

Lake McKusick

Stormwater Retrofit Assessment



Prepared by:



With assistance from:

THE METRO CONSERVATION DISTRICTS

for the

MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION

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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 subwatersheds 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 BMPs 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 and implement BMP projects. 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 in this report. This typically occurs after committed partnerships are developed for each specific target property for which BMPs are planned.

Executive Summary

The 29 catchments of the Lake McKusick subwatershed, and their existing stormwater management practices, were analyzed for annual pollutant loading. Stormwater practice options were compared for each catchment, depending on specific site constraints and characteristics. Potential stormwater BMP retrofits were selected by weighing cost, ease of installation and maintenance and ability to serve multiple functions identified by the City of Stillwater and Middle St. Croix Watershed Management Organization (MSCWMO). Nine of the 29 catchments were selected and modeled at various levels of treatment efficiency. Three small catchments in the northeast portion of the subwatershed sharing a common discharge point were combined into one catchment for this report (catchments 19, 20, and 27 – they will be referred to collectively as “McK-NE”). These nine catchments should be considered the “low-hanging-fruit” within the Lake McKusick Subwatershed.

Total phosphorus (TP) is the major target pollutant within the Lake McKusick subwatershed. Runoff volume reduction should also be considered when ranking priority catchments. Reducing the annual TP loading to the lake by 62 pounds from the subwatershed, in combination with load reductions from other areas, will allow the lake to meet desired TP concentrations. 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 BMP location within the catchment and total BMP area. The recommended treatment levels/amounts summarized here are based on a subjective assessment of potential BMP installations, considering estimated public participation and site constraints. Recommended catchment rankings are based on a relative comparison of the cost per pound of phosphorus reduced over the life of the BMPs. A TP reduction of 21.0 pounds (34% of the target reduction) could be achieved for a total cost of \$103,924, if recommended BMPs are installed within the top 5 ranked catchments according the table below.

Catchment or Pond ID	Retro Type	BMP area (sq ft)	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Est. Cost ¹	O&M Term (years)	Total Est. Term Cost/lb-TP/30 yr	Rank
McK-28	B	200	20	1.1	0.8	\$2,774	30	\$254	1
McK-18	B	2,820	10	10.1	8.2	\$39,273	30	\$339	2
McK-25	B	850	10	2.8	2.0	\$13,984	30	\$394	3
McK-17	B	950	20	4.3	3.8	\$30,590	30	\$406	4
McK-26	B	715	10	2.7	2.4	\$17,303	30	\$418	5
McK-NE²	ED	n/a	4	1.0	0	\$30,250	30	\$1,008	6
McK-08	B	500	9	0.5	0.7	\$9,984	30	\$1,416	7
McK-18SE³	WD	n/a	5	5.0	0	\$125,000	15	\$1,667	8
McK-18NE³	WD	n/a	5	5.0	0	\$150,000	15	\$2,000	9

B = Bioretention (infiltration and/or filtration)

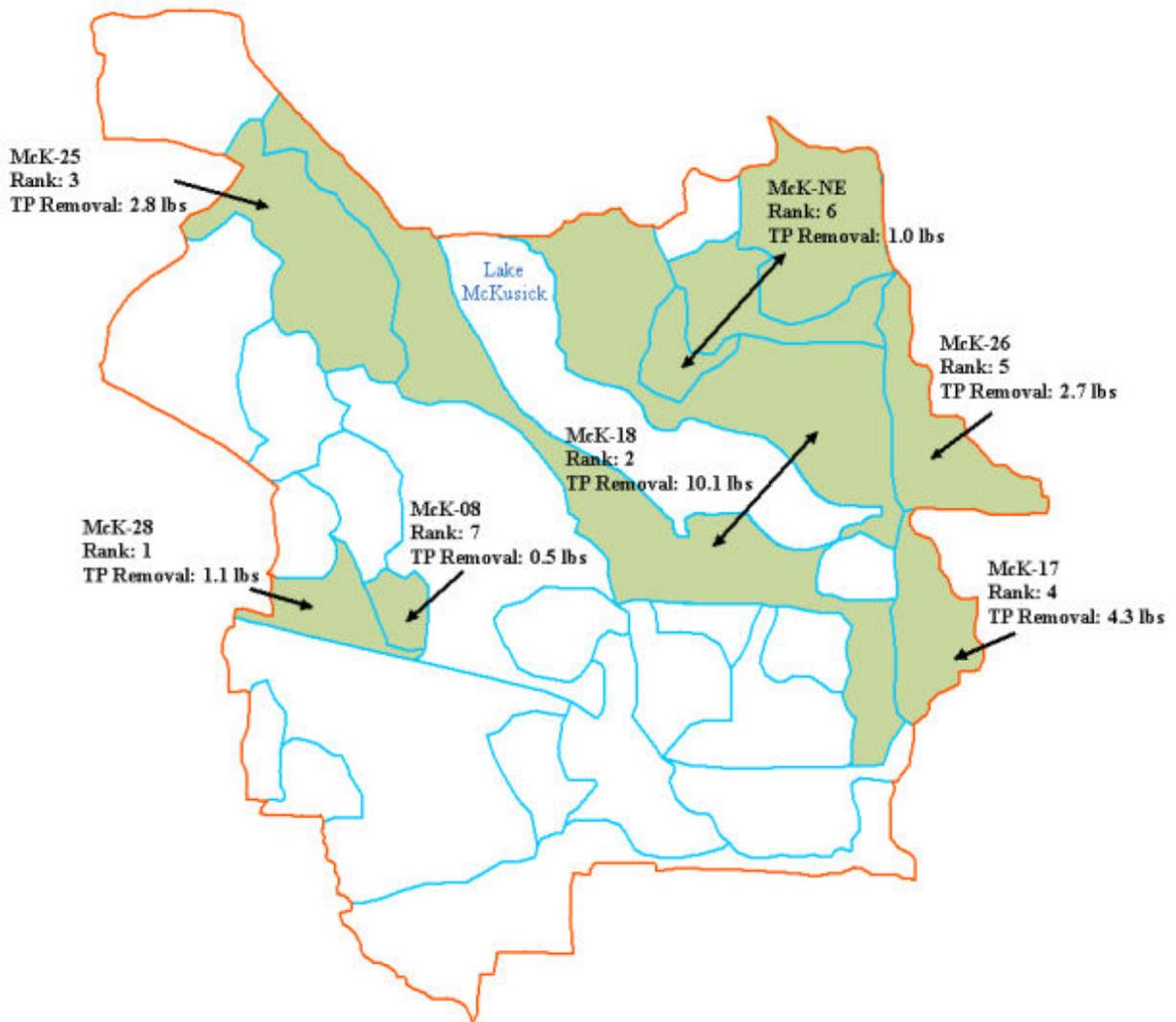
ED = Extended Detention (Pond Maintenance for McK-NE)

WD = New [wet] Detention or Wetland creation

¹Estimated 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.

²Combined catchment, includes McK-19, McK-20, and McK-27

³See “City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake,” Wenck Associates, Inc., October 2007



Top-Ranked Lake McKusick Catchments and TP Removal Potential

About this Document

Document Overview

The Stormwater Retrofit Assessment is a subwatershed management tool used to prioritize stormwater BMP retrofit projects based on BMP performance and cost effectiveness. This process helps maximize the value of each dollar spent.

This document is organized into four main sections that describe the general methods used, individual catchment profiles, a retrofit ranking for the subwatershed, and references used in the assessment protocol. The 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 the general procedures used when assessing the subwatershed. It details the processes of retrofit scoping, desktop analysis, retrofit field reconnaissance investigation, cost/treatment analysis, and catchment ranking. The project-specific details of each procedure 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.

Catchment Profiles

Each catchment profile is labeled with a unique ID to coincide with the catchment name (e.g., MCK-08 for Lake McKusick catchment number 8). This catchment ID is referenced when comparing results across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

Within each Catchment Summary/Description section is a table that summarizes basic information including catchment size, current land cover, land ownership, and estimated annual pollutant load (target pollutant(s) are specified by the LGU). A table of the principal modeling parameters and values is also reported. A brief description of the land cover, stormwater infrastructure and any other important general information is described.

Retrofit Recommendation

The Retrofit Recommendation section describes the conceptual BMP retrofit(s) selected for the catchment area and provides a description of why each specific retrofit option 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 BMP retrofit projects. Additional field inspections will be required to verify project feasibility, but the most ideal locations for BMP project installations are identified here.

Catchment Ranking

Catchment ranking takes into account all of the information gathered during the assessment process to create a prioritized catchment list. The list is sorted by the cost per pound of phosphorus treated within each catchment for the duration of the 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 within catchments, and the list provided is merely a starting point. Final catchment ranking for installation may include:

- Total amount of pollutant removal
- Non-target pollutant reductions
- BMP project visibility
- Availability of funding
- Total project costs
- Educational value

References

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

Appendices

The Appendices section provides supplemental information and/or data used during 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 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.

Description of Lake McKusick and the Contributing Subwatershed

Lake McKusick has a surface area of 45 acres, an average depth of 3 feet, and an ordinary high water level of 851.7 feet. The lake is located within the City of Stillwater in the northeastern suburban Twin Cities metropolitan area. The Lake McKusick subwatershed encompasses approximately 586 acres, including about 192 acres of impervious cover. The primary land use is residential development. The lake ultimately discharges to the St. Croix River. Stormwater is conveyed through a network of storm sewers, channels, and ponds. Much of the development within the subwatershed occurred prior to implementation of regulations requiring stormwater treatment, so there are several areas where minimal treatment of runoff occurs before entering the lake. The most significant phosphorus source to Lake McKusick is from the contributing watersheds. (*City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake*, Wenck Associates, Inc., October 2007)

Washington Conservation District monitors Lake McKusick for total phosphorus, chlorophyll-a, Secchi disk depth (transparency), and other parameters. Although the lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List, it currently is showing a statistically significant improving trend for both average Secchi transparency and average total phosphorus (*MSCWMO 2009 Water Monitoring Report*, Washington Conservation District, 2010).

Phosphorus was chosen as the target pollutant of this assessment to address the lake impairment. The direct drainage area (contributing subwatershed) was chosen as the focus of this assessment. This direct drainage area contributes 18% of the phosphorus load to Lake McKusick. Other phosphorus sources to Lake McKusick include a large annexed area consisting of mostly undeveloped and agricultural land (44%), Long Lake (20%), and Lily Lake (18%). The Wenck plan sets a reduction goal of 62 pounds of phosphorus from the direct drainage area for Lake McKusick. When achieved, this reduction will allow Lake McKusick to meet the MPCA's standard TP concentration of 60 µg/L for shallow lakes. Other efforts are currently underway to address loading from the Long Lake and Lily Lake subwatersheds.

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 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 smaller focus area may be determined.

Lake McKusick Subwatershed Scoping

Pollutants of concern for this subwatershed were identified as TP, TSS, and volume. Goals of the MSCWMO, WCD, and City of Stillwater were considered as well the results of the *City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake*, Wenck Associates, Inc., October 2007.

Step 2: Desktop Retrofit Analysis

Desktop retrofit analysis involves computer-based scanning of the subwatershed for potential BMP retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure. Accurate and current GIS data is 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 storm drainage infrastructure (with invert elevations and flow direction). 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 accumulated sediment, modifying inlet or outlet, 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 to eliminate sites from consideration. The field investigation revealed additional retrofit opportunities that would 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 cells, 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 3 feet 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, evapotranspire, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.
	Filtering	Filters runoff through engineered media and passes it through an under-drain. May consist of a combination of sand, soil, compost, peat, compost, and iron.
	Infiltration	A trench or sump that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering the 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 and permeable pavements.

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Sites most likely address pollutant reduction goals and those that may have simple design/install/maintenance considerations are chosen for a cost/benefit analysis that relatively compares catchments/sites. Treatment concepts are developed taking into account site constraints and the subwatershed treatment objectives. Projects involving complex stormwater treatment interactions and those that may pose a risk for upstream flooding require the assistance of a professional engineer. Conceptual designs at this phase of the design process include cost and pollution reduction estimates. 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, WINSLMM 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	The City of Stillwater sweeps all streets two times per year. Street sweeping was not accounted for in the model.

Lake McKusick Treatment Analysis

For the Lake McKusick treatment analysis, each catchment (and each relevant parcel within them) was first assessed for BMP 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, existing landscape maintenance, available space, and other site-specific 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 total cubic feet of treatment. In cases where live storage was 1 foot deep, this number roughly related to square feet of BMP coverage. An annual cost/TP-removed for each treatment level was then calculated for the life of each BMP that includes 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 (\$/ft ²)	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/ac	30	¹ 40% above construction	\$210 (3 visits)	\$4.21/ft ²
Extended Detention	\$5.00	\$1000/ac	30	¹ \$2800/ac	\$210 (3 visits)	\$12.02*(ft ³ ^{0.75})
Wet Pond	\$5.00	\$1000/ac	30	¹ \$2800/ac	\$210 (3 visits)	\$277.89*(ft ³ ^{0.553})
Stormwater Wetland	\$5.00	\$1000/ac	30	¹ \$2800/ac	\$210 (3 visits)	\$4,800*(DA ac ^{0.484})
Dry Swale	\$3.00	\$0.75/ft ²	30	\$280/100 ft ²	\$210 (3 visits)	\$6.60/ft ²
Water Quality Swale ⁴	\$12.00	\$0.75/ft ²	30	\$1120/1000 ft ²	\$210 (3 visits)	\$13.90/ft ²
Cisterns	\$15.00	³ \$100	30	NA	\$210 (3 visits)	\$16.00/ft ²
French Drain/Dry Well	\$12.00	³ \$100	30	20% above construction	\$210 (3 visits)	\$15.00/ft ²
Infiltration Basin (turf)	\$15.00	\$2000/ac	30	\$1120/ac	\$210 (3 visits)	\$15.10/ft ²
Rain Barrels	\$25.00	³ \$25	30	NA	\$210 (3 visits)	\$25.00/ft ²

Average BMP Cost Estimates						
BMP	Median Inst. Cost (\$/ft ²)	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)
Structural Sand Filter (including peat, compost, iron amendments, or similar) ⁴	\$20.00	\$250/25 In ft	30	\$300/25 In ft	\$210 (3 visits)	\$21.50/ft ²
Impervious Cover Conversion	\$20.00	\$500/ac	30	\$1120/ac	\$210 (3 visits)	\$20.10/ft ²
Stormwater Planter	\$27.00	\$0.75/ft ²	30	20% above construction	\$210 (3 visits)	\$32.20/ft ²
Rain Leader Disconnect Raingardens	\$4.00	\$0.25/ft ²	30	² \$280/100 ft ²	\$210 (3 visits)	\$7.00/ft ²
Simple Bioretention (no engineered soils or under-drains, but w/curb cuts and forebays)	\$10.00	\$0.75/ft ²	30	² \$1120/1000 ft ²	\$210 (3 visits)	\$11.30/ft ²
Moderately Complex Bioretention (incl. engineered soils, under-drains, curb cuts, but no retaining walls)	\$12.00	\$0.75/ft ²	30	² \$1120/1000 ft ²	\$210 (3 visits)	\$13.90/ft ²
Complex Bioretention (same as MCB, but with 1.5 to 2.5 ft partial perimeter walls)	\$14.00	\$0.75/ft ²	30	² \$1400/1000 ft ²	\$210 (3 visits)	\$16.20/ft ²

Average BMP Cost Estimates						
BMP	Median Inst. Cost (\$/ft ²)	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)
Highly Complex Bioretention (same as CB, but with 2.5 to 5 ft partial perimeter walls or complete walls)	\$18.00	\$0.75/ft ²	30	² \$1400/1000ft ²	\$210 (3 visits)	\$19.90/ft²
Underground Sand Filter	\$65.00	\$0.75/ft ²	30	¹ 40% above construction	\$210 (3 visits)	\$91.75/ft²
Stormwater Tree Pits	\$70.00	\$0.75/ft ²	30	¹ 40% above construction	\$210 (3 visits)	\$98.75/ft²
Grass/Gravel Permeable Pavement (sand base)	\$12.00	\$0.75/ft ²	30	¹ 40% above construction	\$210 (3 visits)	\$17.55/ft²
Permeable Asphalt (granite base)	\$10.00	\$0.75/ft ²	30	¹ 40% above construction	\$210 (3 visits)	\$14.00/ft²
Permeable Concrete (granite base)	\$12.00	\$0.75/ft ²	30	¹ 40% above construction	\$210 (3 visits)	\$17.55/ft²
Permeable Pavers (granite base)	\$25.00	\$0.75/ft ²	30	¹ 40% above construction	\$210 (3 visits)	\$35.75/ft²
Extensive Green Roof	\$225.00	\$500/1000 ft ²	30	¹ 40% above construction	\$210 (3 visits)	\$315.50/ft²
Intensive Green Roof	\$360.00	\$750/1000 ft ²	30	¹ 40% above construction	\$210 (3 visits)	\$504.75/ft²

¹May require a professional engineer. Assume engineering costs to be 40% above construction costs

²If 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.

³Not included in total installation cost (minimal).

⁴Assumed to be 15 feet in width.

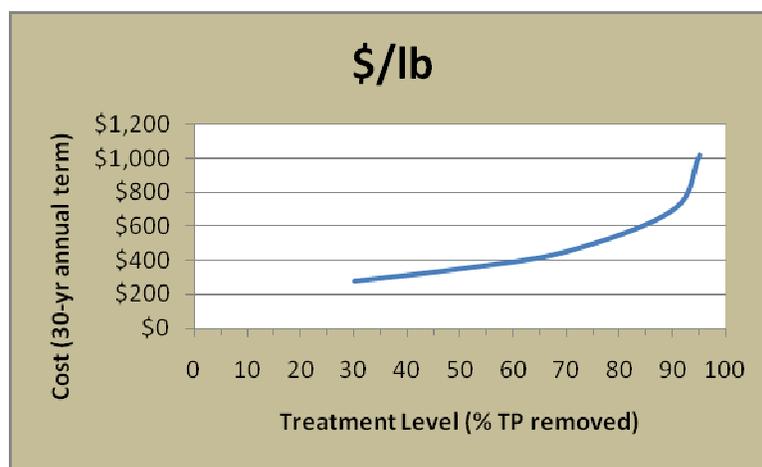
Lake McKusick Cost Analysis

For the Lake McKusick cost analysis, promotion and administration for each commercial/public property was estimated using a non-linear formula dependent on the surface area of BMPs, as the labor associated with outreach, education and administrative tasks typically are reduced with scale. Annual Operation & Maintenance referred to the ft² 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 ft² 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.

Example chart showing total phosphorus treatment vs. cost:



Lake McKusick Evaluation and Ranking

In the Lake McKusick evaluation and ranking, the recommended level of treatment for each catchment, as reported in the Executive Summary table, was chosen by selecting the expected level of treatment 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, a higher level of treatment (as described in the Catchment Profile tables) should be selected. The maps associated with each catchment show potential BMP locations as determined by field review. To meet treatment level goals for a catchment, a minimum percentage of potential BMPs (equaling or exceeding the “BMP Surface Area”) must be installed within that catchment.

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.

For development of the Lake McKusick catchment profile section, 9 out of 29 catchments were selected as the first-tier areas for stormwater retrofit efforts. Those catchments receiving modern stormwater pond treatment, or in some cases 2 or more levels of treatment, were not modeled or further analyzed in this assessment.

McK-28

Term Cost Rank = #1

Catchment Summary	
Acres	9.4
Dominant Land Cover	Residential
Parcels	10
Volume (acre-feet/yr)	4.6
TP (lb/yr)	5.3
TSS (lb/yr)	1,661.0

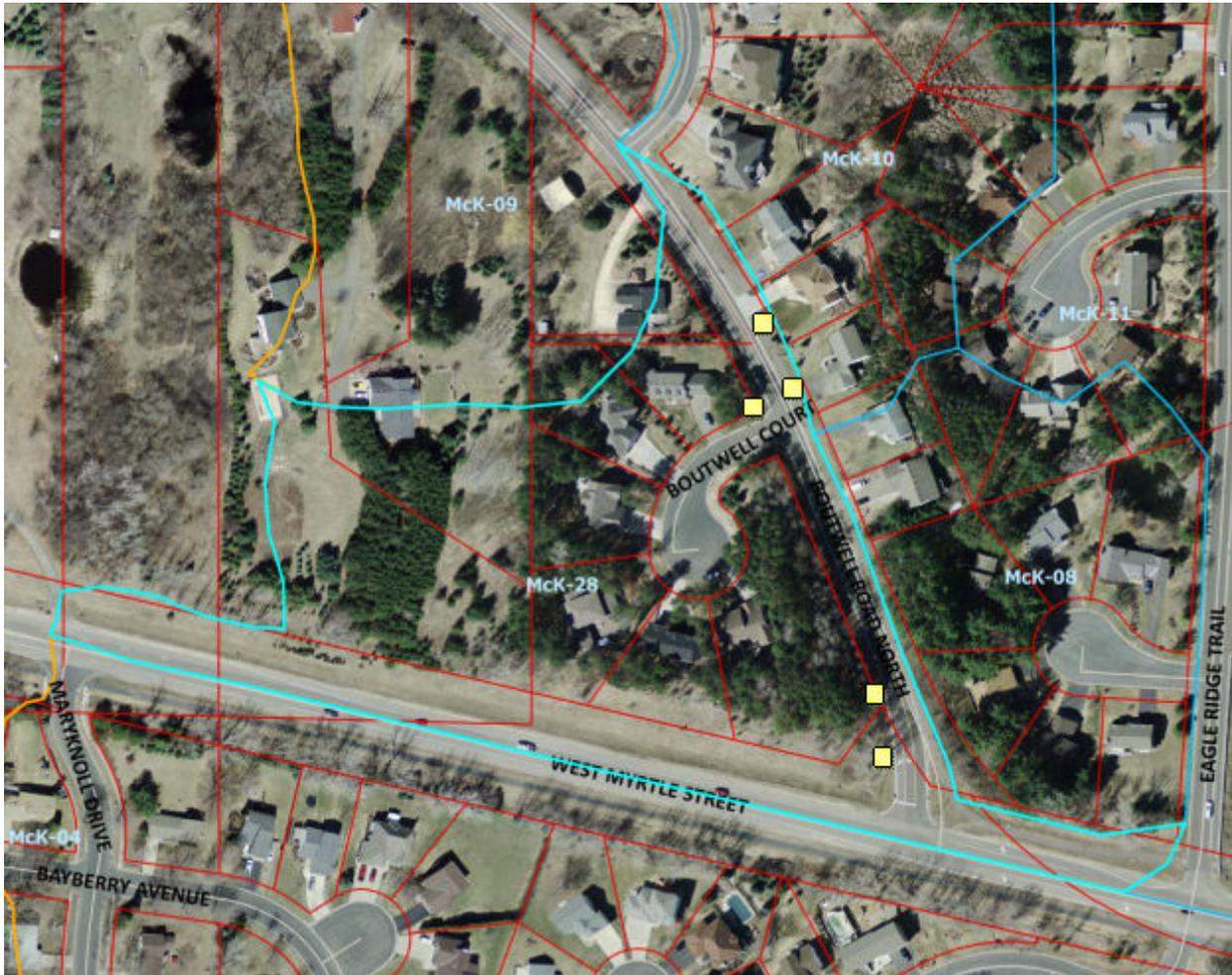
Model Inputs	
Parameter	Input
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.23
Hydraulic Conductivity (in/hr)	1.11

DESCRIPTION

This small catchment is comprised of primarily low-density single-family residential properties, with a strip of open space along West Myrtle Street. Runoff is collected in the existing storm sewer system and discharged to the wetland complex within McK-11. The McK-11 catchment provides some treatment for stormwater before entering to Lake McKusick.

RETROFIT RECOMMENDATION

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 retention is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Due to the limited number of parcels available within this catchment, installing two or three small BMPs should be enough to meet the 20% TP reduction estimate of 1.1 pounds.



 Curb Cut Bioretention

		Cost/Benefit Analysis	TP Reduction Level		
			30%	20%	12%
Treatment	TP Reduction (lb/yr)	1.6	1.1	0.6	
	TSS Reduction (lb/yr)	936	768	590	
	TSS Reduction (%)	56%	46%	36%	
	Volume Reduction (acre-feet/yr)	1.3	0.8	0.5	
	Volume Reduction (%)	28%	17%	10%	
	BMP Surface Area (square feet)	350	200	100	
Costs	Materials/Labor/Design	\$4,855	\$2,774	\$1,387	
	Promotion & Admin Costs	\$733	\$1,102	\$1,826	
	Total Project Cost	\$5,587	\$3,876	\$3,213	
	Annual O&M	\$263	\$150	\$75	
	Term Cost/lb/yr (30 yr)	\$280	\$254	\$303	

McK-18

Term Cost Rank = #2

Catchment Summary	
Acres	108.3
Dominant Land Cover	Residential
Parcels	303
Volume (acre-feet/yr)	86.2
TP (lb/yr)	100.6
TSS (lb/yr)	31,600.0

Model Inputs	
Parameter	Input
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.38
Hydraulic Conductivity (in/hr)	1.06

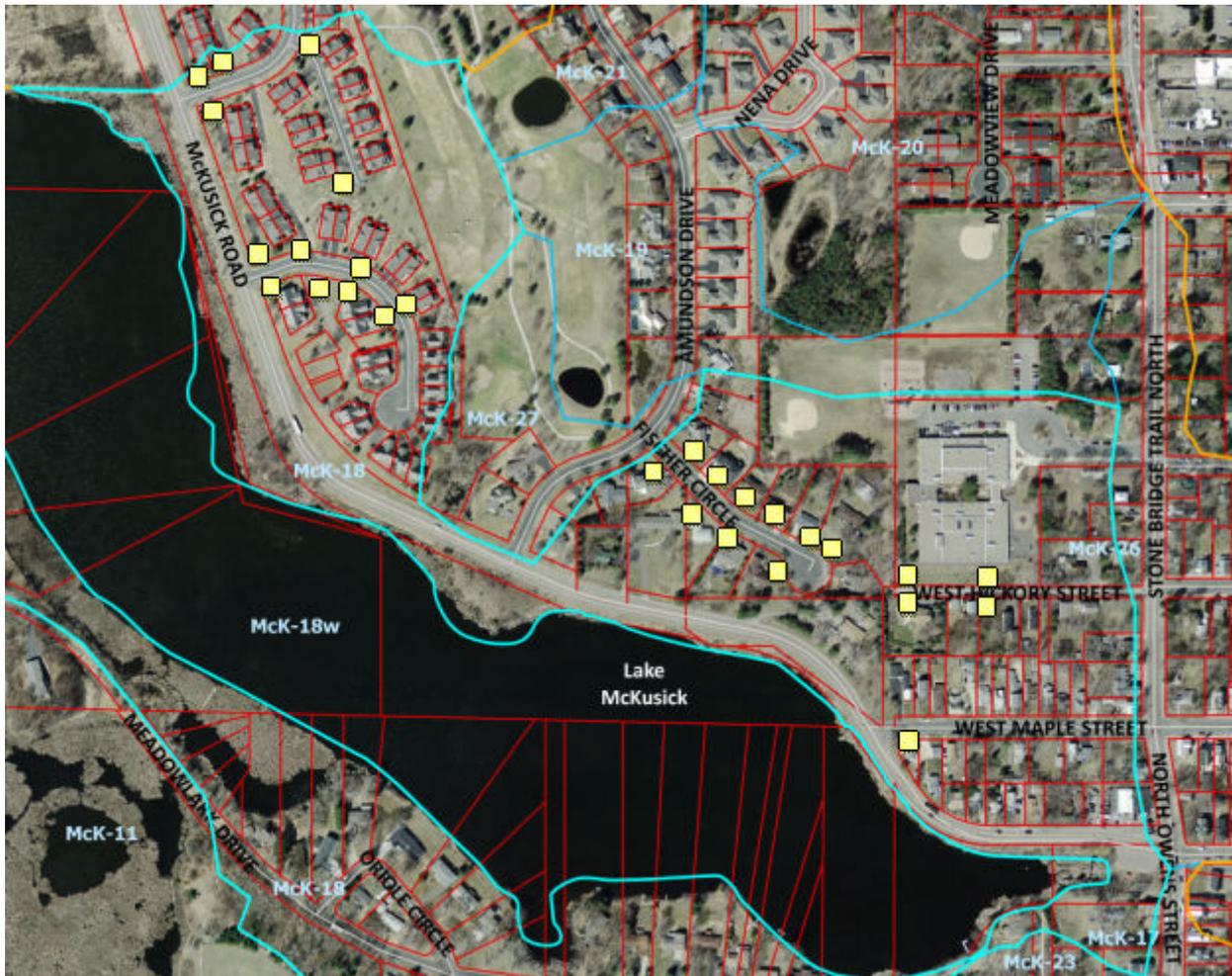
DESCRIPTION

Catchment McK-18 includes the direct drainage areas adjacent to Lake McKusick. It is comprised of primarily medium to medium-high density single/multi-family residential development and open space (wetlands). There are no constructed stormwater ponds within the catchment. There are some existing raingardens (mainly along Meadowlark Drive & Linden Street W) that were constructed by the City when the roads in that area were reconstructed. Stormwater runoff from most of the catchment flows through the existing storm sewer system and directly to Lake McKusick.

RETROFIT RECOMMENDATION

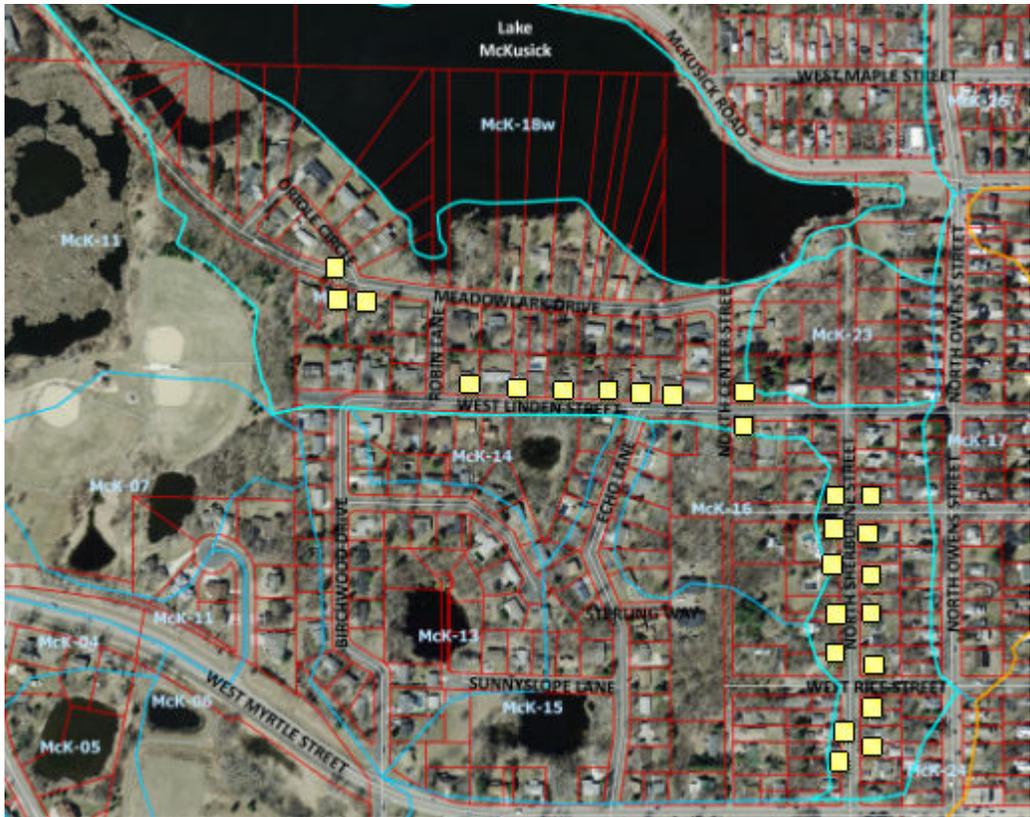
A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. 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, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

Several features make this catchment very attractive for retrofitting. In a few locations, modification or additional bioretention surface area could easily be retrofitted into the existing practices to maximize efficiencies. This catchment appears to be ideal for a neighborhood BMP retrofit effort. Although the 10% TP reduction level was chosen for the executive summary, the 20% level is also feasible. The term cost/lb/yr at the 20% level is \$386, compared to \$339 at the 10% level.



 Curb Cut Bioretention

		TP Reduction Level	
Cost/Benefit Analysis			
Treatment	TP Reduction (lb/yr)	20.1	10.1
	TSS Reduction (lb/yr)	14,100	9,715
	TSS Reduction (%)	45	31%
	Volume Reduction (acre-feet/yr)	17.1	8.2
	Volume Reduction (%)	20	10%
	BMP Size (square feet)	6,400	2,820
Costs	Materials/Labor/Design	\$88,768	\$39,113
	Promotion & Admin Costs	\$88	\$160
	Total Project Cost	\$88,856	\$39,273
	Annual O&M	\$4,800	\$2,115
	Term Cost/lb/yr (30 yr)	\$386	\$339



McK-25

Term Cost Rank = #3

Catchment Summary	
Acres	30.2
Dominant Land Cover	Residential
Parcels	93
Volume (acre-feet/yr)	24.1
TP (lb/yr)	28.1
TSS (lb/yr)	8,810.0

Model Inputs	
Parameter	Input
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.38
Hydraulic Conductivity (in/hr)	0.67

DESCRIPTION

This catchment is comprised of primarily low density, single-family residential development. There are no constructed stormwater ponds within the catchment. There are two existing raingardens, located at the south end of the catchment along Eagle Ridge Trail and at 1013 Eagle Ridge Circle. Stormwater runoff flows through the existing storm sewer system and directly into Lake McKusick.

RETROFIT RECOMMENDATION

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. In several locations, no retainment would be needed. 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, we recommend poured concrete wall retainment to form “box planters” along the streetscape. Soils within the catchment are not as conducive to infiltration as other areas within the subwatershed; engineered soils/soil replacement may be required.

Several features make this catchment very attractive for retrofitting. This catchment appears to be ideal for a neighborhood BMP retrofit effort. Although the 10% TP reduction level was chosen for the executive summary, the 20% level is also feasible. The term cost/lb/yr at the 20% level is \$460, compared to \$394 at the 10% level.



 Curb Cut Bioretention

		Cost/Benefit Analysis	TP Reduction Level	
			20%	10%
Treatment	TP Reduction (lb/yr)		5.6	2.8
	TSS Reduction (lb/yr)		4,108	2,774
	TSS Reduction (%)		46%	31%
	Volume Reduction (acre-feet/yr)		4.3	2.0
	Volume Reduction (%)		18%	8%
	BMP Size (square feet)		2,000	850
Costs	Materials/Labor/Design		\$32,000	\$13,600
	Promotion & Admin Costs		\$206	\$384
	Total Project Cost		\$32,206	\$13,984
	Annual O&M		\$1,500	\$638
	Term Cost/lb/yr (30 yr)		\$460	\$394

McK-17

Term Cost Rank = #4

Catchment Summary	
Acres	13.9
Dominant Land Cover	Residential
Parcels	77
Volume (acre-feet/yr)	18.2
TP (lb/yr)	21.4
TSS (lb/yr)	6,720.0

Model Inputs	
Parameter	Input
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.63
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment is comprised of medium-high density, single-family residential development. Runoff from this catchment does not receive any stormwater treatment and is discharged to Lake McKusick directly through the existing storm sewer system.

RETROFIT RECOMMENDATION

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 retention 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, we recommend poured concrete wall retention to form "box planters" along the streetscape. The opportunities for large curb cut bioretention cells are severely limited in this catchment due to slopes, housing density, and narrow right-of-way.



 Curb Cut Bioretention  Curb Cut Box Planter Bioretention

Cost/Benefit Analysis		TP Reduction Level	
		20%	10%
Treatment	TP Reduction (lb/yr)	4.3	2.1
	TSS Reduction (lb/yr)	2,960	2,015
	TSS Reduction (%)	44%	30%
	Volume Reduction (acre-feet/yr)	3.8	1.8
	Volume Reduction (%)	21%	10%
	BMP Size (square feet)	950	560
Costs	Materials/Labor/Design	\$30,590	\$18,032
	Promotion & Admin Costs	\$354	\$520
	Total Project Cost	\$30,944	\$18,552
	Annual O&M	\$713	\$420
	Term Cost/lb/yr (30 yr)	\$406	\$494

McK-26

Term Cost Rank = #5

Catchment Summary	
Acres	18.4
Dominant Land Cover	Residential
Parcels	100
Volume (acre-feet/yr)	23.3
TP (lb/yr)	27.4
TSS (lb/yr)	8,615.0

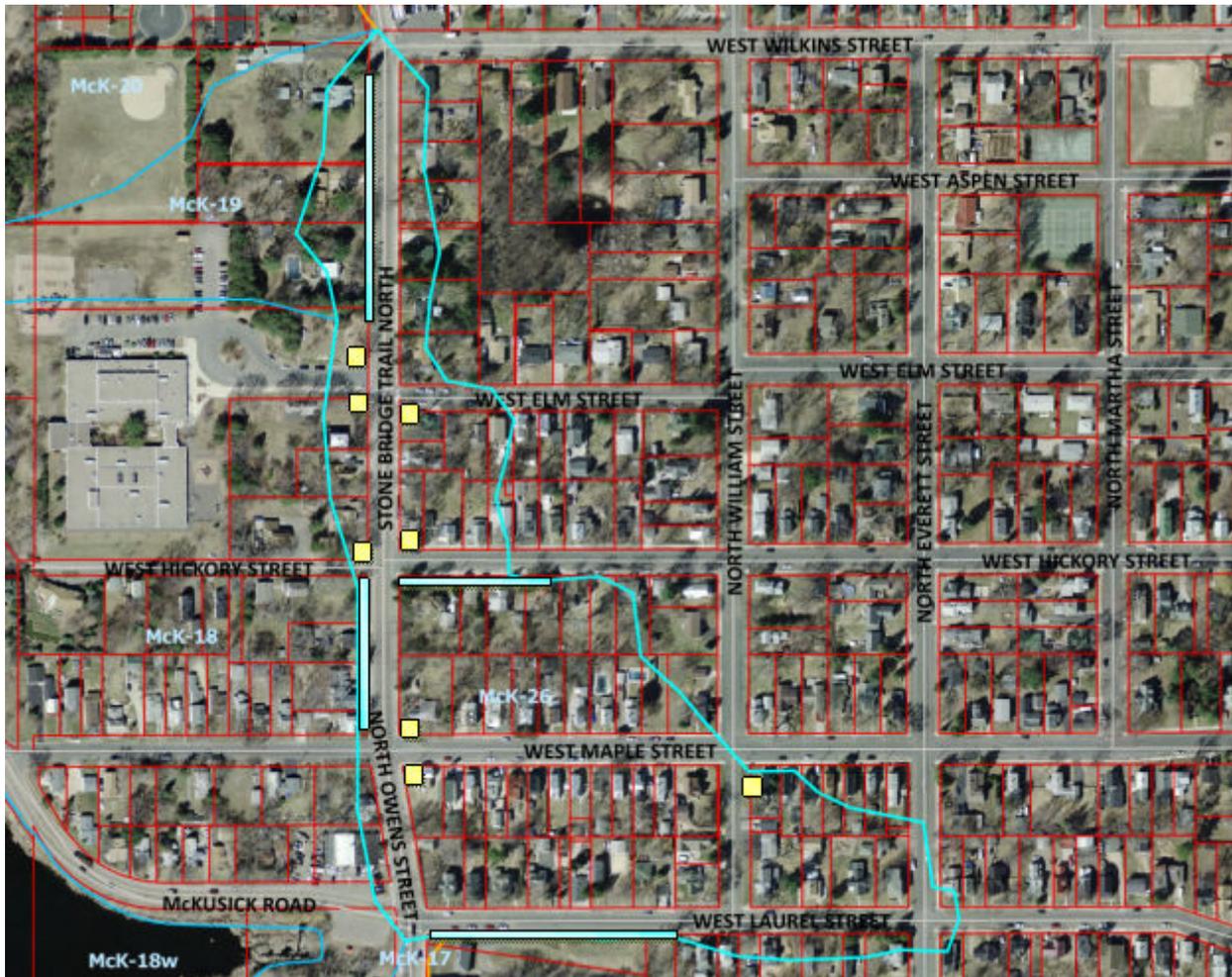
Model Inputs	
Parameter	Input
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.61
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment is comprised of primarily medium-high density, single-family residential development. There are no constructed stormwater ponds within the catchment. Stormwater runoff flows through the existing storm sewer system and directly into Lake McKusick.

RETROFIT RECOMMENDATION

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. In several locations, no retainment would be needed. 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, we recommend poured concrete wall retainment to form "box planters" along the streetscape.



Curb Cut Bioretention
 Curb Cut Box Planter Bioretention

		Cost/Benefit Analysis	TP Reduction Level	
			20%	10%
Treatment	TP Reduction (lb/yr)		5.5	2.7
	TSS Reduction (lb/yr)		3,800	2,580
	TSS Reduction (%)		44%	30%
	Volume Reduction (acre-feet/yr)		4.9	2.4
	Volume Reduction (%)		21%	10%
	Live Storage Volume (cubic feet)		1,965	871
Costs	Materials/Labor/Design		\$39,446	\$17,303
	Promotion & Admin Costs		\$239	\$435
	Total Project Cost		\$39,685	\$17,738
	Annual O&M		\$1,223	\$536
	Term Cost/lb/yr (30 yr)		\$463	\$418

McK-NE

Term Cost Rank = #6

Catchment Summary	
Acres	46.5
Dominant Land Cover	Residential
Parcels	115
Volume (acre-feet/yr)	21.9
TP (lb/yr)	25.2
TSS (lb/yr)	7,887.0

Model Inputs	
Parameter	Input
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.22
Hydraulic Conductivity (in/hr)	1.14

DESCRIPTION

Catchments McK-19, McK-20, and McK-27 were combined to form this catchment due to similar characteristics and a common discharge point. This catchment consists of a mixture of low-density single-family residential and open space, including portions of a golf course. Runoff within the catchment is routed through a series of small ponds before discharging to Lake McKusick.

RETROFIT RECOMMENDATION

A combination of moderately complex bioretention and extended detention is recommended for this catchment. Bioretention will rely 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 retention is employed. In several locations, no retention would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. It may also be feasible to excavate 3 feet of sediment from the stormwater pond closest to Lake McKusick (within catchment McK-27). The 4% level of treatment shown in the chart below reflects this potential BMP. The other two options reflect bioretention BMPs.



Curb Cut Bioretention
 Pond Maintenance

		Cost/Benefit Analysis		TP Reduction Level		
				8%	6%	4%
Treatment	TP Reduction (lb/yr)	1.9	1.4	1.0		
	TSS Reduction (lb/yr)	357	159	261		
	TSS Reduction (%)	3%	1%	2%		
	Volume Reduction (acre-feet/yr)	2.4	4.0	0.0		
	Volume Reduction (%)	11%	18%	0%		
	BMP Surface Area (square feet)	1,500	2,500	n/a		
Costs	Materials/Labor/Design	\$51,000	\$34,960	\$30,000		
	Promotion & Admin Costs	\$254	\$175	\$250		
	Total Project Cost	\$54,803	\$39,328	\$30,250		
	Annual O&M	\$1,125	\$1,875	\$0		
	Term Cost/lb/yr (30 yr)	\$1,554	\$2,276	\$1,008		

McK-08

Term Cost Rank = #7

Catchment Summary	
Acres	4.6
Dominant Land Cover	Residential
Parcels	11
Volume (acre-feet/yr)	4.6
TP (lb/yr)	5.3
TSS (lb/yr)	1,661.0

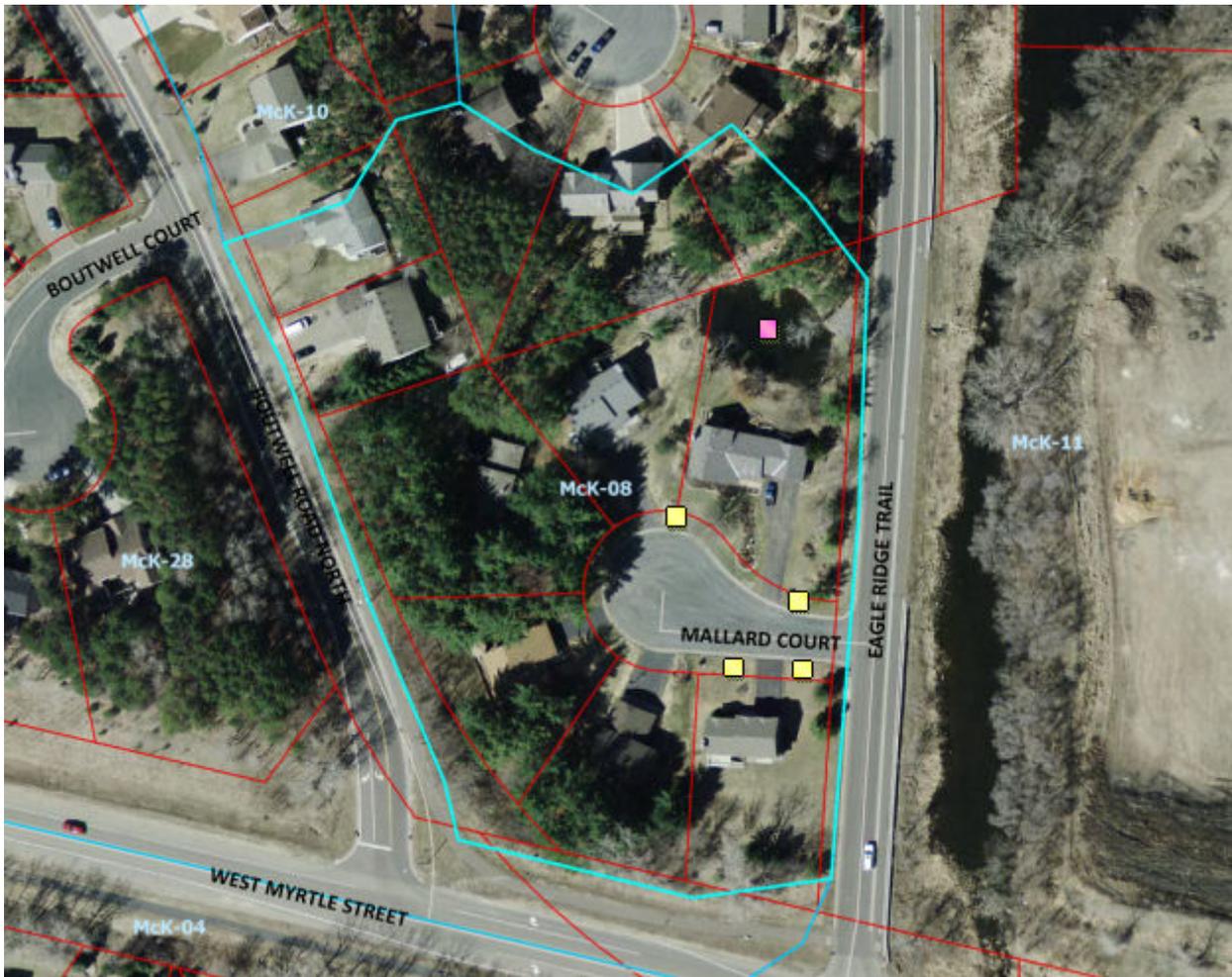
Model Inputs	
Parameter	Input
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.20
Hydraulic Conductivity (in/hr)	0.82

DESCRIPTION

This small catchment is comprised of medium density, single-family residential development. There is one stormwater pond that receives runoff from the catchment and portions of Eagle Ridge Trail. One raingarden in the catchment is located at 100 Mallard Court. The stormwater pond discharges to the wetland in McK-11, which discharges to Lake McKusick.

RETROFIT RECOMMENDATION

Moderately complex bioretention is recommended for this catchment, relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls may be necessary. There are relatively few sites where BMPs could be installed in this catchment. Pond maintenance (sediment removal) may be an option.



Curb Cut Bioretention
 Pond Maintenance

		Cost/Benefit Analysis	TP Reduction Level	
			11%	9%
Treatment	TP Reduction (lb/yr)		0.6	0.5
	TSS Reduction (lb/yr)		113	83
	TSS Reduction (%)		7%	5%
	Volume Reduction (acre-feet/yr)		1.0	0.70
	Volume Reduction (%)		22%	15%
	BMP Size (square feet)		750	500
Costs	Materials/Labor/Design		\$10,635	\$7,160
	Promotion & Admin Costs		\$420	\$565
	Total Project Cost		\$13,787	\$9,984
	Annual O&M		\$563	\$375
	Term Cost/lb/yr (30 yr)		\$1,703	\$1,416

Catchment Ranking

Catchment or Pond ID	Retro Type	BMP area (sq ft)	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Est. Cost ¹	O&M Term (years)	Total Est. Term Cost/lb-TP/30 yr	Rank
McK-28	B	200	20	1.1	0.8	\$2,774	30	\$254	1
McK-18	B	2,820	10	10.1	8.2	\$39,273	30	\$339	2
McK-25	B	850	10	2.8	2.0	\$13,984	30	\$394	3
McK-17	B	950	20	4.3	3.8	\$30,590	30	\$406	4
McK-26	B	715	10	2.7	2.4	\$17,303	30	\$418	5
McK-NE²	ED	n/a	4	1.0	0	\$30,250	30	\$1,008	6
McK-08	B	500	9	0.5	0.7	\$9,984	30	\$1,416	7
McK-18SE³	WD	n/a	5	5.0	0	\$125,000	15	\$1,667	8
McK-18NE³	WD	n/a	5	5.0	0	\$150,000	15	\$2,000	9

B = Bioretention (infiltration and/or filtration)

ED = Extended Detention (Pond Maintenance for McK-NE)

WD = New [wet] Detention or Wetland creation

¹Estimated 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.

²Combined catchment, includes McK-19, McK-20, and McK-27

³See "City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake," Wenck Associates, Inc., October 2007

References

- 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.
- Wenck Associates, Inc. 2007. *City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake*. Prepared for City of Stillwater and Brown’s Creek Watershed District. Stillwater, Minnesota.

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.

Appendix 2 – Summary of Protocol

This protocol attempts to provide a sufficient level of detail to rapidly assess subwatersheds 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 the assessor can look critically 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 Lake McKusick Assessment.

Appendix 3 – Definitions

The following terms are used throughout this document and define the basic terminology used to talk about watersheds and restoration. Many of the terms can have different meanings in different contexts, so it is imperative to define their use within this document.

Best Management Practice (BMP) – One of many different structural or non-structural methods used to treat runoff, including such diverse measures as ponding, street sweeping, bioretention, and infiltration.

Bioretention – A soil and plant-based stormwater management BMP used to filter runoff.

Catchment – Land area within a subwatershed generally having a drainage area of 1 – 100 acres for urban areas, where all water drains to a particular point. Several catchments make up a subwatershed. The existing stormwater infrastructure helps to define a catchment; therefore it is critical to obtain accurate stormwater infrastructure mapping information (including, at a minimum, the location of inlets and pipes, flow direction, and outfall locations) before undertaking a stormwater assessment process.

Raingarden – A landscaping feature that is planted with native perennial plants and is used to manage stormwater runoff from impervious surfaces such as roofs, sidewalks, roads, and parking lots.

Retrofit – The introduction of a new or improved stormwater management element where it either never existed or did not operate effectively.

Stormwater – Water that is generated by rainfall or snowmelt that causes runoff and is often routed into drain systems for treatment or conveyance.

Subwatershed – Land area within a watershed generally having a drainage area of more than 500 acres, where all water drains to a particular point. Several subwatersheds make up a watershed. An example would be the Lake McKusick subwatershed, which is within the boundaries of the Middle St. Croix Water Management Organization (the watershed). Subwatersheds are entirely based on hydrologic conditions, not political boundaries.

Urban – Any watershed or subwatershed with more than 10% total impervious cover.

Watershed – Land area defined by topography, where all water drains to a particular point. Watershed drainage areas are large, ranging from 20 to 100 square miles or more, and are made up of several subwatersheds. There are currently 8 watersheds located either wholly or partially within Washington County, each defined along political boundaries that attempt to mimic hydrologic boundaries.

Appendix 4 – WCD Subwatershed Selection Process

The Washington Conservation District selected the Lily Lake/Lake McKusick subwatersheds for the MCD assessment program through a competitive process. Watershed organizations in Washington County were asked to nominate subwatersheds that were then scored on 5 equally weighted criteria (maximum of 5 points each). There were 7 nominations, of which 2 were chosen for assessments. The results were as follows:

Organization	Subwatershed	C1	C2	C3	C4	C5	TOTAL
RWMWD	Carver Lake	5	5	5	5	5	25
MSCWMO	Lily/McKusick	5	5	5	5	5	25
VBWD	Raleigh Creek	5	5	5	5	3	23
SWWD	Markgrafs Lake	5	5	0	5	4	19
CLFLWD	CL04	5	5	2	2	4	18
RCWD	N. Clear Lake	5	3	2	0	4	15
RCWD	N. Mahtomedi	5	3	2	0	2	12

Criteria

C1 = urban/suburban

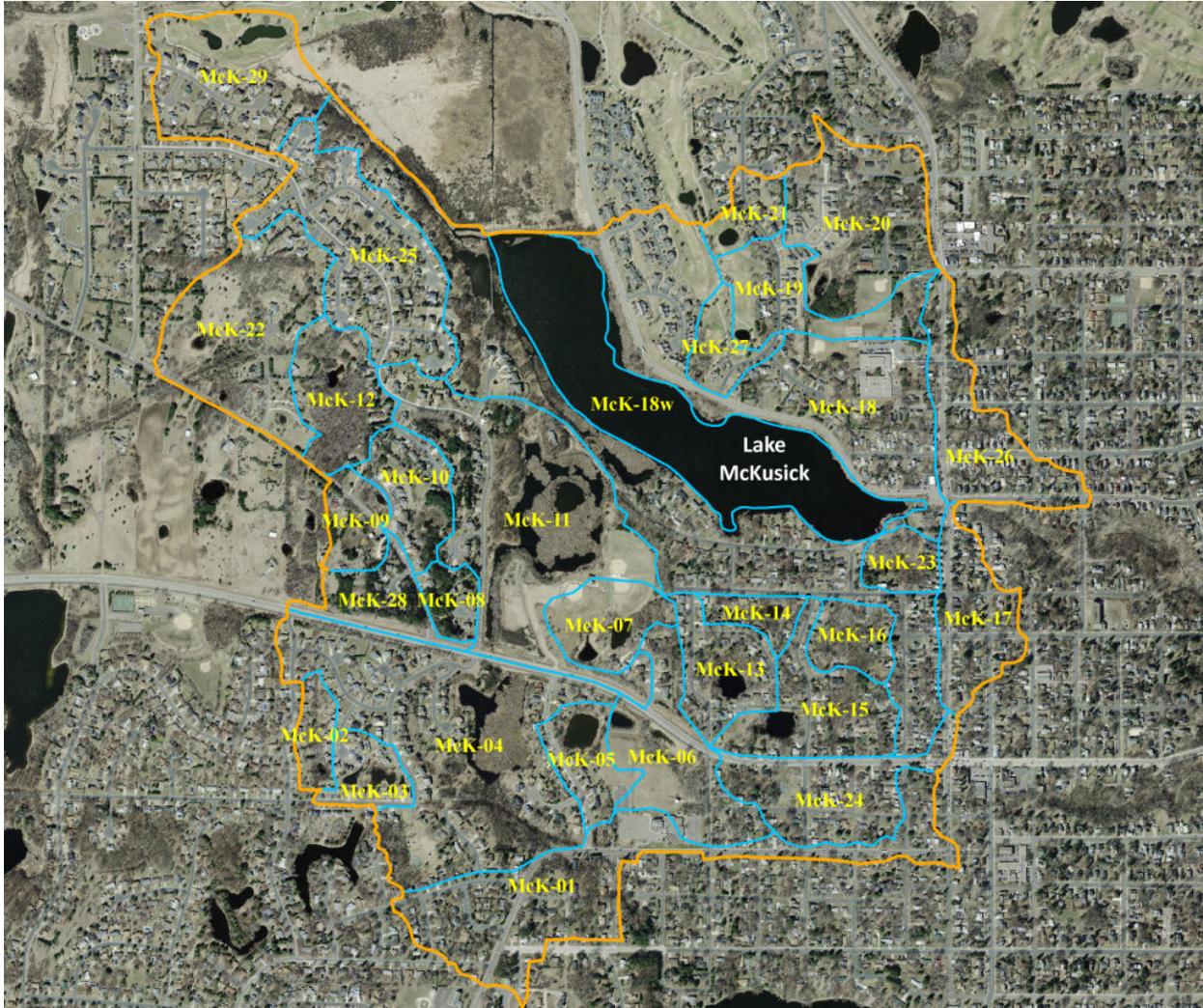
C2 = well-defined subwatershed boundary

C3 = water quality monitoring data

C4 = stormwater infrastructure mapping

C5 = drains to impaired or target water body

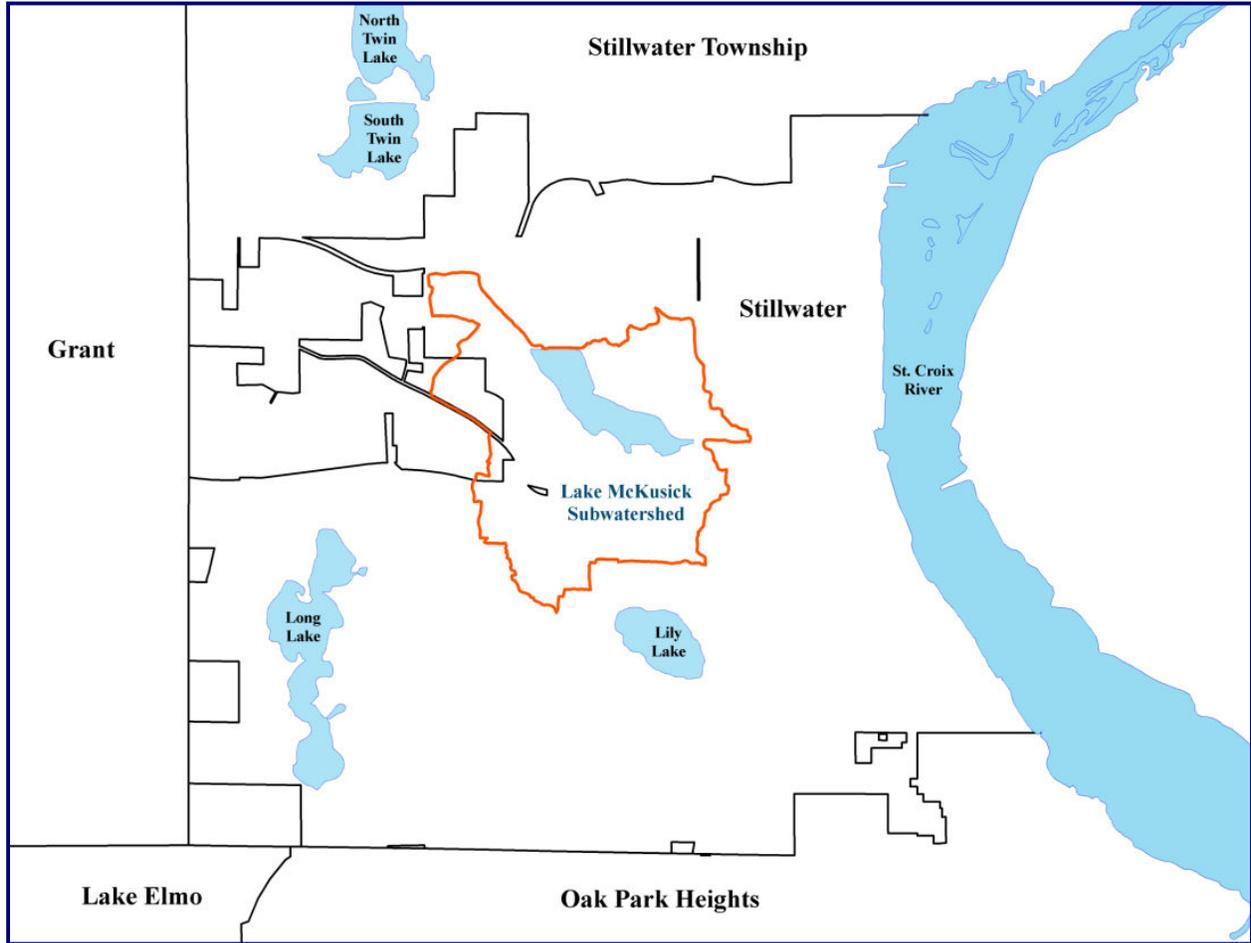
Appendix 5 – Subwatershed Maps



Lake McKusick Subwatershed – Aerial Photo (2009)



Lake McKusick Subwatershed – 29 Catchments (Priority Catchments are Shaded)



Location of the Lake McKusick Subwatershed within Stillwater

