Developing a Framework to Advance Statewide Phosphorus Reduction Credits for Leaf Collection

Bill Selbig and Roger Bannerman
USGS – Wisconsin Water Science Center
September 26, 2018

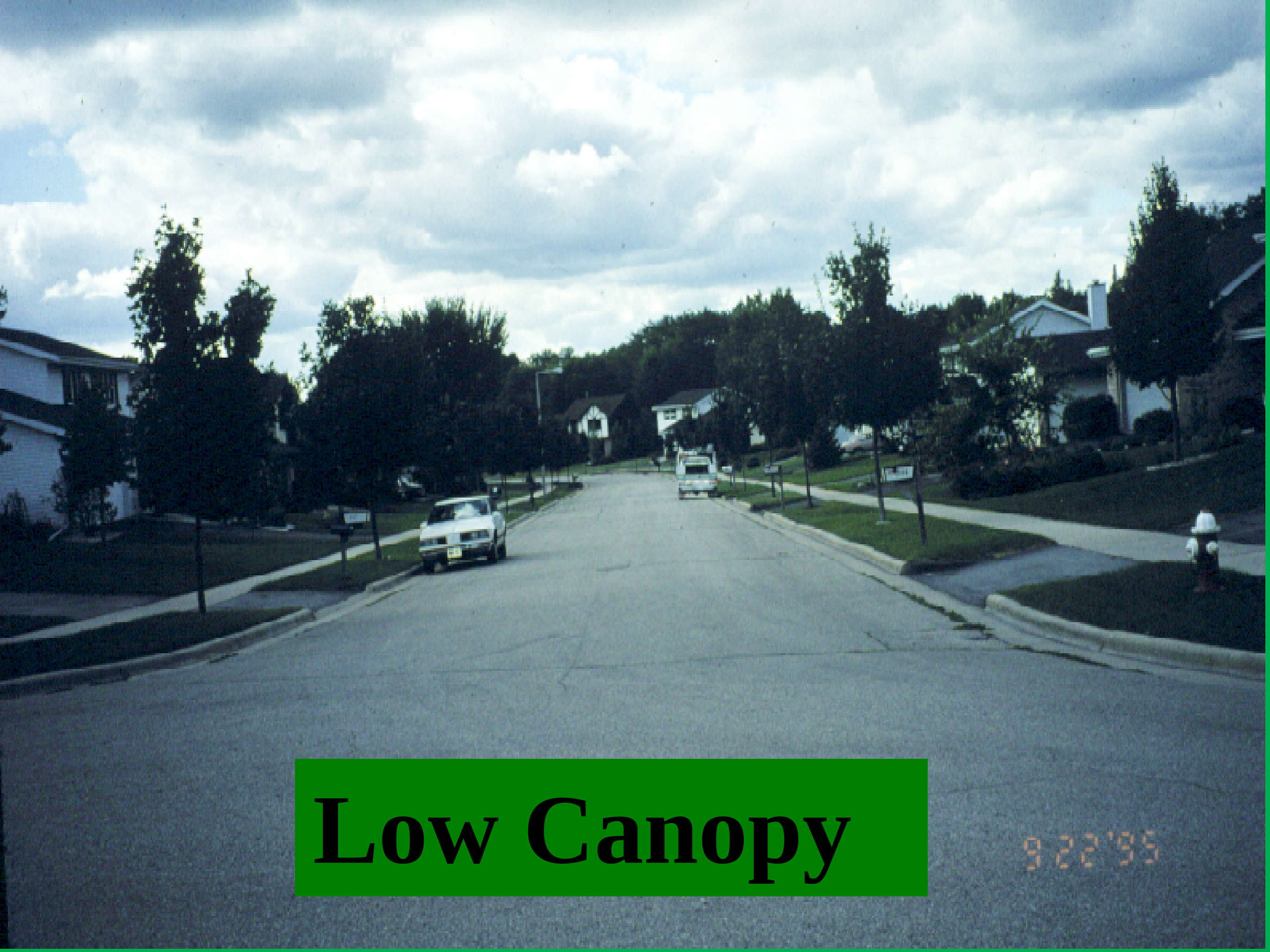
Why Study Leaf Collection?

- Vegetation Most Important Source of Total P in Urban Runoff.
- Fall is the Season with the highest Total P Load.
- Improved Leaf Collection Can Significantly Reduce Annual Total P Loads
- To Describe How to Obtain Credit for Selected Leaf Collection Programs
- To Determine the Most Cost Effective Methods for Leaf Collection.



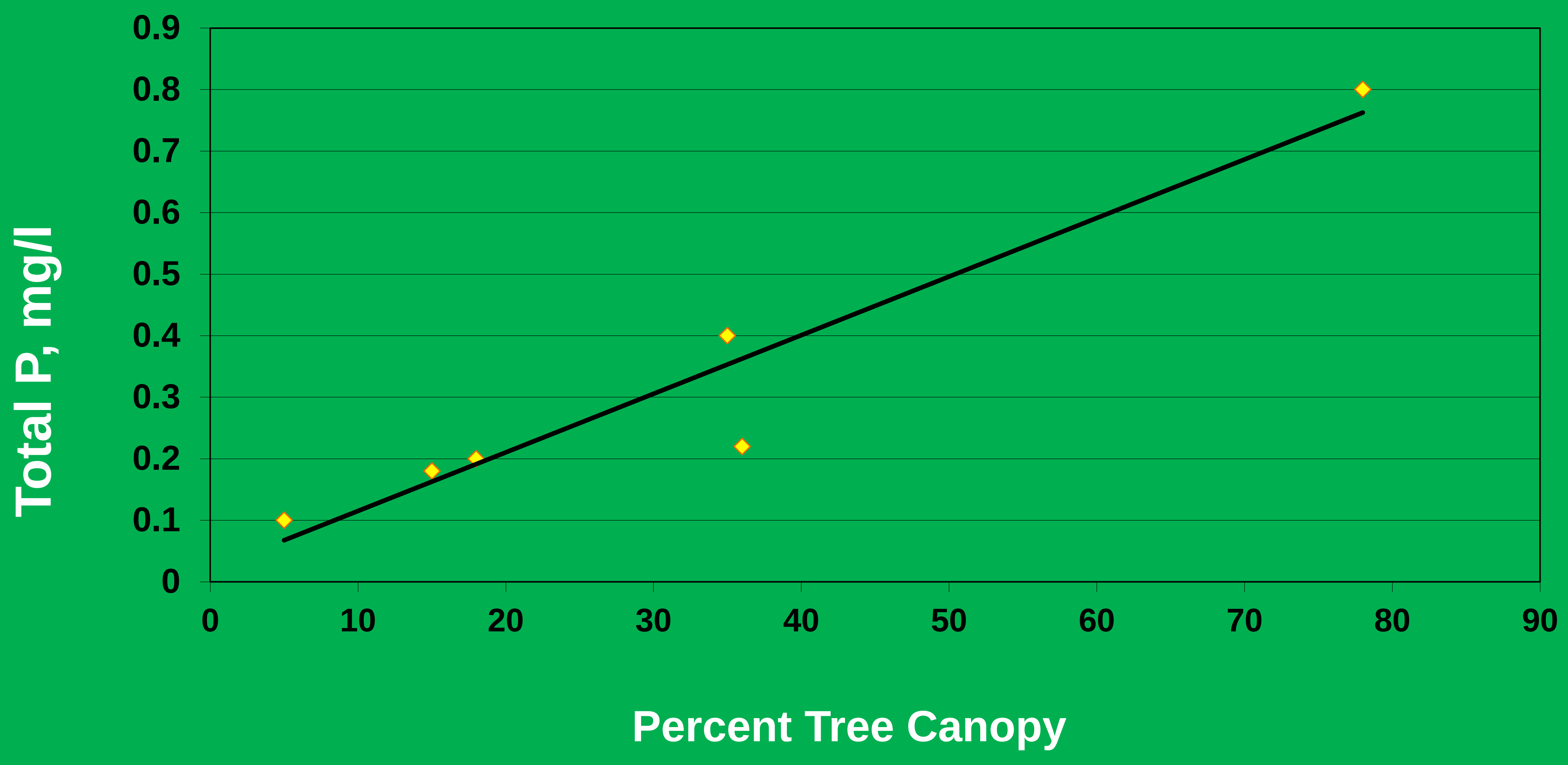
Source Area Sampling





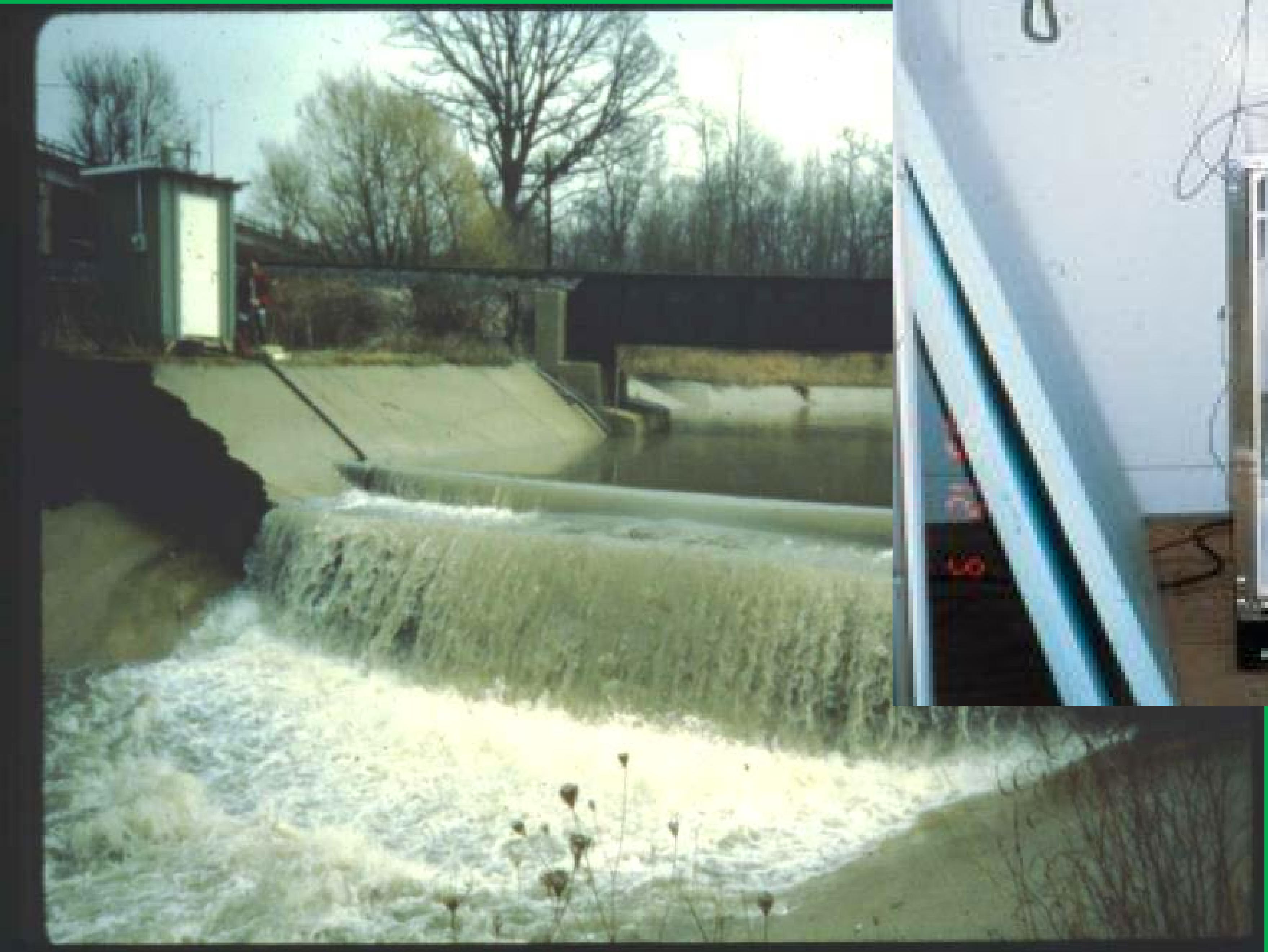
Impact of Tree Canopy on Phosphorus Loads

Effect of Tree Canopy on Levels of Total P in Street Runoff

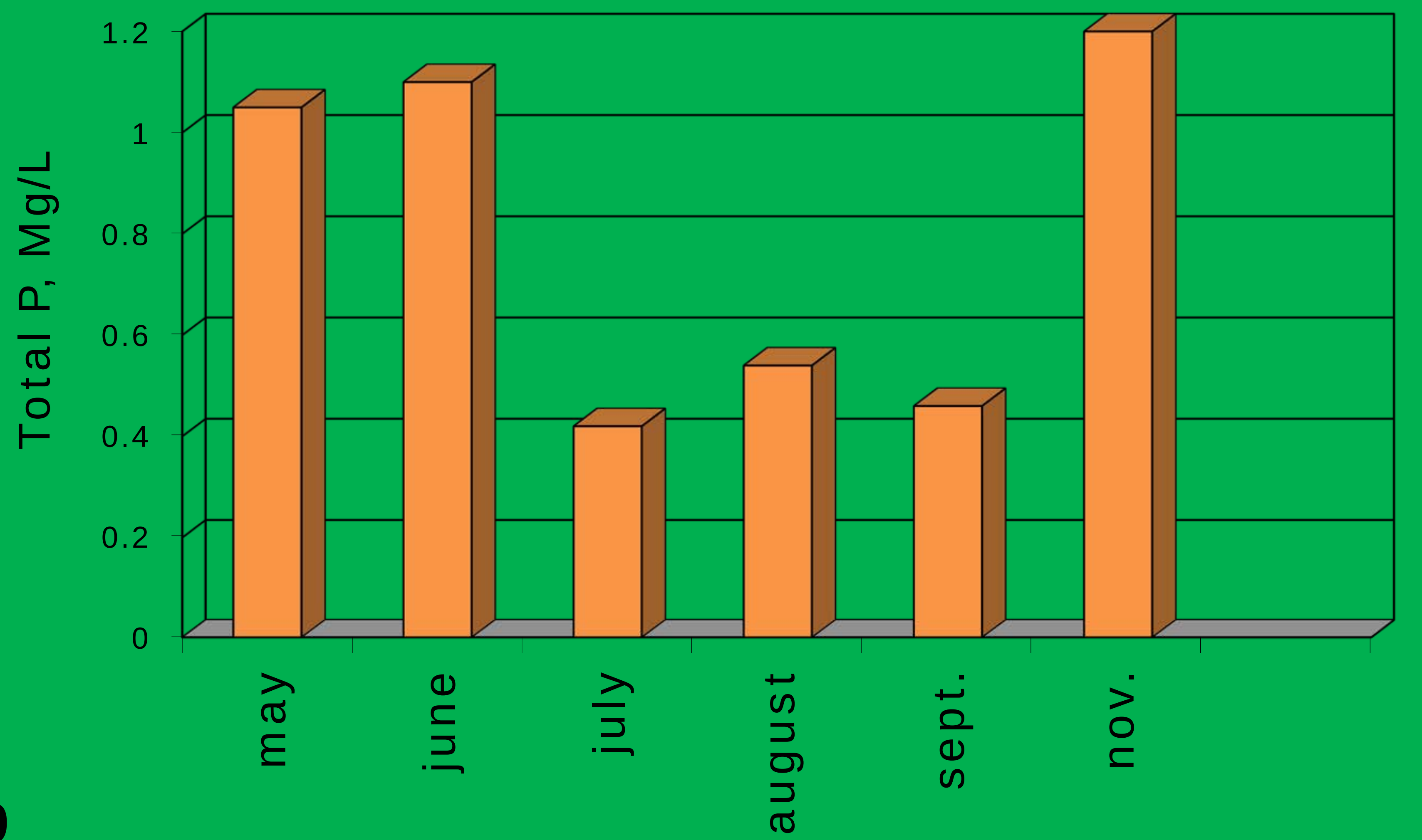


Waschbusch, 1999

Automated Water Quality Sampling Stations



Seasonal Changes in Phosphorus Sources – Monroe Outfall



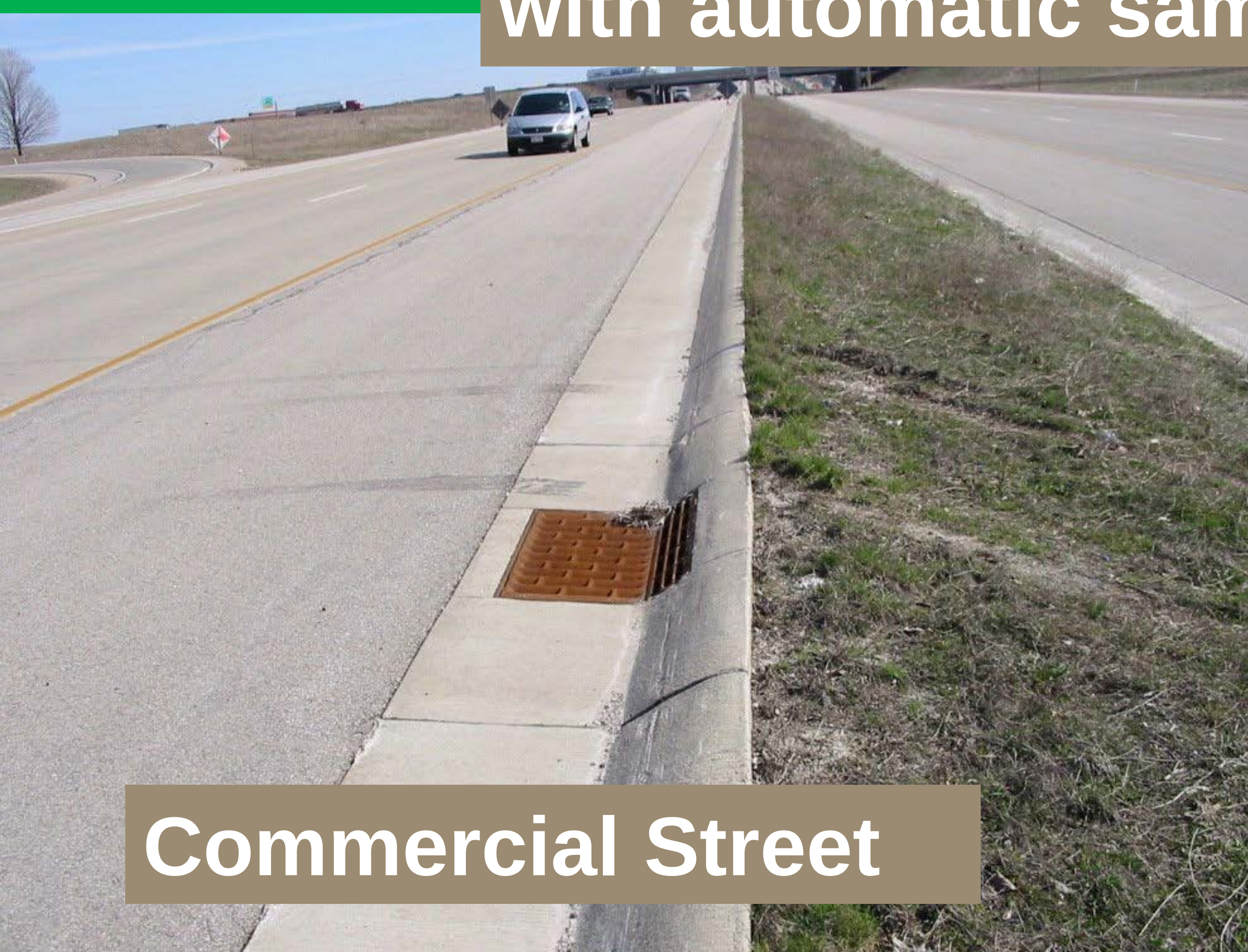
Waschbusch, 1999

Example Applications of DISA

Monitoring source areas and land uses with automatic samplers

Shopping Center

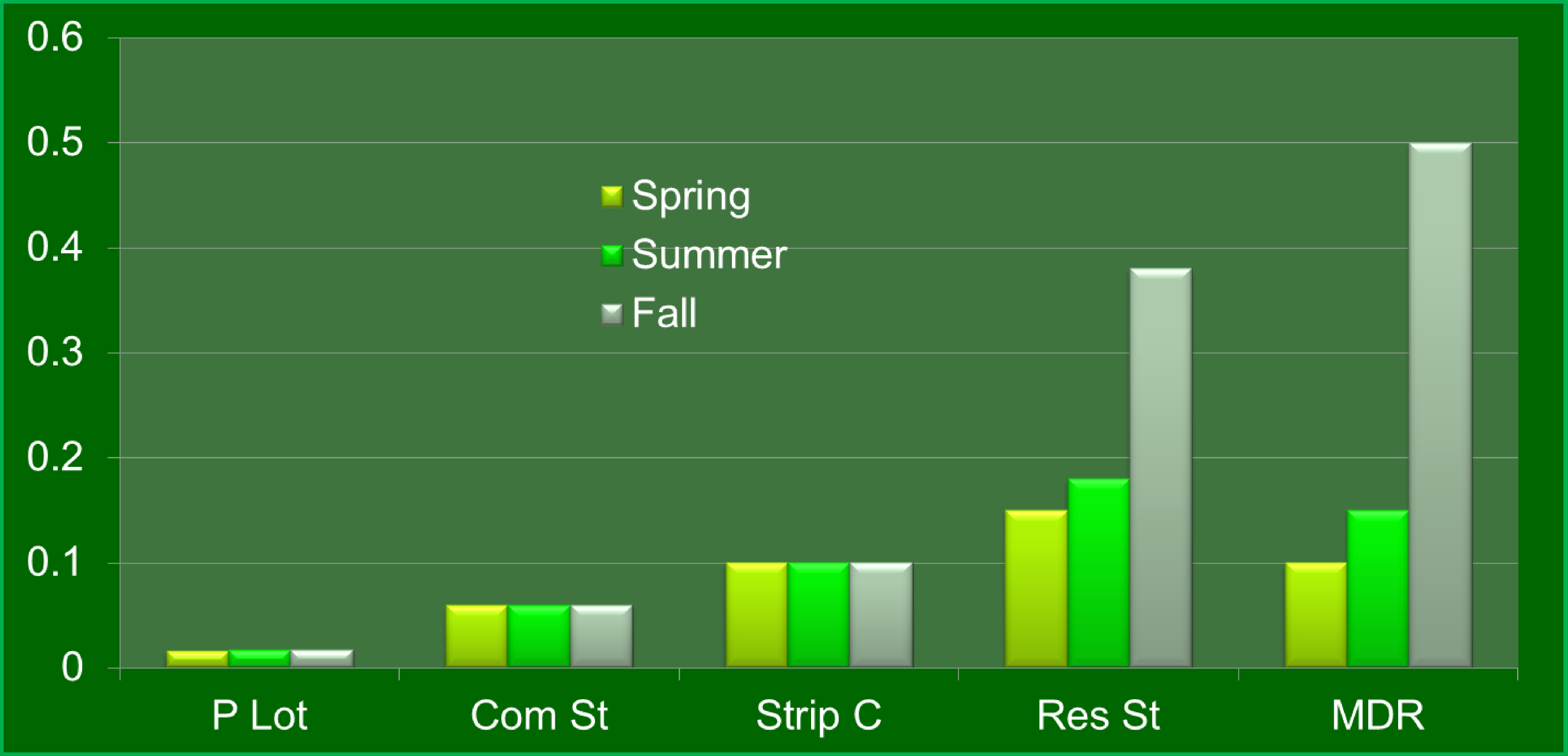
Residential Street

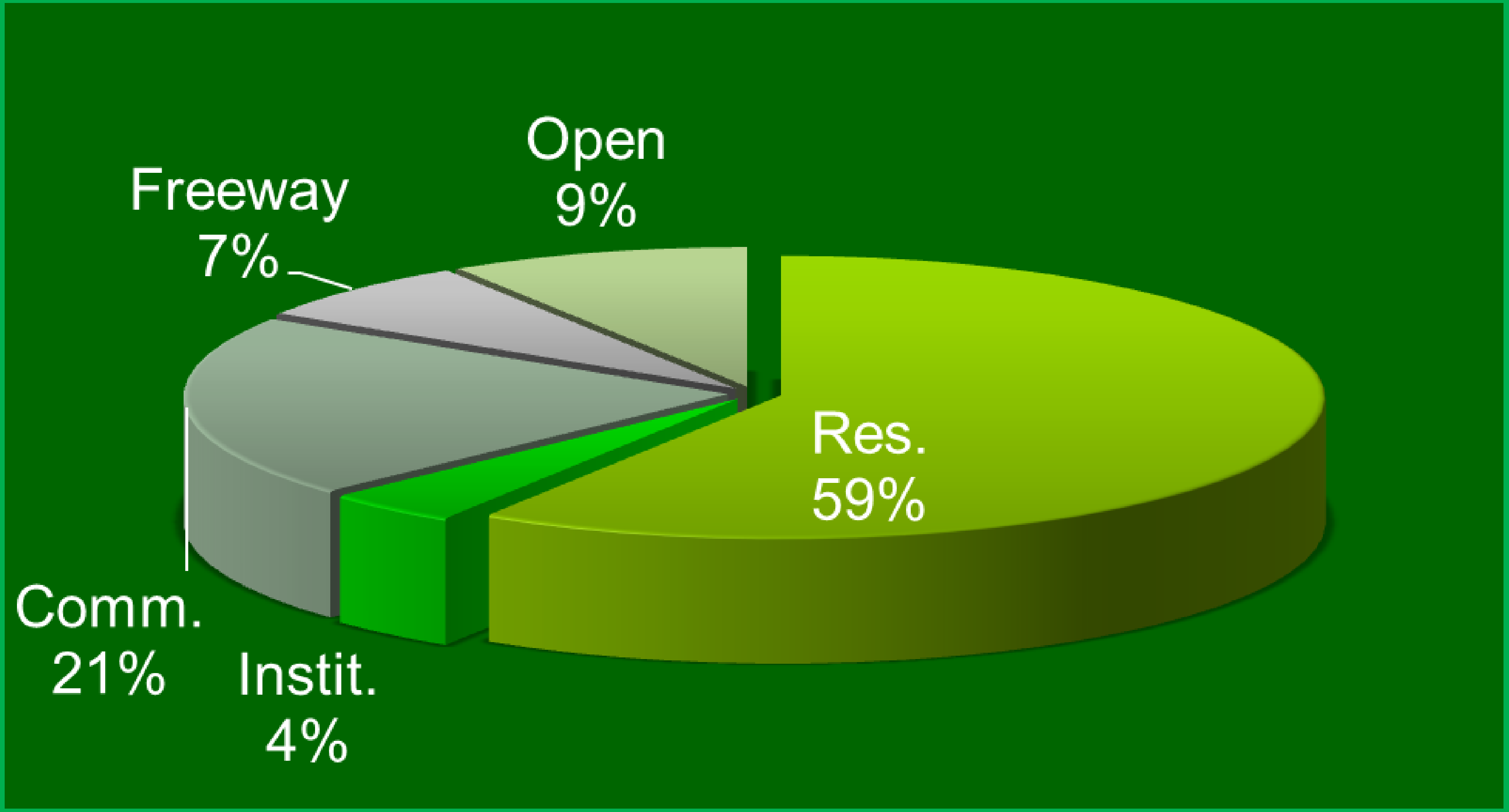


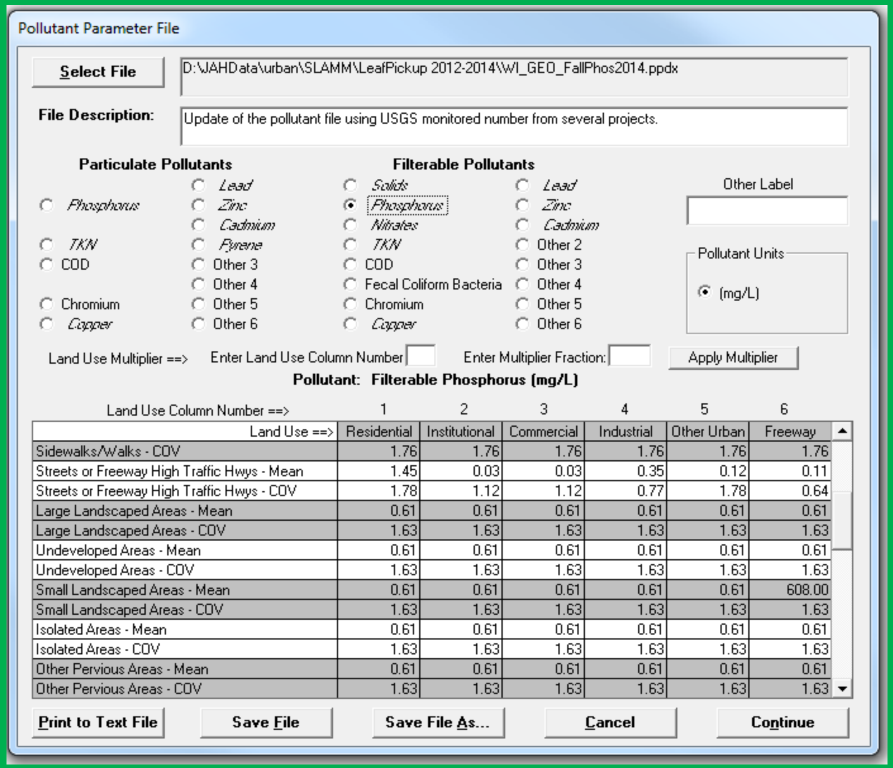
Commercial Street

Strip Commercial

Seasonal Dissolved P, mg/l, Collected with Automatic Samplers, Selbig, 2012







Pollutant Parameter File

Select File D:\JAHData\urban\SLAMM\LeafPickup 2012-2014\WI_GEO_FallPhos2014.ppdx

File Description: Update of the pollutant file using USGS monitored number from several projects.

Particulate Pollutants: Phosphorus, TKN, COD, Chromium, Copper, Lead, Zinc, Cadmium, Pyrene, Other 3, Other 4, Other 5, Other 6

Filterable Pollutants: Solids, Phosphorus, Nitrates, TKN, COD, Fecal Coliform Bacteria, Chromium, Copper, Lead, Zinc, Cadmium, Other 2, Other 3, Other 4, Other 5, Other 6

Other Label

Pollutant Units: (mg/L)

Land Use Multiplier ==> Enter Land Use Column Number Enter Multiplier Fraction: Apply Multiplier

Pollutant: Filterable Phosphorus (mg/L)

Land Use Column Number ==>	1	2	3	4	5	6
Land Use ==>	Residential	Institutional	Commercial	Industrial	Other Urban	Freeway
Sidewalks/Walks - COV	1.76	1.76	1.76	1.76	1.76	1.76
Streets or Freeway High Traffic Hwys - Mean	1.45	0.03	0.03	0.35	0.12	0.11
Streets or Freeway High Traffic Hwys - COV	1.78	1.12	1.12	0.77	1.78	0.64
Large Landscaped Areas - Mean	0.61	0.61	0.61	0.61	0.61	0.61
Large Landscaped Areas - COV	1.63	1.63	1.63	1.63	1.63	1.63
Undeveloped Areas - Mean	0.61	0.61	0.61	0.61	0.61	0.61
Undeveloped Areas - COV	1.63	1.63	1.63	1.63	1.63	1.63
Small Landscaped Areas - Mean	0.61	0.61	0.61	0.61	0.61	608.00
Small Landscaped Areas - COV	1.63	1.63	1.63	1.63	1.63	1.63
Isolated Areas - Mean	0.61	0.61	0.61	0.61	0.61	0.61
Isolated Areas - COV	1.63	1.63	1.63	1.63	1.63	1.63
Other Pervious Areas - Mean	0.61	0.61	0.61	0.61	0.61	0.61
Other Pervious Areas - COV	1.63	1.63	1.63	1.63	1.63	1.63

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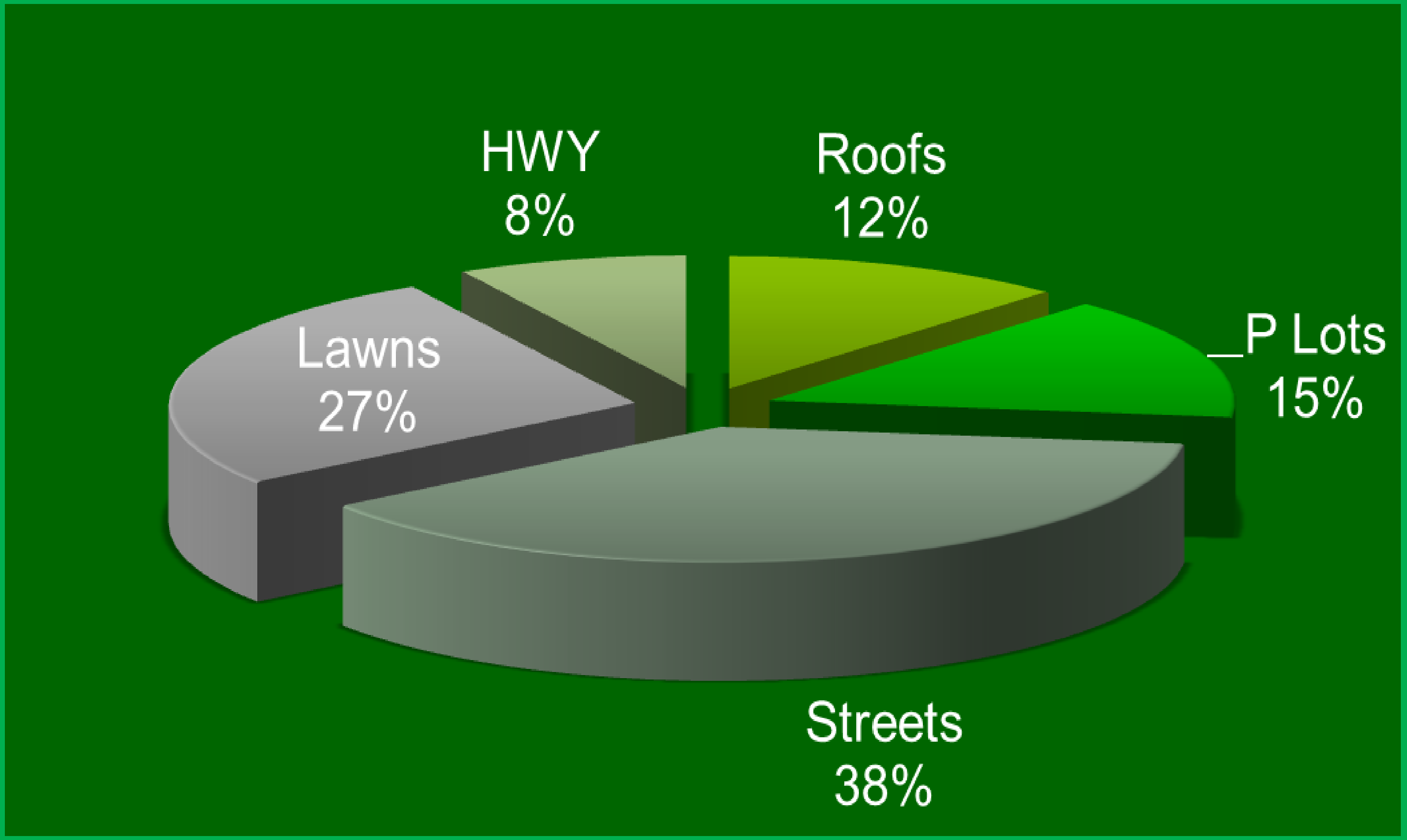
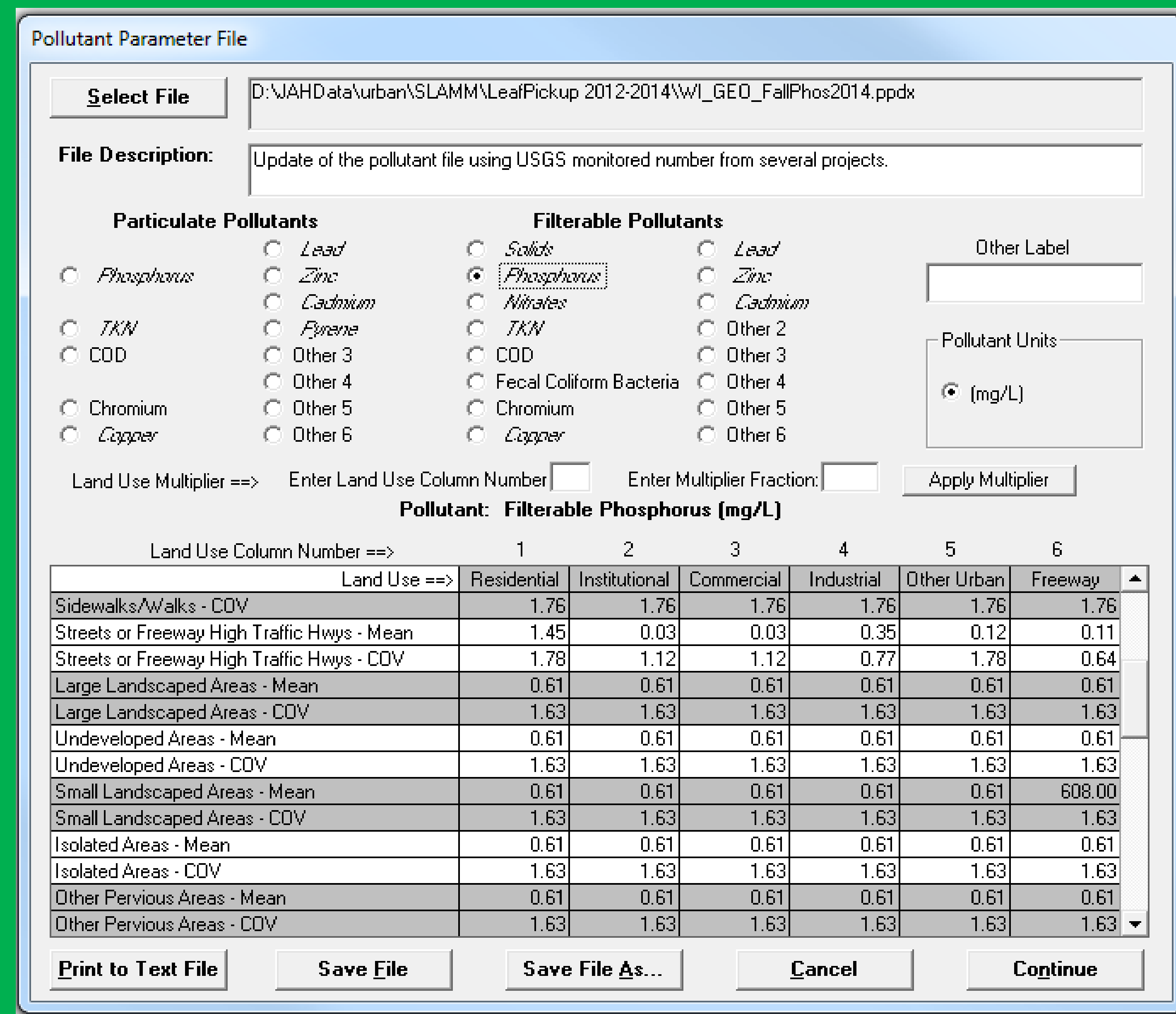
Estimate of Annual Phosphorus Load Using WinSLAMM

% Total P Loads for Four Subwater-sheds in Lake Wingra Basin



Estimate of Annual Phosphorus Load Using WinSLAMM

- 100 acres of medium density residential
- Standardized rainfall for Madison, WI (1980 – 1999)
- Source area concentrations, other than streets, used default values
- Streets were dominate source of runoff for range of precipitation depths measured
- Varied concentration of Phosphorus by season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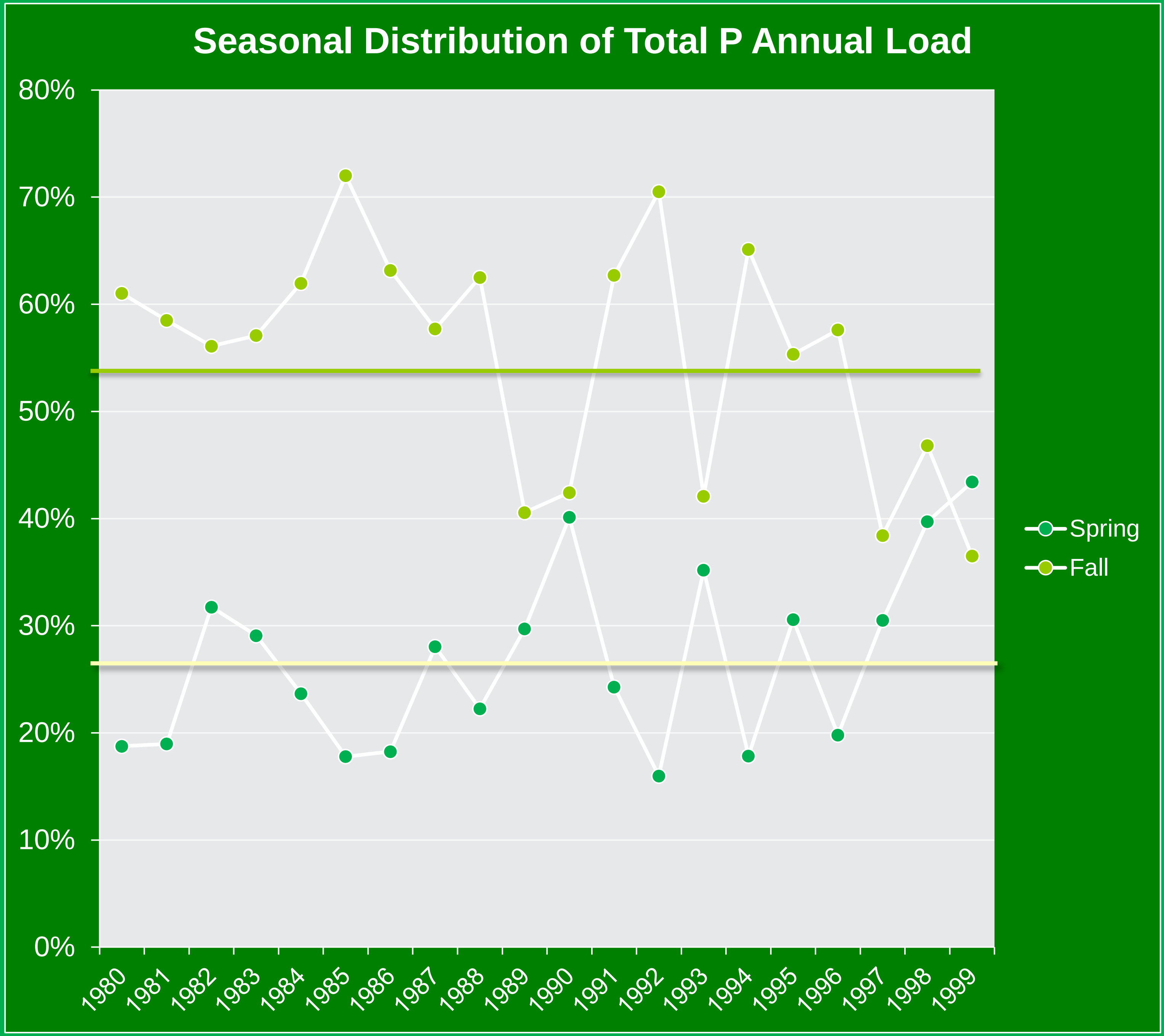
Potential P Reduction with Fall Leaf Collection Program

Season	Minimum %	Maximum %	Mean %
Spring	16	43	33
Summer	10	31	24
Fall	37	72	43



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Partners in Leaf Management Study

Funding Provided by:

Madison

WISCONSIN
DEPT. OF NATURAL RESOURCES

Yahara WINs

DANE COUNTY
OFFICE OF
LAKES & WATERSHEDS

MMSD

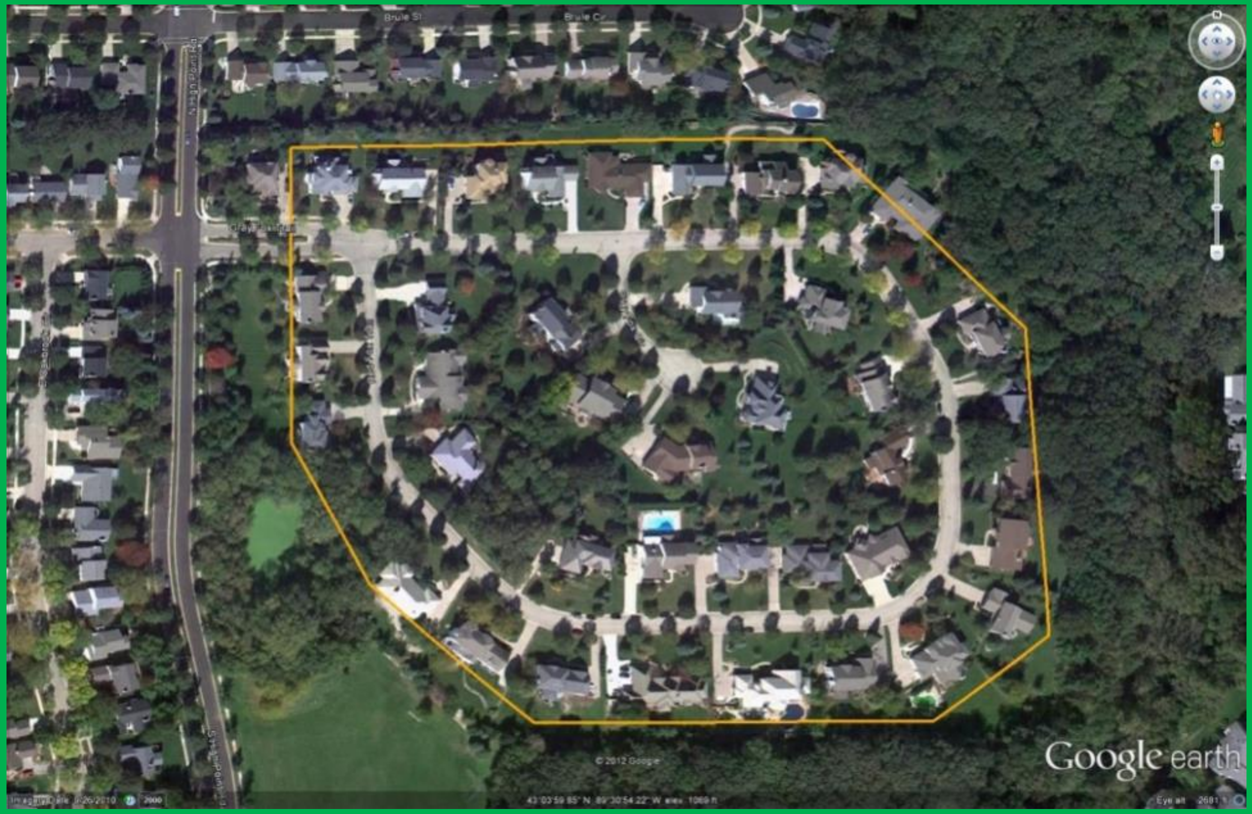
Fund for
Lake Michigan
Clearly making a deep impact.

USGS
science for a changing world

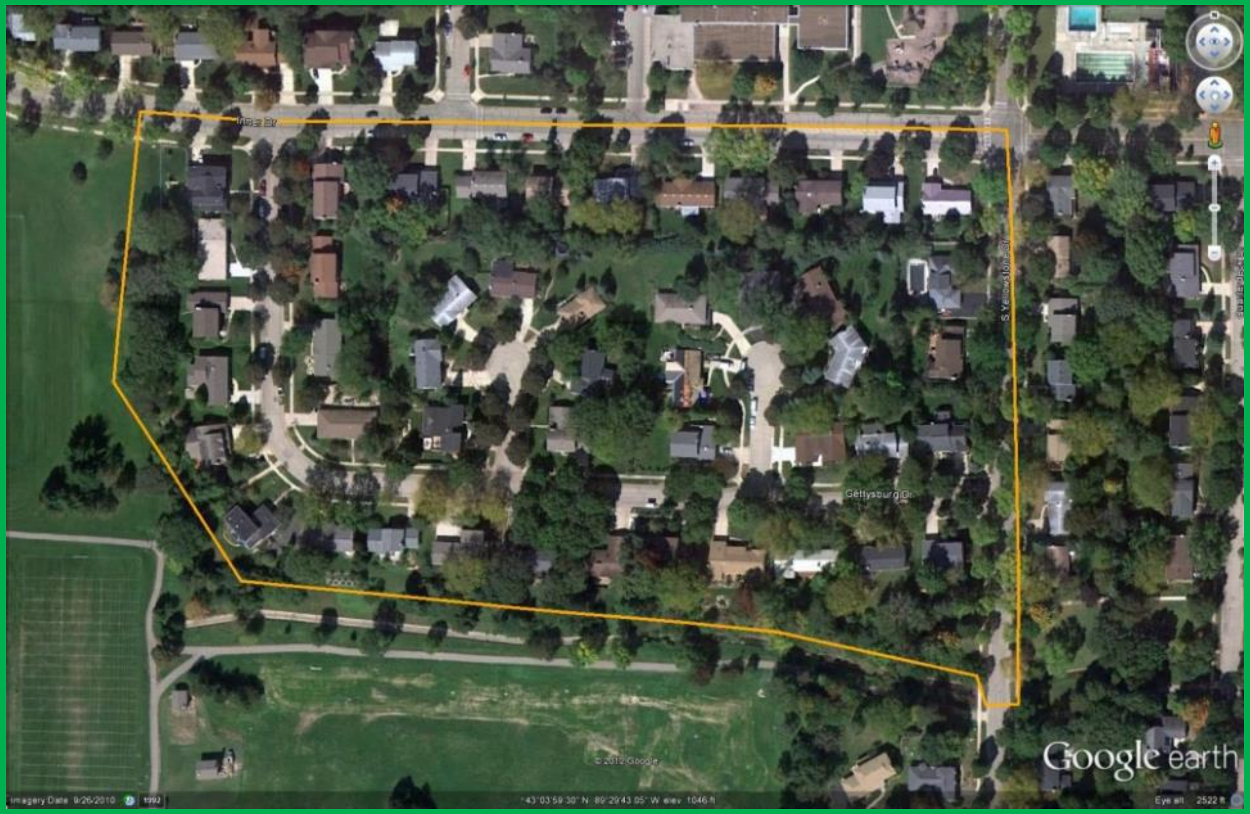
Approach: Paired-basin study design

Type of Leaf Management Program to be Tested					
	2013	**2014**	**2015**	**2016**	**2017**
Control	No Collection	No Collection	No Collection	No Collection	Report
Test	No Collection	Existing	Vacuum	TBD	Report

TBD = to be determined

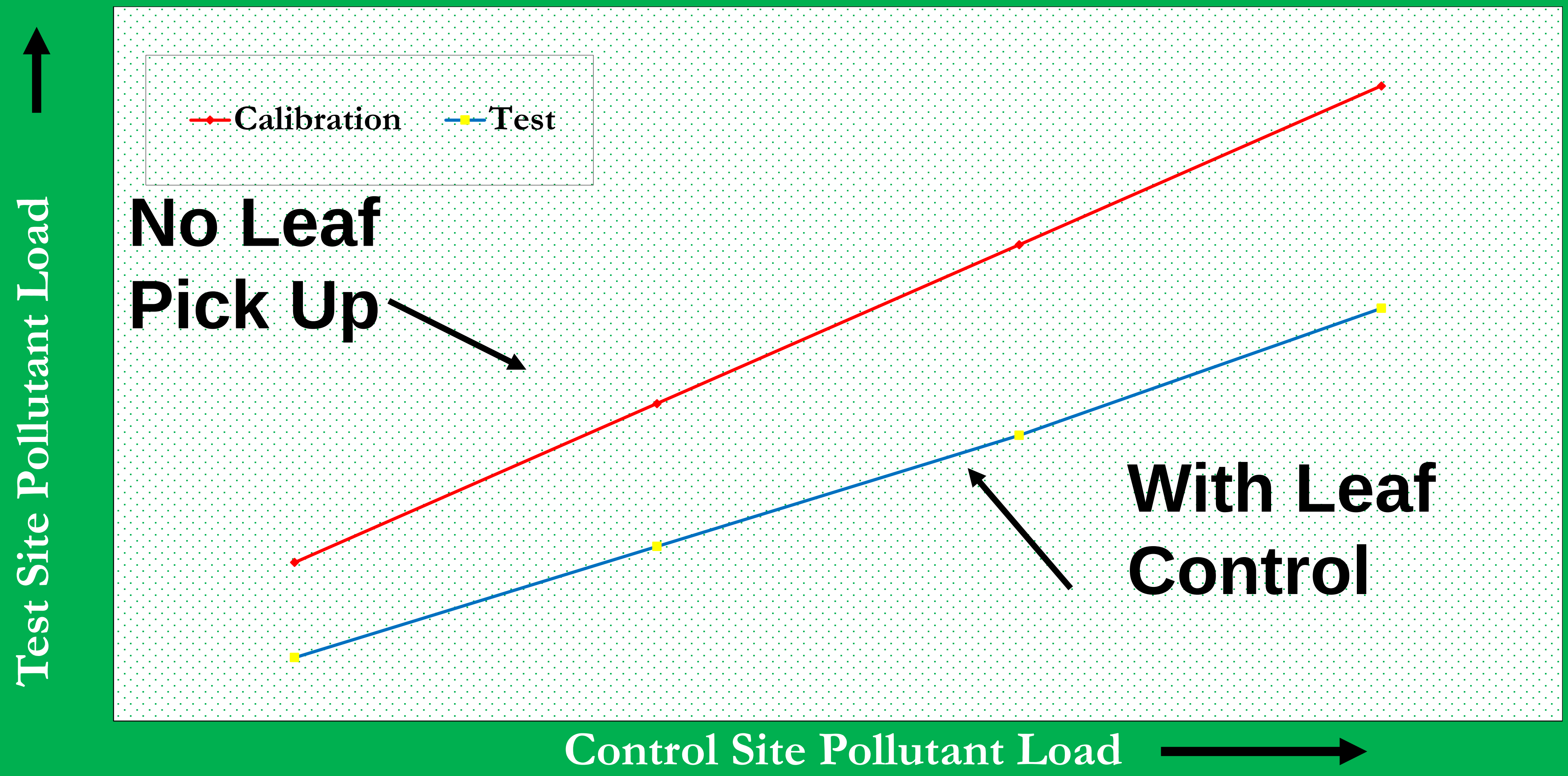


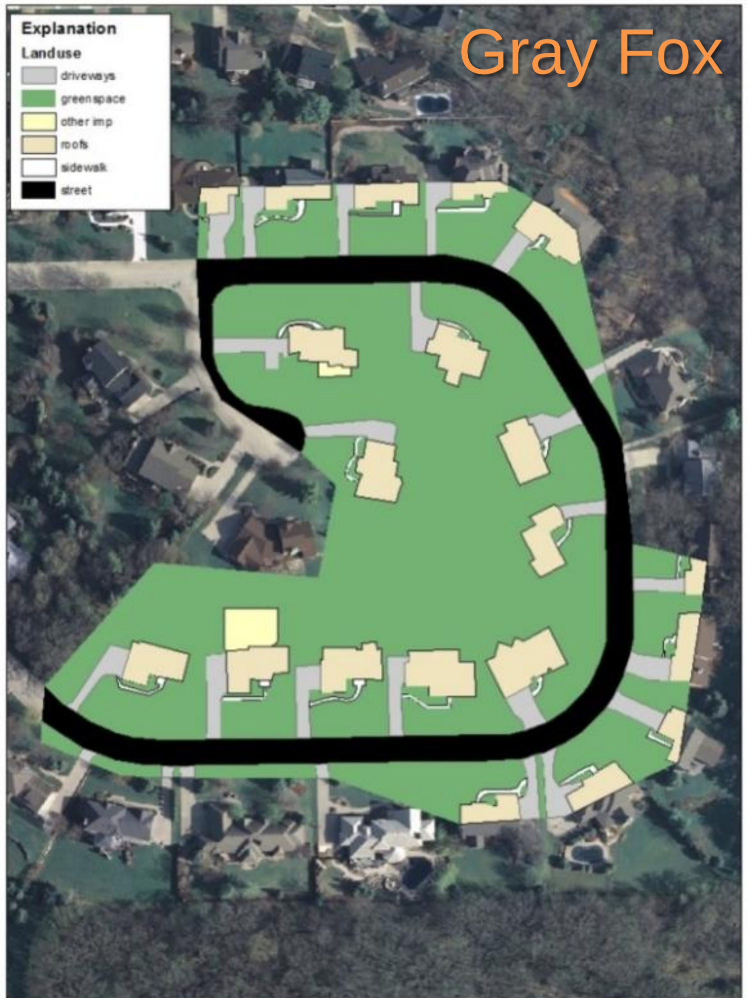
Control
no practices



Test
existing/escalated practices

Expected Change in Relationship Between Control and Test Site Pollutant Loads





	Study Basin			
Source Area	Yellowstone	East Kenosha	West Kenosha	Gray Fox
Area (ac.)	15.9	3.0	2.5	9.1
Streets	17%	19%	17%	14%
Driveways	6%	4%	5%	8%
Roofs	17%	19%	16%	13%
Sidewalks	5%	3%	4%	1%
Lawns/Open	55%	54%	58%	63%
Other Impervious	<1%	0%	0%	1%
Tree Cover	45%	68%	57%	26%

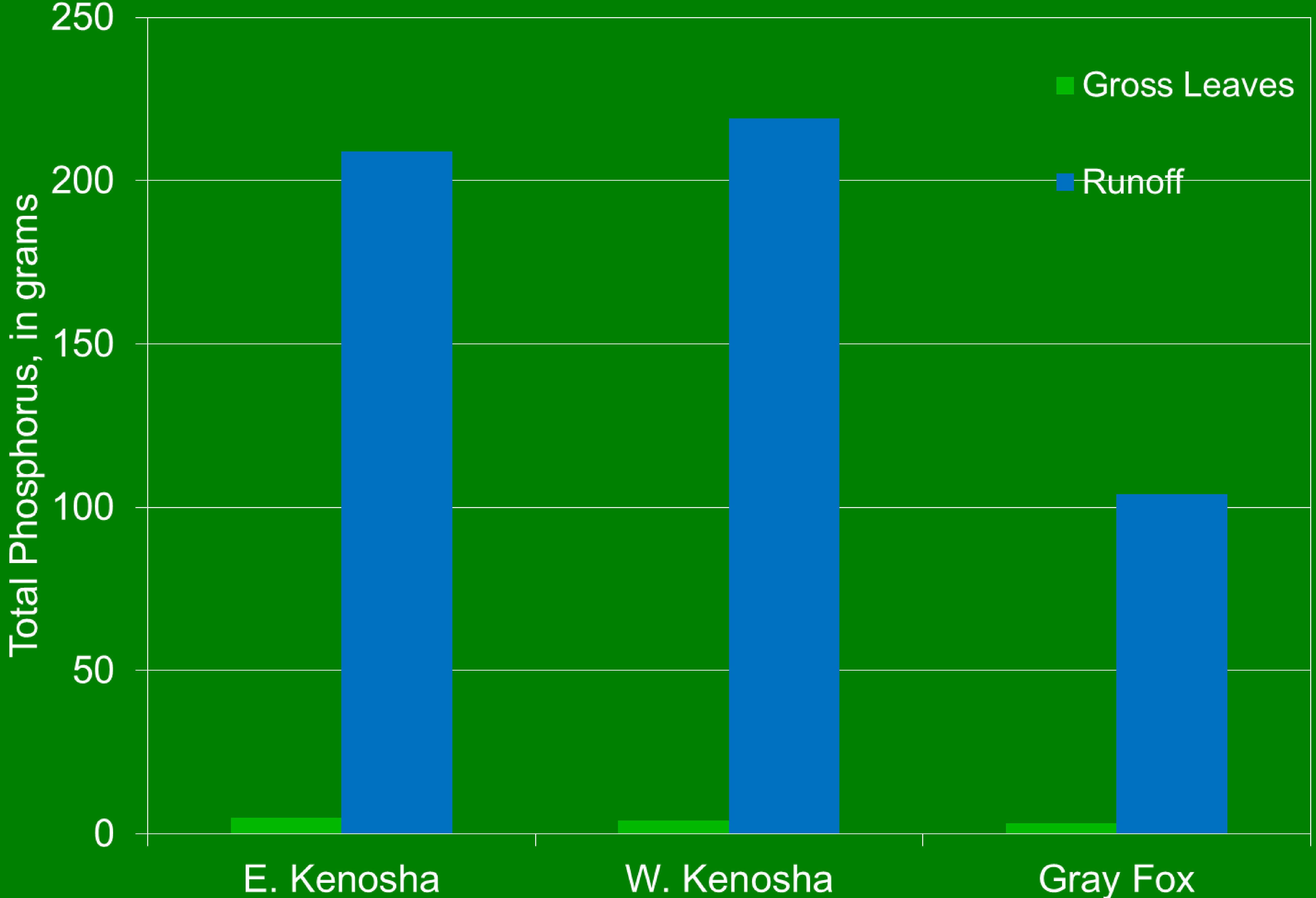
Water Quality Monitoring

Measurement of Phosphorus in Water and Leaves

Photos by USGS

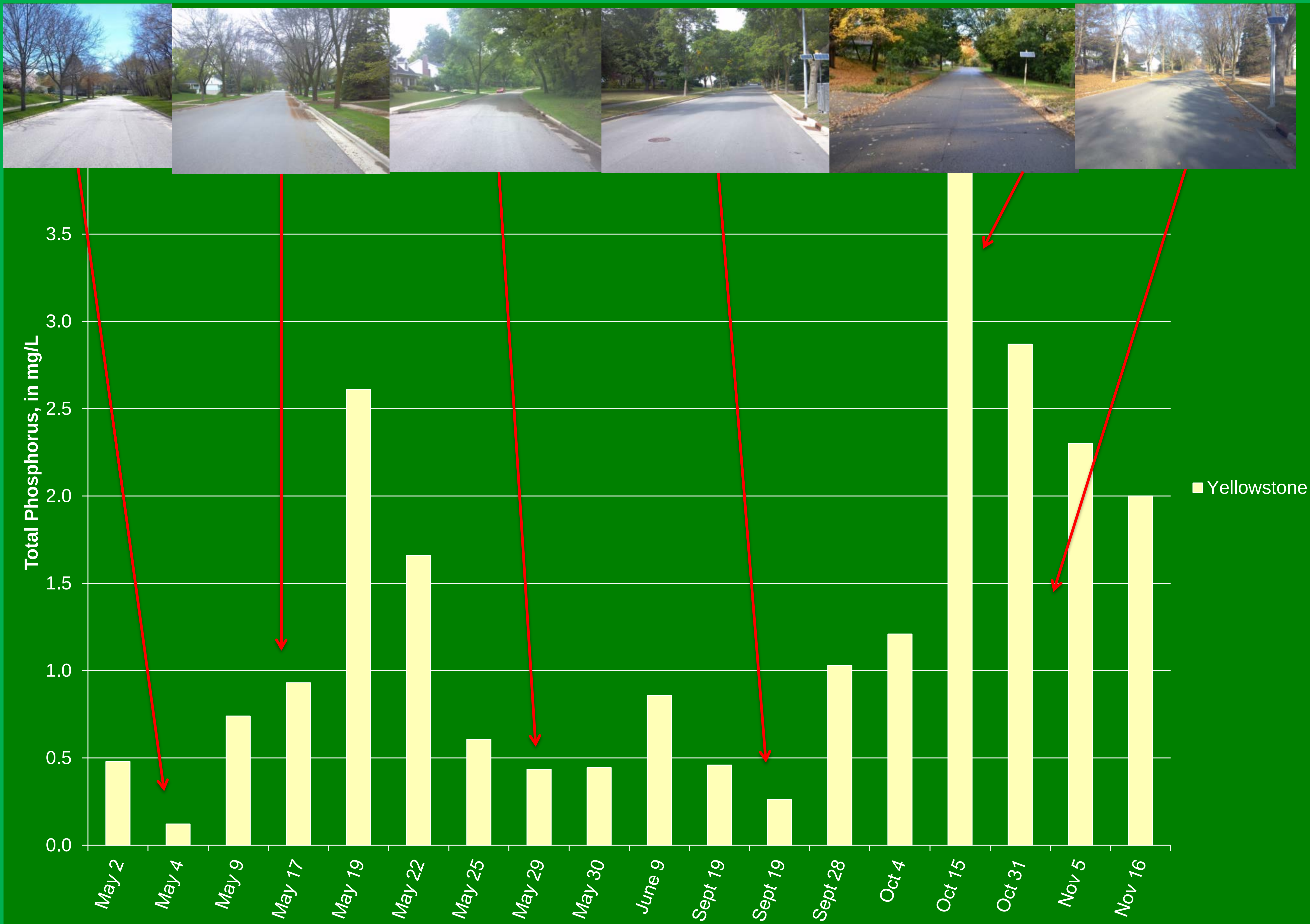
Gross Solids (Leaves) Processing Facility - MMSD

Period 09/19 – 10/28/2013



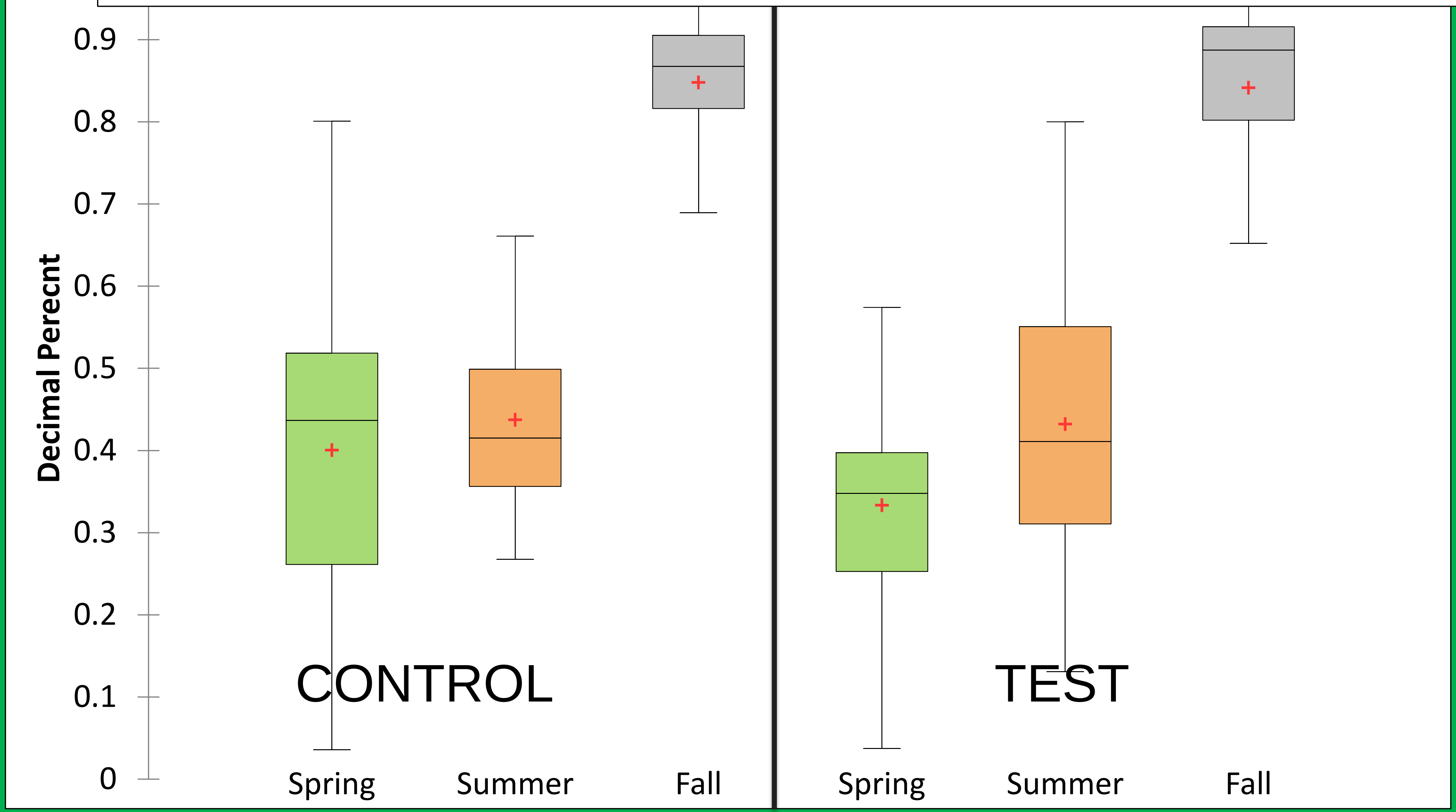
Vegetative “Dam”

Total Phosphorus Concentration – Calibration Phase 2013



Leaf Collection One of few Options to Reduce Dissolved Phosphorus

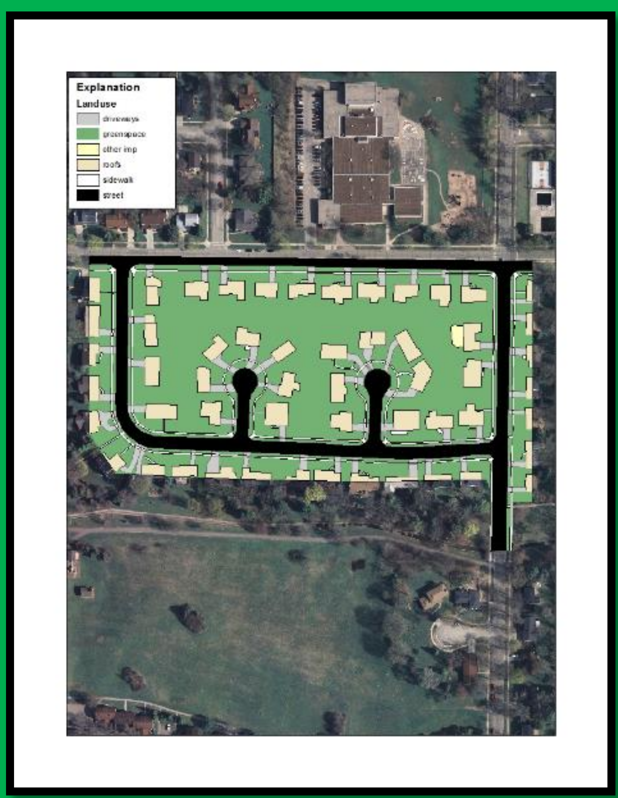
Leaf collection may be one of only a few options to reduce dissolved phosphorus since structural controls do not effectively remove the dissolved fraction.



Study of Leaf Collection Management

Collect water-quality samples from a control and test basin to determine if removing leaves will result in measurable changes in phosphorus loads.

Paired Basin Study Design



Control

Test

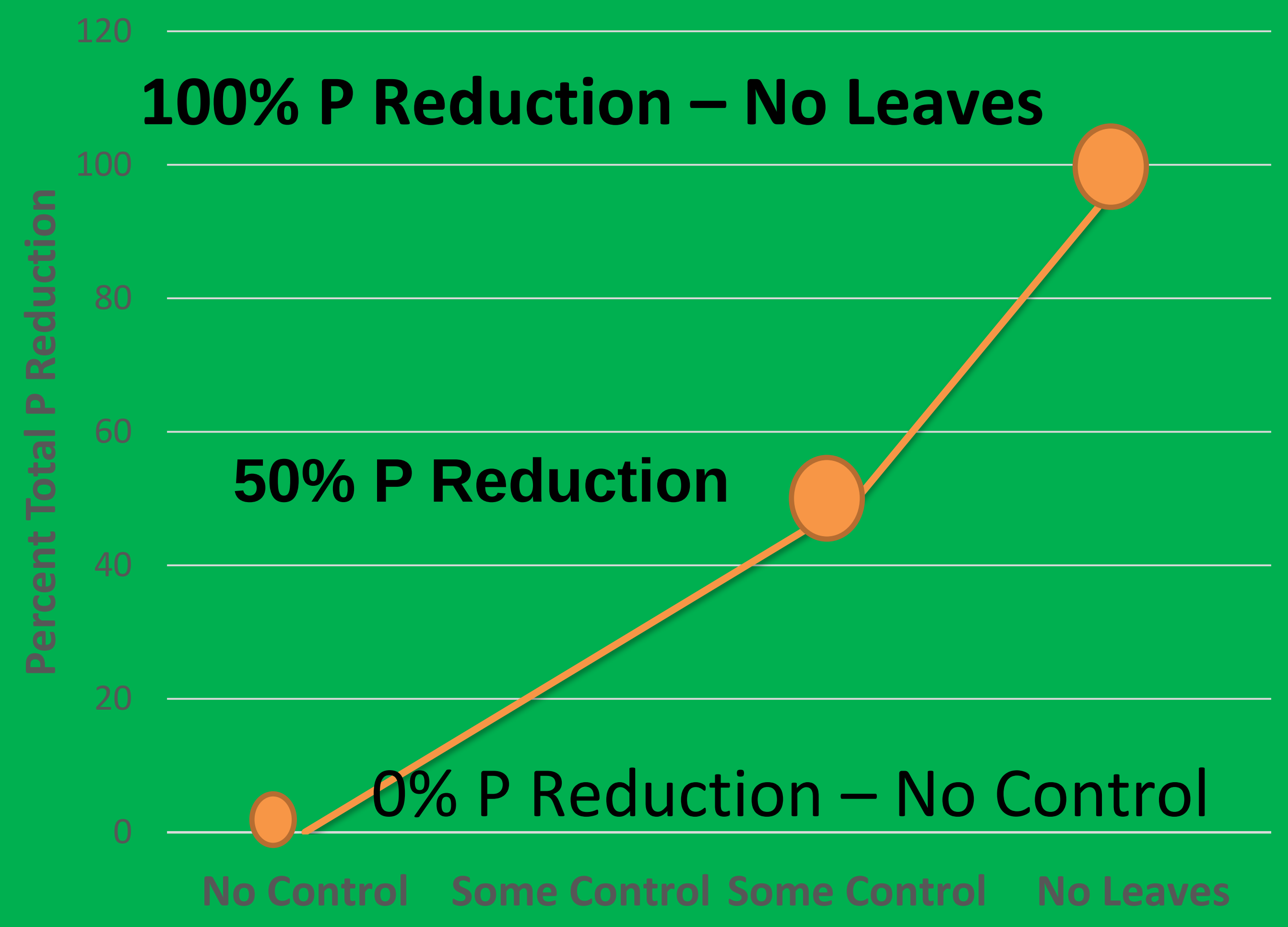
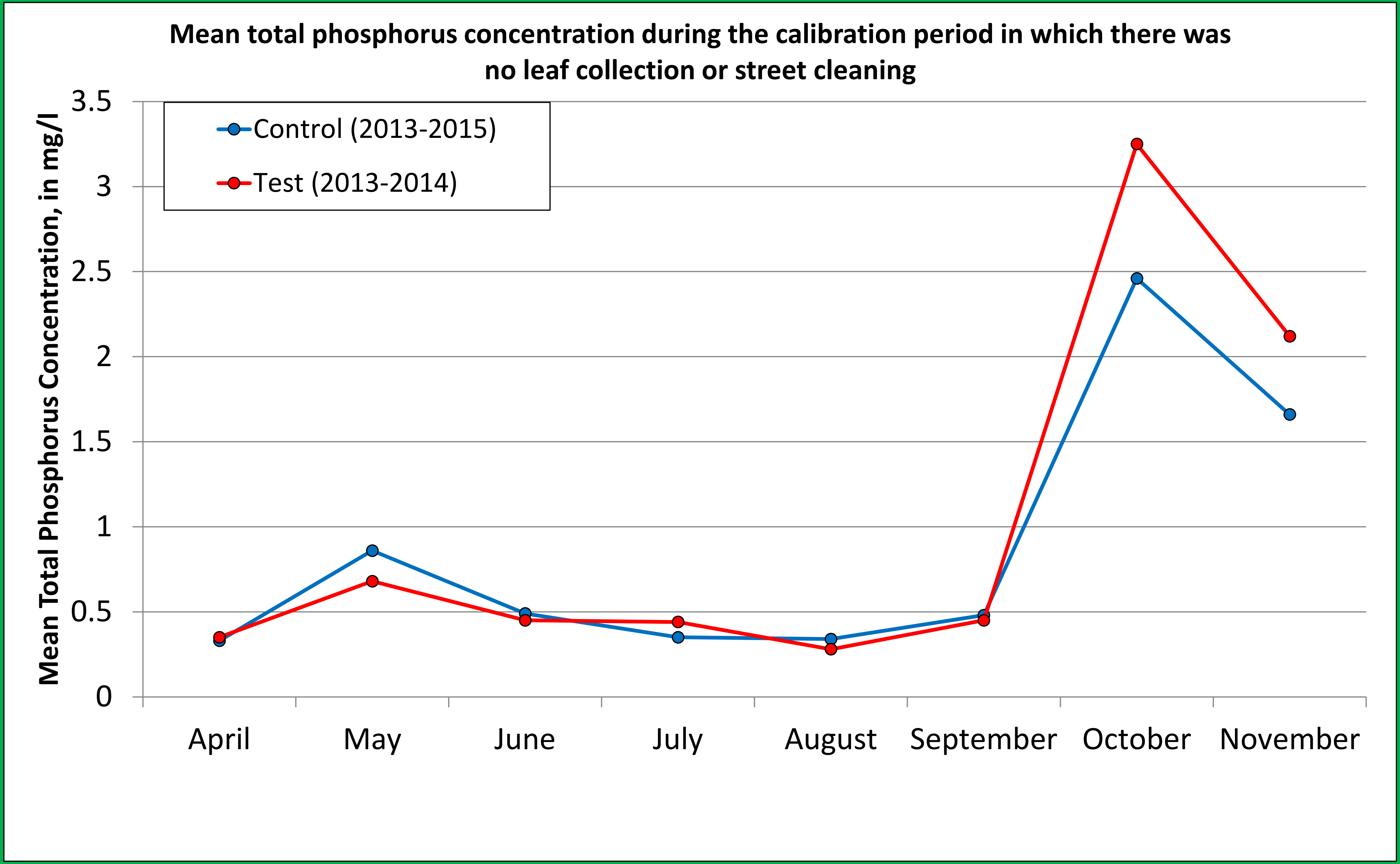


Photo Credit: USGS



Complete Leaf Removal – Maximum Effort (2015)

1. Weekly street cleaning in spring and summer
2. Weekly collection of leaf piles followed by street cleaning in fall

Photo Credit: USGS

Photo Credit: USGS

Plus…

Complete Leaf Removal – Maximum Effort

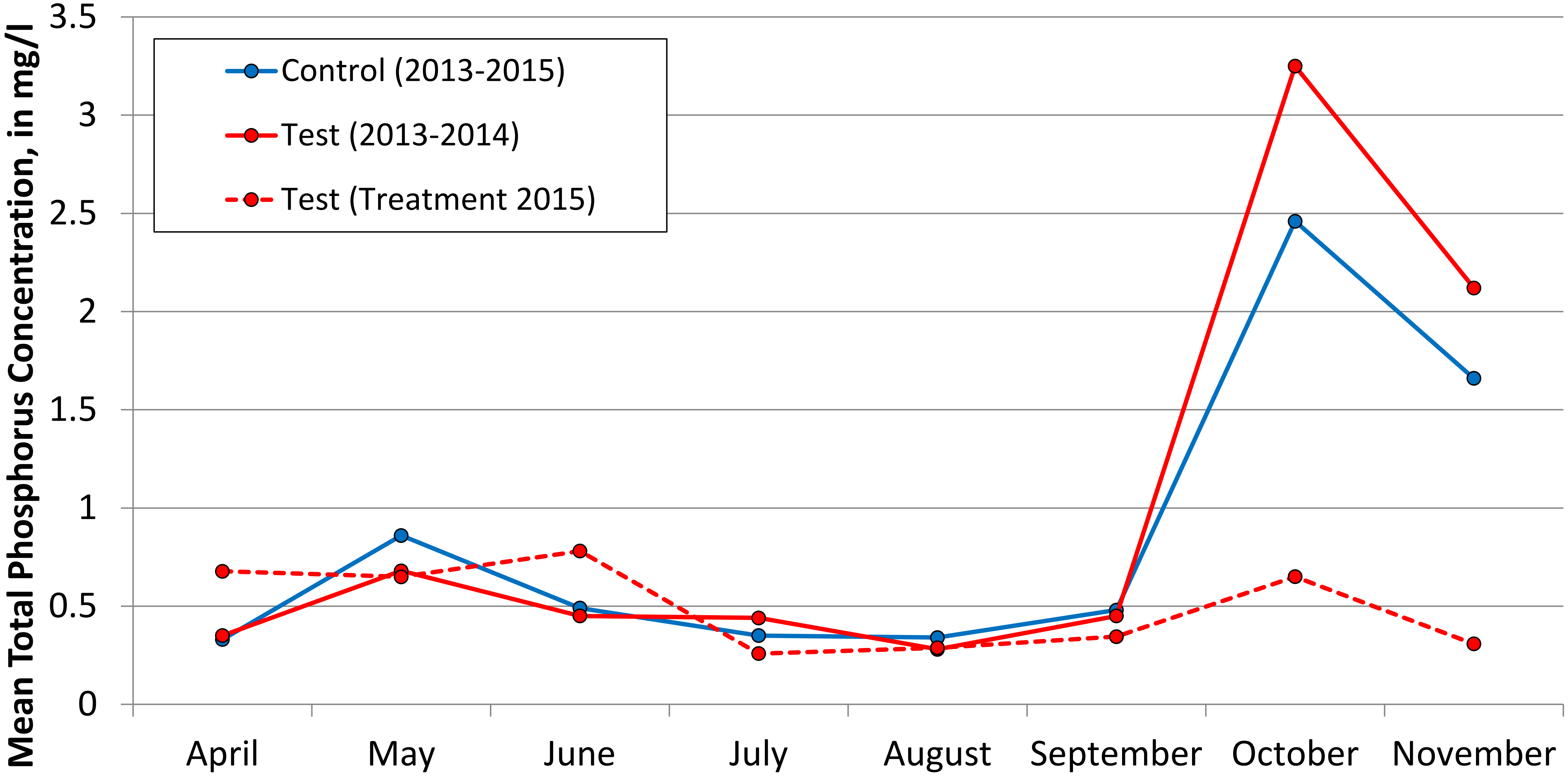
In addition to municipal efforts, USGS field crews would clear all organic debris from street surface prior to rain event

Photo Credit: USGS

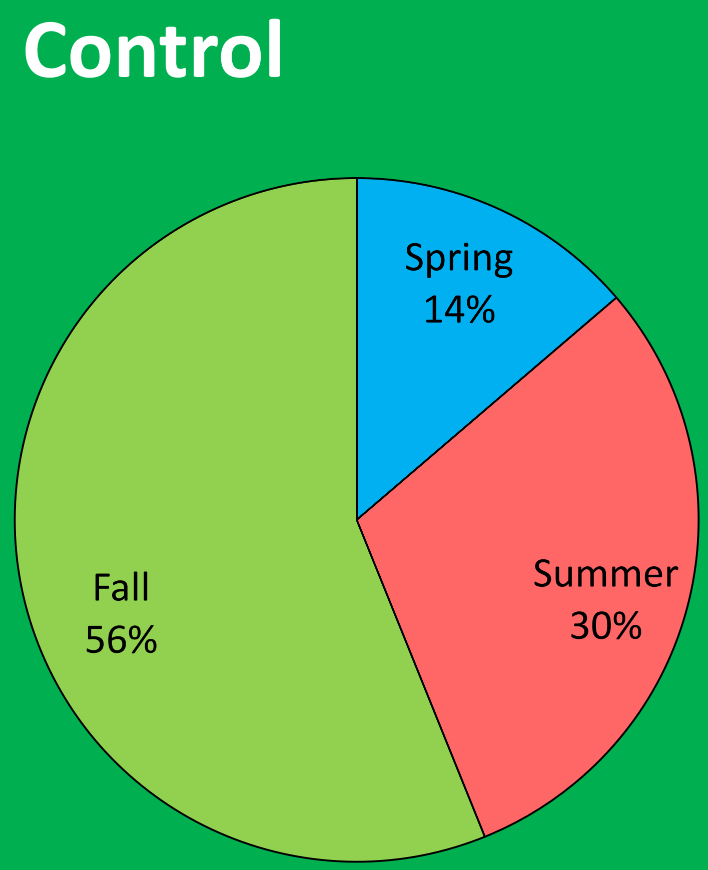
Photo Credit: USGS

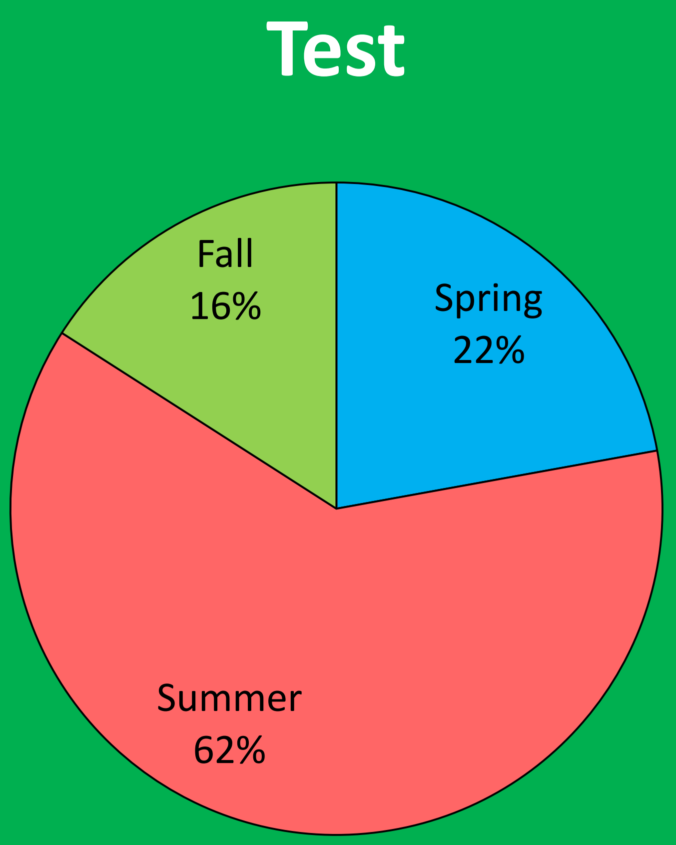
Photo Credit: USGS

Mean total phosphorus concentration during the calibration period compared to the treatment period in which there was weekly leaf collection and/or street cleaning

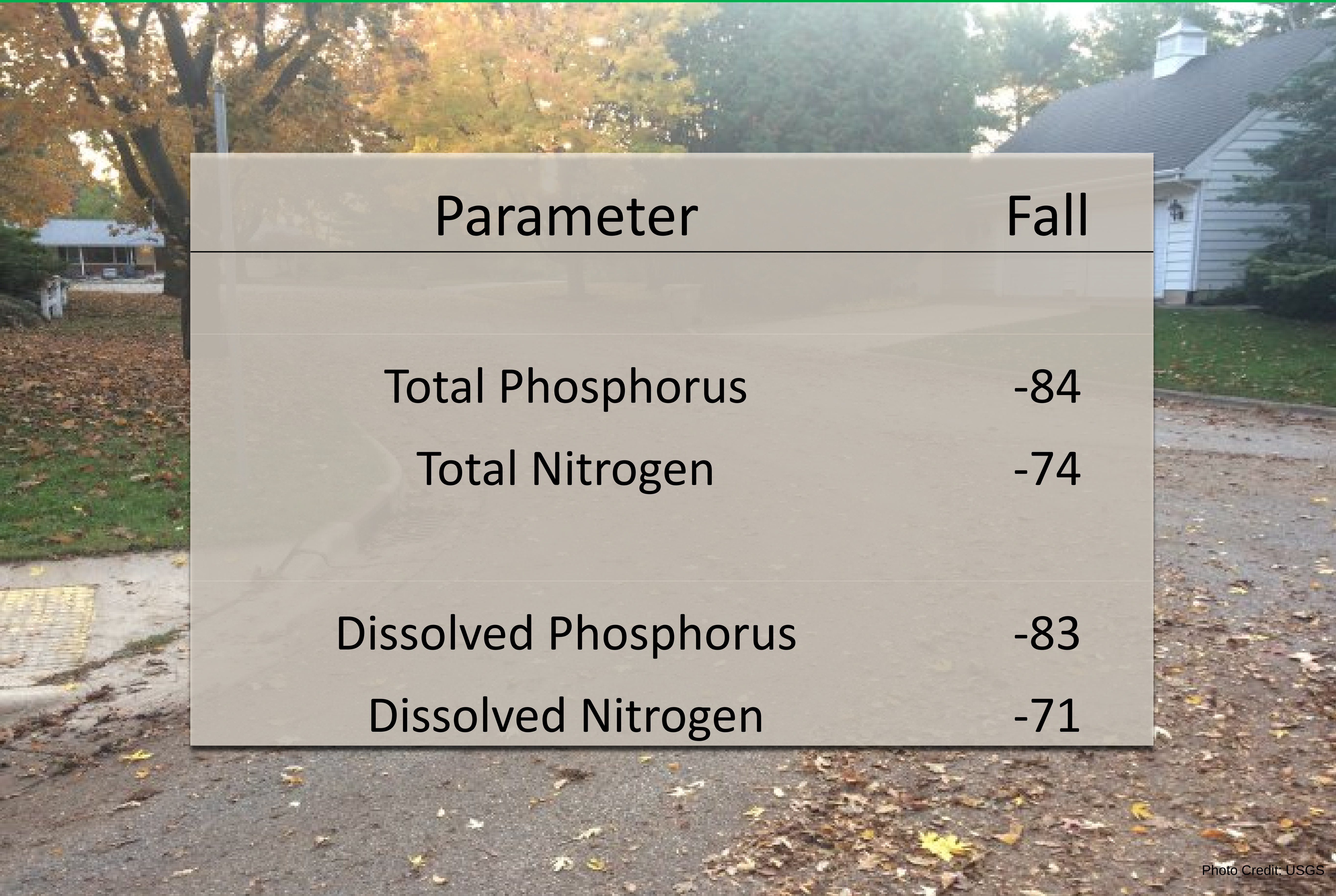


Seasonal Total Phosphorus Yield as a Percent of the 2015 Annual Yield (winter excluded)





Percent Reduction in Nutrient Load - 2015



Parameter	Fall
Total Phosphorus	-84
Total Nitrogen	-74
Dissolved Phosphorus	-83
Dissolved Nitrogen	-71

Photo Credit: USGS

City of Madison – Leaf Transfer plus Sweeping (2016)

1. Transfer leaf piles from terrace into street then pick up with garbage truck
2. Leaf collection followed by street cleaning
3. Frequency = approximately every 20 days

Leaf Transfer and Street Cleaning Every ~20 Days

Reduction of Nutrient Load in Stormwater Using the Transfer Method - 2016

Nutrient	Percent Reduction
Total Phosphorus	40
Total Nitrogen	--
Dissolved Phosphorus	45
Dissolved Nitrogen	--

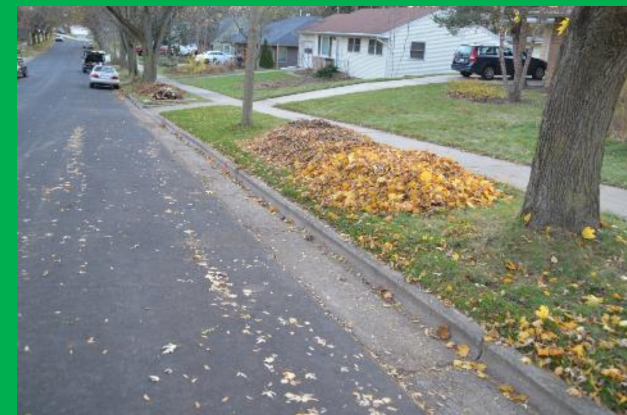
Photo Credit: City of Madison

Preliminary Information – Subject to Revision. Not for Citation or Distribution

What Did We Learn in the Madison Paired Site Projects?

Compared to Leaves on terrace but no cleaning - Baseline

2
0
1
6



Leaves on terrace, transfer & street clean ~3-4x:

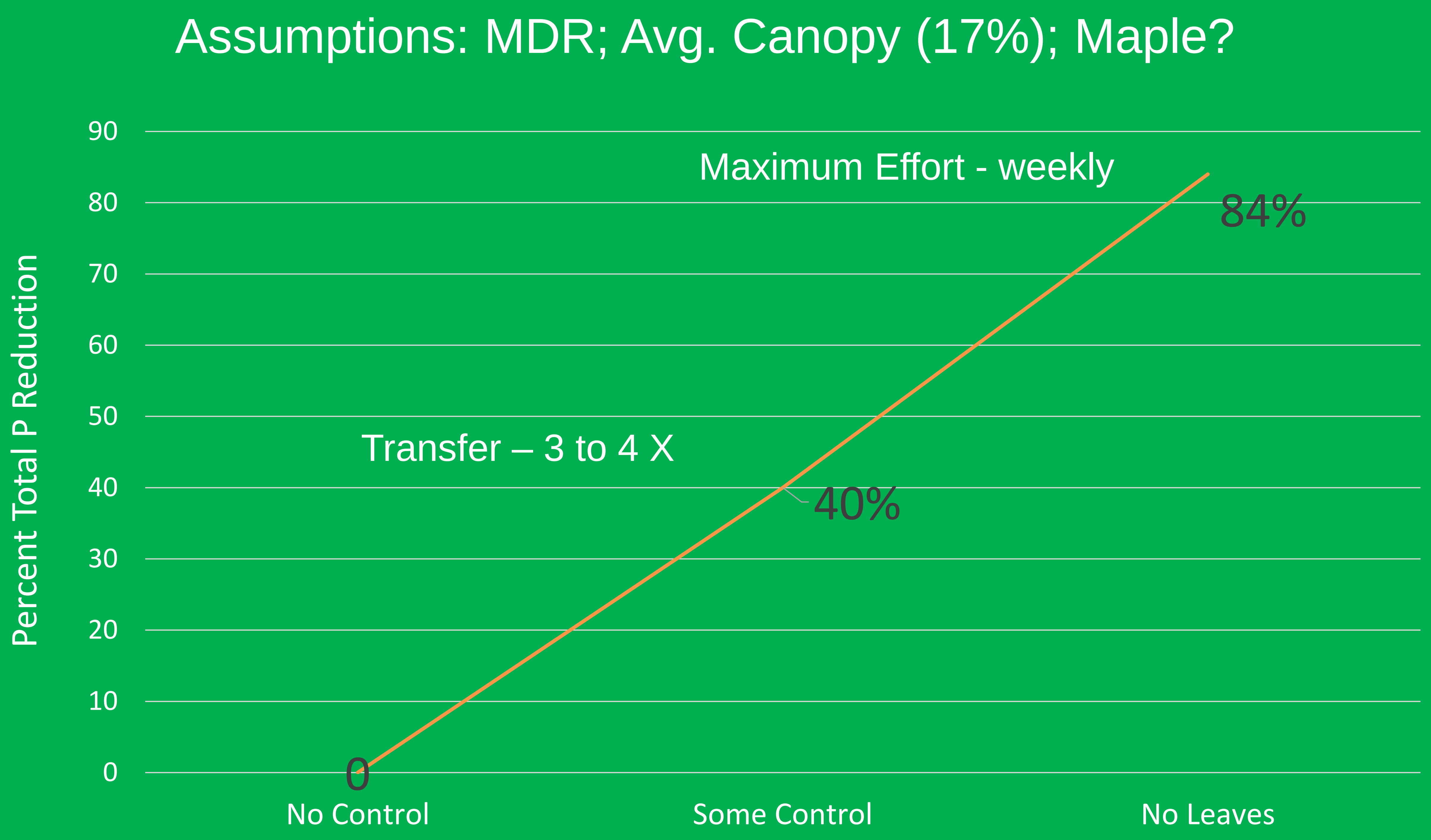
40 Percent Total P Reduction

2
0
1
5

Leaves on terrace, weekly cleaning + Pickup + Pre rain removal

84 Percent Total P Reduction

Study of Leaf Collection Management

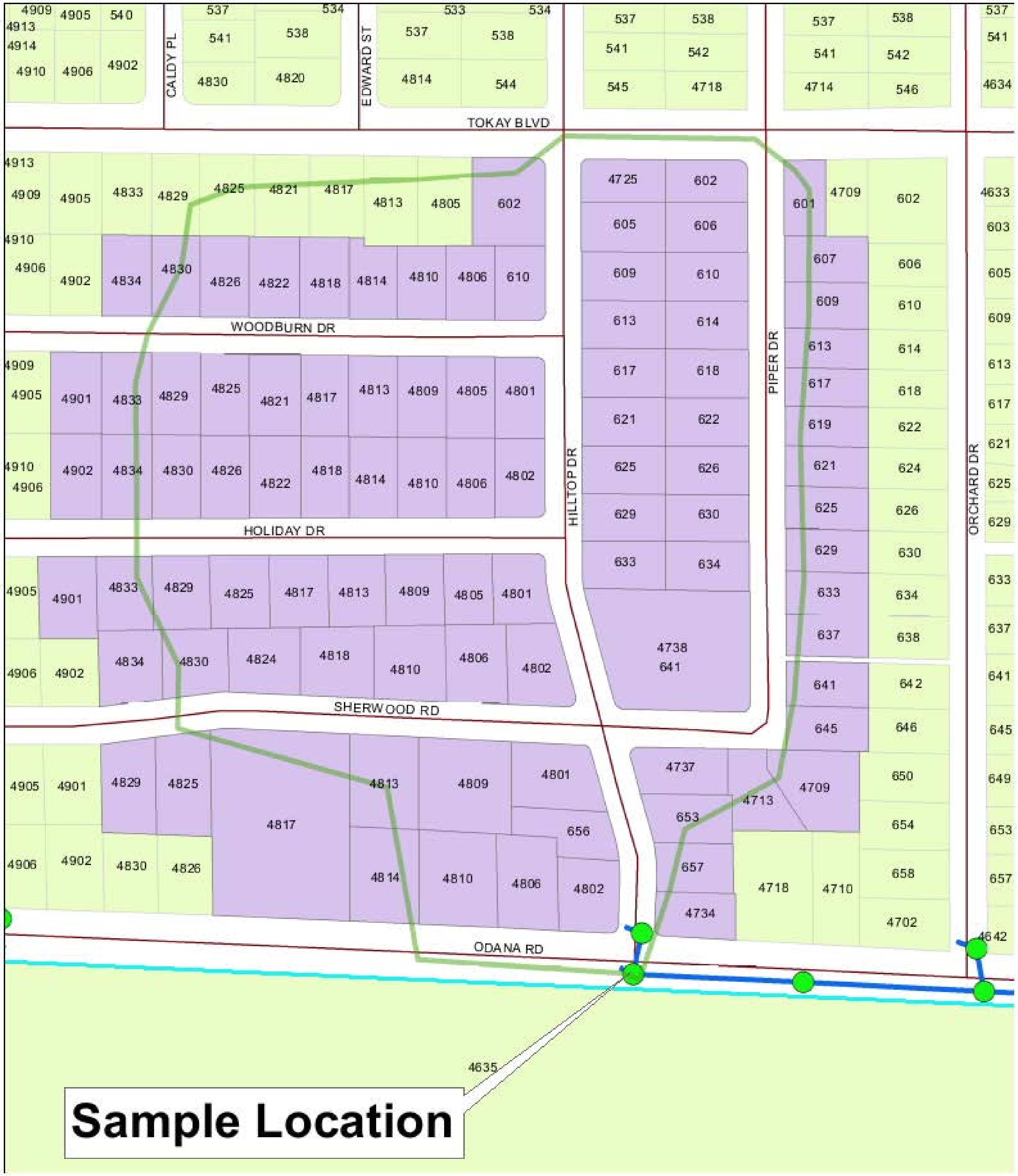


What happened in the fall of 2017?

Use Vacuum System to Clean Streets Once Per Week, but Only Pick-up Leaves four times During the Fall

Before cleaning

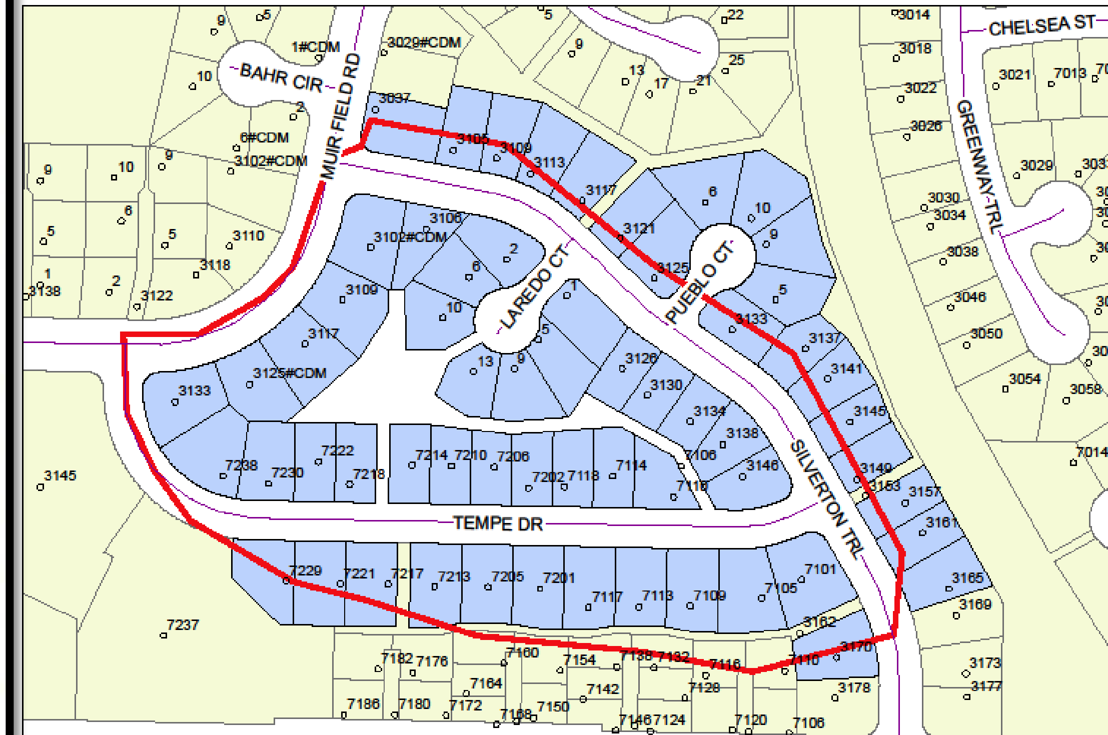
After cleaning



Leaf Pilot Area
Odana

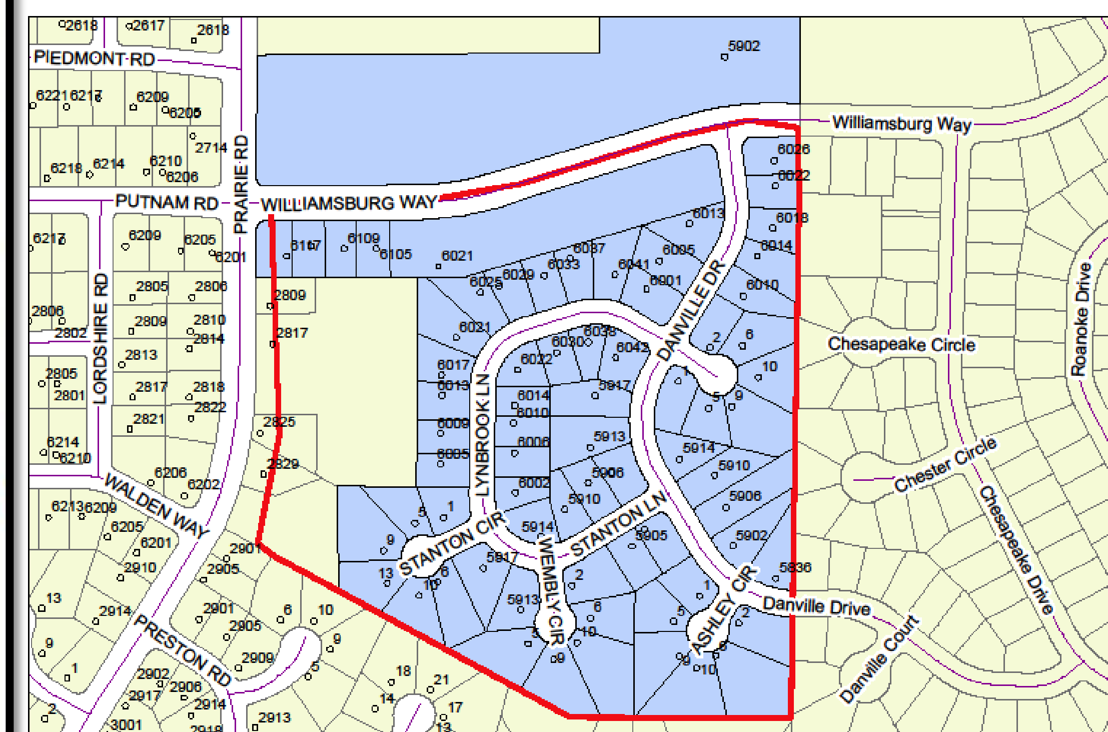
Vacuum Collection Parcel

0 62.5 125 250 375 500 Feet



Leaf Study 2017 - No Collection Parcels
Silverton Study Area

Legend
No Leaf Collection Parcels



Leaf Study 2017 - No Collection Parcels
Danville Study Area

Legend
No Leaf Collection Parcels

Leaf Collection and Street Sweeping Practices

Leaf Collection		Street Cleaning			
Method	**Frequency**	**Method**	**Frequency**	**Program Name**	**Year Completed**
Transfer	Weekly	Mechanical/blower	Pre-event	Maximum	2015
Transfer	3-4x/season	Mechanical	3-4x/season	SOP	2016
Transfer	3-4x/season	Regenerative Air	Weekly	SOP+	2017
Vacuum	Weekly	Regenerative Air	Weekly	Vacuum	2017

Leaf Collection and Street Sweeping Practices RESULTS

Leaf Collection		Street Cleaning			
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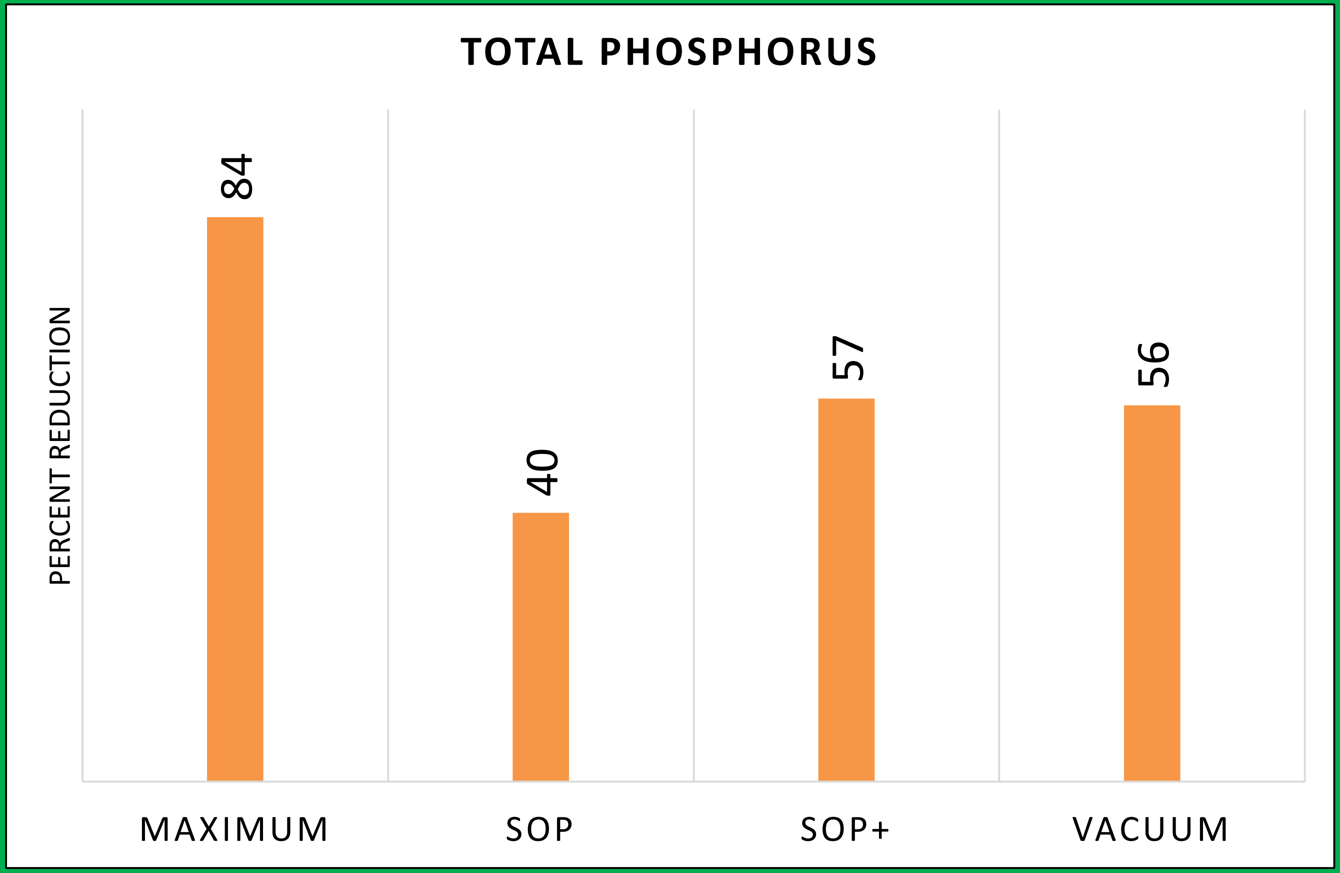

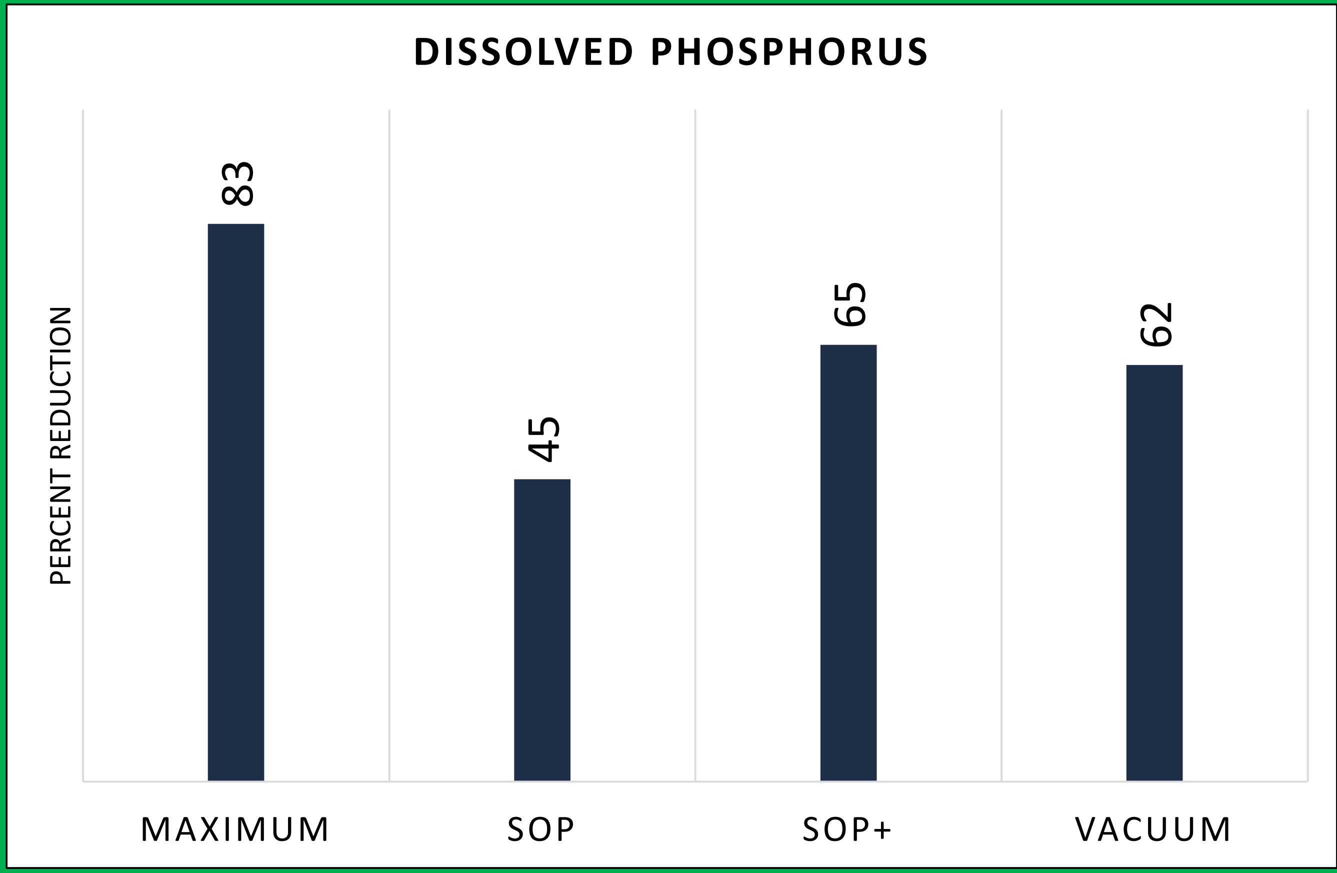

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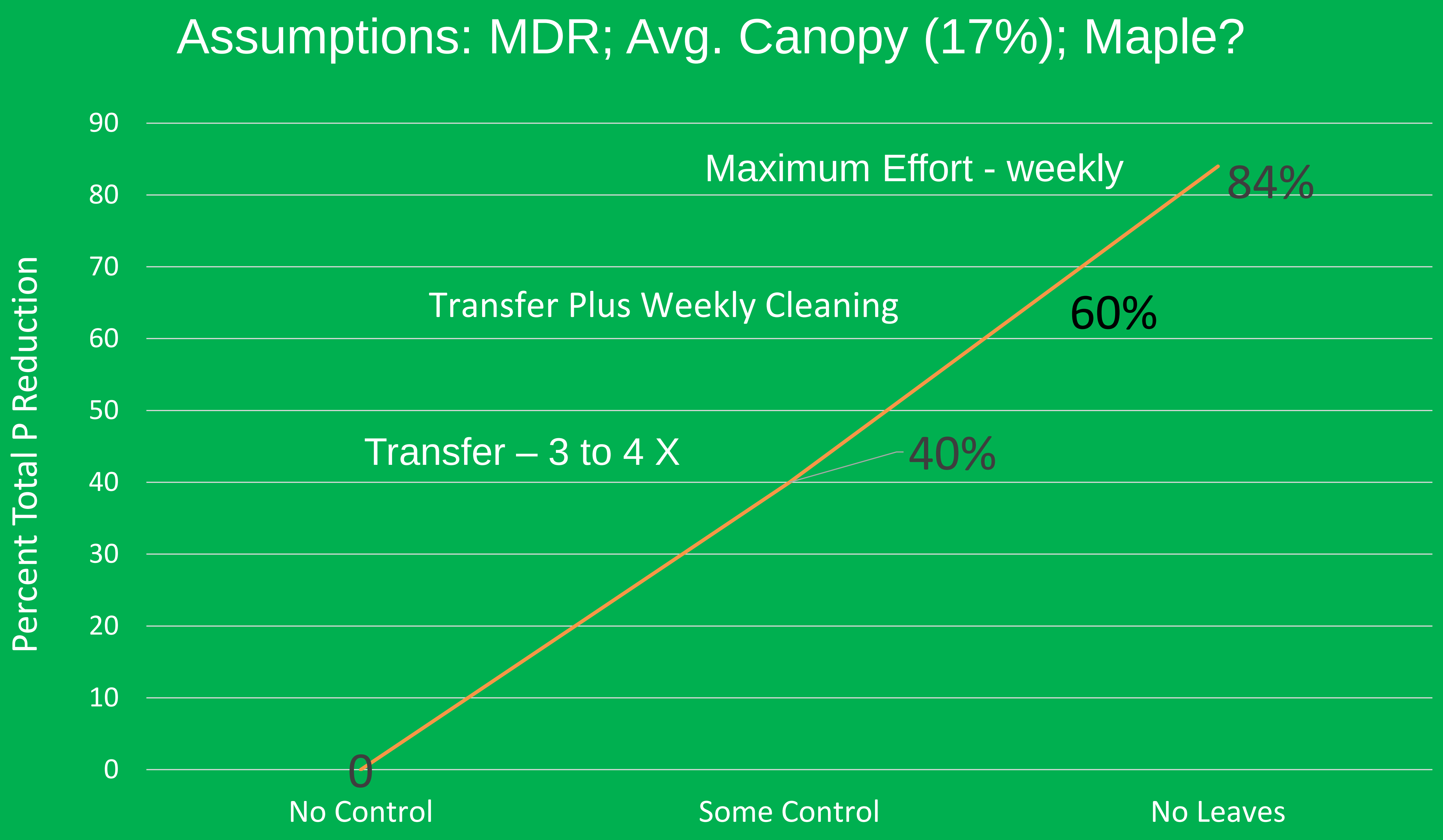

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Phosphorus Reduction Credit for Leaf Management Programs

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DEPT. OF NATURAL RESOURCES

BUREAU OF WATERSHED MANAGEMENT
PROGRAM GUIDANCE

RUNOFF MANAGEMENT POLICY AND MANAGEMENT TEAM
Storm Water Management Program

Wisconsin Department of Natural Resources
101 S. Webster Street, P.O. Box 7921
Madison, WI 53707-7921

Interim Municipal Phosphorus Reduction Credit for Leaf Management Programs

03-08-18
EGAD Number: 3800-2018-01

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APPROVED:

Pam Biersach (signature) — March 8, 2018
Pam Biersach, Director
Bureau of Watershed Management
Date

1

EXAMPLE CALCULATION:

- **Leaf collection and street cleaning (>= 4x) = 40%**
- **Annual phosphorus contribution in Fall = 43%** (based on 20-yr average)
- **MDR land use with high tree canopy in your city = 60%** (as an example)

Annual Phosphorus Reduction Credit = (40% X 43% X 60%) = *10 %*

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Annual Phosphorus Reduction Credit = (60% X 43% X 60%) = *15 %*

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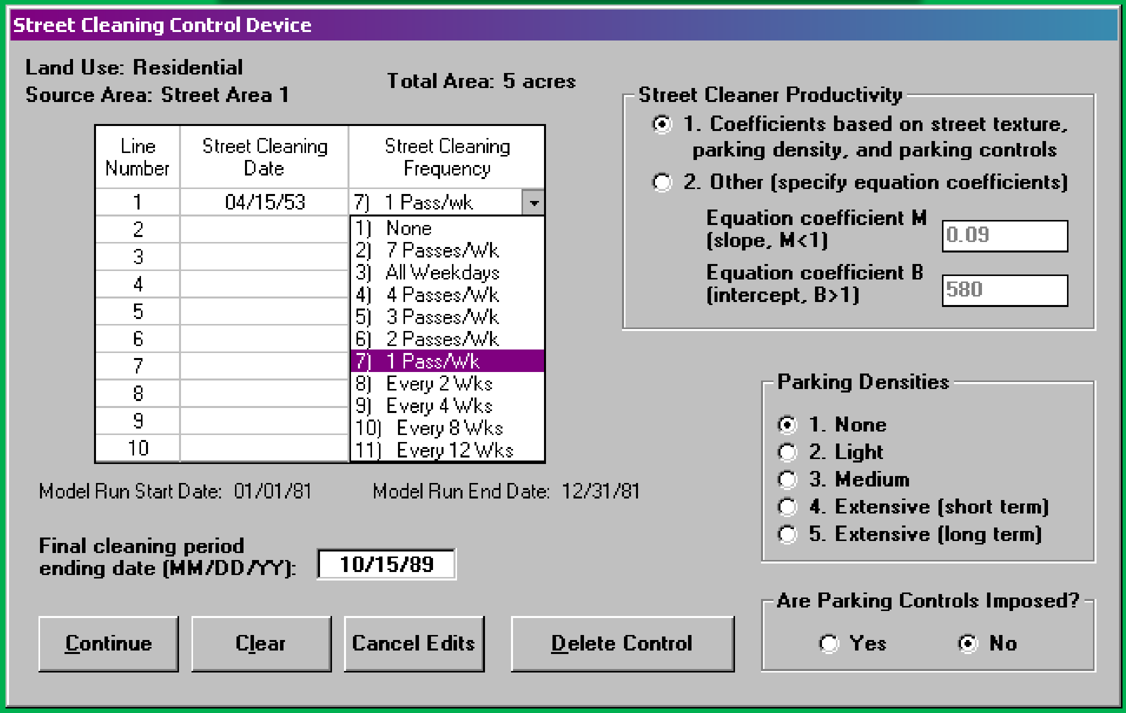
How Do We Use Water Quality Monitoring Results to Predict Leaf Management Benefits?

We can use the percent reductions as measured – very site specific – limited to sites we can afford to monitor

To maximize flexibility, the cities will have to determine the benefits of selected management efforts; the results can be used to calibrate a model



What Variables Do We Hope to Focus On?

Cleaning Frequency

Tree Canopy

Leachable P in leaves.

Leaf Accumulation Rate

Species of Tree

27 out of 35 cities responded

Variable	1 per week	2 per month	1 per season
Frequency of Pickup	11	7	3

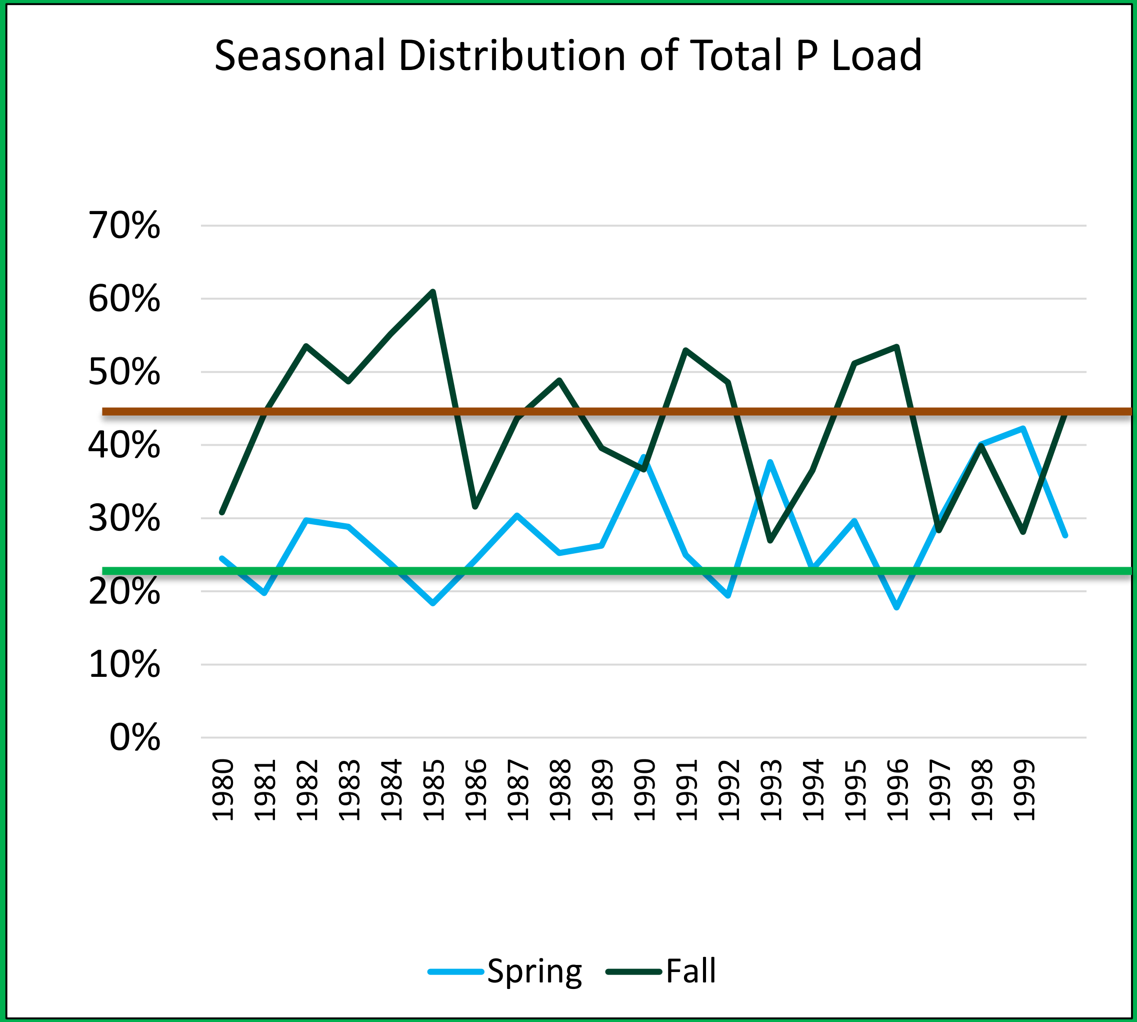
Variable	Street	Terrace	Bags
Placement of Leaves	9	12	3

Variable	Same Day as Pickup	Other
Street Cleaning Schedule	14	8

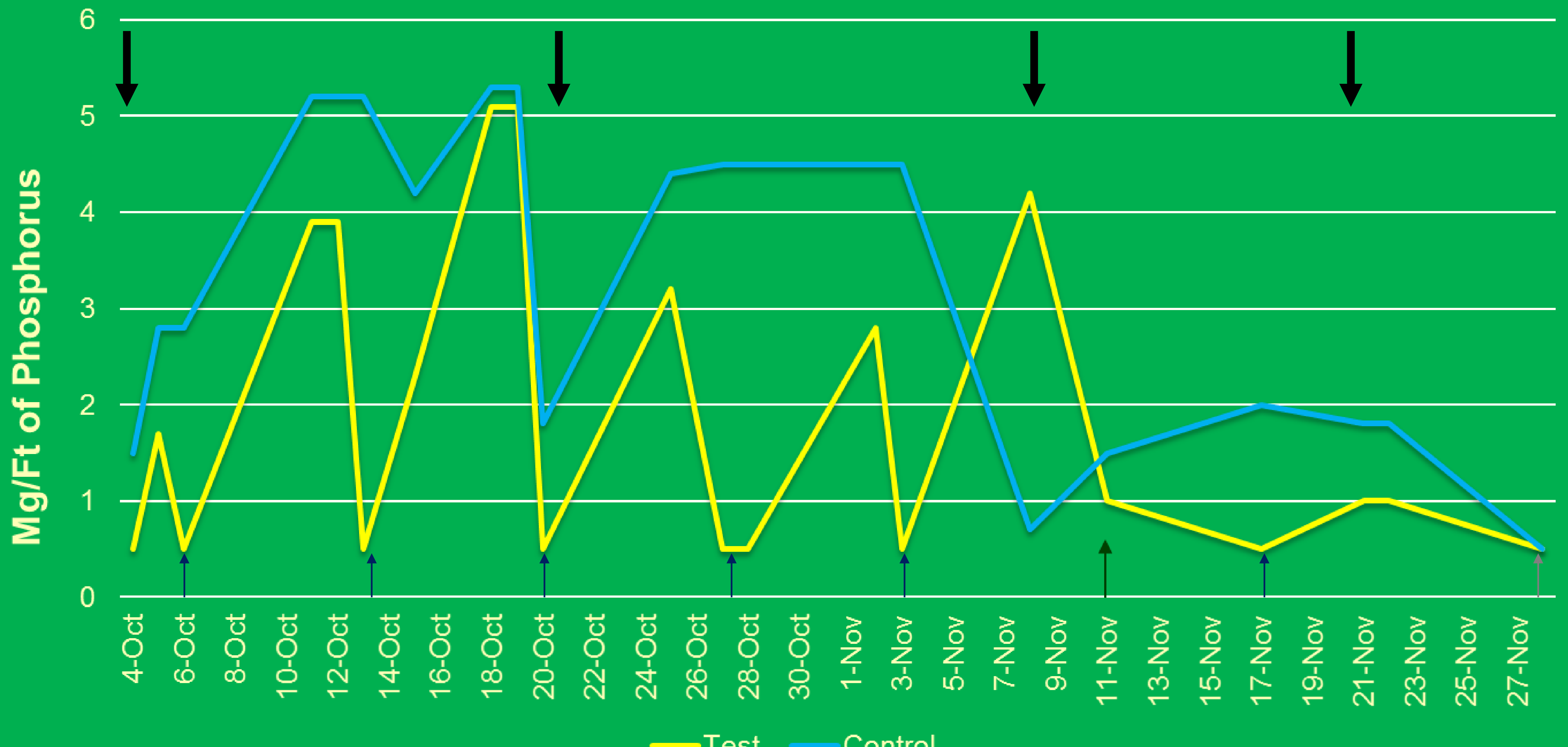
Variable	1 Week	2 Weeks
Avg Time Leaves on Curb	17	4

20-Year Distribution of Annual Phosphorus Load by Season

Season	Minimum %	Maximum %	Mean %
Spring	18	42	**28**
Summer	17	45	**29**
Fall	27	61	**43**



Comparison of Unit Loads Between Test and Control Areas – Mg of P per Ft of Curb



Test Cleaned = ↑

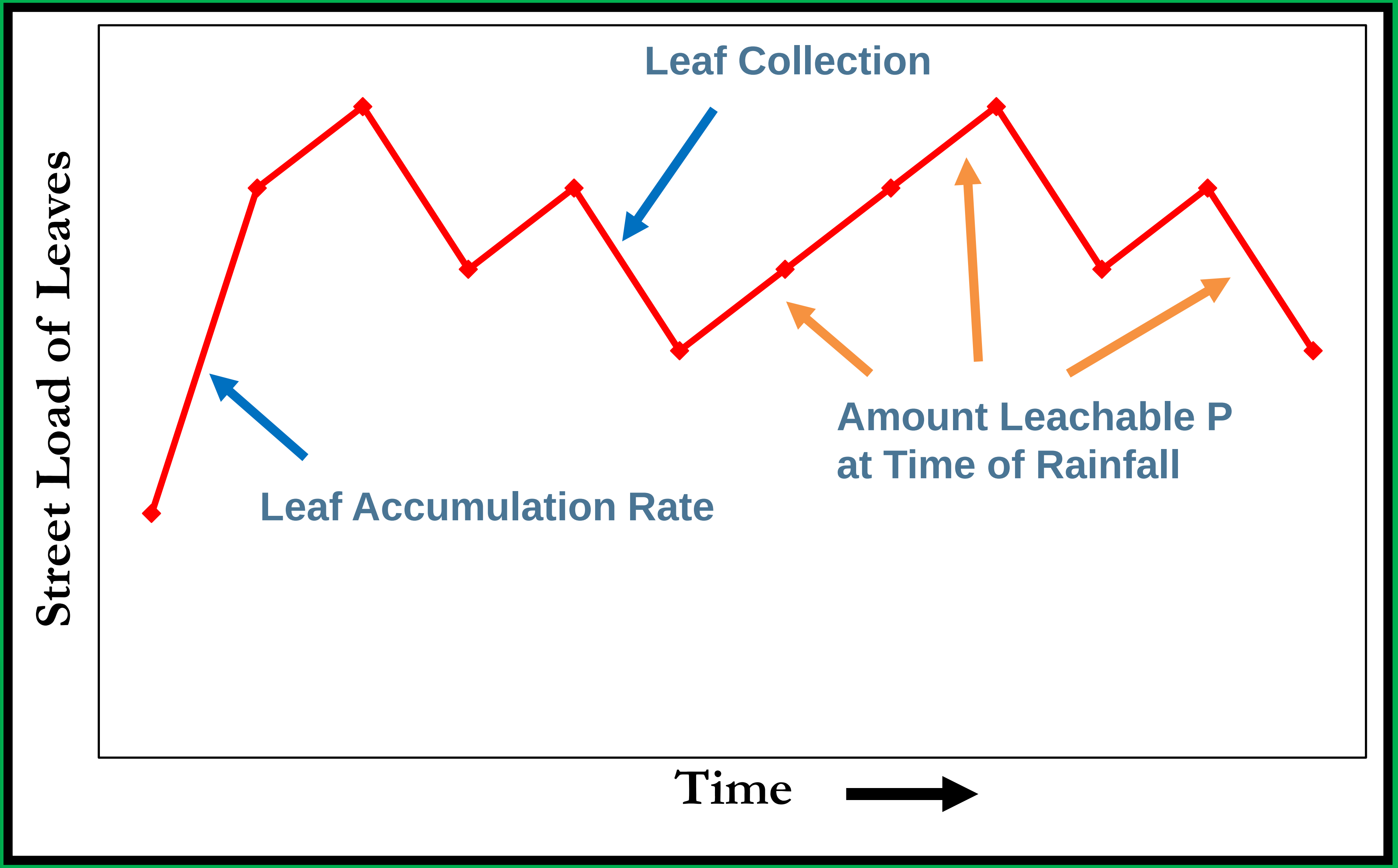
Control Cleaned = ↓

Comparison of Unit Loads Between Test and Control Areas – Mg of P per Ft of Curb

What About Tree Species?

Phosphorus in leaves

Leaf Accumulation Rate



Species of Tree

Estimate of the Amount of Phosphorus Leached from Leaves in the Pilot Area During the Fall of 2015

TABLE 1

Leachable P, total P and % of total P leachable (and standard deviation) from urban street tree leaves and seeds

Species name: Common name	Species name: Scientific name	Leachable P (μg gm^{-1})	Total P (%)	% of total P leachable	Number of samples: Leachable P	Number of samples: Total P
Leaves						
Sugar Maple	Acer saccharum Marsh.	259.9 (113.1)	0.20 (0.032)	13.43 (6.2)	6	3
Silver Maple	Acer saccharinum L.	232.7 (117.6)	0.13 (0.040)	17.7 (6.3)	3	3
Green Ash	Fraxinus pensylvanica Fern.	188.4 (75.1)	0.24 (0.049)	7.0 (0.43)	7	2
Honey Locust	Gleditsia tricanthos L.	176.0 (101.1)	0.44 (0.117)	4.5 (2.3)	8	5
White Ash	Fraxinus americana L.	161.9 (137.9)	0.14 (0.042)	9.6 (0.04)	4	2
American Elm	Ulmus americana L.	158.5 (66.8)	n.d.[b]	n.d.	2	0
Basswood	Tilia americana L.	95.7 (32.1)	0.15 (0.045)	7.8 (2.1)	5	3
Chinese Elm	Ulmus pumila L.	88.6 (36.1)	n.d.	n.d.	2	0
Little Leaf Linden	Tilia cordata L.	86.5 (22.5)	0.09 (n.d.)	6.7 (n.d.)	3	1
Pin Oak	Quercus palustris Muenchh.	81.5 (29.3)	n.d.	n.d.	2	0
Norway Maple	Acer platanoides L.	80.1 (53.9)	0.08 (0.035)	8.4 (3.63)	5	2
Hessian Ash	Fraxinus excelsior L.	66.1 (40.0)	n.d.	n.d.	3	0
Weeping Willow	Salix babylonica L.	38.1 (1.1)	n.d.	n.d.	2	0
All Leaves		148.1 (99.4)	0.22 (0.147)	9.3 (5.4)	52	21
LSD[a]		38.8	0.06	3.4		
Seeds						
Green Ash	Fraxinus pensylvania Fern.	77.6 (n.d.)	0.26 (n.d.)	3.0 (n.d.)	1	1
Sugar Maple	Acer saccharum Marsh.	40.8 (12.5)	0.35 (n.d.)	1.4 (n.d.)	2	1
Little Leaf Linden	Tilia cordata L.	39.2 (11.6)	0.26 (n.d.)	1.8 (n.d.)	2	1
All Seeds		47.5 (18.9)	0.29 (0.052)	2.1 (0.8)	5	3

[a] Least significant difference ($P \leq 0.05$).
[b] n.d. = not determined.

Dorney, 1986

Used published values to estimate leachable P in leaves

Average = 167 µg/g

167 µg/g x 453.6 g/lb = 76,000 µg

Or

0.076 grams of P per lb of leaves

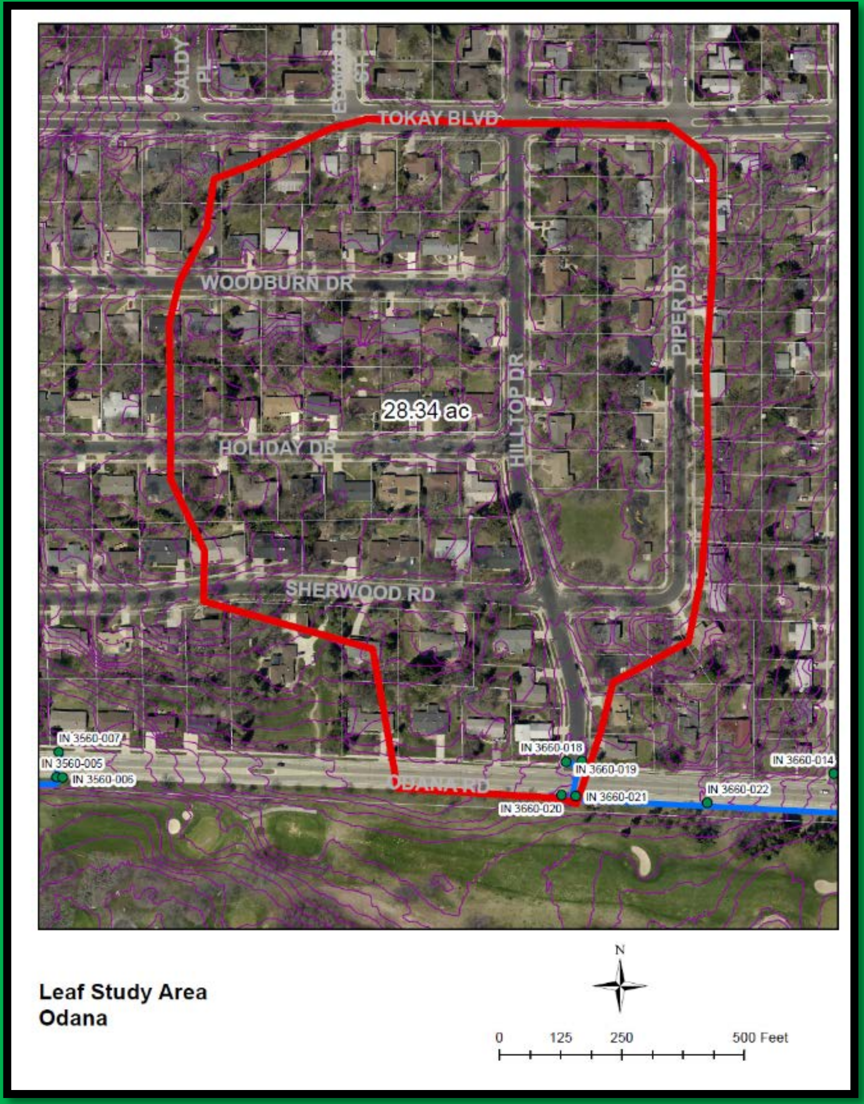
Categories of Leaf Mass on Streets

Category	Average Net Weight, lbs. (lb./ frontage)	Lbs. of Leaves Per Foot of curb
1	5	0.05
2	10	0.13
3	16	0.20
4	25	0.35

Estimating Leachable Phosphorus in Leaves

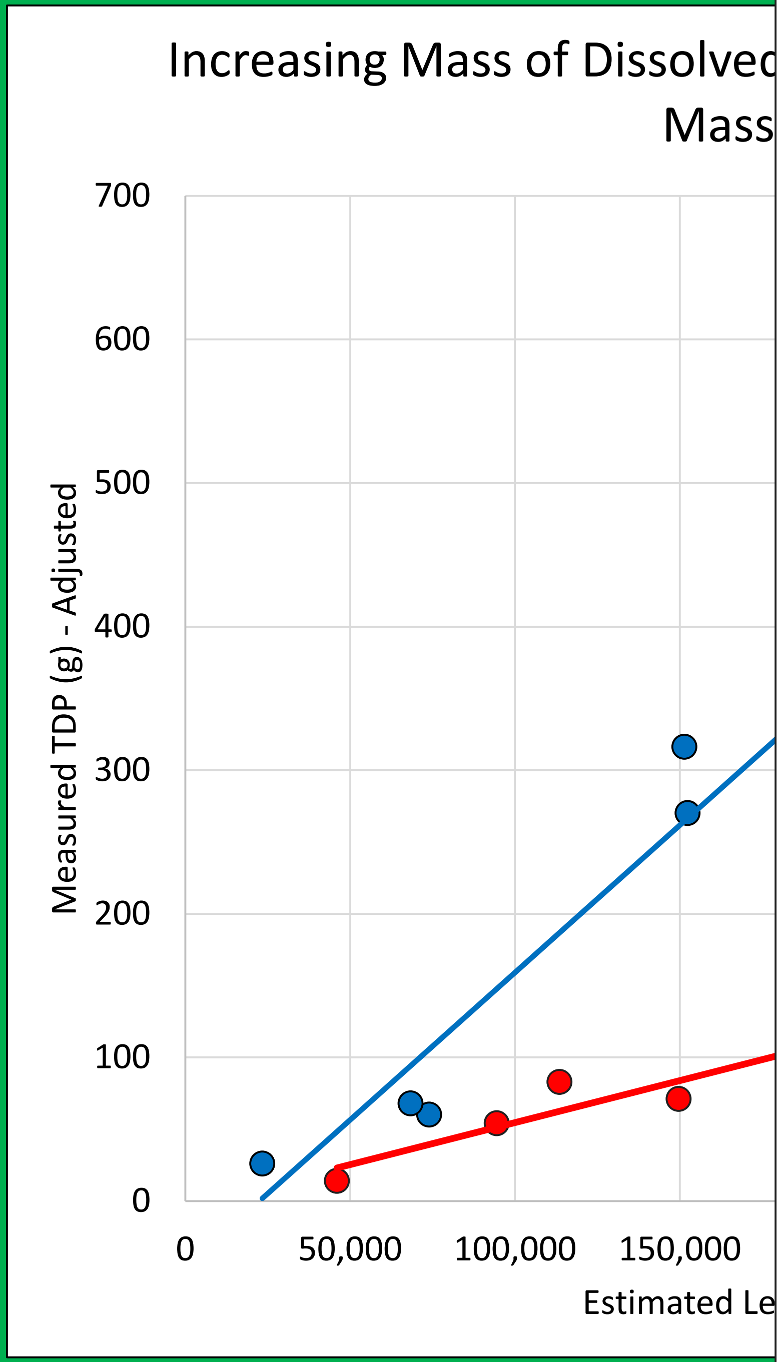
Using water-quality from test site to estimate P in leaves

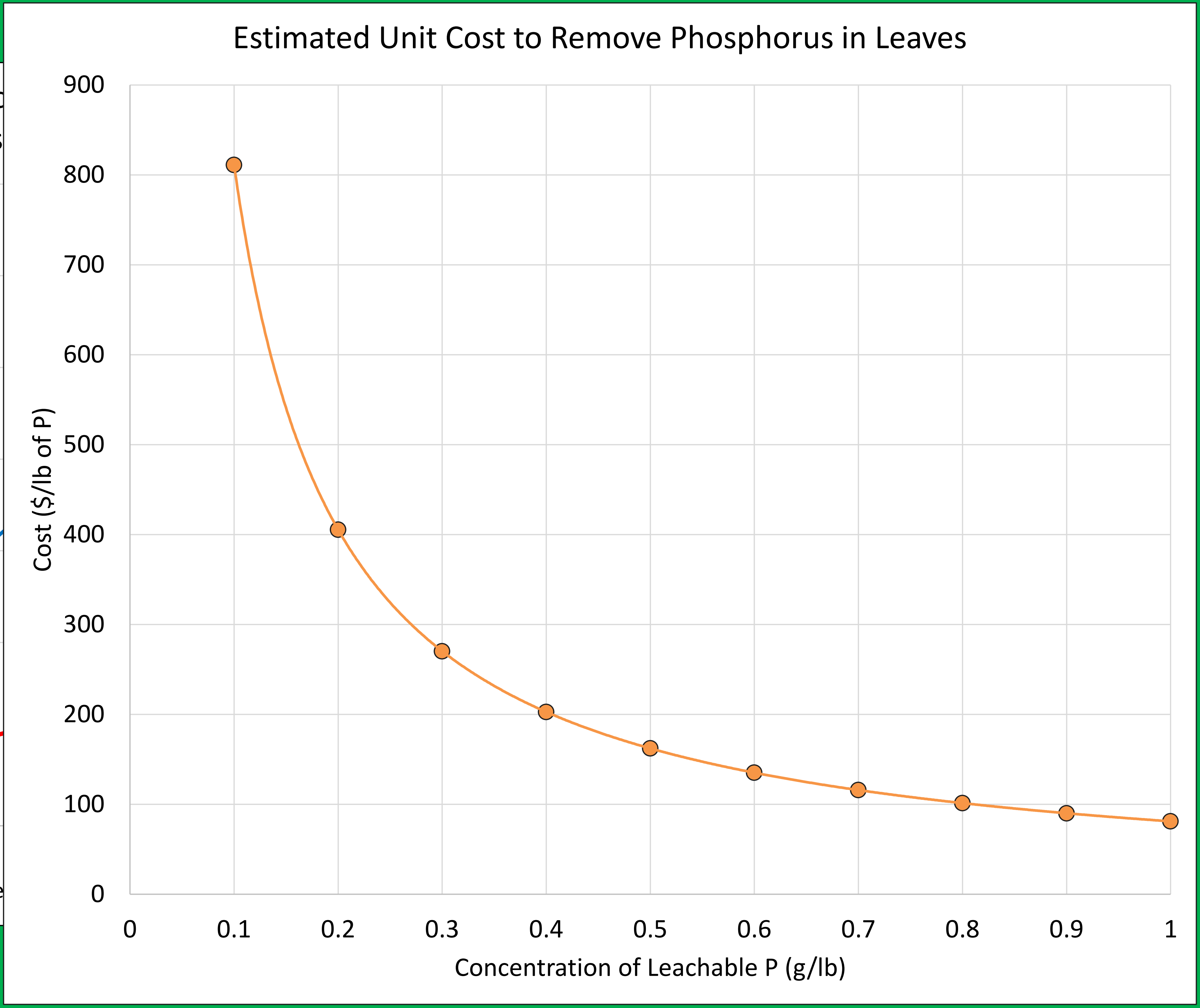
Event	Mass of leaves (g)	Measured P (g)	**Calculated P (mg/g)**
10/06/2016	94,520	36	**0.40**
10/12/2016	205,364	89	**0.40**
10/15/2016	113,543	45	**0.40**
10/25/2016	165,539	297	**1.79**
11/02/2016	149,731	55	**0.40**
11/22/2016	46,040	10	**0.22**



Number we used is 0.17 mg/g – 55% low

Amount of Leachable P in Leaves can Vary





Heavy Canopy

Medium Canopy


10/18/2007


06/13/2007

What Variables Do We Hope to Focus On?

Cleaning Frequency

Tree Canopy

Leachable P in leaves.

Leaf Accumulation Rate

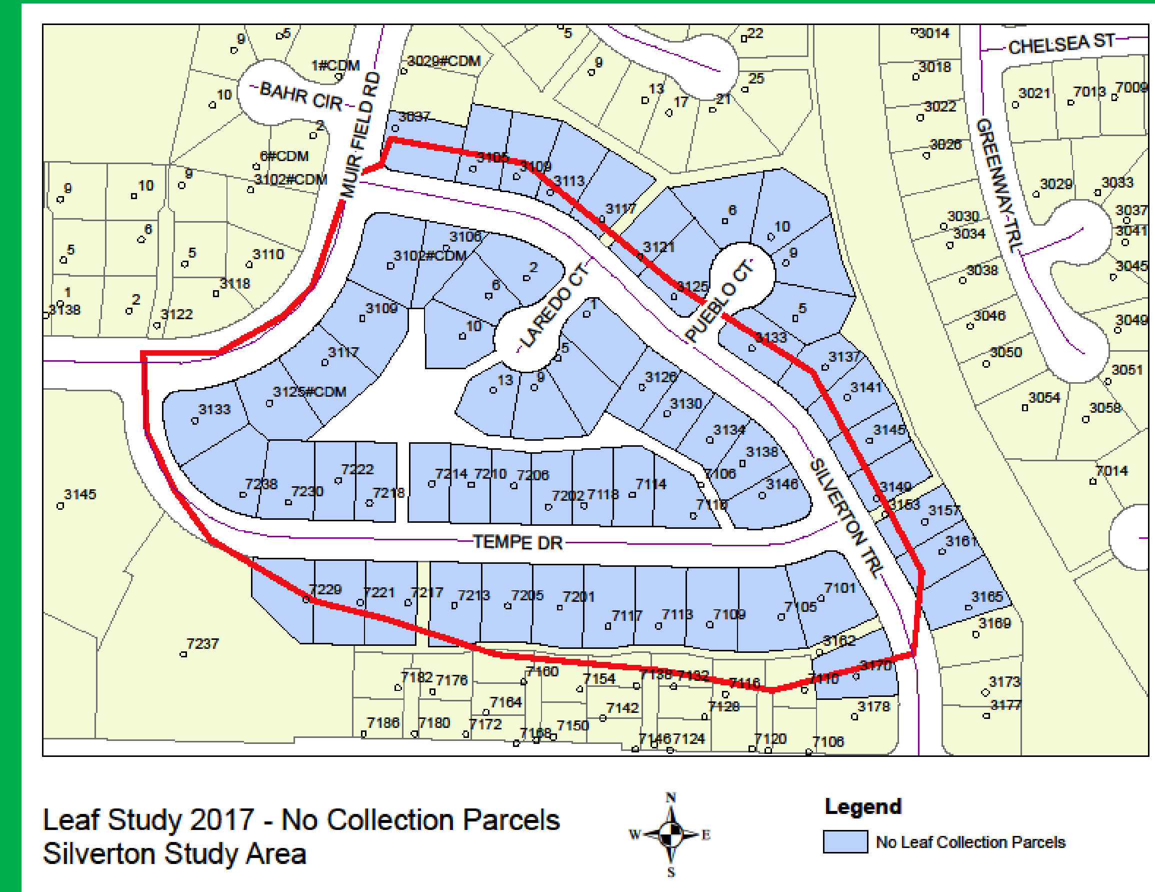
Species of Tree

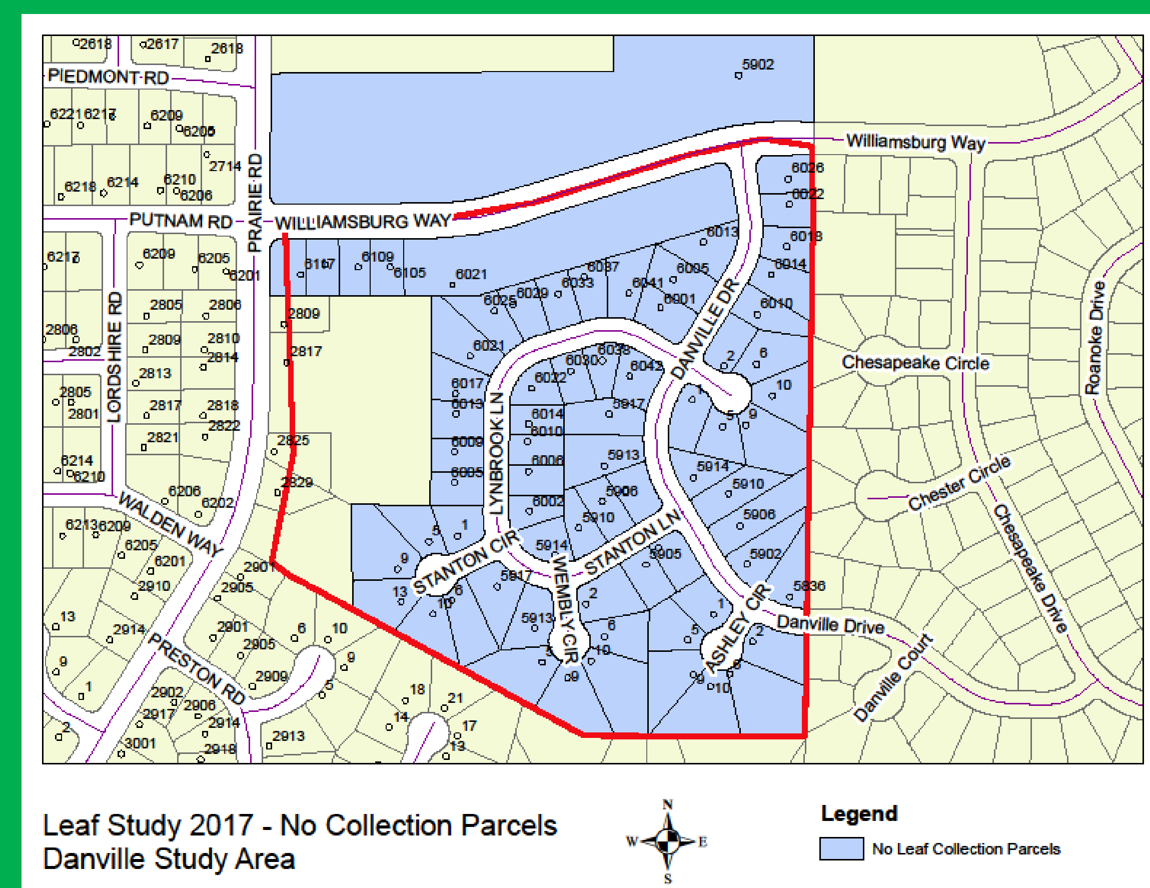
Why Study Leaf Collection?

- Vegetation Most Important Source of Total P in Urban Runoff.
- Fall is the Season with the highest Total P Load.
- Improved Leaf Collection Can Significantly Reduce Annual Total P Loads
- To Describe How to Obtain Credit for Selected Leaf Collection Programs
- To Determine the Most Cost Effective Methods for Leaf Collection.

2018

Leaves on terrace, transfer & street clean ~3-4x:





	Leaf Collection		Street Cleaning			
Canopy	**Method**	**Frequency**	**Method**	**Frequency**	**Year of Completion**	**Comments**
High	Transfer	weekly	Mechanical/blower	Pre-event	2015	Maximum
High	Transfer	3-4 x	Mechanical	Biweekly	2016	SOP
High	Transfer	Biweekly	Regen Air	weekly	2017	SOP+
High	Vacuum	weekly	Regen Air	weekly	2017	Vacuum
Medium	Transfer	3-4 x	Mechanical	Biweekly	2018	SOP
High	Vacuum	3-4 x	none	--	2018	Leaf pile collection only
High	Transfer	Biweekly	Mechanical	weekly	2018	SOP+
Medium	Vacuum	Biweekly	Regen Air	Biweekly	2019	FDL
Medium	None	--	Regen Air	weekly	2019	Oshkosh – leaf piles

Table 1. *Percentage decrease in event-mean concentrations (EMC) of selected constituents in runoff outflow from Monroe Street detention pond, Madison, Wisconsin, February 1987 through April 1988*

[Negative (-) percentage indicates an increase in outflow EMC; --, not determined]

Constituent	Percentage decrease in outflow EMC[1] Maximum	Minimum	Median
Suspended solids	98	-154	88
Total volatile solids	98	-170	45
Total chemical oxygen demand	90	-327	59
Dissolved chemical oxygen demand	85	-53	25
Total chloride	89	-1,650	-245
Total phosphorus	92	-332	42
Dissolved phosphorus	97	-129	41
Dissolved orthophosphorus	98	-160	58
Total Kjeldahl nitrogen	89	-575	38
Dissolved Kjeldahl nitrogen	70	-369	7
Total nitrite plus nitrate	95	-4	65
Total copper	--	--	--
Dissolved copper	67	-175	29
Total lead	94	50	71
Dissolved lead	--	-33	-16

[1]Percentage decrease in EMC computed as: (Inflow EMC-Outflow EMC)/Inflow EMC x 100.

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Questions?