CITY OF LINDSTROM: STORMWATER RETROFIT ASSESSMENT

Prepared by:

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With assistance from:

THE METRO CONSERVATION DISTRICTS

For:

THE CITY OF LINDSTROM & THE CHISAGO LAKES LAKE IMPROVEMENT DISTRICT

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 herein. This typically occurs after the procurement of committed partnerships relative to each specific target parcel slated for the placement of BMPs.

Funding in part for the Stormwater Retrofit Assessment was provided by the Clean Water Fund from the Clean Water, Land and Legacy Amendment.

Contents

Executive Summary

The City of Lindstrom (about 2,100 acres) was broken down into fifty-two 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 City. Sixteen of the 52 catchments were selected and modeled at various levels of treatment efficiencies. These catchments should be considered the "low-hanging-fruit" for stormwater retrofit opportunities within the City of Lindstrom.

The following table summarizes the assessment results. Some catchments are not included in the report due to treatment levels (percent removal rates) for retrofit projects that resulted in a prohibitive BMP size, or number, or were too expensive to justify installation. Reported treatment levels are dependent upon optimal siting 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. As needed, this document will be modified to address new products or updates in the assessment process to make the document more accurate.

Catchment ID	Retrofit Type	Qty of 100 ft^3 BMPs	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Cost Est [1]	O&M Term (years)	Total Est. Term Cost/lb-TP/yr[2]
LINDSTROM-13	B	6	20	1.3	0.6	$8,509	30	$594
LINDSTROM-15	PS, B	22	20	5.0	2.3	$43,223	30	$645
LINDSTROM-16	B	25	20	5.3	2.4	$32,753	30	$557
LINDSTROM-18A	B, PS	5	30	0.8	0.4	$6,531	30	$726
LINDSTROM-18C	B, F	19	43	2.7	1.5	$24,584	30	$823
LINDSTROM-19	B, PS	28	20	5.6	2.6	$36,374	30	$586
LINDSTROM-20	B	106	30	19.8	12.5	$190,134	30	$723
LINDSTROM-23	B, VS	16	20	1.4	0.4	$13,632	30	$1,189
LINDSTROM-27	B	7	20	1.5	0.7	$9,570	30	$587
LINDSTROM-28	B, F	13	50	7.1	5.8	$62,252	30	$564
LINDSTROM-29	B	34	20	6.8	3.2	$44,507	30	$591
LINDSTROM-30	B	12	20	2.6	1.3	$16,361	30	$563
LINDSTROM-33	B	6	20	1.3	0.6	$8,374	30	$566
LINDSTROM-40	B	21	20	4.4	2.2	$27,818	30	$570
LINDSTROM-42	B	15	20	3.6	2.0	$19,700	30	$491
LINDSTROM-48	B	5	30	1.1	0.7	$7,069	30	$595
LINDSTROM-50a	B, G	12	50	1.5	1.0	$17,095	30	$693
LINDSTROM-50b	B	11	20	2.3	1.1	$14,931	30	$580

B = Bioretention (infiltration and/or filtration)
F = Filtration (sand curtain, surface sand filter, sump, etc)
PM = Pond Modification (increased area/depth, additional cells, forebay, and/or outlet modification)
PS = Permeable Surface (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
G = Gully Stabilization

[1]Estimated "Overall Cost" includes design, contracted soil core sampling, materials, contracted labor, promotion and administrative costs (including outreach, education, contracts, grants, etc), pre-construction meetings, installation oversight and 1 year of operation and maintenance costs. [2]"Total Est. Term Cost" includes Overall Cost plus 30 years of maintenance and is divided by 30 years of TP treatment.

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., LINDSTROM-01 for City of Lindstrom catchment 01). 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.

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 2,500 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.

City of Lindstrom Scoping

Pollutants of concern for this subwatershed were identified as Total Phosphorus (TP), Total Suspended Solids (TSS), and Volume. The City of Lindstrom has projects identified that they feel are high priority projects. This assessment will be used to reassure or change their priority list to help meet water quality goals. The City of Lindstrom plans to adopt this Assessment as part of their Capital Improvement Plan (CIP) and will continue to work on completing the highest ranking projects until they are complete.

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:

Stormwater Treated 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 passing it through an under-drain. May consist of a combination of sand, soil, peat, compost and iron.**
	Infiltration	**A rock-filled trench or sump 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 that 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.

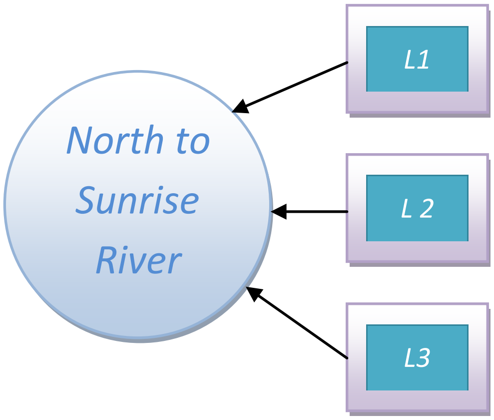
General P8 Model Inputs	
Parameter	Method for Determining Value
Total Area	Source/Criteria
Pervious Area Curve Number	Values from the USDA Urban Hydrology for Small Watersheds TR-55 (1986). A composite curve number was found based on proportion of hydrologic soil group and associated curve numbers for 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.

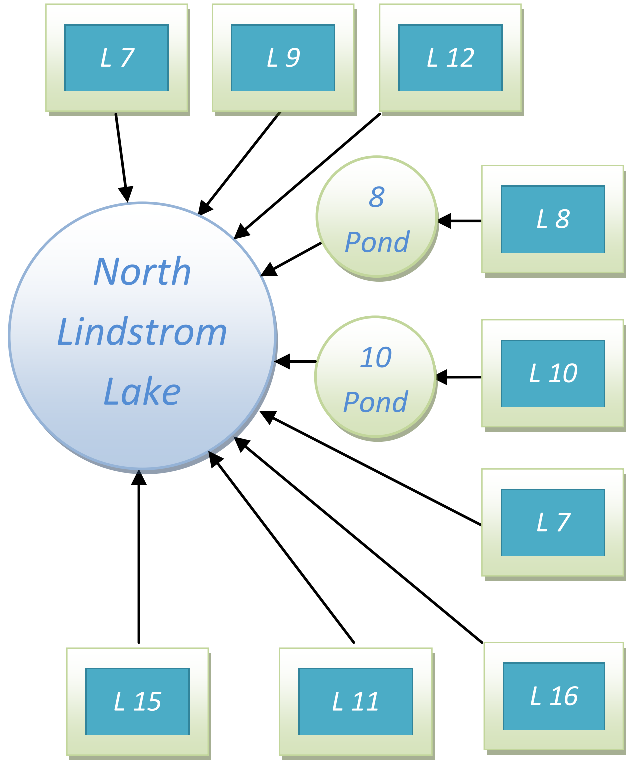
City of Lindstrom Treatment Analysis

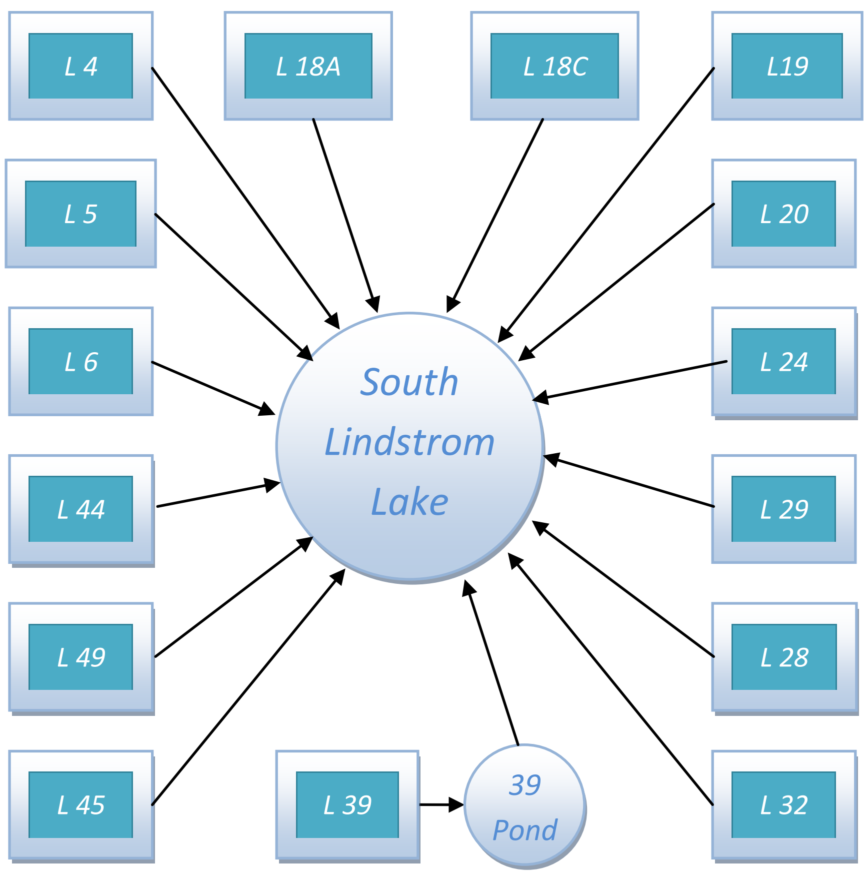
For the City of Lindstrom treatment analysis, each catchment, and each parcel within them, was first assessed for BMP "family" type applicability given specific site constraints and soil types. Pedestrian and car traffic flow, parking needs, snow storage areas, obvious utility locations, existing landscaping, 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.

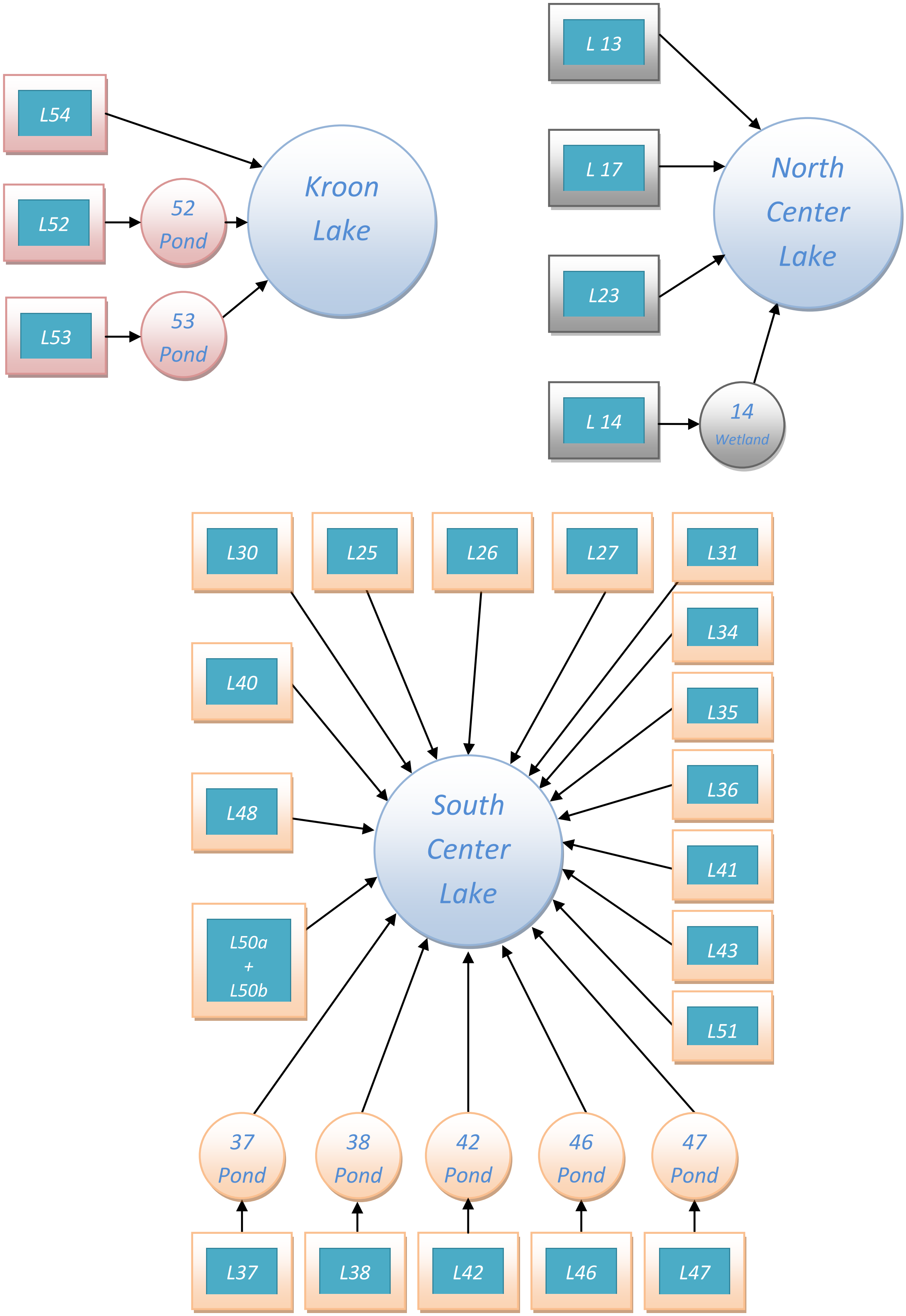
P8 was used to model catchments and a hypothetical BMP located at its outfall. The BMP was sized from the Minimum Acceptable to Maximum Feasible treatment size and results were tabulated in the Catchment Profile section of this document.

The existing stormwater network was modeled in P8 as illustrated in the following diagram:


North to Sunrise River
L1
L 2
L3


L 7
L 9
L 12
8 Pond
L 8
North Lindstrom Lake
10 Pond
L 10
L 7
L 15
L 11
L 16


L 4
L 18A
L 18C
L19
L 5
L 20
L 6
South Lindstrom Lake
L 24
L 44
L 29
L 49
L 28
L 45
L 39
39 Pond
L 32


L 13
L54
L 17
Kroon
Lake
North
Center
Lake
L52
52
Pond
L23
L53
53
Pond
L 14
14
Wetland
L30
L25
L26
L27
L31
L34
L40
L35
L48
L36
South
Center
Lake
L41
L50a
+
L50b
L43
L51
37
Pond
38
Pond
42
Pond
46
Pond
47
Pond
L37
L38
L42
L46
L47

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 ($/sq ft)	Marginal Annual Maintenance Cost (contracted)	O & M Term	Design Cost ($70/hr)	Installation Oversight Cost ($70/hr)	Total Installation Cost (Incl. design & 1-yr maint.)
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, etc.)[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 sq ft	30	20% above construction	$210 (3 visits)	**$32.90/sq ft**
Rain Leader Disconnect Raingardens	$4.00	[2]$25/150 sq ft	30	$280/100 sq ft	$210 (3 visits)	**$6.97/sq ft**

Simple Bioretention (no eng. soils or under-drains, but w/curb cuts and forebays)	$10.00	$0.75/sq ft	30	$840/1000 sq ft	$210 (3 visits)	**$11.59/sq ft**
Moderate Bioretention (incl. engineered soils, under-drains, curb cuts, no retaining walls)	$12.00	$0.75/sq ft	30	$1120/1000 sq ft	$210 (3 visits)	**$13.87/sq ft**
Moderately Complex Bioretention (incl. eng. soils, under-drains, curb cuts, forebays , 2-3 ft retaining walls)	$14.00	$0.75/sq ft	30	$1250/1000 sq ft	$210 (3 visits)	**$16.00/sq ft**
Highly Complex Bioretention (incl. eng. soils, under-drains, curb cuts, forebays, 3-5 ft retaining walls)	$16.00	$0.75/sq ft	30	[4]$1400/1000 sq ft	$210 (3 visits)	**$18.15/sq ft**
Underground Sand Filter	$65.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	**$91.75/sq ft**
Stormwater Tree Pits	$70.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	**$98.75/sq ft**
Grass/Gravel Permeable Pavement (sand base)	$12.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	**$17.55/sq ft**
Permeable Asphalt (granite base)	$10.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	**$14.00/sq ft**
Permeable Concrete (granite base)	$12.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	**$17.55/sq ft**
Permeable Pavers (granite base)	$25.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	**$35.75/sq ft**
Extensive Green Roof	$225.00	$500/1000 sq ft	30	[1]40% above construction	$210 (3 visits)	**$315.50/sq ft**
Intensive Green Roof	$360.00	$750/1000 sq ft	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).

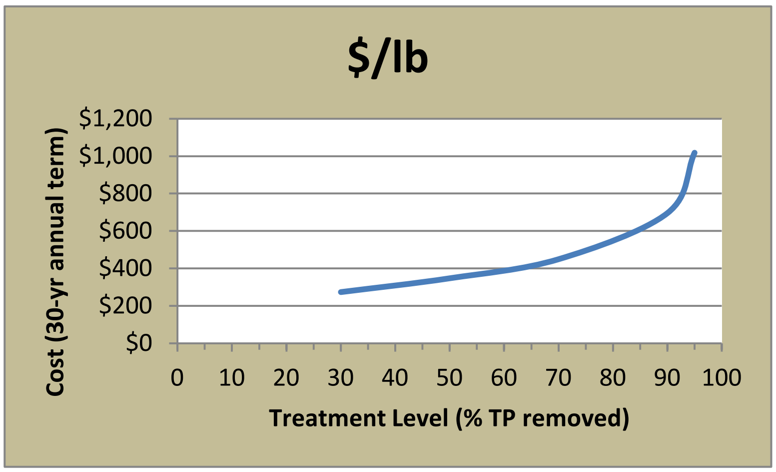
[6]Assumed to be 15 feet in width.

City of Lindstrom Cost Analysis

For the City of Lindstrom cost analysis, promotion and administration for each commercial/public 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 O & M referred to the ft^2 estimates provided in the preceding table. In cases where 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.



City of Lindstrom Evaluation and Ranking

In the City of Lindstrom 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.

City of Lindstrom Catchment Profiles

For development of the City of Lindstrom catchment profile section, 17 out of 52 catchments were selected as the first-tier areas for stormwater retrofit efforts. Those catchments receiving modern stormwater pond treatment, or in some cases 2 levels of treatment, were not modeled or further analyzed in this assessment. It is recommended that after these initial catchments are built out past the recommended reduction levels that catchments 8, 37-39, 46 and their pond networks be modeled. Analyzing pond modification first, then secondary uphill distributed retrofits are recommended. Newer developments with "water quality" stormwater ponds may still be modeled to achieve even more treatment (Catchments 1-3, 10, 12, 47, 52 and 53) after the other catchment projects are completed or deemed impractical. All other catchments not previously identified were either adequately treated with little opportunity for more treatment, or were in need of backyard conservation (i.e. lakeshore restorations, rain leader disconnect rain gardens, rain barrels, etc.).

The catchments that were modeled for treatment possibilities were modeled at many levels of treatment. The first level was sized for the maximum allowed space for bioretention or the estimated highest level of participation, then levels of treatment below the maximum were modeled. Most of the time the Minimum and Middle treatment level ended up being between 20-50% Total Phosphorus removal.

A cost benefit analysis like this example table is included for each catchment:

	Cost/Benefit Analysis	***Annual Marginal Treatment Enhancement***					
		Min		**Mid**		**Max**	
Treatment	**TP (lb/yr)**	1.3	20%	1.9	30%	3.1	50%
	TSS (lb/yr)	931	48%	1,137	58%	1,460	75%
	Volume (acre-feet/yr)	0.6	11%	1.0	19%	1.9	35%
	Live Storage Volume (cubic feet)	511		1,089		2,367	
Costs	**Materials/Labor/Design**	$8,022		$14,288		$31,056	
	Promotion & Admin Costs	$488		$320		$182	
	Total Project Cost	$8,509		$14,608		$31,238	
	Annual O&M	$459		$817		$1,775	
	Term Cost/lb/yr (30 yr)	$594		$705		$909	

E X A M P L E

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LINDSTROM-13

Catchment Summary	
Acres	9.4
Dominant Land Cover	Residential
Parcels	15
Volume (acre-feet/yr)	5.4
TP (lb/yr)	6.2
TSS (lb/yr)	1,947

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.27
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

This catchment is comprised of primarily medium density, single family residential development. There are existing road ditches that are connected under driveways with culverts. These ditches are planted with blue grass and are currently mowed. One portion of the road network is gravel; this transports a significant amount of sediment into the system.

RETROFIT RECOMMENDATION

The current road ditches can be planted to native grasses and forbs to slow water down and increase infiltration rates. At the corner of Olinda Trail (gravel) and Penninsula Avenue bioretention cells are recommended. These cells will need to have heavy-duty pre-treatment that can be easily maintained. This will be crucial in the success of the bioretention in this catchment.

Proposed Bioretention Areas

		Neighborhood Retrofit					
	Cost/Benefit Analysis	*Annual Marginal Treatment Enhancement*					
		Min		Mid		Max	
Treatment	TP (lb/yr)	1.3	20%	1.9	30%	3.1	50%
	TSS (lb/yr)	931	48%	1,137	58%	1,460	75%
	Volume (acre-feet/yr)	0.6	11%	1.0	19%	1.9	35%
	Live Storage Volume (cubic feet)	611		1,089		2,367	
Costs	Materials/Labor/Design	$8,022		$14,288		$31,056	
	Promotion & Admin Costs	$488		$320		$182	
	Total Project Cost	$8,509		$14,608		$31,238	
	Annual O&M	$459		$817		$1,775	
	Term Cost/lb/yr (30 yr)	$594		$705		$909	

LINDSTROM-15

Catchment Summary	
Acres	24.2
Dominant Land Cover	Residential/ Commercial
Parcels	60
Volume (acre-feet/yr)	21.7
TP (lb/yr)	25.4
TSS (lb/yr)	7,979

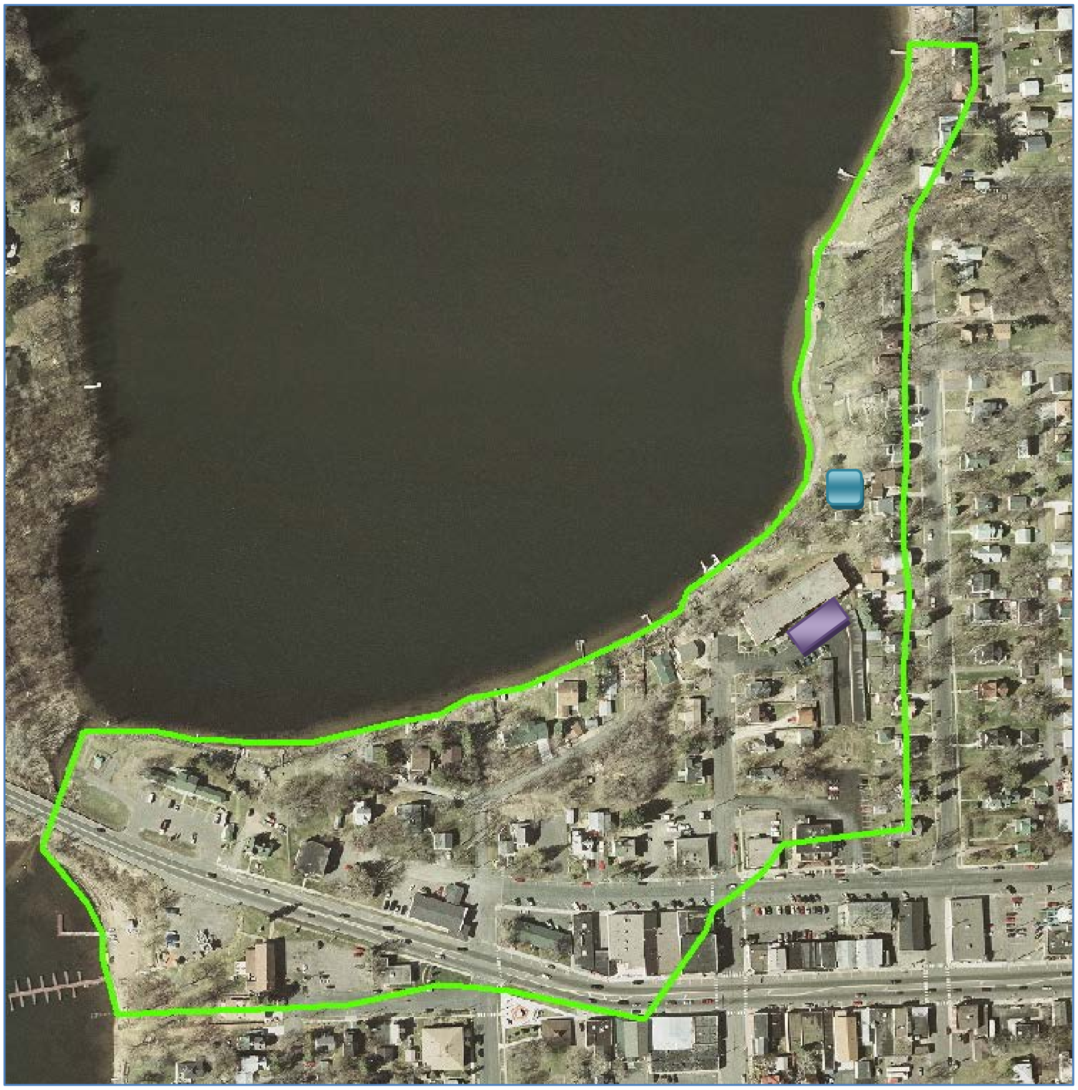
Model Inputs	
Parameter	**Input**
Pervious Curve Number	68
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.43
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

This catchment is made up of a portion of downtown Lindstrom, including Highway 8, and residential lots. A condominium complex is also included in this catchment. The slopes are extremely steep near the lake, leaving little available green space that could be utilized for traditional BMPs.

RETROFIT RECOMMENDATION

Treatment for this catchment may be difficult unless undertaken when an opportunity arises. When pavement in parking lots is scheduled for resurfacing, pervious pavement should be considered. There is very little room for BMPs such as rain gardens or vegetated swales. In locations that are available, backyard conservation should be implemented.



Proposed Permeable Pavement Proposed Bioretention Areas

	Cost/Benefit Analysis	Neighborhood Retrofit					
		Annual Marginal Treatment Enhancement					
		Min		Mid		Max	
Treatment	**TP (lb/yr)**	5.0	20%	7.6	30%	12.7	50%
	TSS (lb/yr)	3,751	47%	4,561	57%	5,840	73%
	Volume (acre-feet/yr)	2.3	11%	3.8	18%	7.4	34%
	Live Storage Volume (cubic feet)	2,382		4,161		8,712	
Costs	**Materials/Labor/Design**	$42,638		$74,482		$155,945	
	Promotion & Admin Costs	$585		$390		$227	
	Total Project Cost	$43,223		$74,871		$156,172	
	Annual O&M	$1,787		$3,121		$6,534	
	Term Cost/lb/yr (30 yr)	$645		$739		$924	

LINDSTROM-16

Catchment Summary	
Acres	33.9
Dominant Land Cover	Residential
Parcels	80
Volume (acre-feet/yr)	22.8
TP (lb/yr)	26.5
TSS (lb/yr)	8,325

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.32
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

This medium density residential home catchment is directed to stormwater pipes and routed directly to a large gully on North Third Avenue. Currently this deep gully is lined with rip rap to prevent in channel erosion. The end of this gully has been repaired a number of times to stop scouring at the bottom. Pump House Park is near the large gully within this catchment.

RETROFIT RECOMMENDATION

Upstream bioretention is recommended for Catchment-16 in the form of curb-cut rain gardens. This will include newly poured curb cut inlets and filtration basins. Due to the heavy soils, soil amendments and pipes will be needed in the basins to ensure proper drainage. Most of the slopes behind the curb in this area are very gradual; however, where elevations of the road and/or slope behind the curb line are more than gradual, retaining walls will be necessary. We will recommend pervious pavement (pavers, concrete, or asphalt) to business owners with large parking lots. There are several locations along the streets by Pump House Park that would be ideal locations for bioretention.

Proposed Bioretention Areas

	Cost/Benefit Analysis	Neighborhood Retrofit					
		Annual Marginal Treatment Enhancement					
		Min		Mid		Max	
Treatment	TP (lb/yr)	2.6	10%	5.3	20%	8.0	30%
	TSS (lb/yr)	2,757	33%	3,918	47%	4,761	57%
	Volume (acre-feet/yr)	1.0	4%	2.4	11%	4.0	18%
	Live Storage Volume (cubic feet)	1,032		2,483		4,356	
Costs	Materials/Labor/Design	$13,540		$32,577		$57,151	
	Promotion & Admin Costs	$333		$176		$117	
	Total Project Cost	$13,873		$32,753		$57,267	
	Annual O&M	$774		$1,862		$3,267	
	Term Cost/lb/yr (30 yr)	$476		$557		$647	

LINDSTROM-18a

Catchment Summary	
Acres	7.9
Dominant Land Cover	Residential
Parcels	9
Volume (acre-feet/yr)	2.4
TP (lb/yr)	2.8
TSS (lb/yr)	875

Model Inputs	
Parameter	**Input**
Pervious Curve Number	67
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.38
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

This small catchment consists of low density residential and open space. Beach Park sits at the bottom of this catchment. This park is highly used and visible as it houses a large swimming beach, playground and winter lake access. Currently there are some erosion issues along the lakeshore due to water running down the fairly large hill as you enter the park.

RETROFIT RECOMMENDATION

Only a small portion of this catchment can be treated by the bioretention suggestions here due to the number of lots that drain directly to the lake. Installing a bioretention cell at the entrance of the park and a lakeshore restoration are the minimum recommended BMPs. Establishing a good quality native buffer along the shoreline will control further erosion and slow water that enters the lake from the road. A portion of the parking lot could be turned into some form of permeable pavement. Due to the heavy soils, soil amendments and pipes will be needed in the basin to ensure proper drainage.

One of the best benefits of these bioretention and restoration practices at this park is the public education benefits of stormwater retrofit practices in a visible location at a busy park.

Proposed Bioretention Areas Proposed Permeable Pavement Proposed Lakeshore Restoration

	Cost/Benefit Analysis	Beach Park Retrofit: Annual Marginal Treatment Enhancement					
		Min		Mid		Max	
Treatment	TP (lb/yr)	0.8	30%	1.1	40%	1.4	50%
	TSS (lb/yr)	510	58%	588	67%	656	75%
	Volume (acre-feet/yr)	0.4	17%	0.6	25%	0.9	38%
	Live Storage Volume (cubic feet)	498		741		1,051	
Costs	Materials/Labor/Design	$6,531		$9,715		$13,783	
	Promotion & Admin Costs	$567		$424		$329	
	Total Project Cost	$7,098		$10,140		$14,111	
	Annual O&M	$373		$555		$788	
	Term Cost/lb/yr (30 yr)	$726		$798		$899	

LINDSTROM-18c

Catchment Summary	
Acres	10.4
Dominant Land Cover	Residential
Parcels	26
Volume (acre-feet/yr)	5.7
TP (lb/yr)	6.6
TSS (lb/yr)	2,072

Model Inputs	
Parameter	**Input**
Pervious Curve Number	67
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.38
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

This small catchment consists of low density residential and open space. Memorial Park sits at the top of this catchment. This park is highly visible in the community. Many visitors to Lindstrom come to the Memorial along Highway 8 and see the South Lindstrom Lake to the south. They then travel toward the lake, which brings them to an “overlook” that is currently not very appealing. The City would like this overlook at the end of Linden Street to be attractive and inviting to visitors.

RETROFIT RECOMMENDATION

Bioretention at intersection of Linden Street and Newell Avenue is possible and would be recommended to achieve the highest level of treatment as well as the area south of Newell Avenue on Linden Street. This bioretention would include curb cut rain gardens relying on newly poured concrete curb cuts. Due to the heavy soils, soil amendments and pipes will be needed in the basin to ensure proper drainage. Near the lake, a terraced bioretention swale will be created to ensure that water travels slowly to the lake. Adding permeable pavers in the turnaround/parking area would increase infiltration and pollutant removal; this is a good option if portions of pavement are going to be replaced anyway. This area will be able to be used as an attractive overlook to South Lindstrom Lake.

One of the best benefits of the bioretention practices within this catchment is the public education benefits of stormwater retrofit practices in a visible location.

Proposed Bioretention Areas

		Dead End Retrofit					
	Cost/Benefit Analysis	*Annual Marginal Treatment Enhancement*					
		Bioretention		Bioretention		Bioretention+Pavers	
Treatment	TP (lb/yr)	2.7	43%	3.4	52%	3.6	57%
	TSS (lb/yr)	1,384	71%	1,547	79%	1,581	81%
	Volume (acre-feet/yr)	1.5	28%	2.2	41%	2.3	43%
	Live Storage Volume (cubic feet)	1,870		2,850		3,100	
Costs	Materials/Labor/Design	$24,534		$37,392		$46,330	
	Promotion & Admin Costs	$50		$50		$50	
	Total Project Cost	$24,584		$37,442		$46,380	
	Annual O&M	$1,403		$2,138		$2,325	
	Term Cost/lb/yr (30 yr)	$823		$996		$1,075	

LINDSTROM-19

Catchment Summary	
Acres	17.3
Dominant Land Cover	Residential
Parcels	53
Volume (acre-feet/yr)	24.0
TP (lb/yr)	28.2
TSS (lb/yr)	8,876

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.67
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

This catchment is a mixture of medium density residential and commercial downtown. The whole catchment is directed to stormwater pipes and routed directly to the lake with no treatment. At the end of this pipe is a large gully that has been fixed a number of times. Currently there are a series of drop structures to bring the piped water down to the lake in a more controlled fashion; however, this is not providing any treatment. The large amount of water through this system also causes a washout at the bottom end of the pipe.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment. This will include newly poured curb cut inlets, filtration basins, and pervious pavement. Due to the heavy soils, soil amendments and pipes will be needed in the basins to ensure proper drainage. Where elevations of the road and/or slope behind the curb line are more than gradual, retaining walls will be necessary. We will recommend pervious pavement (pavers, concrete, or asphalt) to business owners with large parking lots.

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 Bioretention Areas   Proposed Permeable Pavement

	Cost/Benefit Analysis	Bioretention + Permeable Pavement					
		Annual Marginal Treatment Enhancement					
		Min		Mid		Max	
Treatment	TP (lb/yr)	2.8	10%	5.6	20%	8.5	30%
	TSS (lb/yr)	3,004	34%	4,239	48%	5,170	58%
	Volume (acre-feet/yr)	1.1	5%	2.6	11%	4.4	18%
	Live Storage Volume (cubic feet)	1,148		2,760		4,895	
Costs	Materials/Labor/Design	$15,062		$36,211		$64,222	
	Promotion & Admin Costs	$308		$163		$107	
	Total Project Cost	$15,370		$36,374		$64,329	
	Annual O&M	$861		$2,070		$3,671	
	Term Cost/lb/yr (30 yr)	$490		$586		$684	

LINDSTROM-20

Catchment Summary	
Acres	65.7
Dominant Land Cover	Residential
Parcels	110
Volume (acre-feet/yr)	52.1
TP (lb/yr)	61.0
TSS (lb/yr)	19,184

Model Inputs	
Parameter	**Input**
Pervious Curve Number	68
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.41
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

A combination of commercial downtown, medium-density residential and open space make up the land use in this catchment. Aside from the pond at Lindstrom City Hall in the northeast portion of the catchment, the area is largely untreated. The runoff has been known to cause issues in South Lindstrom Lake during high flow situations; therefore, treating runoff and volume at this location is a priority for the City.

RETROFIT RECOMMENDATION

We have a unique opportunity to provide stormwater retrofits to this catchment as there is a City park at the pour point of this catchment. The proposed BMPs include different bioretention opportunities. At a minimum we would like to daylight a stormwater pipe and reroute it to a series of sediment forebays and filtration basins. In addition to the bioretention at the park, uphill treatment of curb-cut rain gardens could be added to reach the maximum treatment.

Proposed Bioretention Areas

		Stormwater Park + Uphill Treatment					
	Cost/Benefit Analysis	***Annual Marginal Treatment Enhancement***					
		Min		**Mid**		**Max**	
Treatment	**TP (lb/yr)**	14.2	23%	19.8	32%	28.2	46%
	TSS (lb/yr)	8,641	45%	10,475	55%	13,123	68%
	Volume (acre-feet/yr)	8.5	16%	12.5	24%	19.0	36%
	Live Storage Volume (cubic feet)	6,960		10,622		17,600	
Costs	**Materials/Labor/Design**	$124,584		$190,134		$315,040	
	Promotion & Admin Costs	$500		$500		$500	
	Total Project Cost	$125,084		$190,634		$315,540	
	Annual O&M	$5,220		$7,967		$13,200	
	Term Cost/lb/yr (30 yr)	$661		$723		$841	

LINDSTROM-23

Catchment Summary	
Acres	23.8
Dominant Land Cover	School
Parcels	1.0
Volume (acre-feet/yr)	6.2
TP (lb/yr)	7.2
TSS (lb/yr)	2,242

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.22
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

The Chisago Lakes Middle School is a complex including one school, two parking lots, and several ball fields. The Chisago Lakes School District is interested in perusing BMPs that can help decrease their water quality impact. There is a curb cut leading to a grassed area at one of the parking lots and ditches along the north and east sides of the ball fields.

RETROFIT RECOMMENDATION

An infiltration basin will be installed at the District Offices parking lot. There is an existing curb cut. Modifications will need to be made to the storm sewer outlet to allow water to enter the basin rather than flowing into the storm drain and entering the lake directly. On the north portion of the property a series of water quality swale plantings is recommended. The ditches that currently convey water to North Center Lake will be modified to slow water down and add deeply rooted native plants or shrubs. The installation of these practices will reduce the amount of mowing that is done at the Middle School; however, maintenance will need to continue on the swales in the form of weed control. By utilizing volunteer and school staff labor, the price of this planting could greatly decrease. Due to the heavy soils, soil amendments and pipes will be needed in the basins to ensure proper drainage. Where elevations of the road and/or slope behind the curb line are more than gradual, retaining walls will be necessary.

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 Bioretention Areas   Proposed Water Quality Swales

		Water Quality Swale + Bioretention					
	Cost/Benefit Analysis	***Annual Marginal Treatment Enhancement***					
		Min		**Mid**		**Max**	
Treatment	**TP (lb/yr)**	1.4	20%	2.1	30%	3.5	50%
	TSS (lb/yr)	1,141	51%	1,369	61%	1,735	77%
	Volume (acre-feet/yr)	0.4	6%	0.6	10%	1.4	23%
	Live Storage Volume (cubic feet)	1,613		3,525		11,739	
Costs	**Materials/Labor/Design**	$13,132		$27,930		$89,271	
	Promotion & Admin Costs	$500		$500		$500	
	Total Project Cost	$13,632		$28,430		$89,771	
	Annual O&M	$1,210		$2,644		$8,217	
	Term Cost/lb/yr (30 yr)	$1,189		$1,710		$3,203	

* It is likely that because of the way the model must be set up in P8 the pollutant reductions are underestimated this catchment. Also, much of the maintenance will be done by School staff – reducing the cost estimate for that portion. Therefore, the cost per pound per year calculation may be greatly overestimated.

LINDSTROM-27

Catchment Summary	
Acres	15.0
Dominant Land Cover	Industrial
Parcels	11
Volume (acre-feet/yr)	6.4
TP (lb/yr)	7.4
TSS (lb/yr)	2,298

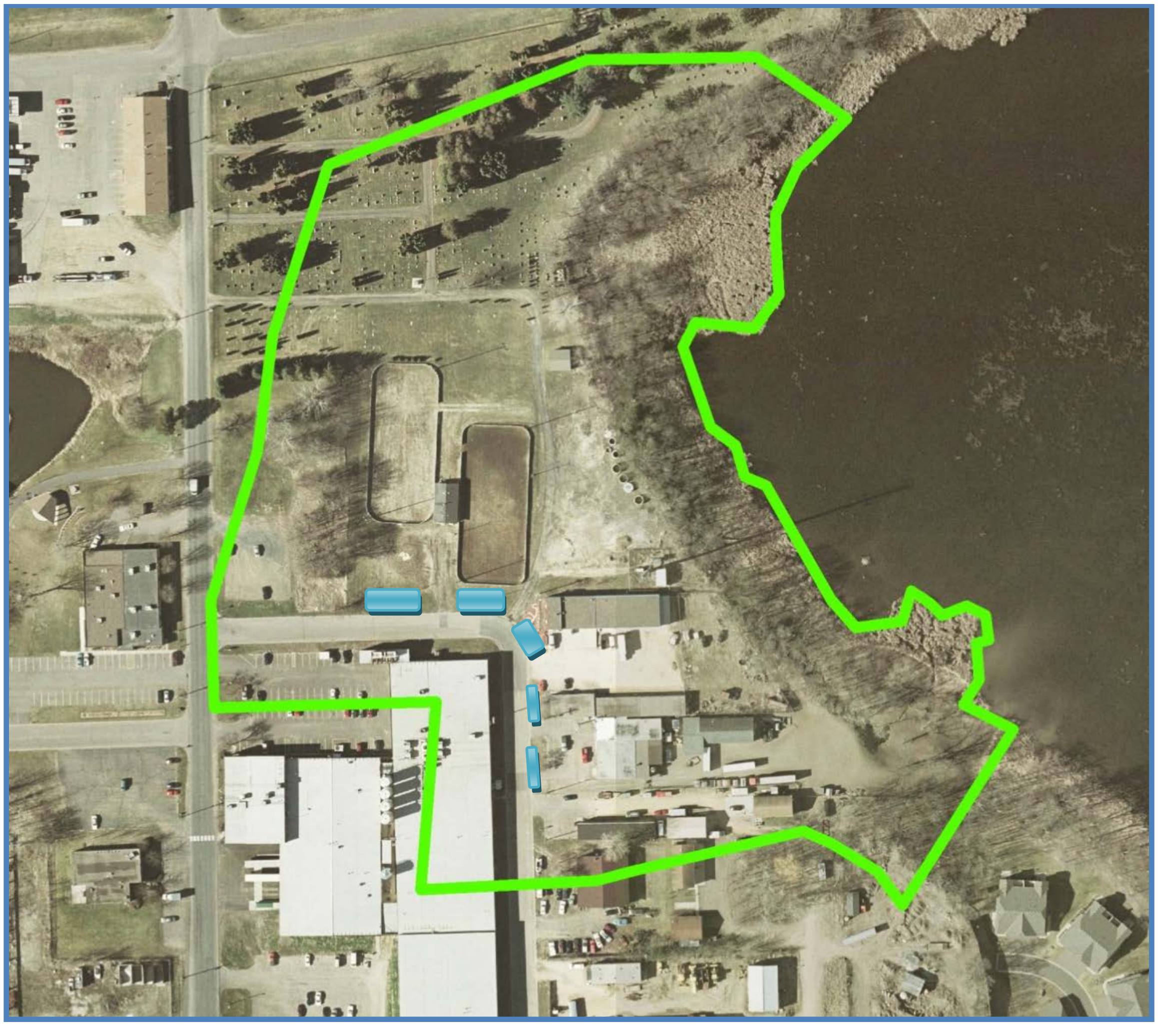
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.2
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

This area is comprised of light industrial, apartments, commercial, large parking lots and open land owned by the city. The City land will ultimately be converted to cemetery at some point in time. Currently there is some landscaping along the road at the apartment building.

RETROFIT RECOMMENDATION

Road right-of-way bioretention basins should be utilized in this catchment. This would capture run-off from the untreated streets and parking lots. Ideally, there will be two large infiltration basins and three smaller basins in the road right of way. At the apartment building and retail locations some bioretention basins with added landscaping could add appeal to the area. Some areas that need to be very low maintenance could be planted with a very simple planting plan for maintenance purposes. Due to the heavy soils, soil amendments and pipes will be needed in the basins to ensure proper drainage. Where elevations of the road and/or slope behind the curb line are more than gradual, retaining walls will be necessary.



Proposed Bioretention Areas

	Cost/Benefit Analysis	Industrial Park Bioretention					
		Annual Marginal Treatment Enhancement					
		Min		Mid		Max	
Treatment	TP (lb/yr)	1.5	20%	2.2	30%	3.7	50%
	TSS (lb/yr)	1,103	48%	1,343	58%	1,725	75%
	Volume (acre-feet/yr)	0.7	11%	1.2	19%	2.3	36%
	Live Storage Volume (cubic feet)	729		1,288		2,805	
Costs	Materials/Labor/Design	$9,570		$16,899		$36,802	
	Promotion & Admin Costs	$429		$283		$161	
	Total Project Cost	$9,999		$17,182		$36,962	
	Annual O&M	$547		$966		$2,104	
	Term Cost/lb/yr (30 yr)	$587		$699		$902	

LINDSTROM-28

Catchment Summary	
Acres	9.7
Dominant Land Cover	Mobile Homes
Parcels	73 homes
Volume (acre-feet/yr)	12.0
TP (lb/yr)	14.2
TSS (lb/yr)	4,467

Model Inputs	
Parameter	**Input**
Pervious Curve Number	58
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.6
Hydraulic Conductivity (in/hr)	1.60

DESCRIPTION

This catchment consists of a well manicured private mobile home park with private streets. There are approximately 73 mobile homes with very little “green space” on the entire parcel. The private streets “dead end” into South Lindstrom Lake. There are a series of curb-cuts to allow water onto the beach at specified locations. The end of road erosion appears to have been a problem for many years. The park has attempted to slow down runoff and reduce erosion by placing rip rap at the curb-cuts. In large rain events, water from Olinda Trail that is not being handled by the storm sewers can enter the park causing more water than anticipated to enter South Lindstrom Lake. Space is potentially limited by water levels and areas needed for dock placement.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and “coffin” style trenches to catch sediment and allowing runoff to weep out of the coffin into a second treatment chamber. These chambers would then weep out to the beach area that will be planted with some native plants to hold the soil in place.

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. The final design and current price of concrete will greatly dictate the cost of this practice.

Proposed Bioretention Areas

	Cost/Benefit Analysis	Coffin Style Treatment Chamber					
		Annual Reduction					
		Min		Mid		Max	
Treatment	TP (lb/yr)	4.3	30%	7.1	50%	12.5	88%
	TSS (lb/yr)	2,333	52%	3,090	69%	4,289	96%
	Volume (acre-feet/yr)	3.6	30%	5.8	48%	10.1	84%
	Live Storage Volume (cubic feet)	1,261		2,573		8,712	
Costs	Materials/Labor/Design	$30,264		$61,752		$209,088	
	Promotion & Admin Costs	$500		$500		$500	
	Total Project Cost	$30,764		$62,252		$209,588	
	Annual O&M	$946		$1,930		$6,534	
	Term Cost/lb/yr (30 yr)	$458		$564		$1,082	

LINDSTROM-29

Catchment Summary	
Acres	55.9
Dominant Land Cover	Residential
Parcels	65
Volume (acre-feet/yr)	29.6
TP (lb/yr)	34.3
TSS (lb/yr)	10,731

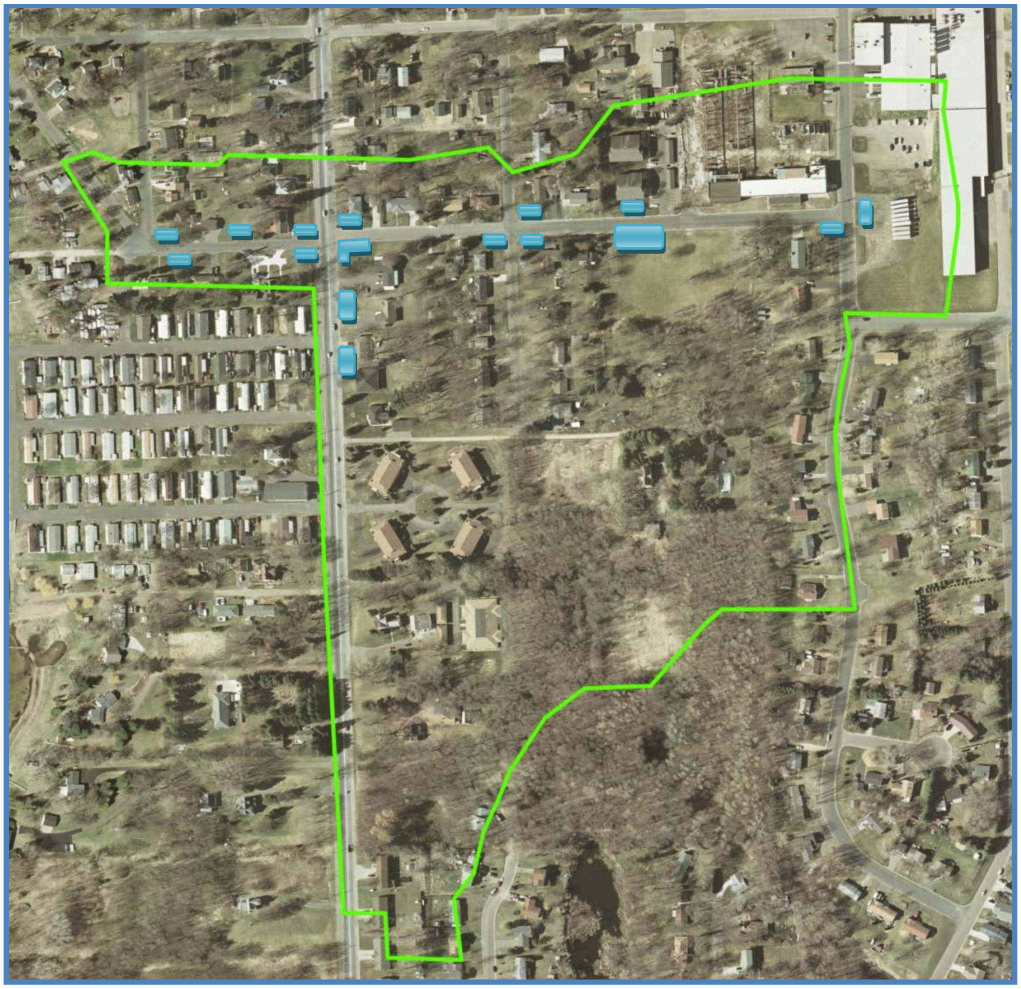
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.25
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

This medium density residential catchment is directed to stormwater pipes and routed directly to one stormwater pipe outlet at the end of Newlander Avenue. The end of this gully has been repaired a number of times to reduce scouring at the end. The most recent repair at the end of the gully was in July of 2010. With low lake levels the stormwater has been causing a large gully to form in the lake bed.

RETROFIT RECOMMENDATION

Upstream bioretention is recommended for Catchment-29 in the form of curb-cut rain gardens and filtration basins. This will include newly poured curb cut inlets and filtration basins. Due to the heavy soils, soil amendments and pipes will be needed in the basins to ensure proper drainage. Most of the slopes behind the curb in this area are very gradual; however, where elevations of the road and/or slope behind the curb line are more than gradual, retaining walls will be necessary. Many locations have been identified as optimal locations for bioretention. One City owned open space location has been identified. This location could include several cell bioretention basins to treat a large portion of the watershed. Reducing the volume and velocity of stormwater in this catchment are crucial.



Proposed Bioretention Areas

		Neighborhood Retrofit					
	Cost/Benefit Analysis	***Annual Marginal Treatment Enhancement***					
		Min		**Mid**		**Max**	
Treatment	**TP (lb/yr)**	3.5	10%	6.8	20%	10.3	30%
	TSS (lb/yr)	3,646	34%	5,141	48%	6,269	58%
	Volume (acre-feet/yr)	1.4	5%	3.2	11%	5.4	18%
	Live Storage Volume (cubic feet)	1,440		3,382		5,994	
Costs	**Materials/Labor/Design**	$18,894		$44,367		$78,647	
	Promotion & Admin Costs	$261		$140		$92	
	Total Project Cost	$19,155		$44,507		$78,739	
	Annual O&M	$1,080		$2,536		$4,496	
	Term Cost/lb/yr (30 yr)	$491		$591		$691	

LINDSTROM-30

Catchment Summary	
Acres	12.7
Dominant Land Cover	Industrial
Parcels	9
Volume (acre-feet/yr)	11.1
TP (lb/yr)	13.0
TSS (lb/yr)	4,092

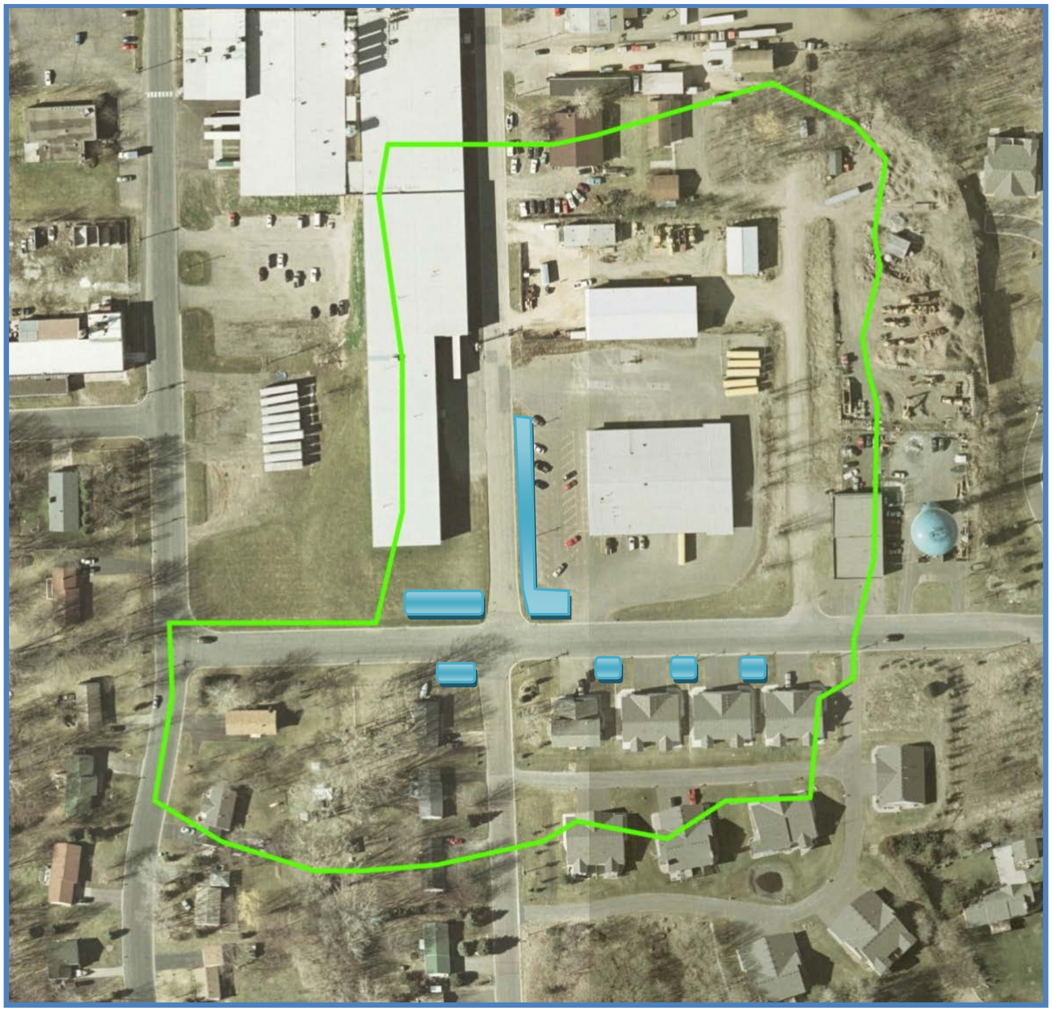
Model Inputs	
Parameter	**Input**
Pervious Curve Number	64
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.42
Hydraulic Conductivity (in/hr)	0.13

DESCRIPTION

This area is comprised of light industrial, large parking lots, single family homes and townhomes. There are many large roofs and large parking lots, which area completely untreated.

RETROFIT RECOMMENDATION

Road right-of-way bioretention basins should be utilized in this catchment. This would capture run-off from the untreated streets and parking lots. Ideally, there will be three large infiltration basins and four smaller basins in the road right of way. On the residential lots curb cut rain gardens will be recommended. On the business owned parcels we recommend lower maintenance bioretention cells. These can have a very simple planting plan for ease of maintenance. Due to the heavy soils, soil amendments and pipes will be needed in the basins to ensure proper drainage. Where elevations of the road and/or slope behind the curb line are more than gradual, retaining walls will be necessary.



Proposed Bioretention Areas

		Bioretention Retrofit					
	Cost/Benefit Analysis	*Annual Marginal Treatment Enhancement*					
		Min		Mid		Max	
Treatment	TP (lb/yr)	1.3	10%	2.6	20%	3.9	30%
	TSS (lb/yr)	1,363	33%	1,944	47%	2,371	58%
	Volume (acre-feet/yr)	0.6	5%	1.3	12%	2.2	20%
	Live Storage Volume (cubic feet)	504		1,225		2,131	
Costs	Materials/Labor/Design	$6,614		$16,067		$27,957	
	Promotion & Admin Costs	$561		$294		$196	
	Total Project Cost	$7,175		$16,361		$28,154	
	Annual O&M	$378		$918		$1,598	
	Term Cost/lb/yr (30 yr)	$475		$563		$650	

LINDSTROM-33

Catchment Summary	
Acres	10.7
Dominant Land Cover	Residential
Parcels	16
Volume (acre-feet/yr)	5.4
TP (lb/yr)	6.3
TSS (lb/yr)	1,967

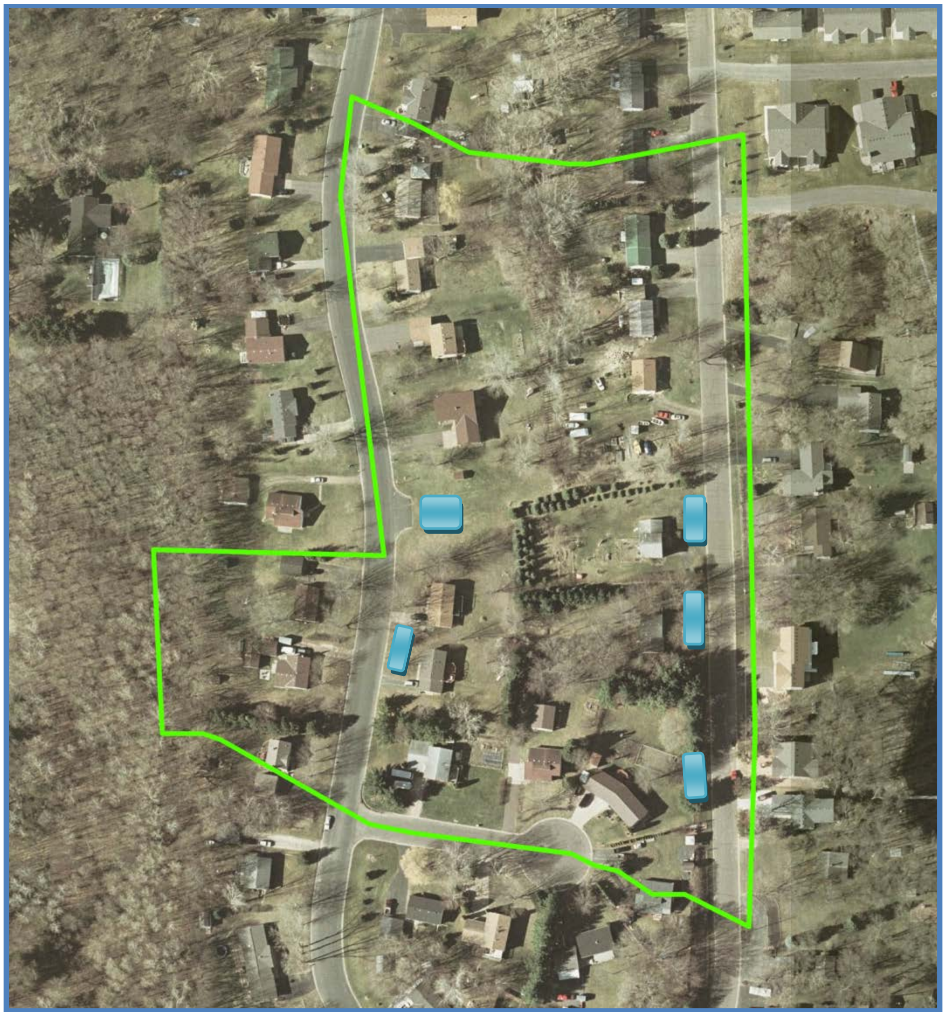
Model Inputs	
Parameter	**Input**
Pervious Curve Number	66
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.24
Hydraulic Conductivity (in/hr)	0.12

DESCRIPTION

This catchment is medium density residential. Most runoff from this catchment enters one set of catch basins and is directly transported to the lake.

RETROFIT RECOMMENDATION

The number of optimal locations for treatment in this area is very few, unless this is combined with a neighboring project, it may not make sense to mobilize a crew for a small reduction in pollutants if funds can be used on a larger project. There is a City road easement area that could be an optimal location for bioretention. Due to the heavy soils, soil amendments and pipes will be needed in the basins to ensure proper drainage. Where elevations of the road and/or slope behind the curb line are more than gradual, retaining walls will be necessary.



Proposed Bioretention Areas

	Cost/Benefit Analysis	Neighborhood Retrofit — *Annual Marginal Treatment Enhancement*					
		Min		Mid		Max	
Treatment	TP (lb/yr)	1.3	20%	1.9	30%	3.1	50%
	TSS (lb/yr)	938	48%	1,143	58%	1,471	75%
	Volume (acre-feet/yr)	0.6	11%	1.0	19%	2.0	38%
	Live Storage Volume (cubic feet)	601		1,051		2,248	
Costs	Materials/Labor/Design	$7,880		$13,783		$29,494	
	Promotion & Admin Costs	$494		$329		$189	
	Total Project Cost	$8,374		$14,111		$29,683	
	Annual O&M	$450		$788		$1,686	
	Term Cost/lb/yr (30 yr)	$566		$662		$852	

LINDSTROM-40

Catchment Summary	
Acres	26.8
Dominant Land Cover	Church/ Residential
Parcels	20
Volume (acre-feet/yr)	19.0
TP (lb/yr)	22.2
TSS (lb/yr)	6,974

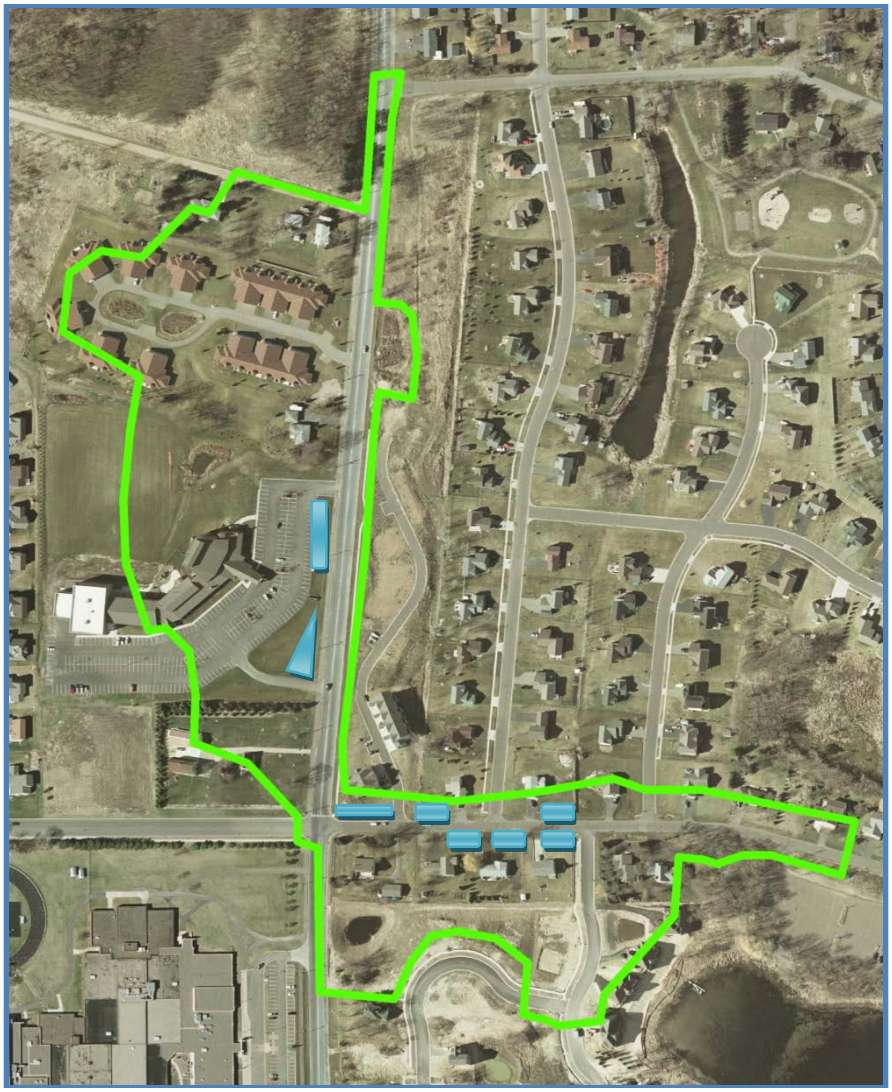
Model Inputs	
Parameter	**Input**
Pervious Curve Number	65
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.35
Hydraulic Conductivity (in/hr)	0.12

DESCRIPTION

Single family homes, town homes, and a very large church dominate this catchment. There is a stormwater pond on one parcel near the outlet of this catchment to South Center Lake. However, the size of this pond compared to the size of the watershed doesn't allow for much storage before the pond becomes overwhelmed. The proximity of this stormwater pond to a home makes a pond retrofit impossible. Currently the bottom of this catchment does not have curb and gutter, allowing water to enter the road ditches at many locations.

RETROFIT RECOMMENDATION

The church within this catchment has a lot of impervious surfaces, and a lot of open space to modify for infiltration. Modification of a surface mounted runoff catch basin and native plantings at the church will allow for treatment on the church site. Utilizing the potential for volunteer labor by the church members could greatly decrease the cost for these bioretention practices. One vegetated road ditch exists in this catchment – modifying this design and expanding it along 295th Street could provide a "treatment train" with many infiltration swales in a row.



Proposed Bioretention Areas

	Cost/Benefit Analysis	Bioretention					
		Annual Marginal Treatment Enhancement					
		Min		Mid		Max	
Treatment	TP (lb/yr)	4.4	20%	6.7	30%	11.1	50%
	TSS (lb/yr)	3,312	47%	4,049	58%	5,208	75%
	Volume (acre-feet/yr)	2.2	12%	3.7	19%	7.2	38%
	Live Storage Volume (cubic feet)	2,105		3,707		7,929	
Costs	Materials/Labor/Design	$27,620		$48,629		$104,023	
	Promotion & Admin Costs	$198		$131		$75	
	Total Project Cost	$27,818		$48,760		$104,099	
	Annual O&M	$1,579		$2,780		$5,946	
	Term Cost/lb/yr (30 yr)	$570		$657		$848	

LINDSTROM-42

Catchment Summary	
Acres	21.4
Dominant Land Cover	Residential
Parcels	35
Volume (acre-feet/yr)	15.1
TP (lb/yr)	17.7
TSS (lb/yr)	5,583

Model Inputs	
Parameter	**Input**
Pervious Curve Number	51
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.34
Hydraulic Conductivity (in/hr)	0.19

DESCRIPTION

Catchment 42 is a medium density residential neighborhood with curb, gutter, and a storm sewer network. The existing “dry pond” does not have much treatment value. The “dry pond” also has a high water table with difficult soils. This was modeled as a flow through system (what goes in, comes out).

RETROFIT RECOMMENDATION

Upstream bioretention is recommended for Catchment-42 in the form of curb-cut rain gardens and filtration basins. This will include newly poured curb cut inlets and filtration basins in optimal locations. Due to the heavy soils, soil amendments and pipes will be needed in the basins to ensure proper drainage. Most of the slopes behind the curb in this area are very gradual; however, where elevations of the road and/or slope behind the curb line are more than gradual, retaining walls will be necessary. Many locations have been identified as optimal locations for bioretention. Three City owned open space locations have been identified. Reducing the volume and velocity of stormwater in this catchment are crucial.

Proposed Bioretention

	Cost/Benefit Analysis	Bioretention					
		Annual Marginal Treatment Enhancement					
		Min		Mid		Max	
Treatment	TP (lb/yr)	3.6	20%	5.3	30%	8.9	50%
Treatment	TSS (lb/yr)	2,580	46%	3,137	56%	5,052	77%
Treatment	Volume (acre-feet/yr)	2.0	13%	2.0	13%	9.8	65%
Treatment	Live Storage Volume (cubic feet)	1,482		2,505		5,114	
Costs	Materials/Labor/Design	$19,444		$32,866		$67,096	
Costs	Promotion & Admin Costs	$256		$174		$104	
Costs	Total Project Cost	$19,700		$33,040		$67,199	
Costs	Annual O&M	$1,112		$1,879		$3,836	
Costs	Term Cost/lb/yr (30 yr)	$491		$562		$683	

LINDSTROM-48

Catchment Summary	
Acres	2.8
Dominant Land Cover	Parking Lot
Parcels	1
Volume (acre-feet/yr)	3.1
TP (lb/yr)	3.6
TSS (lb/yr)	1,132

Model Inputs	
Parameter	**Input**
Pervious Curve Number	49
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.53
Hydraulic Conductivity (in/hr)	0.21

DESCRIPTION

This entire catchment is one parcel located directly next to South Center Lake. It consists of a very large DNR Boat Launch that is drastically sloped toward the lake and some wooded area.

RETROFIT RECOMMENDATION

A large bioretention area is proposed for the entire length of the parking lot to catch the runoff from the parking lot before it enters the lake. This could include low maintenance plantings of native shrubs to aide in infiltration. A few curb cuts currently exist at the bottom of the parking lot. These will be expanded to be in the optimal locations for infiltration.

Proposed Bioretention Areas

		Boat Launch Parking Lot Retrofit					
	Cost/Benefit Analysis	***Annual Marginal Treatment Enhancement***					
		Min		**Mid**		**Max**	
Treatment	**TP (lb/yr)**	1.1	30%	1.8	50%	3.1	86%
	TSS (lb/yr)	648	57%	838	74%	1,107	98%
	Volume (acre-feet/yr)	0.7	23%	1.3	42%	2.6	84%
	Live Storage Volume (cubic feet)	535		1,110		4,356	
Costs	**Materials/Labor/Design**	$7,019		$14,563		$57,151	
	Promotion & Admin Costs	$50		$50		$50	
	Total Project Cost	$7,069		$14,613		$57,201	
	Annual O&M	$401		$833		$3,267	
	Term Cost/lb/yr (30 yr)	$595		$733		$1,669	

LINDSTROM-50a

Catchment Summary	
Acres	22.5
Dominant Land Cover	Golf Course/Gully
Parcels	2
Volume (acre-feet/yr)	3.2
TP (lb/yr)	3.1
TSS (lb/yr)	888

Model Inputs	
Parameter	**Input**
Pervious Curve Number	71
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.03
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

The main land use in this catchment is the Chisago Lakes Golf Course. Much of this property is internally drained and treated in a system of ponds. The property is mostly mowed turf grass. The only impervious surfaces are the parking lot and the Clubhouse. The water leaves the golf course property through a culvert that is piped east to the east side of Olinda Trail. At the end of this pipe, there is a large gully that is actively eroding.

RETROFIT RECOMMENDATION

A vegetated swale is proposed near the front entrance and the parking lot of the golf course. These will capture parking lot runoff on the north end of the catchment. A second swale is proposed near the culvert outlet from the golf course. This area, along the 10th fairway, should be planted to low maintenance native grasses and forbs to slow water down and increase infiltration. The gully at the end of the culvert needs to be stabilized through a rock lined channel to stabilize the eroding gully. Water will be sent through a series of checks to allow time for infiltration while the velocity and sediment is left behind in the stabilized channel.

The cost to fix a gully of this size will be approximately $30,000. Depending on the severity of the erosion, fixing the gully could reduce 2-6 pounds of phosphorus and 2,000-4,000 pounds of sediment from entering South Center Lake per year.

Proposed Water Quality Swales Proposed Gully Stabilization

	Cost/Benefit Analysis	Bioretention + Gully Stabilization Annual Marginal Treatment Enhancement					
		Min		Mid		Max	
Treatment	TP (lb/yr)	0.9	30%	1.5	50%	2.4	77%
Treatment	TSS (lb/yr)	539	48%	693	58%	861	97%
Treatment	Volume (acre-feet/yr)	0.5	11%	1.0	18%	2.2	69%
Treatment	Live Storage Volume (cubic feet)	575		1,285		4,560	
Costs	Materials/Labor/Design	$7,423		$16,595		$58,870	
Costs	Promotion & Admin Costs	$500		$500		$500	
Costs	Total Project Cost	$7,923		$17,095		$59,370	
Costs	Annual O&M	$431		$964		$3,420	
Costs	Term Cost/lb/yr (30 yr)	$756		$693		$2,250	

*Cost estimate and pollution reduction numbers do not include the gully stabilization

LINDSTROM-50b

Catchment Summary	
Acres	13.7
Dominant Land Cover	Residential
Parcels	16
Volume (acre-feet/yr)	9.8
TP (lb/yr)	11.4
TSS (lb/yr)	3,561

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.34
Hydraulic Conductivity (in/hr)	0.10

DESCRIPTION

This catchment is a mixture of townhomes and medium density residential. The whole catchment is directed to road ditches and then enters South Center Lake at one location. Only 14 homes exist in the treatable portion of this catchment.

RETROFIT RECOMMENDATION

Bioretention areas are recommended for Catchment-50b in the form of curb-cut rain gardens. This will include modifying the existing curb cut inlets and adding new filtration basins. Due to the heavy soils, soil amendments and pipes will be needed in the basins to ensure proper drainage. Most of the slopes behind the curb in this area are very gradual; however, where elevations of the road and/or slope behind the curb line are more than gradual, retaining walls will be necessary.

Proposed Bioretention Areas

		Bioretention					
	Cost/Benefit Analysis	*Annual Marginal Treatment Enhancement*					
		Min		Mid		Max	
Treatment	TP (lb/yr)	2.3	20%	3.4	30%	5.7	50%
	TSS (lb/yr)	1,702	48%	2,077	58%	2,677	75%
	Volume (acre-feet/yr)	1.1	11%	1.8	18%	3.6	37%
	Live Storage Volume (cubic feet)	1,114		1,978		4,356	
Costs	Materials/Labor/Design	$14,616		$25,951		$57,151	
	Promotion & Admin Costs	$315		$207		$117	
	Total Project Cost	$14,931		$26,159		$57,267	
	Annual O&M	$836		$1,484		$3,267	
	Term Cost/lb/yr (30 yr)	$580		$693		$908	

Retrofit Ranking

Catchment ID	Retrofit Type	Qty of 100 ft+3 BMPs	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Cost Est [1]	O&M Term (years)	Total Est. Term Cost/lb-TP/yr
LINDSTROM-13	B	6	20	1.3	0.6	$8,509	30	$594
LINDSTROM-15	PS, B	22	20	5.0	2.3	$43,223	30	645
LINDSTROM-16	B	25	20	5.3	2.4	$32,753	30	$557
LINDSTROM-18A	B, PS	5	30	0.8	0.4	$6,531	30	$726
LINDSTROM-18C	B, F	19	43	2.7	1.5	$24,584	30	$823
LINDSTROM-19	B, PS	28	20	5.6	2.6	$36,374	30	$586
LINDSTROM-20	B	106	30	19.8	12.5	$190,134	30	$723
LINDSTROM-23	B, VS	16	20	1.4	0.4	$13,632	30	$1,189
LINDSTROM-27	B	7	20	1.5	0.7	$9,570	30	$587
LINDSTROM-28	B, F	13	50	7.1	5.8	$62,252	30	$564
LINDSTROM-29	B	34	20	6.8	3.2	$44,507	30	$591
LINDSTROM-30	B	12	20	2.6	1.3	$16,361	30	$563
LINDSTROM-33	B	6	20	1.3	0.6	$8,374	30	$566
LINDSTROM-40	B	21	20	4.4	2.2	$27,818	30	$570
LINDSTROM-42	B	15	20	3.6	2.0	$19,700	30	$491
LINDSTROM-48	B	5	30	1.1	0.7	$7,069	30	$595
LINDSTROM-50a	B, G	13	50	1.5	1.0	$17,095	30	$693
LINDSTROM-50b	B	11	20	2.3	1.1	$14,931	30	$580

B = Bioretention (infiltration and/or filtration)
F = Filtration (sand curtain, surface sand filter, sump, etc)
PM = Pond Modification (increased area/depth, additional cells, forebay, and/or outlet modification)
PS = Permeable Surface (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
G = Gully Stabilization
[1]Estimated "Overall Cost" includes design, contracted soil core sampling, materials, contracted labor, promotion and administrative costs (including outreach, education, contracts, grants, etc), pre-construction meetings, installation oversight and 1 year of operation and maintenance costs.

[2]"Total Est. Term Cost" includes Overall Cost plus 30 years of maintenance and is divided by 30 years of TP treatment.

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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 City of Lindstrom Assessment.

Overall Catchment Map

See the following map showing the entire City of Lindstrom subwatersheds and catchments:


City of Lindstrom
L1
L7
L8
L9
L2
North Lindstrom Lake
L10
L13
North Center Lake
L11
L12
L17
L4
L14
L3
L16
L5
L26
L23
L25
L15
L6
L19
L20
L27
L18a
L18c
L24
L30
L31
L28
L29
South Lindstrom Lake
L34
L35
L33
L36
L37
L32
L41
South Center Lake
L38
L39
L40
L43
L44
L42
L48
L45
L47
L46
L51
L50
L49
L52
L53
L54

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