MINNESOTA POLLUTION CONTROL AGENCY

Key Considerations for Developing an Enhanced Street Sweeping Program

Waukesha County, Stormwater Workshop

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April 4, 2024

Presentation Overview

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Why Street Sweeping?

I. Street Sweeping Science

A. A Quick Look Back: 80s to 00s

B. A Fresh Perspective: The Prior Lake, MN Street Sweeping Study

II. Application of Street Sweeping Research

A. Estimating Potential Solids and Nutrient Recovery for Street Sweeping

B. Developing an Enhanced Street Sweeping Plan for Surface Water Quality Benefits

1. What information do you need?
2. Example: Forest Lake

III. Newer Research and Tools, and Guidance

A. Development of a TP Credit for Street Sweeping

IV. Questions

Source Control Makes Sense (when it makes sense)

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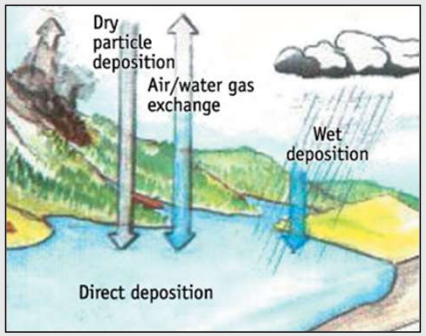
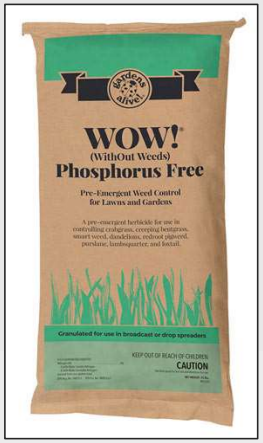
We Can't Control The Weather – but we do enact legislation and local ordinances to reduce pollution.



Street Sweeping = a **good housekeeping practice** that **prevents pollutants** that collect on roadways **from entering our waterways** via the stormwater network.



Fertilizers containing phosphorus cannot be used on lawns and turf in Minnesota unless one of the following situations exists:

- A soil test or plant tissue test shows a need for phosphorus
- A new lawn is being established by seeding or laying sod.
- Phosphorus fertilizer is being applied on a golf course by trained staff.

Highlights from Past Research

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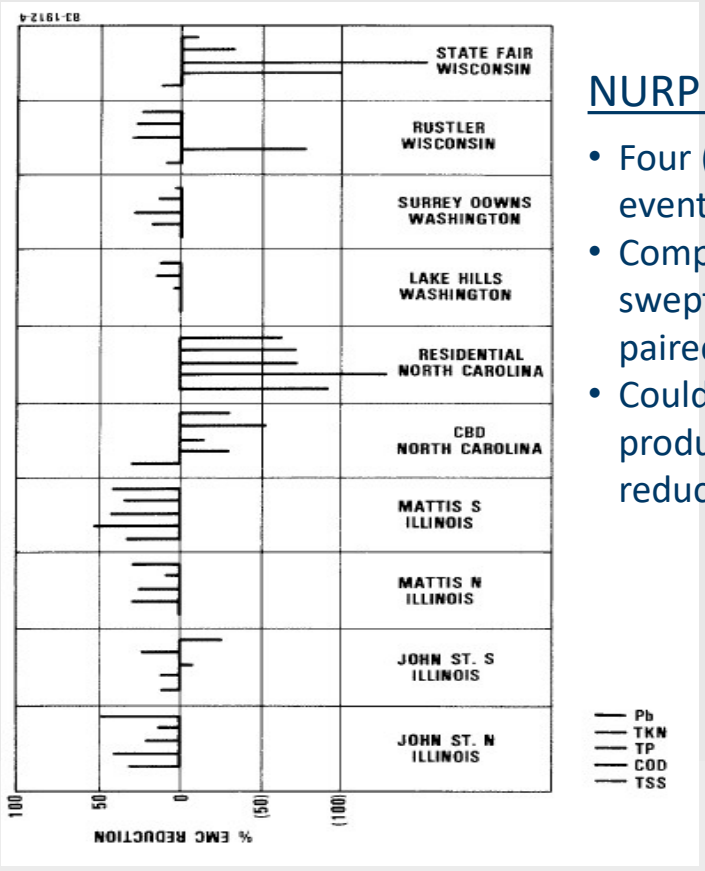
Initial Research Not Very Promising ☹



NURP Data on Sweeping (1983)

- Four (4) states, ten (17) sites, 322 rain events.
- Compared EMCs in roadway runoff for swept/unswept conditions using either paired basins or treatment in serial.
- Could not demonstrate that sweeping produced statistically significant reductions in stormwater EMCs

Better Sweepers, Better Results?

- Use stormwater modeling tools along with measured sweeper pick-up efficiency, street dirt build-up, to estimate pollutant reductions.
- Generally discouraging results. Many sweeps for little benefit.

Modeling Studies (P8, WINSLAMM)

EX. Build-up

$$Load = Load_{max} (1 - e^{-kt})$$

Does not allow for decrease in load over dry periods.

Ex. Wash-off

$$P\text{-removed} = C_p \times (r^k) \times P_o$$

Removal depends on assumed buid-up, P-removed highly sensitive to k.

MUSLE:

$$Yield - 95 (V_i Q_{pi})^{0.56} K_i C_i P_i$$

Highlights from Past Research

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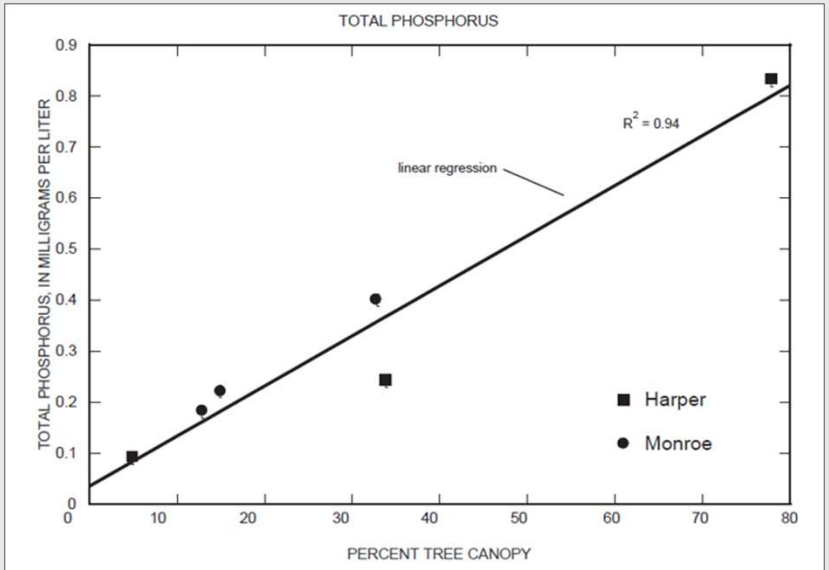

Figure 5. Relations between overhead tree canopy and phosphorus concentrations in street-runoff samples, Harper and Monroe Basins, Madison, Wis. (R^2 = coefficient of determination)

Waschbusch, Selbig, & Bannerman, 1999

- Phosphorus in runoff by source area for residential land use: e.g. – lawns, driveways, rooftops, roadways.
- **Observed a linear relationship between overhead tree canopy cover density & TP concentration of roadway runoff.**

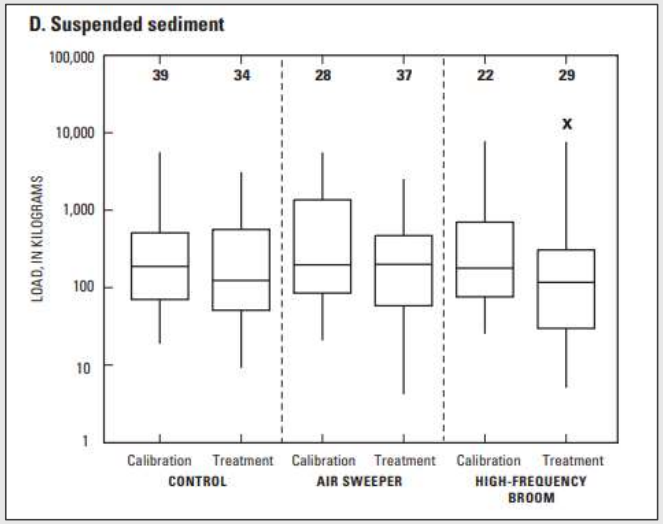

Figure 22. Water-quality sample intake located at a fixed point along the storm-sewer wall.

Selbig & Bannerman, 2007

- Sweeping reduced street dirt yield for d > 63 µm
- No significant reduction in pollutant loads (EMC x flow) even for weekly street sweeping with an air sweeper!
- **Meticulous study** – easier to ID what might be overlooked:
  - Bias in traditional stormwater sampling methods
  - Fate and transport of organic material

Research: Prior Lake, MN (2010-2013)

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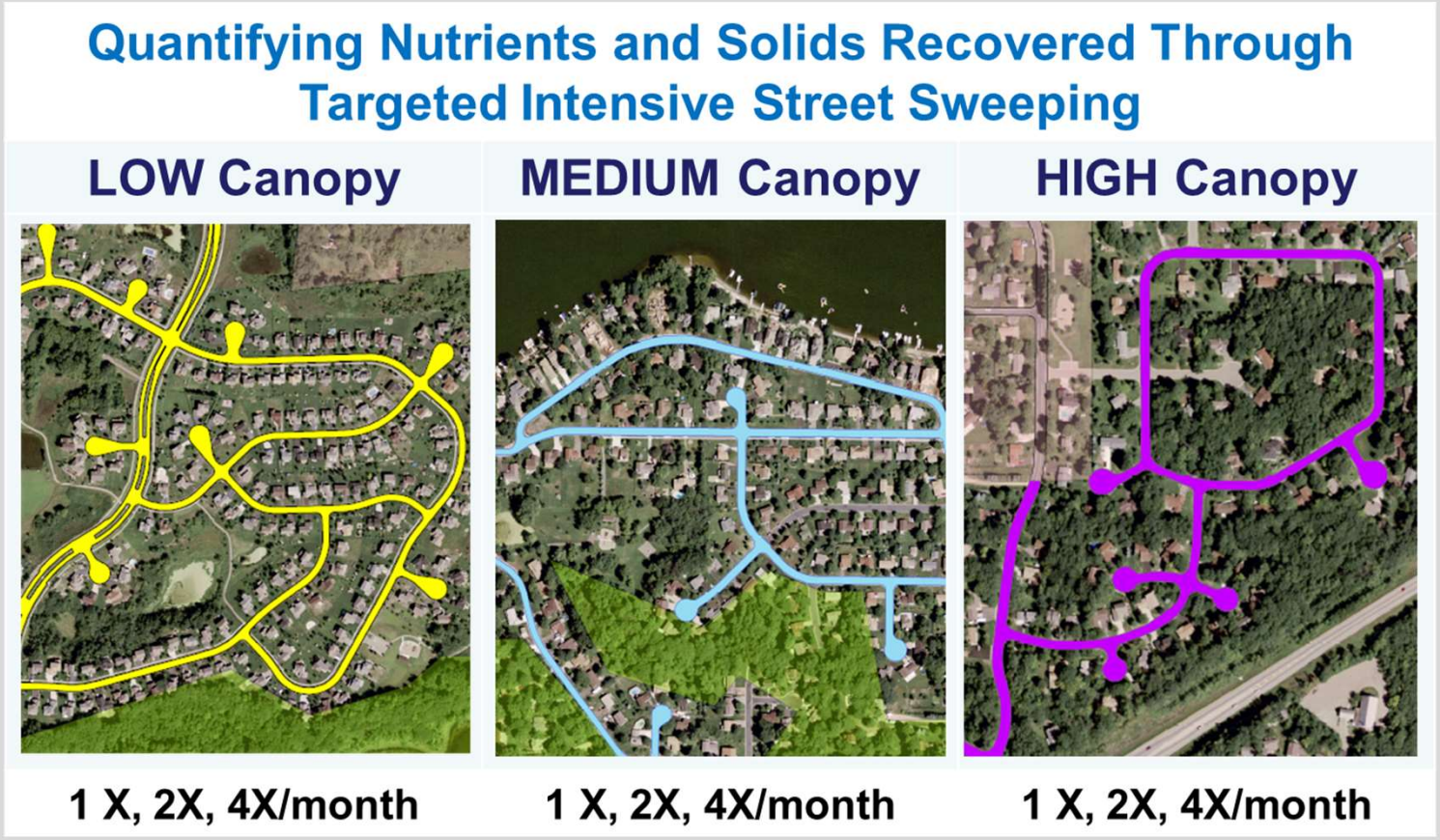
- Three (3)-Year Study with
- Two (2) – Year Field Study Component
- 374 Sweepings Sampled

Looking at the influence of:

- Street Corridor Tree Canopy Density and
- Sweeping Frequency

on the mass of solids and nutrients (TN, TP) recovered through street sweeping.



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Research: Prior Lake, MN (2010-2013)

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Unique Fractionation Scheme Suited to Focus on Nutrients

Sweeper Waste Sample

Fines (<2mm)	Coarse Organics (≥2mm)
	Rocks (≥2mm)

TP, TN, TOC
(Leached during separation process)

TS, TP, TN, TOC, % OM

TS, TP, TN, TOC, % OM

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Key Findings from Prior Lake, MN (2010-2013)

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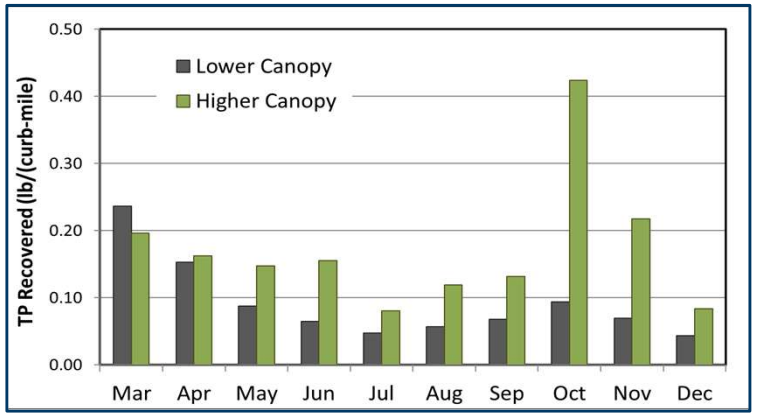
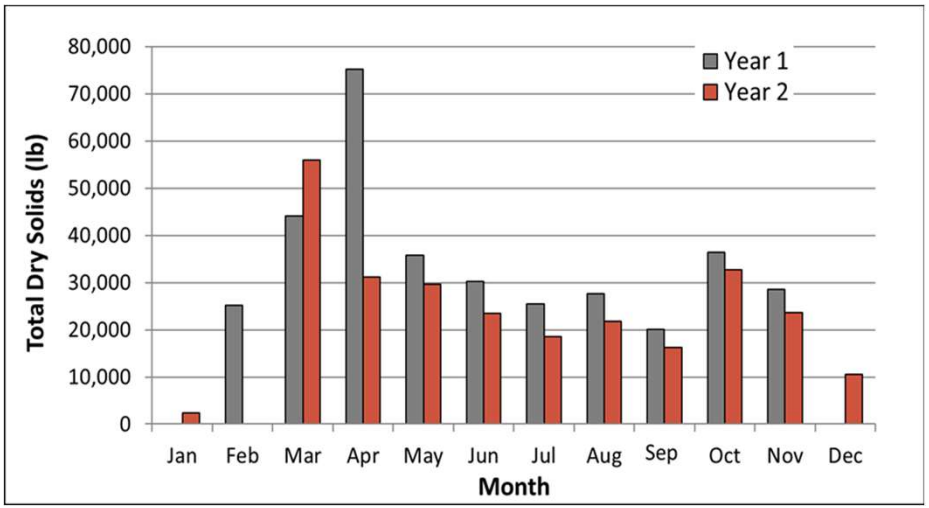
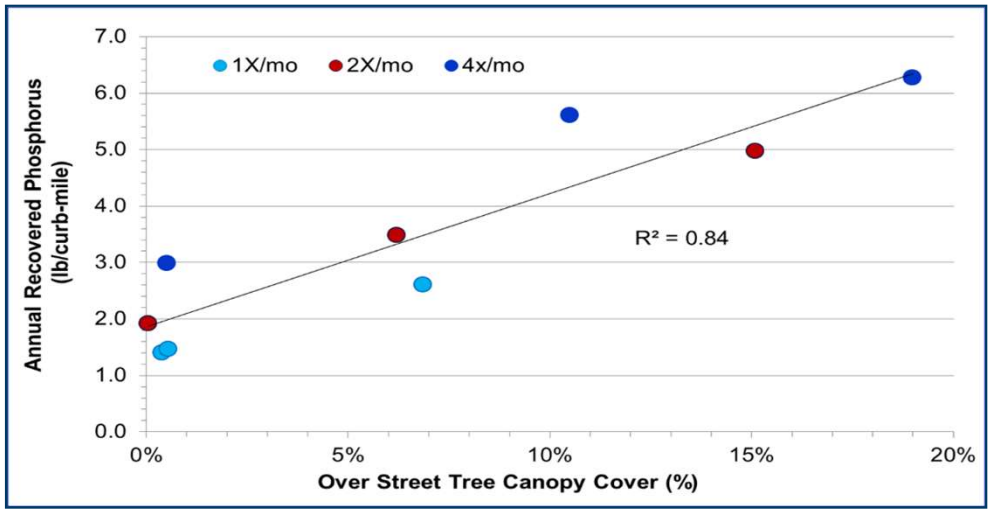


#2 – Roadway tree canopy density is positively corelated with sweeper waste TP loads

#3 – Higher sweeping frequency resulted in greater mass recovery of solids and nutrients.

#1 – Sweeper waste loads vary with season





Key Findings from Prior Lake, MN (2010-2013)

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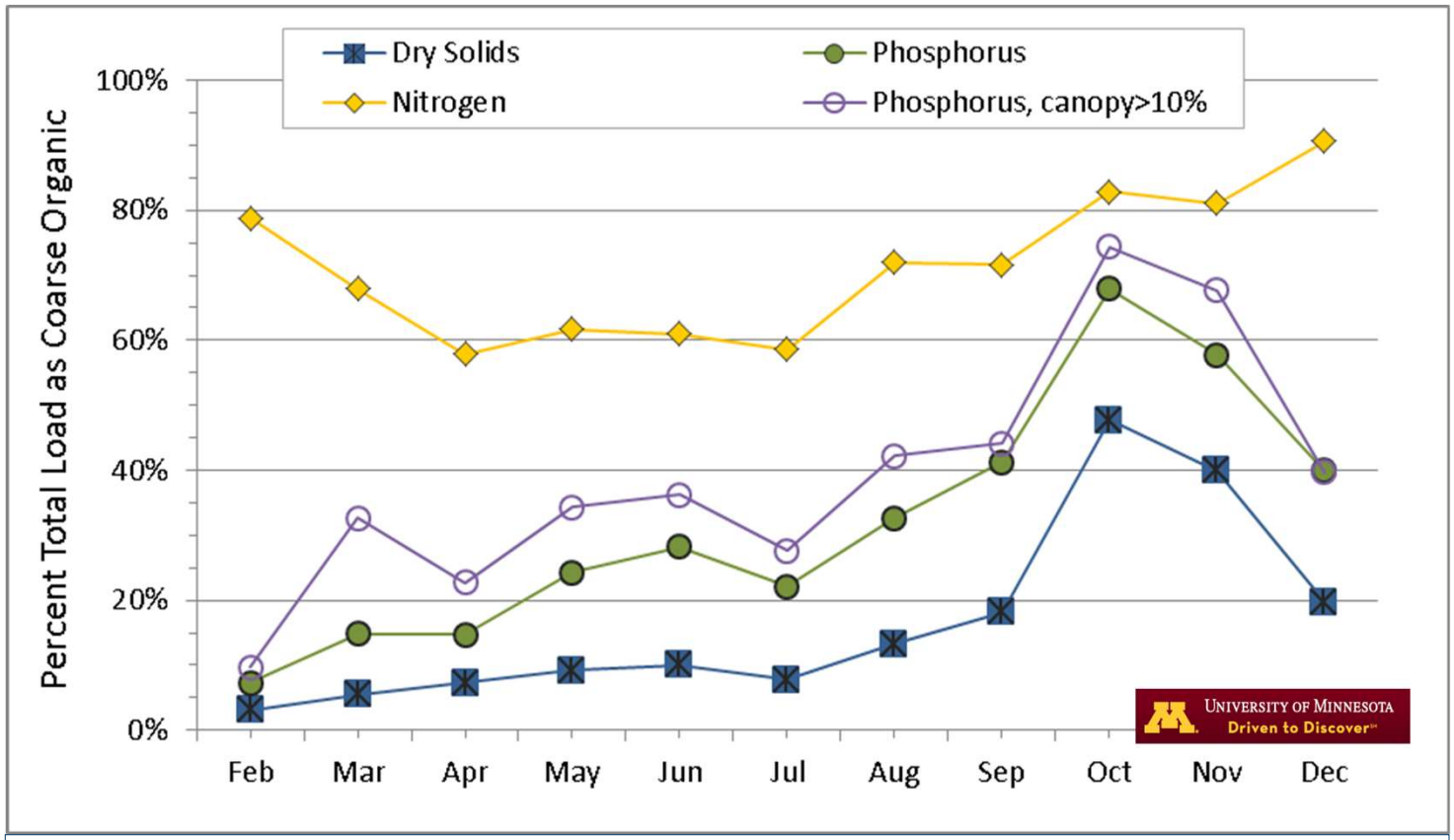

Data points shown represent study averages (all routes) for each month, or for routes with over-street tree canopy cover >10% (purple colored series).

Coarse Organic Material

On Average Contained:

- About **60% or more of TN mass** recovered in all months of the year.
- About **40% - 65% of TP mass** during fall leaf drop season and
- 20% - 40% of the TP mass during spring and summer months.

For Canopy Cover Density Range =

1% - 19% directly over the street

Key Findings from Prior Lake, MN (2010-2013)

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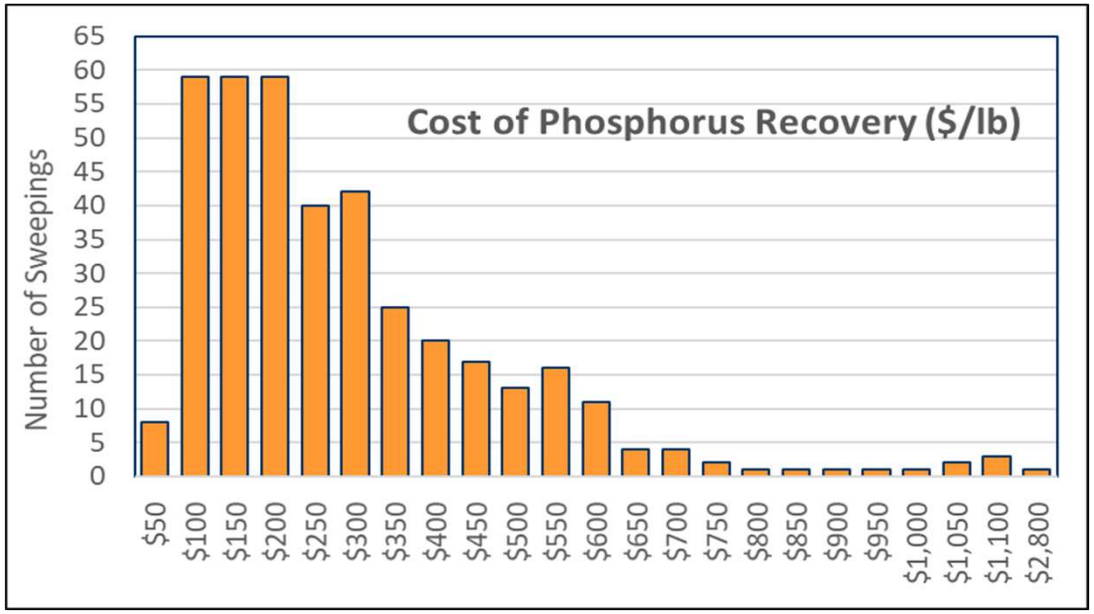
Street Sweeping Can be Very Cost-effective!

Roughly 60% of sweepings < $200 per lb-TP

Key times/Locations – as low as $24 per lb-TP



Cost of Sweeping Event =
{Labor-related costs} + {Vehicle-related costs}

Cost of Sweeping Event =
Sweep time(hr)*$60/hr + Curb-mile Swept (mi)*$5.25/mi

Labor-related Costs	
Labor	$20-40 /hr (wages + benefits+ overhead)
Vehicle-related Costs	
Maintenance	$15,000/year average • Replacement of all sweeping parts once over the vehicle life span plus addition • Annual Maintenance - engine, tires, vehicle systems
Capital Depreciation	[Total Cost of Vehicle + Refurbishment – Resale/Salvage] ÷ Vehicle Life • 8-10 year life of sweeping components • 16-20 year life of vehicle
Fuel	4.8 gal/hr, brush on 1.0 gal/hr, travel and idle mode

Research Products Prior Lake, MN (2010-2013)

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Estimating Pollutant Load Recovery Potential using Regional Research:

Street Sweeping Planning Tool

- Compare sweeping scenarios, develop cost-benefit analysis
- Inputs:
  - Curb-miles swept
  - Month of sweeping
  - Frequency of sweeping
  - Over-street canopy cover density

*Use in combination with other models to Estimate Load Reductions

$$Mass_y = \beta_o + \beta_1(month) + \beta_2(frequency) + \beta_3(canopy)$$

Green boxes are for data supplied by user

Default Cost/curb mile: $ 23.00

Clear Form | Edit Route | Accept Changes

Route ID	H4
Curbmiles	8.1
Average Canopy Cover	19.0%
Route Cost/curbmile	$ 20.00
Priority (optional)	H

Route M4, year1

Running Total: $ 7,582.50

		Predicted (lb)					
Month	Frequency	Wet Solids	Dry Solids	Nitrogen	Phosphorus	Cost	$ Cost/lb P
January							
February							
March							
April	1	8695	6227	17.0	4.3	$ 162.00	$ 37.49
May	1	4462	3254	15.3	3.1	$ 162.00	$ 51.90
June							
July							
August							
September	1	3113	2276	15.0	2.2	$ 162.00	$ 73.22
October	1	6874	3672	31.8	5.8	$ 162.00	$ 28.09
November							
December							
							Average $/lb
Predicted		23143	15430	79.2	15.4	$ 648.00	$ 47.67

Planning Sweeping for Water Quality

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Enhanced Sweeping = Sweeping more than 1X each spring and fall [OR using Tandem Sweeping]

Targeted Sweeping = Sweeping at specific times/locations, within particular drainage basins…for Water Quality

Planning - What You Need

1. Understanding of Water Quality Concerns
2. Mapped Drainage Networks
3. Road Centerline Data
4. Tree Canopy Data (Digital or Aerial Imagery)
5. Metrics for Estimating Solids and Phosphorus Recovery

Strategy

1. Extra Sweeping Late Spring

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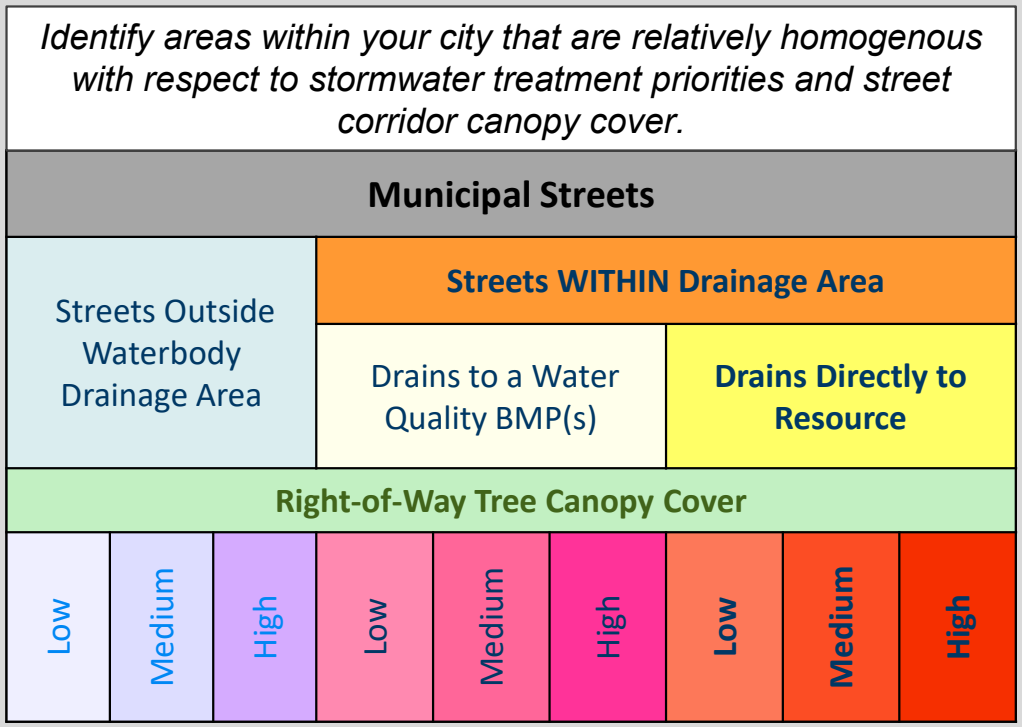
3. Add sweepings working from spring/fall into July

**Prioritize sweeping where streets drain directly to a water resource and/or have dense street corridor canopy*

Identify areas within your city that are relatively homogenous with respect to stormwater treatment priorities and street corridor canopy cover.



Application of Research – Developing an Enhanced Street Sweeping Plan

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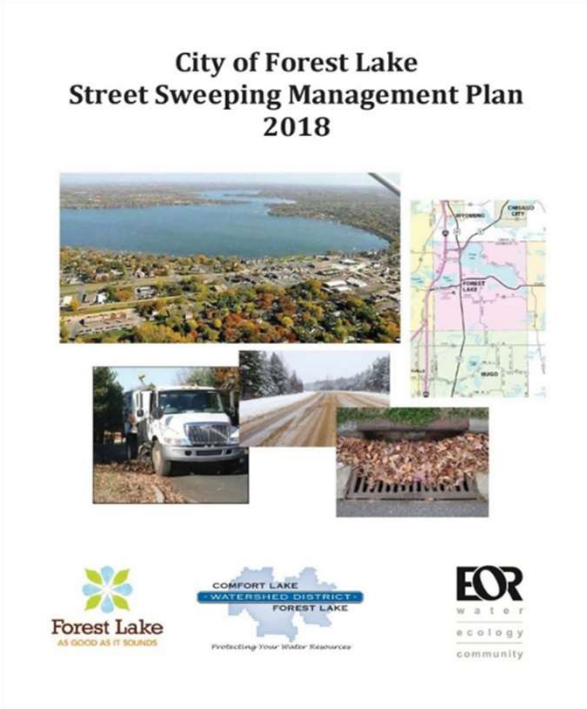
2017 - CWF Accelerated Implementation Grant

Grant: $36,000 **CLFLWD: $9,000**



Study and Plan, Field Monitoring

2018 CWF Project and Practices Grant

Grant: $220,000 **City of FL: $27,500**

CLFLWD: $19,415 **RCWD: $8,085**

Sweeper Purchase, Outreach and Education

Developing an Enhanced Street Sweeping Plan

Step 1: Define Sweeping Zones

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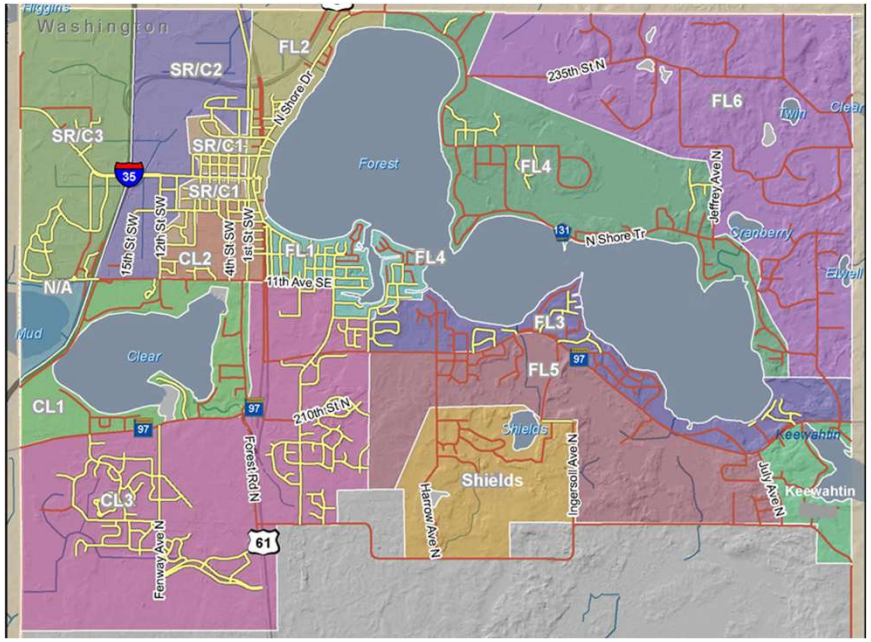
Quantitative Assessments

- Canopy Cover
- Curb-miles (for load reduction estimates)

Qualitative Assessments

- Connectivity to Waterbodies, BMPs
- Street Type, Primary Land Use



GOALS:

1. Identify areas within which pollutant loading is relatively consistent (tree canopy characteristics)
2. Identify areas of higher and lower connectivity to downstream waterbodies

Developing an Enhanced Street Sweeping Plan

Steps 2-3: Estimate Pollutant Load Recovery & Load Reductions

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2. Use Planning Tool from Prior Lake Study to Estimate Solids and Nutrient Recovery

Table 5-2. Summary of estimated annual total solids and phosphorus recovery for the street sweeping scenarios described in Table 5-1 by receiving waterbody.

	Clear Lake		Forest Lake		Shields Lake		Keewahtin Lake		Sunrise River/ Comfort Lake	
Sweeping Scenario	TS	TP	TS	TP	TS	TP	TS	TP	TS	TP
Baseline[1]	34,300	29	71,685	63	3,045	3	3,045	3	21,300	18
Enhanced Baseline	61,600	50	129,230	109	5,570	5	5,570	5	38,250	31
Monthly	95,460	72	199,500	157	8,470	7	8,470	7	59,280	45
Bi-weekly	151,960	113	312,400	240	13,500	10	13,500	10	94,360	71
Weekly	192,530	141								

[1]Based on 2016 contract service practices (mecha
Estimates for all other scenarios are based on sweeping with a vac

3b. Apply Basin Pollutant Capture Rate to Load Recovery = ~Load Reduction to Water Body

	Clear Lake		Forest Lake		Shields Lake		Keewahtin Lake		Sunrise River/ Comfort Lake	
Sweeping Scenario	TS	TP	TS	TP	TS	TP	TS	TP	TS	TP
Baseline[1]	1,989	6.4	53,830	37.0	465	0.7	601	0.9	4,517	6.4
Enhanced Baseline	3,570	11	74,804	64	1,370	1.1	1,943	1.6	13,390	11
Monthly	5,540	16	115,290	91	2,120	1.6	3,010	2.3	20,760	16
Bi-weekly	8,810	25	178,350	137	3,370	3.0	4,790	4.0	33,040	25
Weekly	11,160	31	232,520	180	4,270	3.0	6,070	5.0	41,860	31

[1]Low end based on sweeping with mechanical broom, high end based on sweeping with vacuum type sweeper. Estimates for all other scenarios are based on sweeping with a vacuum type sweeper.

3a. Estimate Pollutant Capture

**Table 5-3. Typical BMP removal efficiencies (Minnesota Stormwa
pollutant removal efficiency of BMPs within each sweeping zone.**

	No BMPs	Detention Pond	Multiple Ponds	Dry Sw		
TP	0%	50%	75%	50%	40%	100%
TSS	0%	85%	95%	85%	73%	100%

TP = total phosphorus; TSS = total suspended solids

Developing an Enhanced Street Sweeping Plan

Steps 4-5: Estimate Costs and Cost-Benefits of Proposed Sweeping

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Estimate costs for a City-owned and operated sweeping program

Table 6-1. 2017 street sweeping annual cost assumptions for the City of Forest Lake

Category	Annual Cost Assumption
Vehicle Depreciation [1]	$27,032/yr
Vehicle refurbishment	$5,000 every 3 years
Vehicle Maintenance	$2,000-$3,000/yr
Labor (wages + benefits)	$45/hr
Diesel Fuel	$3/gal
Disposal Cost	$1/yd^3 of material

Table 6-2. Baseline scenario (spring/fall only sweeping) total annual cost ($) and annual cost-benefit ($/lb-P reduced) of street sweeping by sweeping zone.

Sweeper Type	HUC 12 Watershed	Total Annual Average Cost ($)	10-year Cost-Benefit	
			Phosphorus Recovery from Streets ($/lb-P)	Phosphorus Reduction to Receiving Waterbody ($/lb-P)
Contract Sweeper	Clear Lake	$19,544	$613	$2,758
	Forest Lake	$32,293	$461	$791
	Shields Lake	$1,504	$518	$2,074
	Keewahtin Lake	$1,512	$522	$1,467
	Sunrise River/Comfort Lake	$11,648	$582	$1,643
	TOTAL	**$66,500**	**$521**	**$1,172**
City-Owned Sweeper	Clear Lake	$11,049	$346	$1,559
	Forest Lake	$18,290	$261	$448
	Shields Lake	$851	$293	$1,174
	Keewahtin Lake	$856	$295	$830
	Sunrise River/Comfort Lake	$6,587	$329	$929
	TOTAL	**$37,633**	**$295**	**$663**

Developing an in-house sweeping program would save $$

Recommendations based on spending for contract sweeping service in previous year.

Table 7-1. Cost-benefit of recommended street sweeping scenarios based on sweeping zone characteristics

Waterbody	Sweeping Zone	Sweeping Priority[1]	Curb-miles	Number of Sweepings		
				Base Priority	Enhanced (Recommended)	Maximum
Clear Lake	CL1	WQ	13.5	7	**12**	28
	CL2	P/M	9.2	4	**7**	7
	CL3	P/M	47.4	4	**7**	7
Forest Lake	FL1	WQ	17.3	7	**12**	28
	FL2	WQ	12.9	7	**12**	28
	FL3	WQ	18.7	7	**12**	14
	FL4	P/M	27.2	4	**7**	7
	FL5	P/M	11.0	4	**7**	7
	FL6	P/M	28.8	4	**7**	7
Shields Lake	Shields	WQ[2]	5.4	7	**12**	14
Keewahtin Lake	Keewahtin	P/M	5.4	4	**7**	7
Sunrise River/Comfort Lake	SR/C1	WQ[2]	20.3	7	**12**	14
	SR/C2	P/M	8.6	4	**7**	7
	SR/C3	P/M	12.9	4	**7**	7
Total Curb-miles				1,220	**2,085**	2,900
Solids Reduction Compared to Baseline (20 tons/yr)				+26	**+48**	+66
Phosphorus Reduction Compared to Baseline (57 lb/yr)				+54	**+110**	+140
Estimated Annual Cost				$53,810	**$68,301**	$82,296
Estimated Annual Cost – Reduced Sweeper Purchase Price[3]				$32,232	**$46,294**	$60,394

[1] WQ = Water quality benefit (direct drainage areas of lakes), P/M = BMP preservation and maintenance benefit (indirect w

[2] TMDL watershed

[3] With grant funding of $220,000 towards the cost of a regenerative air sweeper

Continued Research in Minnesota 2018 – 2022(?)

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Credit Calculator Tool

MS4's Receive TP Credit for Sweeping

Inputs:

1. Fresh Mass of Sweepings
   or
2. Curb-miles swept

*Greater credit give for Method #1

Street Sweeping Credit Calculator

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Enter your data in YELLOW spaces based on the type of data you have available. If no data is available, leave blank. Output units match input units (e.g. per year or per event)

If any required data inputs are missing, an error message will occur or output cells will appear blank.

Project or Watershed Area: Example Lake Drainage Area Name

Input Data

Option 1: Dry Mass Data		Option 2: Wet Mass Data		Option 3: Miles Swept Data	
Required Inputs:		*Required Inputs:*		*Required Inputs:*	
Street Sweeper Dry Mass (lbs)	100	Street Sweeper Wet Mass (lbs)		Miles Swept (miles)	
Season of Data Collection	Fall Leaf Collection	Season of Data Collection	Non-Fall Collection	*Note: if 1 mile of roadway is swept twice, input 2 miles.*	
Optional Input:		*Optional Inputs:*			
Percent Organic Matter (%)	50	Percent Moisture (%)			
Note: if you have organic matter data, season does not matter		Percent Organic Matter (%)			
		Note: if you have organic matter and moisture data, season does not matter.			

Phosphorus Concentration or Removal Rate

		Dry Mass (lbs)		Area of Road Swept (acres)	
P Concentration (mg P/ kg dry mass)	1340	P Concentration (mg P/ kg dry mass)	414	P Removal Rate (lbs / ac / pass)	0.00017

Phosphorus Load Reduction

Total Phosphorus Removed (lbs)	0.13	Total Phosphorus Removed (lbs)		Total Phosphorus Removed (lbs)	

Validation through Additional Research

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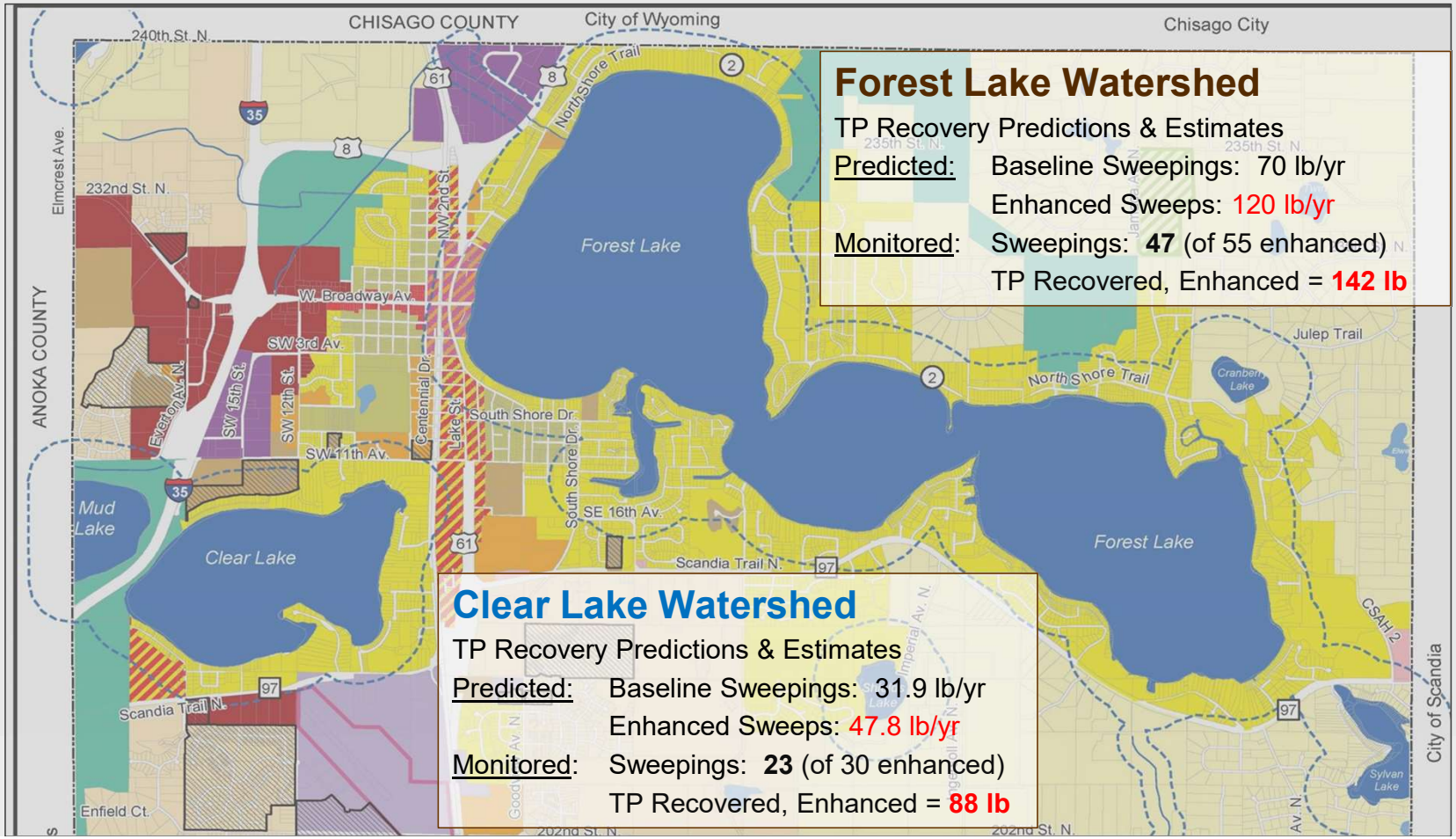


Forest Lake Watershed

TP Recovery Predictions & Estimates

Predicted: Baseline Sweepings: 70 lb/yr

Enhanced Sweeps: 120 lb/yr

Monitored: Sweepings: **47** (of 55 enhanced)

TP Recovered, Enhanced = **142 lb**

Clear Lake Watershed

TP Recovery Predictions & Estimates

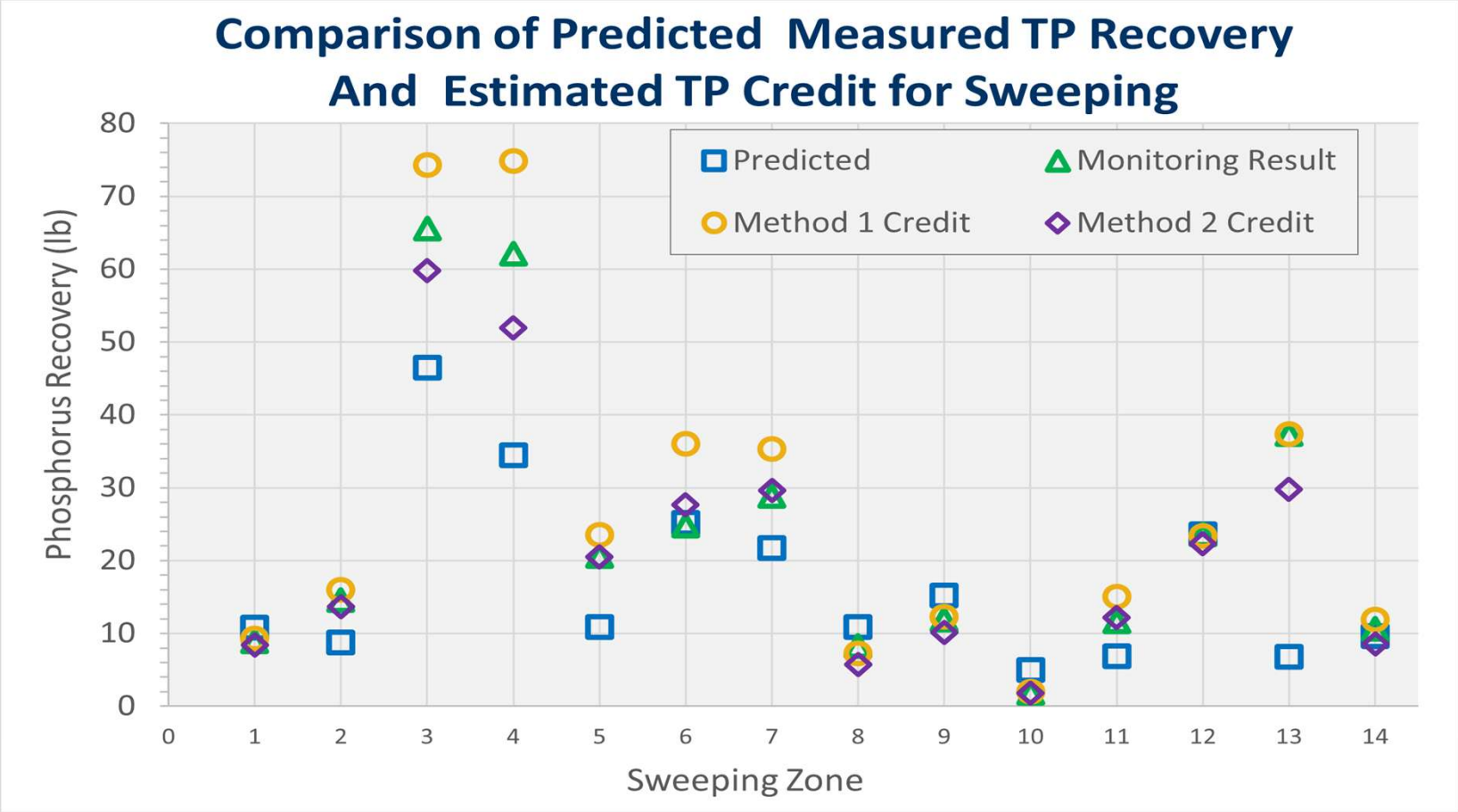
Predicted: Baseline Sweepings: 31.9 lb/yr

Enhanced Sweeps: 47.8 lb/yr

Monitored: Sweepings: **23** (of 30 enhanced)

TP Recovered, Enhanced = **88 lb**

Example: Forest Lake, MN



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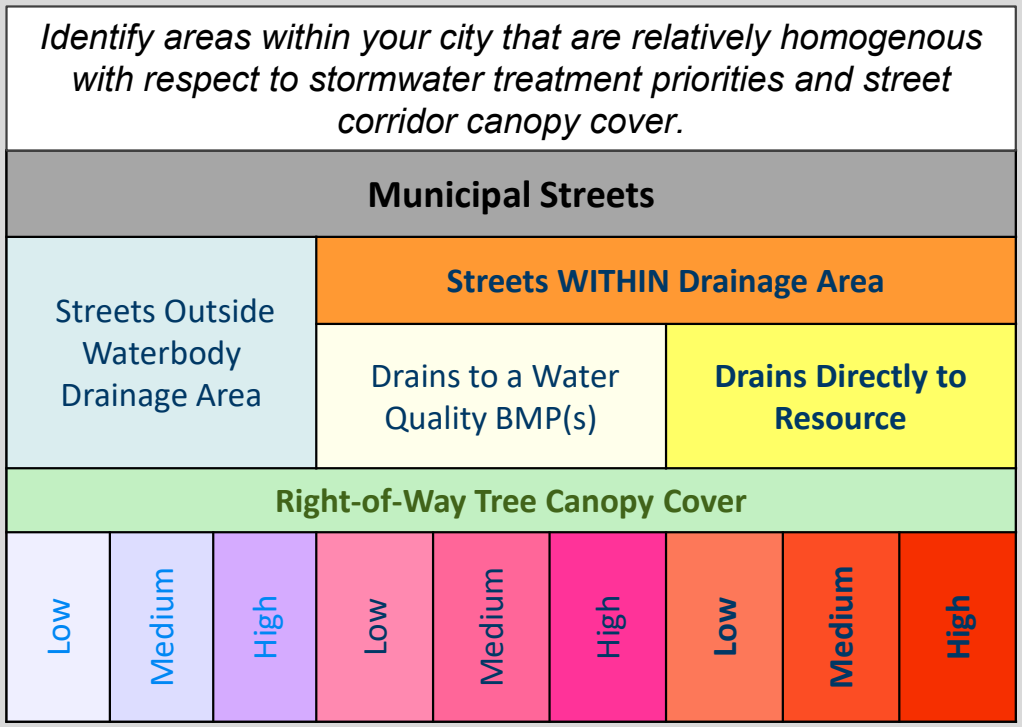

Resources for Developing an Enhanced Street Sweeping Plan

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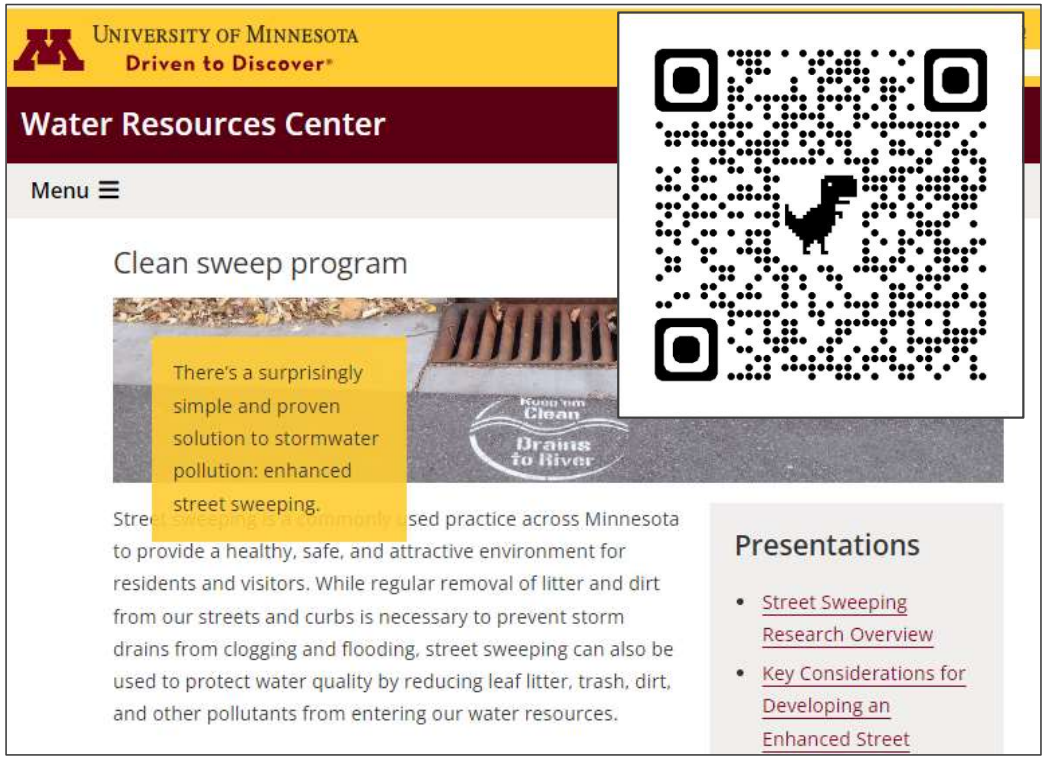
Resources for Planning Sweeping are Available through the University of MN Clean Sweep Program: https://wrc.umn.edu/clean-sweep-program



CLEAN SWEEP
EDUCATION & TRAINING PROGRAM

Quick Estimating Tool for Total Solids and Phosphorus

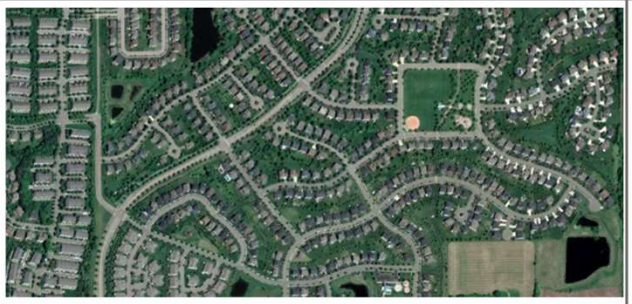
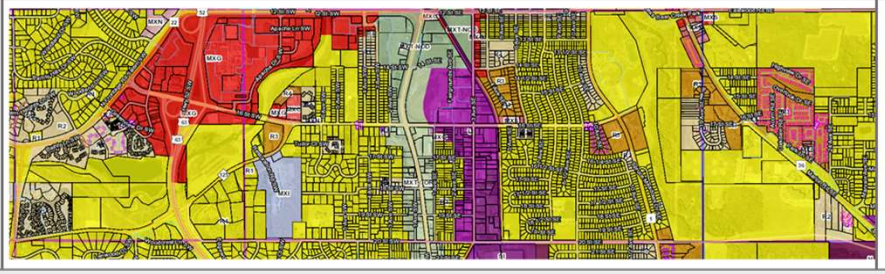
Before investing in a new or enhanced street sweeping program, one of the most important questions is:
What will the predicted benefits be for the proposed street sweeping efforts?

Estimating Total Solids Recovery: *Fresh Weight Basis*

Table 2. Recommended metrics for estimating solids recovery based on the timing and frequency of sweeping, **fresh weight-basis.**

	Median Solids Recovery (lb/lane-mile, fresh mass basis*)			
	Sweeping frequency: once per month *or less frequent*		Sweeping frequency: twice per month	
	Right of Way Tree Canopy Cover		Right of Way Tree Canopy Cover	
Season	0-5% (low)	>5% (all other)	0-5% (low)	>5% (all other)
Spring (Apr - Jun)	228	483	195	358
Summer (Jul-Sept)	180	335	178	300
Fall (Oct-Nov)	218	608	168	488

*The average moisture content of sweeping was approximately 20% in spring and summer and 37.5% in fall.

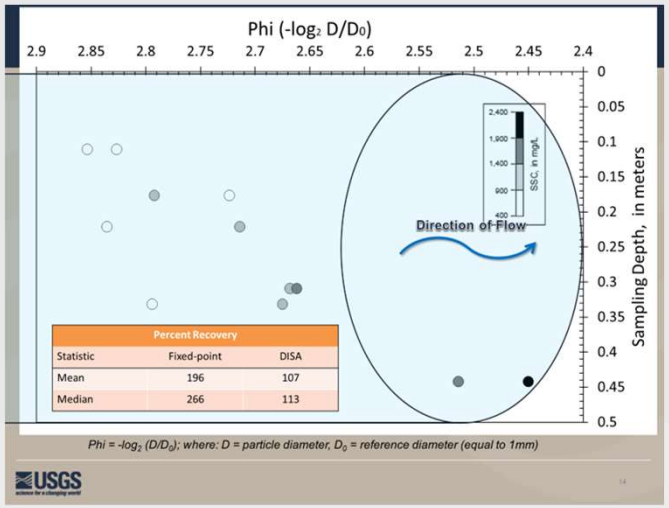
Canopy Rating:	Low Canopy Cover (<5% Cover)	Medium Canopy Cover (5% - 20%Cover)	High Canopy Cover (>20 % Cover)
Typical Characteristics:	No/few boulevard trees; roadway, curb lines, shoulders easily distinguished; few mature trees within front-yard setback areas	Curb lines partially obscured in some areas; mature/maturing trees present within front yard setback areas or medians, roadway generally discernable.	Curb lines often not discernable; roadway partially or completely occluded by tree canopy; mature trees along medians and within front yard setback areas.
Street Scale			
Development Scale			
			
Zoning Scale			

Madison, WI Street Sweeping and Related Studies

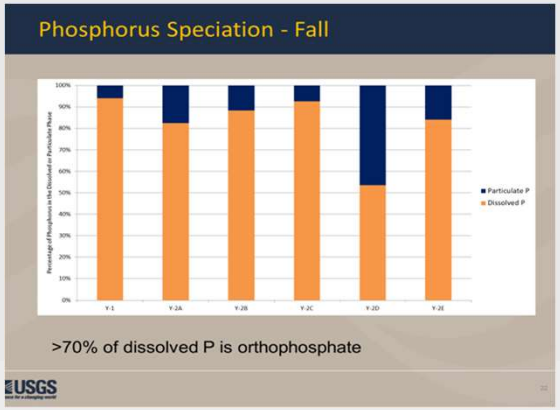
William R Selbig, Research Hydrologist, USGS, Upper Midwest Water Science Center

MINNESOTA POLLUTION CONTROL AGENCY

Depth-Integrated Stormwater Sampling and PSD (~2013, 2019)



Partitioning of TP in Stormwater (~2013-14)



Trees, phosphorus, and street sweeping, and more!

Monitoring and predicting the impacts of trees on urban stormwater volume reduction, 2022

Using leaf collection and street cleaning to reduce nutrients in urban stormwater, 2019

Particle-size distribution from urban land use and source areas, 2019

QUESTIONS?

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