Powers Lake

Stormwater Retrofit Assessment

Prepared by:

WASHINGTON CONSERVATION DISTRICT

With assistance from:

THE METRO CONSERVATION DISTRICTS

for the

SOUTH WASHINGTON WATERSHED DISTRICT

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Table of Contents

Executive Summary 4
About this Document 5
  Document Overview 5
    Methods 5
    Retrofit Profiles 5
    Retrofit Ranking 6
    References 6
    Appendices 6
Methods 7
  Selection of Subwatershed 7
  Subwatershed Assessment Methods 7
    Step 1: Retrofit Scoping 7
    Step 2: Desktop Retrofit Analysis 7
    Step 3: Retrofit Reconnaissance Investigation 8
    Step 4: Treatment Analysis/Cost Estimates 9
    Step 5: Evaluation and Ranking 13
Catchment Profiles 14
Retrofit Ranking 29
References 30
Appendices 31
  Appendix 1—Catchments not included in Ranking Table 31
  Summary of Protocol 31
  Overall Catchment Map 31

This report details a subwatershed stormwater retrofit assessment resulting in recommended catchments for placement of Best Management Practice (BMP) retrofits that address the goals of the Local Governing Unit (LGU) and stakeholder partners. This document should be considered as *one part* of an overall watershed restoration plan including educational outreach, stream repair, riparian zone management, discharge prevention, upland native plant community restoration, and pollutant source control. The methods and analysis behind this document attempt to provide a sufficient level of detail to rapidly assess sub-watersheds of variable scales and land-uses to identify optimal locations for stormwater treatment. The time commitment required for this methodology is appropriate for *initial assessment* applications. This report is a vital part of overall subwatershed restoration and should be considered in light of forecasting riparian and upland habitat restoration, pollutant hot-spot treatment, agricultural and range land management, good housekeeping outreach and education, and others, within existing or future watershed restoration planning.

The assessment's background information is discussed followed by a summary of the assessment's results; the methods used and catchment profile sheets of selected sites for retrofit consideration. Lastly, the retrofit ranking criteria and results are discussed and source references are provided.

Results of this assessment are based on the development of catchment-specific *conceptual* stormwater treatment best management practices that either supplement existing stormwater infrastructure or provide quality and volume treatment where none currently exists. Relative comparisons are then made between catchments to determine where best to initialize final retrofit design efforts. Final, site-specific design sets (driven by existing limitations of the landscape and its effect on design element selections) will need to be developed to determine a more refined estimate of the reported pollutant removal amounts reported here-in. This typically occurs after the procurement of committed partnerships relative to each specific target parcel slated for the placement of BMPs.

Executive Summary

The Powers Lake subwatershed consists of forty-three catchments. Selected catchments and their existing stormwater management practices were analyzed for annual pollutant loading. Stormwater practice options were compared, for each catchment, given their specific site constraints and characteristics. A stormwater practice was selected by weighing cost, ease of installation and maintenance and ability to serve multiple functions identified by the South Washington Watershed District (SWWD) and the City of Woodbury. Seven of the 43 catchments were selected and modeled at various levels of treatment efficiencies. These catchments should be considered the “low-hanging-fruit” within the Powers Lake Subwatershed. If BMPs are implemented at the recommended levels, a total of 27.8 pounds of phosphorus, or 18% of the target MPCA load reduction (9% of the target SWWD load reduction) could be achieved within a small area of the Powers Lake subwatershed.

The following table summarizes the assessment results. Treatment levels (percent removal rates) for retrofit projects that resulted in a prohibitive BMP size, or number, or were too expensive to justify installation are not included. Reported treatment levels are dependent upon optimal site selection and sizing. The recommended treatment levels/amounts summarized here are based on a subjective assessment of what can realistically be expected to be installed considering expected public participation and site constraints.

Catchment ID	Retro Type	Live Storage Volume (ft^3)	TP Reduction (%)[1]	TP Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Overall Est. Cost[2]	O&M Term (years)	Total Est. Term Cost/lb-TP/yr
PL1-1-OF	B	1,500	20	9.1	7.4	$23,483	30	$210
PLFOXRN_PD-P	B	970	14	5.0	6.7	$16,106	30	$253
PLPL9ADDP1-P	B	750	18	1.4	1.6	$12,992	30	$711
PLPLADP1P1-P	B	1,550	26	4.4	5.7	$24,173	30	$447
PLPLADP1P2-P	B	325	33	0.7	0.8	$6,777	30	$671
2-COMBINED[3]	B	1,550	23	7.2	8.4	$24,173	30	$273
TOTALS	-	**6,645**	-	**27.8**	**30.6**	**$107,704**	-	-

B = Bioretention (infiltration and/or filtration)

[1] TP Reduction calculated from the annual treatment achieved by new BMPs alone compared to existing catchment P load
[2] Estimated overall costs include design, contracted soil core sampling, materials, contracted labor, promotion and administrative costs (including outreach, education, contracts, grants, etc), pre-construction meetings, installation oversight and 30 years of operation and maintenance costs.
[3] PLPL1ADDP1-P and PLPL1ADDWT-P were combined for the purposes of this study

About this Document

Document Overview

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

This document is organized into four major sections that describe the general methods used, individual catchment profiles, a resulting retrofit ranking for the subwatershed and references used in this assessment protocol. In some cases, and Appendices section provides additional information relevant to the assessment.

Under each section and subsection, project-specific information relevant to that portion of the assessment is provided with an ***Italicized Heading***.

Methods

The methods section outlines general procedures used when assessing the subwatershed. It overviews the processes of retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis and project ranking. Project-specific details of each process are defined if different from the general, standard procedures.

NOTE: the financial, technical, current landscape/stormwater system, and timeframe limits and needs are highly variable from subwatershed to subwatershed. This assessment uses some, or all, of the methods described herein.

Retrofit Profiles

When applicable, each retrofit profile is labeled with a unique ID to coincide with the subwatershed name (e.g., PL1-1-OF for the area surrounding Powers Lake). This ID is referenced when comparing projects across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

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

Retrofit Recommendation

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

Cost/Treatment Analysis

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

Site Selection

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

Retrofit Ranking

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

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

References

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

Appendices

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

Methods

Selection of Subwatershed

Before the subwatershed stormwater assessment begins, a process of identifying a high priority water body as a target takes place. Many factors are considered when choosing which subwatershed to assess for stormwater retrofits. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Assessments supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the assessment also rank highly. The Powers Lake subwatershed is a priority of the SWWD based on increasing phosphorus level trends. Wasteload allocation (storm-sewered runoff) from the subwatershed must be reduced by 25%, or 152.9 lbs/yr, to meet the MPCA standard for total phosphorus. To meet SWWD goals, wasteload allocation must be reduced by 50%, or 297.7 lbs/yr.

In areas without clearly defined studies, such as TMDL or officially listed water bodies of concern, or where little or no monitoring data exist, metrics are used to score subwatersheds against each other. In large subwatersheds (e.g., greater than 2500 acres), a similar metric scoring is used to identify areas of concern, or focus areas, for a more detailed assessment. This methodology was slightly modified from Manual 2 of the *Urban Stormwater Retrofit Practices* series.

Subwatershed Assessment Methods

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

Step 1: Retrofit Scoping

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

Powers Lake Subwatershed Scoping

Pollutant(s) of concern for this subwatershed identified as: total phosphorus. Goals of the SWWD, Washington Conservation District (WCD), and City of Woodbury were considered as well as the Powers Lake Management Plan, Houston Engineering, Inc., 2010).

Step 2: Desktop Retrofit Analysis

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

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

Step 3: Retrofit Reconnaissance Investigation

After identifying potential retrofit sites through this desktop search, a field investigation was conducted to evaluate each site. 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.

The following stormwater BMPs were considered for each catchment/site:

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

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Sites most likely to be conducive to addressing the LGU goals and appear to be simple-to-moderate in design/install/maintenance considerations are chosen for a cost/benefit analysis in order to relatively compare catchments/sites. Treatment concepts are developed taking into account site constraints and the subwatershed treatment objectives. Projects involving complex stormwater treatment interactions or pose a risk for upstream flooding require the assistance of a certified engineer. Conceptual designs, at this phase of the design process, include a cost estimate and estimate of pollution reduction. Reported treatment levels are dependent upon optimal site selection and sizing.

Modeling of the site is done by one or more methods such as with P8, WINSLAMM or simple spreadsheet methods using the Rational Method. Event mean concentrations or sediment loading files (depending on data availability and model selection) are used for each catchment/site to estimate relative pollution loading of the existing conditions. The site's conceptual BMP design is modeled to then estimate varying levels of treatment by sizing and design element. This treatment model can also be used to properly size BMPs to meet LGU restoration objectives.

General P8 Model Inputs	
Parameter	**Method for Determining Value**
Total Area	**Source/Criteria**
Pervious Area Curve Number	**Values from the USDA Urban Hydrology for Small Watersheds TR-55 (1986). A composite curve number was found based on proportion of hydrologic soil group and associated curve numbers for open space in fair condition (grass cover 50%-75%).**
Directly Connected Impervious Fraction	**Calculated using GIS to measure the amount of rooftop, driveway and street area directly connected to the storm system. Estimates calculated from one area can be used in other areas with similar land cover.**
Indirectly Connected Impervious Fraction	**Wisconsin urban watershed data (Panuska, 1998) provided in the P8 manual is used as a basis for this number. It is adjusted slightly based on the difference between the table value and calculated value of the directly connected impervious fraction.**
Precipitation/Temperature Data	**Rainfall and temperature recordings from 1959 were used as a representation of an average year.**
Hydraulic Conductivity	**A composite hydraulic conductivity rate is developed for each catchment area based on the average conductivity rate of the low and high bulk density rates by USDA soil texture class (Rawls et. al, 1998). Wet soils where practices will not be installed are omitted from composite calculations.**
Particle/Pollutant	**The default NURP50 particle file was used.**
Sweeping Efficiency	**Unless otherwise noted, street sweeping was not accounted for.**

Powers Lake Treatment Analysis

For the Powers Lake treatment analysis, each catchment, and each parcel within them, was first assessed for BMP "family" type applicability given specific site constraints and soil types. Pedestrian and car traffic flow, parking needs, snow storage areas, obvious utility locations, existing landscaping, surface water runoff flow, project visibility, "cues of care" in relation to existing landscape maintenance, available space and several other factors dictated the selection of one or more potential BMPs for each site.

P8 was used to model catchments and a hypothetical BMP located at its outfall. The BMP was sized from the 10-50% treatment size and results were tabulated in the Catchment Profile section of this document.

Cost Estimates

Each resulting BMP (by percent TP-removal dictated sizing) was then assigned estimated design, installation and first-year establishment-related maintenance costs given its ft^3 of treatment. In cases where live storage was 1-ft, this number roughly related to ft^2 of coverage. An annual cost/TP-removed for each treatment level was then calculated for the life-cycle of said BMP which included promotional, administrative and life-cycle operations and maintenance costs. The following table provides the BMP cost estimates used to assist in cost-analysis:

Average BMP Cost Estimates						
BMP	Median Inst. Cost ($/ft²)	Marginal Annual Maintenance Cost (contracted)	O & M Term	Design Cost ($70/hr)	Installation Oversight Cost ($70/hr)	Total Installation Cost (Includes design & 1-yr maintenance)
Pond Retrofits	$3.00	$500/acre	30	[1]40% above construction	$210 (3 visits)	**$4.21/sq ft**
Extended Detention	$5.00	$1000/acre	30	[3]$2800/acre	$210 (3 visits)	**$5.09/sq ft**
Wet Pond	$5.00	$1000/acre	30	[3]$2800/acre	$210 (3 visits)	**$5.09/sq ft**
Stormwater Wetland	$5.00	$1000/acre	30	[3]$2800/acre	$210 (3 visits)	**$5.09/sq ft**
Water Quality Swale[6]	$12.00	$250/100 ln ft	30	$1120/100 ln ft	$210 (3 visits)	**$12.91/sq ft**
Cisterns	$15.00	[5]$100	30	NA	$210 (3 visits)	**$15.00/sq ft**
French Drain/Dry Well	$12.00	[5]$100	30	20% above construction	$210 (3 visits)	**$14.40/sq ft**
Infiltration Basin	$15.00	$500/acre	30	$1120/acre	$210 (3 visits)	**$15.04/sq ft**
Rain Barrels	$25.00	[5]$25	30	NA	$210 (3 visits)	**$25.00/sq ft**
Structural Sand Filter (including peat, compost, iron amendments, or similar)[6]	$20.00	$250/25 ln ft	30	$300/25 ln ft	$210 (3 visits)	**$21.47/sq ft**
Impervious Cover Conversion	$20.00	$500/acre	30	$1120/acre	$210 (3 visits)	**$20.04/sq ft**
Stormwater Planter	$27.00	$50/100 ft²	30	20% above construction	$210 (3 visits)	**$32.90/sq ft**
Rain Leader Disconnect Raingardens	$4.00	[2]$25/150 ft²	30	$280/100 ft²	$210 (3 visits)	**$6.97/sq ft**
Simple Bioretention (no engineered soils or under-drains, but w/curb cuts and forebays)	$10.00	$0.75/ft²	30	$840/1000 ft²	$210 (3 visits)	**$11.59/sq ft**

Moderate Bioretention (incl. engineered soils, under-drains, curb cuts, no retaining walls)	$12.00	$0.75/ft^2	30	$1120/1000 ft^2	$210 (3 visits)	**$13.87/sq ft**
Moderately Complex Bioretention (incl. engineered soils, under-drains, curb cuts, forebays , 2-3 ft retaining walls)	$14.00	$0.75/ft^2	30	$1250/1000 ft^2	$210 (3 visits)	**$16.00/sq ft**
Highly Complex Bioretention (incl. engineered soils, under-drains, curb cuts, forebays, 3-5 ft retaining walls)	$16.00	$0.75/ft^2	30	[4]$1400/1000ft^2	$210 (3 visits)	**$18.15/sq ft**
Underground Sand Filter	$65.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$91.75/sq ft**
Stormwater Tree Pits	$70.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$98.75/sq ft**
Grass/Gravel Permeable Pavement (sand base)	$12.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$17.55/sq ft**
Permeable Asphalt (granite base)	$10.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$14.00/sq ft**
Permeable Concrete (granite base)	$12.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$17.55/sq ft**
Permeable Pavers (granite base)	$25.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$35.75/sq ft**
Extensive Green Roof	$225.00	$500/1000 ft^2	30	[1]40% above construction	$210 (3 visits)	**$315.50/sq ft**
Intensive Green Roof	$360.00	$750/1000 ft^2	30	[1]40% above construction	$210 (3 visits)	**$504.75/sq ft**

[1]Likely going to require a licensed, contacted engineer.

[2]Assumed landowner, not contractor, will maintain.

[3]LRP would only design off-line systems not requiring an engineer. For all projects requiring an engineer, assume engineering costs to be 40% above construction costs.

[4]If multiple projects are slated, such as in a neighborhood retrofit, a design packet with templates and standard layouts, element elevations and components, planting plans and cross sections can be generalized, design costs can be reduced.

[5]Not included in total installation cost (minimal).

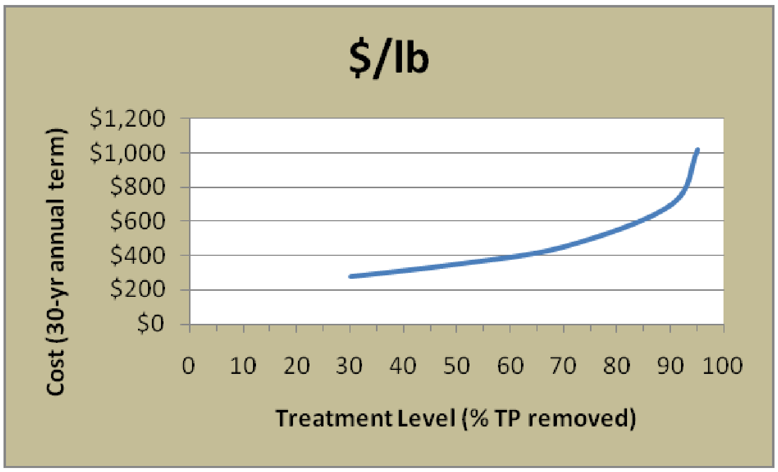
[5]Assumed to be 15 feet in width.

Powers Lake Cost Analysis

For the Powers Lake cost analysis, promotion, and administration for each property was estimated using a non-linear formula dependent on total number of 100 ft^3 treatment cells (BMPs), as the labor associated with outreach, education and administrative tasks typically see savings with scale. Annual Operation & Maintenance referred to the ft^2 estimates provided in the preceding table. In cases were multiple BMP types were prescribed for an individual site, both the estimated installation and maintenance-weighted means by ft^2 of BMP were used to produce cost/benefit estimates.

Step 5: Evaluation and Ranking

The results of each site were analyzed for cost/treatment to prescribe the most cost-efficient level of treatment.



Powers Lake Evaluation and Ranking

In the Powers Lake evaluation and ranking, the recommended level of treatment for each catchment, as reported in the Executive Summary Table, was chosen by selecting the level of treatment expected to get considering public buy-in and above a minimal amount needed to justify crew mobilization and outreach efforts to the area. Should the cumulative expected load reduction of the recommended catchment treatment levels not meet LGU goals, moving up one level of treatment (as described in the Catchment Profile tables) should then be selected.

Catchment Profiles

The following pages provide catchment-specific information that was analyzed for stormwater BMP retrofit treatment at various levels. The recommended level of treatment reported in the Ranking Table is determined by weighing the cost-efficiency vs. site specific limitations about what is truly practical in terms of likelihood of being granted access to optimal BMP site locations, expected public buy-in (partnership) and crew mobilization in relation to BMP spatial grouping.

Powers Lake Catchment Profiles

For development of the Powers Lake catchment profile section, 7 out of 43 catchments were selected as the first-tier areas for stormwater retrofit efforts. Those catchments where development occurred under stringent stormwater management standards were not modeled or further analyzed in this assessment. After BMPs are installed for the initial 7 catchments to meet the desired reduction levels, the remaining catchments and their pond networks should be modeled.

PL1-1-OF

Catchment Summary	
Acres	83.3
Dominant Land Cover	Residential
Volume (acre-feet/yr)	49.5
TP (lb/yr)	45.5
TSS (lb/yr)	5048.1

Model Inputs	
Parameter	**Input**
Pervious Curve Number	61
Indirectly connected Impervious Fraction	0.224
Directly Connected Impervious Fraction	0.056
Hydraulic Conductivity (in/hr)	1.52

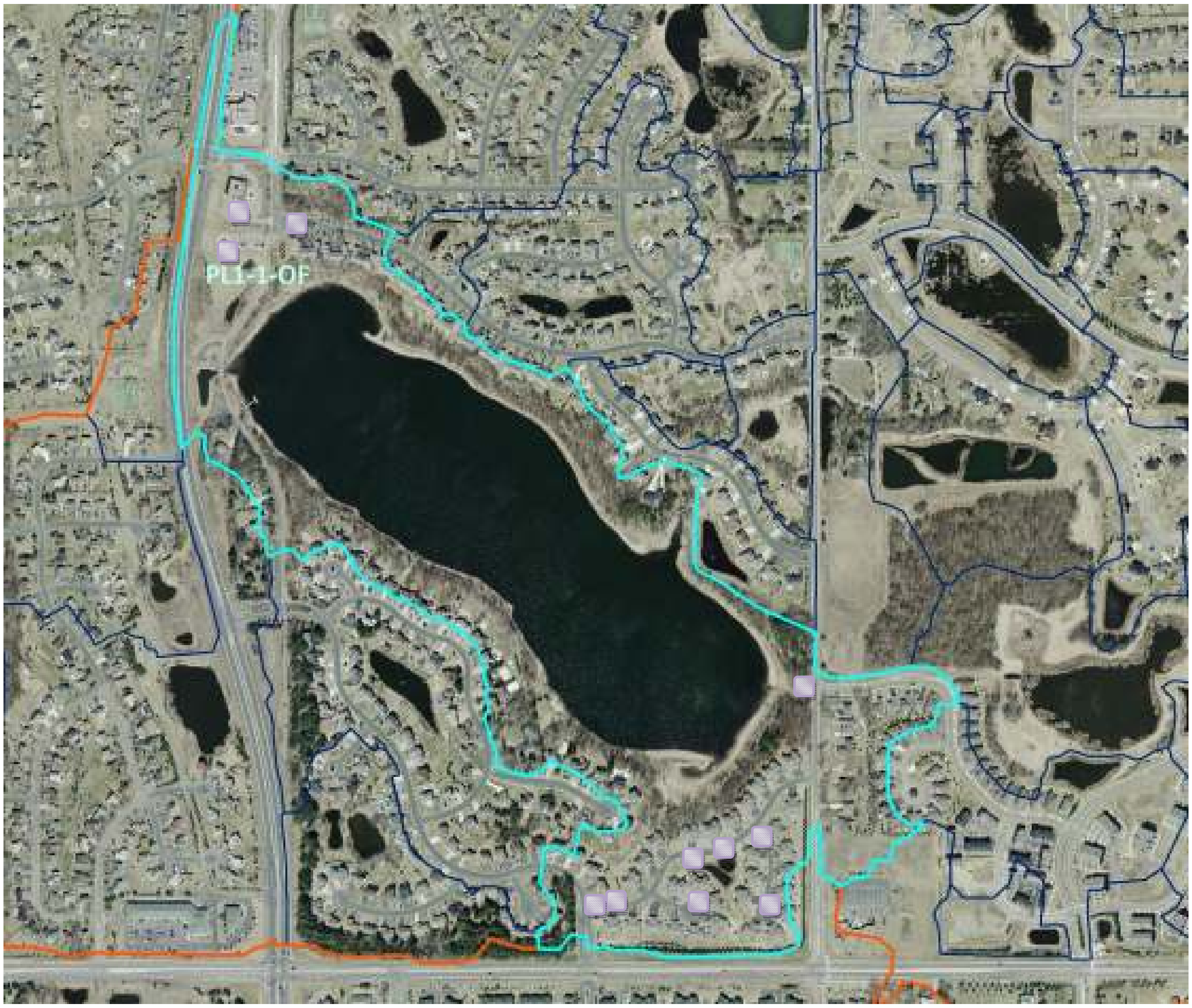
DESCRIPTION

This catchment is comprised of primarily medium density, single-family residential development and open space adjacent to Powers Lake. Opportunities for large BMPs exist at the north end of the subwatershed on public property (park and fire station).

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, poured concrete walls can form “box planters” along the streetscape.

For the sake of estimating costs per volume of water treated, we approximated a ft^2 pricing as some marriage of each of these forms of stormwater practices.



Proposed Curb Cut Bioretention

<table>
<tr><td></td><td></td><td></td><td></td><td colspan="6">RETROFIT OPTIONS</td></tr>
<tr><td></td><td rowspan="2">Cost/Benefit Analysis</td><td rowspan="2">Existing Loading</td><td rowspan="2">Existing Treatment</td><td colspan="6">Annual Treatment (Supplemental and Existing BMPs)</td></tr>
<tr><td></td><td colspan="2">Level 1 (10% TP)</td><td colspan="2">Level 2 (20% TP)</td><td colspan="2">Level 3 (30% TP)</td></tr>
<tr><td rowspan="4">Treatment</td><td>TP (lb/yr)</td><td>45.5</td><td>0.0</td><td>4.5</td><td>0.0</td><td>9.1</td><td>0.0</td><td>13.6</td><td>0.0</td></tr>
<tr><td>TSS (lb/yr)</td><td>5048</td><td>0.0</td><td>1655</td><td>0.0</td><td>2375</td><td>0.0</td><td>2930</td><td>0.0</td></tr>
<tr><td>Volume (acre-ft/yr)</td><td>49.5</td><td>0.0</td><td>3.4</td><td>0.0</td><td>7.4</td><td>0.0</td><td>11.9</td><td>0.0</td></tr>
<tr><td>Live Storage (ft^3)</td><td colspan="2"></td><td colspan="2">700</td><td colspan="2">1500</td><td colspan="2">2900</td></tr>
<tr><td rowspan="4">Costs (30-yr)</td><td>BMP Type</td><td colspan="2"></td><td colspan="2">Bioretention – 2</td><td colspan="2">Bioretention – 2</td><td colspan="2">Bioretention – 2</td></tr>
<tr><td>Total Project Cost</td><td colspan="2"></td><td colspan="2">$12,278</td><td colspan="2">$23,483</td><td colspan="2">$42,595</td></tr>
<tr><td>Annual O&M</td><td colspan="2"></td><td colspan="2">$525</td><td colspan="2">$1,125</td><td colspan="2">$2,175</td></tr>
<tr><td>Term Cost/lb/yr</td><td colspan="2"></td><td colspan="2">$208</td><td colspan="2">$210</td><td colspan="2">$264</td></tr>
</table>

PLFOXRN_PD-P

Catchment Summary	
Acres	58.7
Dominant Land Cover	Residential
Volume (acre-feet/yr)	36.8
TP (lb/yr)	28.8
TSS (lb/yr)	378.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	61
Indirectly connected Impervious Fraction	0.2752
Directly Connected Impervious Fraction	0.0688
Hydraulic Conductivity (in/hr)	2.56

DESCRIPTION

This catchment is comprised of primarily medium density, single-family residential development.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, poured concrete walls can form “box planters” along the streetscape.

For the sake of estimating costs per volume of water treated, we approximated a ft^2 pricing as some marriage of each of these forms of stormwater practices.

Proposed Curb Cut Bioretention

	Cost/Benefit Analysis	Existing Loading	Existing Treatment	RETROFIT OPTIONS					
				Annual Treatment (Supplemental and Existing BMPs)					
				Level 1 (10% TP)		Level 2 (20% TP)		Level 3 (30% TP)	
Treatment	TP (lb/yr)	36.8	8.9	3.7	7.7	7.4	6.5	11.0	5.4
Treatment	TSS (lb/yr)	4128	3750	1241	2531	1827	1968	2277	1549
Treatment	Volume (acre-ft/yr)	36.8	0.0	3.2	0.0	6.7	0.0	10.2	0.0
Treatment	Live Storage (ft^3)			550		970		1700	
Costs (30-yr)	BMP Type			Bioretention – 2		Bioretention – 2		Bioretention – 2	
Costs (30-yr)	Total Project Cost			$10,114		$16,106		$26,239	
Costs (30-yr)	Annual O&M			$413		$728		$1,275	
Costs (30-yr)	Term Cost/lb/yr			$300		$253		$287	

PLPL1ADDP1-P (part of 2-COMBINED)

Catchment Summary	
Acres	32.8
Dominant Land Cover	Residential
Volume (acre-feet/yr)	7.1
TP (lb/yr)	7.8
TSS (lb/yr)	884

Model Inputs	
Parameter	**Input**
Pervious Curve Number	61
Indirectly connected Impervious Fraction	0.304
Directly Connected Impervious Fraction	0.076
Hydraulic Conductivity (in/hr)	2.28

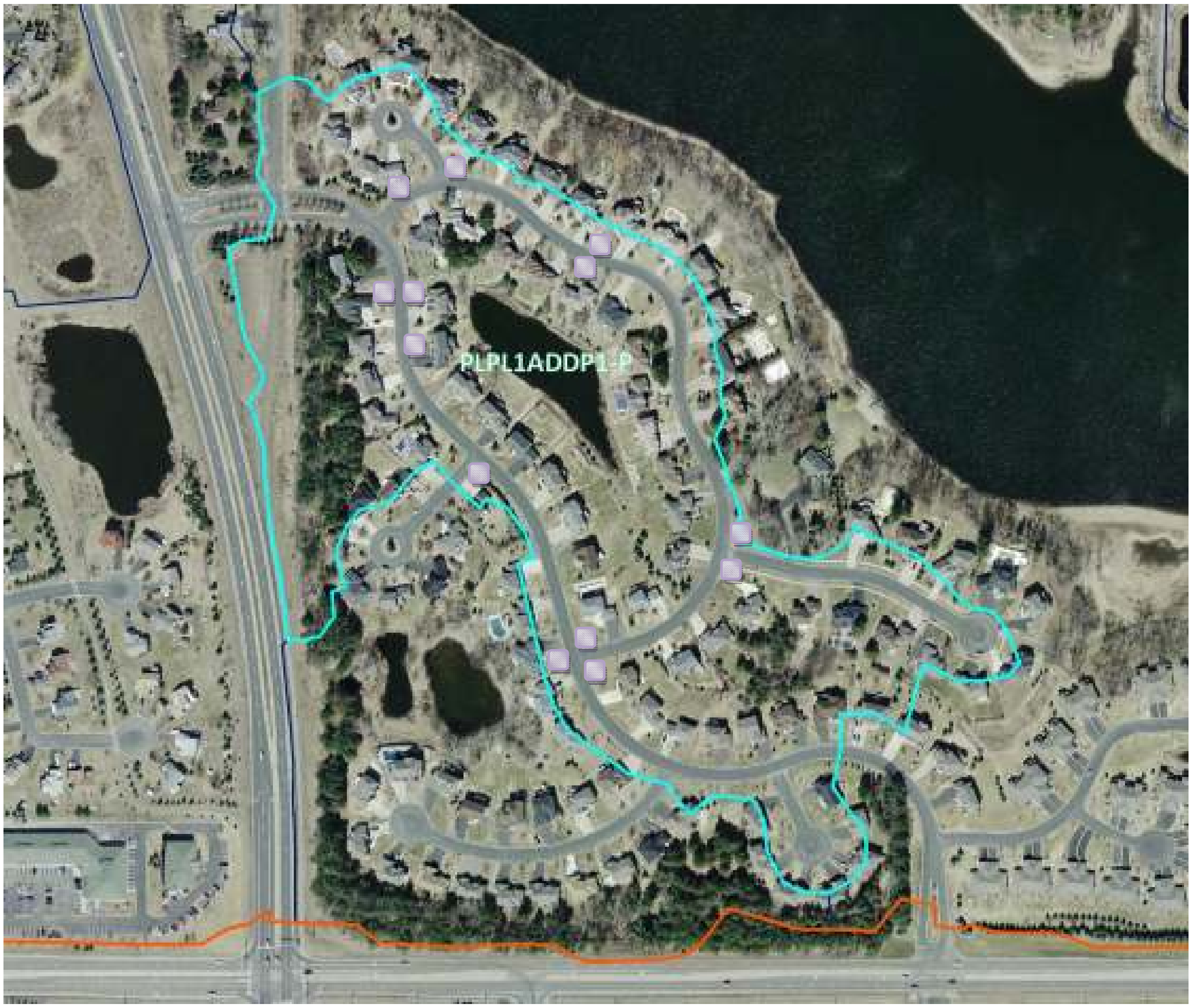
DESCRIPTION

This catchment is comprised of primarily medium density, single-family residential development. Catchment is combined with PLPL1ADDWT-P for retrofit options table.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, poured concrete walls can form “box planters” along the streetscape.

For the sake of estimating costs per volume of water treated, we approximated a ft^2 pricing as some marriage of each of these forms of stormwater practices.



Proposed Curb Cut Bioretention

	Cost/Benefit Analysis	Existing Loading	Existing Treatment	RETROFIT OPTIONS — Annual Treatment (Supplemental and Existing BMPs)					
				Level 1 (10% TP)		Level 2 (20% TP)		Level 3 (30% TP)	
Treatment	TP (lb/yr)	30.7	6.6	9.9	6.6	11.9	6.6	13.8	6.6
Treatment	TSS (lb/yr)	3443	3074	3117	3074	3127	3074	3150	3074
Treatment	Volume (acre-ft/yr)	31.0	0.0	3.8	0.0	6.3	0.0	8.4	0.0
Treatment	Live Storage (ft^3)			620		1060		1550	
Costs (30-yr)	BMP Type			Bioretention – 2		Bioretention – 2		Bioretention – 2	
Costs (30-yr)	Total Project Cost			$11,128		$17,369		$24,173	
Costs (30-yr)	Annual O&M			$465		$795		$1,163	
Costs (30-yr)	Term Cost/lb/yr			$253		$259		$273	

PLPL1ADDWT-P (part of 2-COMBINED)

Catchment Summary	
Acres	17.1
Dominant Land Cover	Residential
Volume (acre-feet/yr)	9.8
TP (lb/yr)	8.5
TSS (lb/yr)	941

Model Inputs	
Parameter	**Input**
Pervious Curve Number	61
Indirectly connected Impervious Fraction	0.1936
Directly Connected Impervious Fraction	0.0484
Hydraulic Conductivity (in/hr)	2.30

DESCRIPTION

This catchment is comprised of primarily medium density, single-family residential development. Catchment is combined with PLPL1ADDP1-P for retrofit options table.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, poured concrete walls can form “box planters” along the streetscape.

For the sake of estimating costs per volume of water treated, we approximated a ft^2 pricing as some marriage of each of these forms of stormwater practices.

Proposed Curb Cut Bioretention

				RETROFIT OPTIONS					
	Cost/Benefit Analysis	Existing Loading	Existing Treatment	Annual Treatment (Supplemental and Existing BMPs)					
				Level 1 (10% TP)		Level 2 (20% TP)		Level 3 (30% TP)	
Treatment	TP (lb/yr)	30.7	6.6	9.9	6.6	11.9	6.6	13.8	6.6
	TSS (lb/yr)	3443	3074	3117	3074	3127	3074	3150	3074
	Volume (acre-ft/yr)	31.0	0.0	3.8	0.0	6.3	0.0	8.4	0.0
	Live Storage (ft^3)			620		1060		1550	
Costs (30-yr)	BMP Type			Bioretention – 2		Bioretention – 2		Bioretention – 2	
	Total Project Cost			$11,128		$17,369		$24,173	
	Annual O&M			$465		$795		$1,163	
	Term Cost/lb/yr			$253		$259		$273	

PLPL9ADDP1-P

Catchment Summary	
Acres	10.5
Dominant Land Cover	Residential
Volume (acre-feet/yr)	7.1
TP (lb/yr)	7.8
TSS (lb/yr)	884

Model Inputs	
Parameter	**Input**
Pervious Curve Number	61
Indirectly connected Impervious Fraction	0.3416
Directly Connected Impervious Fraction	0.0854
Hydraulic Conductivity (in/hr)	0.54

DESCRIPTION

This catchment is comprised of primarily medium density, single-family residential development.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, poured concrete walls can form “box planters” along the streetscape.

For the sake of estimating costs per volume of water treated, we approximated a ft^2 pricing as some marriage of each of these forms of stormwater practices.

Proposed Curb Cut Bioretention

	Cost/Benefit Analysis	Existing Loading	Existing Treatment	RETROFIT OPTIONS					
				Annual Treatment (Supplemental and Existing BMPs)					
				Level 1 (10% TP)		Level 2 (20% TP)		Level 3 (30% TP)	
Treatment	TP (lb/yr)	7.8	2.0	1.6	1.3	2.3	1.1	3.1	0.8
Treatment	TSS (lb/yr)	884	824	465	366	557	279	629	212
Treatment	Volume (acre-ft/yr)	7.1	0.0	0.9	0.0	1.6	0.0	2.2	0.0
Treatment	Live Storage (ft^3)			400		750		1200	
Costs (30-yr)	BMP Type			Bioretention – 2		Bioretention – 2		Bioretention – 2	
Costs (30-yr)	Total Project Cost			$7,906		$12,992		$19,324	
Costs (30-yr)	Annual O&M			$300		$563		$1900	
Costs (30-yr)	Term Cost/lb/yr			$626		$711		$813	

PLPLADP1P1-P

Catchment Summary	
Acres	22.7
Dominant Land Cover	Residential
Volume (acre-feet/yr)	15.3
TP (lb/yr)	16.7
TSS (lb/yr)	1903

Model Inputs	
Parameter	**Input**
Pervious Curve Number	61
Indirectly connected Impervious Fraction	0.3416
Directly Connected Impervious Fraction	0.0854
Hydraulic Conductivity (in/hr)	1.66

DESCRIPTION

This catchment is comprised of primarily medium density, single-family residential development.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, poured concrete walls can form “box planters” along the streetscape.

For the sake of estimating costs per volume of water treated, we approximated a ft^2 pricing as some marriage of each of these forms of stormwater practices.

Proposed Curb Cut Bioretention

	Cost/Benefit Analysis	Existing Loading	Existing Treatment	RETROFIT OPTIONS: Annual Treatment (Supplemental and Existing BMPs) — Level 1 (10% TP)		Level 2 (20% TP)		Level 3 (30% TP)	
Treatment	TP (lb/yr)	16.7	4.4	3.3	3.2	5.0	2.6	6.7	2.1
Treatment	TSS (lb/yr)	1903	1786	893	913	1100	718	1268	562
Treatment	Volume (acre-ft/yr)	15.3	0.0	2.7	0.0	4.2	0.0	5.7	0.0
Treatment	Live Storage (ft^3)			550		1000		1550	
Costs (30-yr)	BMP Type			Bioretention – 2		Bioretention – 2		Bioretention – 2	
Costs (30-yr)	Total Project Cost			$10,114		$16,528		$24,173	
Costs (30-yr)	Annual O&M			$413		$750		$1,163	
Costs (30-yr)	Term Cost/lb/yr			$357		$407		$447	

PLPLADP1P2-P

Catchment Summary	
Acres	3.8
Dominant Land Cover	Residential
Volume (acre-feet/yr)	2.5
TP (lb/yr)	2.1
TSS (lb/yr)	25

Model Inputs	
Parameter	**Input**
Pervious Curve Number	68
Indirectly connected Impervious Fraction	0.3344
Directly Connected Impervious Fraction	0.0836
Hydraulic Conductivity (in/hr)	0.95

DESCRIPTION

This catchment is comprised of primarily medium density, single-family residential development.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, poured concrete walls can form “box planters” along the streetscape.

For the sake of estimating costs per volume of water treated, we approximated a ft^2 pricing as some marriage of each of these forms of stormwater practices.

Proposed Curb Cut Bioretention

				RETROFIT OPTIONS					
	Cost/Benefit Analysis	Existing Loading	Existing Treatment	Annual Treatment (Supplemental and Existing BMPs)					
				Level 1 (10% TP)		Level 2 (20% TP)		Level 3 (30% TP)	
Treatment	TP (lb/yr)	2.1	0.7	0.8	0.4	1.1	0.3	1.4	0.2
	TSS (lb/yr)	25	284	188	103	214	214	235	61
	Volume (acre-ft/yr)	2.5	0.0	0.6	0.0	0.8	0.0	1.1	0.0
	Live Storage (ft^3)			200		325		500	
Costs (30-yr)	BMP Type			Bioretention – 2		Bioretention – 2		Bioretention – 2	
	Total Project Cost			$4,827		$6,777		$9,384	
	Annual O&M			$150		$244		$375	
	Term Cost/lb/yr			$622		$671		$764	

Retrofit Ranking

Catchment ID	Retro Type	Live Storage Volume (ft^3)	TP Reduction (%)[1]	TP Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Overall Est. Cost[2]	O&M Term (years)	Total Est. Term Cost/lb-TP/yr
PL1-1-OF	B-2	1,500	20	9.1	7.4	$23,483	30	$210
PLFOXRN_PD-P	B-2	970	14	5.0	6.7	$16,106	30	$253
PLPL9ADDP1-P	B-2	750	18	1.4	1.6	$12,992	30	$711
PLPLADP1P1-P	B-2	1,550	26	4.4	5.7	$24,173	30	$447
PLPLADP1P2-P	B-2	325	33	0.7	0.8	$6,777	30	$671
2-COMBINED[3]	B-2	1,550	23	7.2	8.4	$24,173	30	$273
TOTALS	**-**	**6,645**	**-**	**27.8**	**30.6**	**$107,704**	-	-

B = Bioretention (infiltration and/or filtration), 2 = moderately complex

[1] TP Reduction calculated from the annual treatment achieved by new BMPs alone compared to existing catchment P load.
[2] Estimated overall costs include design, contracted soil core sampling, materials, contracted labor, promotion and administrative costs (including outreach, education, contracts, grants, etc), pre-construction meetings, installation oversight and 30 years of operation and maintenance costs.
[3] PLPL1ADDP1-P and PLPL1ADDWT-P were combined for the purposes of this study.

References

Houston Engineering, Inc. 2010. *Powers Lake Management Plan.* Prepared for the South Washington Watershed District. Woodbury, Minnesota.

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

Panuska, J. 1998. *Drainage System Connectedness for Urban Areas*. Memo. Wisconsin Dept of Natural Resources. Madison, WI.

Rawls et. al. 1998. *Use of Soil Texture, Bulk Density, and Slope of the Water Retention Curve to Predict Saturated Hydraulic Conductivity*. Transactions of the ASAE. Vol 41(4): 983-988. St. Joseph, MI.

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

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

USDA. 1986. *Urban Hydrology for Small Watersheds TR-55*. Second Edition. Washington, DC.

Walker, W.W. 2007. *P8: Urban Catchment Model, V 3.4.* Developed for the USEPA, Minnesota PCA and the Wisconsin DNR.

Appendices

Appendix 1—Catchments not included in Ranking Table

Catchments not included in ranking table were excluded for a number of reasons, mainly involving connectivity to the receiving water. After BMPs are installed within the priority catchments, it is recommended that the watershed revisit the entire subwatershed to determine other catchments that, while they may be conducive to retrofitting, were not considered a high priority for this report.

Summary of Protocol

This protocol attempts to provide a sufficient level of detail to rapidly assess sub-watersheds or catchments of variable scales and land-uses. It provides the assessor defined project goals that aid in quickly narrowing down multiple potential sites to a point where he/she can look a little more closely at site-specific driven design options that affect, sometimes dramatically, BMP selection. We feel that the time commitment required for this methodology is appropriate for most initial assessment applications and has worked well thus far for the Powers Lake Assessment.

Overall Catchment Map

See below for a map showing the entire Powers Lake subwatershed and selected catchments (labeled):