig 3: Proposed Re-Use System



Legend

Irrigation Main Lines

- Central
- Northeast
- Northwest
- Southeast
- Southwest
- Storm Sewer Struct
- Storm Sewer
- Water Main
- Water Main Struct
- Sanitary Sewer
- Sanitary Sewer Struct
- Potential Re-Use Ponds
- Parcels
- Irrigation Line from Ponds

N
W E
S

0 50 100 200
Feet
1 inch = 300 feet

Data Source: SWWD
Projection: MN Washington Co.
Map Published: 09-29-2013
Author: DWM

HRGreen

Appendix B

				OPINION OF PROBABLE COST - CONCEPT LEVEL					
				TAMARACK MALL STORMWATER RE-USE					
				WOODBURY, MN					
				PREPARED BY - HR GREEN, INC.					
				January 24, 2013					
				NORTH RE-USE SYSTEM		**WEST RE-USE SYSTEM**		**SOUTHEAST RE-USE SYSTEM**	
ITEM NO.	**ITEM DESCRIPTION**	**UNIT**	**UNIT COST**	**QUANTITY**	**EXTENDED COST**	**QUANTITY**	**EXTENDED COST**	**QUANTITY**	**EXTENDED COST**
GENERAL									
	GENERAL CONDITIONS (MOBILIZATION, TRAFFIC CONCTROL, ETC) (10%)	LS	VARIES	1	$ 41,000	1	$ 22,000	1	$ 21,000
EARTHWORK									
	TOP SOIL ON-SITE	CY	$ 9	150	$ 1,350	150	$ 1,350	150	$ 1,350
	EXCAVATION	CY	$ 9	500	$ 4,500	500	$ 4,500	500	$ 4,500
	SOIL DISPOSAL	CY	$ 9	100	$ 900	100	$ 900	100	$ 900
	BACKFILL	CY	$ 9	400	$ 3,600	400	$ 3,600	400	$ 3,600
DEMOLITION									
	CLEARING AND GRUBBING BY AREA	AC	$ 10,500	0.06	$ 619	0.06	$ 619	0.06	$ 619
	PAVEMENT REMOVAL	SY	$ 9	1823	$ 16,408	400	$ 3,600	578	$ 5,200
	CURB REMOVAL	LF	$ 2	150	$ 300	50	$ 100	50	$ 100
SITE RESTORATION									
	PAVEMENT REPLACEMENT	SY	$ 45	1823	$ 82,040	400	$ 18,000	578	$ 26,000
	CURB REPLACEMENT	LF	$ 16	150	$ 2,400	50	$ 800	50	$ 800
PIPING									
	PVC GRAVITY SANITARY SEWER, TRENCHED	LF	$ 50	30	$ 1,500	30	$ 1,500	30	$ 1,500
	DUCTILE IRON FITTINGS	LB	$ 9	850	$ 7,650	850	$ 7,650	850	$ 7,650
	DUCTILE IRON ECCENTRIC PLUG VALVES	EA	VARIES	1	$ 2,850	1	$ 2,200	1	$ 2,850
	DUCTILE IRON CHECK VALVES	EA	VARIES	1	$ 2,700	1	$ 2,100	1	$ 2,700
	DIP FORCE MAIN (WITHIN WET WELL)	LF	$ 30	20	$ 600	20	$ 600	20	$ 600
	PVC FORCE MAIN (TO CONNECTION(S))	LF	$ 45	3250	$ 146,250	450	$ 20,250	650	$ 29,250
	REDUCED PRESSURE ZONE BACKFLOW PREVENTER AND CONNECTION	EA	$ 5,000	3	$ 15,000	1	$ 5,000	1	$ 5,000
STRUCTURES									
	PRECAST MANHOLE IN POND	EA	$ 4,500	1	$ 4,500	1	$ 4,500	1	$ 4,500
	TOP SLAB, WET WELL	EA	$ 2,000	1	$ 2,000	1	$ 2,000	1	$ 2,000
	BOTTOM SLAB, WET WELL	EA	$ 1,000	1	$ 1,000	1	$ 1,000	1	$ 1,000
	PRECAST MANHOLE, WET WELL	LF	$ 500	20	$ 10,000	20	$ 10,000	20	$ 10,000
METALS									
	VENT	EA	$ 500	1	$ 500	1	$ 500	1	$ 500
SITE WORK AND LANDSCAPING									
	HYDRAULIC SEEDING, FERTILIZING AND MULCHING	AC	$ 3,200	0.50	$ 1,600	0.50	$ 1,600	0.50	$ 1,600
	SILT FENCE, INSTALLATION	LF	$ 2	800	$ 1,600	400	$ 800	200	$ 400
	SILT FENCE, REMOVAL OF SEDIMENT	LF	$ 0.1	800	$ 80	400	$ 40	200	$ 20
	SILT FENCE, REMOVAL OF DEVICE	LF	$ 0.1	800	$ 80	400	$ 40	200	$ 20
PUMP STATION									
	SUBMERSIBLE PUMP, PUMP BOX, INTERNAL PIPING, AND CONTROLS	EA	VARIES	1	$ 81,900	1	$ 73,710	1	$ 81,900
ELECTRICAL									
	CONDUIT	LF	$ 15	600	$ 9,000	1600	$ 24,000	200	$ 3,000
	TRANSFORMER	EA	$ 5,000	1	$ 5,000	1	$ 5,000	1	$ 5,000
POND LINING									
	AQUABLOK	LBS	$ 0.19	295460	$ 56,200	307922	$ 58,600	0	$ -
	RIVER ROCK	CY	$ 55	0	$ -	0	$ -	274	$ 15,100
			CONSTRUCTION SUBTOTAL		**$ 503,000**		**$ 277,000**		**$ 239,000**
			CONTINGENCY (20%)		**$ 101,000**		**$ 55,000**		**$ 48,000**
			ENGINEERING DESIGN AND CONSTRUCTION OVERSIGHT		**$ 121,000**		**$ 67,000**		**$ 58,000**
			LOCATION SUBTOTAL		**$ 725,000**		**$ 399,000**		**$ 345,000**
			GRAND TOTAL		**$**				**1,470,000**

ASSUMPTIONS:

ADEQUATE POWER TO FEED THE 460V, 3 PHASE PUMP STATION IS AVAILABLE FROM HUDSON ROAD, RADIO DRIVE AND TAMARACK ROAD, TRANFORMERS WILL BE LOCATED AT PUMP STATIONS
NO FLOW METERING
NO BACK UP POWER FOR PUMP STATION
NO FLOW METERING OR WATER TREATMENT REQUIRED
CONTROLS WITHIN PUMP STATION BOX, NOT SEPERATE BUILDING
EASEMENT AND LEASE AGREEMENTS ARE NOT NEEDED
RPZ VALVE NEEDED AT CONNECTION TO WATERMAIN
RELATIVELY EASY ACESSS ART WATERMAIN CONNECTION TO IRRIGATION SYSTEM, MINOR DISTRURBANCE EXPECTED
PIPING WILL BE DRAINED IN FALL AND THEREFORE PIPE CAN BE SHALLOW
PUMP STATION EQUIPMENT IS REQUIRED TO BE EXPLOSION PROOF (CLASS 1, DIV 2)
SINGLE PUMP IN PUMP STATIONS

Appendix C

Basis of Design: Tamarack Mall Stormwater Pond Reuse Irrigation Systems

Source Pond	Irrigation System	Average Daily Demand per Line Based on Recorded Usage (ac•ft)	Average Daily Demand per Line (ac•ft)	Average Daily Demand per Line (gpm)	Number of Hours for Application of Flow	Average Peak Demand per Line (Used for OPC) (gpm)	Force Main Diameter for 6 ft/s Velocity (in)	Wet Well MH Inside Diameter (ft)	Elevation Head (ft)	Pressure Head (ft)	Friction Head (ft)	TDH (ft)	Pump Wire to Water Efficiency	Motor Horse Power Required	Number of Pumps	Notes
North	Central	0.03	0.03	6.8	1	163	3.3	6.0	31	139	15	185	0.6	13	1	
	NE	0.05	0.06	13.6	1	326	4.7	7.0	25	139	15	179	0.6	25	1	Controlling Location for North Pond
	NW	0.04	0.05	11.3	1	272	4.3	7.0	31	139	15	185	0.6	21	1	
West	SW	0.04	0.04	9.1	1	217	3.8	6.0	11	139	15	165	0.6	15	1	
Southeast	SE	0.06	0.06	13.6	1	326	4.7	7.0	7	139	15	161	0.6	22	1	

Appendix D

OPINION OF PROBABLE COST - CONCEPT LEVEL

TAMARACK MALL IRON ENHANCED SAND FILTERS

WOODBURY, MN

PREPARED BY - HR GREEN, INC.

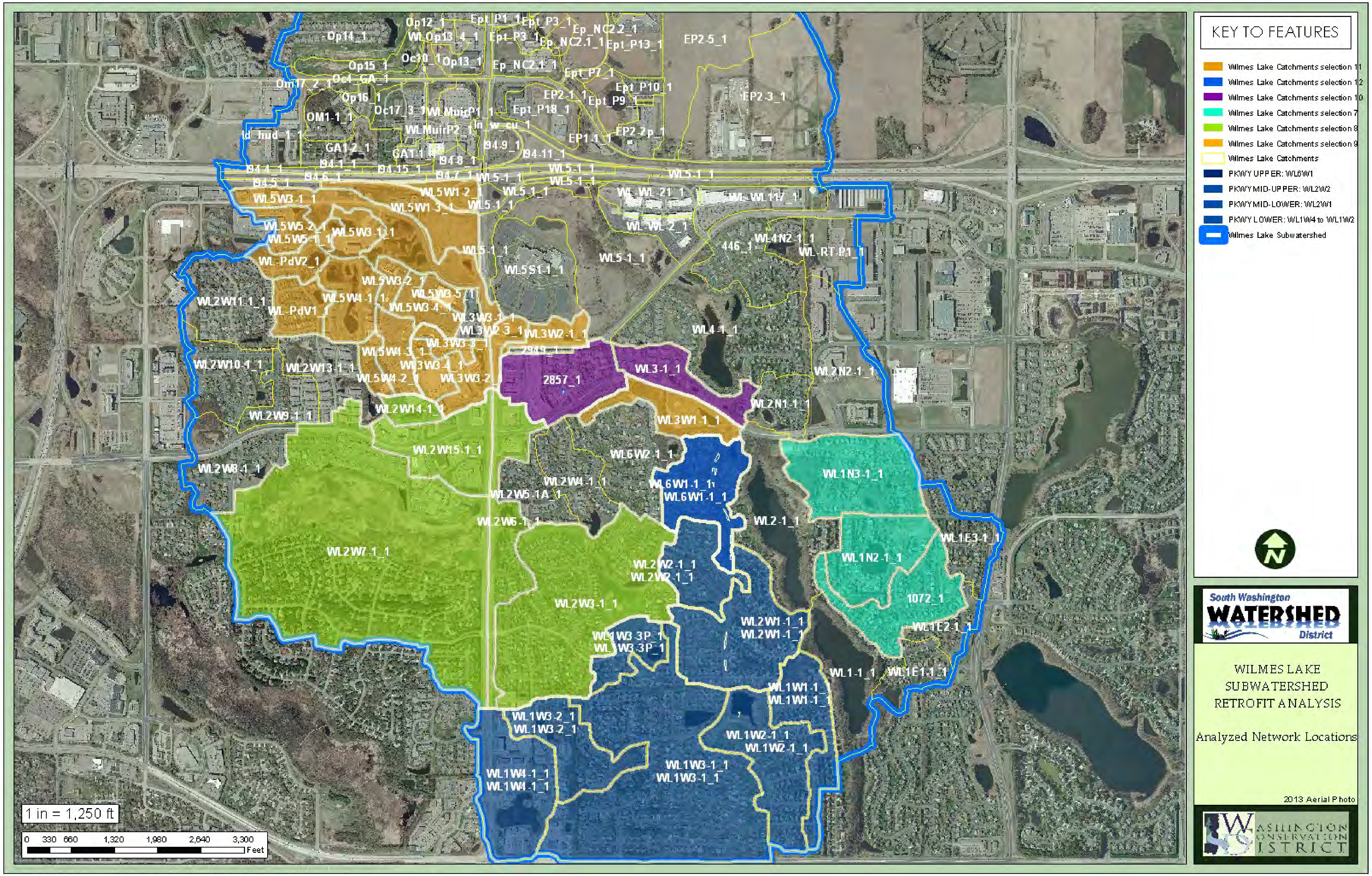
January 24th, 2014

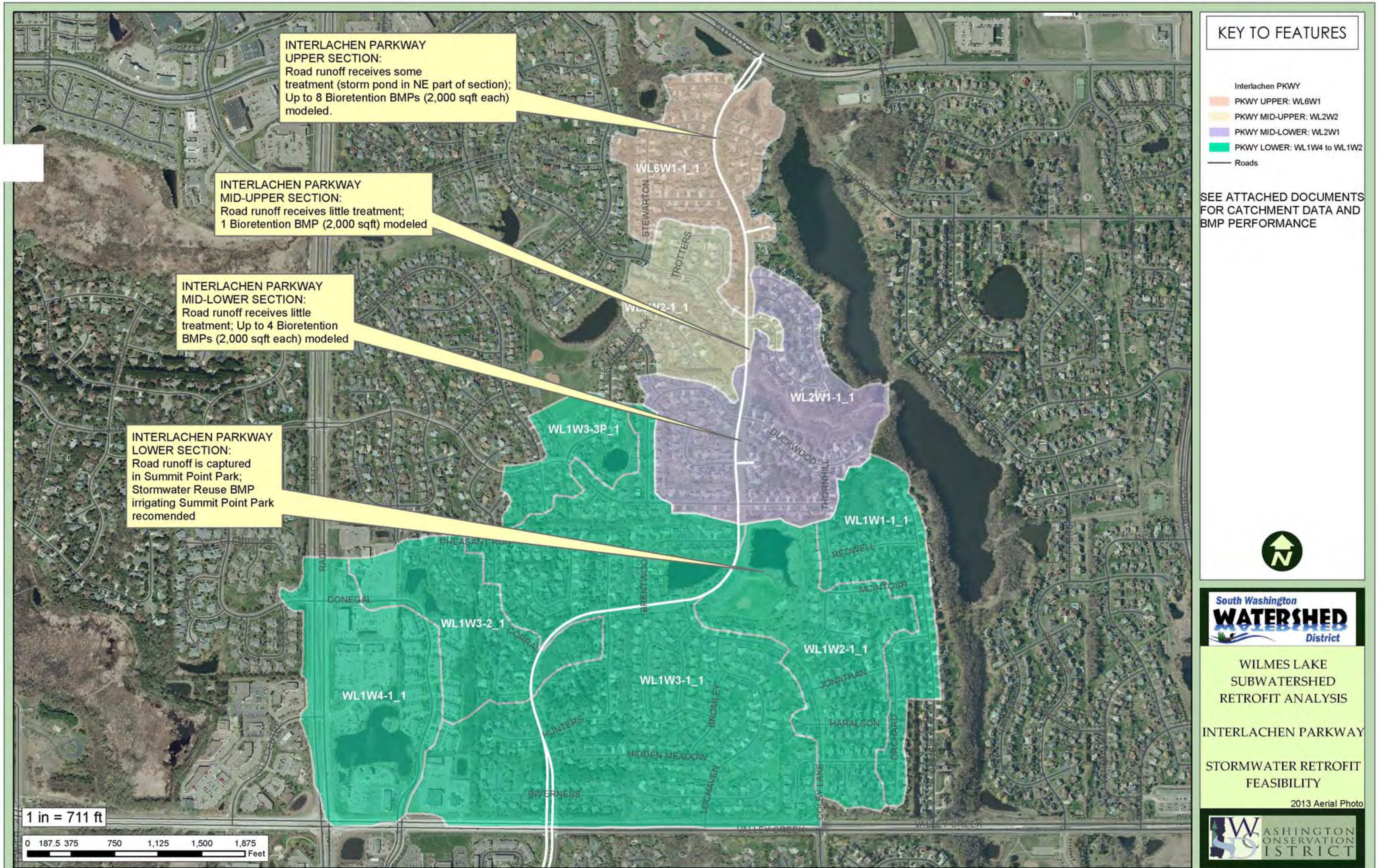
ITEM NO.	MN DOT NO.	ITEM	UNIT	ESTIMATED QUANTITY	UNIT COST	TOTAL
1.1 SE Pond						
1.1.1	2502.541	6" Perforated Drain Tile	LF	700	$ 13	$9,400
1.1.2		Drain Tile Cleanout	EA	8	$ 250	$2,000
1.1.3	2451.511	Coarse Filter Aggregate	CY	136	$ 40	$5,500
1.1.4	2451.513	Fine Filter Aggregate	CY	180	$ 28	$5,100
1.1.5	ETI-CC-1004	Iron Filings (Connelly GPM, Inc.)	TON	8	$ 1,410	$11,600
1.1.6	2511.501	4-8" Crushed, Washed Limestone (Class II RipRap)	CY	45	$ 87	$4,000
1.1.7	2502.541	8" Non-Perforated Drain Tile	LF	15	$ 15	$300
1.1.8		Tee Joint	EA	1	$ 40	$100
1.1.9		Cross Tee Joint	EA	1	$ 120	$200
1.1.10		Remove Existing Structure	EA	1	$ 1,000	$1,000
1.1.11		48" Outlet Structure	EA	1	$ 4,500	$4,500
					CONSTRUCTION SUBTOTAL	**$44,000**
					CONSTRUCTION CONTIGENCY (20%)	**$9,000**
					PRELIM AND FINAL ENGINEERING DESIGN, PERMITTING AND CONSTRUCTION OVERSIGHT (20%)	**$11,000**
					TOTAL SE POND	**$64,000**
1.2 S Pond						
1.2.1	2502.541	6" Perforated Drain Tile	LF	750	$ 13	$10,100
1.2.2		Drain Tile Cleanout	EA	8	$ 250	$2,100
1.2.3	2451.511	Coarse Filter Aggregate	CY	92	$ 40	$3,700
1.2.4	2451.513	Fine Filter Aggregate	CY	314	$ 28	$8,800
1.2.5	ETI-CC-1004	Iron Filings (Connelly GPM, Inc.)	TON	16	$ 1,410	$23,000
1.2.6	2511.501	4-8" Crushed, Washed Limestone	CY	78	$ 87	$6,800
1.2.7	2502.541	8" Non-Perforated Drain Tile	LF	15	$ 15	$300
1.2.8		Tee Joint	EA	1	$ 40	$100
1.2.9		Cross Tee Joint	EA	1	$ 120	$200
1.2.10		Remove Existing Structure	EA	1	$ 1,000	$1,000
1.2.11		48" Outlet Structure	EA	1	$ 4,500	$4,500
					CONSTRUCTION SUBTOTAL	**$61,000**
					CONSTRUCTION CONTIGENCY (20%)	**$13,000**
					PRELIM AND FINAL ENGINEERING DESIGN, PERMITTING AND CONSTRUCTION OVERSIGHT (20%)	**$15,000**
					TOTAL S POND	**$89,000**
1.3 All Ponds						
1.3.1	2502.541	6" Perforated Drain Tile	LF	1,450	$ 13	$19,500
1.3.2		Drain Tile Cleanout	EA	16	$ 250	$4,100
1.3.3	2451.511	Coarse Filter Aggregate	CY	228	$ 40	$9,200
1.3.4	2451.513	Fine Filter Aggregate	CY	494	$ 28	$13,900
1.3.5	ETI-CC-1004	Iron Filings (Connelly GPM, Inc.)	TON	24	$ 1,410	$34,500
1.3.6	2511.501	4-8" Crushed, Washed Limestone (Class II Riprap)	CY	123	$ 87	$10,800
1.3.7	2502.541	8" Non-Perforated Drain Tile	LF	30	$ 15	$500
1.3.8		Tee Joint	EA	2	$ 40	$100
1.3.9		Cross Tee Joint	EA	2	$ 120	$300
1.3.10		Remove Existing Structure	EA	2	$ 1,000	$2,000
1.3.11		48" Outlet Structure	EA	2	$ 4,500	$9,000
					CONSTRUCTION SUBTOTAL	**$104,000**
					CONSTRUCTION CONTIGENCY (20%)	**$21,000**
					PRELIM AND FINAL ENGINEERING DESIGN, PERMITTING AND CONSTRUCTION OVERSIGHT (20%)	**$25,000**
Opinion of Probable Cost - Concept Level						**$150,000**

*Using Bid Tabulation from Williams Pond, City of St. Paul

* For Fine Filter aggregate & seed mix used MNDOT ave Bid Price for 2011

Appendix D Concept Plans:


KEY TO FEATURES
Wilmes Lake Catchments selection 11
Wilmes Lake Catchments selection 12
Wilmes Lake Catchments selection 10
Wilmes Lake Catchments selection 7
Wilmes Lake Catchments selection 8
Wilmes Lake Catchments selection 9
Wilmes Lake Catchments
PKWY UPPER: WL6W1
PKWY MID-UPPER: WL2W2
PKWY MID-LOWER: WL2W1
PKWY LOWER: WL1W4 to WL1W2
Wilmes Lake Subwatershed
N
South Washington
WATERSHED
District
WILMES LAKE
SUBWATERSHED
RETROFIT ANALYSIS
Analyzed Network Locations
2013 Aerial Photo
WASHINGTON CONSERVATION DISTRICT
1 in = 1,250 ft
0 330 660 1,320 1,980 2,640 3,300
Feet
WL5W3-1_1
WL-PdV2_1
WL-PdV1_1
WL2W11-1_1
WL2W10-1_1
WL2W13-1_1
WL2W9-1_1
WL2W8-1_1
WL2W7-1_1
WL2W14-1_1
WL2W15-1_1
WL2W5-1A_1
WL2W6-1_1
WL2W4-1_1
WL2W3-1_1
WL2W2-1_1
WL2W1-1_1
WL6W2-1_1
WL6W1-1_1
WL3W1-1_1
WL3-1_1
2857_1
WL4-1_1
WL2N2-1_1
WL2N1-1_1
WL2-1_1
WL1N3-1_1
WL1N2-1_1
1072_1
WL1E3-1_1
WL1E2-1_1
WL1E1-1_1
WL1-1_1
WL1W1-1_1
WL1W2-1_1
WL1W3-1_1
WL1W3-2_1
WL1W3-3P_1
WL1W4-1_1
WL5-1_1
WL5S1-1_1
EP2-5_1
EP2-3_1
EP1-1_1

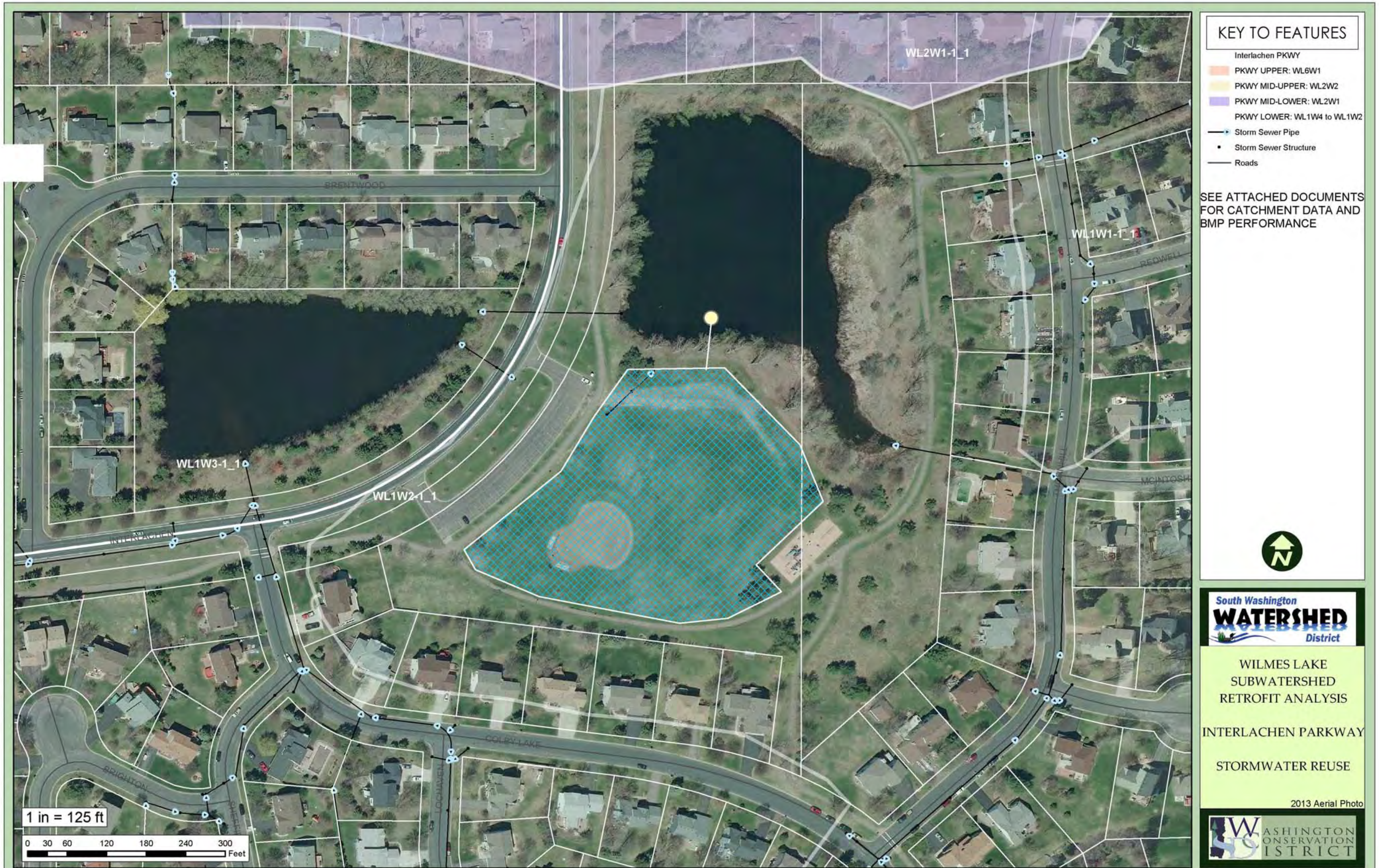


INTERLACHEN PARKWAY UPPER SECTION: Road runoff receives some treatment (storm pond in NE part of section); Up to 8 Bioretention BMPs (2,000 sqft each) modeled.
INTERLACHEN PARKWAY MID-UPPER SECTION: Road runoff receives little treatment; 1 Bioretention BMP (2,000 sqft) modeled
INTERLACHEN PARKWAY MID-LOWER SECTION: Road runoff receives little treatment; Up to 4 Bioretention BMPs (2,000 sqft each) modeled
INTERLACHEN PARKWAY LOWER SECTION: Road runoff is captured in Summit Point Park; Stormwater Reuse BMP irrigating Summit Point Park recomended
WL6W1-1_1
WL2W1-1_1
WL1W3-3P_1
WL1W1-1_1
WL1W3-2_1
WL1W2-1_1
WL1W3-1_1
WL1W4-1_1
1 in = 711 ft
0 187.5 375 750 1,125 1,500 1,875 Feet
KEY TO FEATURES
Interlachen PKWY
PKWY UPPER: WL6W1
PKWY MID-UPPER: WL2W2
PKWY MID-LOWER: WL2W1
PKWY LOWER: WL1W4 to WL1W2
Roads
SEE ATTACHED DOCUMENTS FOR CATCHMENT DATA AND BMP PERFORMANCE
South Washington WATERSHED District
WILMES LAKE SUBWATERSHED RETROFIT ANALYSIS
INTERLACHEN PARKWAY
STORMWATER RETROFIT FEASIBILITY
2013 Aerial Photo
WASHINGTON CONSERVATION DISTRICT


KEY TO FEATURES
Interlachen PKWY
PKWY UPPER: WL6W1
PKWY MID-UPPER: WL2W2
PKWY MID-LOWER: WL2W1
PKWY LOWER: WL1W4 to WL1W2
Storm Sewer Pipe
Storm Sewer Structure
Roads
SEE ATTACHED DOCUMENTS FOR CATCHMENT DATA AND BMP PERFORMANCE
SUBCATCHMENT DRAINAGE AREA TO BIORETENTION BMP LOCATIONS
WL6W1-1_1
WL2W2-1_1
WL2W1-1_1
INTERLACHEN
EDINBURGH
TROTTERS
SCARBOROUGH
1 in = 225 ft
0 55 110 220 330 440 550 Feet
South Washington WATERSHED District
WILMES LAKE SUBWATERSHED RETROFIT ANALYSIS
INTERLACHEN PARKWAY
WL6W1 - BMP LOCATIONS
2013 Aerial Photo
WASHINGTON CONSERVATION DISTRICT


KEY TO FEATURES
Interlachen PKWY
PKWY UPPER: WL6W1
PKWY MID-UPPER: WL2W2
PKWY MID-LOWER: WL2W1
PKWY LOWER: WL1W4 to WL1W2
Storm Sewer Pipe
Storm Sewer Structure
Roads
SEE ATTACHED DOCUMENTS FOR CATCHMENT DATA AND BMP PERFORMANCE
South Washington WATERSHED District
WILMES LAKE SUBWATERSHED RETROFIT ANALYSIS
INTERLACHEN PARKWAY
WL2W2 - BMP LOCATIONS
2013 Aerial Photo
WASHINGTON CONSERVATION DISTRICT
WL6W1-1_1
STEWARTON
TROTTERS
INTERLACHEN
WL2W2-1_1
SUBCATCHMENT DRAINAGE AREA TO BIORETENTION BMP LOCATION
WL2W1-1_1
SCARBOROUGH
WL1W3-3P_1
WL1W3-1_1
1 in = 175 ft
0 45 90 180 270 360 450 Feet


WL6W1-1_1
WL2W2-1_1
SUBCATCHMENT DRAINAGE AREA
TO BIORETENTION BMP LOCATIONS
WL2W1-1_1
WL1W3-3P_1
WL1W1-1_1
WL1W3-1_1
WL1W2-1_1
DUCKWOOD
PINEHURST
1 in = 200 ft
0 50 100 200 300 400 500
Feet
KEY TO FEATURES
Interlachen PKWY
PKWY UPPER: WL6W1
PKWY MID-UPPER: WL2W2
PKWY MID-LOWER: WL2W1
PKWY LOWER: WL1W4 to WL1W2
Storm Sewer Pipe
Storm Sewer Structure
Roads
SEE ATTACHED DOCUMENTS FOR CATCHMENT DATA AND BMP PERFORMANCE
South Washington WATERSHED District
WILMES LAKE SUBWATERSHED RETROFIT ANALYSIS
INTERLACHEN PARKWAY
WL2W1 - BMP LOCATIONS
2013 Aerial Photo
WASHINGTON CONSERVATION DISTRICT


KEY TO FEATURES
Interlachen PKWY
PKWY UPPER: WL6W1
PKWY MID-UPPER: WL2W2
PKWY MID-LOWER: WL2W1
PKWY LOWER: WL1W4 to WL1W2
Storm Sewer Pipe
Storm Sewer Structure
Roads
SEE ATTACHED DOCUMENTS FOR CATCHMENT DATA AND BMP PERFORMANCE
South Washington WATERSHED District
WILMES LAKE SUBWATERSHED RETROFIT ANALYSIS
INTERLACHEN PARKWAY
STORMWATER REUSE
2013 Aerial Photo
WASHINGTON CONSERVATION DISTRICT
WL2W1-1_1
WL1W1-1_1
WL1W3-1_1
WL1W2-1_1
BRENTWOOD
INTERLACHEN
MCINTOSH
1 in = 125 ft
0 30 60 120 180 240 300
Feet