Modeling Applications to Integrate TMDLs and Permitted MS4s

Webinar Speakers:

Kevin Kirsch, PE

Caroline Burger, PE

Jim Bachhuber, PH

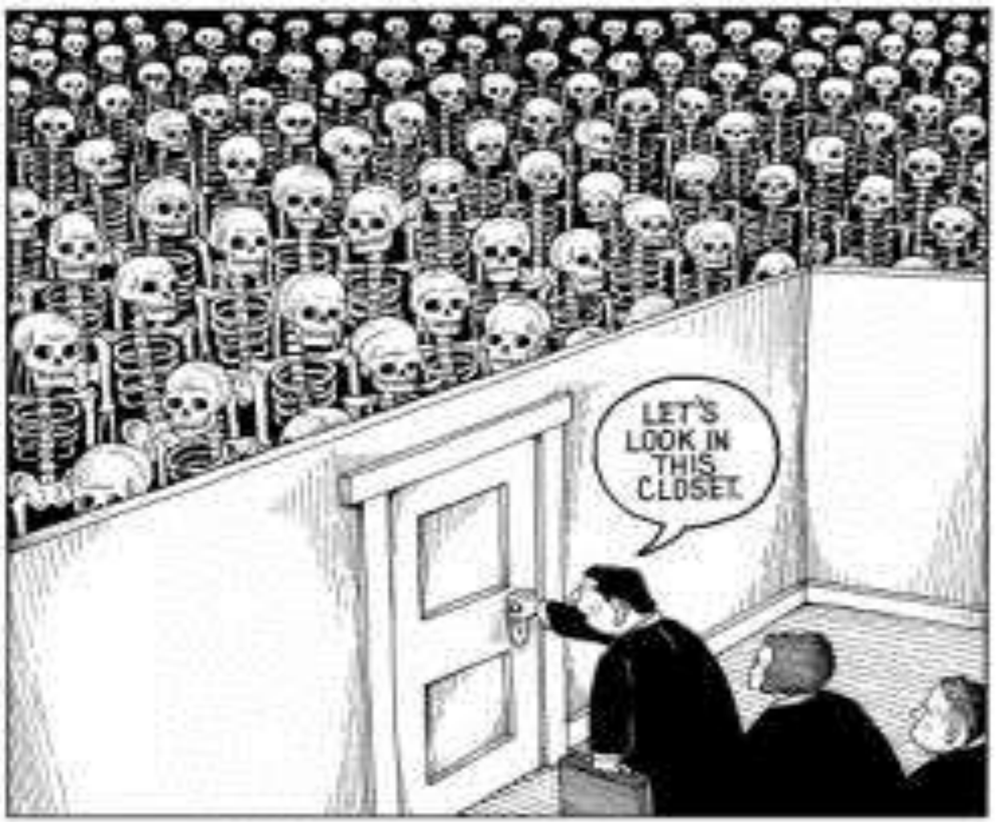
Roger Bannerman

Wisconsin Dept. of Natural Resources · Brown and Caldwell · USGS science for a changing world

Presentation Overview:

- **Kevin Kirsch, PE**
  - Background Information On TMDLs
  - Basin Scale TMDLs and Municipal Scale Analysis
  - MS4 TMDL Implementation Guidance
- **Caroline Burger, PE**
  - Modeling Approach and WINSLAMM
  - Small Storm Hydrology, Runoff, and Pollutants
  - Model Overview and Applications
- **Jim Bachhuber, PH**
  - Models for TMDL Compliance
  - Example MS4 Modeling Analysis
- **Roger Bannerman**
  - SLAMM Calibration and Verification
  - New Sampling Techniques
  - Seasonality of Loads
  - Evaluation of Management Practices
  - Emerging and New Research

What is a TMDL?

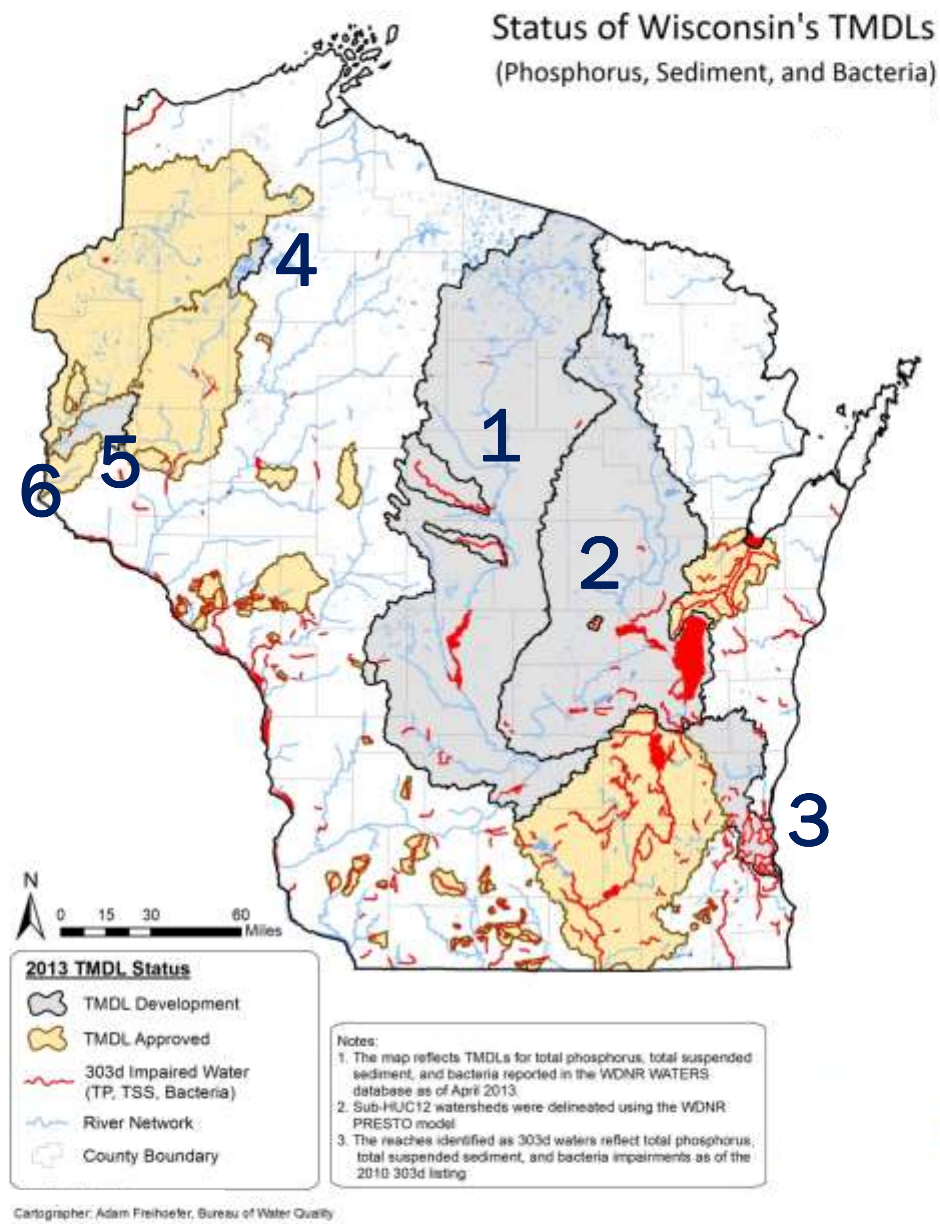


"A TMDL reveals the skeleton in the closet"

Dean Maraldo, EPA

TMDLs Under Development

1. Wisconsin River Basin
   - Phosphorus
2. Upper Fox-Wolf Basin
   - Phosphorus and TSS
3. Milwaukee River Basin
   - Phosphorus, TSS, and Bacteria
4. Lac Courte Oreilles
   - Phosphorus (Key-Element Plan)
5. Lake Mallalieu
   - Phosphorus
6. Lake Pepin Interstate TMDL
   - Phosphorus and TSS



What are TMDLs?

EPA requires that waters listed as impaired on Wisconsin's 303-d list have TMDLs developed.

TMDLs determine the amount of a pollutant a waterbody can receive and still meet water quality standards.

Total **M**aximum **D**aily **L**oad =

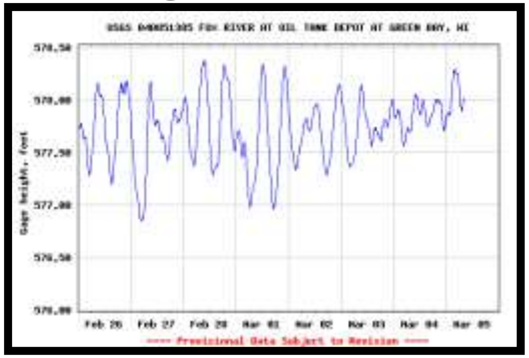
Load Allocation

\+

Waste Load Allocation

\+

Margin of Safety



TMDL Allocations

Waste Load Allocation

WWTPs / POTWs
Industries
Permitted MS4s
Non-Metallic Mines
Construction Sites
NCCWs

Load Allocation

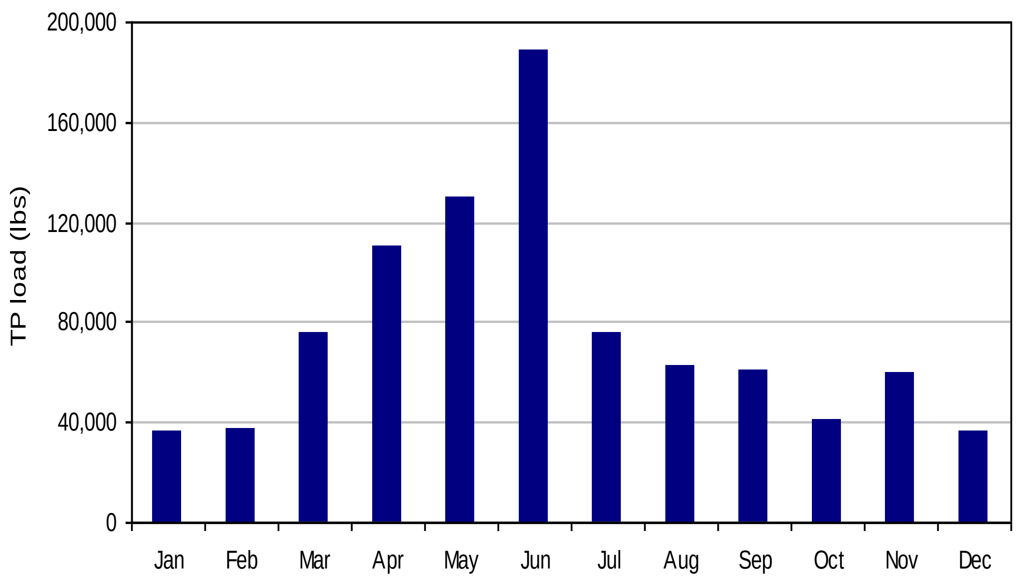
Agricultural
Non-permitted MS4s
Background

- **MS4 = Municipal Separate Storm Sewer System**

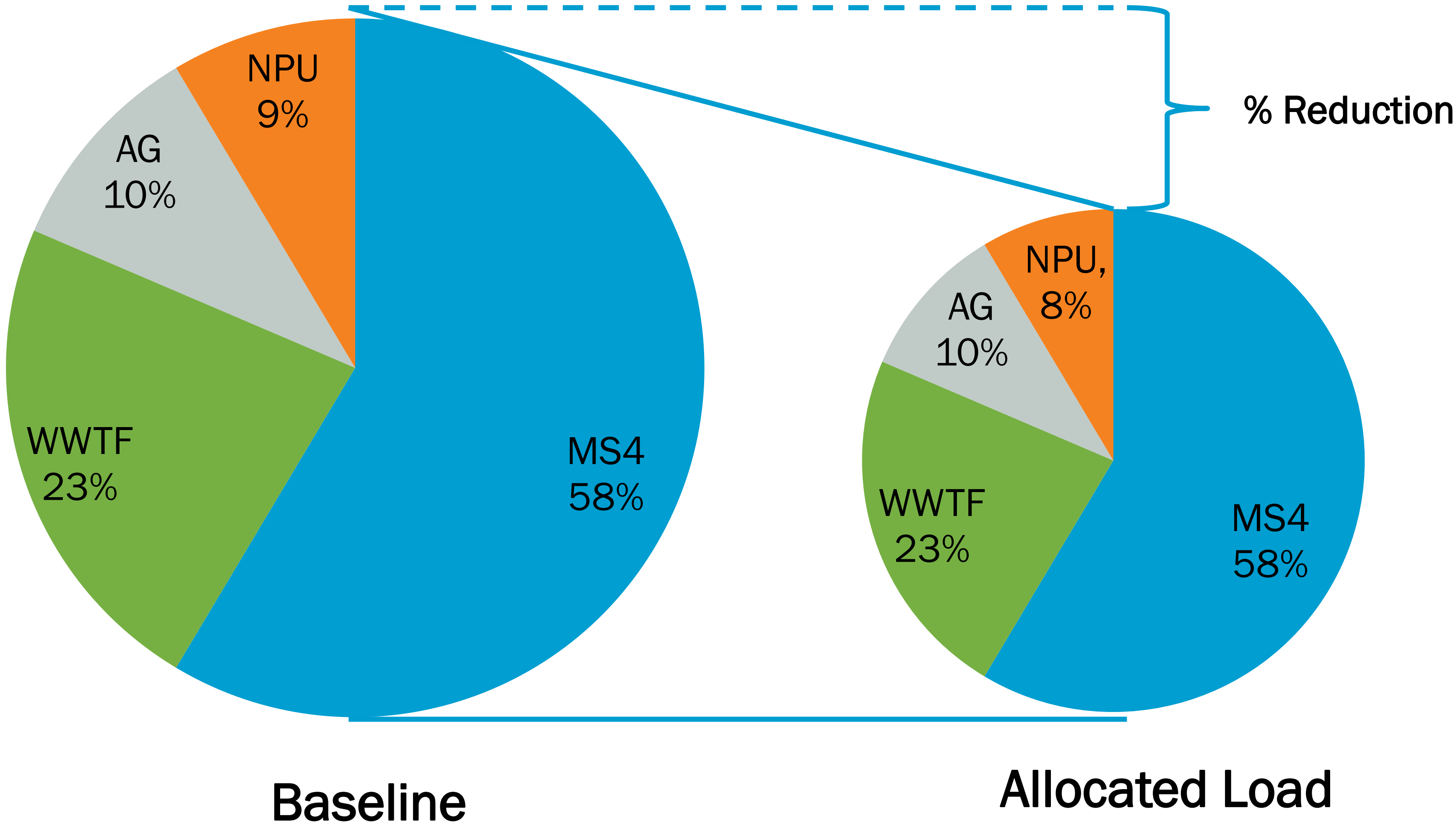
- A conveyance system including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, constructed channels or storm drains
  - Owned or operated by a municipality
  - Designed or used for collecting or conveying storm water
  - Not a combined sewer system
  - Not part of a publicly owned wastewater treatment works

Expression of Allocations

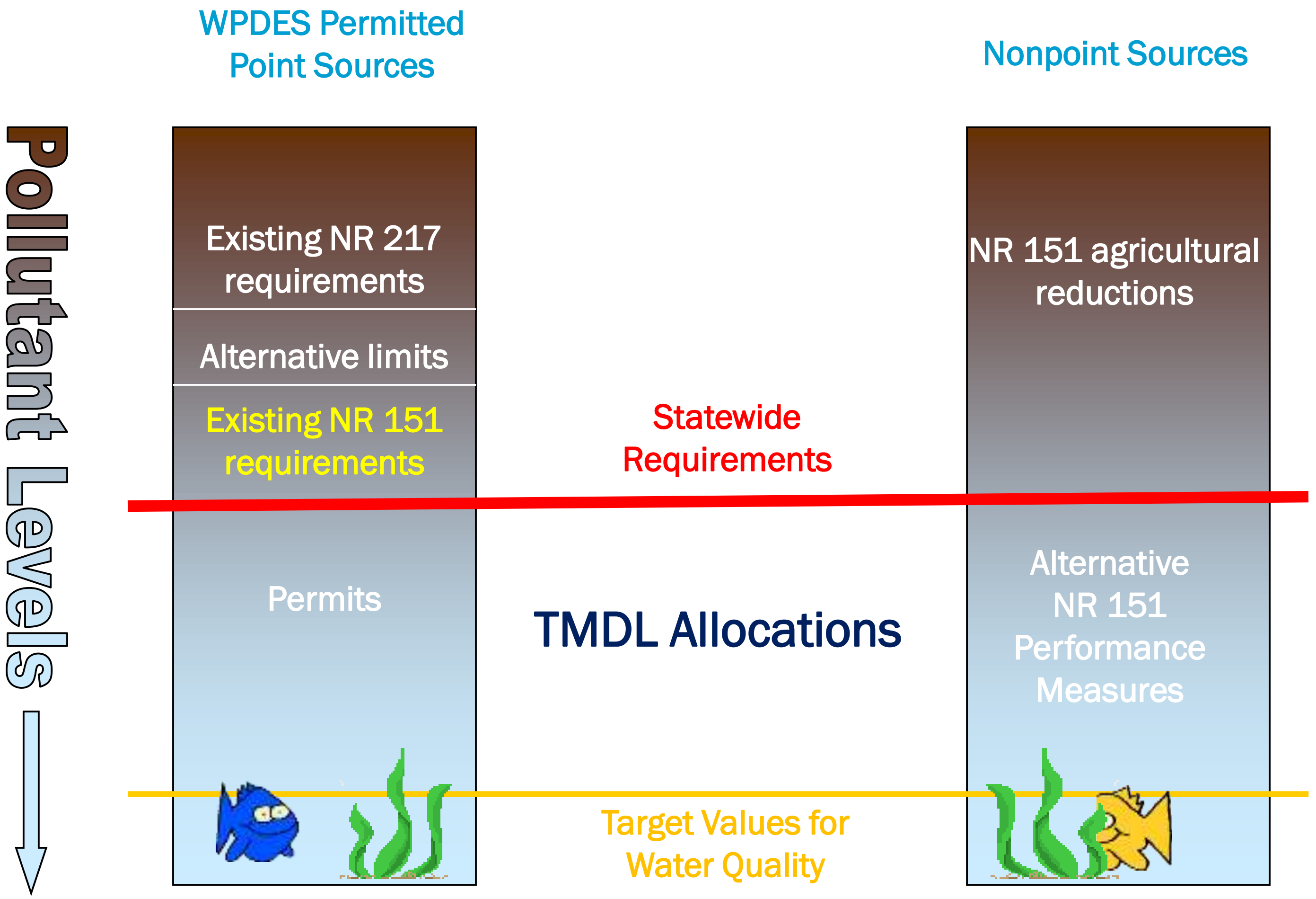
- TMDL must expression allocations by mass and on a daily basis (lbs./day).
- The TMDL can be implemented on different time steps such as monthly, seasonal, or annual.



Allocation Approach



Define an Equitable Baseline Condition



Model Load Terminology:

No Controls	• Discharged from urban model area **with no stormwater controls**
Existing Conditions	• Discharged from urban model area **with existing stormwater controls**
Baseline Conditions	• Discharged from urban model area **with stormwater controls that achieve the reductions required by NR 151**

Baseline: Ch. NR 151, Wis. Adm. Code Runoff Management

Subchapter III – Non-Agricultural Performance Standards

- Post-construction performance standards for new development and redevelopment

- Developed urban area performance standard for municipalities

  - 20% / 40% reduction in TSS that enters waters of the state

  - Evidence of meeting the performance standard shall be based on the use of a model or an equivalent methodology approved by the department. Acceptable models and model versions include SLAMM version 9.2 and P8 version 3.4 or subsequent versions of those models.

  - Modeling guidance outlines use of standard land use files and parameters.

MS4 modeling guidance

This section of the Wisconsin DNR Runoff Management web site is intended for use by highly technical professionals.

Download the modeling guidance developed for municipalities permitted under the Municipal Separate Storm Sewer System (MS4) WPDES program. The guidance discusses minimum pollutant loading analyses for total suspended solids and phosphorus, including percent TSS reductions to be assessed and areas required to be included in the calculations. The guidance on grass swales provides additional information on how to model the water quality benefits of this practice to establish water quality credits. The MS4 TMDL Implementation Guidance provides direction to MS4 permittees and their consultants on how Total Maximum Daily Load (TMDL) waste load allocations will be implemented within MS4 permits. This guidance also discusses how an MS4 permittee will be expected to model its MS4 service area and storm water management measures to show compliance with TMDL requirements.

MS4 municipalities must, to the maximum extent practicable, implement a reduction in total suspended solids in runoff that enters waters of the state as compared to no controls. See the Errata notes at the end of the table for updates to the standards.

MS4 modeling guidance	Download	Date
MS4 TMDL Implementation Guidance	[PDF]	10/2014
MS4 TMDL Implementation Guidance Addendum A (Percent Reduction)	[PDF]	02/2016
MS4 Modeling - NR 151.13 (20/40% TSS Standard)	[PDF]	11/2010
Process to assess and model grass swales (TSS reduction)	[PDF]	11/2010
Internally Drained Area Guidance	[PDF]	04/2009

Storm Water Runoff

Learn more
about storm water runoff

Plan
with technical standards

Technical standards

- Construction standards
- Post-construction standards
- Turf nutrient management
- SLAMM and P-8 models
- Recarga Model
- MS4 modeling guidance
- Groundwater mounding calc.
- West Nile virus

Related links

- Learn more
- Construction permits
- Industrial permits
- Municipal permits
- Guidance & resources

Most urban modeling analysis done with either SLAMM or P-8.

Models used for both new development and established urban areas (retrofit of management practices)

PV & Associates

Helping the fishies one mouse-click at a time.

Model Use

WinSLAMM has been used in every state in the US and in many countries around the world to quantify stormwater runoff volume and pollution loading and evaluate the effectiveness of stormwater control measures. Below is a list of just a few of the places WinSLAMM is referenced and/or used.

State Stormwater Quality Manuals

WinSLAMM is specifically identified as an approved model in the following Stormwater Design Manuals and Administrative Codes.

- Delaware
- Georgia
- Minnesota
- New York
- Wisconsin

WinSLAMM is referenced in the following Stormwater Design Manuals.

- Ohio
- Pennsylvania

Small Storm Hydrology (the hydrology method WinSLAMM is based on) and other work by Dr. Pitt is referenced the the following Stormwater Design Manuals.

- Alaska
- California
- Connecticut
- Hawaii
- Iowa
- Maryland
- Maine
- Mississippi
- New Hampshire
- New Jersey
- Rhode Island
- Vermont
- Virginia
- Washington

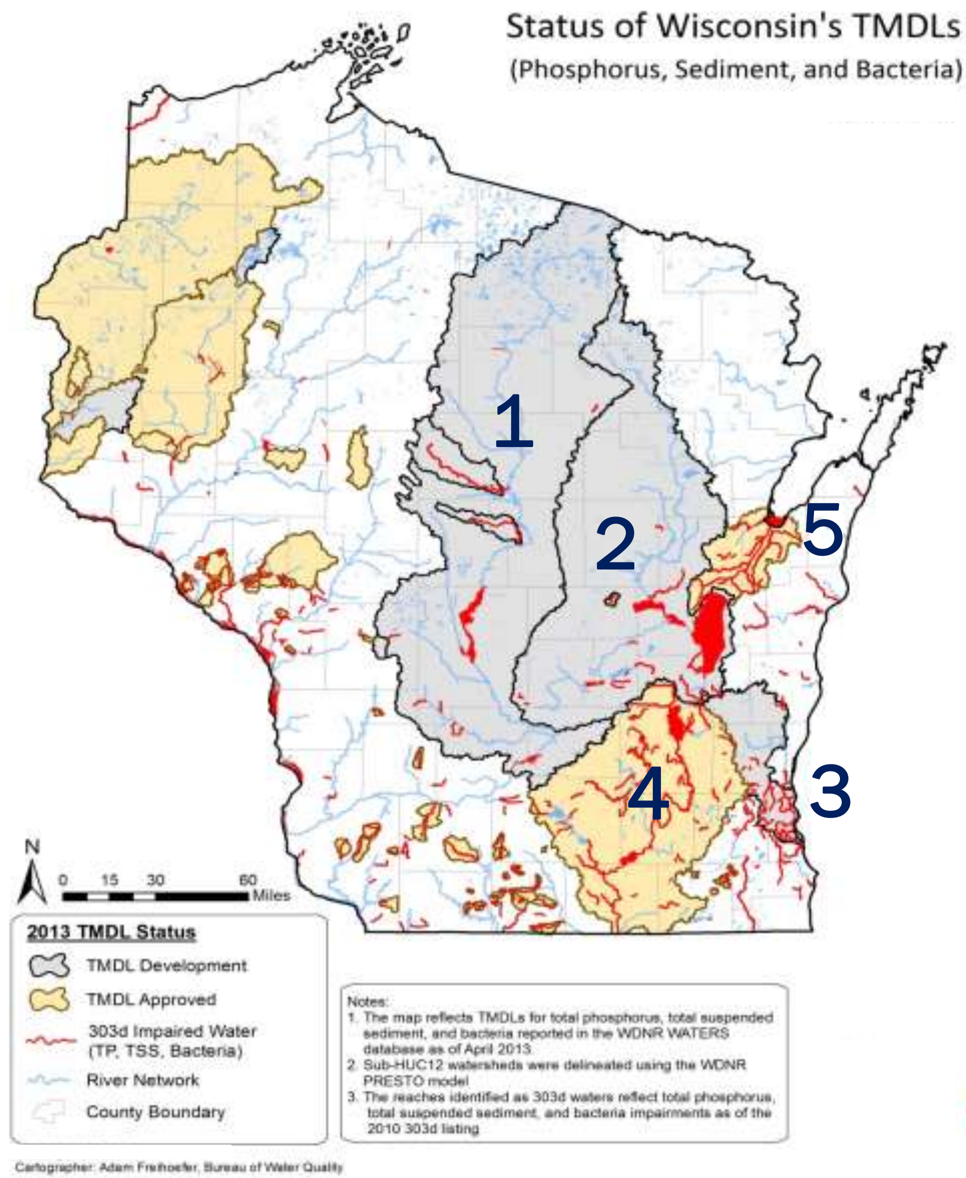
Government Agency Use

- U.S. Navy (San Diego, CA; Puget Sound area, WA; Norfolk, VA)
- U.S. EPA (Ocean County and Millburn NJ; Kansas City, MO; various locations around the U.S. for assistance on developing new stormwater regulations, etc.)
- Cincinnati Metropolitan Sewer District
- Lincoln, NE
- Calgary, Alberta, Canada

WinSLAMM will be used for the Strategic Department of Energy (DOE) Environmental Research and Development Program (SERDP) (San Diego, CA; Seattle area, WA) and New York City, NY.

Basin Scale TMDLs and MS4 Modeling

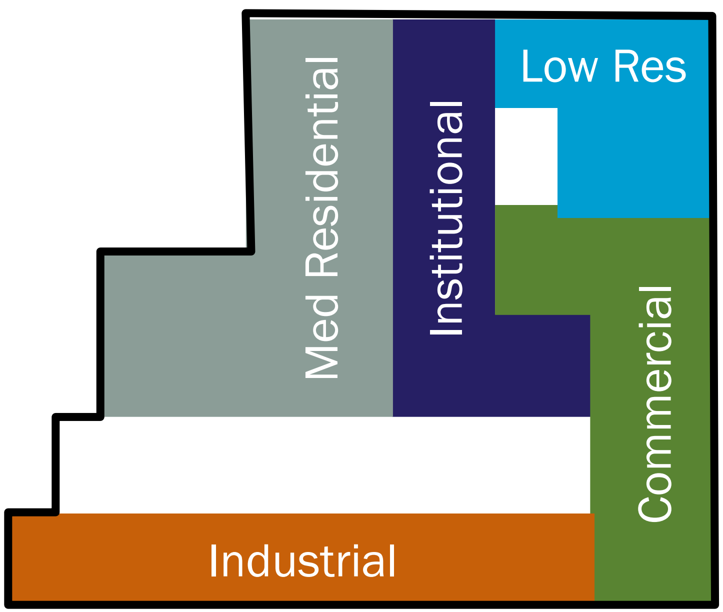
1. Wisconsin River Basin
   - SLAMM
2. Upper Fox-Wolf Basin
   - SLAMM
3. Milwaukee River Basin
   - HSPF calibrated to SLAMM
4. Rock River Basin
   - SLAMM
5. Lower Fox TMDL
   - SWAT – SLAMM Combination



SLAMM Modeling for TMDL – Unit Load Approach

TMDL Development
Load per-unit-area load approach

TMDL Implementation
Detailed Approach



SLAMM Modeling Assumptions

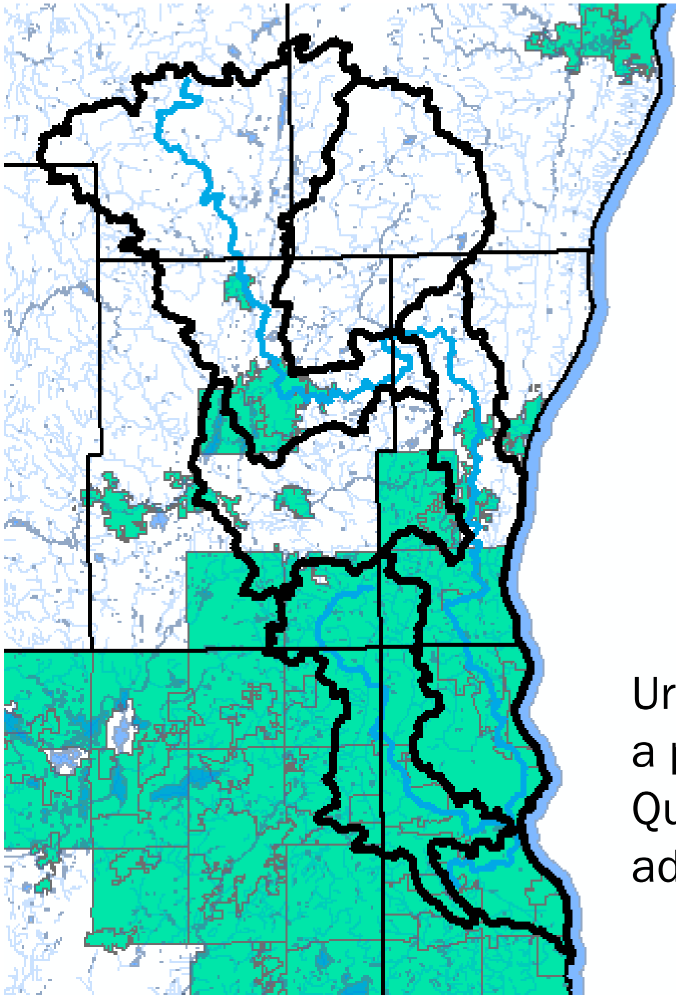
	Standard Land Use	Drainage	Existing Conditions	Baseline Conditions
WinSLAMM Model A (Permitted MS4s)	Medium Density Residential No-Alleys	Storm sewer w/ curb and gutter	Reduce by existing reduction rate	Reduce TSS loads by 20%, and TP load by equivalent amount
WinSLAMM Model B (Unpermitted Areas)		Swale drainage	No reduction	No reduction

SLAMM Modeling for TMDLs

Why don't you just use the loads from permitted MS4 reports already submitted?

	NR 151	TMDL Development
Area Modeled	Established Urban Area Defined in NR 151	Entire City/Village
Land Use Conditions	Varied	Current
Model Timeframe	1- or 5- years,	TMDL Simulation Period
Winter Season Loading	No	Yes
Load Outputs	Average Annual (1981)	Monthly averages for TMDL Simulation Period

MS4s Within the Milwaukee Basin TMDL



- 43 permitted MS4s
- 12 General Permits
- 7 Individual Specific (2 non-traditional)
- 24 Individual Group (5 groups total)

Urban loading analysis performed using HSPF as part of a previous study (2020 Watershed Plan/Regional Water Quality Management Plan). HSPF loads adjusted/calibrated to match overall SLAMM loads.

Addressing Combined Sewer Areas

Combined sewers only cover portions of Milwaukee and Shorewood.

SLAMM modeling analysis showed approximately a 95% reduction in stormwater loading in the combined sewer area.

After construction of the deep tunnel system CSOs have averaged just under three times per year during extreme events.

CSOs are regulated under Milwaukee Metro's permit which includes a long-term control plan.

CSOs are not assigned allocations.

TMDL Allocations and Percent Reductions

- TMDL identifies each permitted municipality and assigns a WLA for each reachshed / municipality combination.

- Once EPA has approved a TMDL, the next permit issued must contain an expression of the WLAs consistent with the assumptions and requirements contained in the TMDL

- Calculates a percent reduction from baseline.

$$Percent\ Reduction = 100\ \times -\left(1 - \left(\frac{WLA\ Loading\ Allocation}{Baseline\ Loading\ Condition}\right)\right)$$

Challenges with Expression of TMDL as Mass

- The aerial extent of the MS4 and its boundary may not match that of the TMDL due to incorporation of new areas, expansion of the municipal boundary and non-traditional MS4s (i.e. WisDOT & county highways).

- Basin scale TMDLs are rarely able to account for watersheds modified by storm sewers.

- Difference between the models used to create the TMDL versus the compliance tools used by the MS4 – will not calculate the same mass.

Percent Reduction Framework

- Builds on the existing MS4 modeling already required under NR 151 and the municipal wide analysis already conducted to comply with requirements stipulated in NR 151.13.

- EPA allowed a percent reduction approach because DNR has a defined no controls scenario and model files/parameters.

- The use of a percent reduction framework allows both the MS4 and DNR the ability to implement the reductions without having to reallocate and track WLAs across reachsheds, MS4s, and other land uses.

Percent Reduction Framework

- Percent reduction expressed based on regulatory requirements.

- For a TMDL that uses 20% reduction as the baseline loading condition (TMDLs approved after January 1, 2012) the conversion to the NR 151.13 **no-controls** modeling condition is:

  TSS Percent Reduction = 20 + (0.80 * % control in TMDL)

  TP Percent Reduction = 15 + (0.85 * % control in TMDL)

- For a TMDL that uses 40% reduction as the baseline loading condition (TMDLs approved prior to January 1, 2012) the conversion to the **no-controls** modeling condition is:

  TSS Percent Reduction = 40 + (0.60 * % control in TMDL)

  TP Percent Reduction = 27 + (0.73 * % control in TMDL)

Implementation of Percent Reduction Framework

- The percent reduction calculated to meet the TMDL is applied to the no controls load, which provides the mass that needs to be controlled by the MS4. This mass maybe different from that stipulated by the TMDL WLA.

- The MS4 area includes the entire acreage that the MS4 is responsible for; subtract areas not under the jurisdiction of the permittee.

- As new MS4 area is added or subtracted, the same TMDL percent reduction is applied to these new areas.

Implementation of Percent Reduction Framework

NEW GUIDANCE DRAFTED for:

- Calculating MS4 percent reduction where TMDL did not allocate WLA for permitted MS4 (February 2016)

$$TSS\ \%\ Reduction = 20 + (0.80\ \times \%NPU\ reduction\ from\ baseline\ in\ TMDL)$$

NPU = non-permitted urban

- Internally Drained Areas (final drafting in progress)
  - Non-navigable & non-wetland
  - Navigable waterbody or wetland
  - Gravity drained versus pumped out of internal depression

TMDL Compliance

- TMDL reductions are modeled or simulated predictions of reductions needed to meet water quality standards. Ambient stream monitoring will ultimately be required to de-list impaired waters and show compliance with the TMDL.
- Compliance with TMDL requirements will need to be achieved on a reach by reach basis. Ultimately water quality standards must be met in-stream at the compliance point for each reachshed - the farthest most downstream point of each reachshed.
- Under a TMDL, EPA does <u>not</u> acknowledge the concept of maximum extent practicable as defined in s. NR 151.006, Wis. Adm. Code, but rather compliance schedules can be structured in SWMPs and permits to allow MS4s time to meet TMDL goals.

Anticipated Compliance Schedule

- MS4 permittees will have the primary role in establishing their own benchmarks for each 5-year permit term. Benchmarks are to be identified prior to each 5-year permit reissuance.
- It is possible that certain benchmarks will not be easily quantifiable but there needs to be documentation that such achieving benchmarks will reduce the discharge of pollutants of concern.
- Specific requirements laid out in permit and TMDL document.

TMDL Reach
MS4 TMDL I
MS4 Existing
Modeled MS4
Modeled MS4

Benchmark (BM)	Control s)
N/A	
1	reduction)
2	
3	
4	reduction)
5	
6	
7	

* The TSS an

Descripti	Outf Affecte BM co	Aff Draina (as m	Impleme Da	I	BM	MS4 Cumulative % Control (from no controls)
Existing	All	A	Ongo			TSS: 32% TP: 24%
Increased Roadwa	All	A	1/1/2		(30%	TSS: 35% TP: 26% (Accounts for 5 years of reduction)
Implemen Clea	001 003 004 008	1A 3A 4C 8	1/1/2	(	(eff. r	TSS: 44% TP: 32%
Impleme Waste C	All	A	1/1/2	(	(eff. r	TSS: 46% TP: 37%
Ordinanc Redevel	All	A	1/1/2		(30%	TSS: 49% TP: 39% (Accounts for 5 years of reduction)
Retrofit 2	002	E	1/1/2			TSS: 51% TP: 40%
New	005	5B	1/1/2			TSS: 54% TP: 42%
Stabilize N between	003	3D a	1/1/2		Streamb count ag	TSS: 54% TP: 42%

MS4 GP Section 1.5.4
Approved TMDL Implementation

- Sections 1.5.4.1 and 1.5.4.2 – Compliance schedule for meeting TMDL implementation provisions based on when TMDL approved
- Section 1.5.4.3 – Update storm sewer system map, identify areas to exclude (given 18 – 24 months)
- Section 1.5.4.4 – Tabular summary of modeling analysis, existing storm water controls (given 42 - 48 months)
- Section 1.5.4.5 – Written plan to show progress toward meeting TMDL pollutant reductions (42 – 48 months)

Business Licenses & Regulations Recreation Education Contact Join DNR Search or Keywords

Municipal storm water permits

Important information concerning the DNR's MS4 General Permits

On October 27, 2014, 33 municipalities were notified to apply for coverage under the MS4 General Permit No. S050181-1.

» View received Notice of Intent applications

- WPDES General Permit WI-S050075-2 [PDF]
- WPDES General Permit WI-S050181-1 [PDF]
- List of municipalities covered under WPDES General Permit WI-S050075-2 [PDF]
- List of municipalities notified to apply for coverage under WDPES General Permit WI-S050181-1 [PDF]
- NOI application Form 3400-191 [PDF]

Webinar recording

On April 14, 2015, the DNR presented a webinar on the guidance for implementation of Total Maximum Daily Loads (TMDLs) through MS4 permits [PDF]. A recording of the webinar and a copy of the program slides are available at the UW-Extension Natural Resources Webinars webpage [exit DNR].

More than two hundred municipalities in Wisconsin that include cities, villages, towns and counties within urbanized areas are required to have Municipal Separate Storm Sewer System (MS4) permits under

Storm water runoff

Learn more
about storm water runoff

Plan
with technical standards

Municipal permits

- Permit overview
- Municipal permittees
- Incoming MS4 NOIs
- Presentations and fact sheets
- Whose pond is it anyway?

Related links

- Learn more
- Construction permits
- Industrial permits
- Technical standards
- Guidance & resources

Contact information
For information on this page, contact:

Special Thanks to:

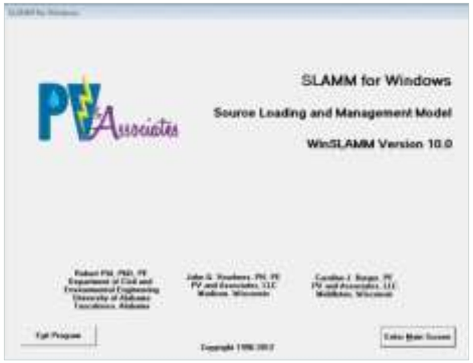
Dave Werbach, USEPA Region 5
Bob Newport, USEPA Region 5 (retired)

Modeling Applications to Integrate TMDLs into MS4 Permits

Explaining the Tool

May | 2016

Caroline Burger; PE
Brown & Caldwell
Milwaukee, WI



WDNR Model Development & Selection

- After decades of development, WDNR identified WinSLAMM, P8, or equivalent for regulatory compliance.
- WDNR sets strict standards on how the models are applied for regulatory compliance.
- Over 95% of the 200+ Phase I & II MS4s use WinSLAMM.
- This presentation will focus on WinSLAMM functions and how the model is applied for MS4 permit compliance.

WISCONSIN
DEPT. OF NATURAL RESOURCES

What Questions can be Answered with WinSLAMM?

- What are the critical sources of volumes and pollutants?
- What are the pollutant loadings for different land uses with no controls?
- What volume and pollutant levels result from different development scenarios?
- How effective are treatment practices in controlling pollutants and reducing volumes?
- What combinations of stormwater controls will best meet regulatory requirements?
- How much do the SCMs cost?

What Questions can be Answered with WinSLAMM? (said a different way)

- Urban drainage areas with the highest and lowest pollution loads
- How much pollution control do various stormwater treatment systems achieve from a watershed or an individual site?
- If a TMDL requires an MS4 to reduce stormwater phosphorus by “X”, which combination of SCMs best achieves the goal?
- How much runoff volume reduction can be achieved with an LID subdivision compared to a traditional development?

What Questions cannot be Answered with WinSLAMM?

- No snowmelt or baseflow conditions
- Does not consider in-stream processes (but links into receiving water models)
- Transfers hydrographs and particle size distributions between control practices to model practices in series, but does not provide *complete* routing
- Does not model construction site erosion losses
- **Not intended for design storm or rural analysis**

What Pollutants can be Evaluated?

- Volume
- Solids
- Phosphorus
- Nitrates
- TKN
- COD
- Fecal Coliform Bacteria

- Chromium
- Copper
- Lead
- Zinc
- Cadmium
- Pyrene
- Other – if have data

Simulates Particulate and Dissolved Forms

What SCMs can be Evaluated?

- Wet Detention Ponds
- Porous Pavement
- Street Cleaning
- Catchbasin Cleaning
- Grass Swales and Grass Filters
- Biofiltration/bioretention
- Infiltration
- Green Roofs / Blue Roofs
- Proprietary Controls (media filters and hydrodynamic devices)
- Beneficial Uses/ Reuse / Cisterns

Background & History

- Development Began in mid-1970's
  - Early EPA street cleaning projects
  - San Jose and Coyote Creek (CA)
  - Castro Valley and other NURP projects
- Mid-1980's - Model used in Agency Programs:
  - Ottawa bacteria stormwater management program
  - Toronto Area Watershed Management Strategy
  - Wis. Dept. of Natural Resources: Priority Watershed Program
- Intensive data collection started in WI in early 1990s
- First Windows version developed in 1995
- National and regional research integrated into model.
- Continuous updating based on user needs and new research.

Unique Features of WinSLAMM (and why it was developed)

- WinSLAMM based on actual monitoring results at many scales and conditions.
- Early research project results in the 1970s did not conform to typical stormwater assumptions (especially rainfall-runoff relationships and sources of pollutants).
- Initial versions of the model focused on site hydrology, particulate sources and transport (and public works practices). Other control practices added as developed and as monitoring data becomes available.

Summary of Model in 3 Points:

1. Uses local, measured, continuous rainfall data;
2. Generates:
   - A pollutant concentration;
   - and runoff volume
   - for each source area
   - for each rain event
3. SCM performance is simulated using actual processes for each stormwater control measure
   - For example: ponds use Stoke's law for particle size settling depending on particle size and density

Small Storm Hydrology

For Urban Stormwater Quality,
WinSLAMM bases its analysis on the concept of Small Storm Hydrology

Three Rainfall Categories (R. Pitt):

1. *Small Rains*

- Accounts for most events, by number
  - Typically can be easily captured for infiltration or on-site beneficial uses
  - Relatively low <u>individual</u> pollutant loadings, but frequent discharges
  - Key rains associated with water quality violations (concentration), e.g. bacteria and total recoverable heavy metals
  - “Every” time it rains, some numeric discharge concentration objectives are likely to be exceeded, therefore, eliminate the runoff (infiltrate)

Three Rainfall Categories (R. Pitt):

2. *Medium Rains*

- Responsible for most pollutant mass discharges

  - Smaller events in this category can be easily captured and infiltrated or re-used

  - Larger events in this category need to be treated.

  - Typically responsible for about 75% of pollutant discharges

Three Rainfall Categories (R. Pitt):

3. *Large Rains*

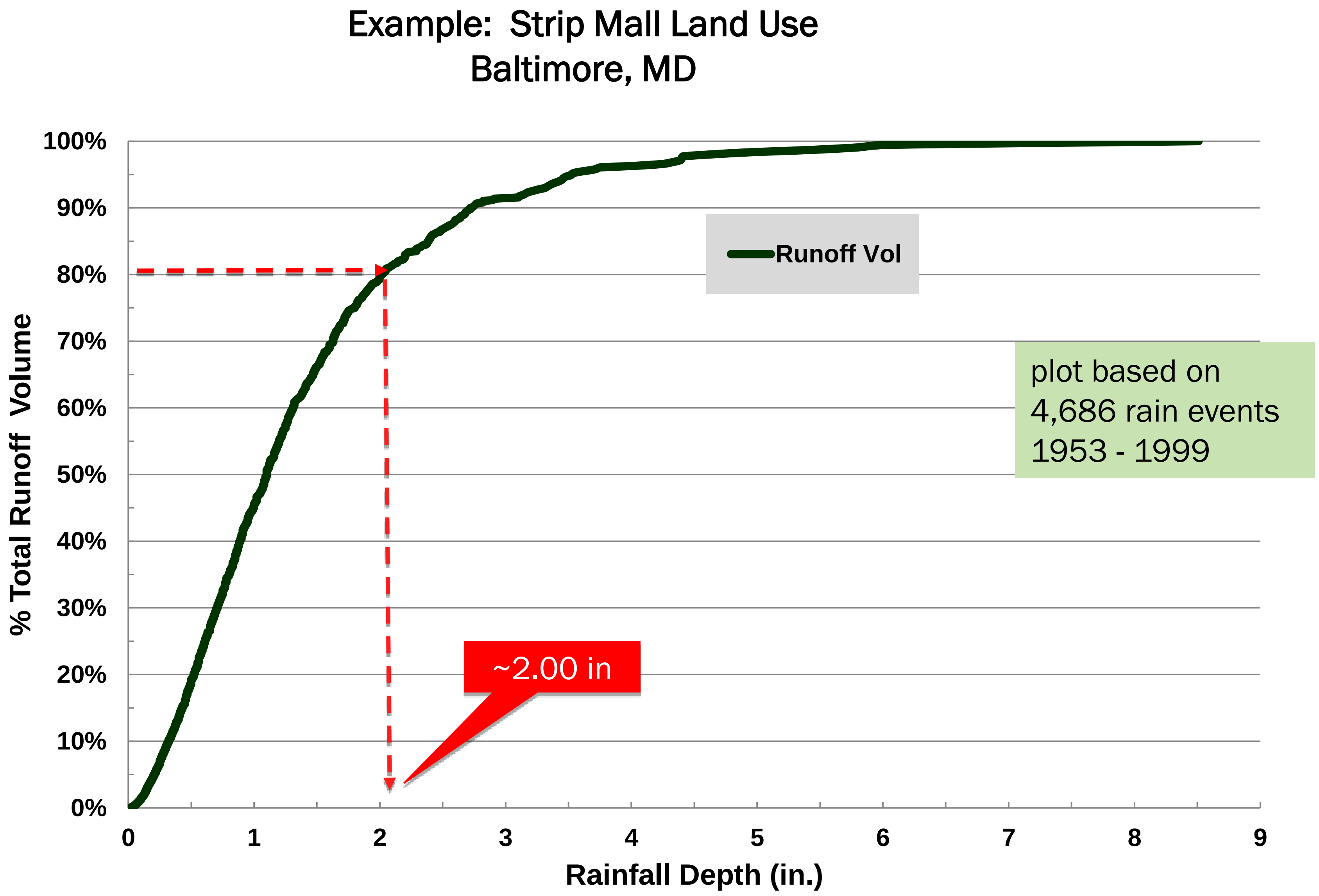
- Infrequent Large Events
  - Not cost effective to treat all runoff
  - Very important for flooding and significant erosion issues
  - Treatment practices designed for smaller storms can mitigate impacts of larger events to some extent

Small Storm Hydrology

Most of the pollutants in stormwater runoff come from small and moderate size storms . . .

. . .in contrast to design storms, because the smaller storms are much more frequent and account for the majority of runoff volume…

Rainfall vs Runoff Volume



Small Storm Hydrology – Pollutants

Pollutant loadings in small storms vary by Land Use, such as . . .

- Residential
- Commercial
- Industrial
- Institutional

and by Source Areas like . . .

- Roofs
- Parking
- Sidewalks
- Streets
- Landscaped Areas

WinSLAMM calculates runoff volume and pollution load at the Source Area Level

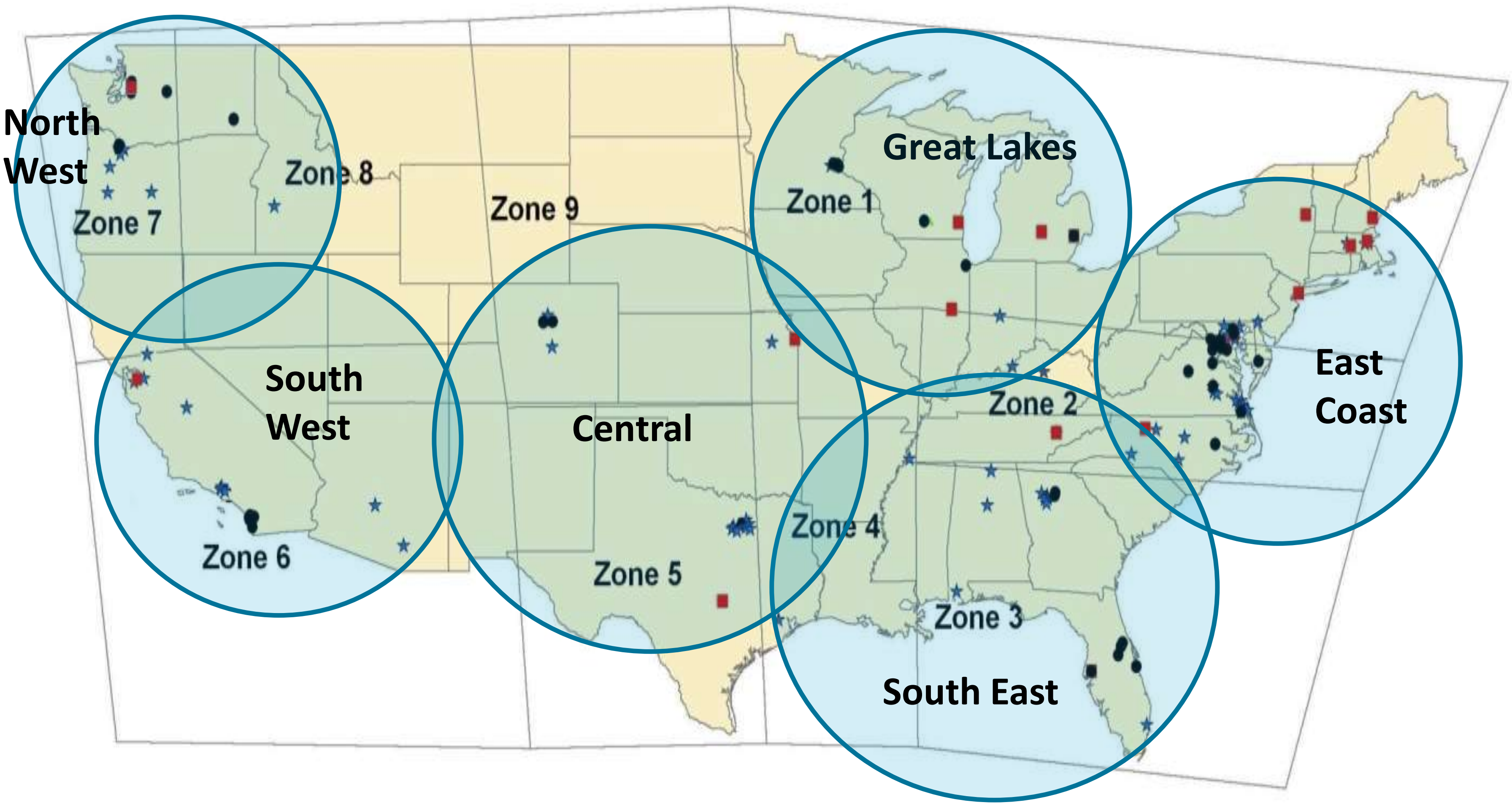
WinSLAMM Runoff Volume and Pollutant Algorithms

The model is driven through the use of data files and calibrated parameter files

Calibrated Parameter Files

- Rainfall File (*.ran)
- Runoff Coefficient File (*.rsv)
- Particulate Solids Concentration File (*.pscx)
- Pollutant Probability Distribution File (*.ppdx)
- Particle Size Parameter File (*.cpz)

National Stormwater Quality Database

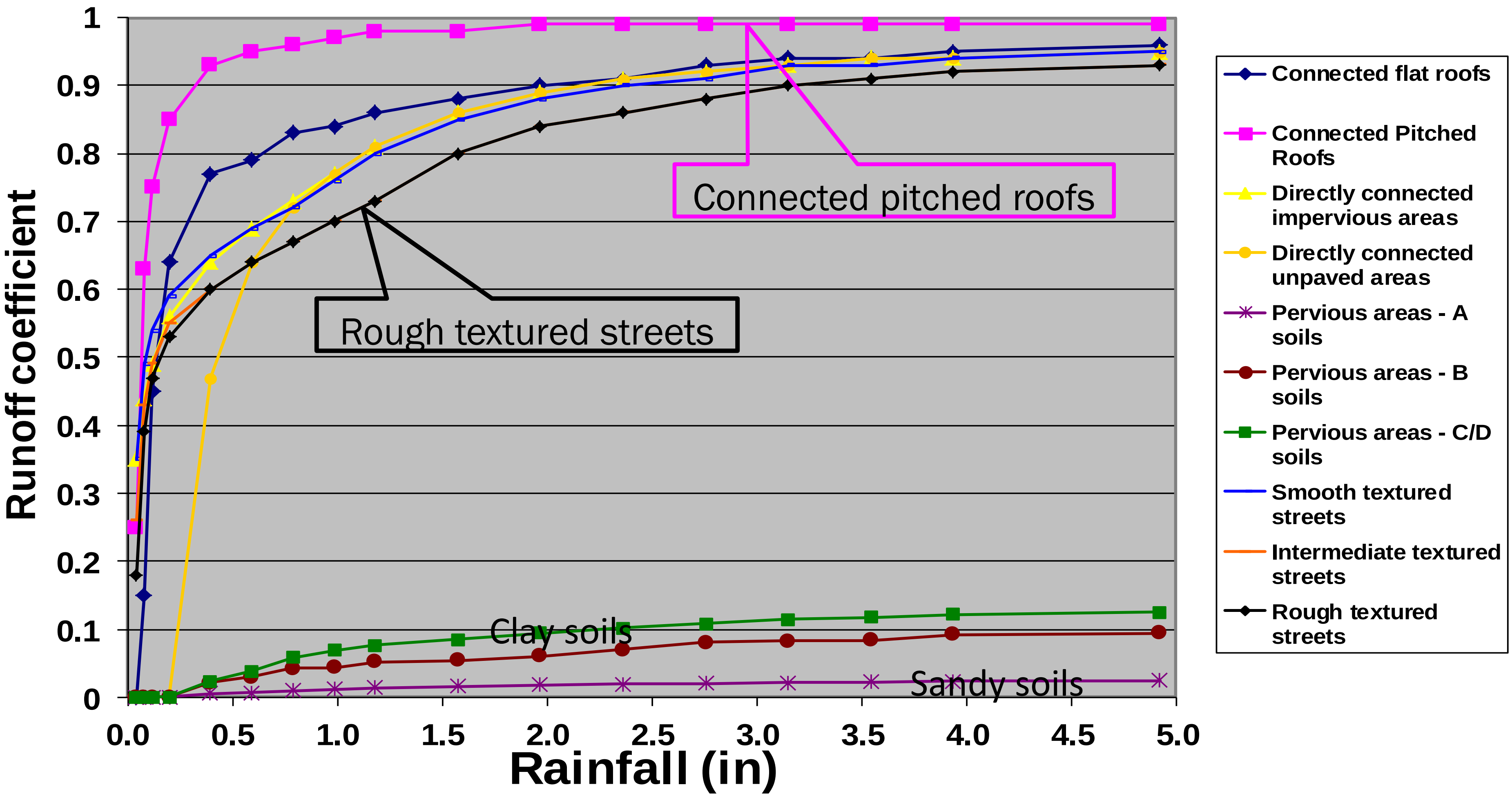


Runoff Volume:

Runoff Volume (cf) = Rainfall Depth (in.) *
Source Area (ac.) *
Runoff Coefficient *
Unit Conversion

For each source area and each rain event

Runoff Generation versus Rainfall Depth



Not much difference between the different source areas for the large, drainage design storms, but much larger differences for the small and intermediate-sized rains.

Particulate Solids Loading:

Sediment Loading (lbs.) =

PSC Coefficient (mg/L) *

Runoff Volume (cf.) *

Unit Conversion

For each <u>source area</u> in each land use and each rain event

Pollutant Loading:

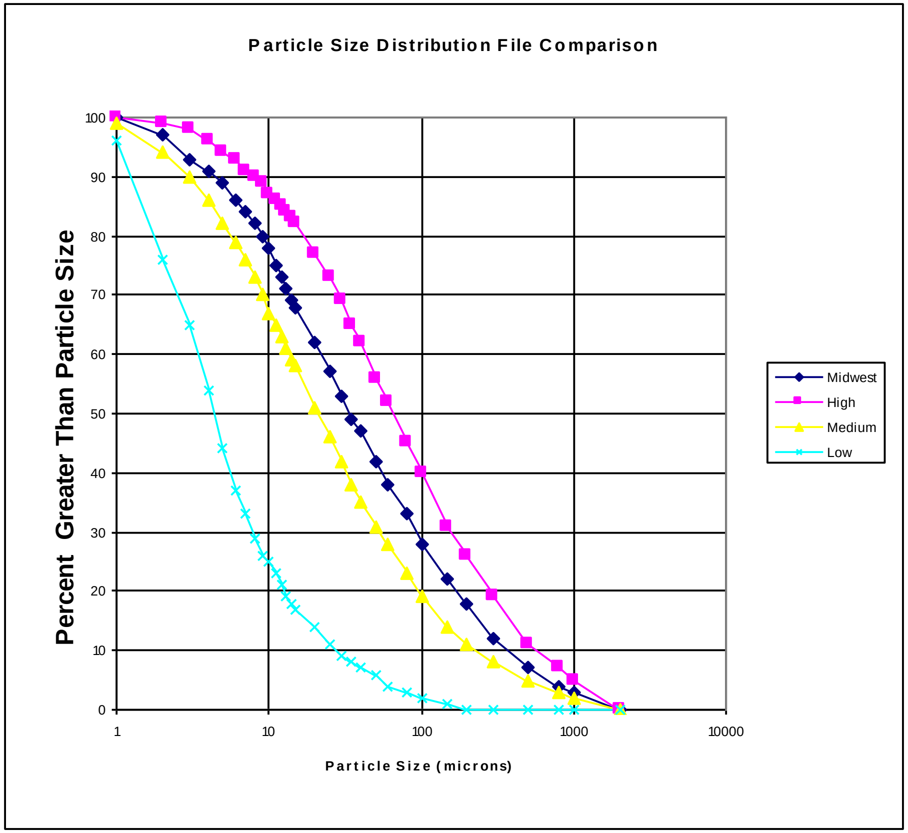
Particulate Pollutant Loading (lbs) = Particulate Solids Loading (lbs) * PPD Coefficient (mg/kg) * Unit Conversion

Dissolved Pollutant Loading (lbs) = Runoff Volume (cf) * PPD Coefficient (mg/L) * Unit Conversion

For each source area in each land use and each rain event

Particle Size Distribution and Hydrographs

- Particle Size Distribution (PSD) and Hydrographs Routed Through SCMs
- Hydrographs Created for every SCM



- PSDs and Hydrographs are modified by every SCM (where applicable)
- PSDs and Hydrographs are combined and modified as runoff moves through the treatment trains
- 6 minute time step (default)

Building a Model File

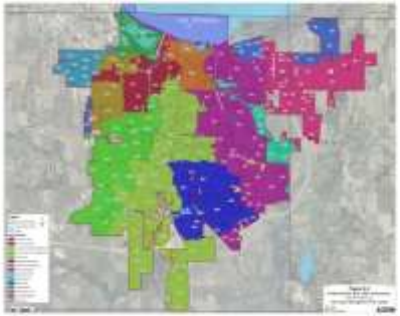
Information Needed

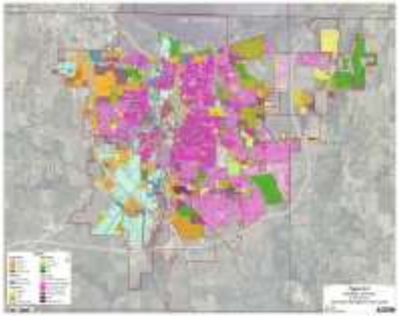
1. Drainage Area(s)
2. Land Use - type and area

   Commercial, Freeway, Industrial, Institutional, Other Urban, Residential
3. Source Areas - type and area

   Roof, Parking, Driveway, Sidewalk, Street, Landscaped, Water Body
4. Source Area parameters and characteristics

   Soil type, Connected imperviousness, Street texture, etc.
5. Stormwater Control Measures





Large Project Areas use Standard Land Uses

Standard Land Use:

- A model file for "average" condition for a land use
- Conditions based on numerous field measurements
- Can be modified for local conditions.
- Has a default area of 100 acres
- Standard Land Use general categories are:

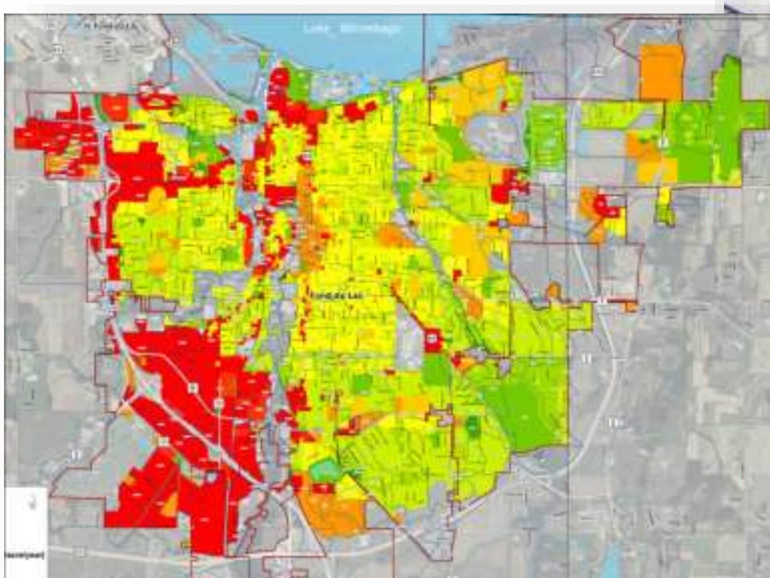
Residential	Institutional
Commercial	Industrial
Freeway	Other Urban (open space)

- There are about 42 "default" SLUs

What is WinSLAMM Used for?

Project Scales

- Single Source Area
  (roof, parking lot, street, etc.)
- Site (e.g. 40-ac residential subdivision, 5-ac commercial development)
- Watershed
- Municipal



Types of Projects

- Green Infrastructure

  “EPA intends the term "green infrastructure" to generally refer to systems and practices that use or mimic natural processes to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse stormwater or runoff on the site ***where it is generated****.” - http://water.epa.gov/polwaste/green/#works*

- Low Impact Development

  “The U.S. Environmental Protection Agency (EPA) considers LID to be a management approach and set of practices that can reduce runoff and pollutant loadings by managing runoff as close to its ***source(s)*** *as possible. LID includes:*

  - *overall site design approaches (holistic LID, or LID integrated management practices)*
  - *individual small-scale stormwater management practices (isolated LID practices)*
  - *Practices that promote the use of natural systems for infiltration, evapotranspiration and the harvesting and use of rainwater.” - http://water.epa.gov/polwaste/green/#works*

- TMDL Compliance
- New and Re-development Ordinance Compliance
- Stormwater Management Plans
- Alternatives Analysis
- SCM Design

Model Detailed Output Examples

- By event, month, year, or multiple years:
  - Runoff volume and pollutant load
  - % volume and pollution reduction from an SCM
- Pollutant EMC by event, season, or other.
- SCM Performance Indicators:
  - Bypass volume by event, year, or other
  - Length of time and when biofilter has standing water.
  - Frequency, duration, and volume of WQ Pond overflow
  - Reduction in catch basin performance as sump fills over time.


Questions?

Comprehensive Plan Approach for Meeting Stormwater TMDL Waste Load Allocations

- Wisconsin's Approach

Jim Bachhuber PH
Brown & Caldwell
Milwaukee, WI

Regulatory and Modeling Guidelines

Using Models for TMDL Compliance

– Meeting Numeric Standards

MS4 Permit Regulations in WI

- Same 6 “minimum measures“
- TMDL requirements are added to all re-issued and new Phase I & II MS4 Permits.
- TSS & TP load reduction is numeric standard.
- Load reduction based on an approved model.
- Must follow WDNR modeling guidelines.


Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Rock River Basin

Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Rock, Walworth, Washington, and Waukesha Counties, Wisconsin

July 2011

Wisconsin Department of Natural Resources

Page 1 of 26
WPDES Permit No. WI-S050075-2

WISCONSIN DEPT. OF NATURAL RESOURCES

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

GENERAL PERMIT TO DISCHARGE UNDER THE WISCONSIN POLLUTANT DISCHARGE ELIMINATION SYSTEM
WPDES PERMIT NO. WI-S050075-2

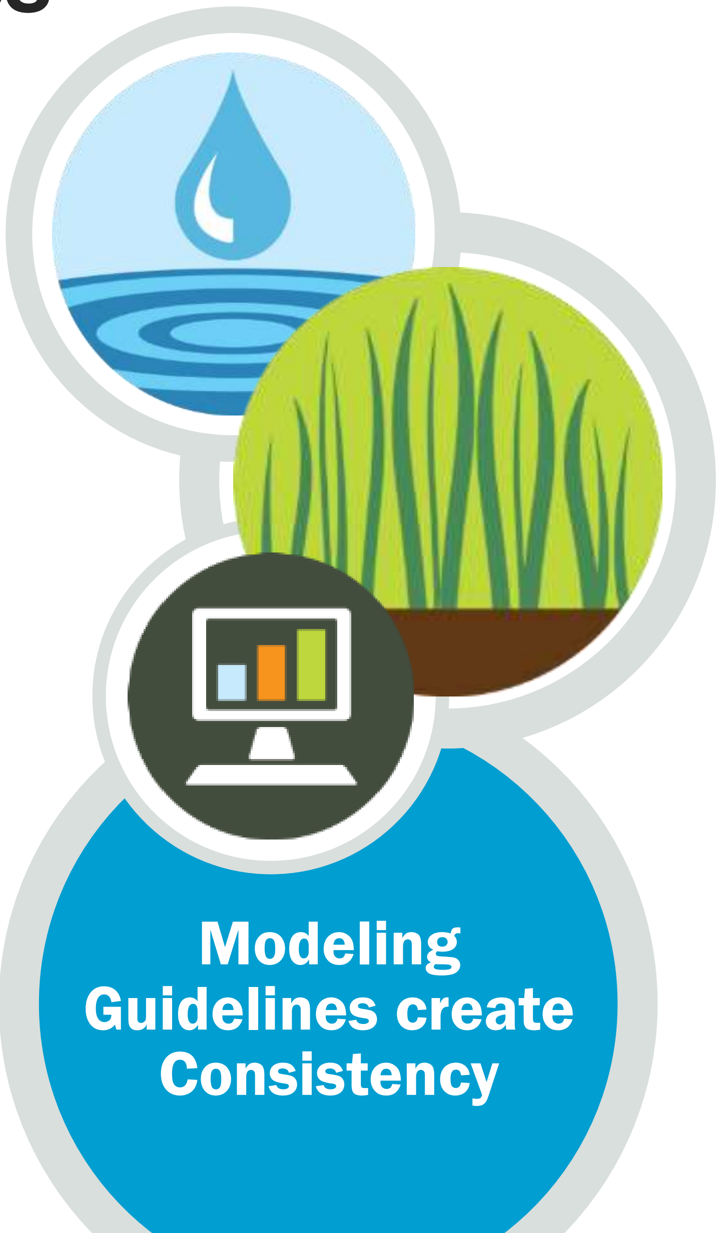
MS4 Numeric Goal Example:

WLA: Reduce Annual TP Load by: **50%**

1. Reduction from a “Base Condition” defined by WDNR
2. Example 50% Reduction Goal related to TP loading > WLA .
3. TP Goal is set for each impaired water within an urban area.

WDNR Modeling Guidelines

- Rainfall data standardized (State has 5 regions)
- Municipal land use represented by source area categories.
- Soil Hydrologic Groups from NRCS.
- Requirements for determining "Regulated Area".
- Starting Point (base conditions) are standardized.
- All Existing and Proposed SCMs included in modeling.



Pollution Reduction Compliance Procedure

1. Use Computer Model to Calculate "Base Condition" TP Load.
   - Base Condition assumes all previous regulations are met.
2. Use Model to Calculate Existing % Control & Optimize Proposed Management.
3. Identify Measures to Meet Required TP Reduction.
4. Prepare Schedule for Implementation.

Municipal Example: Base Conditions

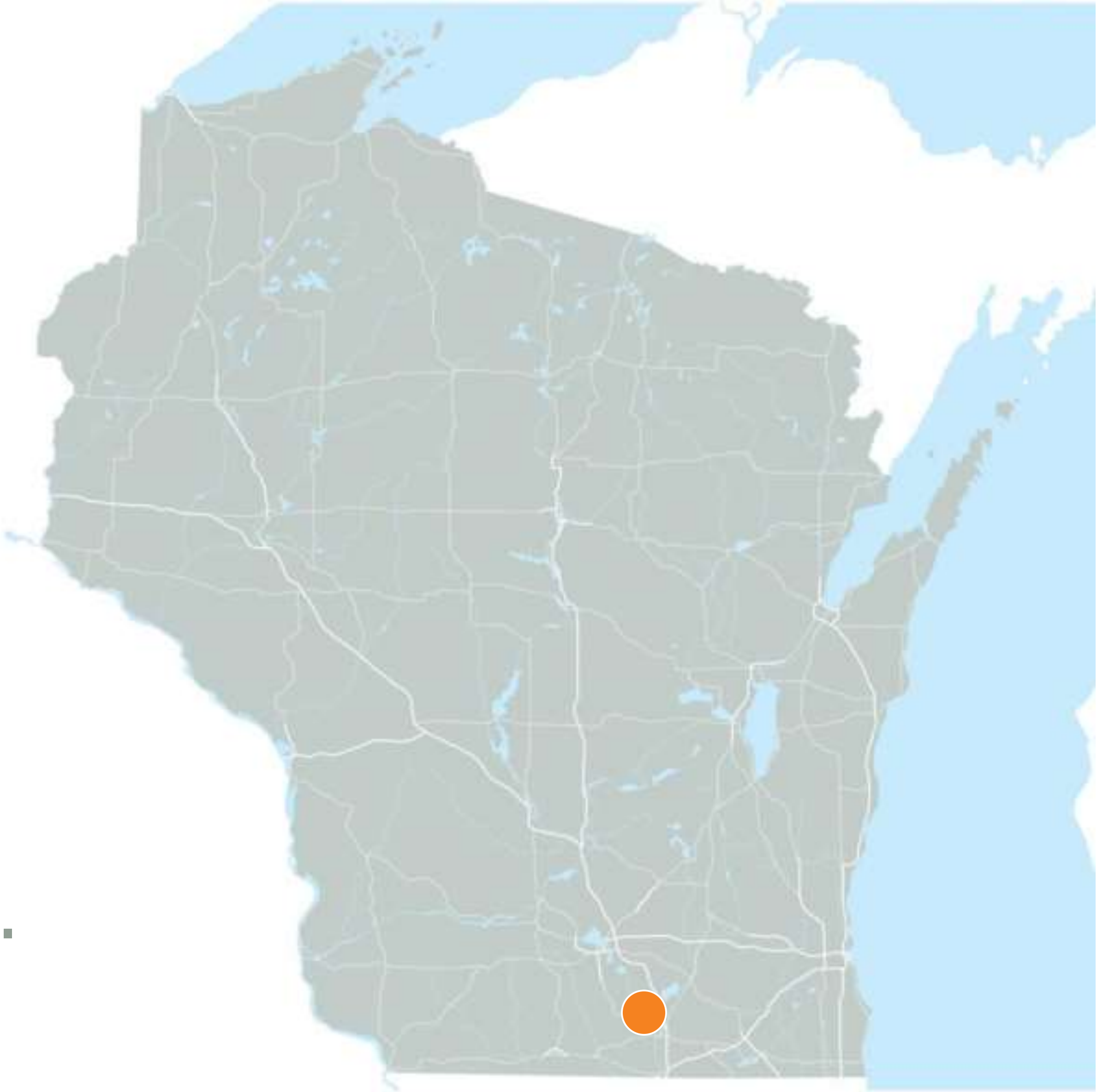
Using Models for TMDL Compliance

– Meeting Numeric Standards

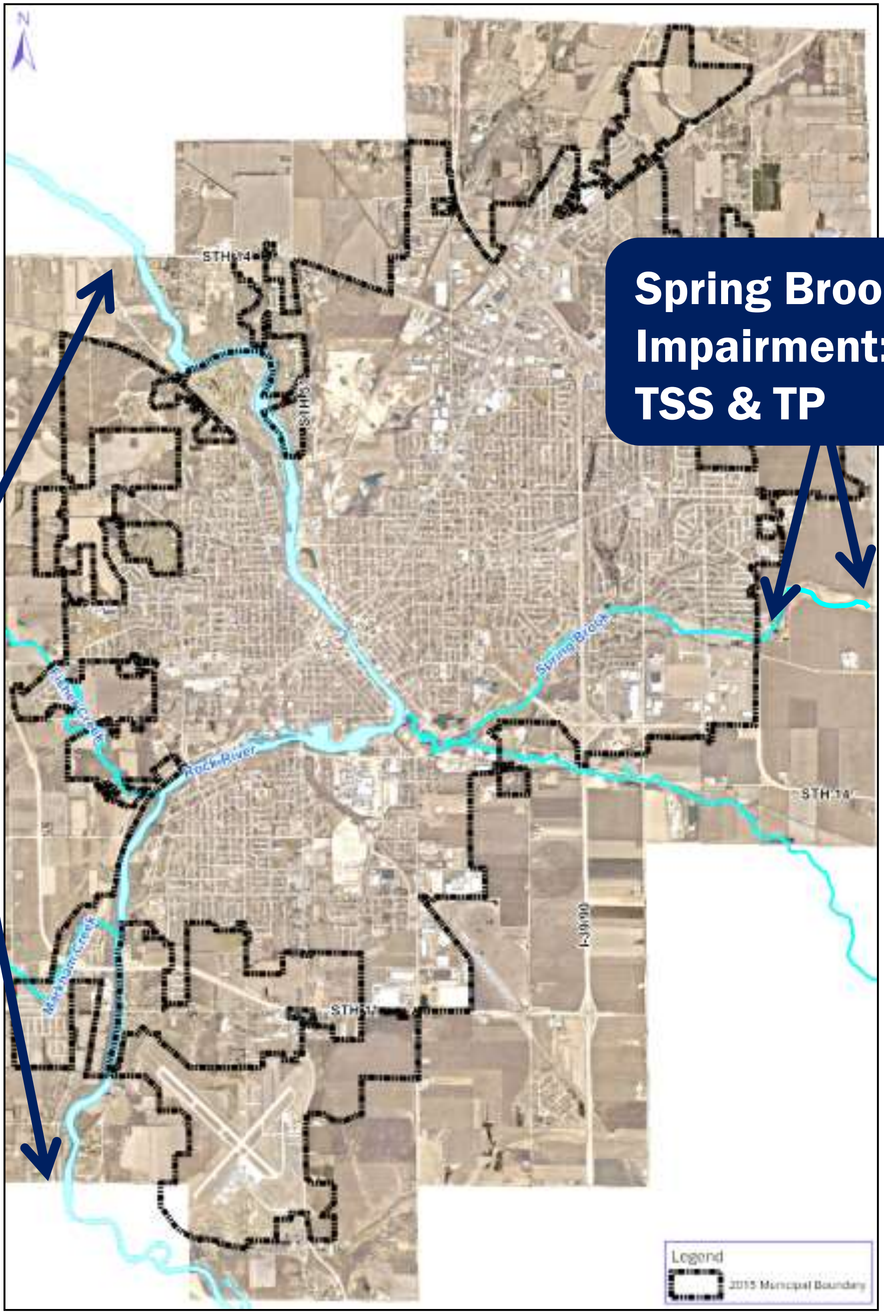
Example

City of Janesville, Wisconsin

- Population: 63,800.
- Municipal Area: 18,000 acres.
- In Rock River TMDL.



Water Resources & Impaired Waters

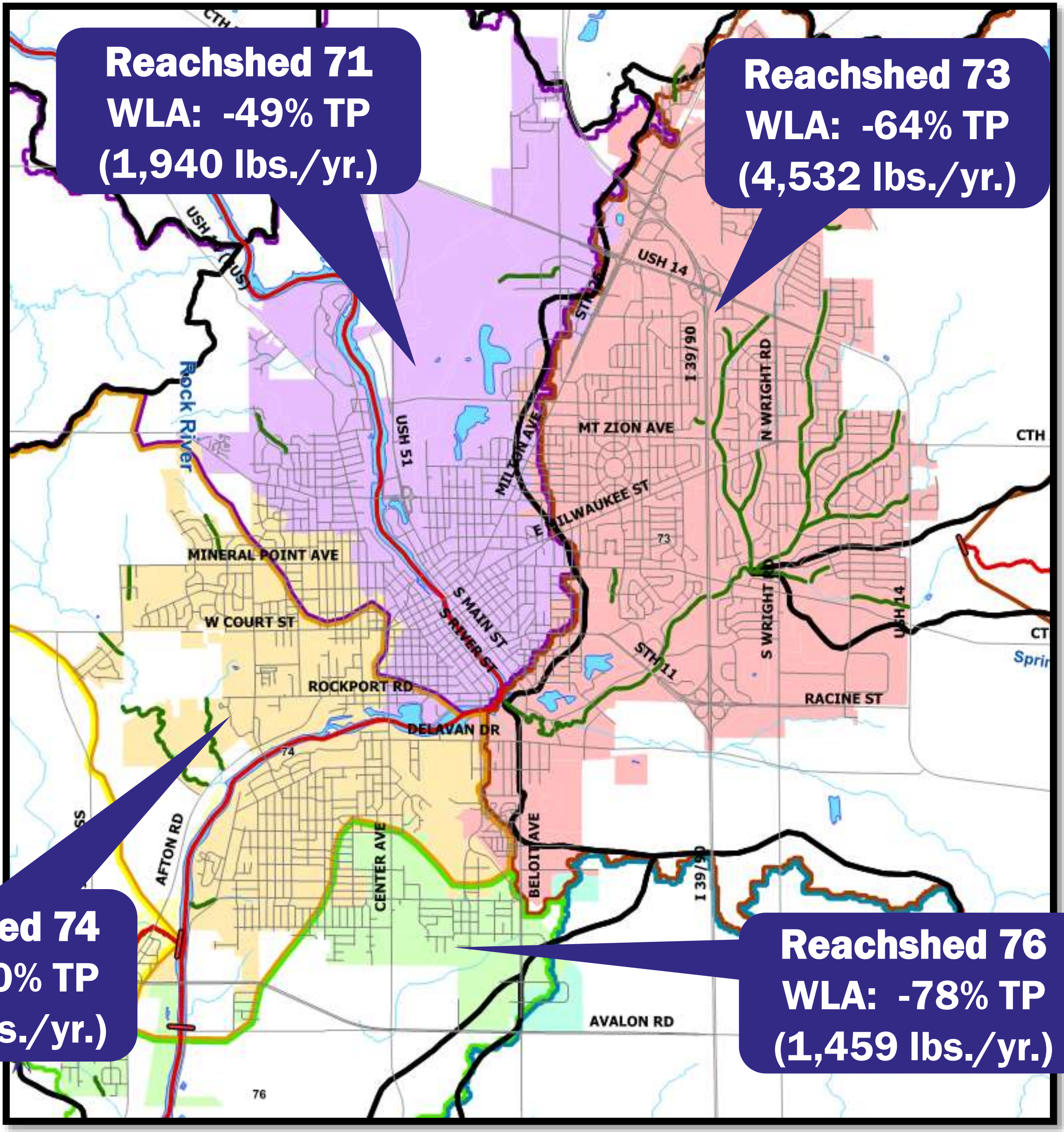


Rock River Impairment: TSS & TP

Spring Brook Cr. Impairment: TSS & TP

Correcting TMDL Watersheds

- Each Watershed has unique TP & TSS WLA
- Each Watershed has unique TP & TSS Load Reduction



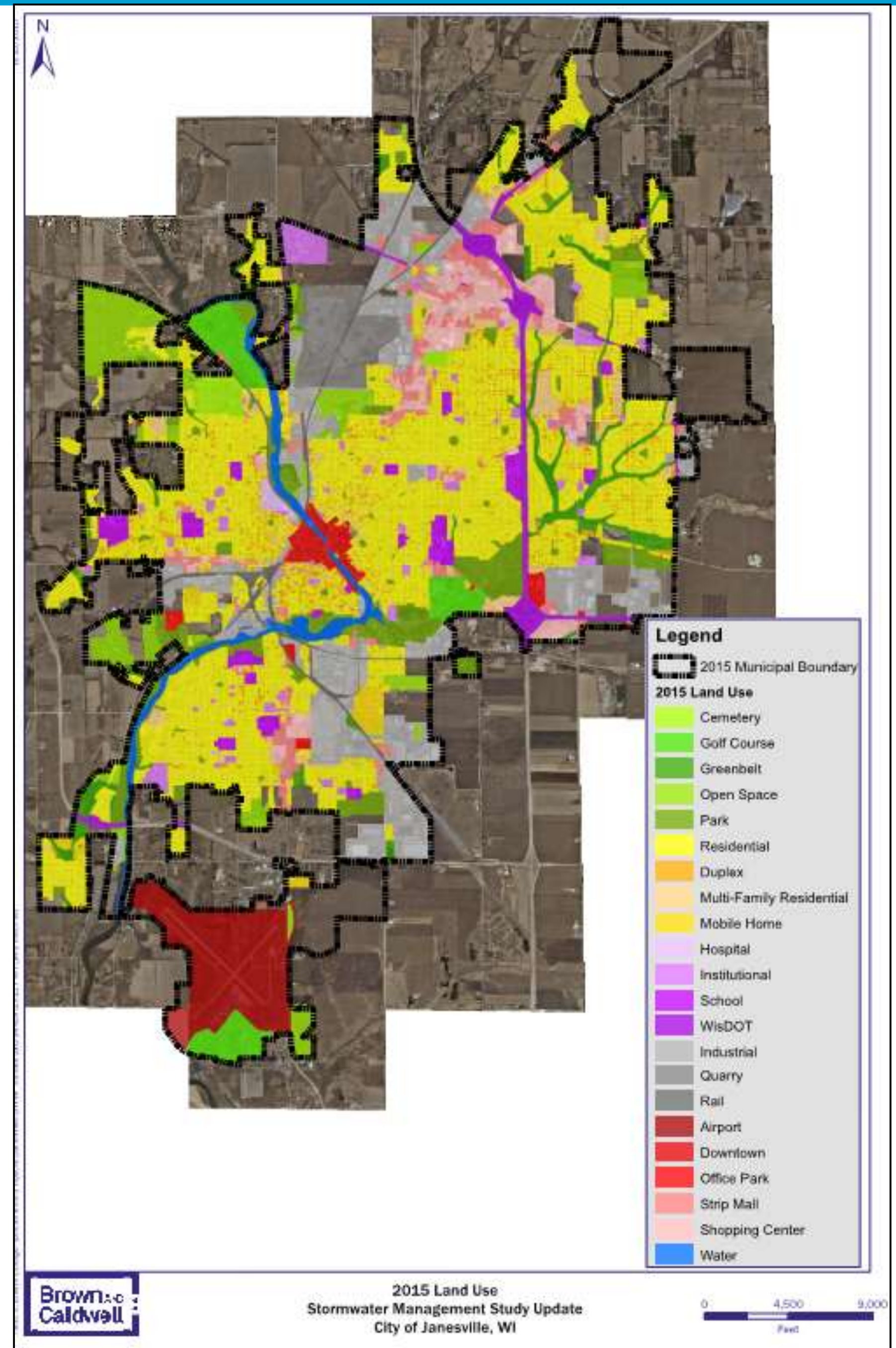
Project Area – Determine "MS4 Regulated" Area

Project Area – Determine "MS4 Regulated" Area

Account for Existing SCMs

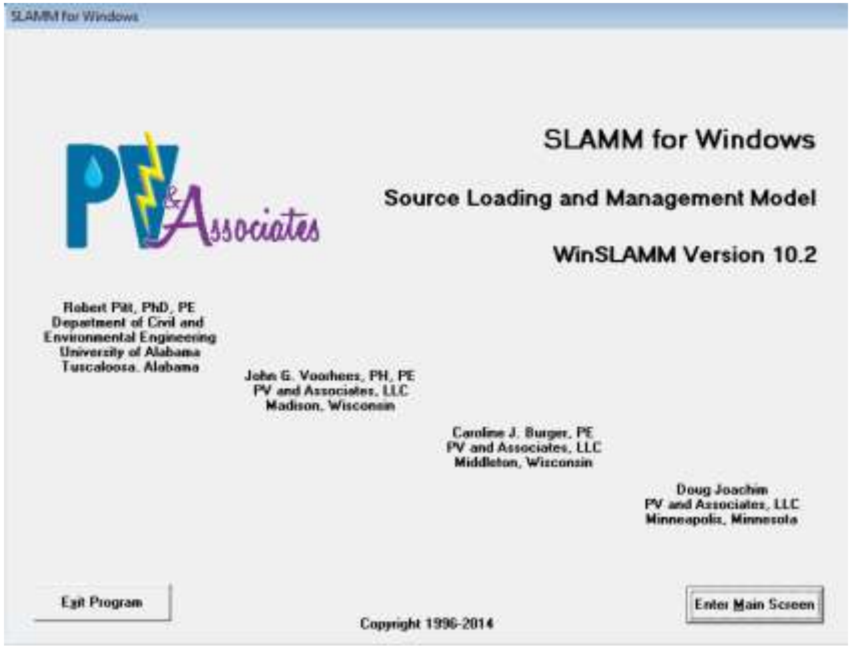
Non-Structural

Water Quality Land Uses – Matched to Model Input

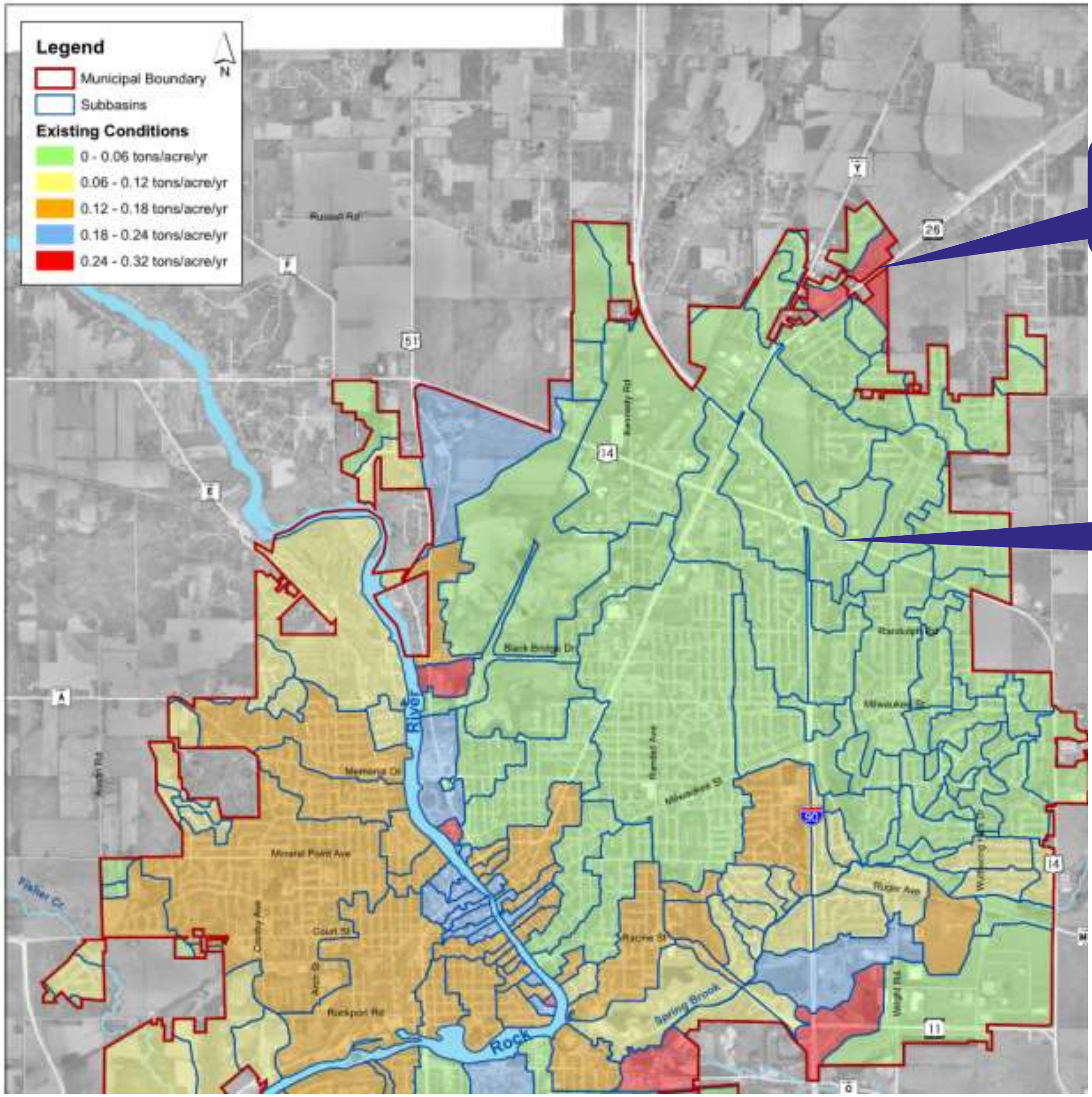


Conduct Modeling

- Use Computer Model to Calculate "Base Condition" Loading.
- Defined by WDNR: "Meet Pre-TMDL Regulations".
- This is Starting Point for TMDL Compliance.



Base Conditions Pollution Load



Red: Higher Pollution Load

Green: Lower Pollution Load

Municipal Example: Plan to Meet WLA

Using Models for TMDL Compliance

– Meeting Numeric Standards

Pollution Reduction Compliance Procedure

1. Identify Measures to Meet Required TP (or other pollutant) Reduction.
2. Analyze Measures with Model to Optimize Approach.
3. Implement Plan.

Implementation Plan

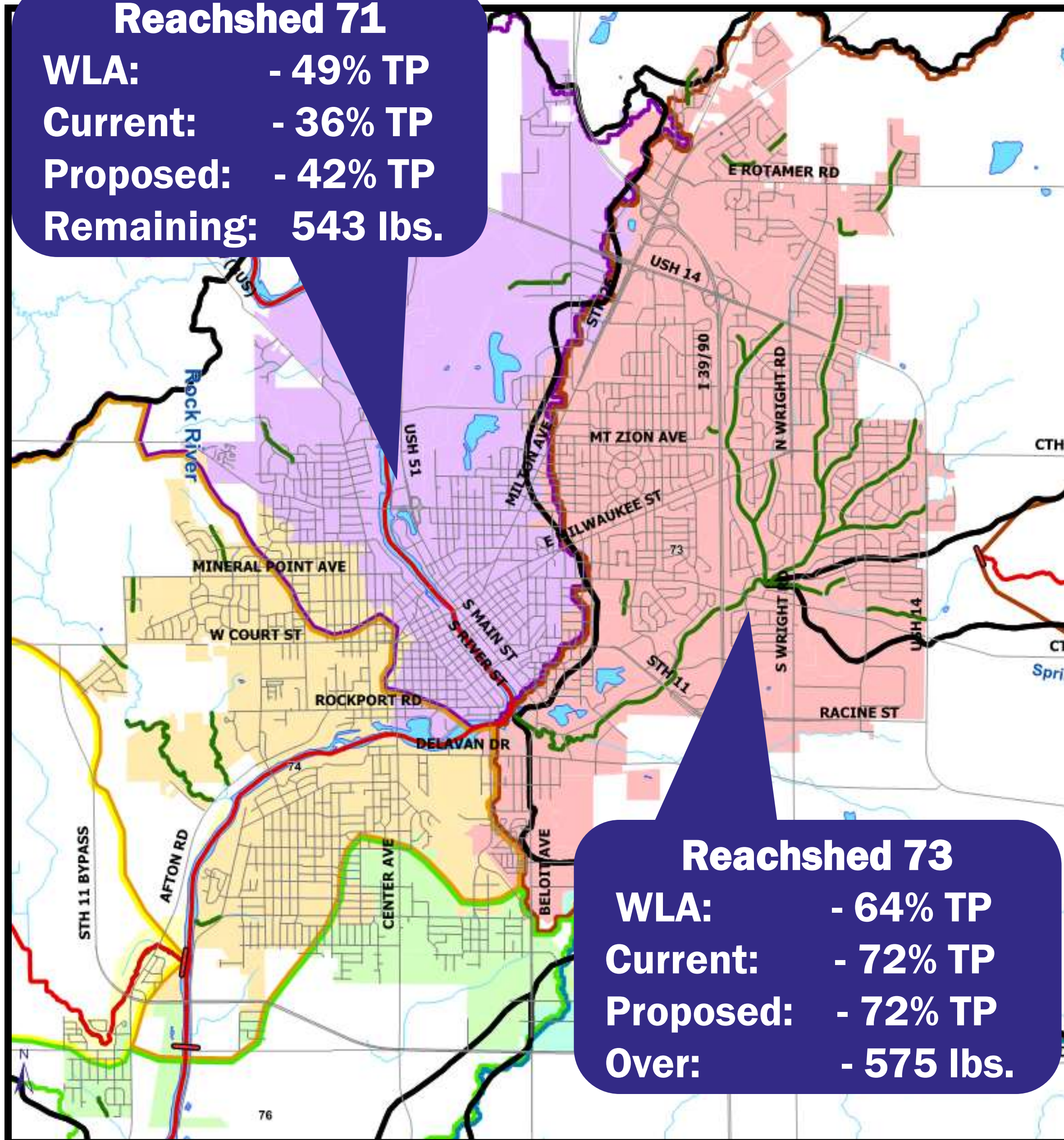
- ID Measures to Meet Each “Reachshed’s” TP WLA.
- Measures:
  - Maintain / Enhance Existing Green Belt System.
  - Convert Existing Dry Basins to SW Quality Ponds.
  - Maximize GI / SW Management With Each Redevelopment.
  - Incorporate GI Into Street Reconstruction Projects.
- ~ $7.54 MM

Full Implementation Achievements

Plan:
- Schedule feasible progress
- Re-assess after 10 years

Reachshed 71
WLA: - 49% TP
Current: - 36% TP
Proposed: - 42% TP
Remaining: 543 lbs.

Reachshed 73
WLA: - 64% TP
Current: - 72% TP
Proposed: - 72% TP
Over: - 575 lbs.



Summary and Conclusions

Using Models for TMDL Compliance

– Meeting Numeric Standards

Summary and Conclusions

- Standardized modeling approach provides:
  - Clear guidance for analysis and reporting
  - Establish normalized base condition for comparisons
  - Level playing field
  - Objective measure of progress
  - Maximum flexibility for local strategies
  - Not restricted by "spreadsheets" and unit load approaches
- Same numeric approach is applied to other pollutants.
- Retrofitting of SCMs in urban area is feasible up to a point.
- After feasible SCMs implemented, longer term plan of compliance by redevelopment or new technology.

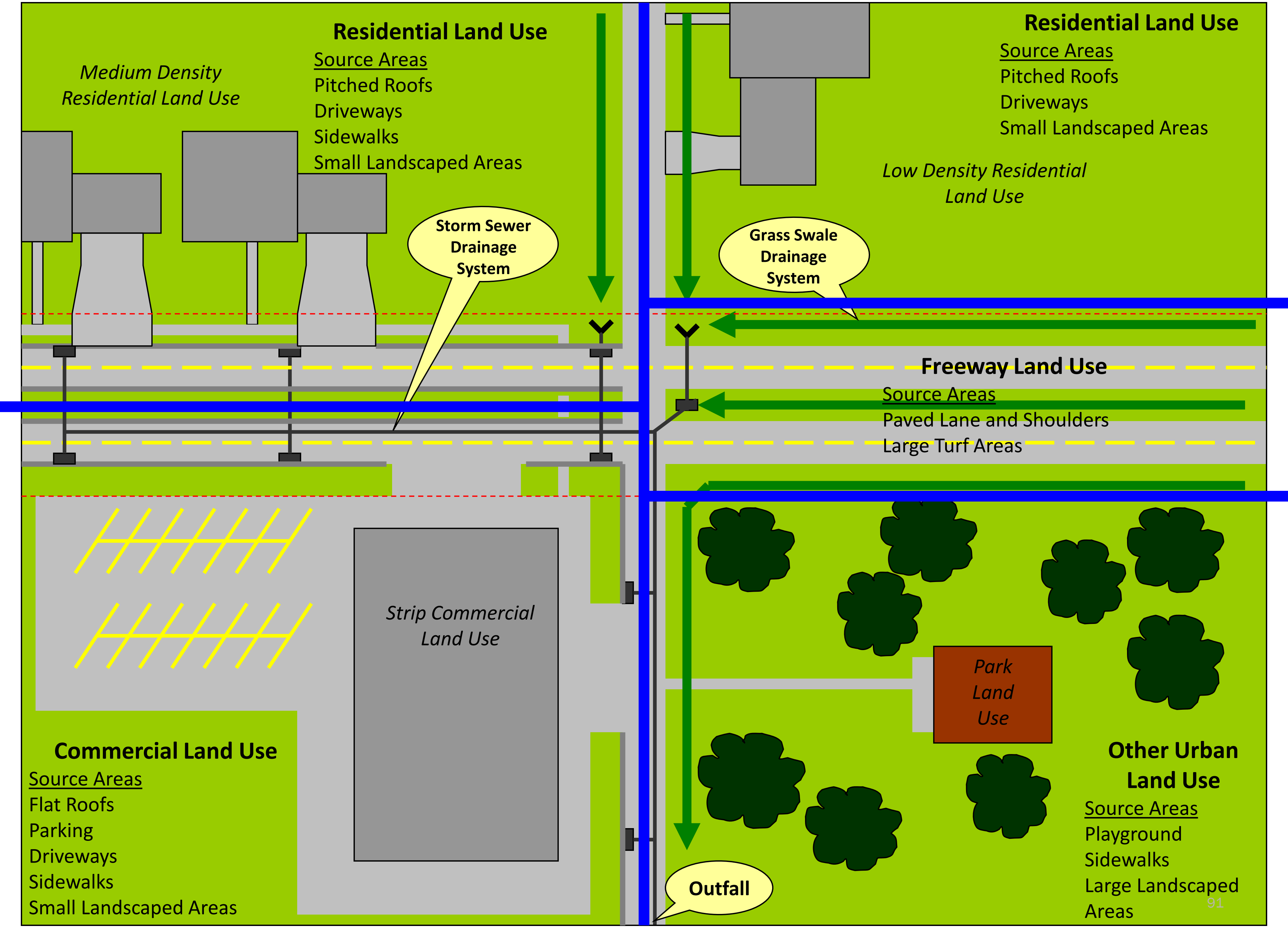
SLAMM Calibration and Verification

SLAMM Strength – Based on Extensive Field Monitoring Data

Monitoring Source Areas – Lawns, Roofs, etc.

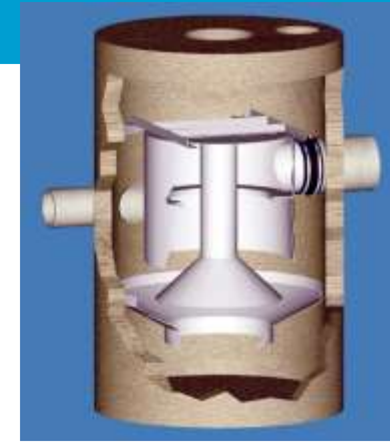
Loads from Land Uses

Evaluating Stormwater Control Measures

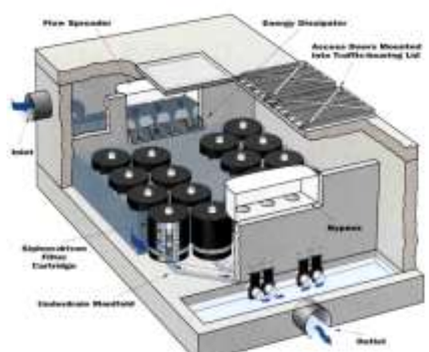


Residential Land Use
Source Areas
Pitched Roofs
Driveways
Sidewalks
Small Landscaped Areas
Medium Density Residential Land Use
Storm Sewer Drainage System
Residential Land Use
Source Areas
Pitched Roofs
Driveways
Small Landscaped Areas
Low Density Residential Land Use
Grass Swale Drainage System
Freeway Land Use
Source Areas
Paved Lane and Shoulders
Large Turf Areas
Strip Commercial Land Use
Commercial Land Use
Source Areas
Flat Roofs
Parking
Driveways
Sidewalks
Small Landscaped Areas
Park Land Use
Other Urban Land Use
Source Areas
Playground
Sidewalks
Large Landscaped Areas
Outfall

Stormwater Control Measures in SLAMM



- Wet Detention Ponds
- Porous Pavement
- Street Cleaning
- Catchbasin Cleaning
- Grass Swales and Grass Filters
- Biofiltration/bioretention
- Green Roofs
- Proprietary Controls (media filters and hydrodynamic devices)
- Beneficial Uses





Source Area Sampling



End of Pipe Monitoring :Mass Balance

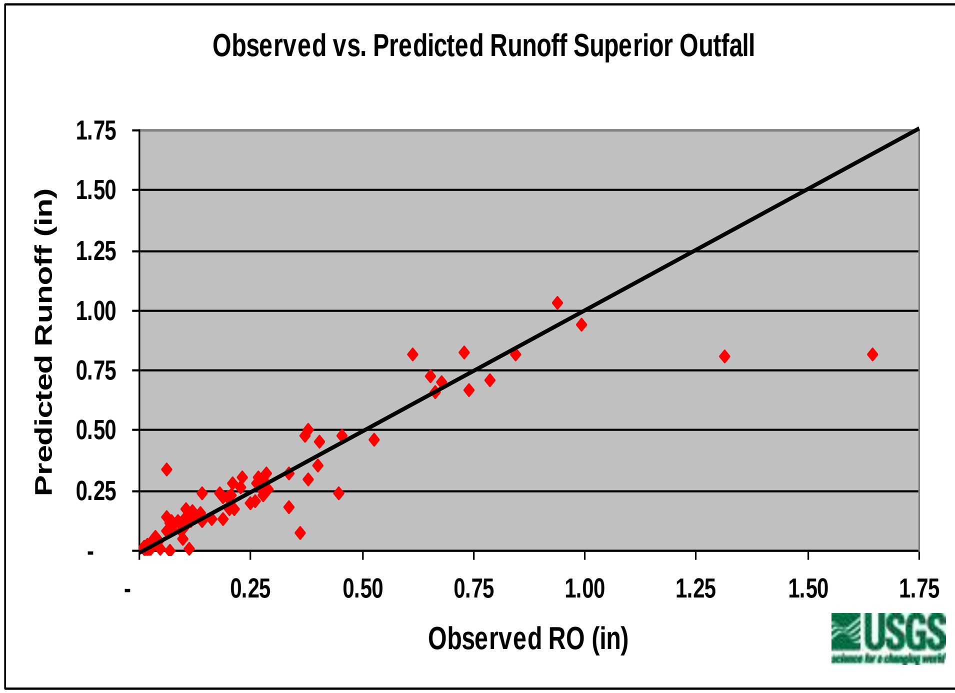
Description of Seven Study Areas

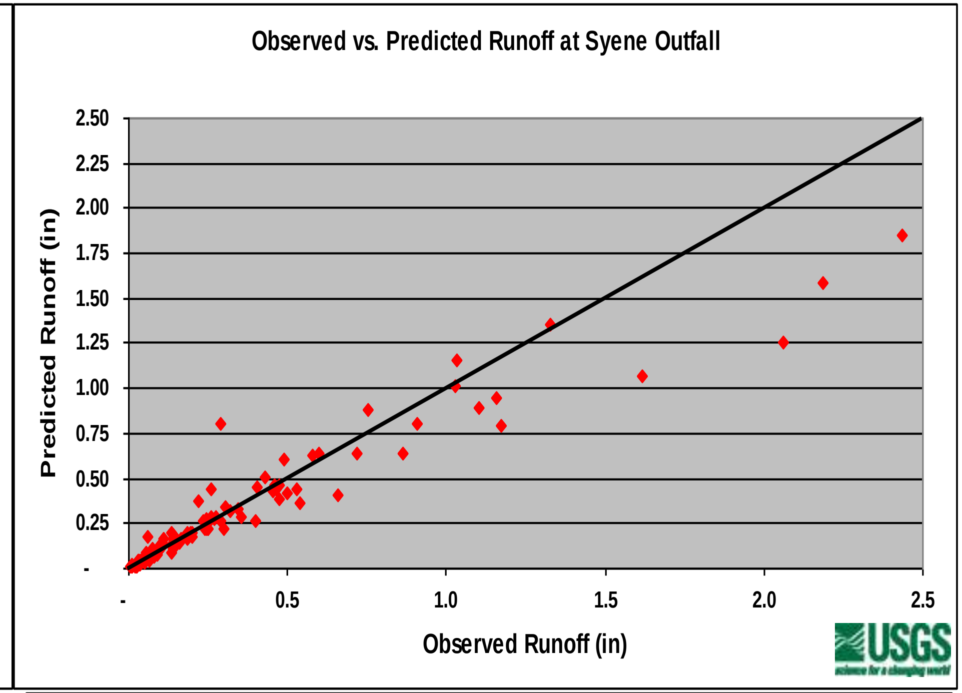
SITE	LAND USE	ACRES	FLOW	Conc.
Harper	Residential	41	55	32
Monroe	Residential	232	75	71
Canterbury	Residential	964	55	23
Marquette	Resid/Com.	288	64	14
Superior	Commercial	22	91	21
Syene Rd.	Industrial	114	108	82
Badger Rd.	Maint. Yard	4	40	18

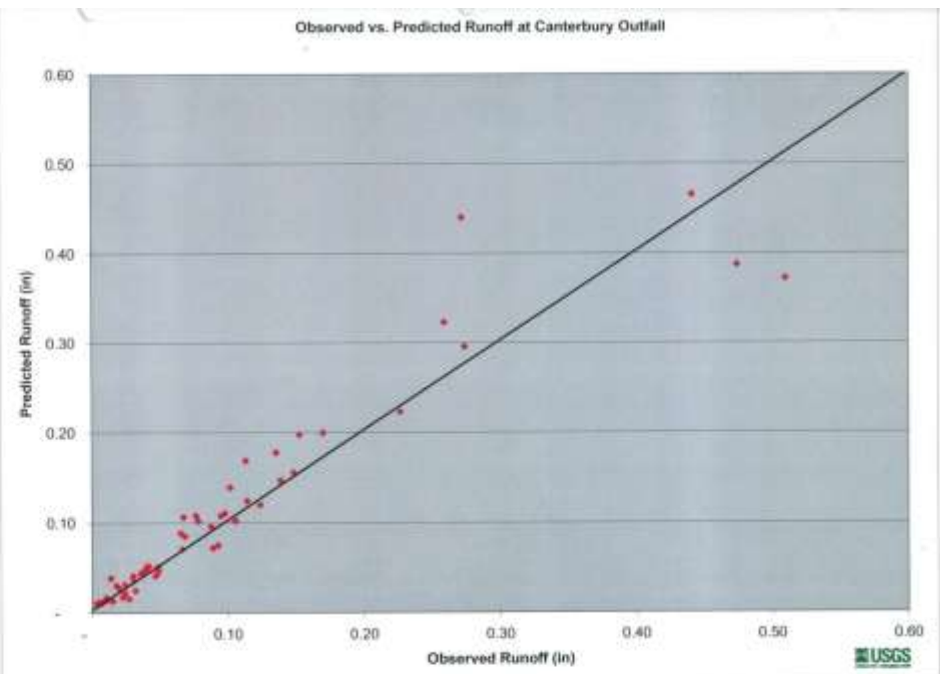
Sites with Source Area and End of the Pipe Monitoring

Measured versus Modeled Runoff, inches

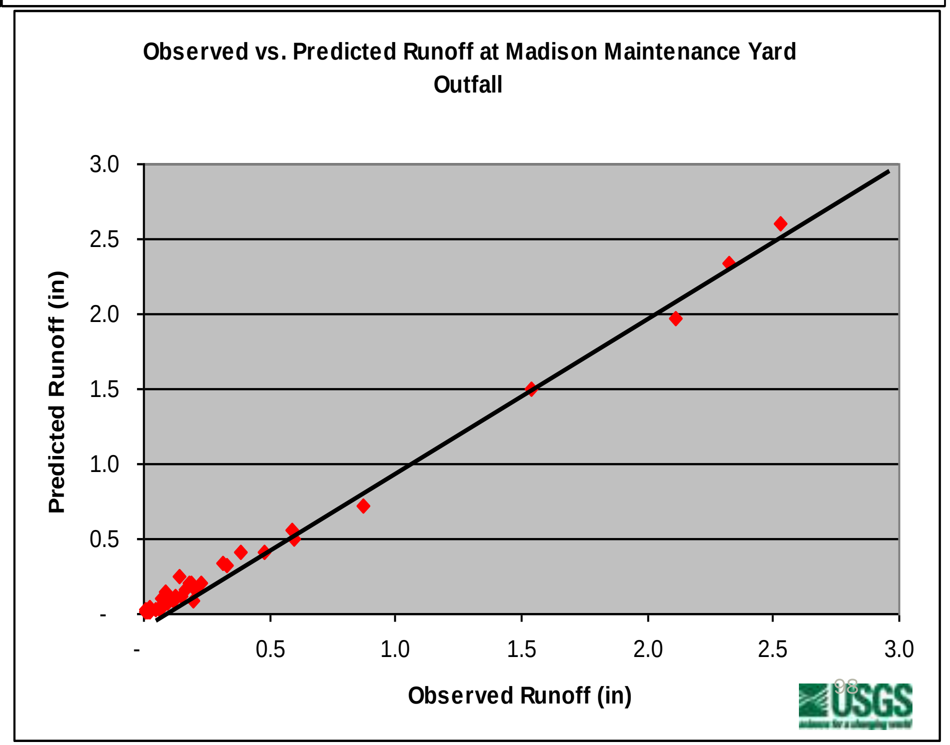
SITE	Number of Events	Measured Runoff	Modeled Runoff	Difference, %
Monroe	75	8.2	8.8	7%
Canterbury	55	5.4	5.9	10%
Marquette	64	2.4	2.4	0%
Superior	91	19.8	20.2	2%
Syene	108	29.5	28.7	-3%
Badger	40	14.9	14.3	-4%


Observed vs. Predicted Runoff Superior Outfall
Predicted Runoff (in)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
-
- 0.25 0.50 0.75 1.00 1.25 1.50 1.75
Observed RO (in)
USGS
science for a changing world


Observed vs. Predicted Runoff at Syene Outfall
Predicted Runoff (in)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
-
- 0.5 1.0 1.5 2.0 2.5
Observed Runoff (in)
USGS
science for a changing world


Observed vs. Predicted Runoff at Canterbury Outfall
Predicted Runoff (in)
0.60
0.50
0.40
0.30
0.20
0.10
-
- 0.10 0.20 0.30 0.40 0.50 0.60
Observed Runoff (in)
USGS

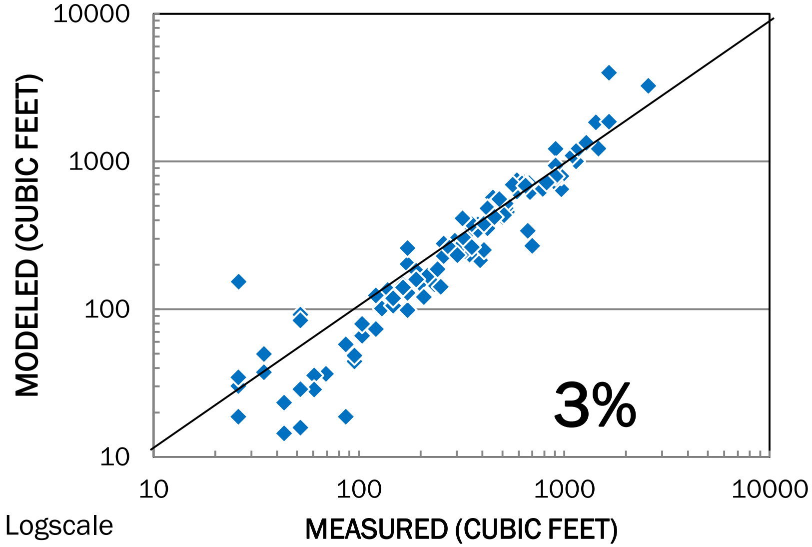
Draft 5/16/01


Observed vs. Predicted Runoff at Madison Maintenance Yard Outfall
Predicted Runoff (in)
3.0
2.5
2.0
1.5
1.0
0.5
-
- 0.5 1.0 1.5 2.0 2.5 3.0
Observed Runoff (in)
USGS
science for a changing world

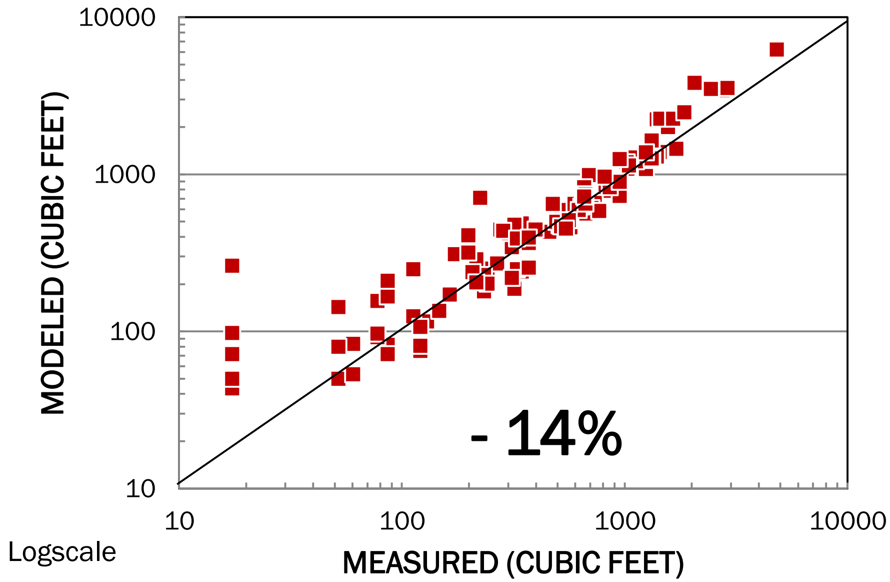
Runoff Volume Comparison

Number of Rainfalls 124
Total Rain Depth 57 in.

Cell-1



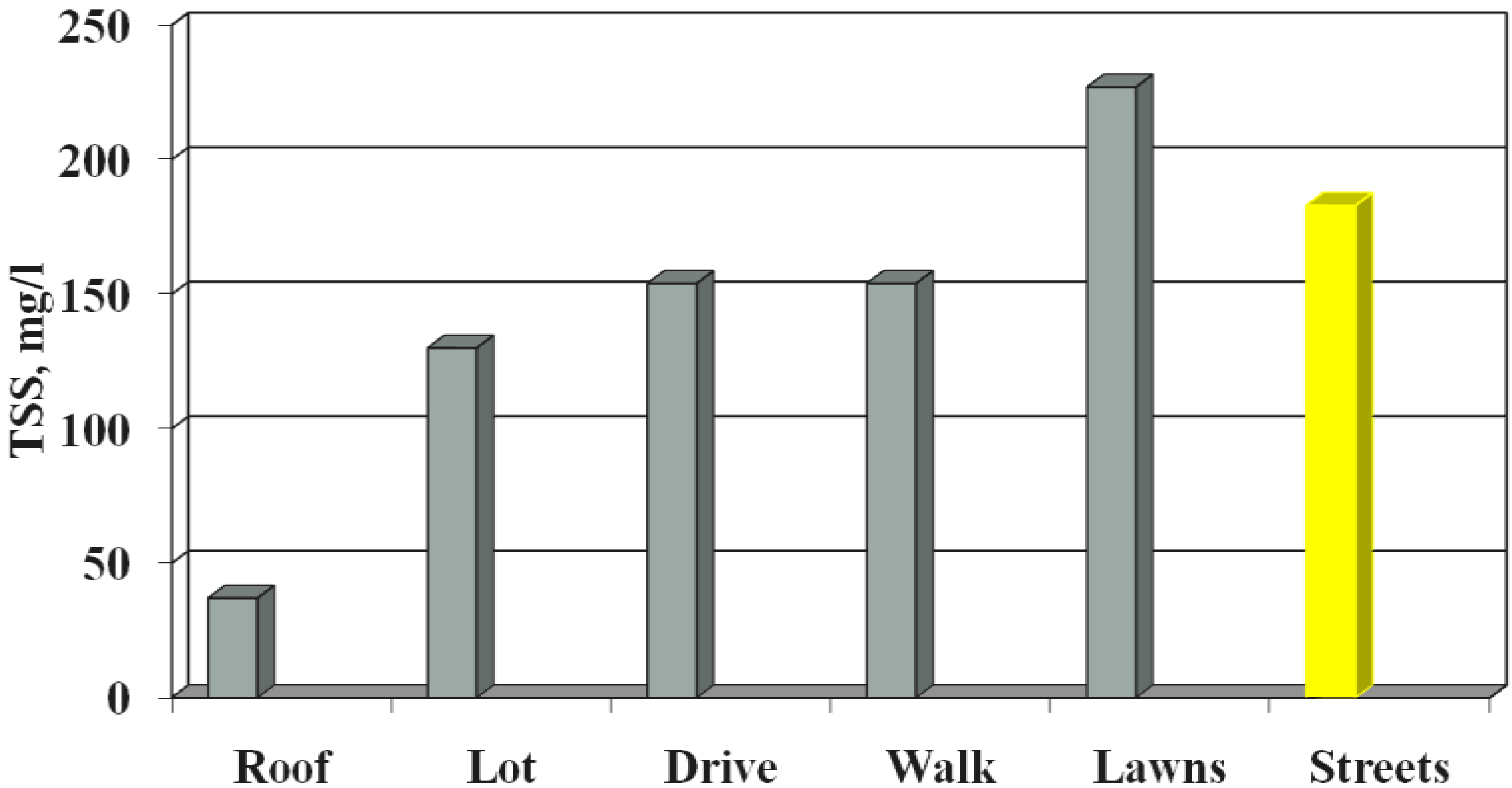
Cell-2



Type of Pollutants

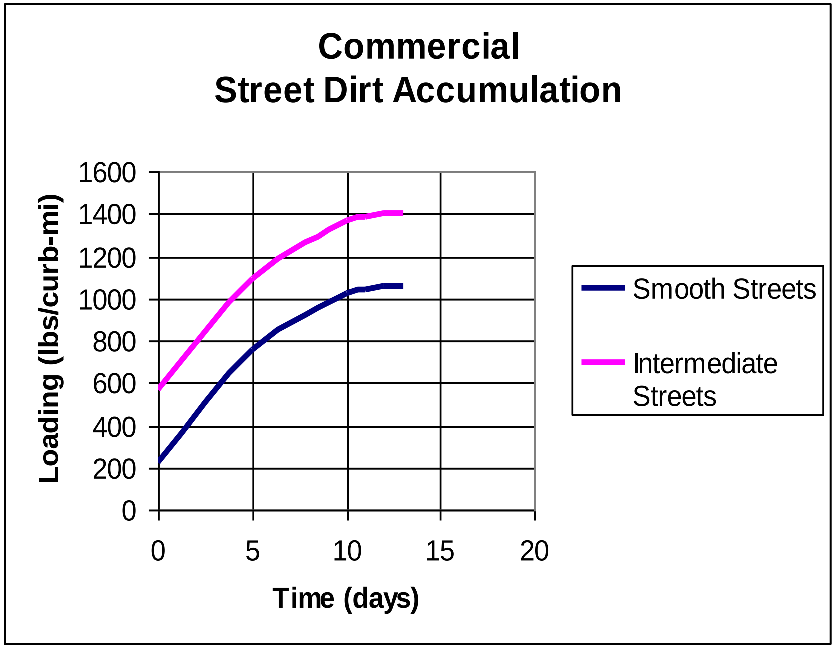
- Suspended Solids
- Total Solids
- Total Phosphorus
- Total Lead
- Total Zinc
- Total Copper
- Dissolved Phosphorus
- Dissolved Lead
- Dissolved Zinc
- Dissolved Copper

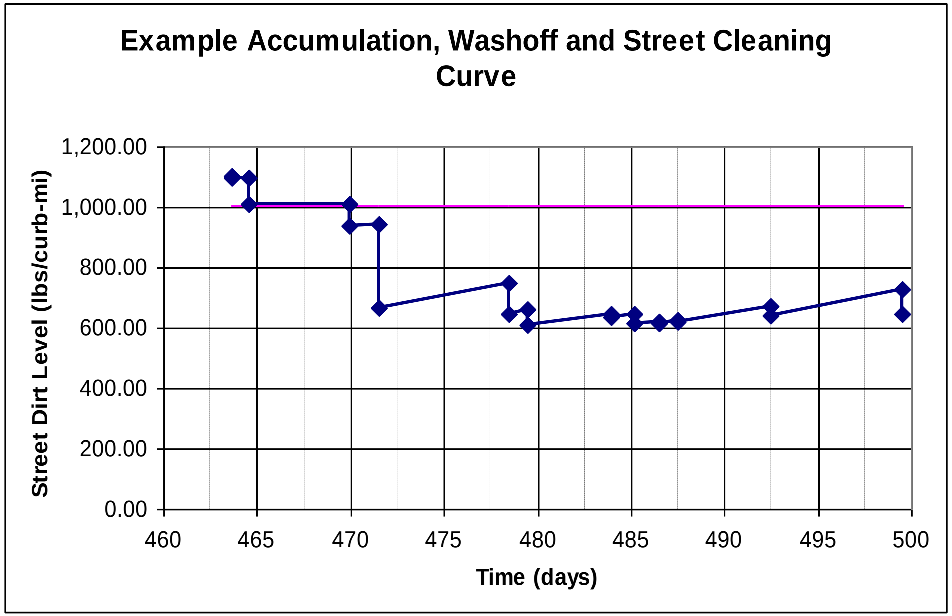
Residential TSS Concentrations Used in SLAMM - .psc



Street Dirt Changes Over Time

Street dirt washoff and runoff

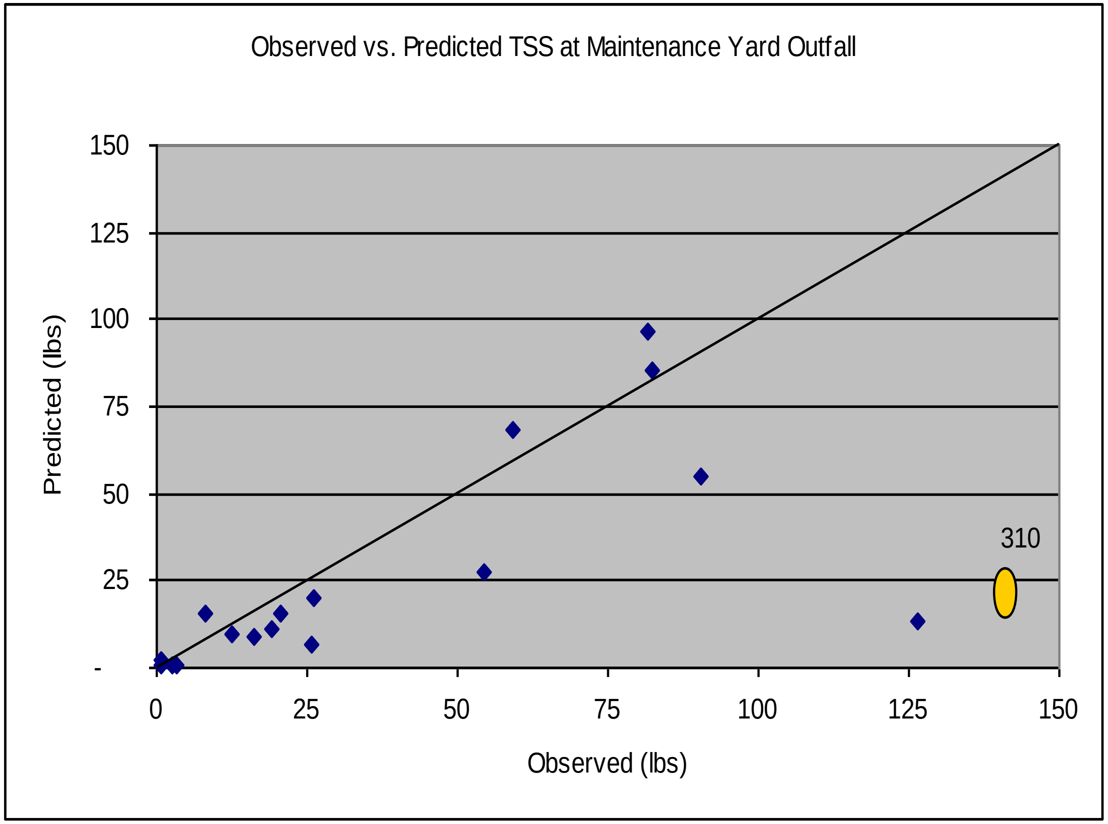


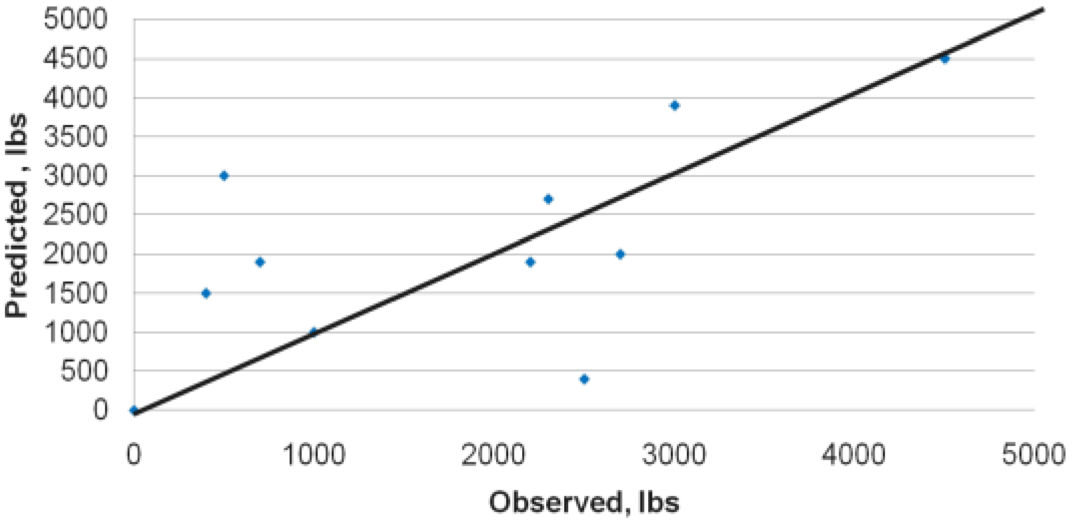


Comparison of Measured and Predicted Suspended Solids Loads

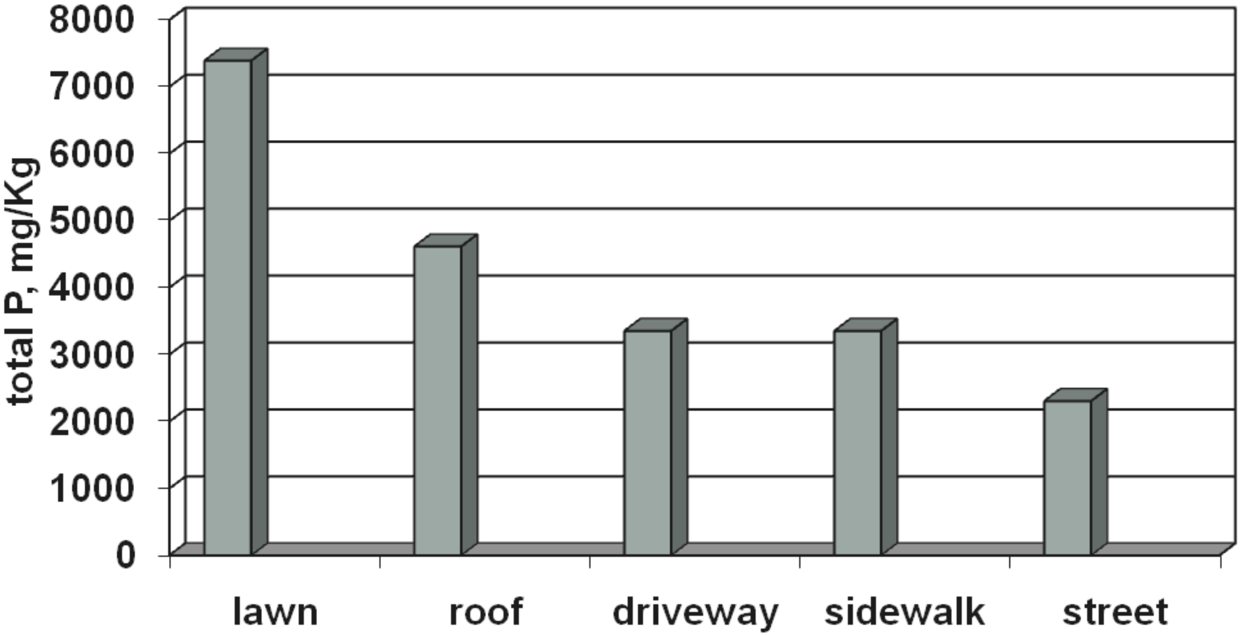
Site	Landuse	Percent Difference
Harper	Residential	11%
Marquette	Resid./Comm.	28%
Canterbury	Resid./Comm.	35%
Superior	Commercial	-30%
Syene	Light Industrial	1%
Badger Rd.	Light Industrial	-14%

Comparison of Measured and Predicted Suspended Solids Loads

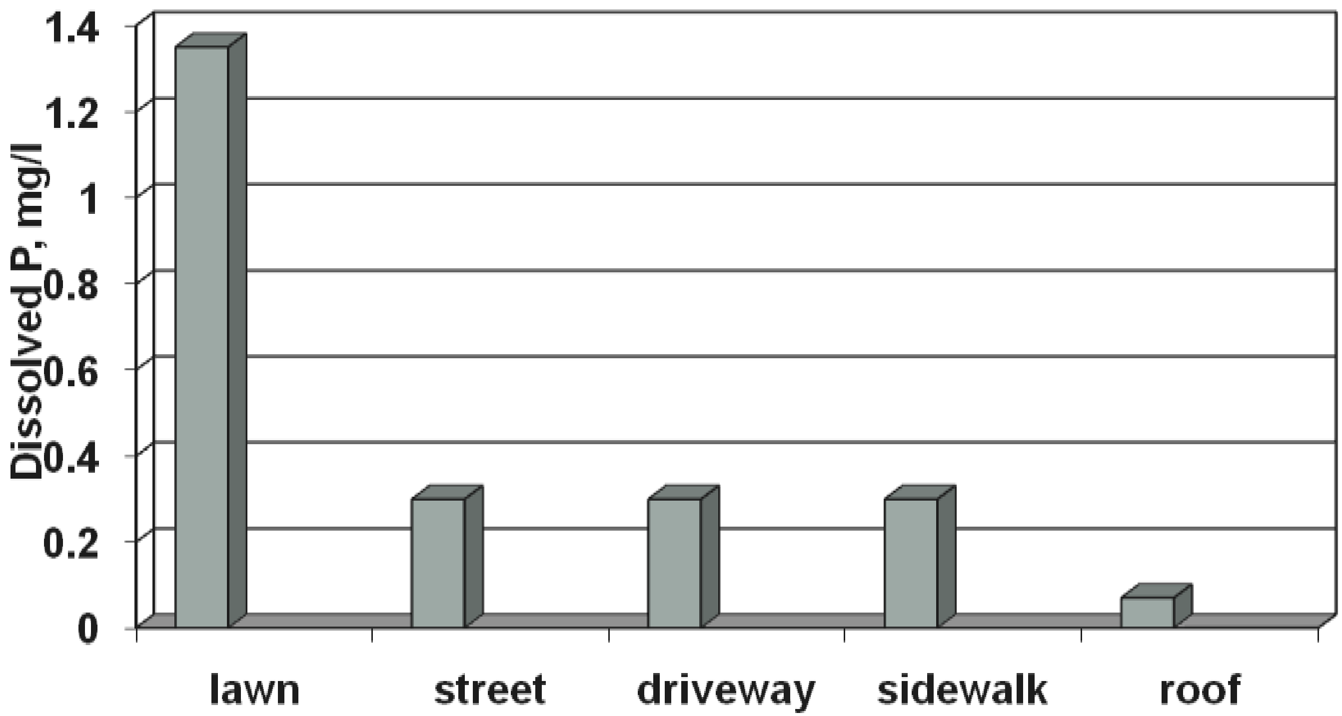




Residential P Values Used in SLAMM



Particulate P

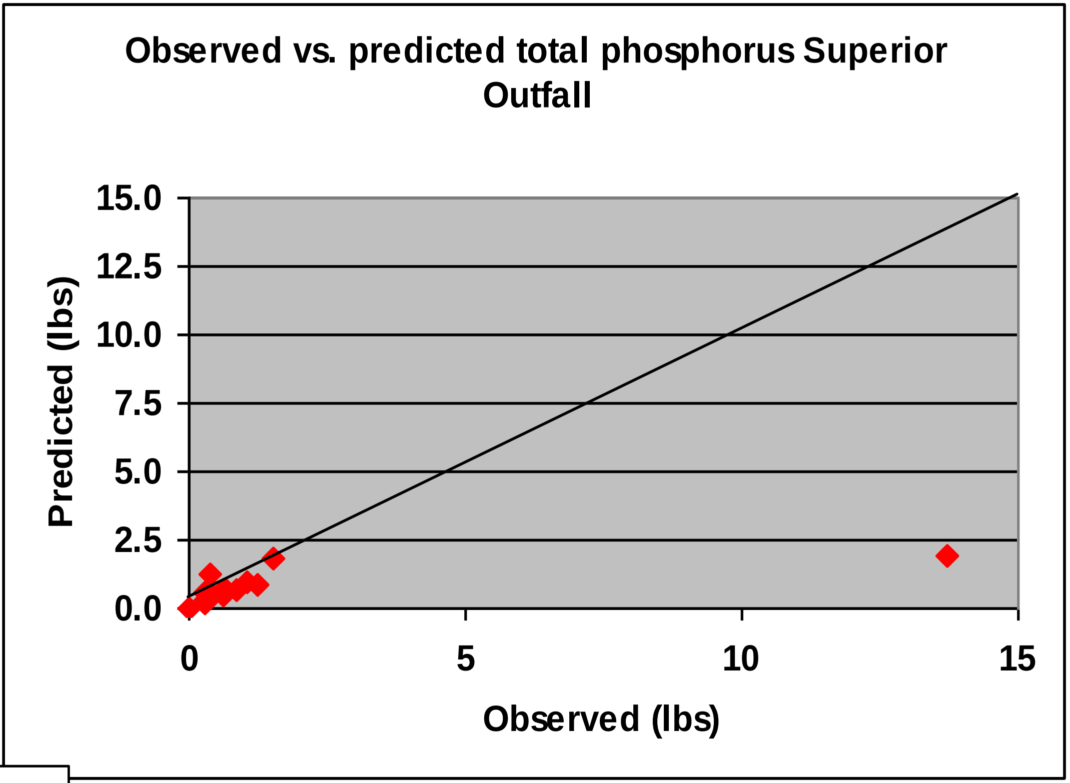


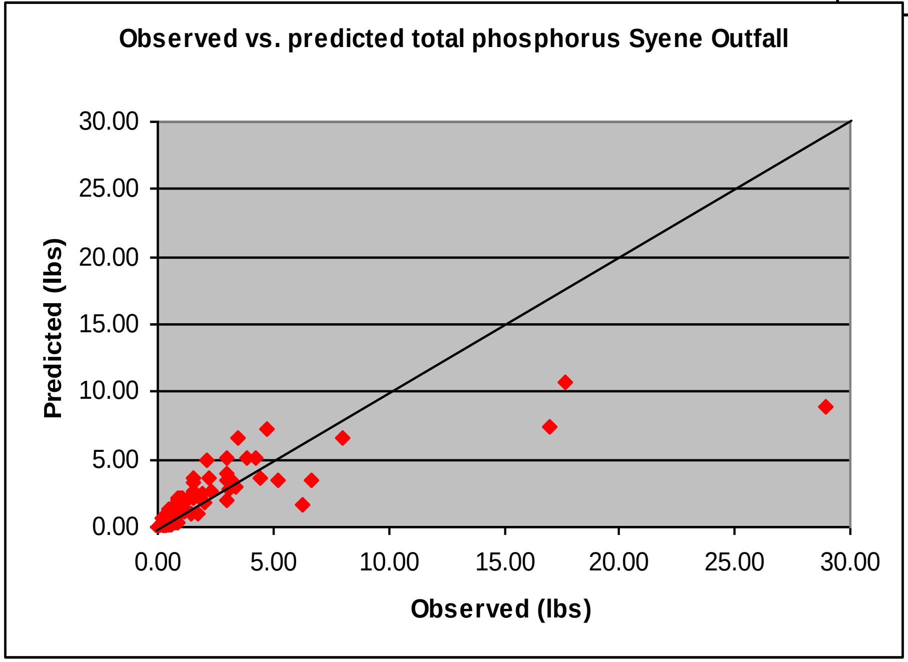
Dissolved P

Measured versus Modeled Total P Loads, pounds

Site	Number of Events	Measured Load	Modeled Load	Percent Difference
Harper	33	12	16	33%
Canterbury	24	406	472	16%
Marquette	16	49	80	65%
Superior	19	10	6	- 40%
Syene	77	182	204	12%

Measured versus Modeled Total P Loads, pounds

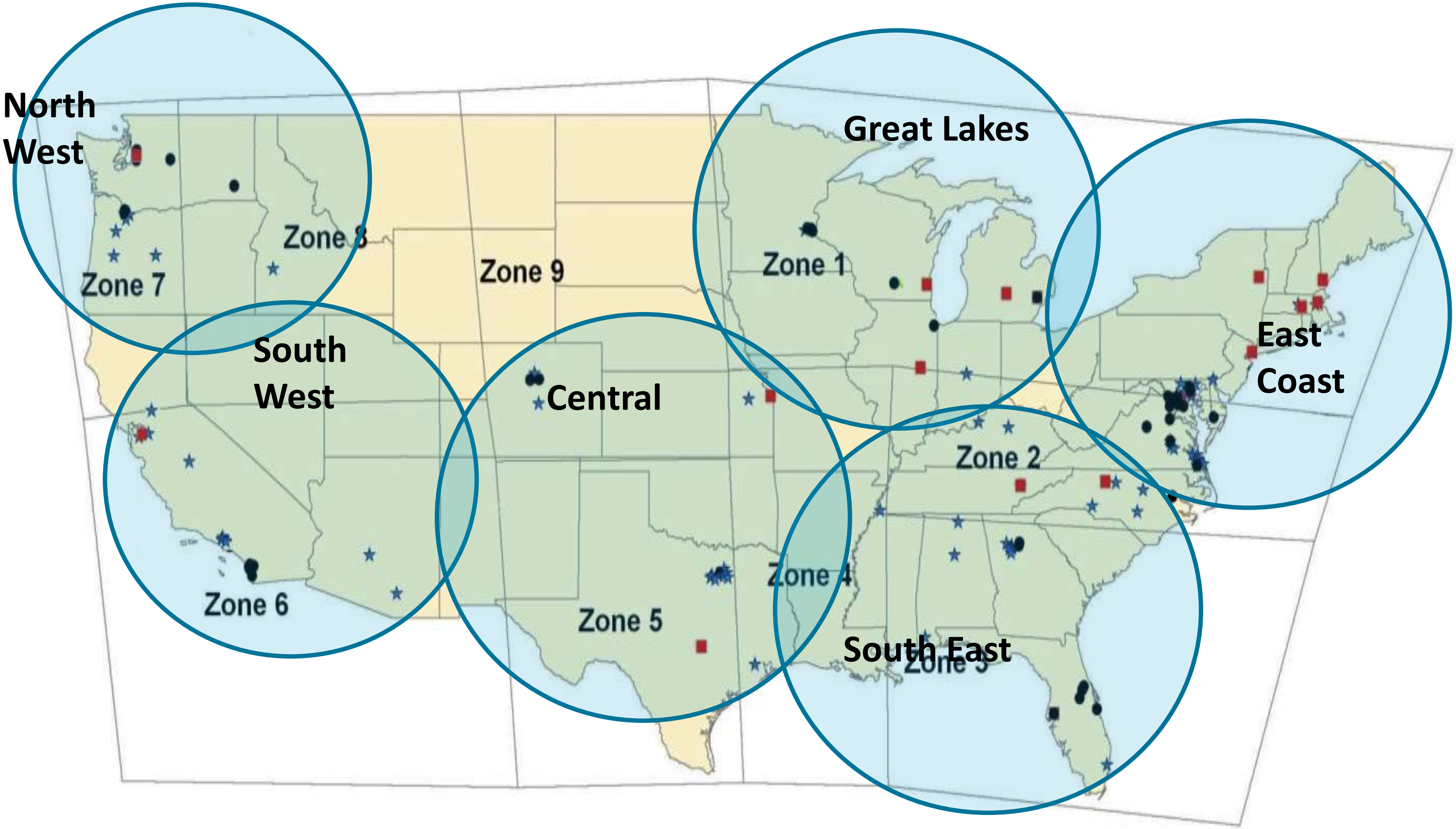




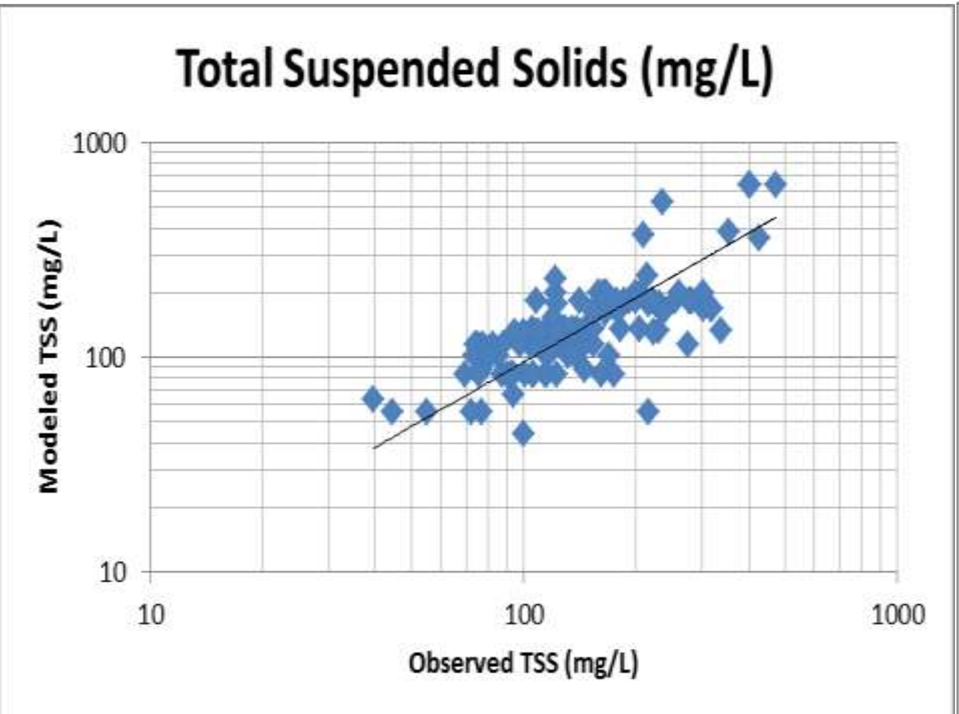
Measured and Modeled Water Volumes and TSS Loads for Two Highway Sites in Milwaukee

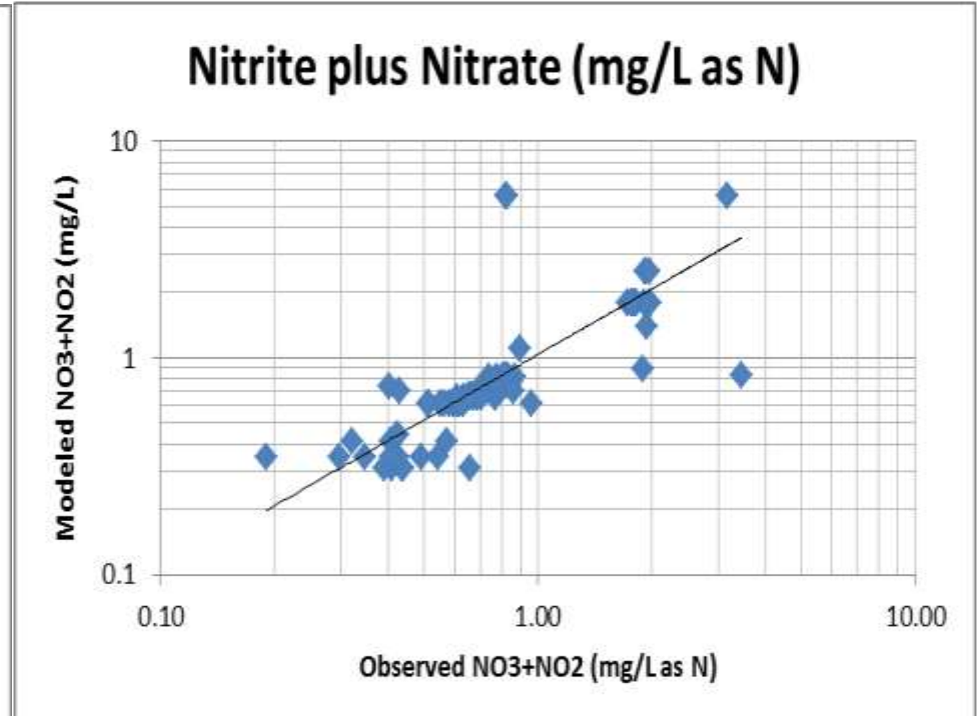
Site	Runoff Volumes, cubic feet			TSS Loads, lbs.		
	Measured	Modeled	Difference	Measured	Modeled	Difference
North Site	19,976	20,401	-2%	121	85	30%
South Site	7,888	7,825	1%	52	53	-1%

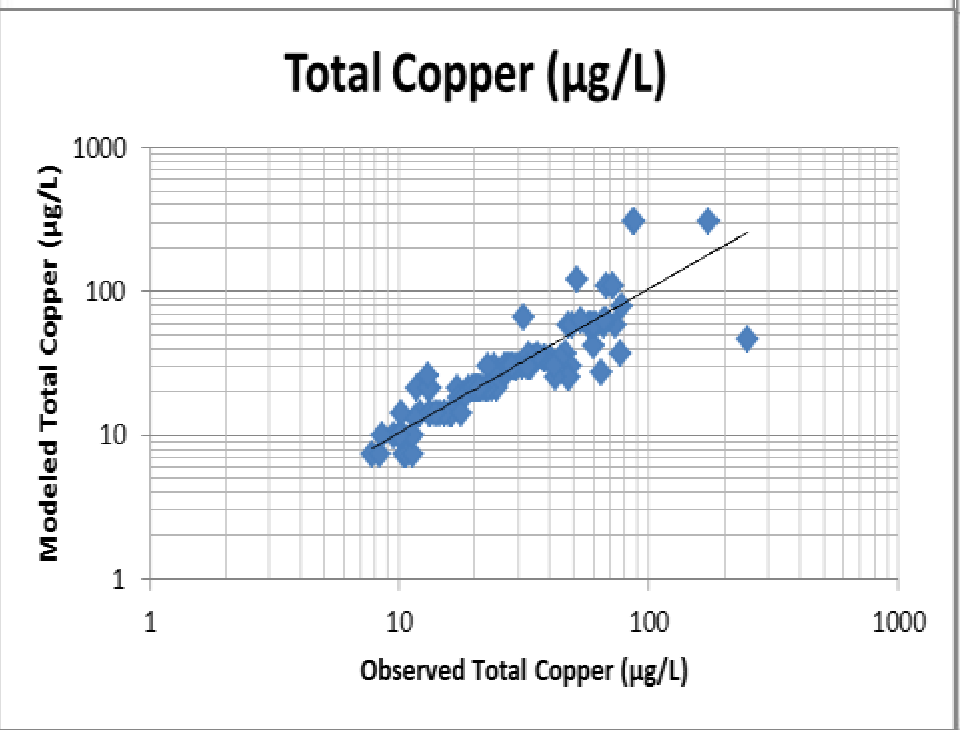
National Stormwater Quality Database Information used to Prepare Regional Calibrations with WinSLAMM

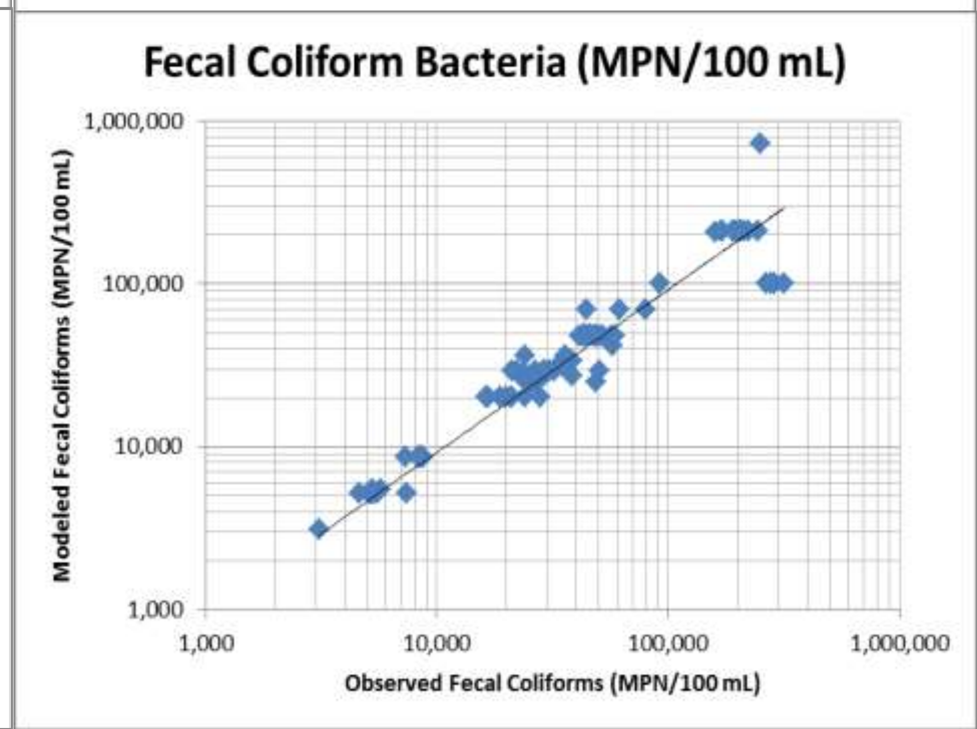


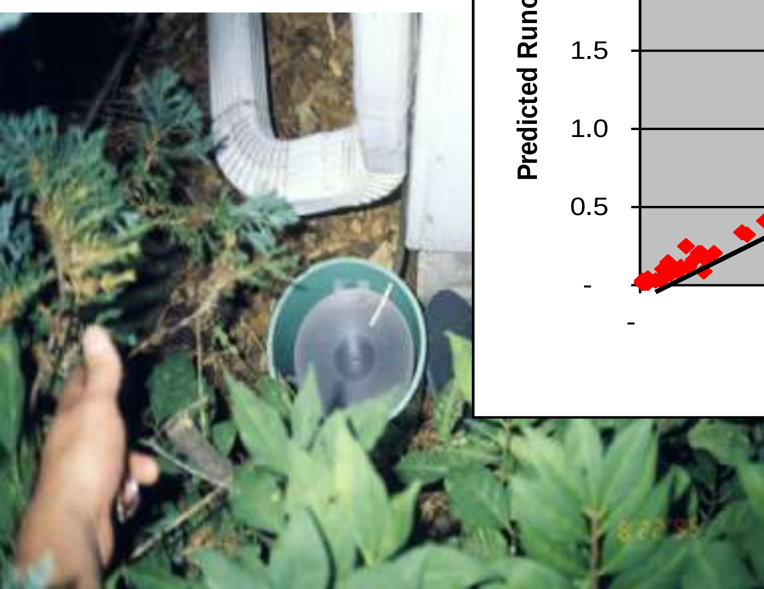
All models require calibration and verification. The NSQD data is a good place to start, but additional locally collected information is necessary for the greatest reliability.

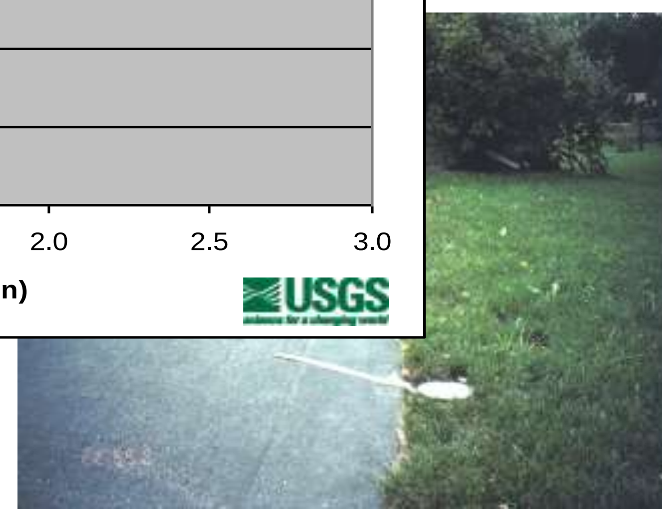

Total Suspended Solids (mg/L)
Modeled TSS (mg/L)
Observed TSS (mg/L)
1000
100
10
10
100
1000

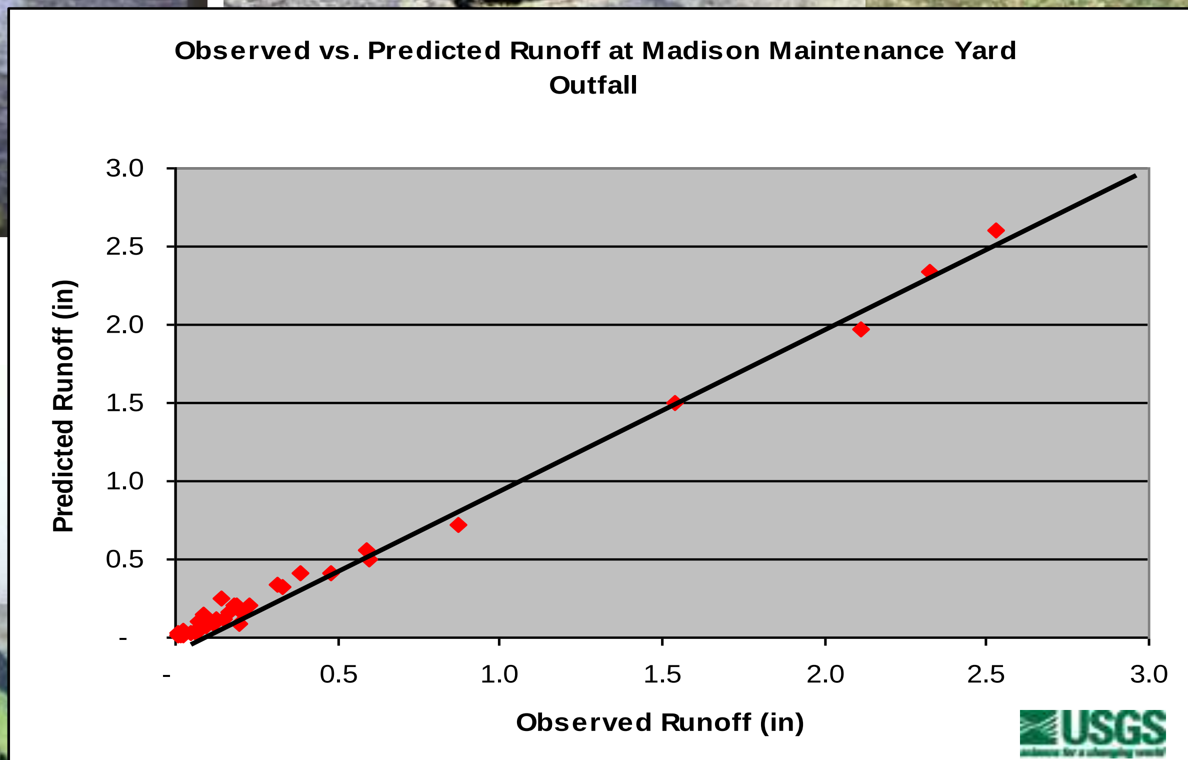

Nitrite plus Nitrate (mg/L as N)
Modeled NO3+NO2 (mg/L)
Observed NO3+NO2 (mg/L as N)
10
1
0.1
0.10
1.00
10.00

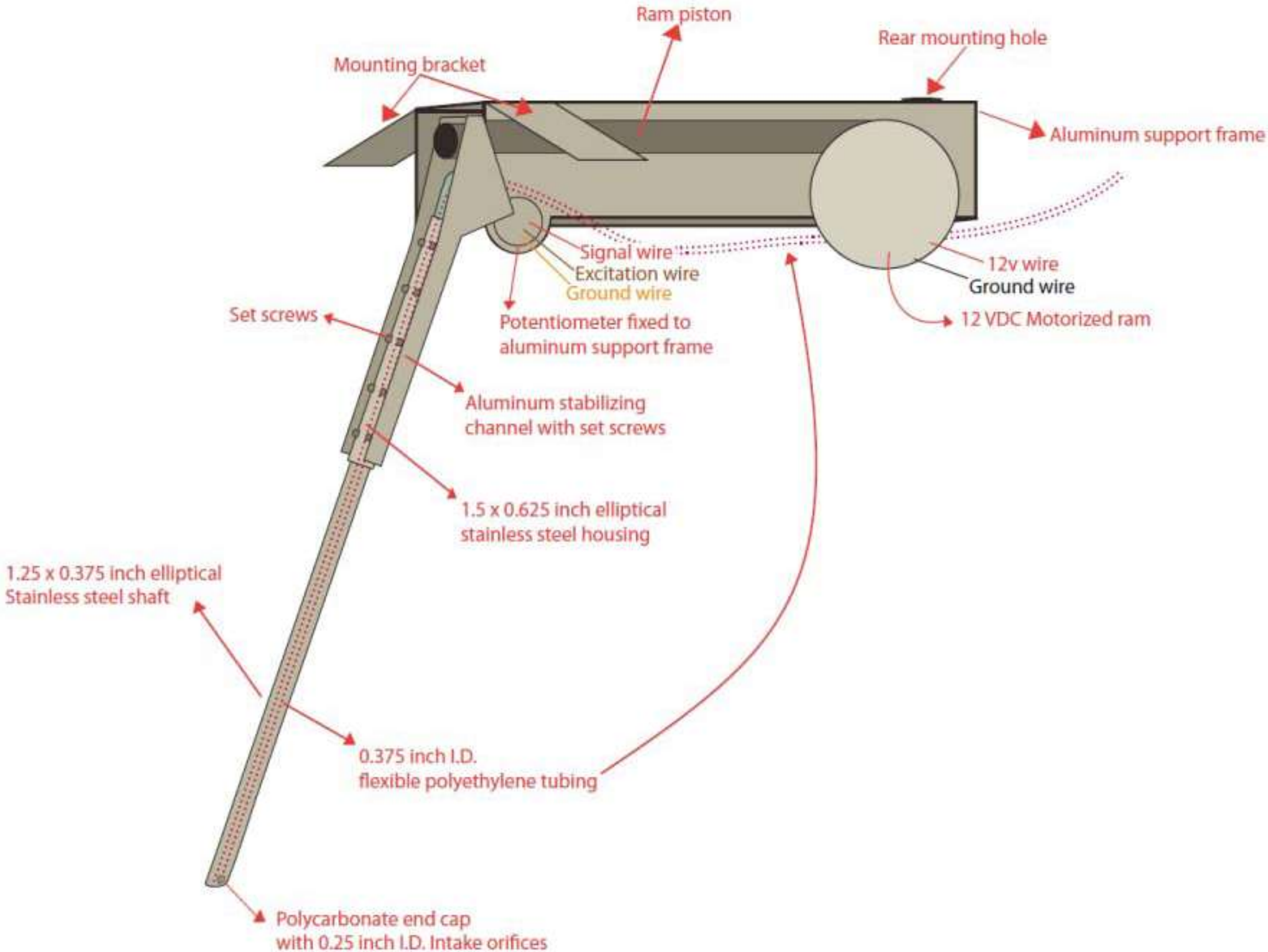

Total Copper (µg/L)
Modeled Total Copper (µg/L)
Observed Total Copper (µg/L)
1000
100
10
1
1
10
100
1000


Fecal Coliform Bacteria (MPN/100 mL)
Modeled Fecal Coliforms (MPN/100 mL)
Observed Fecal Coliforms (MPN/100 mL)
1,000,000
100,000
10,000
1,000
1,000
10,000
100,000
1,000,000



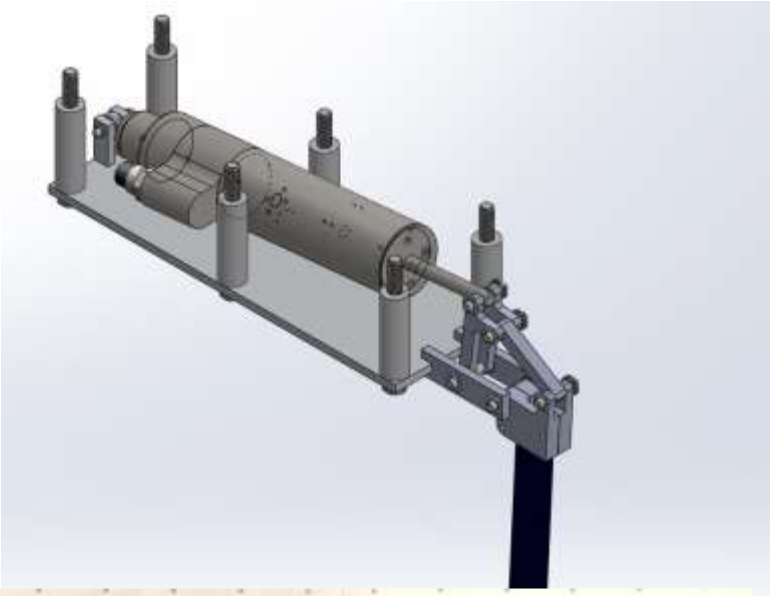



Observed vs. Predicted Runoff at Madison Maintenance Yard Outfall
Predicted Runoff (in)
3.0
2.5
2.0
1.5
1.0
0.5
-
-
0.5
1.0
1.5
2.0
2.5
3.0
Observed Runoff (in)
USGS



Ram piston
Rear mounting hole
Mounting bracket
Aluminum support frame
Signal wire
Excitation wire
Ground wire
12v wire
Ground wire
Set screws
Potentiometer fixed to
aluminum support frame
12 VDC Motorized ram
Aluminum stabilizing
channel with set screws
1.5 x 0.625 inch elliptical
stainless steel housing
1.25 x 0.375 inch elliptical
Stainless steel shaft
0.375 inch I.D.
flexible polyethylene tubing
Polycarbonate end cap
with 0.25 inch I.D. Intake orifices

New Method: Depth-Integrated Sample Arm (DISA)



- Compact design (2" diameter x 10" length)
- Fully submersible
- 170 degrees of travel
- Variable rate of travel
- Adjusted for rotational velocity
- 200 lbs. of force
- Quick-connect waterproof cable

Example Applications of DISA

DISA reduces variability in SSC concentration data

Location	Sampler	COV
Parking Lot	Fixed	2.7
	DISA	0.9
Arterial Street	Fixed	2.3
	DISA	0.7
Residential	Fixed	1.3
	DISA	0.8
Mixed Use	Fixed	1.0
	DISA	0.6

Monitoring source areas and land uses with automatic samplers

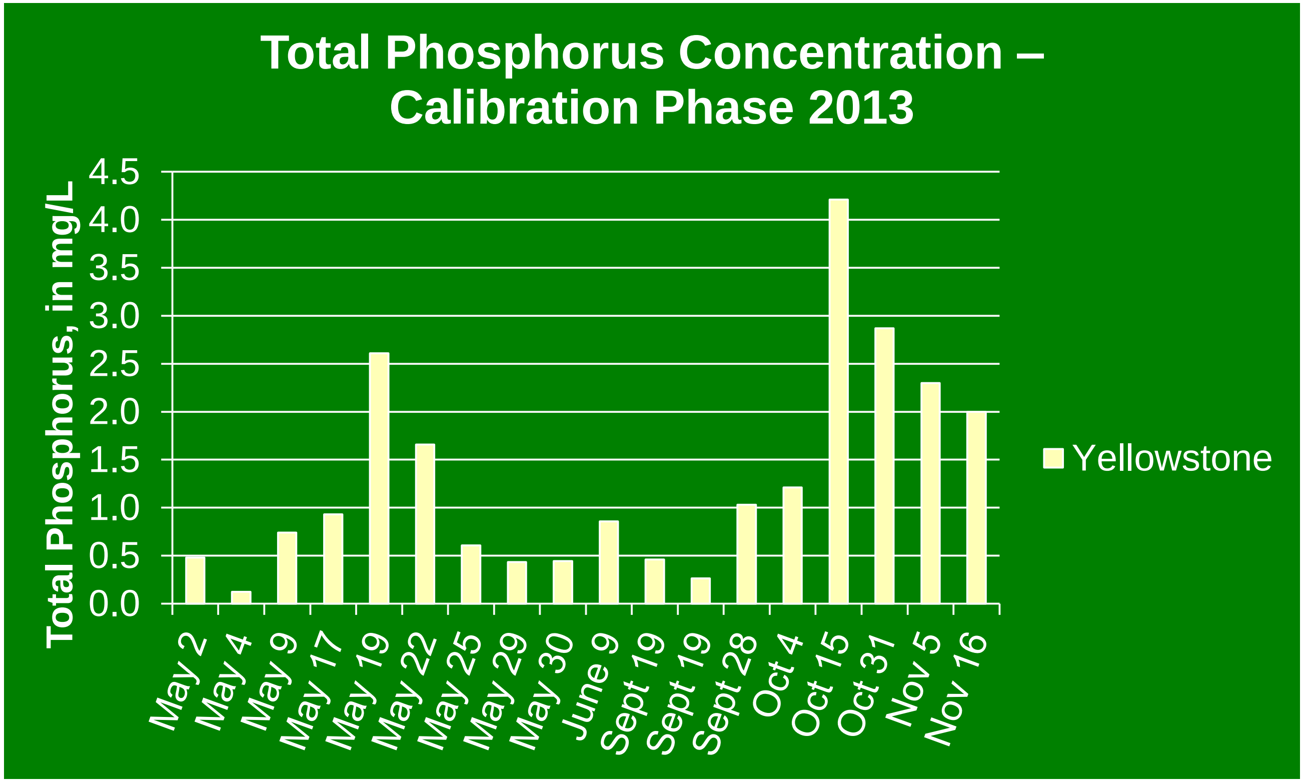
Shopping Center

Residential Street

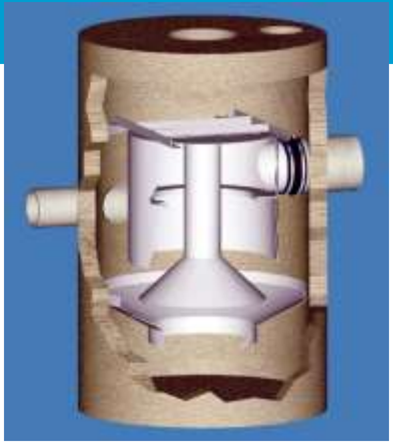
Commercial Street

Strip Commercial

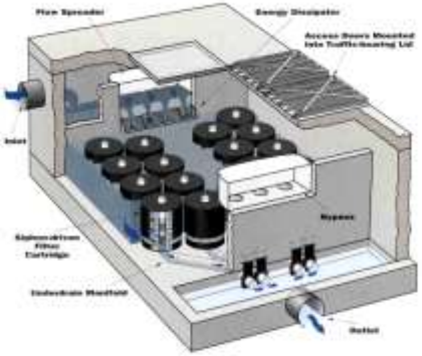
Seasonal Changes in Phosphorus Sources – Monroe Outfall



Stormwater Control Measures in SLAMM



- Wet Detention Ponds
- Porous Pavement
- Street Cleaning
- Catchbasin Cleaning
- Grass Swales and Grass Filters
- Biofiltration/bioretention
- Green Roofs
- Proprietary Controls (media filters and hydrodynamic devices)
- Beneficial Uses



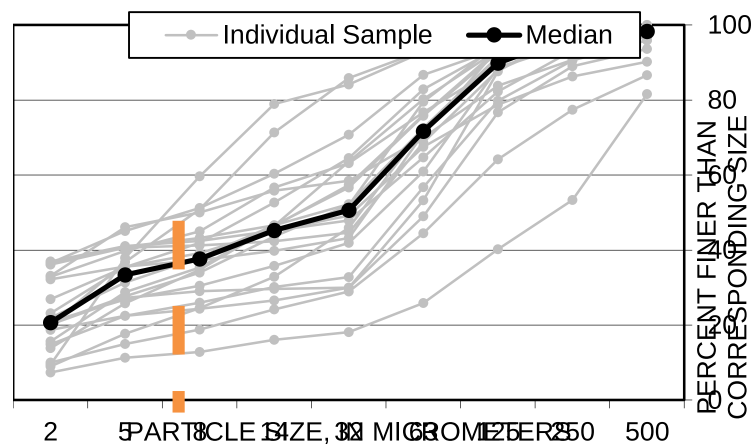
Permeable Pavement

Current Research Projects

Bioretention with Sand

Grass Swale

Leaf Mgt.

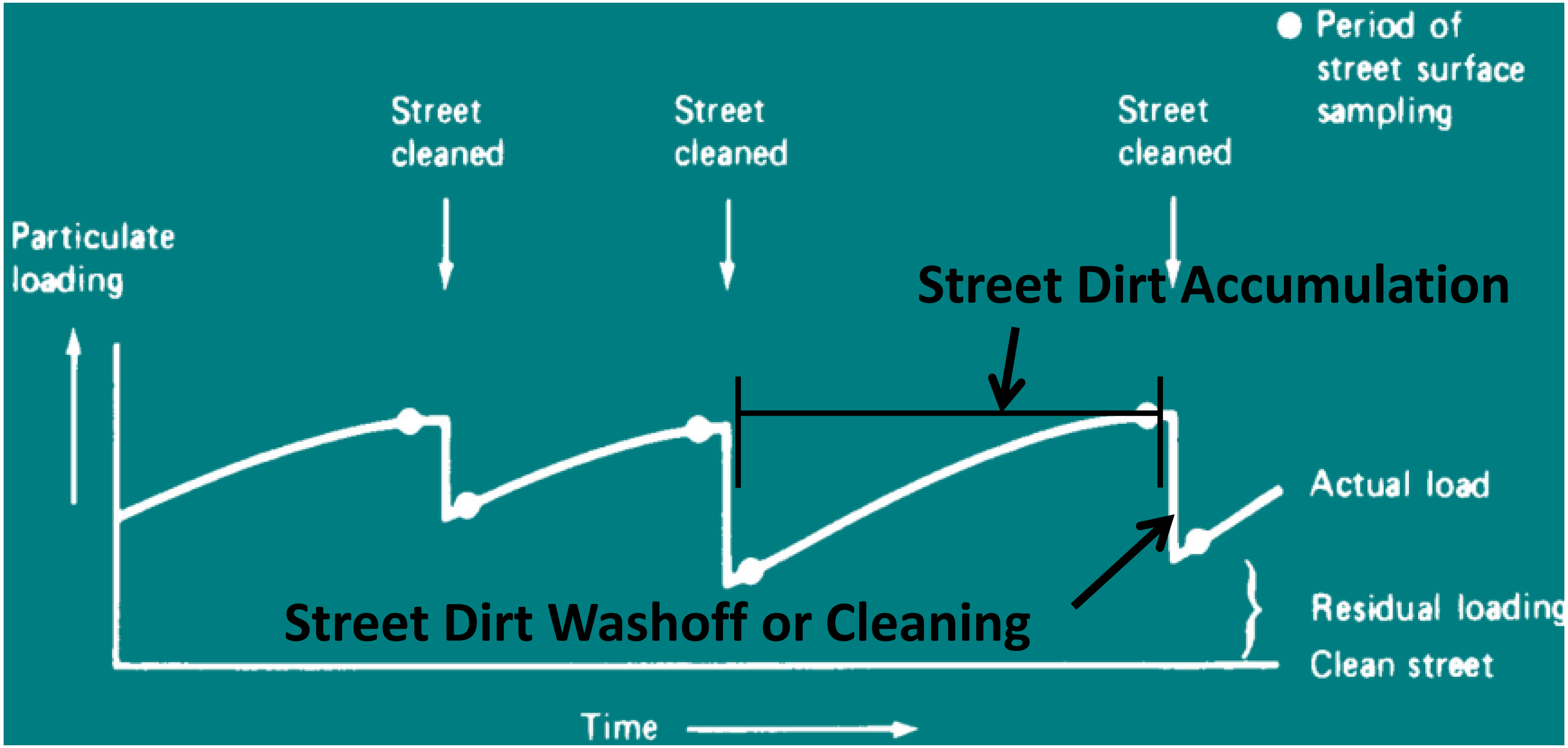


Particle Size Dist


Suffolk Rd.
Piping Rock Rd.
Hampstead Rd.
Tollman Ter.
Crabapple Ln.
Bartlett Ln.
Flad Ave.
Manor Green Dr.
Aspen Rd.
Teal Dr.
ELGIN Pelican
ELGIN
7/15/2005
ELGIN Crosswind

Street Dirt Washoff and Accumulation

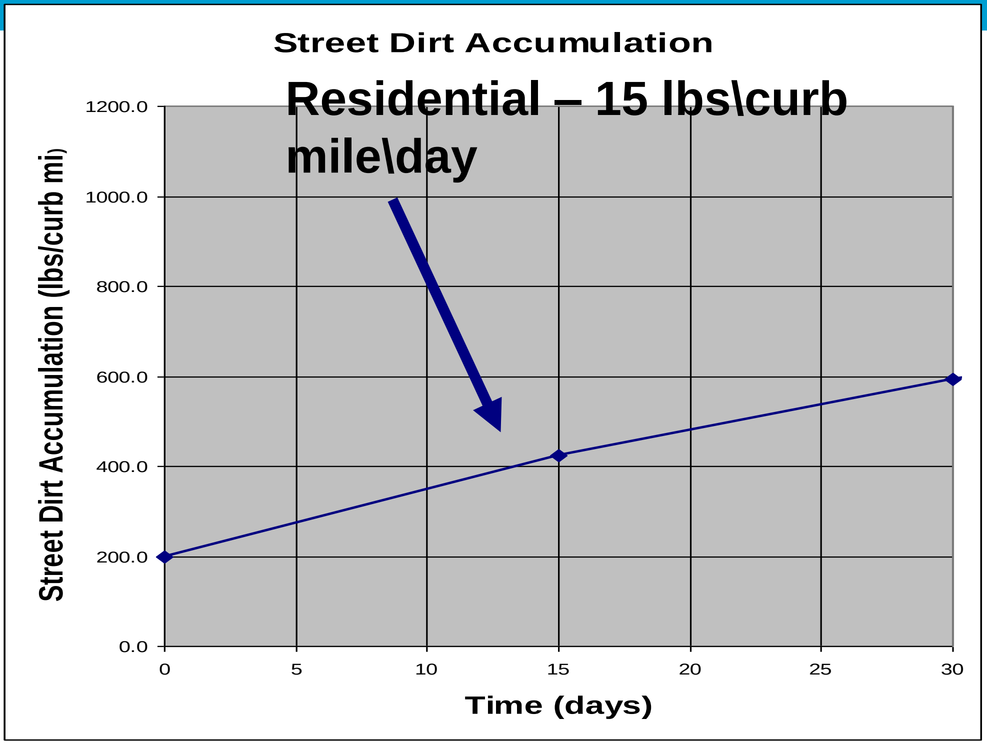
Sawtooth Pattern Associated with Deposition and Removal of Particulates on Urban Street



Pitt 1979

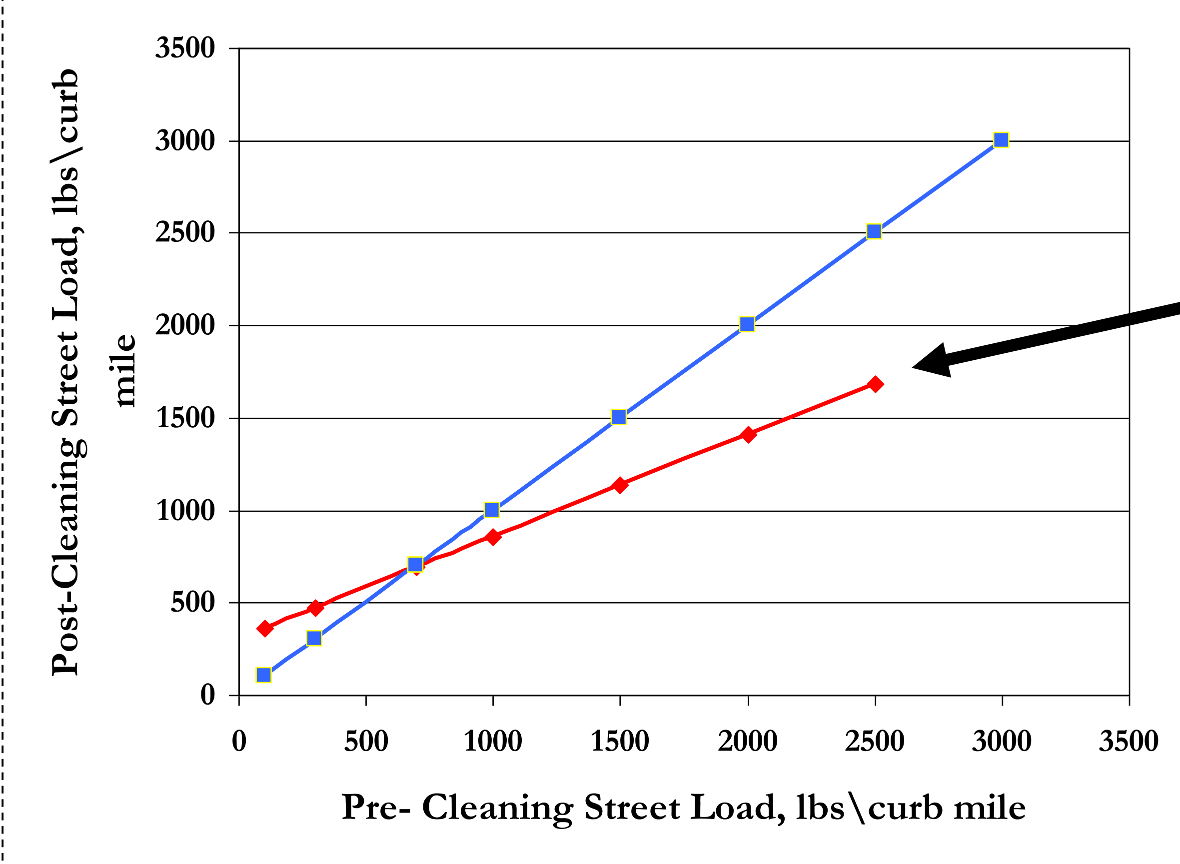
Measure Changes in Street Dirt Loads with Vacuum Cleaners – 2 Tons

Street Loads Measured Before and After Every Cleaning; over time; and before and after rain



Street Load, lbs\curb mile	Rain Intensity of 3 mm\hr. (0.12 in\hr)	Rain Intensity of 12 mm\hr. (0.47 in\hr)
1400	0.20	0.26
400	0.15	0.35

Wash Off Coefficients for Smooth and Intermediate Streets

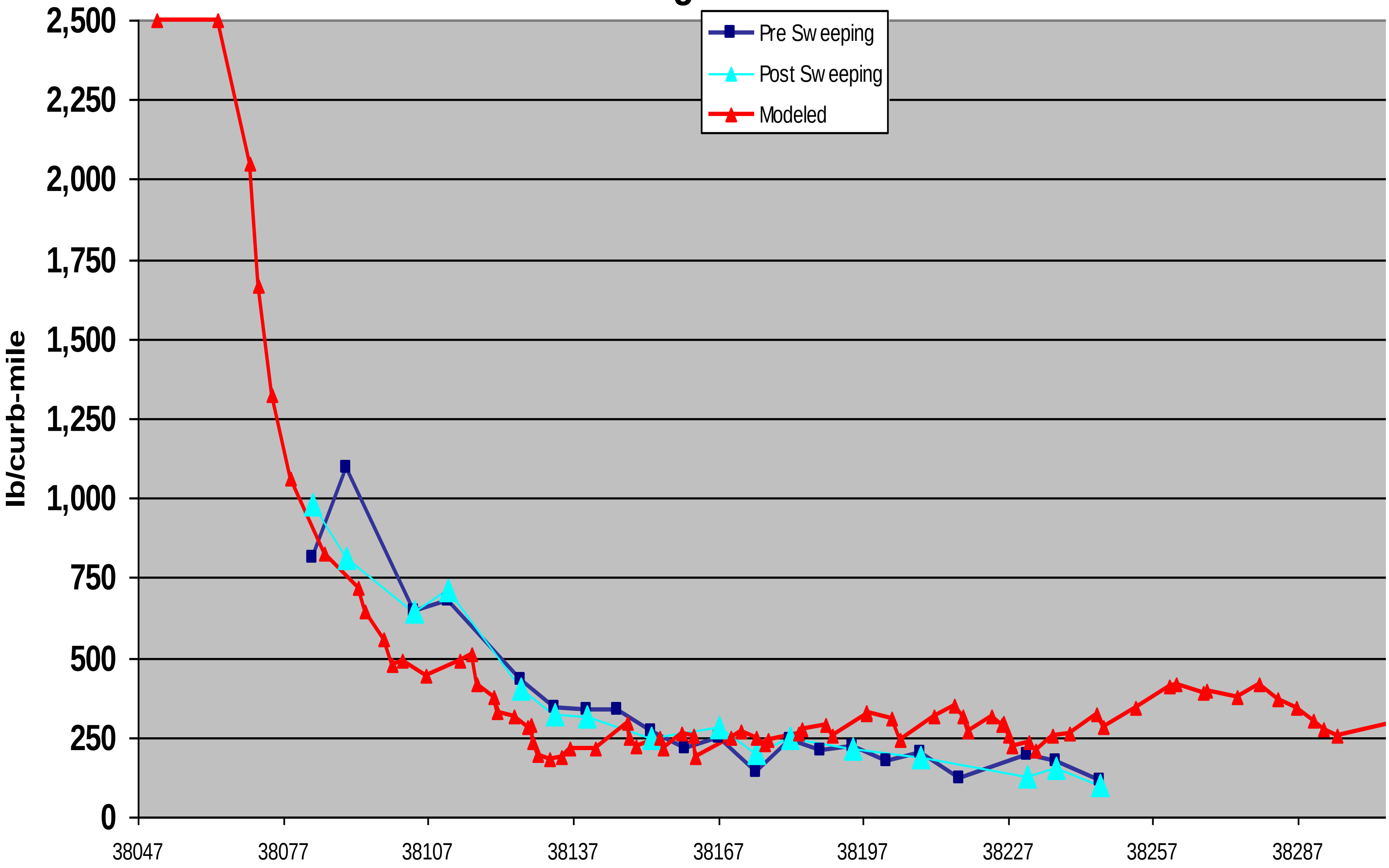


$Y = 0.55X + 310$

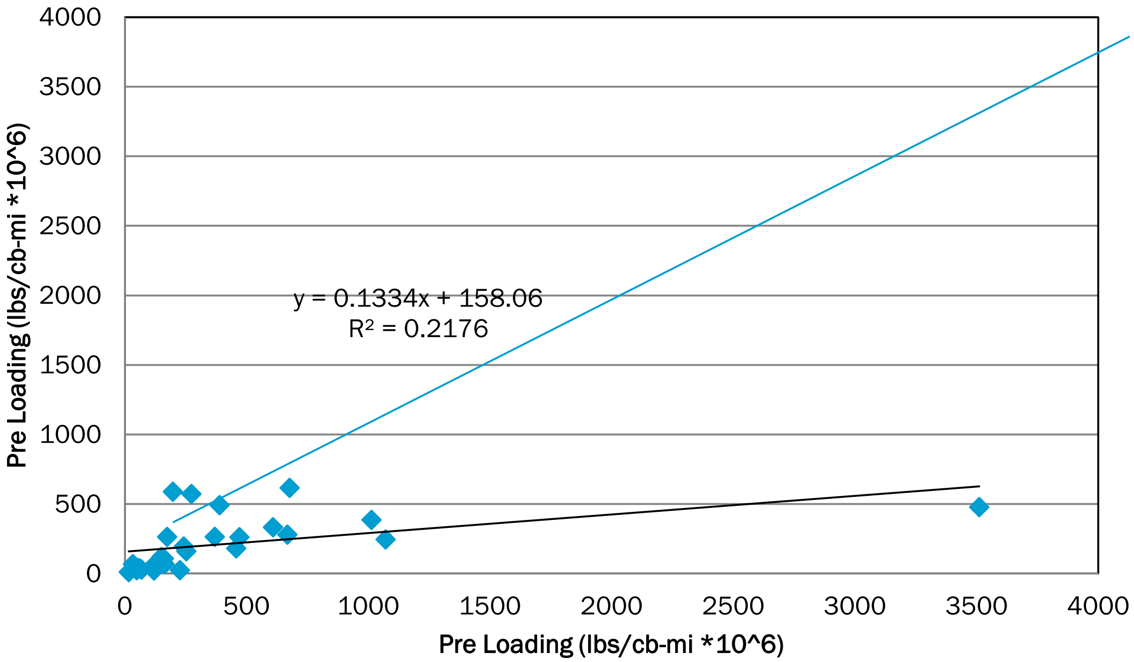
Residential, Intermediate Texture; Light Parking; No controls

Productivity Curve for Broom Cleaner

Measured Versus Modeled Street Loads With Mechnical Broom Street Cleaning - Residential 2004



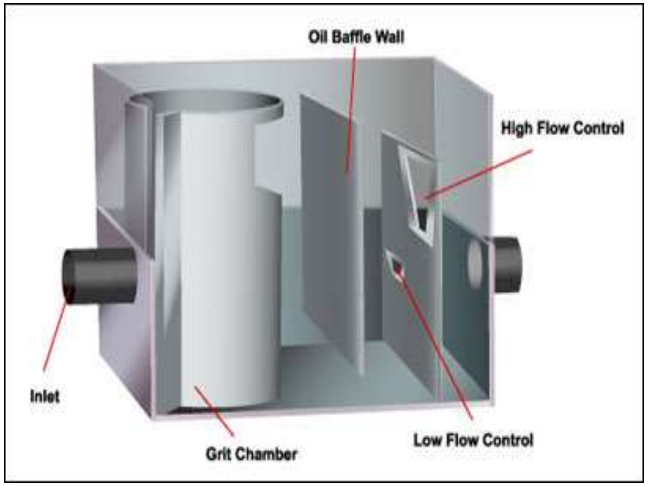
PCB Productivity Function for Three Site



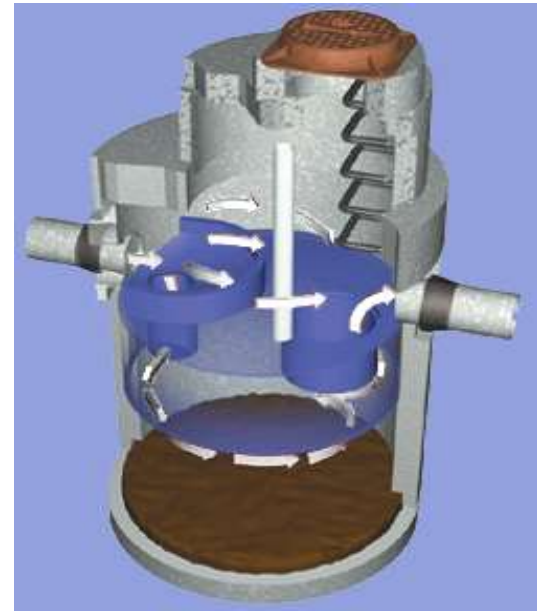
Percent PCB Efficiency produced from WinSLAMM model

Sites	PCB Efficiency (Percent)
CUT	30
HOF	30
LEO	24

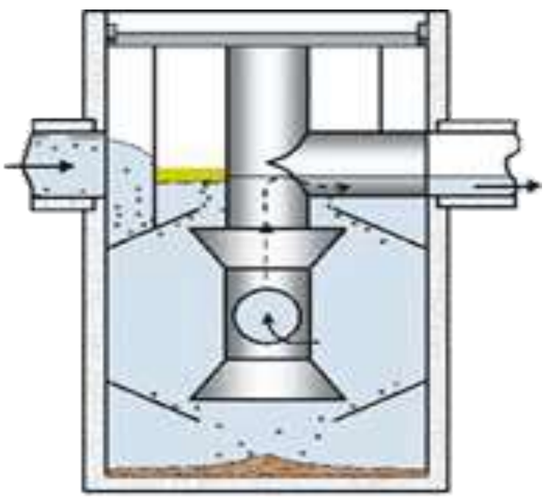
Examples of Proprietary BMPs Using Settling for Treatment



Vortechs



Stormceptor

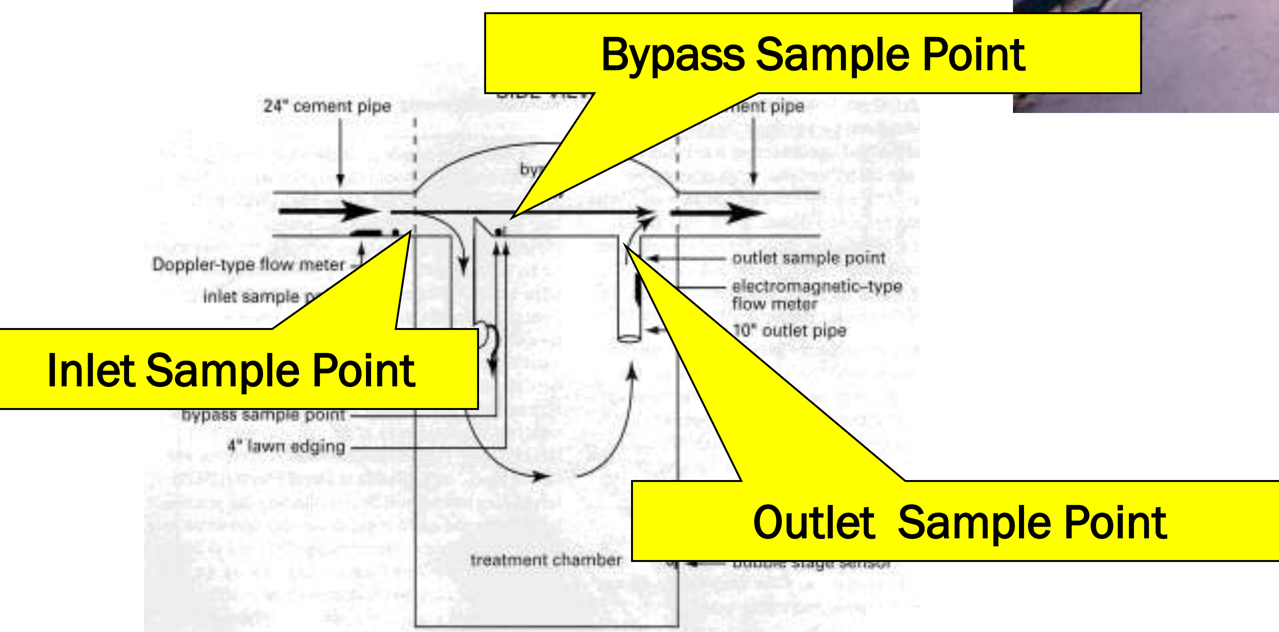


DownStream Defender

Benefits:

- Underground
- Easy to Install
- Easy Maintenance

Site Conditions – Hydrodynamic Separators



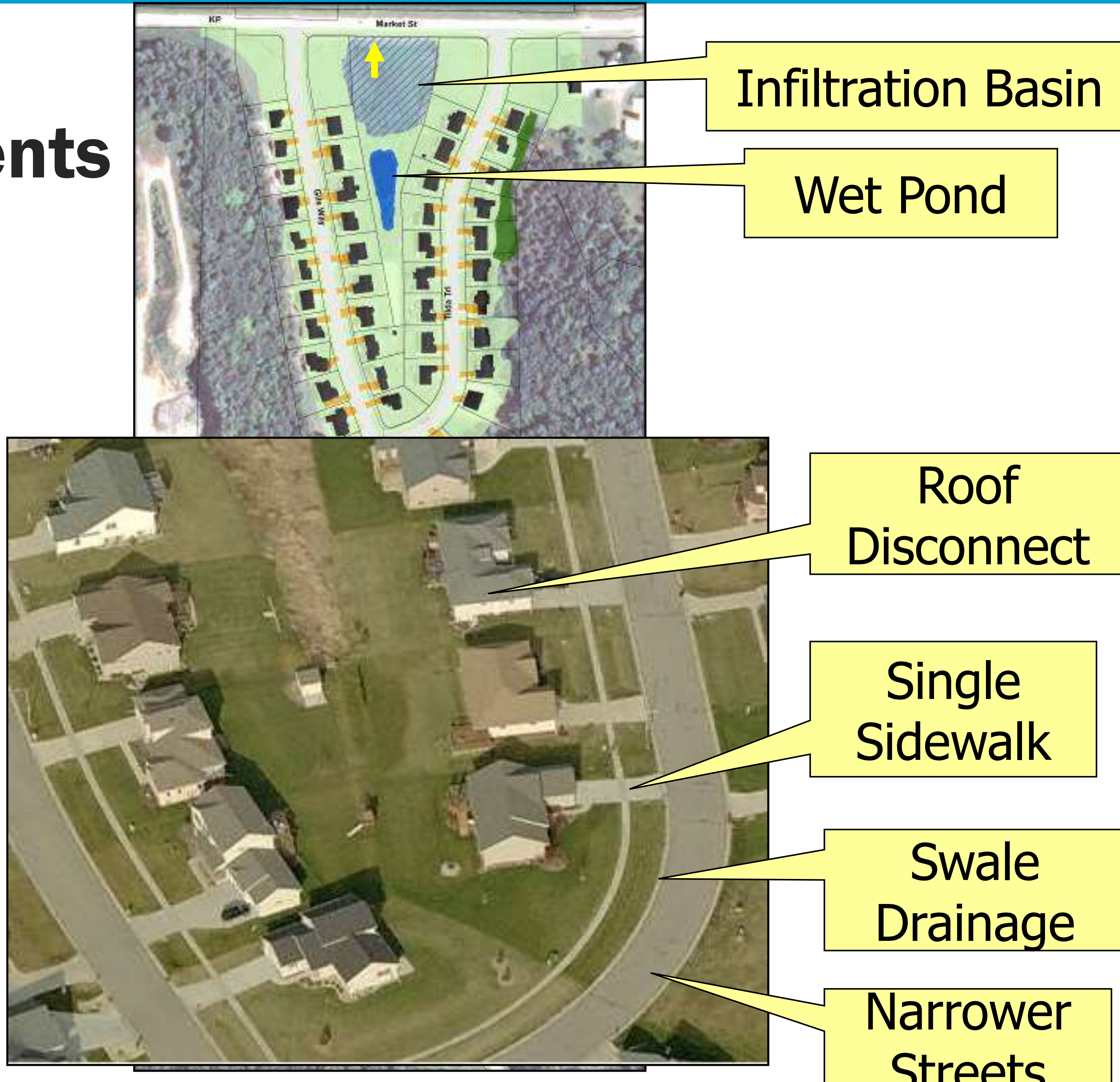
Comparison of Monitored vs Modeled

	Stormceptor™			*Vortechs™*		
	Measured	**Modeled**	**% Diff.**	**Measured**	**Modeled**	**% Diff.**
Water Volume, (cu ft)	85,600	73,893	14 %	10,466	10,633	- 2 %
TSS Load, (lbs.)	939	814	13 %	63	68	- 8 %

Comparison of Measured and Modeled TSS Reductions

	Measured TSS Reductions	SLAMM / DETPOND Estimates with *Measured PSD and Rainfall*
Stormceptor	6%	12%
Vortechs	25%	19%

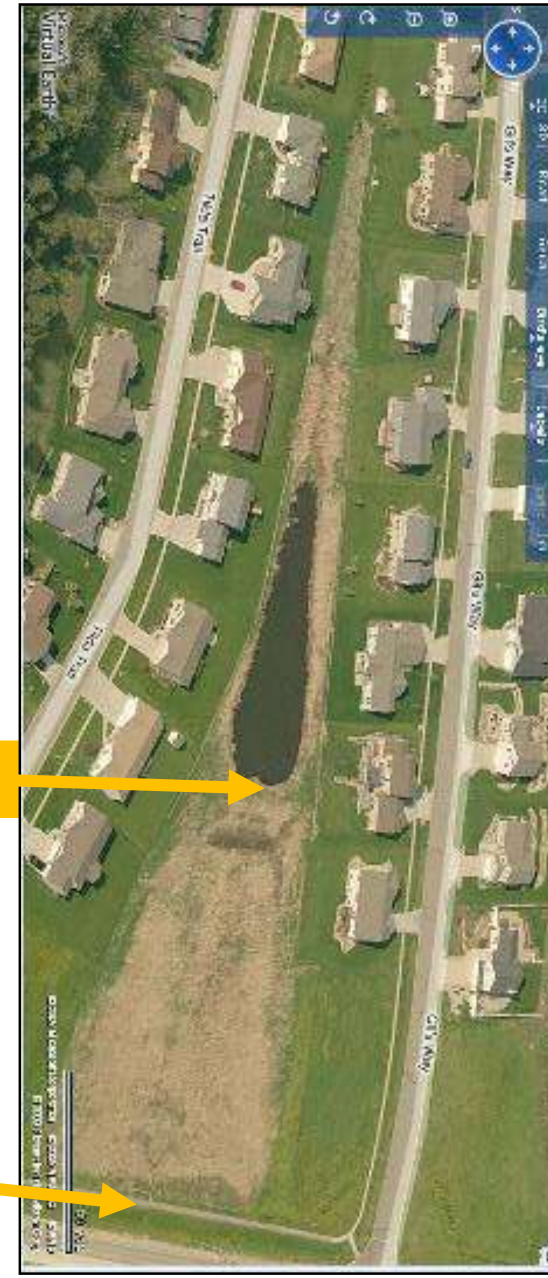
LID Components



USGS Monitoring

Monitoring conducted Oct. 1999 – Sept. 2005

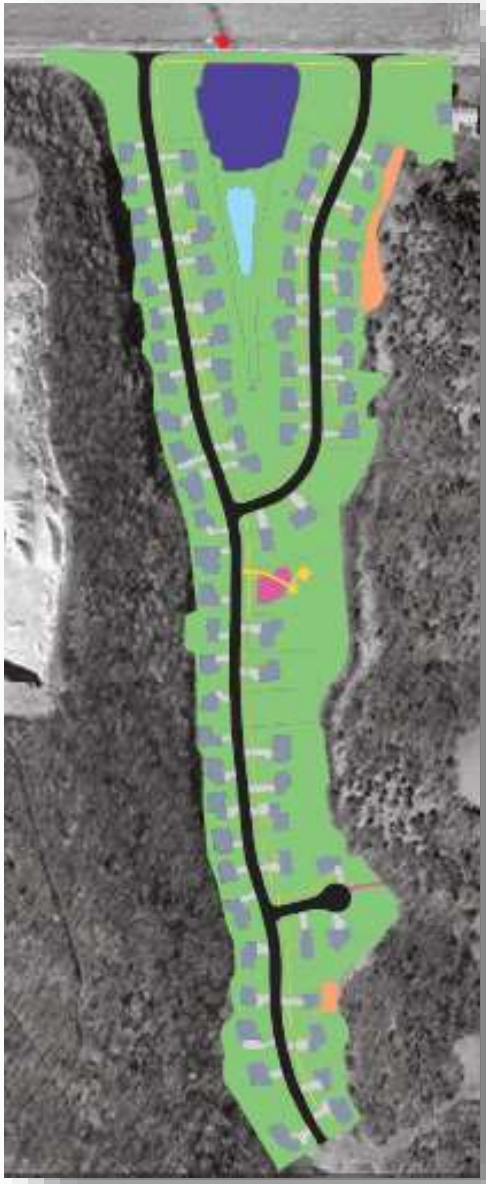
- Fully automatic flow and sampling station
- Recording rain gauge



Modeling Effort

Runoff Volume Results for 2004 to 2005

System Location	Monitoring Results	Modeling Results	
		Original Infiltration Rate *(0.3 in/hr)*	Calibrated Infiltration Rates
	(cf)	(cf)	(cf)
Rainfall	5,349,000	5,349,000	5,349,000
After Infiltration Basin	144,000	196,000	144,000
% Runoff Retained	97%	96%	97%



Modeling Effort

Runoff Volume Reduction by Component for 2004 - 2005

System Location	Monitoring Results	Modeling Results	
		Original Infiltration Rate *(0.3 in/hr)*	Calibrated Infiltration Rates
	%	%	%
Before Swales	?	84	84
After South Swales	95	94	97
After Infiltration Basin	97	96	97

Land Use 60% Lawn and All Roofs Disconnected

SLAMM Strength – Based on Extensive Field Monitoring Data

Monitoring Source Areas – Lawns, Roofs, etc.

Loads from Land Uses

Evaluating Stormwater Control Measures

Questions?