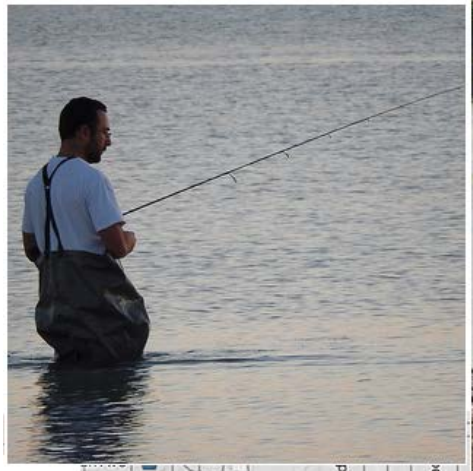
City of Edina, MN
Street Sweeping Management Plan
October, 2015



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Executive Summary

Street sweeping practices were evaluated to quantify the water quality benefits of current sweeping practices and proposed enhanced street sweeping within the drainage areas of Edina's priority waters. Priority waters were identified based on review of the Edina Comprehensive Water Resources Management Plan (CWRMP) including the recent Lake & Pond Management Policy Amendment. Total solids (TS) and total phosphorus (TP) recovery for street sweeping within the drainage of individual priority waters were estimated using a street sweeping planning calculator tool developed by the University of Minnesota. Load recovery was estimated for sweeping with a mechanical broom sweeper and for sweeping with a regenerative air sweeper at each defined level of effort. Load reductions (total solids, total phosphorus) for priority waters were estimated using pollutant removal efficiencies for stormwater catchments estimated by Barr (2011) through P8 modeling. A simple cost-benefit analysis was also completed for each level of effort/sweeper type evaluated. Costs were estimated based on the cost of current practices, manufacturer's literature, and through comparison with a recent university of MN study, *Quantifying Nutrient Removal through Street Sweeping*.

Pollutant load recovery and load reductions were estimated for three levels of effort: baseline sweeping (current practice), which consists of one sweeping each in the spring and fall using a mechanical broom sweeper; monthly sweeping, which was approximated as 7 sweeping per year (Apr-Oct); and bi-weekly sweeping, which was approximated as 14 sweepings per year (Apr-Oct). Differences in load recovery for the two sweeper types (mechanical broom, regenerative air) were based on review of manufacturer's literature, street sweeper pick-up efficiency studies, and solids loading patterns observed in University of MN study. Current sweeping practices are estimated to recover about 208,926 lb solids and 185 lb phosphorus each year within the drainage area of priority waters. Within the Minnehaha Creek watershed area current practices are estimated to reduce phosphorus loads to Minnehaha Creek by about 48 lb. Enhanced sweeping is expected to increase load recovery by the following amounts:

- Sweeping with a regenerative air sweeper (or similar technology) would increase load recovery by about 47% for TS and 37% for TP to 305,064 lb solids per year and 253 lb phosphorus per year for baseline sweeping.
- Within the Minnehaha Creek watershed area, sweeping with a regenerative air (or similar high-efficiency sweeper) is expected to increase the load reduction achieved through current practices by 29% to 62 lb/yr. The proposed sweeper upgrade would nearly achieve the target load reduction (67 lb/yr) required by the Minnehaha Creek Watershed District Management Plan at the current sweeping frequency.
- Sweeping monthly with a regenerative air sweeper would increase load recovery by about 250% for TS and 200% for TP over baseline to 731,559 lb solids per year and 564 lb phosphorus per year.
- Sweeping bi-weekly with a regenerative air sweeper would increase load recovery by over 400% for TS and nearly 400% for TP over baseline to 1,165,494 lb solids per year and 905.3 lb phosphorus per year.

Although the vehicle cost is greater, sweeping with a high-efficiency sweeper is more cost effective than sweeping with a mechanical broom sweeper due to the increased load recovery that is possible with this vehicle type. Monthly sweeping with a high-efficiency sweeper was found to be the most cost-effective option with an average cost of $152/lb for phosphorus recovery compared to the baseline cost-efficiency of $205/lb. Given the advantage in load recovery and cost-effectiveness when a higher efficiency sweeping is used, it is recommended that mechanical broom sweepers be replaced, or supplemented with a higher efficiency sweeper. It is also recommended that sweeping frequency be increase to about monthly sweeping (or greater) during the snow-free season.

1. Purpose

The purpose of this investigation was to estimate the water quality benefits, defined as the total solids (TS) and total phosphorus (TP) load reductions to priority waters, of current street sweeping practices in the City of Edina and the projected benefits of enhanced street sweeping. A simple cost-benefit analysis was completed to compare the cost-effectiveness of different sweeping practices and to identify the optimal practice from a cost-effectiveness standpoint.

2. Background

Most cities do some amount of street sweeping each year to improve road safety and appearance, but when considering best management practices (BMPs) for water quality, street sweeping is often overlooked. Intuitively, street sweeping makes sense. Pollutants removed from the street are not available for transport to the storm sewer network. In agreement with this, several recent studies, which make use of newer sweeping technologies and advances in stormwater management, have reported that street sweeping offers a very cost-effective and efficient means to reduce pollutant loads to storm sewer infrastructure and to downstream waters (Beretta et. al (2011), SPU (2009), Kalinosky et. al (2013), others). Additional benefits of street sweeping include reduced clogging and flooding of storm drains, reduced maintenance to downstream stormwater infrastructure, improved safety for pedestrians, and even reduced presence of pests.

Under the current MS4 Stormwater Pollution Prevention Plan (SWPPP, reissue date August 1, 2013), the City of Edina has established street sweeping as a BMP with the following measureable goal and timeframe:

> *The City will brush or vacuum sweep street a minimum of twice annual in an effort to reduce the amount of sediment, trash, and organic material from reaching the storm sewer system and water resources.*

Street sweeping efforts in Edina have increased since the previous SWPPP authorization in 2006. At that time, the measureable goals included sweeping once annually and the pollution prevention/good housekeeping BMP under item MCM 6.0 included the following language on street sweeping:

> *The City will continue with the current street sweeping program, identify improvements, and implement changes to reduce storm water pollutants.*

This investigation is consistent with the goal to identify improvements as stated above.

3. Water Resources

There are over two hundred water bodies, ranging in size from lakes to small stormwater detention basins within the city limits of Edina. Most of these waterbodies are part of larger flow networks that drain to Minnehaha Creek (HUC 070102060605) or Ninemile Creek (HUC 070200121108), both of which flow through the City of Edina. Many of Edina's lakes and ponds are integral to the stormwater system. This means that they provide water management services such as flood storage and pollutant capture which protects downstream waters. It also means that they are vulnerable to degradation if the stormwater they receive carries excessive pollution. Source control BMPs, such as street sweeping, limit the amount of pollution that is transferred from urban landscapes to Edina's waterbodies through the stormwater system.

The City of Edina Comprehensive Water Resources Management Plan (CWRMP) was reviewed to identify water quality goals and priorities that can be addressed through enhanced street sweeping. Identified priorities and stormwater management goals described in sections 3.1-3.2 and section 4. Priorities include nutrient management/aquatic vegetation management; pollutant load reductions required by regional TMDLs; and adherence to non-degradation policies.

3.1. City of Edina Lake and Pond Amendment to the Comprehensive Water Resources Management Plan (CWRMP)

In 2014, the city of Edina established services levels for aquatic vegetation management of lakes and ponds in the City of Edina Lake & Pond Management Policy Amendment to the Comprehensive Water Resources Management Plan (CWRMP). Lake and pond management was prioritized and assigned a service level of 'none', 'low', 'medium', or 'high' using a rating scheme that included the following criteria: waterbody size, water quality, aesthetics and nuisance abatement, shoreline owner involvement, and public access. The prioritization scheme adopted in the Lake & Pond Policy Amendment was used to define sweeping zones for evaluation of current sweeping and enhanced sweeping practices (Table 1). A full description of the prioritization scheme and policy development is given in the Lake & Pond Management Policy Amendment (City of Edina, 2014).

Table 1. Summary of priority waterbodies by HUC 12 with associated service level and land cover characteristics. Street sweeping was evaluated within the drainage areas of waterbodies shown in **bold font**.

HUC 12	Major Drainage	Waterbody	Service Level	Land Use Types
Minnehaha Creek 070102060605	Northwest Minnehaha Creek*	**Harvey Lake**	Low	R
		Lake Pamela	High	R
		Melody Lake	High	R
		Minnehaha Creek (direct drainage)	*(TMDLs)*	R (87%), PCD (2%); APD (1%);
	Northeast Minnehaha Creek*	**Minnehaha Creek**	*(TMDLs)*	R (97%), PCD/PID (11%); MDD (2%)
	Southeast Minnehaha Creek*	**Minnehaha Creek**	*(TMDLs)*	R
Ninemile Creek 070200121108	Ninemile Creek - North	**Hawkes Lake**	Low	R
		Highland Lake	Medium	R
		Mirror Lake	Low	R
		Unnamed nr Schaefer and Harold Wood l[§]	Low	R
		Mud Lake	Low	R
		Unnamed nr Parkwood & Knoll[§]	Low	R
		Other Parkwood Ponds[§]	Low/none	R
	Ninemile Creek - Central	**Creek Valley Pond**[§]	Low	R
	Ninemile Creek - South Fork	**Arrowhead Lake**	High	R
		Indianhead Lake	Medium	R
	Southwest Ponds	**Long Brake Trail**	Low	R
	Lake Cornelia/Lake Edina/Adam's Hill	**Cornelia - North**	High	R 95%); POD/PCD (6%)
		Cornelia - South	High	R
		Lake Edina	High	R/PSR (96%); POD/PCD (4%)
		Lake Nancy[§]	Medium	R
		Otto Pond[§]	Low	R
		Point of France[§]	Low	PCD (71%), R (14%); RMD (8%); POD (6%); APD (1%);
		Swimming Pool Pond[§]	Medium	R (86%), PSR (4%); RMD (7%); APD (2%); POD (1%)
		(West Garrison)	*(none)*	*R (89%); PCD (11%)*
	Ninemile Creek (direct drainage not listed above)		*(Future TMDLs)*	*(not quantified)*

* Also part of the drainage area for Lake Hiawatha (Lake Hiawatha Phosphorus TMDL, 2014).

[§]Included in sweeping zone for a downstream waterbody.

3.2. Impaired Waters and TMDLs

The current 303d list for Minnesota includes four waterbodies that lie within the City of Edina municipal boundaries, one of which has an approved TMDL (Table 2). In addition to these, the City of Edina is included in the categorical wasteload allocation for MS4 stormwater permits in the Lake Hiawatha total phosphorus TMDL. In the Lake Hiawatha TMDL, the allowable stormwater load for the City of Edina (424.4 lb/yr) is about half the estimated existing load (841.4 lb/yr for 2001-2011, Tetra Tech 2013). As additional TMDLs are approved and implementation plans are developed, the City of Edina may need to provide documentation of pollutant load reductions. TMDLs addressing nutrient impairments will most likely be written for total phosphorus (TP). Excess phosphorus is also a candidate cause for low dissolved oxygen (DO). Total suspended solids (TSS) is a candidate cause for fish and macroinvertebrate bioassessment impairments.

Table 2. Impaired waters located within the City of Edina jurisdiction.

Lake Name (MN DNR LAKE ID)	HUC 12	Listing Year	TMDL Target Start/Completion	Affected Use	Pollutant/Stressor
Impaired Waters Located Within the City of Edina					
Lake Cornelia (North) 27-0028-01	Nine Mile Creek 070102061302	2008	2014/2018	Aquatic Recreation:	Nutrients/Eutrophication Biological Indicators
Lake Edina 27-0029-00		2008	2014/2018		
Nine Mile Creek 07020012-518		2004	2024/2028	Aquatic Life	Chloride
					Fish Bioassessment
Minnehaha Creek 07010206-539	Minnehaha Creek 070102061108	2008	2020/2024	Aquatic Life	Chloride
		2014	2009/2015		Fish Bioassessment
		2008	2020/2024		Macroinvertabrate Bioassessment
		2004	2020/2024		Dissolved Oxygen
		2010	Approved 2014	Aquatic Recreation	Fecal Coliform
Downstream Impaired Waters					
Lake Hiawatha 27-0018-00	Minnehaha Creek 070102061108	2002	Approved 2014	Aquatic Recreation	Nutrient/Eutrophication Biological Indicators

4. Stormwater Management Goals

4.1. Non-degradation Policies

Two major watershed districts have jurisdictions which lie within the City of Edina municipal boundaries – the Nine Mile Creek Watershed District (NMCWD) and the Minnehaha Creek Watershed District (MCWD). Stormwater management rules for both of these watersheds included non-degradation policies that apply to both water quality and volume control. Enhanced street sweeping may provide assurance for non-degradation of water quality by reducing pollutant loads, and may address non-degradation of stormwater volume by reducing loss rate of storage volume through siltation/sedimentation of stormwater ponds.

4.2. Minnehaha Creek Watershed District (MCWD)

Per the MCWD Comprehensive Water Resources Management Plan the City of Edina is required to reduce its annual phosphorus load to Minnehaha Creek by 67 pounds[1]. This requirement has been fulfilled with the implementation of capital improvements since 2000, but additional reductions may be achieved through recent capital improvements and best management practices (BMPs) including street sweeping. Phosphorus reductions achieved through current sweeping practices were estimated at 350 lb/yr city-wide by Barr (2011). The estimated load reductions for current sweeping practices outlined in section 6.1 are defined instead by major drainage area. Current sweeping practices in the Minnehaha Watershed area of the City of Edina are expected to reduce phosphorus loads to Minnehaha Creek by about 48 lb. Sweeping with a regenerative air (or similar high-efficiency sweeper) is expected to increase the load reduction achieved by current practices to 62 lb/yr.

4.3. Good Housekeeping/Maintenance

In addition to water quality benefits, regular street sweeping may reduce needed maintenance on stormwater ponds and infrastructure by reducing sedimentation, siltation and clogging. Increased dead storage volume is listed as a potential implementation activity for several stormwater ponds throughout Edina in Section 15, Table 15A of the Edina CWRMP. Enhanced sweeping within stormwater pond drainage areas may extend the maintenance cycle for these and other ponds.

[1] As stated in Section 15.2.1 of the City of Edina Comprehensive Water Resources Management Plan.

5. Methods

5.1. Identification of Sweeping Zones

The sweeping zones (direct drainage areas) for which pollutant load recovery were estimated are shown in Figure 1 (all areas combined) and Appendix A (individual zones). Sweeping zones were identified based on the priorities outline in Sections 3 and 4. With a few exceptions, sweeping zones were defined for all ponds with a priority rating higher than 'none' (City of Edina, 2014) and for Minnehaha Creek and Nine Mile Creek. Sweeping zones include all streets located within the direct drainage areas of the water body of interest. For the purpose of estimating recoverable loads, the direct drainage area is defined as any street draining to the water body of interest that cannot be included in the direct drainage area of another priority water.

The estimated pollutant load recovery within the total drainage area and the total load reduction to each priority water are reported in section 6. For some water bodies, the total drainage area includes the direct drainage areas of other (upstream) priority lakes or ponds (see also section 5.2.2 and section 5.2.3). Streets located in landlocked basins were not included in load recovery estimates for priority waters, however, sweeping may be useful in these areas to extend the life of local stormwater BMPs.

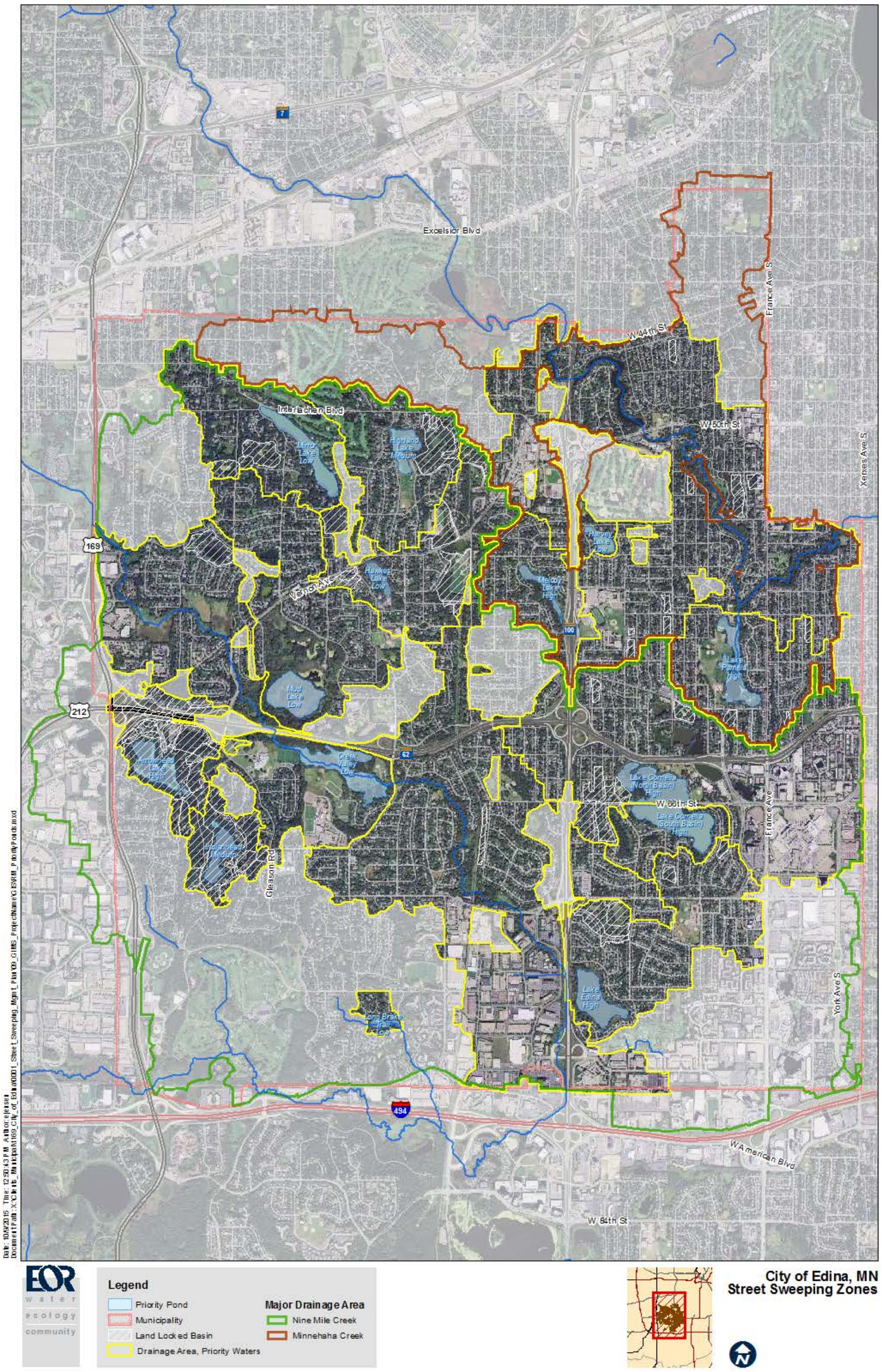

Figure 1. Direct drainage areas for priority waters (as defined for street sweeping goals) in the City of Edina, MN.
See Appendix AAppendix for maps of individual sweeping zones.

5.2. Methods for Estimating Load Recovery and Load Reductions

Pollutant recovery was estimated using a street sweeping planning calculator tool developed by the University of MN, 'Estimating Nutrient and Solids Load Recovery through Street Sweeping' (Kalinosky, et. al, 2014). The tool predicts average solids and nutrient load recovery based on the timing and frequency of sweeping; and density of tree canopy cover over the street. The tool was calibrated using street sweeping data from Prior Lake, MN and is intended for use in comparable settings (climate and geography). In order to calculate estimated solids recovery, it was necessary to first determine the length of street surfaces located within each drainage area shown in Figure 1 (section 5.2.1); and to estimate the average over-street tree canopy for these streets (section 5.2.1).

5.2.1. Tree Canopy Assessment

Tree canopy covers were visually inspected using 2013 color FSA aerial photographs of the Edina area. Areas of street with similar canopy cover were assigned a score of 1-5 corresponding to the range of canopy cover densities described in Table 3. Visual examples of tree canopy covers are included in Appendix B. Using tree canopy cover scores for individual street segments, a weighted average tree canopy cover was calculated for each street sweeping zone. Weighted average canopy cover scores were then translated to an over-street percent canopy cover for the purpose of estimating recoverable solids loads. Over-street percent tree canopy covers were assigned based upon comparison to tree canopies quantified in Prior Lake, MN (Kalinosky, et. al, 2013).

Table 3. Tree Canopy Rating Scheme

Assigned Score	Canopy Description		Over-Street Canopy Cover*
0	None	None over street, very few or no immature tree in yards/lots.	0%
1	Very Low	Immature trees near street, very little/no over street canopy, very low tree density in yards/lots.	2%
2	Low	Some visible cover over the street, mostly immature trees, general low density of trees.	5%
3	Medium	Visible cover over portions of the street, mix of immature and mature trees in yards/lots.	10%
4	Medium-High	Visible canopy over portions of the street, fairly dense, uniform canopy across yards, or stands of mature tree in backyards/common areas.	14%
4.5	High	Visible canopy along the majority of the street, uniform canopy of mature tree across yards/stands of mature trees in backyards/common areas.	18%
5	Very High	Very dense canopy, canopy cover fairly continuous across lot and street boundaries on aerial photos.	25%

*Based on comparison to quantified tree canopies in Prior Lake, MN (Kalinosky, et. al, 2013).

5.2.1. Spatial Analysis of Edina Roads

Streets length was summarized by sweeping zone using digital maps of Edina roads and the sweeping zones defined in Appendix A (GIS). The distance to be swept in each sweeping zone (number of curb-miles) was defined as twice the length of polylines representing the roadway, or approximately one sweeper pass along each curb line of the street. In reality, some roadways have two or more driving lanes in each direction of traffic. In such cases, load recovery estimates represent a lower bound for expected load recovery. Additional driving lanes are expected to increase the recovery of inorganic particulates compared to streets in similar settings with a single driving lane in each direction. Note that state and federal highways were excluded from sweeping zone summaries since maintenance responsibilities fall to other jurisdictions.

The assigned service level, curb-miles of street, average tree canopy cover, and land use characteristics for sweeping zone are outlined in Table 4. The total curb-miles of street for which pollutant load recovery was estimated are 345.0, about 82% of total curb-miles of street in the City of Edina. Estimates do not include state and federal highways or streets in areas outside of defined sweeping zones.

Table 4. Summary of sweeping zone characteristics including service level of the waterbody, average over-street tree canopy cover, and total curb-miles of street (length of street x 2).

Major Drainage	Waterbody/Sweeping Zone	Service Level	Estimated Over-street % Canopy (weighted average)	Curb-miles of Street in Direct Drainage Area
Minnehaha Creek HUC 070102060605	**Harvey Lake**	Low	14%	1.1
	Lake Pamela	High	13%	14.4
	Melody Lake	High	9%	11.5
	Minnehaha Creek (all other)	*(TMDLs)*	14%	65.5
Ninemile Creek HUC 070200121108	**Hawkes Lake**	Low	13%	16.6
	Highland Lake	Medium	13%	10.6
	Mirror Lake	Low	16%	8.9
	Mud Lake	Low	13%	17.1
	Arrowhead Lake	High	12%	5.7
	Indianhead Lake	Medium	16%	4.8
	Long Brake Trail	Low	15%	1.0
	Cornelia - North	High	12%	43.5
	Cornelia - South	High	12%	3.7
	Lake Edina	High	12%	20.1
	Ninemile Creek (all other)	*(Future TMDLs)*	12.0%	116.0

5.2.2. Solids Recovery Rates

Total solids and nutrient recovery were estimated for streets located within the direct drainage areas of priority waters. Pollutant recovery was estimated three levels of effort:

1. Baseline effort – all streets are swept once in the spring and once in the fall.
2. Monthly sweeping – all streets are swept once per month during the snow-free season (taken as April – October).
3. Bi-weekly sweeping – all streets are swept twice per month during the snow-free season (April – October).

In the monthly and bi-weekly sweeping scenarios, a sweeping season of April through October was assumed. For the initial sweeping event in each scenario (the first sweeping in April), load recovery was estimated as the average of predicted recovery for single sweepings in March and April. In the calculator tool, initial sweepings in these two months represent the high and low end of loading intensities encountered during spring cleaning operations. Pollutant load recovery estimated using the calculator tool depends on the density of over-street tree canopy cover. Total solids and phosphorus loading rates for each of the three defined levels of effort are outlined for a range of over-street tree canopy covers in Table 5.

Table 5. Estimated load recovery rates (lb/curb-mile/yr) for total solids and total phosphorus for three levels of effort, sweeping with a regenerative air (or comparable) sweeper.

		Baseline Sweeping		Monthly Sweeping		Bi-weekly Sweeping	
Canopy Cover Description*	Over-street % Canopy Cover§	TS	TP	TS	TP	TS	TP
None	0	522	0.4	1363	1.0	2265	1.6
Very Low	2	616	0.5	1467	1.1	2439	1.8
Low	5	688	0.6	1639	1.2	2725	6.5
Medium	10	827	0.7	1972	1.5	3278	2.5
Medium-High	14	959	0.8	2286	1.8	3801	3.0
High	18	1112	1.0	2651	2.2	4406	3.5
Very High	25	1440	1.3	3433	16.1	5707	4.8

* See Appendix B for examples.
§Average for the street length under consideration.

5.2.3. Load Reduction Estimates

To estimate pollutant reductions to priority waters (as opposed to pollutant recovery from streets) it was necessary to take into account pollutant removal through BMPs located along flow paths to priority waters. Load reductions were estimated by applying removal efficiencies for P8 ponds (Barr, 2011) to the recovered load estimates for streets located within the direct drainage area of each P8 pond. Individual P8 pond removal efficiencies are summarized by sweeping zone in Appendix D. Pollutant removal estimates were applied recursively to account for serial removal of pollutants along flow paths to priority waters. Expected pollutant load reductions to priority waters are reported as the recovered load minus any expected removal through modeled BMPs (P8 ponds). Load reductions estimates are based on the following assumptions:

- All solids on street surface will be transferred to the stormsewer system and on to downstream waters over time.
- The design efficiency of modeled BMPs can be applied to solids which typically collect on street surfaces (including organic material).
- The design efficiency of modeled BMPs is preserved through regular maintenance.

Pollutant reductions to priority waters are expected to vary somewhat from estimates. Structural BMPs and other practices, such as curbside rain garden or vegetated swales, which were not included in the P8 model, would increase overall pollutant removal and therefore decrease the overall pollutant reduction through street sweeping. Factors which decrease pollutant removal such as decreased efficiency of BMPs between maintenance periods would increase the pollutant reduction to priority waters through street sweeping. It should be noted that regular street sweeping is expected to extend the useful life of structural BMPs by reducing solids loads. This benefit, although not quantified here, should be considered in setting street sweeping policy.

5.2.4. Estimating Load Recovery for Different Sweeper Types

Because the pick-up efficiency of street sweepers varies among different makes and models, the amount of pollutant that can be recovered through street sweeping depends not only on factors that contribute to pollutant accumulation, but also on the type of sweeper used. Currently, all street sweeping in the City of Edina is done using mechanical broom sweepers which have been shown to have lower overall pick-up efficiency compared to higher efficiency technologies, such as regenerative air and vacuum assist street sweepers. The calculator tool used to estimate pollutant load recovery, however, is based on results for regenerative air technology. To get a more accurate estimate of load recovery at the baseline effort, discounts reflecting the lower pickup efficiency of mechanical broom sweepers were applied to estimates predicted by the calculator tool. Discounts were also applied at increased levels of effort in order to compare load recovery for mechanical broom and regenerative air (or similar) technologies. The rationale for the discounts applied is described in detail in Appendix C.

Table 6. Discounts applied to load recovery predictions to estimate recoverable loads for mechanical broom sweepers.

Mar-Apr, Sep-Nov		May-Aug	
TS	**TP**	**TS**	**TP**
32%	26%	38%	35%

6. Load Recovery and Load Reduction Estimates

6.1. Baseline Street Sweeping

The baseline street sweeping effort consists of one sweeping each in the spring and fall.

6.1.1. Load Recovery

Estimated solids and phosphorus recovery for the baseline sweeping effort in the area of interest is outlined by priority watershed in Table 7. Current sweeping practices are expected to remove approximately 56 lb-TP per year in the Minnehaha Creek subwatershed area and approximately 129 lb-TP per year in the Ninemile Creek subwatershed area. Recovery of phosphorus could be increased by approximately 40-47% (72 lb-TP/yr, 181 lb-TP/yr) if regenerative air (or similar) technology were used for sweeping.

6.1.2. Load Reductions

In the Ninemile Creek subwatershed overall pollutant loading to priority waters is reduced by from 3% - 94% (median value 39%) by structural BMPs that intercept stormwater. This rate of pollutant removal is based on design efficiencies for modeled BMPs. Actual removal by these structures may decline as sediment accumulates in structures between scheduled maintenance practices. The estimated overall pollutant reduction to waterbodies within the Ninemile Creek subwatershed area is about 66 lb TP/year for baseline sweeping with a mechanical broom sweeper. Load reductions could be increased to about 93 lb-TP/yr if a higher efficiency sweeper technology were used.

Note that load reductions to individual priority waters in the Minnehaha Creek subwatershed area are equal to recovered loads for the same priority waters. Structural BMPs that were included in the P8 model for the Minnehaha Creek Watershed were located largely in landlocked areas or the watersheds of 'low', or 'no' priority waters (section 3.1). For the priority waters listed in Table 7, no modeled BMPS were located in the upstream drainage area and therefore the load reduction is equal to load recovery in the direct drainage area. Pollutant removal was, however, modeled for the priority waters themselves. Modeled removal efficiencies for Harvey Lake, Lake Pamela, and Melody Lake are included in Appendix D. These removal efficiencies were taken into account in estimating the total load reduction to Minnehaha Creek for each sweeping scenario.

Based on the information available, the pollutant reduction to Minnehaha Creek for the baseline sweeping effort is 47.8 lb-TP/yr. The load reduction can be increased to 61.5 lb-TP/yr if a higher-efficiency sweeper is used.

Table 7. Estimated total solids and phosphorus recovery and load reduction estimates for baseline sweeping effort using mechanical broom and regenerative air technologies.

				Estimated Watershed Load* Recovery (lb)				Reduction to Waterbody through Sweeping (lb)				% Increased Recovery Sweeper Upgrade†	
				Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper			
HUC 8	Waterbody	Curb-miles *	Service Level	TS	TP	TS	TP	TS	TP	TS	TP	TS	TP
Minnehaha Creek HUC 070102060605	**Harvey Lake**	1.1	Low	831	0.7	1,121	0.9	831	0.7	1,121	0.9	47%	32%
	Lake Pamela South	8.1	High	5,648	4.9	7,501	6.2	5,648	4.9	7,501	6.2		
	Lake Pamela North[1]	14.4 (6.3)	High	9,885	8.5	13,334	11.0	9,885	8.5	13,334	11.0		
	Melody Lake	11.5	High	6,603	5.9	9,707	7.8	6,603	5.9	9,707	7.8		
	Minnehaha Creek *(direct drainage)*	*65.4*	*(TMDLs)*	46,565	40.8	62,815	52.4	46,565	40.8	62,815	52.4		
	Minnehaha Creek Subtotal**			**63,883**	**55.9**	**86,977**	**72.1**	**48,616**	**47.8**	**65,591**	**61.5**		
Ninemile Creek HUC 070200121108	**Arrowhead Lake** *(Landlocked basin)*	5.7	High	3,803	3.5	5,591	4.6	2,322	2.6	3,413	3.5		
	Centennial Lakes	*6.7*	*Low/No*	5,960	5.0	8,761	6.7	5,140	4.7	7,556	6.3		
	Cornelia North	43.5	High	19,731	17.7	29,008	23.2	10,415	12.6	15,311	16.8		
	Cornelia South[2]	47.2 (3.7)	High	21,571	19.4	31,713	25.5	2,357	8.9	3,465	11.7		
	Hawkes Lake[3]	27.2 (16.6)	Low	17,132	14.1	25,187	20.7	6,984	9.7	10,763	13.5		
	Highland Lake	10.6	Low	5,755	5.9	9,816	8.1	5,565	5.4	9,492	7.4		
	Indianhead Lake *(Landlocked basin)*	4.8	Medium	2,954	2.8	4,342	3.7	2,411	2.4	3,544	3.2		
	Lake Edina[4]	67.3 (20.1)	High	40	37.1	60,099	48.8	4467	18.7	6,567	22.4		
	Long Brake Trail	1.0	Low	40,879	0.7	1,091	0.9	742	0.7	1,091	0.9		
	Mirror Lake	8.9	Low	4,350	4.1	6,394	5.4	2,726	3.5	4,007	4.6		
	Mud Lake[5]	43.6 (17.1)	Low	27,908	23.0	41,022	33.8	7,254	13.8	10,663	20.3		
	Ninemile Creek *(direct drainage)*	*122.6*	*(Future TMDL)*	71,163	63.9	109,482	92.0	34,870	31.3	53,646	45.1		
	Ninemile Creek Subtotal**			**145,043**	**128.8**	**218,087**	**180.8**	**48,616**	**66.3**	**75,973**	**93.2**		

§ Total recoverable watershed load - includes recoverable loads in upstream catchments.

§§Load reduction estimate to priority water body based on P8 pond removal efficiencies (Barr, 2011). Removal efficiencies were applied to recoverable loads within the catchment of any modeled P8 pond or priority water and applied in series to determine overall reduction to a given water body. Expected reductions in total solids (TS) are approximated using TSS removal efficiencies although the two constituents are not equivalent.

*Total drainage area. Curbmiles of street located within the subwatershed of upstream priority waters are shown in parenthesis.

**Recovered loads and load reductions in upstream priority waters are not double counted in HUC 12 subtotals. Subtotals for major drainage areas (HUC12) are based on the total watershed load (not including landlocked basins) or reduced load based on P8 pond linkages (see Appendix D).

[1] Upstream priority water = Pamela South

[2] Upstream priority water = Cornelia North

[3] Upstream priority water = Highland Lake

[4] Upstream priority waters = Cornelia South, Cornelia North

[5] Upstream priority waters = Hawkes Lake, Highland Lake

†Compares watershed load recovery using regenerative air technology to load recovery using mechanical broom, median value of reported.

6.2. Enhanced Sweeping Scenario 1 – Monthly Street Sweeping

The monthly sweeping scenario is defined as 7 sweepings per year- one each in the months April – October.

6.2.1. Load Recovery

Estimated solids and phosphorus recovery for monthly sweeping is outlined by priority watershed in Table 8. Monthly sweeping practices are expected to remove approximately 113 lb-TP per year in the Minnehaha Creek subwatershed area and approximately 279 lb-TP per year in the Ninemile Creek subwatershed area. Recovery of phosphorus could be increase by approximately 43% (164 lb-TP/yr, 400 lb-TP/yr) if a higher efficiency sweeper were used, a 200% increase over baseline sweeping with a mechanical broom sweeper.

6.2.2. Load Reductions

The estimated overall pollutant reduction to Minnehaha Creek is 96.3 lb-TP/yr for monthly sweeping with mechanical broom (see also discussion in section 6.1.2). For Ninemile Creek, the estimated overall pollutant reduction to waterbodies is about 144 lb-TP/year. Load reductions could be increased to about 135 lb-TP/yr and 209 lb-TP/yr in Minnehaha Creek and Ninemile Creek respectively if a higher efficiency sweeper technology were used. Estimated load reductions represent an increase of almost 200% over load reductions for baseline sweeping with a mechanical broom sweeper.

Table 8. Estimated total solids and phosphorus recovery and load reduction estimates for monthly sweeping effort using mechanical broom and regenerative air technologies.

				Estimated Watershed Load§ Recovery (lb)				Reduction to Waterbody through Sweeping§§ (lb)				% Increased Recovery Sweeper Upgrade†		% Increased Reduction compared to baseline, mechanical††	
				Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper					
Major Drainage (HUC 12)	Waterbody	Curb-miles*	Service Level	TS	TP	TS	TP	TS	TP	TS	TP	TS	TP	TS	TP
Minnehaha Creek HUC 070102060605	**Harvey Lake**	1.1	Low	1,705	1.5	2,625	2.1	1,705	1.5	2,625	2.1	54%	43%	244%	195%
	Lake Pamela South	8.1	High	11,798	9.9	17,881	13.7	11,798	9.9	17,881	13.7				
	Lake Pamela North[1]	14.4 (6.3)	High	20,647	17.4	31,788	24.3	20,647	17.4	31,788	24.3				
	Melody Lake	11.5	High	14,755	12.1	22,722	17.3	14,755	12.1	22,722	17.3				
	Minnehaha Creek *(direct drainage)*	*65.4*	*(TMDLs)*	97,255	81.9	149,733	114.6	97,255	81.9	149,733	114.6				
	Minnehaha Creek Subtotal**			**134,362**	**112.8**	**211,941**	**163.8**	**101,549**	**96.3**	**156,344**	**134.9**				
Ninemile Creek HUC 070200121108	**Arrowhead Lake** *(Landlocked basin)*	5.7	High	8,500	7.1	13,090	10.1	5,192	5.3	7,996	7.6				
	Centennial Lakes	*6.7*	*Low/No*	*13,314*	*9.9*	*20,504*	*14.2*	*11,479*	*9.4*	*17,678*	*13.4*				
	Cornelia North	43.5	High	44,090	35.9	67,898	51.0	23,271	26.0	35,856	37.0				
	Cornelia South[2]	47.2 (3.7)	High	48,205	39.2	74,236	55.8	5,267	18.0	8,141	26.7				
	Hawkes Lake[3]	26.5 (15.9)	Low	36,547	30.3	60,044	45.9	15,619	19.7	25,658	29.9				
	Highland Lake	10.6	Low	12,870	11.4	23,400	17.9	12,448	11.0	22,628	16.3				
	Indianhead Lake *(Landlocked basin)*	4.8	Medium	6,603	5.7	10,168	8.1	5,390	5.0	8,300	7.1				
	Lake Edina[4]	67.3 (20.1)	High	93,040	76.9	143,282	109.4	10,166	35.3	15,713	52.3				
	Long Brake Trail	1.0	Low	1,659	1.4	2,555	2.0	1,659	1.4	2,555	2.0				
	Mirror Lake	8.9	Low	9,723	8.4	14,973	12.0	6,093	7.2	9,385	10.2				
	Mud Lake[5]	43.6 (17.1)	Low	66,531	50.9	97,792	74.8	17,293	30.5	25,418	44.9				
	Ninemile Creek *(direct drainage)*	*122.6*	*(Future TMDL)*	169,491	141.5	261,015	202.3	83,050	69.3	127,898	99.1				
	Ninemile Creek Subtotal**			**340,445**	**279.0**	**519,618**	**400.4**	**118,261**	**143.6**	**180,969**	**208.5**				

§ Total recoverable watershed load - includes recoverable loads in upstream catchments.

§§Load reduction estimate to priority water body based on P8 pond removal efficiencies (Barr, 2011). Removal efficiencies were applied to recoverable loads within the catchment of any modeled P8 pond or priority water and applied in series to determine overall reduction to a given water body. Expected reductions in total solids (TS) are approximated using TSS removal efficiencies although the two constituents are not equivalent.

*Total drainage area. Curbmiles of street located within the subwatershed of upstream priority waters are shown in parenthesis.

**Recovered loads and load reductions in upstream priority waters are not double counted in HUC 12 subtotals. Subtotals for major drainage areas (HUC12) are based on the total watershed load (not including landlocked basins) or reduced load based on P8 pond linkages (see Appendix D).

1 Upstream priority water = Pamela South

2 Upstream priority water = Cornelia North

3 Upstream priority water = Highland Lake

4 Upstream priority water = Cornelia South, Cornelia North

5 Upstream priority water = Hawkes Lake, Highland Lake

†Compares watershed load recovery using regenerative air technology to load recovery using mechanical broom, median value reported.

††Compares reduction to waterbody using regenerative air technology to reduction to water body for baseline sweeping (mechanical broom), median value reported.

6.3. Enhanced Sweeping Scenario 2 – Bi-Weekly Street Sweeping

The bi-weekly sweeping scenario is defined as 14 sweepings per year- two each in the months April – October.

6.3.1. Load Recovery

Estimated solids and phosphorus recovery for bi-weekly sweeping is outlined by priority watershed in Table 9. Bi-weekly sweeping practices are expected to remove approximately 183 lb-TP per year in the Minnehaha Creek subwatershed area and approximately 460 lb-TP per year in the Ninemile Creek subwatershed area. Recovery of phosphorus could be increased by 32% - 44% (241 lb-TP/yr, 665 lb-TP/yr) if a higher efficiency sweeper were used, an increase of 223% over baseline sweeping with a mechanical broom sweeper.

6.3.2. Load Reductions

The estimated overall pollutant reduction to Minnehaha Creek is 158 lb-TP/yr for monthly sweeping with mechanical broom (see also discussion in section 6.1.2). For Ninemile Creek, the estimated overall pollutant reduction to waterbodies is about 236 lb-TP/year. Load reductions could be increased to about 226 lb-TP/yr and 342 lb-TP/yr in Minnehaha Creek and Ninemile Creek respectively if a higher efficiency sweeper technology were used.

Table 9. Estimated total solids and phosphorus recovery and load reduction estimates for bi-weekly sweeping effort using mechanical broom and regenerative air technologies.

				Estimated Watershed Load[§] Recovery (lb)				Reduction to Waterbody through Sweeping[§§] (lb)				% Increased Recovery Sweeper Upgrade[†]		% Increased Reduction compared to baseline, mechanical[††]	
				Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper					
Major Drainage (HUC 12)	**Waterbody**	**Curb-miles***	**Service Level**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**
Minnehaha Creek HUC 070102060605	**Harvey Lake**	1.1	Low	2,430	2.1	3,767	3.0	2,430	2.1	3,767	3.0	55%	44%	426%	344%
	Lake Pamela South	8.1	High	19,480	16.3	29,726	22.9	19,480	16.3	29,726	22.9				
	Lake Pamela North[1]	14.4 (6.3)	High	34,090	28.5	52,846	40.7	34,090	28.5	52,846	40.7				
	Melody Lake	11.5	High	21,182	17.6	32,832	25.3	21,182	17.6	32,832	25.3				
	Minnehaha Creek *(direct drainage)*	*65.4*	*(TMDLs)*	160,580	135.3	248,933	193.2	160,580	135.3	248,933	193.2				
		Minnehaha Creek Subtotal**		**218,282**	**183.4**	**304,694**	**240.8**	**167,635**	**158.3**	**259,868**	**226.2**				
Ninemile Creek HUC 070200121108	**Arrowhead Lake** *(Landlocked basin)*	5.7	High	12,159	10.3	18,847	14.8	7,408	7.8	11,482	11.2				
	Centennial Lakes	*6.7*	*Low/No*	*18,765*	*14.7*	*29,086*	*21.2*	*14,934*	*9.8*	*23,147*	*20.0*				
	Cornelia North	43.5	High	63,057	52.1	97,741	74.9	33,283	37.7	51,668	54.3				
	Cornelia South[2]	47.2 (3.7)	High	68,943	57.1	106,864	82.0	7,533	26.2	11,722	37.7				
	Hawkes Lake[3]	26.5 (15.9)	Low	52,221	44.4	99,821	76.8	22,319	29.7	42,656	50.1				
	Highland Lake	10.6	Low	18,355	16.4	38,901	29.9	17,750	11.0	37,618	27.3				
	Indianhead Lake *(Landlocked basin)*	4.8	Medium	9,406	8.3	14,579	11.9	7,676	5.6	11,898	10.5				
	Lake Edina[4]	67.3 (20.1)	High	111,178	92.6	238,192	181.7	16,790	58.0	26,127	83.5				
	Long Brake Trail	1.0	Low	2,989	2.1	4,632	3.0	2,989	2.1	4,632	3.0				
	Mirror Lake	8.9	Low	13,844	12.2	21,458	17.5	8,676	10.4	13,444	14.9				
	Mud Lake[5]	43.6 (17.1)	Low	110,605	85.1	162,575	125.1	28,749	51.1	42,257	75.1				
	Ninemile Creek *(direct drainage)*	*122.6*	*(Future TMDL)*	282,063	234.3	433,943	337.2	138,211	114.8	212,632	165.2				
		Ninemile Creek Subtotal**		**563,168**	**460.2**	**860,800**	**664.5**	**195,414**	**236.4**	**299,093**	**341.7**				

[§] Total recoverable watershed load - includes recoverable loads in upstream catchments.

[§§] Load reduction estimate to priority water body based on P8 pond removal efficiencies (Barr, 2011). Removal efficiencies were applied to recoverable loads within the catchment of any modeled P8 pond or priority water and applied in series to determine overall reduction to a given water body. Expected reductions in total solids (TS) are approximated using TSS removal efficiencies although the two constituents are not equivalent.

*Total drainage area. Curbmiles of street located within the subwatershed of upstream priority waters are shown in parenthesis.

**Recovered loads and load reductions in upstream priority waters are not double counted in HUC 12 subtotals. Subtotals for major drainage areas (HUC12) are based on the total watershed load (not including landlocked basins) or reduced load based on P8 pond linkages (see Appendix D).

[1] Upstream priority water = Pamela South

[2] Upstream priority water = Cornelia North

[3] Upstream priority water = Highland Lake

[4] Upstream priority water = Cornelia South, Cornelia North

[5] Upstream priority water = Hawkes Lake, Highland Lake

†Compares watershed load recovery using regenerative air technology to load recovery using mechanical broom, median value reported.

††Compares reduction to waterbody using regenerative air technology to reduction to water body for baseline sweeping (mechanical broom), median value reported.

6.4. Costs Benefit Analysis

Total costs and cost-efficiencies ($/lb-P) were estimated for baseline, monthly and bi-weekly sweeping scenarios. The cost-basis of street sweeping ($/curb-mile) is not constant and depends on the sweeper type and financing; and the cost of vehicle maintenance, labor, and fuel. Total costs for each sweeping scenario were calculated using the component costs and assumptions outlined below.

Category		Cost Basis
Sweeper	Mechanical Broom	$18,200 - vehicle depreciation* $3,700 - vehicle maintenance*
	Higher Efficiency	$23,700 - vehicle depreciation $4,800 - vehicle maintenance
Labor (wages + benefits)		$75/hr
Diesel Fuel		$3/gal

* City of Edina, Public Works Department

Cost Basis Assumptions:

- Sweepers are owned by the City of Edina.
- Sweeper operational speed = 4.5 mph
- An additional 1.5 hrs of labor is required for every 4 hrs of sweeping time
- Total transit miles (brush off) are about 3 times total swept miles
- On average, sweeper fuel consumption is 5 mpg
    - [(brush off time, empty) + (brush on time)+ (brush off time, full capacity)]
- 1 vehicle is sufficient for baseline and monthly sweeping, 2 vehicles are required for sweeping above this level of effort based on labor hours required compared to sweeping timeframe.
- Sufficient staffing is assumed.

Sweeping is most cost-effective when solids loading to streets is greatest. Since solids loading varies over the course of the year adding sweepings at certain times of the year (summer) is less cost-effecting than adding sweepings at peak loading intensities (spring, fall). Although sweeping operations can be further optimized to take advantage of these differences, the cost calculations presented here are based on regular sweeping at the frequency specified for each level of effort.

Estimated sweeping costs at each defined level of effort are summarized in sections 6.4.1 - 6.4.3. Cost are outlined in detail for loads recovered within the direct drainage area of priority waters in Table 13 for sweeping with mechanical broom and Table 14 for sweeping with a high efficiency sweeper. Costs are also outlined in detail for load recovery within the total drainage area of each priority water for sweeping with a high efficiency sweeper in Table 15.

6.4.1. Cost Effectiveness of Baseline Sweeping

Solids loading tends to peak in the spring (winter residuals) and again in the fall (leaf drop) which makes the singular spring and fall sweepings that make up the baseline sweeping effort among the most efficient (lb/curb-mile). However, at the baseline effort, the cost of sweeping is driven by the flat cost of vehicle financing. This drives the cost-effectiveness of sweeping down compared to monthly sweeping (section 6.4.2).

Based on the assumptions outlined above, the cost basis for baseline sweeping with a mechanical broom sweeper and with a higher efficiency sweeper are $56.50 and $66 per curb-mile of sweeping respectively. Estimated total costs and cost-efficiencies for baseline sweeping are summarized in Table 10 and outlined in detail in Table 13 - Table 15 . Note that while sweeping is less expensive for a mechanical broom sweeper on a per-mile basis, it is less cost effective ($/lb-P recovered) due to the reduced solids recovery compared to higher efficiency sweepers.

Table 10. Cost and cost-efficiency of street sweeping in defined sweeping zones (Appendix B) at the baseline effort by major subwatershed.

Sweeper Type	HUC 12 Watershed	Cost ($)	Cost-efficiency, Phosphorus Recovery ($/lb-P)	Cost-efficiency, Phosphorus Reduction* ($/lb-P)
Mechanical Broom	Minnehaha Creek	10,348	185	194
	Ninemile Creek	27,532	214	415
Higher Efficiency	Minnehaha Creek	12,048	167	196
	Ninemile Creek	32,050	177	344

*Based on estimated sub-catchment pollutant removal efficiency, see section 6.1.2.

6.4.2. Cost Effectiveness of Monthly Sweeping

Since monthly sweeping can be completed using a single sweeper, the vehicle financing cost does not increase for monthly sweeping compared to baseline sweeping. Labor and fuel costs increase such that the total cost is approximately 2X the cost of baseline sweeping; however, solids recovery increases by more than 2-fold over baseline, making monthly sweeping more cost-effective than the baseline effort.

Based on the assumption outlined above, the cost basis for baseline sweeping with a mechanical broom sweeping is $34, and with a regenerative air sweeper $37 per curb-mile of sweeping. Estimated total costs and cost-efficiencies for monthly sweeping are summarized in Table 11 and outlined in detail in Table 13 - Table 15 .

Table 11. Cost and cost-efficiency of street sweeping in defined sweeping zones (Appendix B) for monthly sweeping by major subwatershed.

Sweeper Type	HUC 12 Watershed	Cost ($)	Cost-efficiency, Phosphorus Recovery ($/lb-P)	Cost-efficiency, Phosphorus Reduction* ($/lb-P)
Mechanical Broom	Minnehaha Creek	21,943	194	204
	Ninemile Creek	58,343	209	406
Higher Efficiency	Minnehaha Creek	26,631	144	175
	Ninemile Creek	62,860	157	301

*Based on estimated sub-catchment pollutant removal efficiency, see section 6.2.2.

6.4.3. Cost Effectiveness of Bi-weekly Sweeping

Based on the number of vehicle hours required, bi-weekly sweeping cannot be completed in all defined sweeping zone during the period April-October unless a second vehicle is used. Although a second sweeper might not be financed in the same manner a primary sweeper, for the sake of keeping cost estimates simple, the vehicle finance cost was doubled to account for the additional sweeper in the bi-weekly sweeping scenario. Labor and fuel costs also double compared to monthly sweeping making the total cost for bi-weekly sweeping 2X the cost of monthly sweeping. Total load recovery increases over baseline and monthly sweeping when street are swept bi-weekly, but sweeping efficiency (lb/curb-mile recovered) tends to decrease as sweeping intervals decrease. For this reason, bi-weekly sweeping is less cost-effective than monthly sweeping; however, the cost-effectiveness of bi-weekly sweeping with a higher-efficiency sweeper is comparable to baseline sweeping with a mechanical broom sweeper.

Based on the assumption outlined above, the cost basis for baseline sweeping with a mechanical broom sweeping is $34, and with a regenerative air sweeper $37 per curb-mile of sweeping. Total cost ad cost-efficiencies for bi-weekly sweeping are summarized in Table 12 and outlined in detail in Table 13 - Table 15 .

Table 12. Cost and cost-efficiency of street sweeping in defined sweeping zones (Appendix B) for bi-weekly sweeping by major subwatershed.

Sweeper Type	HUC 12 Watershed	Cost ($)	Cost-efficiency, Phosphorus Recovery ($/lb-P)	Cost-efficiency, Phosphorus Reduction* ($/lb-P)
Mechanical Broom	Minnehaha Creek	43,887	239	249
	Ninemile Creek	116,685	254	494
Higher Efficiency	Minnehaha Creek	47,261	196	209
	Ninemile Creek	125,720	189	368

*Based on estimated sub-catchment pollutant removal efficiency, see section 6.3.2.

Table 13. Summary of estimated costs and cost-efficiencies of phosphorus recovery within direct drainage areas for each waterbody (see 5.1) for baseline, monthly, and bi-weekly sweeping scenarios.

Estimates are based on recovery using a **mechanical broom** sweeper. The cost basis for estimates is $56.50 (baseline) or $34 (monthly, bi-weekly) per curb-mile of sweeping.

				Recovered Phosphorus (lb)*			Baseline Sweeping Costs		Monthly Sweeping Costs		Bi-weekly Sweeping Costs	
HUC 8	Waterbody	Service Level	Curb-miles, Direct Drainage Area	Baseline	Monthly	Bi-weekly	$	$/lb-P	$	$/lb-P	$	$/lb-P
Minnehaha Creek HUC 070102060605	**Harvey Lake**	Low	1.1	0.7	1.5	2.1	$ 124	$ 178	$ 264	$ 176	$ 527	$ 251
	Lake Pamela South	High	8.1	4.9	9.9	16.3	$ 917	$ 188	$ 1,944	$ 196	$ 3,888	$ 239
	Lake Pamela North	High	6.3	3.7	7.4	12.2	$ 713	$ 195	$ 1,510	$ 203	$ 3,020	$ 247
	Melody Lake	High	10.6	5.9	12.1	17.6	$ 1,199	$ 203	$ 2,541	$ 210	$ 5,082	$ 289
	Minnehaha Creek *(all other*)*	*(TMDLs)*	*65.5*	40.8	81.9	135.3	$ 7,407	$ 182	$ 15,700	$ 192	$ 31,401	$ 232
	Minnehaha Creek Subtotal*		**91.6**	**55.9**	**112.8**	**183.4**	**$ 10,348**	**$ 185**	**$ 21,932**	**$ 194**	**$ 43,865**	**$ 239**
Ninemile Creek HUC 070200121108	**Arrowhead Lake** *(Landlocked basin)*	High	5.7	3.5	7.1	10.3	$ 645	$ 184	$ 1,366	$ 192	$ 2,733	$ 265
	Centennial Lakes	*Low/No*	*6.7*	*5.0*	*9.9*	*14.7*	$ 758	$ 152	$ 1,606	$ 162	$ 3,212	$ 219
	Cornelia North	High	43.5	17.7	35.9	52.1	$ 4,921	$ 279	$ 10,427	$ 291	$ 20,854	$ 400
	Cornelia South	High	3.7	1.8	3.4	4.9	$ 419	$ 239	$ 887	$ 263	$ 1,774	$ 359
	Hawkes Lake	Low	16.6	14.1	30.3	44.4	$ 1,799	$ 127	$ 3,811	$ 126	$ 7,622	$ 172
	Highland Lake	Low	10.6	5.5	11.4	16.4	$ 1,199	$ 218	$ 2,541	$ 223	$ 5,082	$ 310
	Indianhead Lake *(Landlocked basin)*	Medium	3.9	2.8	5.7	8.3	$ 543	$ 194	$ 1,151	$ 202	$ 2,301	$ 277
	Lake Edina	High	20.1	17.7	37.7	69.4	$ 2,274	$ 128	$ 4,818	$ 128	$ 9,636	$ 139
	Long Brake Trail	Low	1.0	0.7	1.4	2.1	$ 113	$ 167	$ 240	$ 173	$ 479	$ 232
	Mirror Lake	Low	8.9	4.1	8.4	12.2	$ 1,007	$ 246	$ 2,133	$ 254	$ 4,267	$ 350
	Mud Lake	Low	17.1	23.0	50.9	85.1	$ 1,934	$ 84	$ 4,099	$ 81	$ 8,198	$ 96
	Ninemile Creek *(all other*)*	*(Future TMDL)*	*122.6*	44.3	99.8	173.5	$ 13,868	$ 313	$ 29,387	$ 294	$ 58,774	$ 339
	Ninemile Creek Subtotal*		**244.1**	**128.8**	**279.0**	**460.2**	**$ 27,532**	**$ 214**	**$ 53,343**	**$ 209**	**$ 116,685**	**$ 254**
						TOTAL**	**$ 37,880**	**$ 205**	**$ 80,275**	**$ 205**	**$ 160,550**	**$ 250**

* Recovered TP loads for direct drainage areas only (does not include loads recovered from streets located in upstream drainage areas). Recovery with **mechanical broom sweeper**.

**Includes Landlocked areas.

Table 14. Summary of estimated costs and cost-efficiencies of phosphorus recovery within direct drainage areas for each waterbody (see 5.1) for baseline, monthly, and bi-weekly sweeping scenarios.

Estimates are based on recovery using a **regenerative air** (or similar) sweeping technology. The cost basis for estimates is $66 (baseline) or $37 (monthly, bi-weekly) per curb-mile of sweeping.

				Recovered Phosphorus (lb)*			Baseline Sweeping Costs		Monthly Sweeping Costs		Bi-weekly Sweeping Costs	
HUC 8	Waterbody	Service Level	Curb-miles	Baseline	Monthly	Bi-weekly	$	$/lb-P	$	$/lb-P	$	$/lb-P
Minnehaha Creek HUC 070102060605	**Harvey Lake**	Low	1.1	0.9	2.1	3.0	$ 145	$ 161	$ 284	$ 135	$ 568	$ 189
	Lake Pamela South	High	8.1	6.2	13.7	22.9	$ 1,068	$ 173	$ 2,094	$ 153	$ 4,189	$ 183
	Lake Pamela North	High	6.3	4.8	10.6	17.8	$ 1,830	$ 167	$ 3,590	$ 148	$ 7,180	$ 176
	Melody Lake	High	10.6	7.8	17.3	25.3	$ 1,396	$ 179	$ 2,738	$ 158	$ 5,475	$ 216
	Minnehaha Creek *(all other*)*	*(TMDLs)*	*65.5*	54.4	114.6	193.2	$ 8,612	$ 164	$ 16,890	$ 147	$ 33,780	$ 175
	Minnehaha Creek Subtotal*		**91.6**	**72.0**	**158.3**	**262.2**	**$ 12,048**	**$ 167**	**$ 23,631**	**$ 144**	**$ 47,261**	**$ 196**
Ninemile Creek HUC 070200121108	**Arrowhead Lake** *(Landlocked basin)*	High	5.7	4.6	10.1	14.8	$ 751	$ 163	$ 1,472	$ 146	$ 2,944	$ 199
	Centennial Lakes	*Low/No*	*6.7*	*6.7*	*14.2*	*21.2*	$ 882	$ 132	$ 1,730	$ 122	$ 3,461	$ 163
	Cornelia North	High	43.5	23.2	51.0	74.9	$ 5,728	$ 247	$ 11,234	$ 220	$ 22,468	$ 300
	Cornelia South	High	3.7	2.3	4.8	7.1	$ 6,215	$ 244	$ 12,190	$ 218	$ 24,380	$ 297
	Hawkes Lake	Low	16.6	12.7	27.1	40.3	$ 3,582	$ 173	$ 7,025	$ 153	$ 14,049	$ 183
	Highland Lake	Low	10.6	8.1	16.3	23.6	$ 1,396	$ 173	$ 2,738	$ 153	$ 5,475	$ 183
	Indianhead Lake *(Landlocked basin)*	Medium	3.9	3.7	8.1	11.9	$ 514	$ 139	$ 1,007	$ 124	$ 2,014	$ 169
	Lake Edina	High	20.1	23.3	35.0	51.4	$ 8,862	$ 182	$ 17,381	$ 159	$ 34,762	$ 191
	Long Brake Trail	Low	1.0	0.9	6.2	9.2	$ 132	$ 146	$ 258	$ 129	$ 517	$ 174
	Mirror Lake	Low	8.9	5.4	12.0	17.5	$ 1,172	$ 217	$ 2,299	$ 192	$ 4,597	$ 263
	Mud Lake	Low	17.1	13.0	19.3	32.2	$ 5,741	$ 170	$ 11,260	$ 151	$ 22,520	$ 180
	Ninemile Creek *(all other*)*	*(Future TMDL)*	*122.6*	92.0	202.3	337.2	$ 16,143	$ 176	$ 31,662	$ 157	$ 63,325	$ 188
	Ninemile Creek Subtotal*		**243.4**	**180.8**	**400.4**	**664.5**	**$ 32,050**	**$ 177**	**$ 62,860**	**$ 157**	**$ 125,720**	**$ 189**
	TOTAL**						$ 46,244	$ 173	$ 90,700	$ 152	$ 181,401	$ 190
	TOTAL $_{regenerative\ air}$ – TOTAL $_{mechanical\ broom}$						$ 6,570.00	$ (29.85)	$ 6,570.00	$ (50.93)	$ 13,140.00	$ (58.29)
	% Increase over mechanical broom						17%	**-15%**	8%	**-25%**	8%	**-23%**

* Recovered TP loads for direct drainage areas only (does not include loads recovered from streets located in upstream drainage areas). Recovery with **high efficiency sweeper**.

**Includes Landlocked areas.

Table 15. Summary of estimated costs and cost-efficiencies of phosphorus recovery within the TOTAL drainage area for each waterbody for baseline, monthly, and bi-weekly sweeping scenarios.

Estimates are based on recovery using a **regenerative air** (or similar) sweeping technology. The cost basis for estimates is $66 (baseline) - $37 (monthly, bi-weekly) per curb-mile of sweeping. Load recovery for monthly sweeping (**bold red font**) is the most cost-effective among the scenarios.

				Baseline Sweeping Costs§			Monthly Sweeping Costs§			Bi-weekly Sweeping Costs§		
HUC 8	Waterbody	Service Level	Total Curb-miles*	$	$/lb-P recovered	$/lb-P reduced†	$	$/lb-P recovered	$/lb-P reduced†	$	$/lb-P recovered	$/lb-P reduced†
Minnehaha Creek	**Harvey Lake**	Low	1.1	$ 145	$ 161	$ 242	$ 284	**$ 135**	$ 203	$ 568	$ 189	$ 284
	Lake Pamela South	High	8.1	$ 1,068	$ 173	$ 173	$ 2,094	**$ 153**	$ 153	$ 4,189	$ 183	$ 183
	Lake Pamela North[1]	High	13.9	$ 1,830	$ 167	$ 167	$ 3,590	**$ 148**	$ 148	$ 7,180	$ 176	$ 176
	Melody Lake	High	10.6	$ 1,396	$ 179	$ 269	$ 2,738	**$ 158**	$ 238	$ 5,475	$ 216	$ 325
	Minnehaha Creek *(all other*)*	*(TMDLs)*	*96.8*	$ 8,612	$ 164	$ 164	$ 16,890	**$ 147**	$ 147	$ 33,780	$ 175	$ 175
	Minnehaha Creek Subtotal		**122.4**	**$ 12,048**	**$ 167**	**$ 196**	**$ 23,631**	**$ 144**	**$ 175**	**$ 47,261**	**$ 196**	**$ 209**
Ninemile Creek	**Arrowhead Lake** *(Landlocked basin)*	High	5.7	$ 751	$ 163	$ 214	$ 1,472	**$ 146**	$ 194	$ 2,944	$ 199	$ 263
	Centennial Lakes	*Low/No*	*6.7*	$ 882	$ 132	$ 140	$ 1,730	**$ 122**	$ 129	$ 3,461	$ 163	$ 173
	Cornelia North	High	43.5	$ 5,728	$ 247	$ 341	$ 11,234	**$ 220**	$ 304	$ 22,468	$ 300	$ 414
	Cornelia South[2]	High	47.2	$ 6,215	$ 244	$ 531	$ 12,190	**$ 218**	$ 457	$ 24,380	$ 297	$ 647
	Hawkes Lake[3]	Low	27.9	$ 3,582	$ 173	$ 265	$ 7,025	**$ 153**	$ 235	$ 14,049	$ 183	$ 281
	Highland Lake	Low	8.7	$ 1,396	$ 173	$ 189	$ 2,738	**$ 153**	$ 168	$ 5,475	$ 183	$ 201
	Indianhead Lake *(Landlocked basin)*	Medium	3.9	$ 514	$ 139	$ 160	$ 1,007	**$ 124**	$ 142	$ 2,014	$ 169	$ 192
	Lake Edina[4]	High	66.6	$ 8,862	$ 182	$ 396	$ 17,381	**$ 159**	$ 332	$ 34,762	$ 191	$ 416
	Long Brake Trail	Low	1.0	$ 132	$ 146	$ 146	$ 258	**$ 129**	$ 129	$ 517	$ 174	$ 174
	Mirror Lake	Low	8.9	$ 1,172	$ 217	$ 255	$ 2,299	**$ 192**	$ 225	$ 4,597	$ 263	$ 309
	Mud Lake[5]	Low	39.1	$ 5,741	$ 170	$ 283	$ 11,260	**$ 151**	$ 251	$ 22,520	$ 180	$ 300
	Ninemile Creek *(all other*)*	*(Future TMDL)*	*122.6*	$ 16,143	$ 176	$ 358	$ 31,662	**$ 157**	$ 319	$ 63,325	$ 188	$ 383
	Ninemile Creek Subtotal		**243.3**	**$ 32,050**	**$ 177**	**$ 344**	**$ 62,860**	**$ 157**	**$ 301**	**$ 125,720**	**$ 189**	**$ 368**
			TOTAL**	**$ 46,244**	**$ 173**	**$ 276**	**$ 90,700**	$ 152	**$ 244**	**$ 181,401**	**$ 190**	**$ 298**

*Total curb-miles and include upstream areas.

§Cost-efficiency based on cumulative phosphorus recovery and load reductions (recovered loads and load reductions as reported in Table 7 - Table 9)

**Includes Landlocked areas.

[1] Upstream priority water = Pamela South

[2] Upstream priority water = Cornelia North

[3] Upstream priority water = Highland Lake

[4] Upstream priority water = Cornelia South, Cornelia North

[5] Upstream priority water = Hawkes Lake, Highland Lake

7. Recommendations

Although current street sweeping practices are expected to be among the most efficient (lb/curb-mile), the cost-efficiency ($/lb recovered) of sweeping could be improved significantly by using a regenerative air or other high efficiency street sweeper. Based on the expected recovery for different sweeper types and sweeping frequencies, the following recommendations are made:

- Upgrade street sweeping vehicle(s) to regenerative air or other high-efficiency sweeper type to realize an increase in cost-efficiency of about 24% for baseline sweeping. This is expected to increase total cost for baseline sweeping by about 4%, but will increase load recovery of solids by 47% and recovery of phosphorus by 37%.

- Increase the number of sweeping to monthly sweeping during the snow–free season or similar. Utilizing street sweeping vehicles during a greater portion of the year decreases the cost-basis ($/curb-mile) of sweeping compared to baseline and improves cost-efficiency. Sweeping at monthly intervals with a high efficiency sweeper in priority watersheds is expected to increase the recovery of solids by 250% and the recovery of phosphorous by 200% compared to current practice. The cost-basis is lowered from about $66/curb-mile to about $37/curb-mile of sweeping and the cost-efficiency is improved from $173/lb-P recovered to $152/lb-P recovered.

- Consider additional sweeping in high priority watersheds (waterbodies with high service level). Addition sweeping may require increasing the size of the street sweeping fleet. Depending on how well sweepers are utilized, the cost-efficiency of sweeping at bi-weekly (or higher) frequency may be comparable to that of current practices and the cost of phosphorus recovery relatively inexpensive compared to recovery through structural BMPs.

8. References

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Appendix A

Street sweeping zones

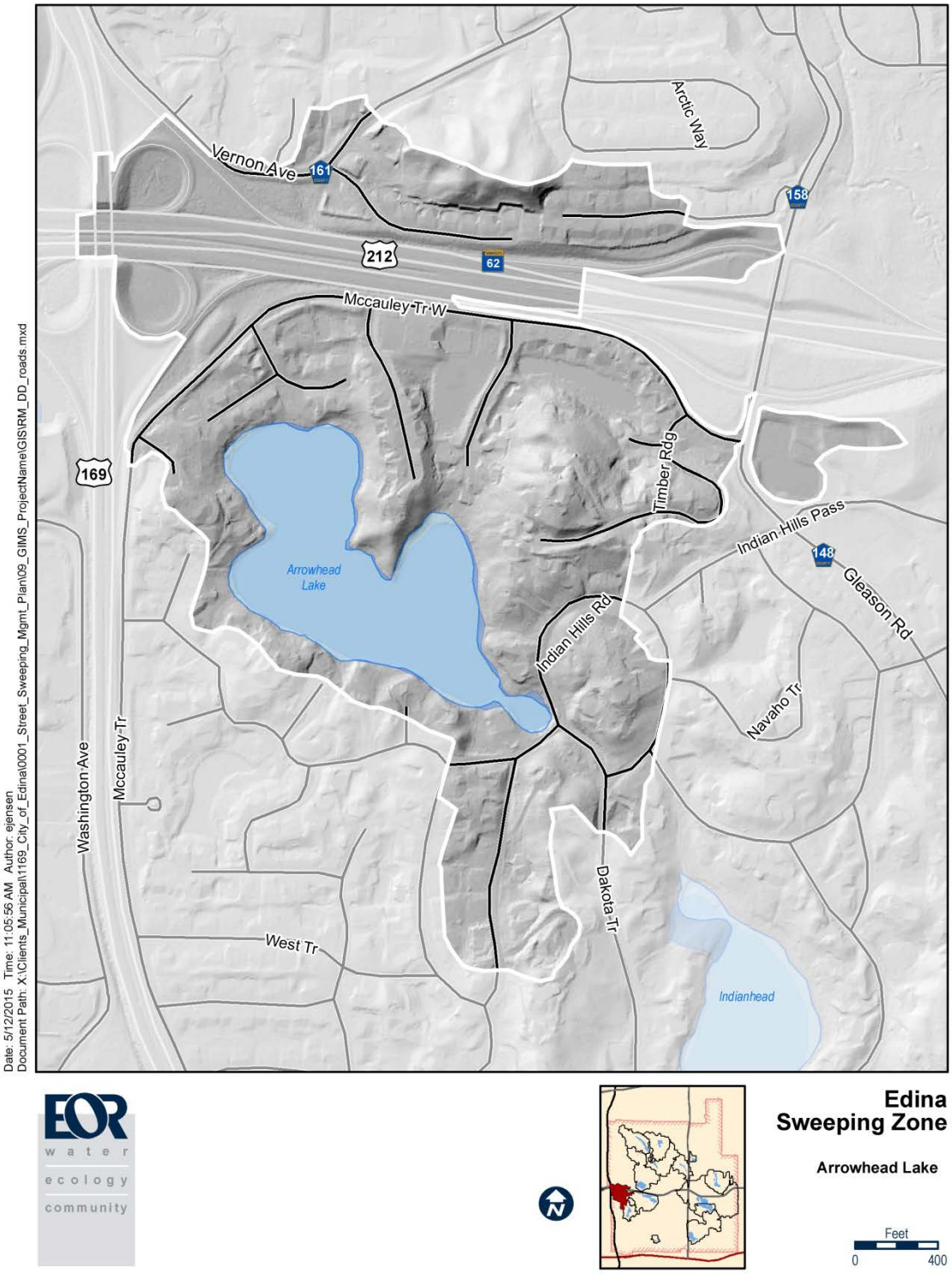

Figure 2 . Direct drainage area for Arrowhead Lake includes upstream catchments of non-priority ponds. The service level for Arrowhead Lake is 'high'.

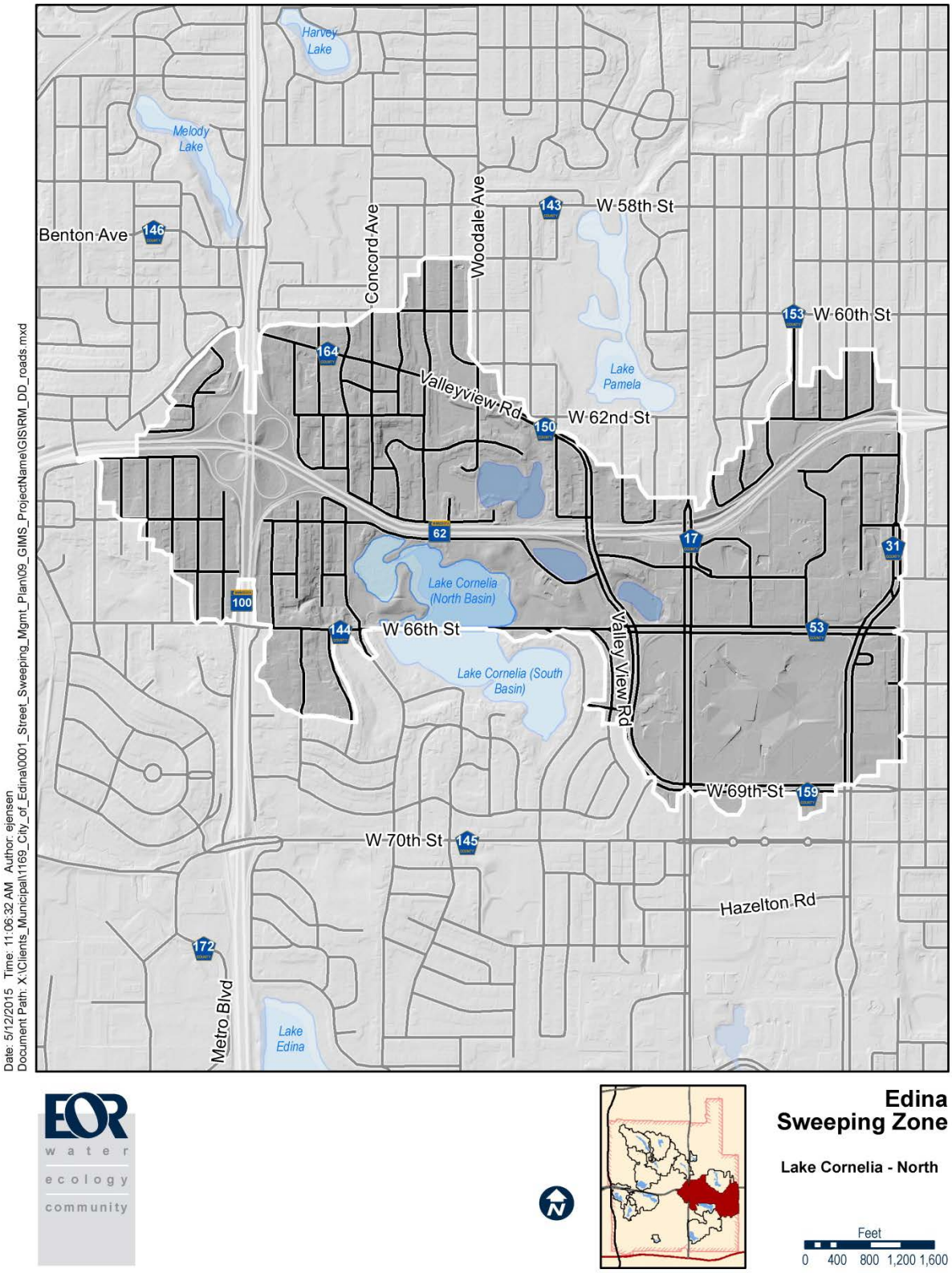

Figure 3. Direct drainage area for Cornelia Lake North (includes upstream catchments of non-priority ponds). The service level for Cornelia Lake North is 'high'.

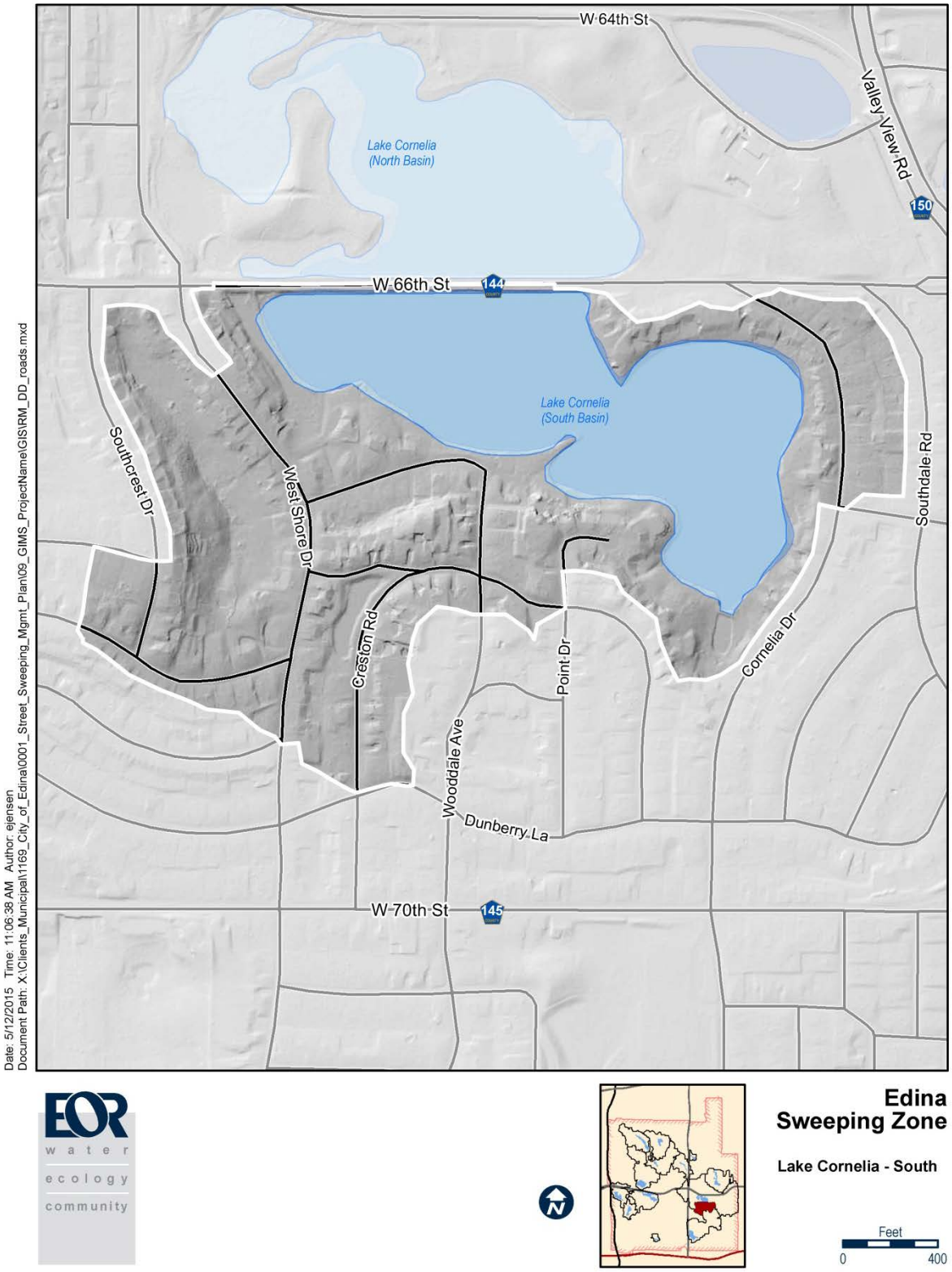

Figure 4. Direct drainage area for Cornelia Lake South (includes upstream catchments of non-priority ponds). The service level for Cornelia Lake South is 'high'.

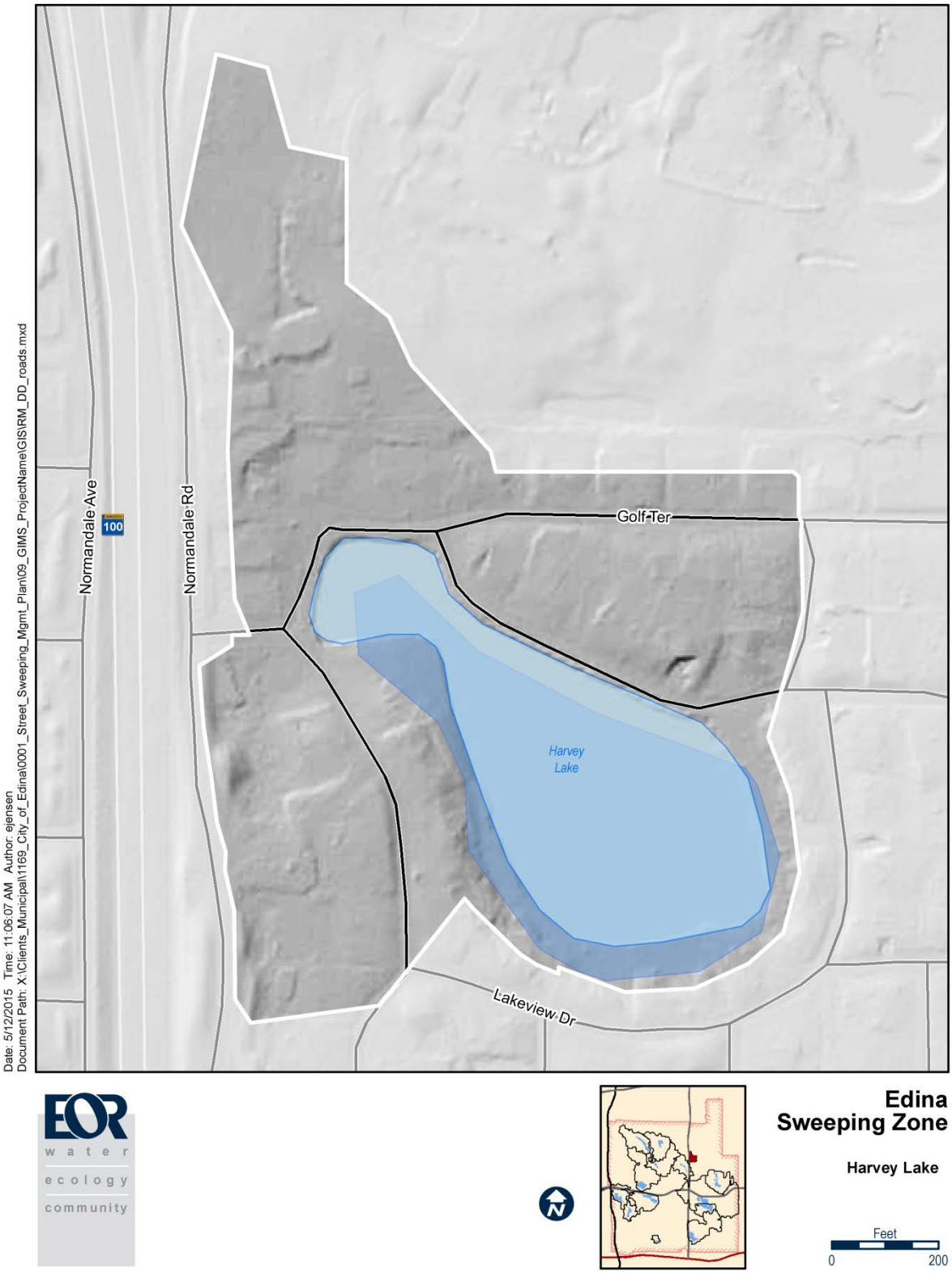

Figure 5. Direct drainage area for Harvey Lake. The service level for Highlands Lake is 'low'.

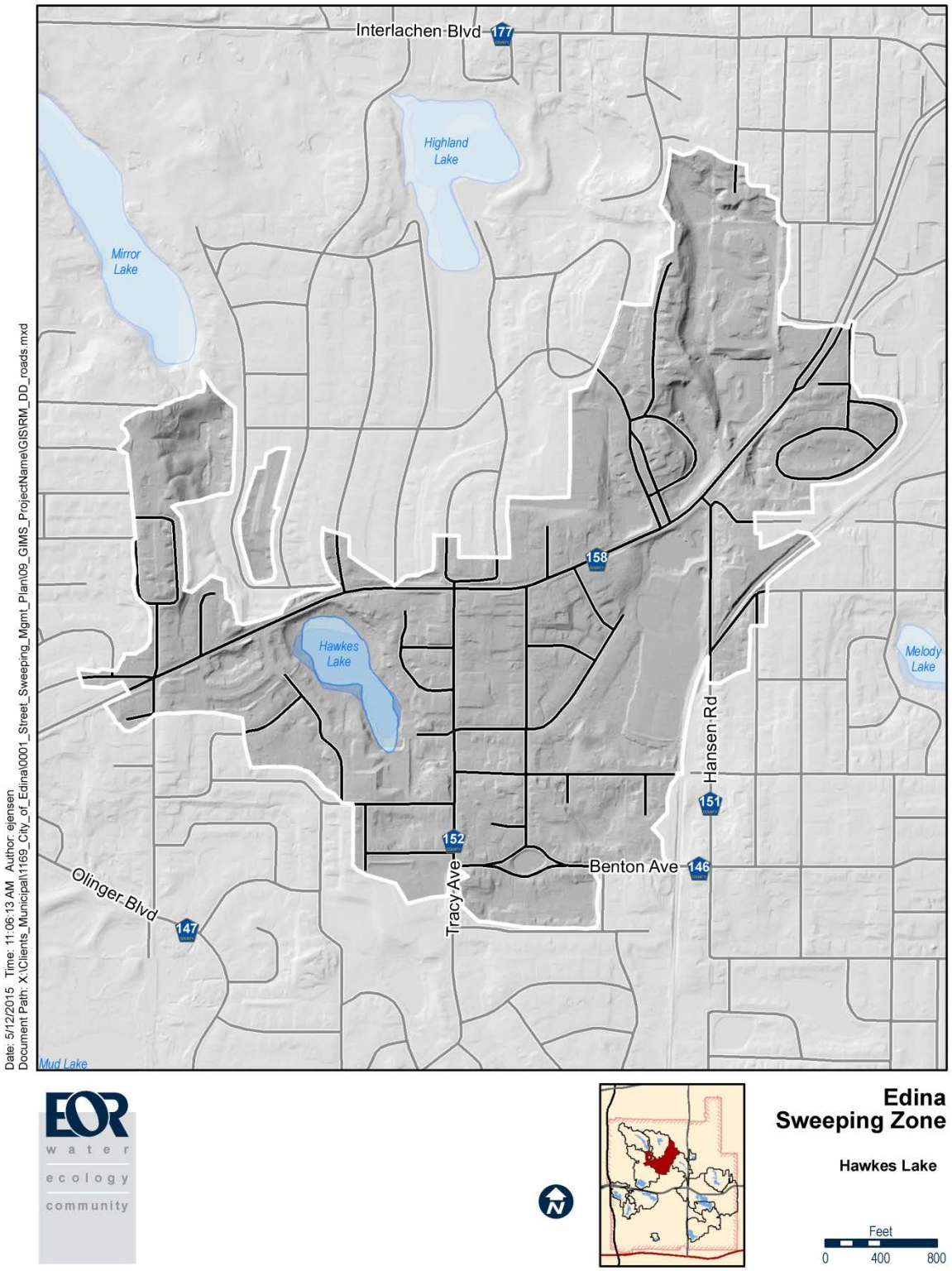

Figure 6. Direct drainage area for Hawkes Lake (includes upstream catchments of non-priority ponds). The service level for Hawkes Lake is 'low'.

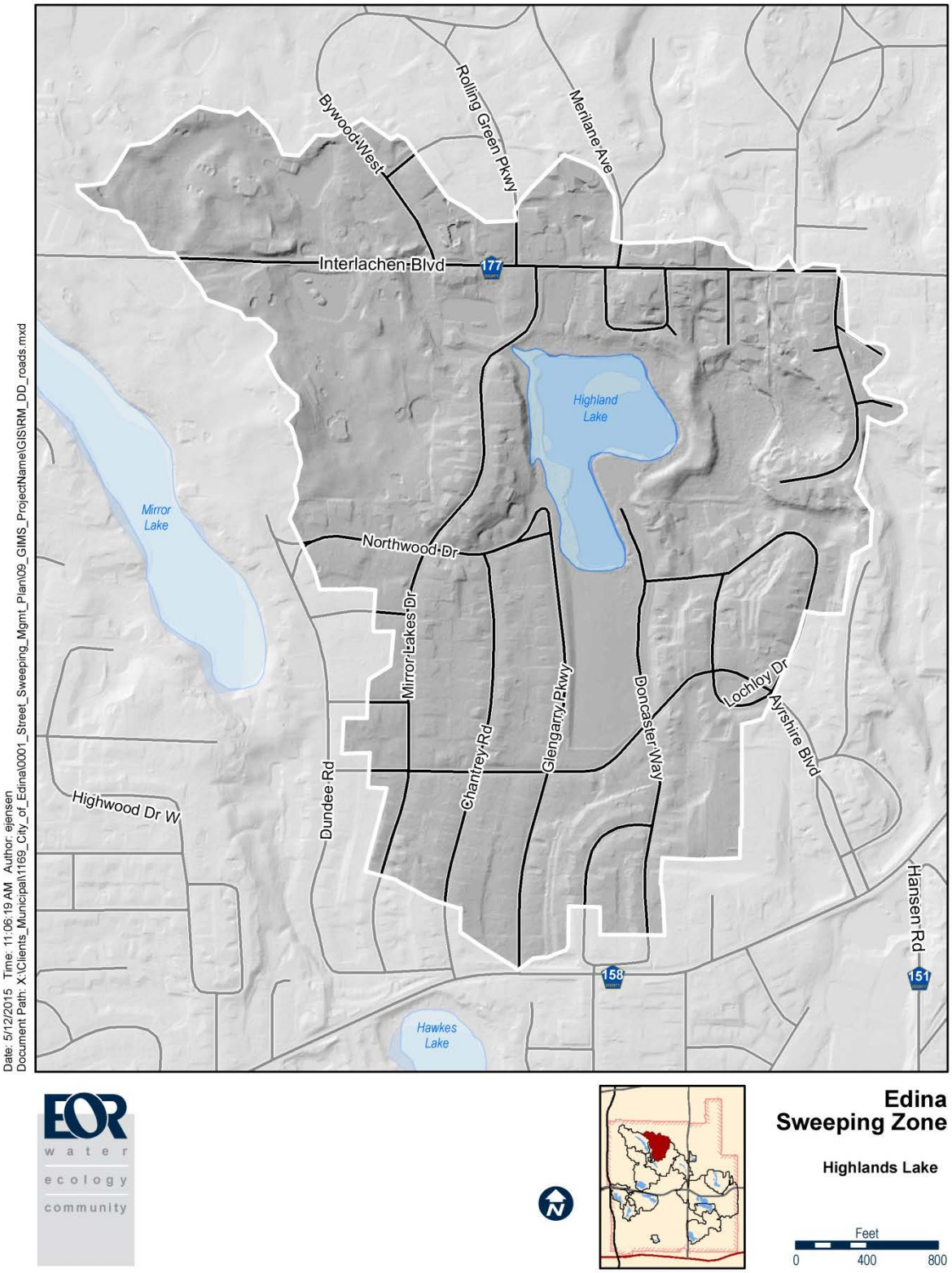

Figure 7. Direct drainage area for Highland Lake (includes upstream catchments of non-priority ponds). The service level for Highland Lake is 'low'.

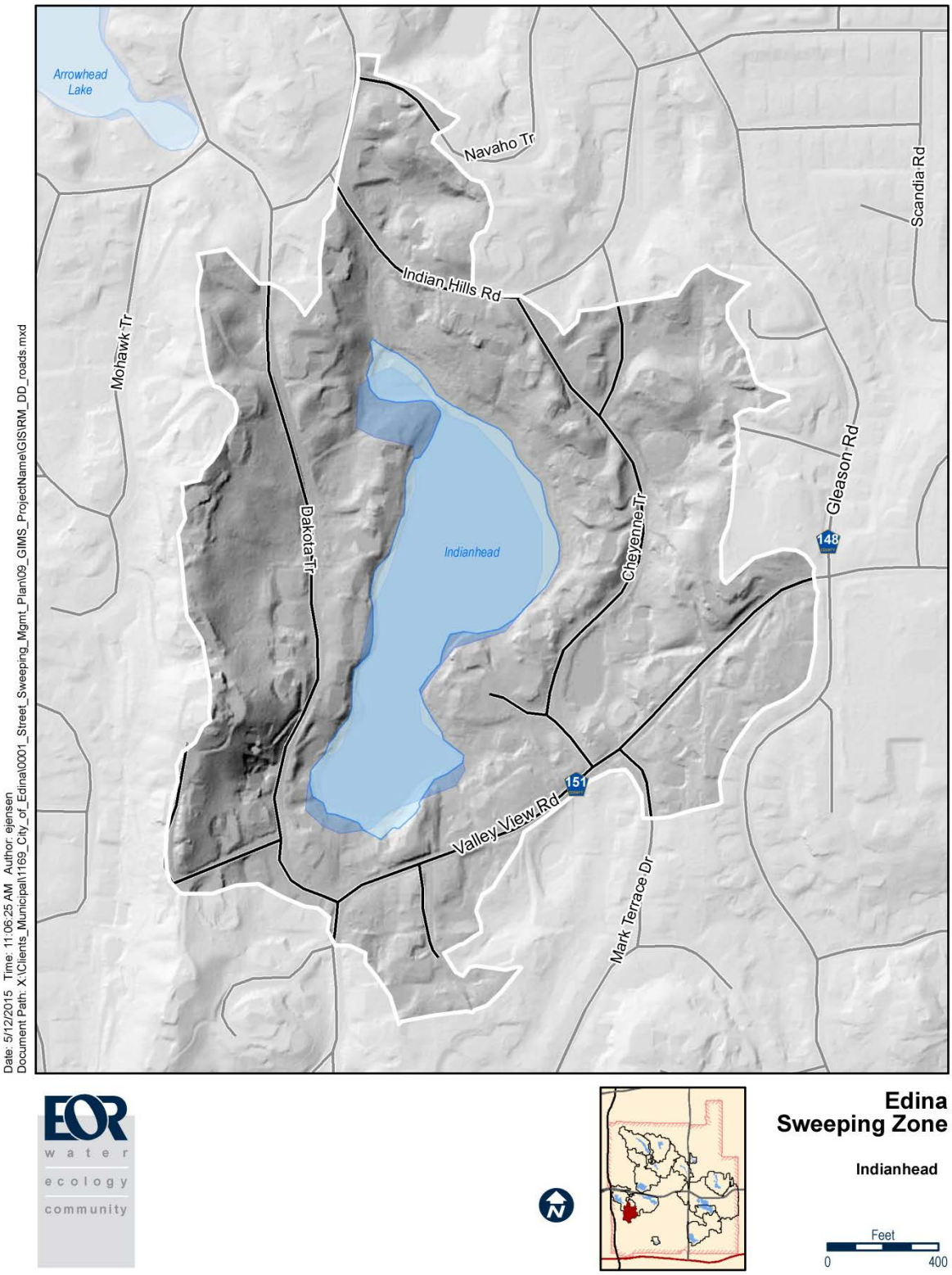

Figure 8. Direct drainage area for Indianhead Lake (includes upstream catchments of non-priority ponds). The service level for Indianhead is 'medium'.

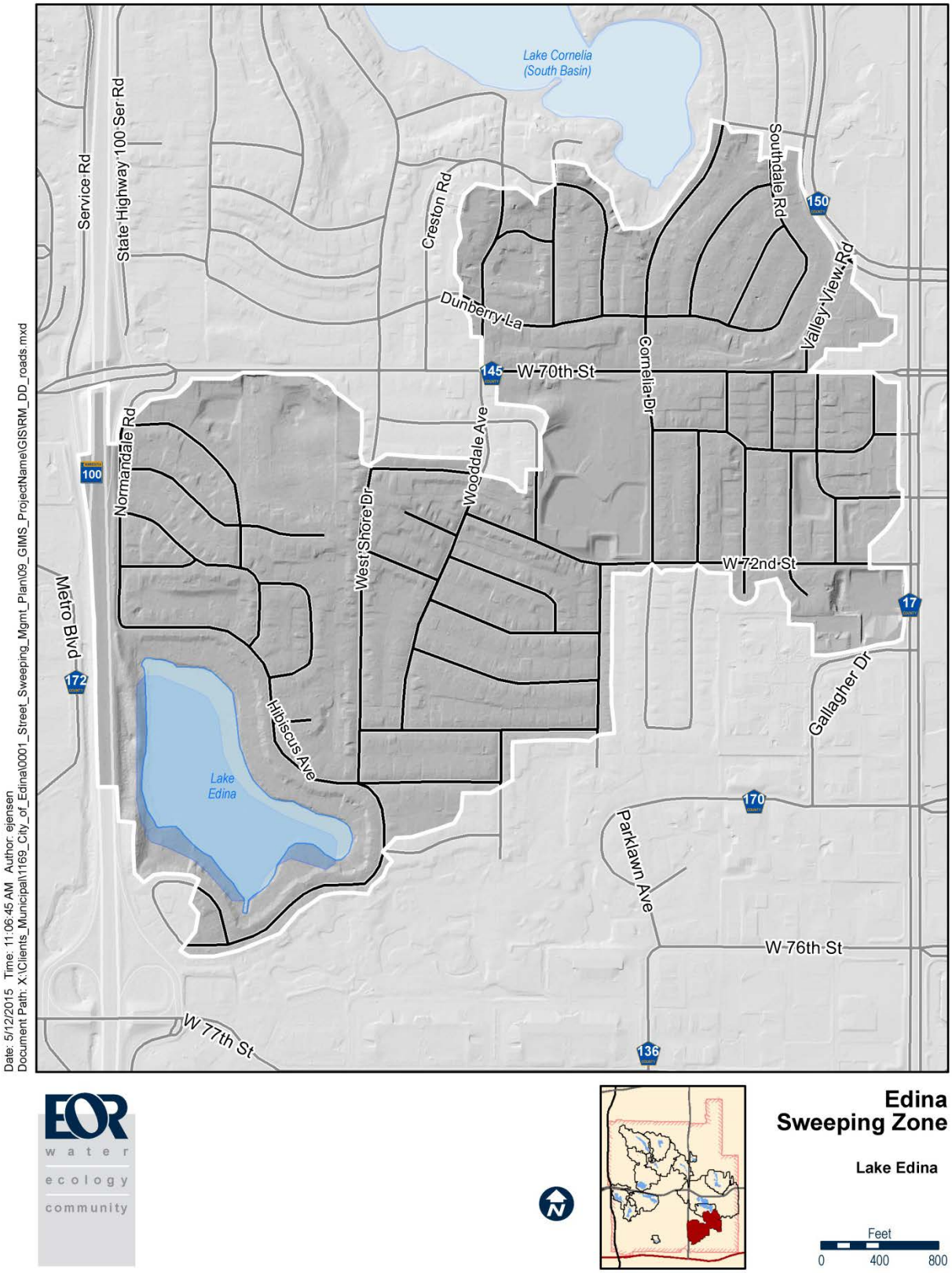

Figure 9. Direct drainage area for Lake Edina. The service level for Lake Edina is 'high'.

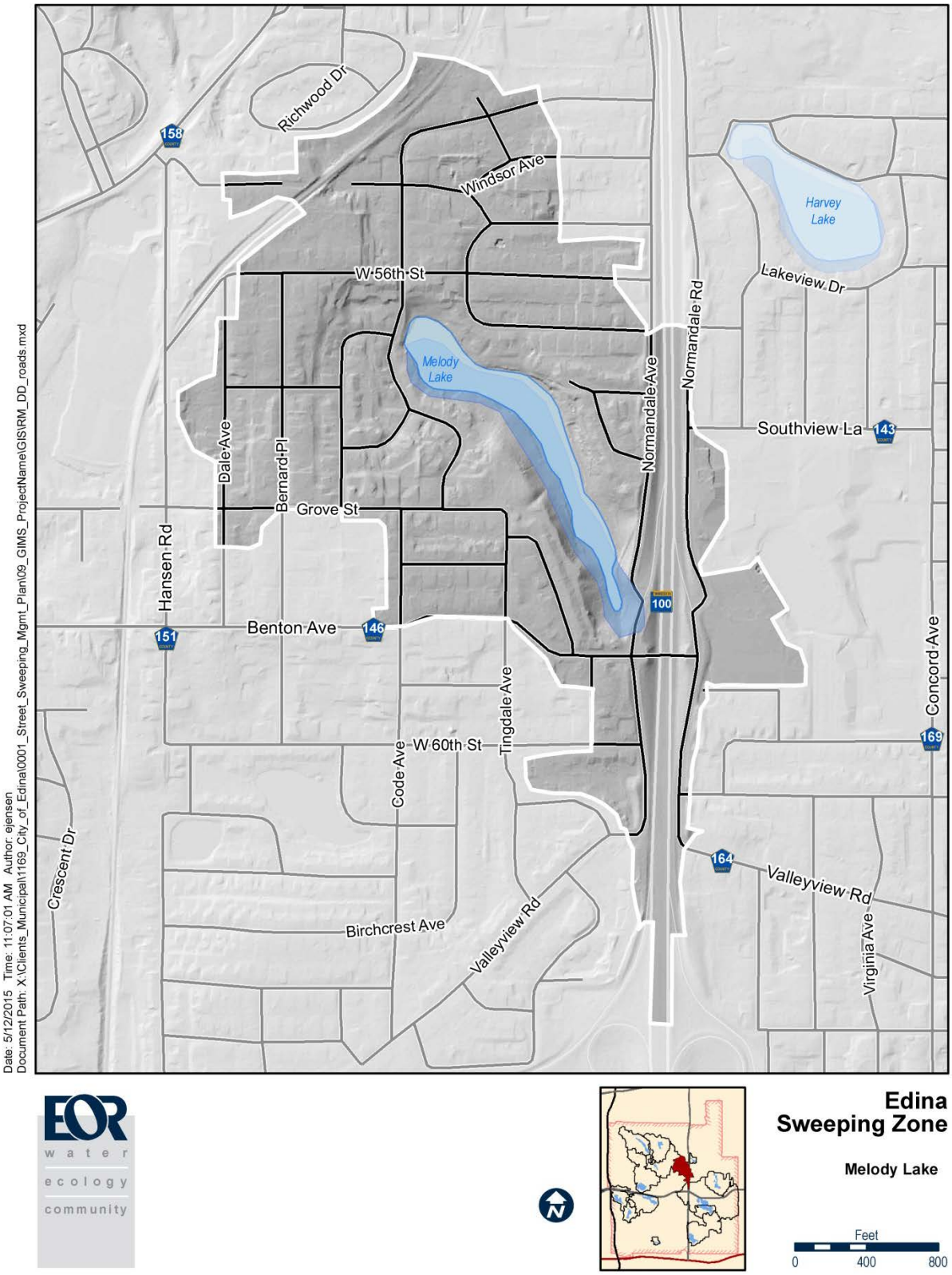

Figure 10. Direct drainage area for Melody Lake. The service level for Melody Lake is 'high'.

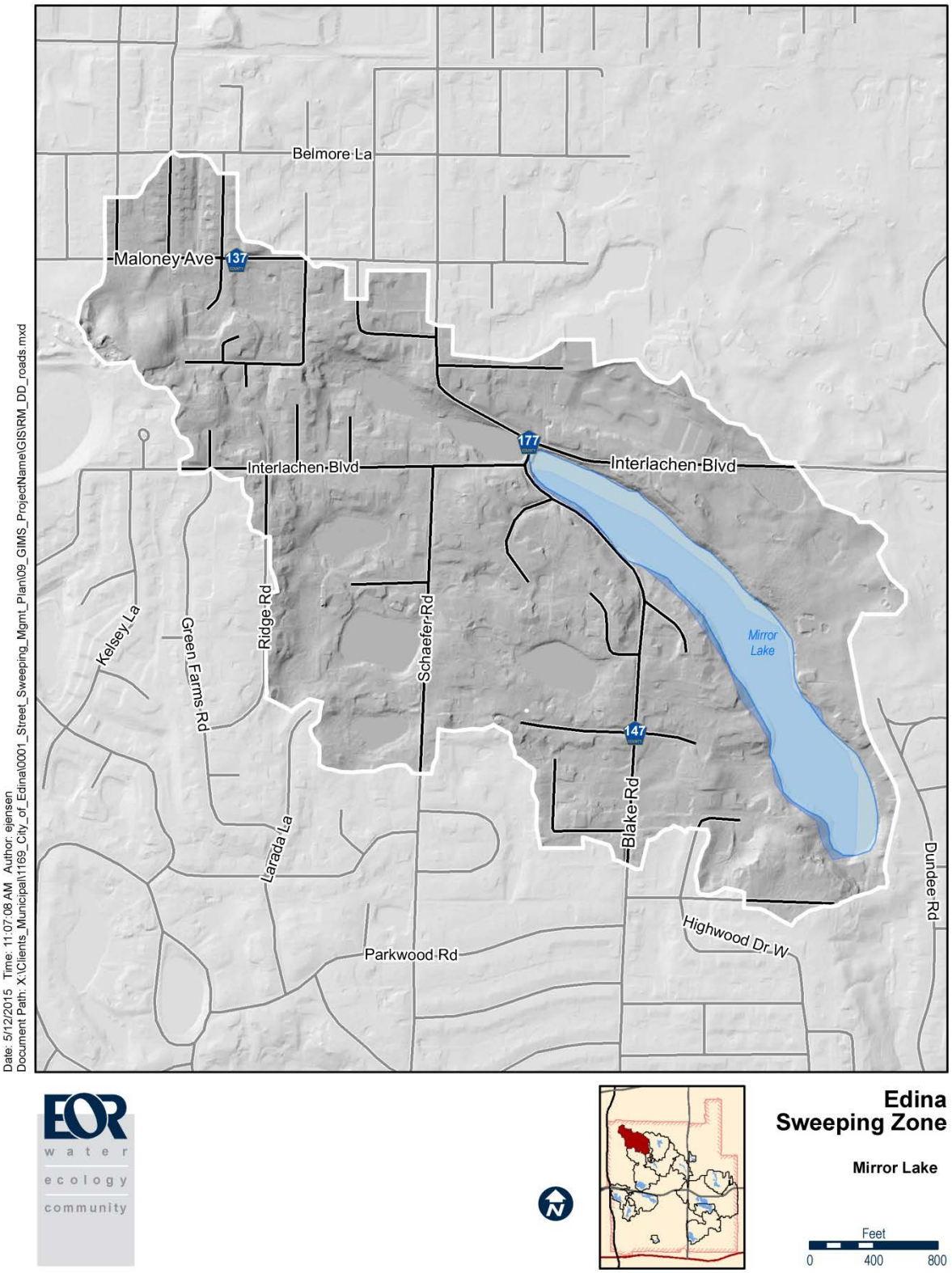

Figure 11. Direct drainage area for Mirror Lake (includes upstream catchments of non-priority ponds). The service level for Mirror Lake is 'low'.

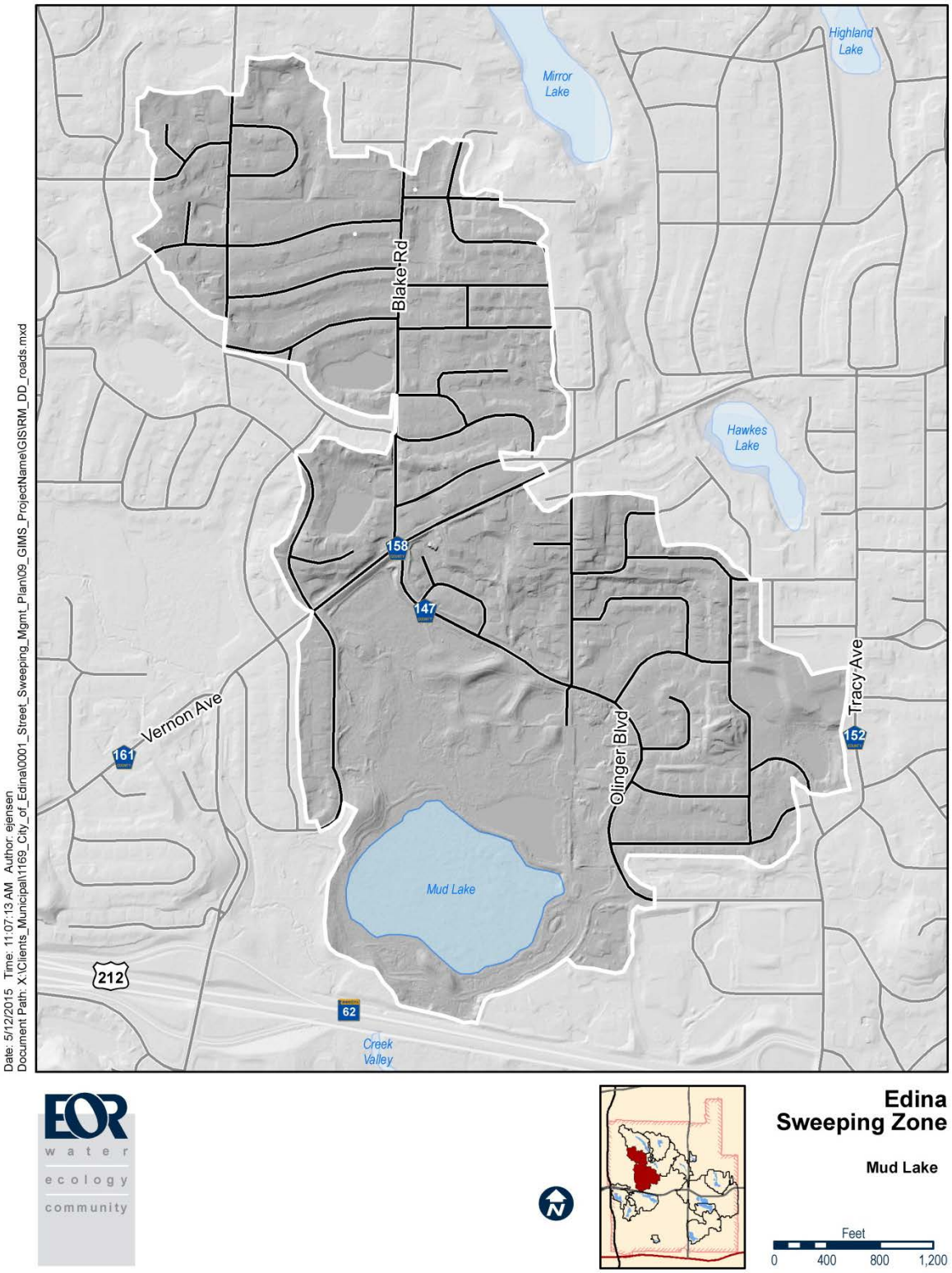

Figure 12. Direct drainage area for Mud Lake (includes upstream catchments of non-priority ponds). The service level for Mud Lake is 'low'.

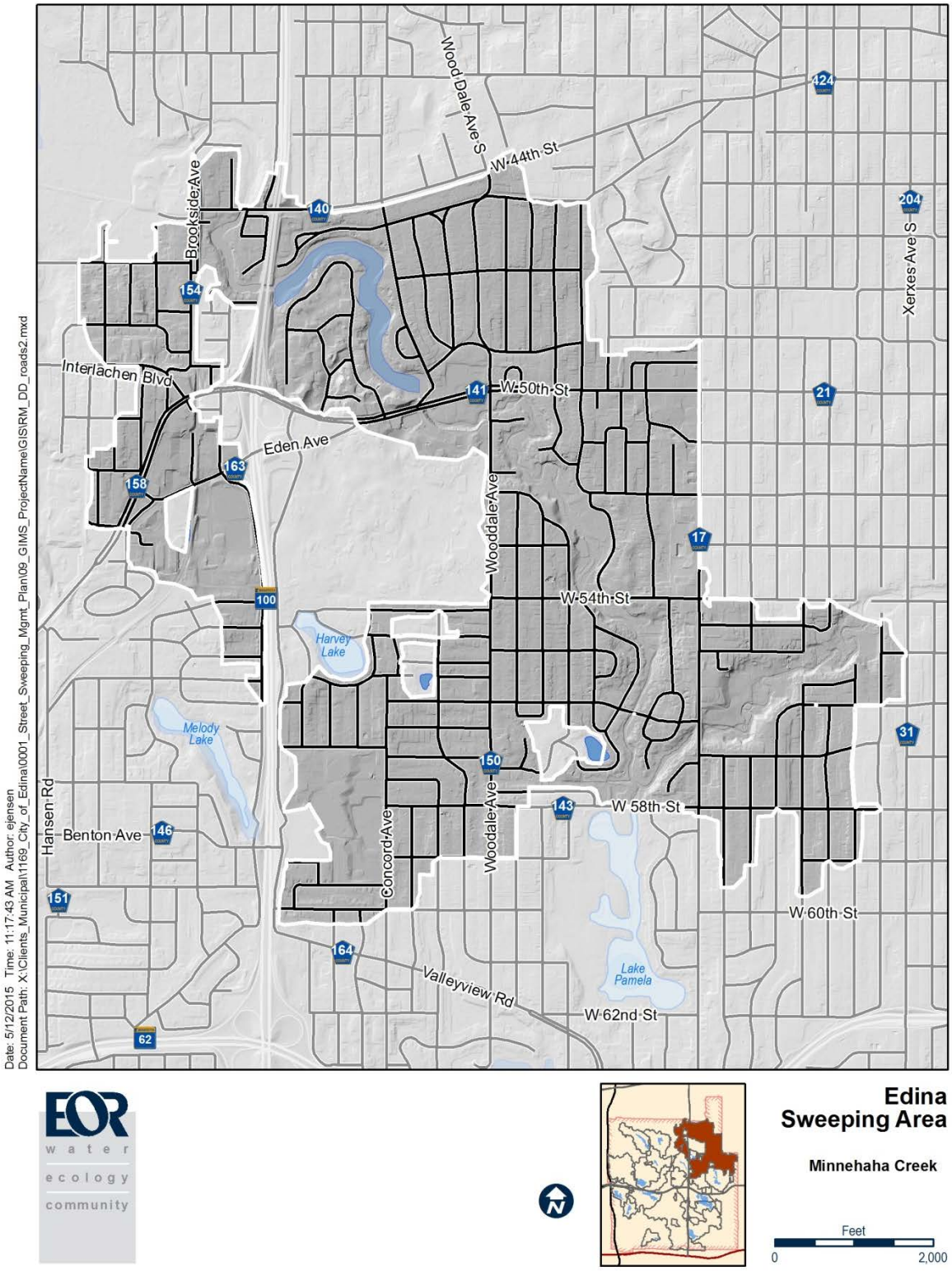

Figure 13. Direct drainage area for Minnehaha Creek (does not include drainage areas for upstream priority waters or landlocked subbasins). Water quality concerns include the Lake Hiawatha TMDLs for excess nutrients and Minnehaha Creek 303d listings (see Section 3.2).

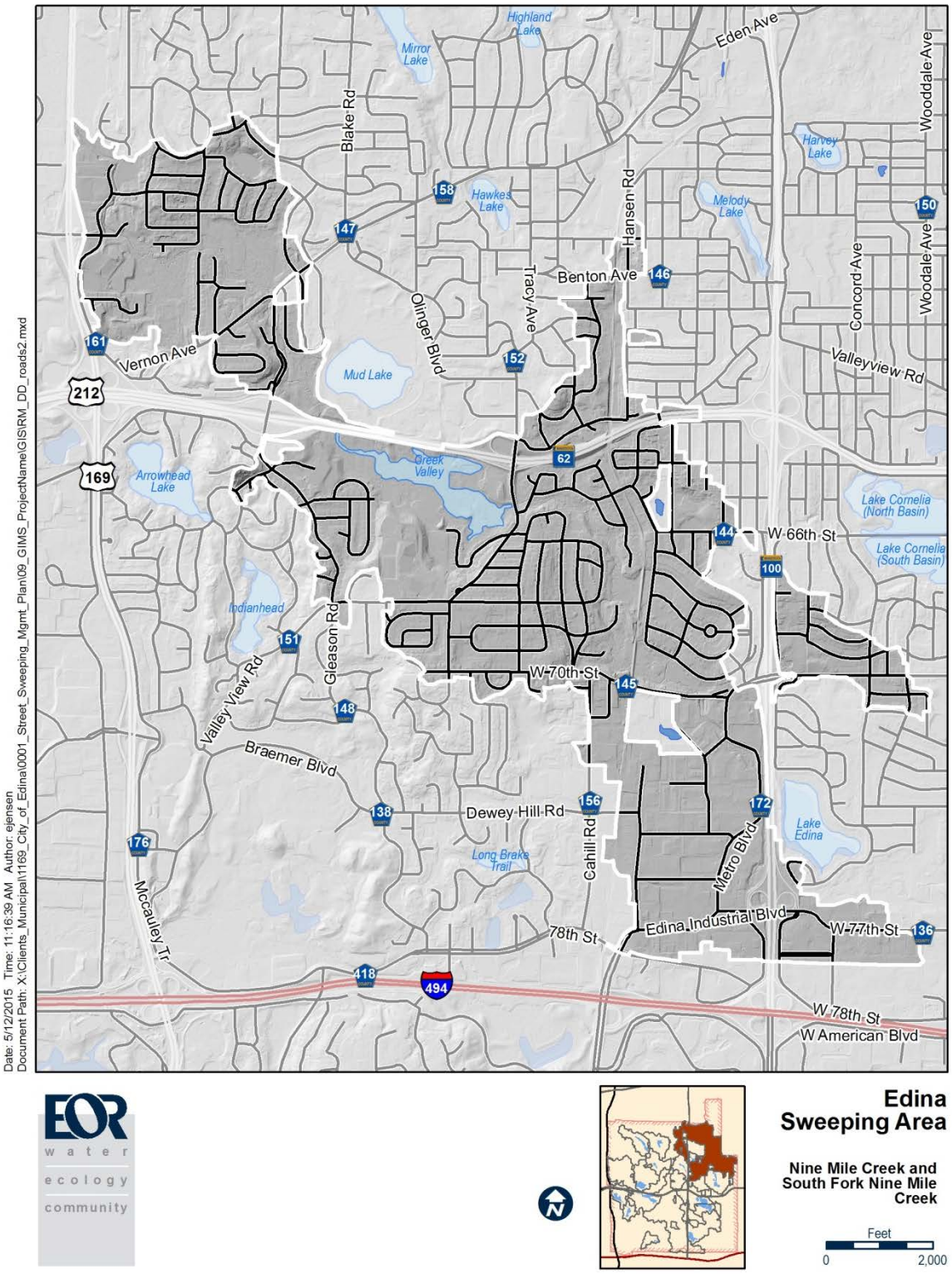

Figure 14. Direct drainage area for Ninemile Creek (does not include drainage areas for upstream priority waters or landlocked subbasins). Water quality concerns include impairments for aquatic life and aquatic recreation for Ninemile Creek (see Section 3.2).

Appendix B

Tree Canopy Examples

Examples of very low canopy cover (canopy rating score =1)

Examples of low canopy cover (canopy rating score=2)

Examples of medium canopy cover (canopy rating score=3.0)

Examples of medium-high canopy cover (canopy rating score =4.0)

Examples of very high canopy cover (canopy rating score =5).

Appendix C

Excerpted from EOR, 10/6/2014

III. Load Recovery for Different Sweeper Types

The range of reported street sweeper pick-up efficiencies is fairly broad, but some trends are consistent across different sources. In general, the pickup performance of street sweepers decreases with particle size, but the difference across particle size classes is greater for mechanical broom technologies than for higher efficiency sweepers (regenerative air or vacuum) (Figure 15). Higher efficiency sweepers generally outperform mechanical sweepers across all particle size classes, however, for the largest material (rock, trash), differences may be minimal.

Class Name	Material Particle Size (mm)	Removal Efficiency (%) [mechanical broom sweeper]		Removal Efficiency (%) [vacuum sweeper]	
Gravel	2.0	Range 60 - 79%[1] 9 - 40%[2]	Average 69%[1] 21%[2]	Range n/a[1] 31 – 94%[2]	Average n/a[1] 71%[2]
Medium to very coarse sand	0.25 – 2.0				
Very fine to fine sand	0.050 – 0.250				
Silt	0.002 – 0.050 [3]	Range 16 – 48 %[1] 13 – 13 %[2]	Average 21%[1] 13%[2]	Range n/a[1] 39 – 81 %[2]	Average n/a[1] 60%[2]
Clay	<0.002				

Figure 15. Comparison of removal efficiencies, mechanical broom and vacuum sweeper technologies, fine and coarse particle size ranges as reported in MNDOT, 2008.

In addition to variation with particle size, sweeper pick up efficiency tends to decrease with loading intensity and the gap in performance between higher efficiency and mechanical broom sweepers tends to widen as load intensities decreases (Table 16). Based on the influence of particle-size and loading intensity, discount levels for mechanical broom were set at two levels. For those months of the year when load intensity tends to be greatest (March through April and mid-September through mid-November), predicted load recovery was reduced 10-15% for coarse material (>2mm) and 30% for fine material (< 2mm). At other times of the year, predicted loads were reduced by 20% for coarse material and 40% for fine material. The expected proportion of fine and coarse material for different months of the year was taken from monitored load recovery in Prior Lake, MN (Table 17). Fine material tends to dominate street accumulations in the early spring but the ratio of fine to coarse material decreases from spring to autumn (Kalinosky, 2014). The ratio of fine to coarse material also depends on over-street tree canopy density. Fine to coarse ratio for 'medium' canopy cover were used to estimate the reduced efficiency of mechanical broom compared regenerative air technology at different time of the year.

The classification of 'fine' and 'coarse' material in Table 17 is different than the NURP particle sizes classes. For this reason, the discount in pick-up performance for fine material was decreased compared to the reported average for silt and clay shown in Figure 15. The discount for coarse material was increased somewhat compared to the reported average to for very fine sand to gravel because organic material, which can make up a significant portion of recovered loads, was not included in performance testing.

Table 16. Comparison of overall pick-up efficiencies for different sweeping technologies and loading intensities (Sutherland, 1995). Efficiencies are based on pick up of street dirt simulant, NURP particle size distribution 13% fine (d < 63 μm), 40% medium (250 μm ≤ d ≤ 2000 μm), and 47% coarse (d ≥ 2000 μm).

Pavement Loading (lbs/acre)	Pickup Efficiency* (%)			
	NURP Mechanical	Newer Mechanical	Regenerative Air	Vacuum Sweeper
10	0%	31%	50%	70%
100	28%	55%	87%	89%
250	45%	66%	89%	89%
500	53%	70%	90%	89%
1000	57%	71%	91%	89%

Table 17. Ratio of fine (< 2mm) to coarse organic (>2mm) solids by month for different tree canopy cover ratings. (Kalinosky, et. al, 2014). Medium canopy is taken to represent 'average' ratios.

Canopy	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Low	180.3	43.6	24.0	20.2	25.0	15.0	8.7	3.2	14.1
Medium	22.1	14.5	10.8	15.2	10.4	6.6	3.9	1.3	1.4
High	22.8	7.0	6.5	7.5	10.0	5.9	3.7	0.9	1.2

Finally, since the character of the material that accumulates on street changes from one season to the next, the concentration of nutrients in each particle size fraction also varies with season (Figure 16). To estimate the total phosphorus recovered by mechanical broom sweepers, the same discounts for coarse and fine loads were applied to expected phosphorus recovery, but the ratio of coarse to fine loads were based on results for phosphorus recovery in Prior Lake (coarse : fine phosphorus as opposed to coarse: fine total solids). The discounts reported in Table 6 are the average for months included as high or low loading intensity with the value for each month computed as follows:

Total discount, high intensity months =

(10-15% X expected ratio of coarse solids/phosphorus) + (20% X expected ratio or fine solids/phosphorus)

Total discount, low intensity months =

(20% X expected ratio of coarse solids/phosphorus) + (40% X expected ratio or fine solids/phosphorus)

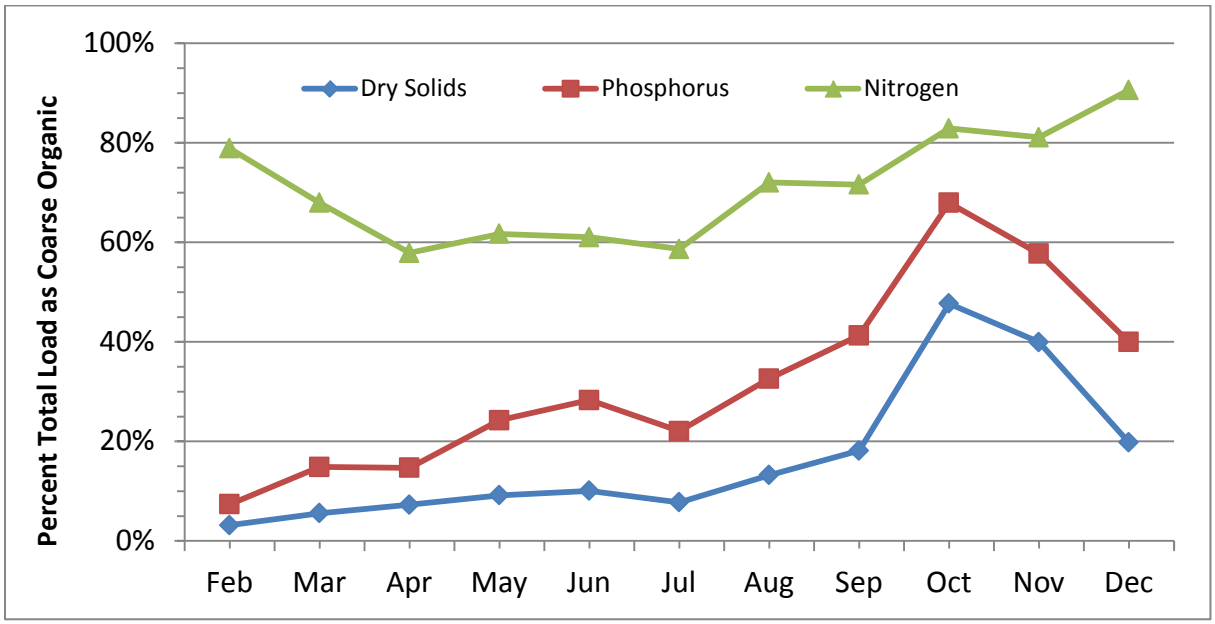

Figure 16. Seasonal pattern in the partitioning of solids and nutrients between the fine and coarse fractions of sweeper waste.

Appendix D

Table 18. Summary of P8 ponds by priority water. Priority waters modeling in P8 are shown in bold font.

(Pollutant removal efficiencies for priority waters were applied in estimates of load reduction to downstream waterbodies).

Priority Watershed	Device Name	Device Type	TP Removal Efficiency	TSS Removal Efficiency	Comment
Arrowhead Lake	**AH_1**	**pond**	**95%**	**100%**	**landlocked basin**
Arrowhead Lake	AH_32	pond	41%	73%	upstream to landlocked basin
Arrowhead Lake	AH_4	pond	61%	94%	upstream to landlocked basin
Arrowhead Lake	AH_6	pond	57%	89%	upstream to landlocked basin
Colonial Ponds	CO-2	pond	82%	99%	
Colonial Ponds	CO_1	pond	57%	95%	
Colonial Ponds	CO_4	pond	51%	94%	
Colonial Ponds	CO_7	pond	67%	98%	
Colonial Ponds	CO_5	pond	73%	97%	
Colonial Ponds	CO_3	pond	63%	97%	
Eden Prairie	EP_1	pond	44%	76%	
Hawkes Lake	HL_24	pond	63%	96%	
Hawkes Lake	**HL_1**	**general**	**43%**		
Hawkes Lake	HL_44	pond	100%	100%	
Hawkes Lake	HL_40	pond	66%	98%	
Hawkes Lake	HL_28	pond	50%	96%	
Hawkes Lake	HL_9	pond	57%	91%	
Hawkes Lake	HL_39	pond	100%	100%	landlocked basin
Hawkes Lake	HL_13	pond	64%	97%	landlocked basin
Hawkes Lake	HL_50	pond	99%	100%	landlocked basin
Harvey Lake	MHS_22		69%	99%	(no P8 ponds upstream)
Highlands Lake	HI_22	pond	62%	97%	
Highlands Lake	HI_21	pond	60%	99%	
Highlands Lake	HI_20	pond	100%	100%	
Highlands Lake	HI_17	pond	59%	97%	
Highlands Lake	HI_5	pond	44%	94%	
Highlands Lake	**HI_1**	**general**	**58%**		
Highlands Lake	HI_18	general	44%	98%	
Highlands Lake	HI_13	pond	100%	100%	landlocked basin
Indian Pond	IP_1	pond	100%	100%	landlocked basin
Indianhead	**IH_1**	**pond**	**100%**	**100%**	**landlocked basin**

Priority Watershed	Device Name	Device Type	TP Removal Efficiency	TSS Removal Efficiency	Comment
Indianhead	IH_14	pond	61%	93%	upstream to landlocked basin
Lake Cornelia - North	**NC_62**	**pond**	**44%**	**95%**	
Lake Cornelia - North	NC_88	general	51%	82%	
Lake Cornelia - North	NC_30	general	73%	99%	
Lake Cornelia - North	NC_2	general	31%	88%	
Lake Cornelia - North	NC_5	general	62%	93%	
Lake Cornelia - North	NC_4	general	52%	82%	
Lake Cornelia - North	NC_3	general	37%	78%	
Lake Cornelia - North	NC_78	pond	67%	99%	landlocked basin
Lake Cornelia - North	NC_72	pond	46%	86%	landlocked basin
Lake Cornelia - North	NC_135	pond	100%	100%	landlocked basin
Lake Cornelia - North	NC_6	pond	100%	100%	landlocked basin
Lake Cornelia - South	**SC_1**	**general**	**12%**	**93%**	
Lake Cornelia - South	SC_2	pond	21%	56%	
Lake Cornelia - South	SC_3	pond	66%	97%	
Lake Edina	LE_38	general	39%	71%	
Lake Edina	**LE_1**	**general**	**28%**	**94%**	
Lake Edina	LE_51	pond	100%	100%	landlocked basin
Lake Edina	LE_54	pond	100%	100%	landlocked basin
Lake Edina	LE_44	pond	100%	100%	landlocked basin
Lake Pamela North	LP_14		18%	63%	
Lake Pamela South	LP-26		48%	94%	(no P8 ponds upstream)
Long Brake Trail	SWP_4	pond	41%	97%	
Melody Lake	ML_8		65%	96%	(no P8 ponds upstream)
Mirror Lake	ML_40	pond	36%	98%	
Mirror Lake	ML_38	pond	45%	98%	
Mirror Lake	ML_16	general	58%	99%	
Mirror Lake	ML_32	pond	37%	93%	
Mirror Lake	ML_2	pond	57%	91%	
Mirror Lake	ML_3	pond	63%	98%	
Mirror Lake	ML_19	pond	10%	43%	
Mirror Lake	ML_6	pond	66%	98%	
Mirror Lake	ML_15	pond	71%	100%	
Mirror Lake	**ML_1**	**general**	**62%**	**99%**	**Lake**
Mirror Lake	ML_28	pond	100%	100%	landlocked basin
Mirror Lake	ML_26	pond	100%	100%	landlocked basin
Mirror Lake	ML_27	pond	100%	100%	upstream to landlocked basin
Mud Lake	**MD_1**	**pond**	**26%**	**96%**	

Priority Watershed	Device Name	Device Type	TP Removal Efficiency	TSS Removal Efficiency	Comment
Mud Lake	**MD_50**	**pond**	**8%**	**93%**	
Mud Lake	MD_11	pond	7%	61%	
Mud Lake	MD_2	pond	45%	99%	
Mud Lake	MD_28	pond	67%	99%	
Mud Lake	MD_7	pond	66%	98%	
Mud Lake	MD_21	pond	74%	100%	
Mud Lake	MD_27	general	79%	85%	
Mud Lake	MD_29	pond	64%	97%	
Mud Lake	MD_39	pond	100%	100%	
Mud Lake	MD_3	pond	13%	72%	
Mud Lake	MD_4	pond	66%	96%	
Mud Lake	MD_13	pond	68%	99%	
Mud Lake	MD_15	pond	6%	58%	
Mud Lake	MD_25	general	55%	97%	
Nine Mile Central	NMC_114	pond	37%	88%	
Nine Mile Central	NMC_77	pond	69%	99%	
Nine Mile Central	NMC_112	pond	65%	97%	
Nine Mile Central	NMC_70	pond	51%	91%	
Nine Mile Central	NMC_44	pond	66%	98%	
Nine Mile North	NMN_62	pond	39%	91%	
Nine Mile North	NMN_63	pond	59%	86%	
Nine Mile North	NMN_77	pond	71%	97%	
Nine Mile North	NMN_55	pond	74%	99%	
Nine Mile North	NMN_76	pond	100%	100%	
Nine Mile North	NMN_49	pond	40%	78%	
Nine Mile North	NMN_48	pond	61%	94%	
Nine Mile North	NMN_27	pond	49%		
Nine Mile North	NMN_20	pond	53%	89%	
Nine Mile North	NMN_24	pond	30%	68%	
Nine Mile North	NMN_84	pond	61%	94%	landlocked basin
Nine Mile North	HL_25	pond	100%	100%	landlocked basin
Nine Mile North	NMN_73	pond	62%	86%	landlocked basin
Nine Mile North	NMN_74	pond	92%	99%	landlocked basin
Nine Mile North	NMN_50	pond	100%	100%	landlocked basin
Nine Mile North	NMN_75	pond	75%	100%	landlocked basin
Nine Mile South	NMS_28	pond	63%	92%	
Nine Mile South	NMS_40	pond	64%	93%	
Nine Mile South	NMS_103	pond	60%	93%	
Nine Mile South	NMS_88	pond	62%	99%	

Priority Watershed	Device Name	Device Type	TP Removal Efficiency	TSS Removal Efficiency	Comment
Nine Mile South	NMS_23	pond	2%	13%	
Nine Mile South	NMS_104	pond	17%	45%	
Nine Mile South	NMS_72	pond	15%	40%	
Nine Mile South	NMS_74	pond	14%	48%	
Nine Mile South	NMS_79	pond	53%	90%	
Nine Mile South	NMS_76	pond	49%	79%	
Nine Mile South	NMS_84	pond	100%	100%	landlocked basin
Nine Mile South Fork	NMSB_3	pond	37%	76%	
Nine Mile South Fork	NMSB_57	pond	31%	83%	
Nine Mile South Fork	NMSB_90	general	3%	22%	
Nine Mile South Fork	NMSB_8	pond	66%	91%	
Nine Mile South Fork	NMSB_86	pond	1%	16%	
Nine Mile South Fork	NMSB_85	general	31%	69%	
Nine Mile South Fork	NMSB_7	pond	27%	59%	
Nine Mile South Fork	NMSB_5	pond	50%	99%	
Nine Mile South Fork	NMSB_62	pond	18%	96%	
Nine Mile South Fork	NMSB_33	pond	68%	100%	
Nine Mile South Fork	NMSB_12	pond	3%	13%	
Nine Mile South Fork	NMSB_6	pond	48%	96%	
Nine Mile South Fork	NMSB_2	pond	11%	35%	
Nine Mile South Fork	NMSB_34	pond	77%	100%	
Nine Mile South Fork	NMSB_15	general	16%	49%	
Nine Mile South Fork	NMSB_59	pond	95%	99%	landlocked basin
Pawnee Pond	PA_6	pond	64%	96%	
Pawnee Pond	PA_1	general	61%	97%	
Pawnee Pond	PA_9	pond	100%	100%	landlocked basin
Southwest Ponds	SWP_47	pond	62%	94%	
Southwest Ponds	SWP_34	pond	36%	87%	
Southwest Ponds	SWP_59	pond	62%	95%	
Southwest Ponds	SWP_35	pond	53%	89%	
Southwest Ponds	SWP_2	pond	24%	89%	
Southwest Ponds	SWP_1	pond	5%	71%	
Southwest Ponds	SWP_3	pond	67%	98%	
Southwest Ponds	SWP_10	pond	67%	96%	
Southwest Ponds	SWP_5	pond	24%	80%	
Southwest Ponds	SWP_14	pond	65%	99%	
Southwest Ponds	SWP_57	pond	100%	100%	
Southwest Ponds	SWP_37	pond	74%	99%	landlocked basin
Southwest Ponds	SWP_40	pond	100%	100%	landlocked basin

Priority Watershed	Device Name	Device Type	TP Removal Efficiency	TSS Removal Efficiency	Comment
Southwest Ponds	SWP_31	pond	100%	100%	landlocked basin
Southwest Ponds	SWP_33	pond	100%	100%	landlocked basin
Southwest Ponds	SWP_58	pond	74%	99%	landlocked basin
Southwest Ponds	SWP_9	pond	100%	100%	landlocked basin