

2. WinSLAMM Theory, Practice, and Calibration



Bogota getting washed... Universidad de los Andes completed stormwater planning and demonstrations using WinSLAMM

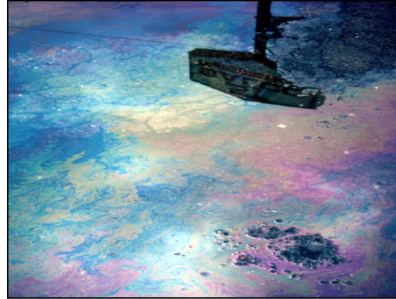
1

WinSLAMM – What is it?

- Source Loading And Management Model for Windows
- Calculates Urban Stormwater Pollutant Loads and Quantifies their Reductions through the application of Stormwater Control Practices
- Applicable to:
 - Specific Control Practice Design
 - Site Development Analysis
 - Drainage Basin/MS4 Planning and Design
 - TMDL Reduction Determination

We will cover . . .

- WinSLAMM Purpose, History and Unique Features
- Model Applications
- Small Storm Hydrology
- Basic Program Structure and Operation
- Model Calibration
- Treatment Practices
- Model Input/Output



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WinSLAMM Can Answer These Types of Policy Questions . . .

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

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Background & History

- **Development Began in mid-1970's**
 - Early EPA street cleaning and receiving water projects (San Jose and Coyote Creek, CA)
 - Castro Valley (CA), Bellevue (WA), Milwaukee (WI) 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.**
- **Current graphical interface released, after three years of work, in 2012.**
- **Continuously being updated based on user needs and new research results.**

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Unique Features of WinSLAMM and Why it was Developed

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

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Model Applications

Model Can Be Applied on Multiple Scales –

- Large Scale, MS4/TS4 Analysis
- Site Development Analysis (Apartment Complex, Shopping Center, Hospital Complex, Residential Development, Highway Interchange)
- Analysis of Single Practice

Model Applications

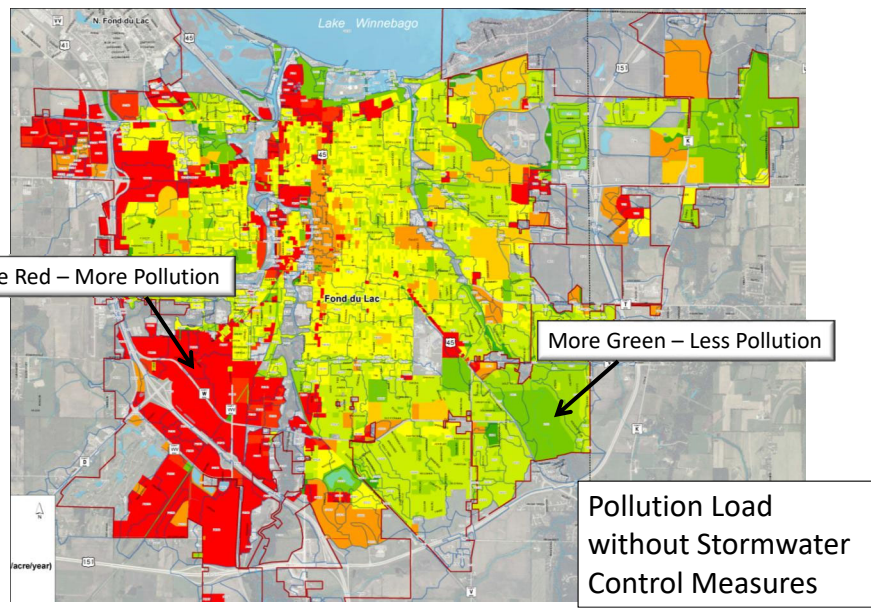
Large Scale, City-wide Analysis

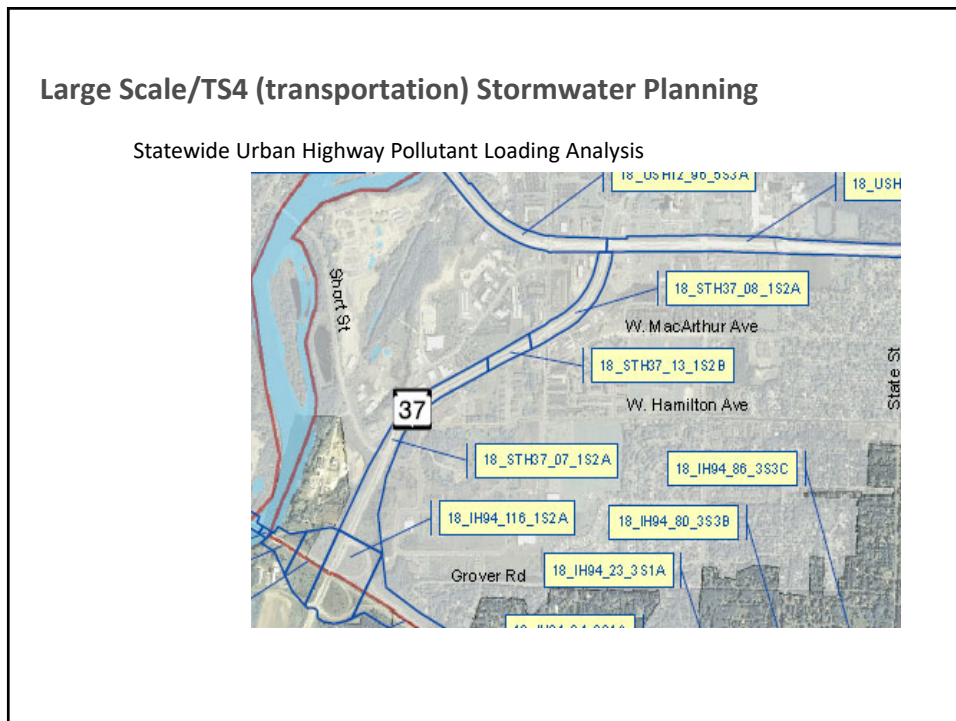
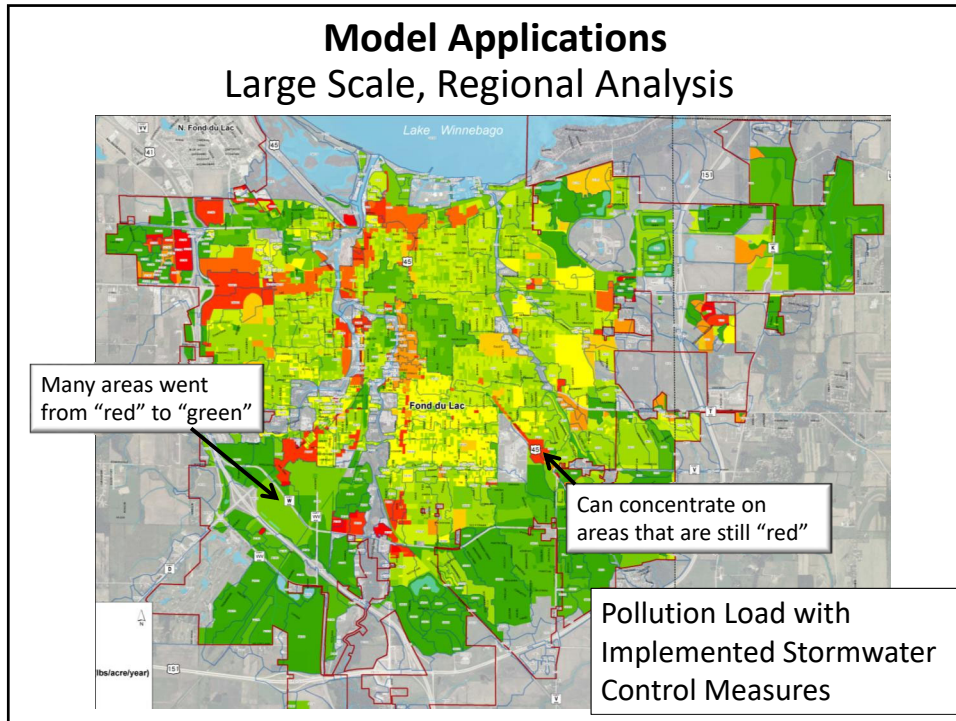
Analysis Procedure -

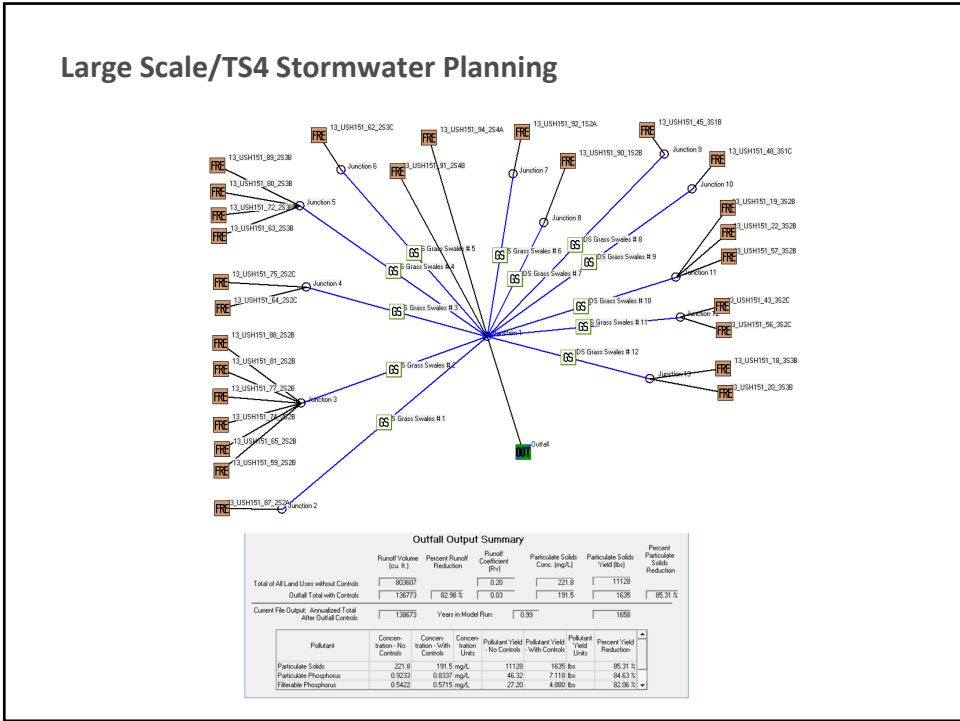
- Inventory drainage basins and land uses
- Evaluate existing pollutant loads and runoff volumes (base condition).
- Adjust base condition with existing stormwater control practices.
- Evaluate additional practices to cost-effectively achieve pollutant reduction goals.

Model Applications

Large Scale, Regional Analysis





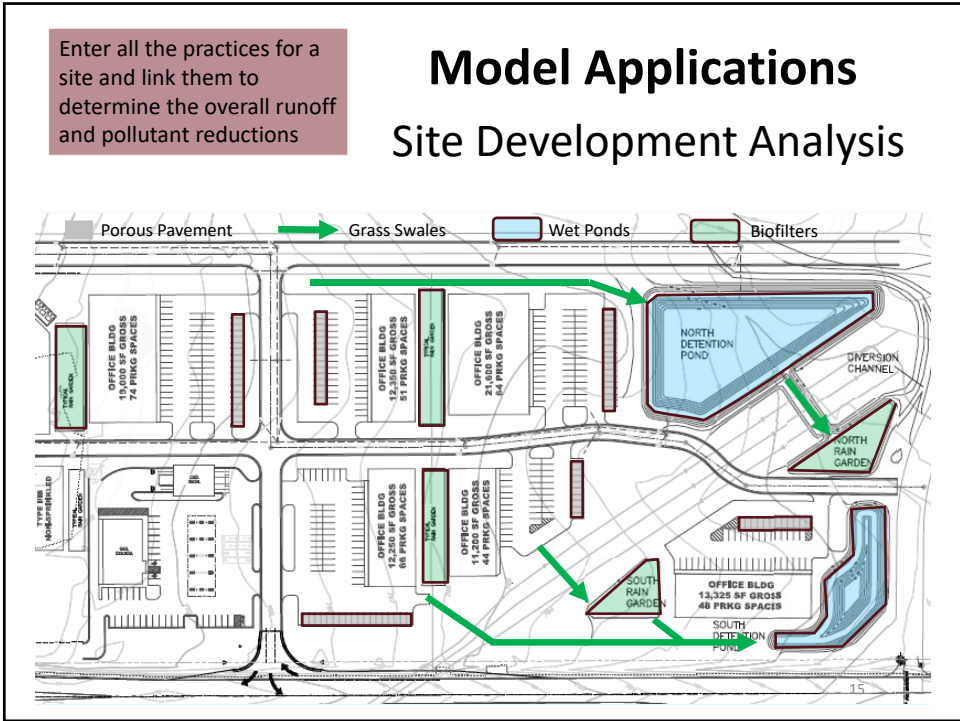


Model Applications

Site Development Analysis

Analysis Procedure -

- Inventory site characteristics (soil type, percent imperviousness, etc.)
- Locate selected stormwater controls throughout the site
- Determine volume and pollutant reduction achieved with selected stormwater control practices.



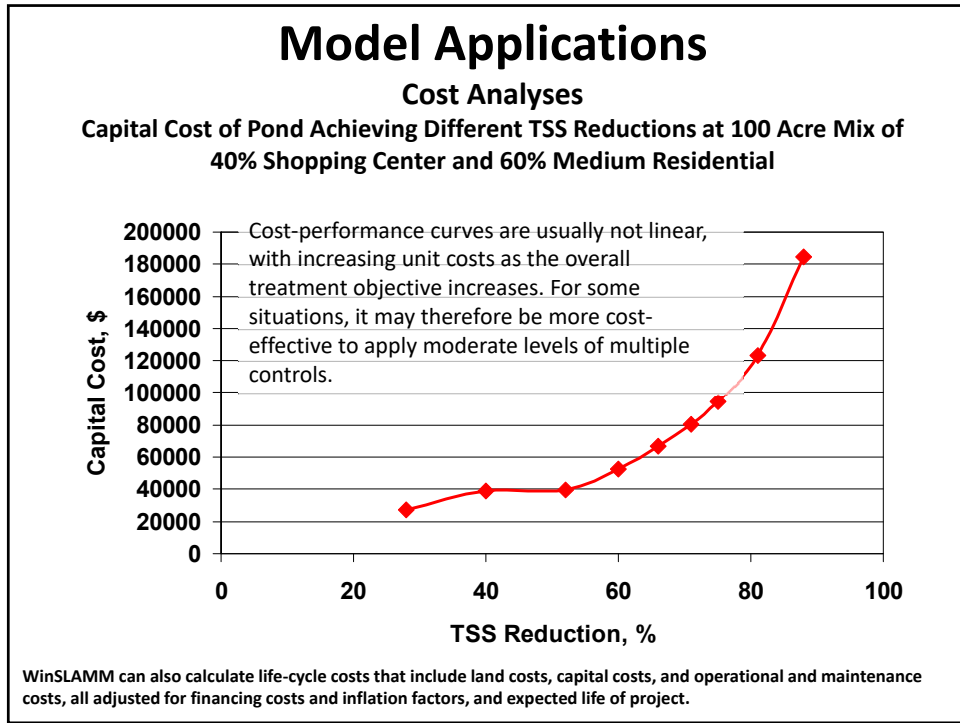
Model Applications

Single Practice Analysis

Wet Detention Pond –
Analyze the performance of a specific pond for a specific site

Volume and Pollutant Reduction for Biofilters –
bioretention, rain gardens, infiltration basins

The complex block contains two photographs. The top-left photo shows a wet detention pond with a grassy bank and a line of trees in the background. The bottom-right photo shows a biofilter installation, which is a rectangular concrete structure with a grate on top, situated in a landscaped area with trees and a building in the background.



We will cover . . .

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- **Small Storm Hydrology**
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Small Storm Hydrology – Runoff Volume

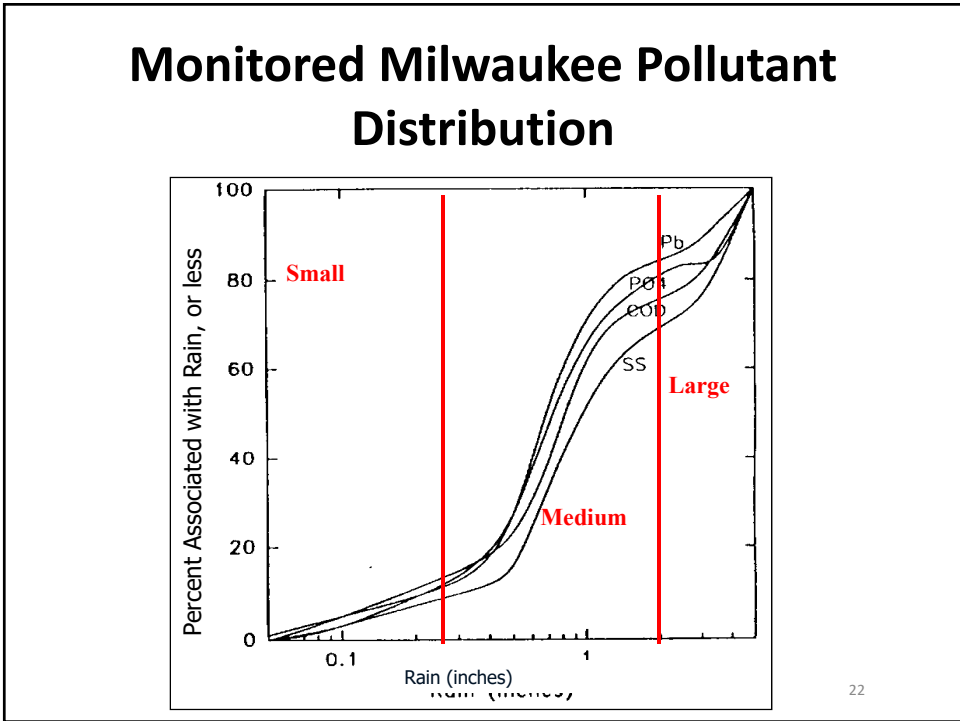
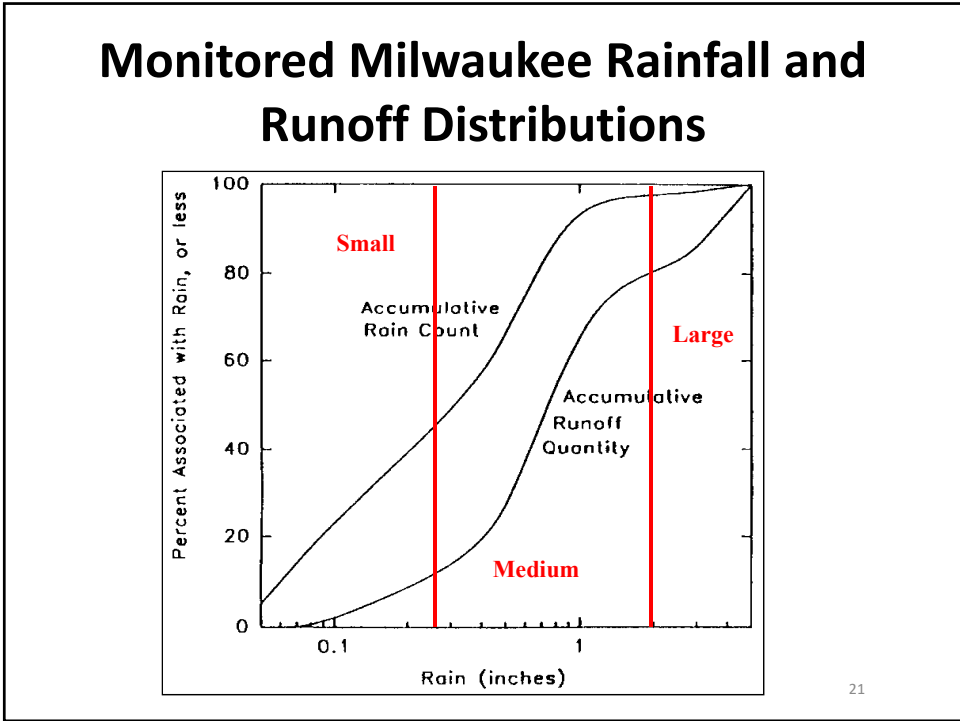


Most of the pollutants in stormwater runoff come from small and moderate size storms . . .

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

Knowing the Runoff Volume is the Key to Estimating Pollutant Mass

- There is usually a simple relationship between rain depth and runoff depth in urban systems.
- Changes in rain depth affects the relative contributions of runoff and pollutant mass discharges:
 - Directly connected impervious areas contribute most of the flows during relatively small rains
 - Disturbed urban soils may dominate during larger rains



Rainfall Sorts into Three Distinct Categories

- Small Rains – Accounts for most events, by number
 - Typically can be easily captured for infiltration or on-site beneficial uses
 - Relatively low pollutant loadings, but frequent discharges
 - Key rains associated with water quality violations, e.g. bacteria and total recoverable heavy metals
 - “Every” time it rains, some numeric discharge concentration objectives may be exceeded. Therefore, try to eliminate the small events

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Rainfall Sorts into Three Distinct Categories

- 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

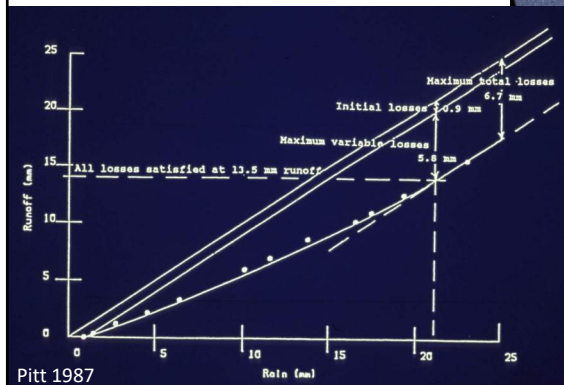
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Rainfall Sorts into Three Distinct Categories

- Large Rains – Infrequent Large Events
 - Not cost effective to treat all runoff
 - Typically cause flooding and significant erosion
 - Treatment practices designed for smaller storms will mitigate impacts of larger events to some extent

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Controlled tests in small areas were used in conjunction with long-term rainfall/runoff monitoring at larger parking lot areas to develop actual hydrological relationships for paved areas, the most significant source of runoff for most urban areas during small to intermediate-sized rains.



This is an example of a rainfall-runoff plot from one of many controlled street washoff and runoff tests. About 1/3 of the rainfall is infiltrated through the street pavement for many of these events (up to 20 mm rains in this plot). No further infiltration was observed for larger events, resulting in classical pavement R_v values of 0.8 to 0.95 for large rains of interest for drainage design.

Pitt 1987

Tree Interception of Rainfall over Directly Connected Paved Areas

Mature Trees Over Paved Parking Areas for Significant Interception



Newly Planted Trees will Require Many Years before Significant Interception



Photos from misc. Internet sources

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Several years of monitoring of rainfall interception under large and small urban trees with data incorporated into WinSLAMM

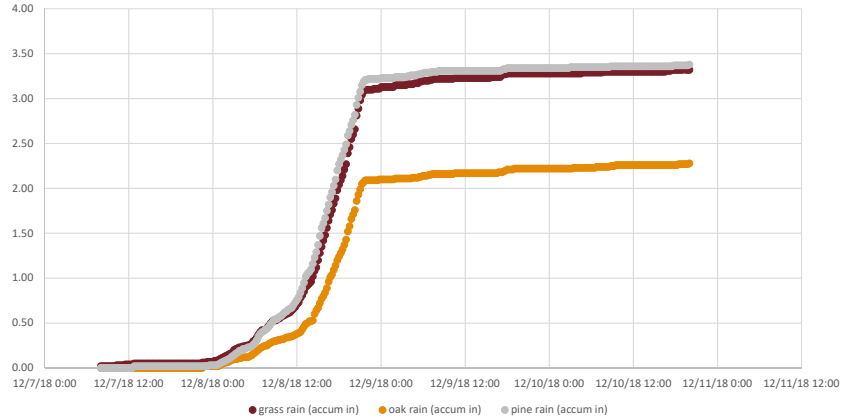
Rain gage under deciduous Water Oak:



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Cumulative rain plots (3.32 inches, December 7 to 11, 2018)

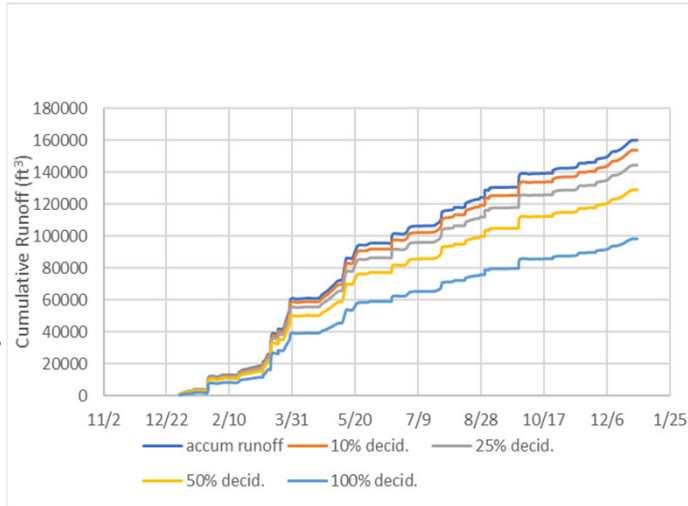
The following plot is the cumulative rainfall at the background location (surrounded by grass) vs. the cumulative throughfall measured under the large pine and oak trees:



It is obvious that the throughfall under the pines were little different compared to the background rainfall, while the oak had substantial throughfall reductions.

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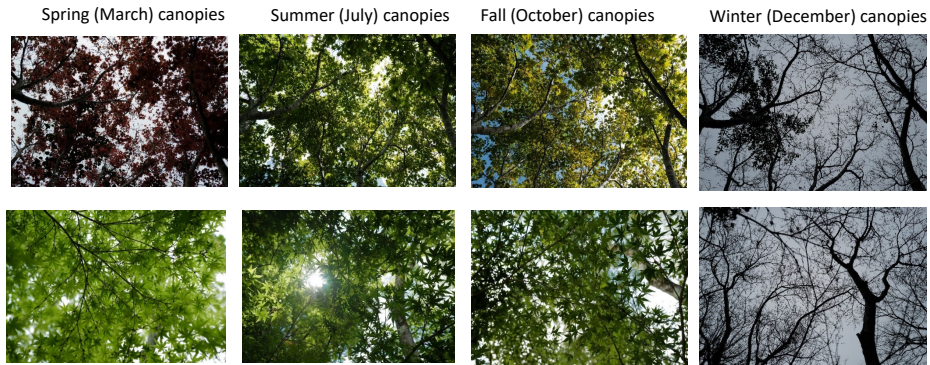
WinSLAMM calculated throughfall production functions for varying amounts of large deciduous tree cover over directly connected paved parking area.



Maximum 100% deciduous tree cover resulted in about 40% runoff reduction from the paved area

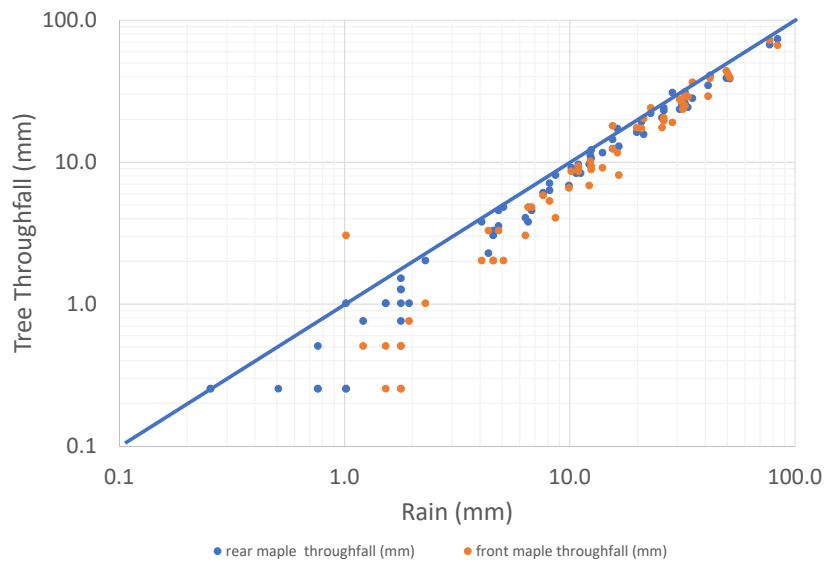
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Tree Canopies of Smaller Japanese Maples for Different Seasons



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Scatterplot of Tree Throughfall vs. Rain Depths for Japanese Maples



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Tree Interception Conclusions

- Urban trees add substantially to the standard of living of residents and are highly desirable.
- Urban trees have been recommended as a solution for urban drainage and flooding problems.
- Few data are available quantifying these benefits under actual field conditions, especially under a wide range of rain conditions for different tree species and seasons.
- Literature describing urban tree interception at many international locations indicate that canopy interception benefits are limited.
- During the measurements described above, tree specie type and rainfall had the greatest effect on throughfall; the large deciduous tree (even with few leaves during winter conditions) intercepted much more rainfall than the large conifer tree, likely due to the massive branch structure.
- Small and/or immature trees have much smaller interception benefits.

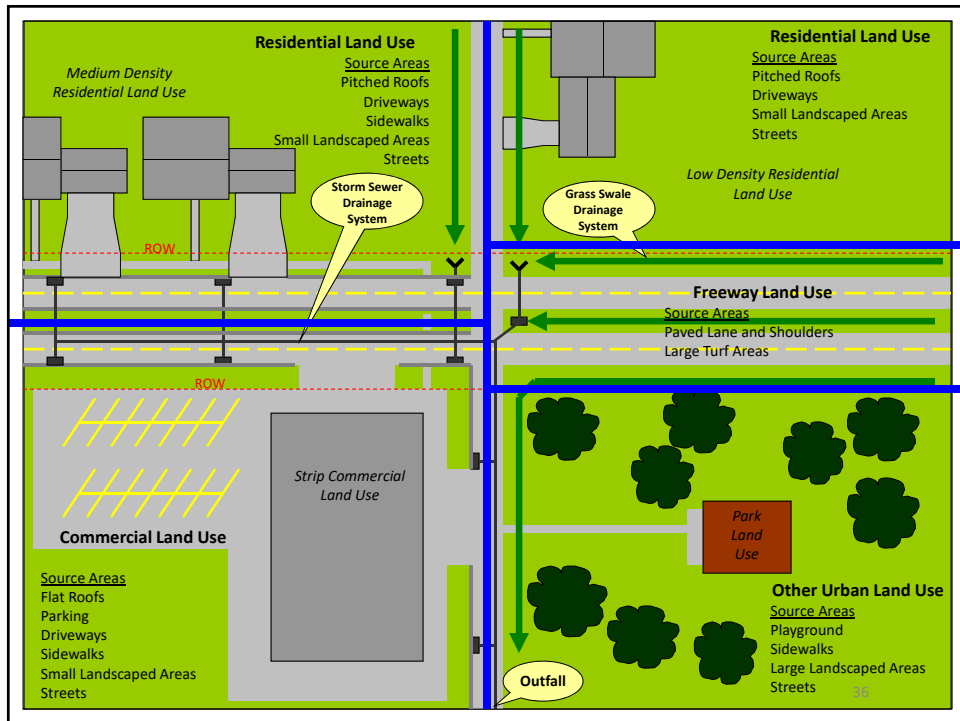
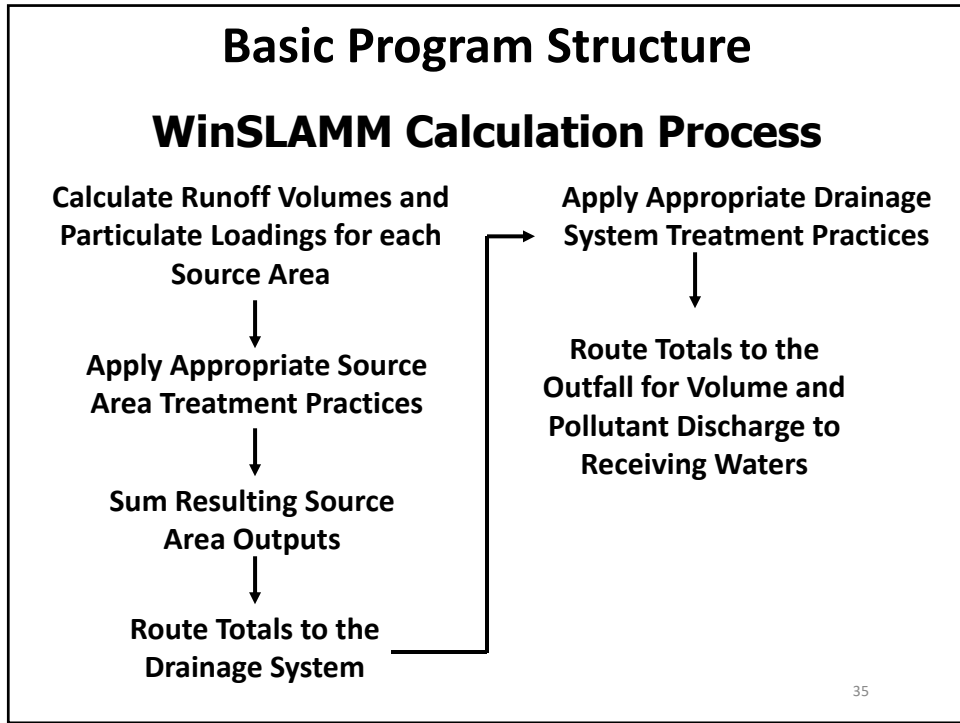
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We will cover . . .

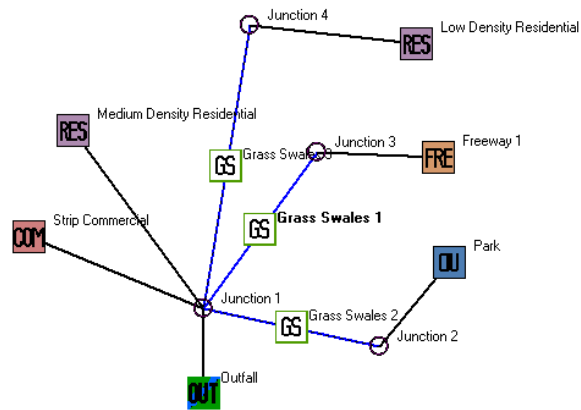
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Modeled Drainage System from Previous Slide



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The Basic Program Structure Information is Entered in the Land Development Characteristic (.mdb) database file:

1. Appropriate Parameter Files
2. Land Use type and area
3. Size of all Source Areas
4. Source Area parameters and characteristics (soil type, connected imperviousness, street texture, etc.)
5. Control Practice designs

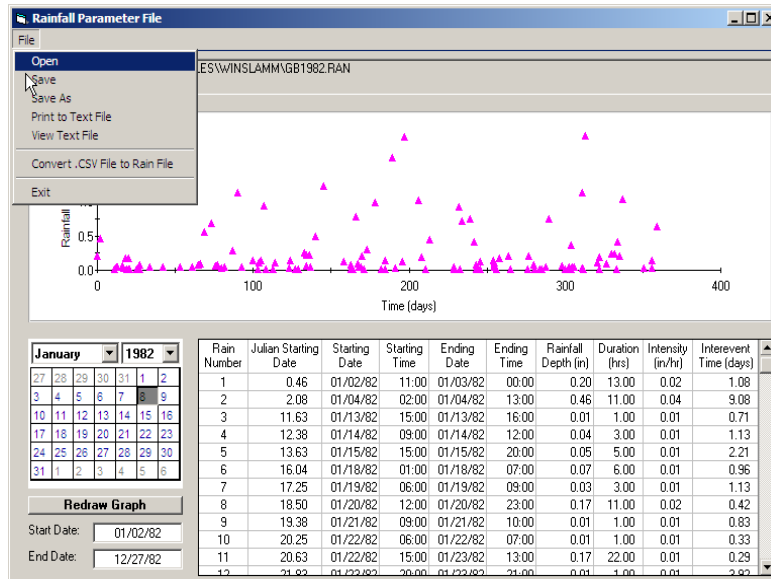
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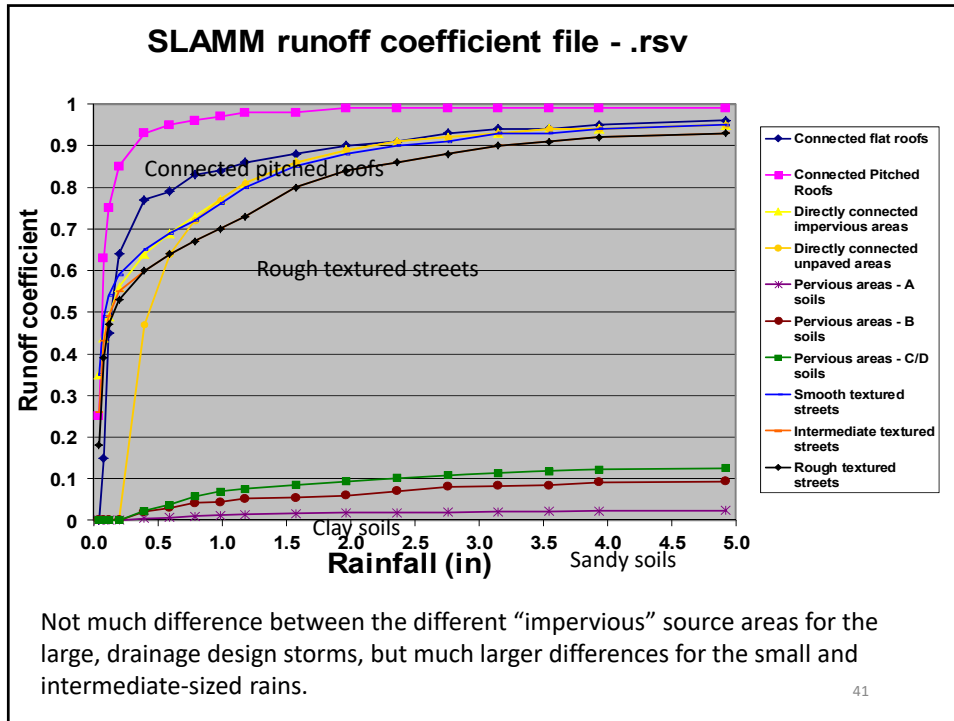
The model is driven through the use of data files and calibrated parameter files:

- Rainfall File (*.ran)
- Runoff Coefficient File (v10*.rsv)
- Particulate Solids Concentration File (*.pscx)
- Pollutant Probability Distribution File (*.ppdx)
- Particle Size Parameter File (*.cpz)

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Rainfall Parameter File – Can Include Many Years/Decades of Rainfall Information





Runoff Volume

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

Residential Land Use

Medium Density Residential Land Use

Source Areas
 Pitched Roofs
 Driveways
 Sidewalks
 Small Landscaped Areas

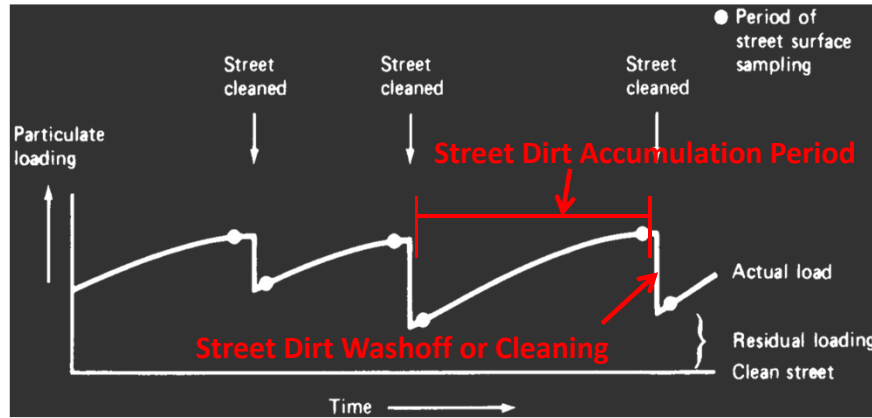
Storm Sewer Drainage System

Rainfall Depth (in) ==>		0.26		0.71		0.41	
Source Area	Area (ac)	Rv	Runoff (cf)	Rv	Runoff (cf)	Rv	Runoff (cf)
Residential Land Use							
Roof - Connected	0.15	0.876	124	0.957	370	0.932	208
Roof - Disconnected	0.20	0.005	1	0.037	19	0.020	6
Driveway	0.15	0.692	98	0.903	349	0.761	170
Sidewalk	0.04	0.689	26	0.902	93	0.756	45
Small Landscape Area	1.25	0.007	8	0.037	120	0.022	40
Street	0.30	0.696	197	0.903	698	0.761	340
Total	2.09		454		1649		809

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Street Dirt Washoff and Accumulation

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



Pitt 1979

Pollutant File

- Depicts the pollutant concentrations (and variability) for source areas and land uses.
- Regionally calibrated files available, or may be user-defined based on local data.
- File extension: *.ppdx

Pollutant Parameter File

Select File: C:\PROGRAM FILES\WINSLAMM\W1_GEO01.PPD

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

- Sulfate
- Phosphorus
- Nitrate
- 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/kg)

Pollutant: Particulate Copper (mg/kg)

Land Use ==>	Residential	Institutional	Commercial	Industrial	Other Urban	Freeway
Roofs - Mean	91.30	96.00	96.00	853.00	91.30	859.00
Roofs - CDV	1.32	1.01	1.01	0.86	1.32	0.86
Paved Parking/Storage - Mean	84.20	84.20	84.20	84.00	84.20	84.00
Paved Parking/Storage - CDV	0.69	0.69	0.69	0.80	0.69	0.80
Unpaved Parking/Storage - Mean	62.20	62.20	62.20	62.20	62.20	62.20
Unpaved Parking/Storage - CDV	1.04	1.04	1.04	1.04	1.04	1.04
Playground - Mean	62.20	62.20	62.20	62.20	62.20	62.20
Playground - CDV	1.04	1.04	1.04	1.04	1.04	1.04
Driveways - Mean	62.20	62.20	62.20	62.20	62.20	62.20
Driveways - CDV	1.04	1.04	1.04	1.04	1.04	1.04
Sidewalks/Walks - Mean	62.20	62.20	62.20	62.20	62.20	62.20
Sidewalks/Walks - CDV	1.04	1.04	1.04	1.04	1.04	1.04
Street Areas - Mean	34.40	105.00	105.00	67.30	34.40	200.00

Buttons: Print to Text File, Save File, Save File As..., Cancel, Continue

Pollutant Loading:

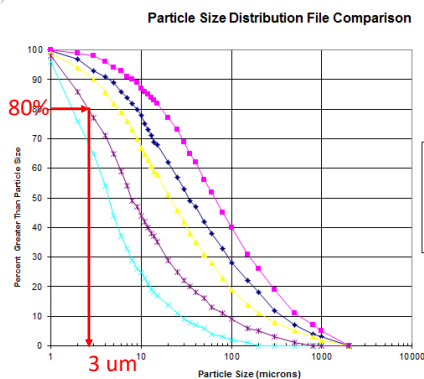
$$\text{Particulate Pollutant Loading (lbs)} = \text{Particulate Solids Loading (lbs)} * \text{PPD Coefficient (mg/kg)} * \text{Unit Conversion}$$

$$\text{Dissolved Pollutant Loading (lbs)} = \text{Runoff Volume (ft}^3\text{)} * \text{PPD Coefficient (mg/L)} * \text{Unit Conversion}$$

Note: the PPD file (containing the pollutant particulate strengths and filterable pollutant concentrations) has an optional Monte Carlo component to account for observed stormwater concentration variations.

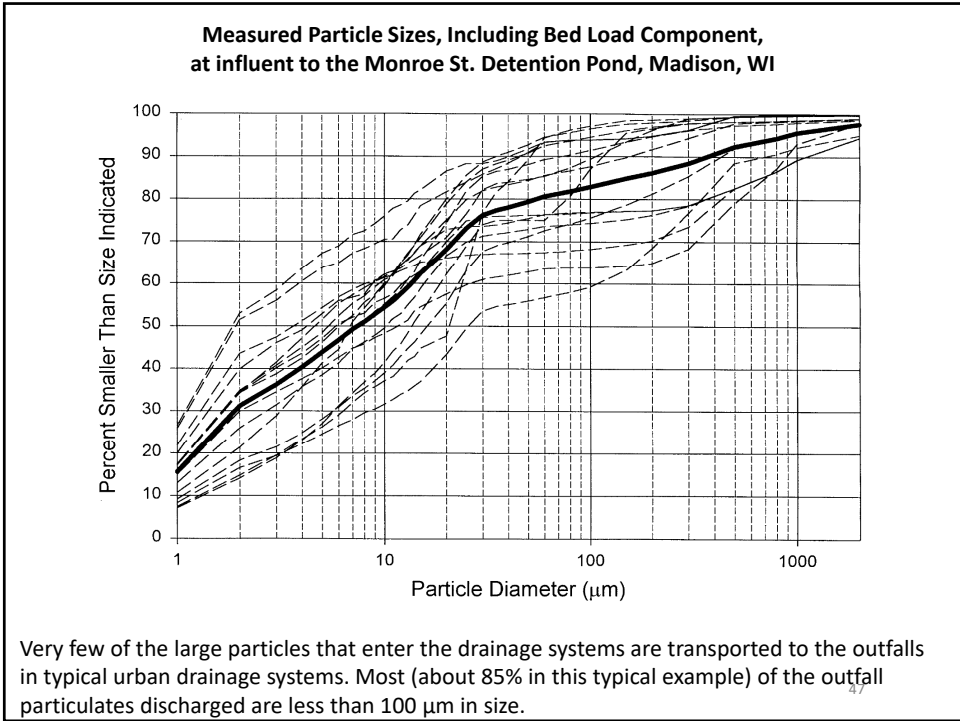
Critical Particle Size Files

Used for devices using sedimentation such as wet detention ponds, catchbasins, hydrodynamic devices, biofilters, grass swales, grass filters, media filters, etc.



- A number of .cpz files are included with the program, or can be created using locally available psd data

For 80% reduction, the particle size for control is 3 um



Mass balance measurements in the drainage system and at the outfall used to determine the fate and transport of the urban particulates. Much of the larger particulates that are not washed off are lost from the paved surfaces by fugitive dust by winds and traffic turbulence.

Measured fugitive dust losses from traffic (San Jose, Pitt 1979)

Keyes, good asphalt	0.33 grams/vehicle-mi
Keyes, oil and screens asphalt	18 grams/vehicle-mi
Tropicana, good asphalt	2.5 grams/vehicle-mi



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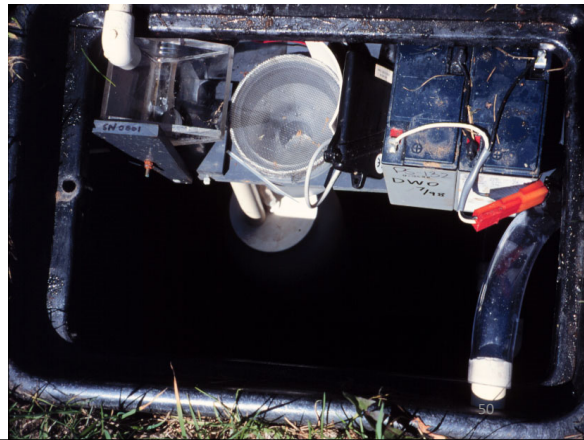
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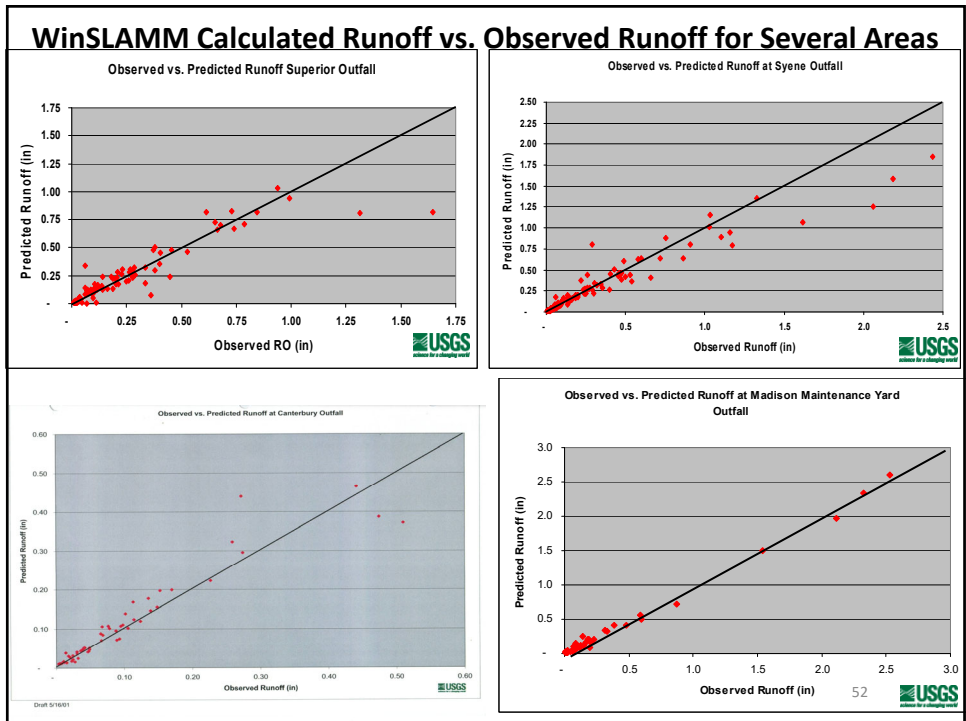
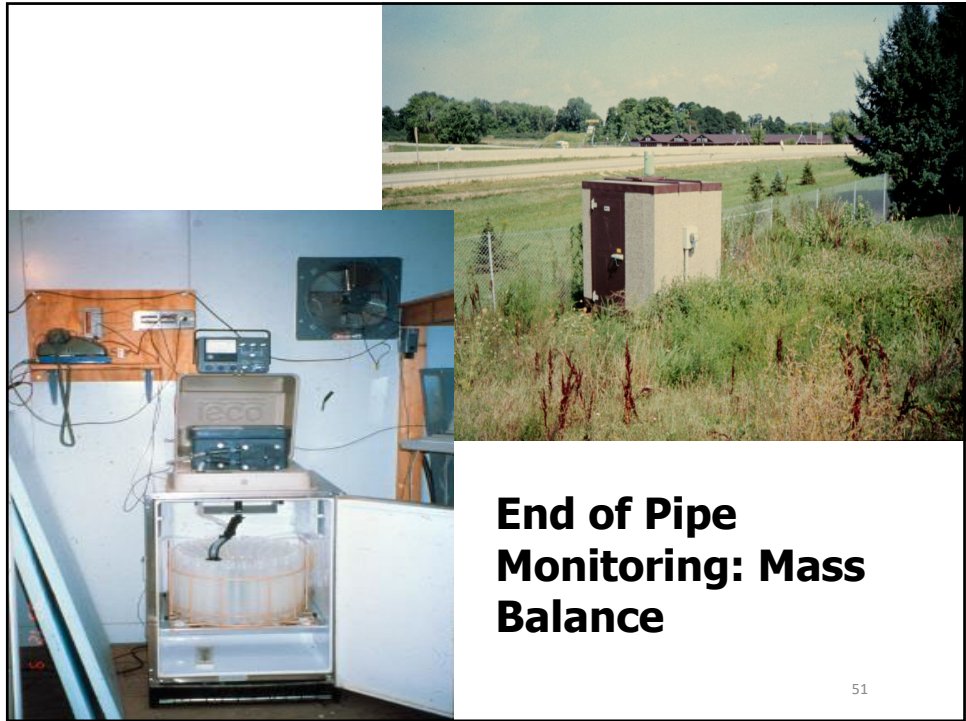


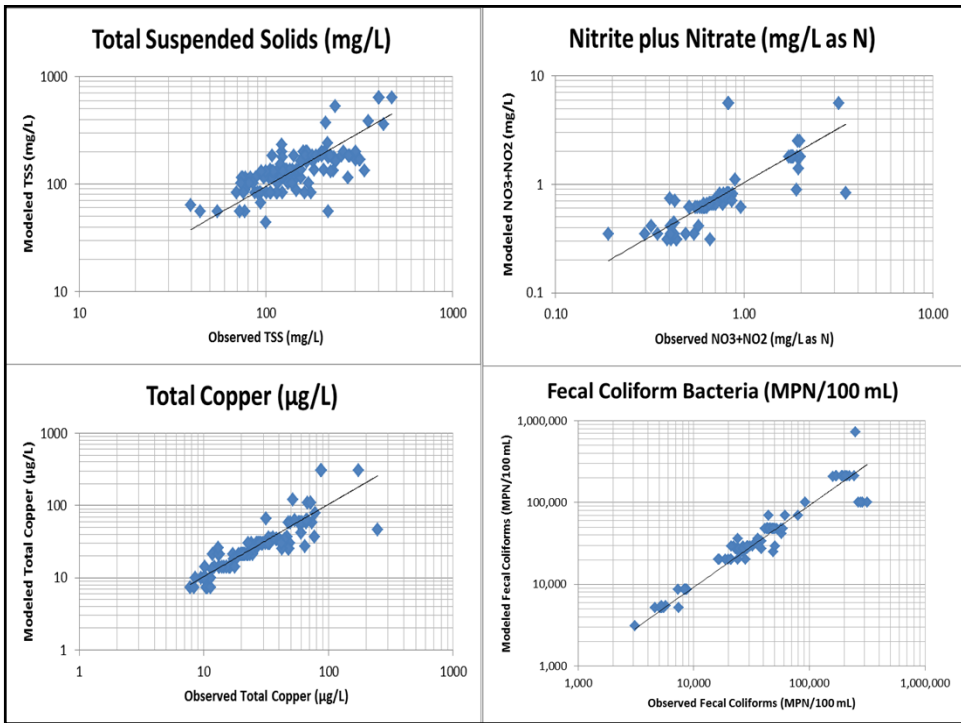
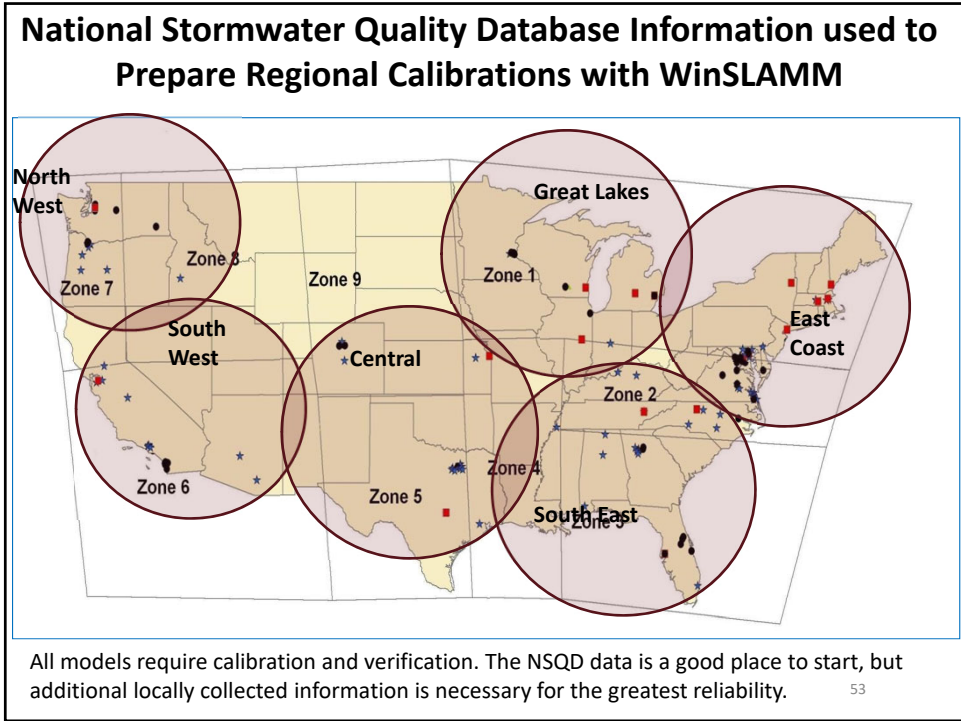
Lawn Sheet Flow Sampler: Tipping Bucket for Flow and Cone Splitter for Water Sample

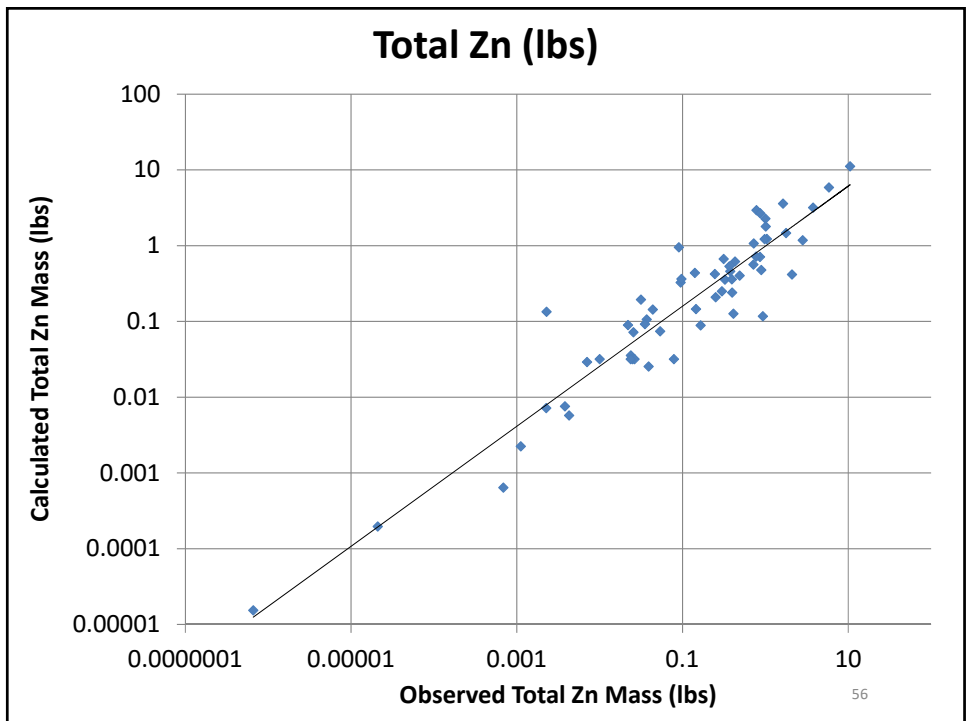
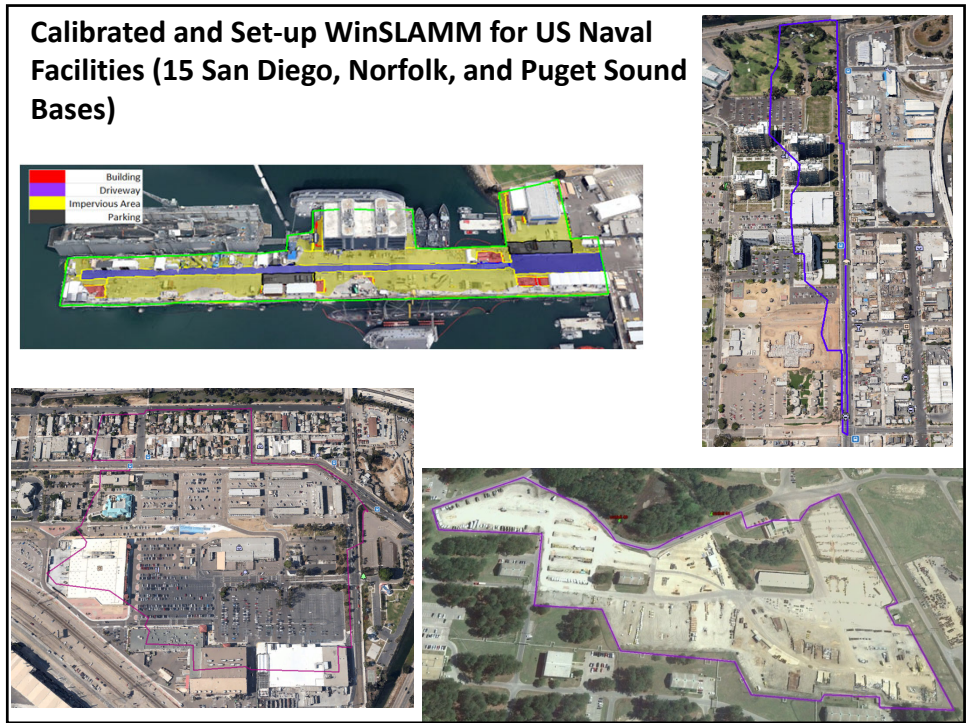
Model Strength – Based on Extensive Field Monitoring Data:

- Source Areas – Roofs, Streets, etc.
- End of Pipe – Many Land uses
- Stormwater Control Practices









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Basic Program Structure Control Devices



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



Wet Detention Control Device

Pond Number 1
Drainage System Control Practice

Select Particle Size Distribution File
Not needed - calculated by program

Initial Stage Elevation (ft):

Peak to Average Flow Ratio:

Maximum Inflow into Pond (cfs)
Enter 0 or leave blank for no limit:

Copy Pond Data Paste Pond Data

Enter fraction (greater than 0) that you want to modify all pond areas by and then select 'Modify Pond Areas' button:

Modify Pond Areas

Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.000
1	0.01	0.3700
2	1.00	0.4200
3	2.00	0.4700
4	3.00	0.5200
5	4.00	0.5800
6	5.00	0.6400
7	6.00	0.7000
8	7.00	0.7700
9	8.00	0.8400
10		
11		
12		
13		
14		
15		
16		
17		

Recalculate Cumulative Volume

Add Sharp Crested Weir

Weir Length (ft)

Height from datum to bottom of weir opening (ft)

Add V-Notch Weir

Weir Angle (180 degrees)

Height from datum to bottom of weir opening (ft)

Number of V-Notch weirs

Remove Orifice Set 1

Orifice Diameter (ft)

Invert elevation above datum (ft)

Number of orifices in set

Add Orifice Set 2

Orifice Diameter (ft)

Invert elevation above datum (ft)

Number of orifices in set

Add Orifice Set 3

Orifice Diameter (ft)

Invert elevation above datum (ft)

Number of orifices in set

Add Stone Weeper

Width at bottom of weeper (ft)

Weeper side slope [H:1V]

Upstream side slope [H:1V]

Downstream side slope [H:1V]

Horizontal flow path length at top of weeper (ft)

Average rock diameter (ft)

Distance from bottom to top of weeper (ft)

Height from datum to bottom of weeper (ft)

Add Vertical Stand Pipe

Pipe diameter (ft)

Height above datum (ft)

Month	Evaporation (in/day)	Water Withdraw Rate (ac-ft/day)
Jan	0.00	0.000
Feb	0.00	0.000
Mar	0.00	0.000
Apr	0.00	0.000
May	0.00	0.000
Jun	0.00	0.000
Jul	0.00	0.000
Aug	0.00	0.000
Sep	0.00	0.000
Oct	0.00	0.000
Nov	0.00	0.000
Dec	0.00	0.000

Stage (ft)	Natural Seepage Rate (in/hr)	Other Outflow Rate (cfs)
0.00	0.00	0.000
0.01	0.00	0.000
1.00	0.00	0.000
2.00	0.00	0.000
3.00	0.00	0.000
4.00	0.00	0.000
5.00	0.00	0.000

Remove Broad Crested Weir (Required)

Weir crest length (ft)

Weir crest width (ft)

Height from datum to bottom of weir opening (ft)

Add Seepage Basin

Infiltration rate (in/hr)

Width of device (ft)

Length of device (ft)

Invert elevation of seepage basin inlet above datum (ft)

Delete Pond Cancel Continue

Control Practice #: 1 CP Index #: 1

Conceptual Issues – Pond Geometry and Scour

The “dead” storage is needed to prevent scour of previously deposited material and should be at least 3 ft. deep over the sediment. Sediment storage volume is also needed and can be estimated using the program, or should be at least 2 ft. deep.

Porous Pavement Control Device

First Source Area Control Practice
 Land Use: Commercial 1
 Source Area: Paved Parking 1
 Total Porous and Impervious Pavement Area: 1.000 ac.
 Porous pavement area (acres): 0.400
 Inflow Hydrograph Peak to Average Flow Ratio: 3.8

Surface Pavement Layer Infiltration Rate Data
 Initial Infiltration Rate (in/hr): 100.00
 Surface Pavement Percent Solids Removal Upon Cleaning (0-100): 50.0
 Enter either these three values:
 Percent of Infiltration Rate After 3 Years (0-100):
 Percent of Infiltration Rate After 5 Years (0-100):
 Time Period Until Complete Clogging Occurs (yrs):
 Or this value:
 Surface Clogging Load (lb/sf): 0.10

Restorative Cleaning Frequency
 Never Cleaned
 Three Times per Year
 Semi-Annually
 Annually
 Every Two Years
 Every Three Years
 Every Four Years
 Every Five Years
 Every Seven Years
 Every Ten Years

Pavement Geometry and Properties

1 - Pavement Thickness (in)	3.0
Pavement Porosity (>0 and <1)	0.25
2 - Aggregate Bedding Thickness (in)	9.0
Aggregate Bedding Porosity (>0 and <1)	0.25
3 - Aggregate Base Reservoir Thickness (in)	9.0
Aggregate Base Reservoir Porosity (>0 and <1)	0.25
Porosity Pavement Area to Agg Base Area Ratio	1.00

Outlet/Discharge Options

Perforated Pipe Underdrain Diameter, if used (inches)	3.00
4 - Perforated Pipe Underdrain Outlet Invert Elevation (inches above Datum)	6.0
Number of Perforated Pipe Underdrains (<250)	1
Subgrade Seepage Rate (in/hr) - select below or enter	0.050
Use Random Number Generation to Account for Uncertainty in Seepage Rate	<input type="checkbox"/>
Subgrade Seepage Rate COV	1.60
Underdrain Discharge Percent TSS Reduction (0-100) or leave blank for program to calculate	0

Select Subgrade Seepage Rate

<input type="radio"/> Sand - 8 in/hr	<input type="radio"/> Clay loam - 0.1 in/hr
<input type="radio"/> Loamy sand - 2.5 in/hr	<input checked="" type="radio"/> Silty clay loam - 0.05 in/hr
<input type="radio"/> Sandy loam - 1.0 in/hr	<input type="radio"/> Sandy clay - 0.05 in/hr
<input type="radio"/> Loam - 0.5 in/hr	<input type="radio"/> Silty clay - 0.04 in/hr
<input type="radio"/> Silt loam - 0.3 in/hr	<input type="radio"/> Clay - 0.02 in/hr
<input type="radio"/> Sandy silt loam - 0.2 in/hr	

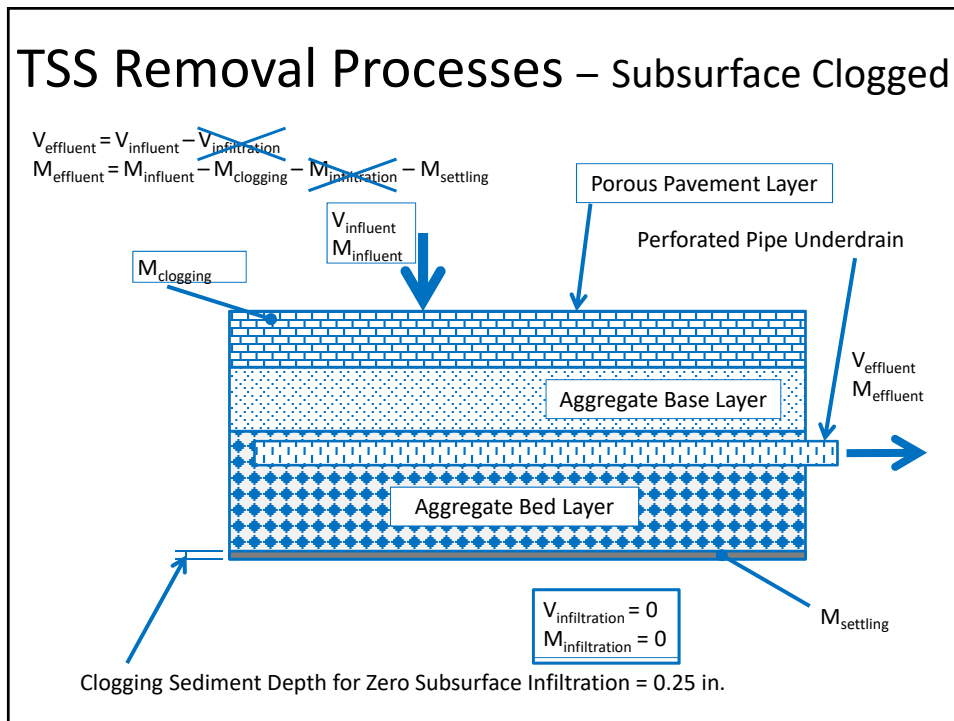
Percent of Total Area that is Porous Pavement: 40.0 %

Porosity Pavement Data **Paste Porosity Pavement Data**

Porosity Pavement Geometry Schematic

Delete Control **Cancel** **Continue**

Control Practice #: 1 Land Use #: 1 Source Area #: 13 Porosity Pavement Device Number 1



Street Cleaning

Full-scale street cleaning tests using conventional and high-energy street cleaners (street dirt loading and washoff monitoring and outfall water quality monitoring)



Street Cleaning Control Device

Land Use: Residential Total Area: 3.92
 Source Area: Street Area 1

Select Street Cleaning Dates OR Street Cleaning Frequency

Line Number	Street Cleaning Date	Street Cleaning Frequency
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Model Run Start Date: 03/01/81 Model Run End Date: 11/30/81

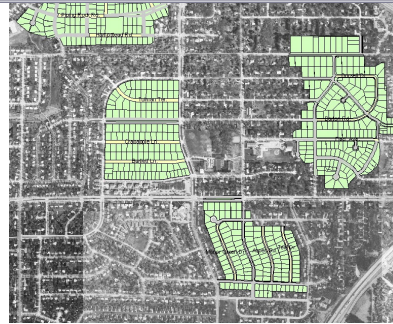
Final cleaning period ending date (MM/DD/YYYY): Apply the first year of sweeping dates to all subsequent years

Type of Street Cleaner
 Mechanical Broom Cleaner
 Vacuum or Regenerative Air Cleaner

Street Cleaner Productivity
 1. Coefficients based on street texture, parking density and parking controls
 2. Other (specify equation coefficients)
 Equation coefficient M (slope, M < 1)
 Equation coefficient B (intercept, B > 1)

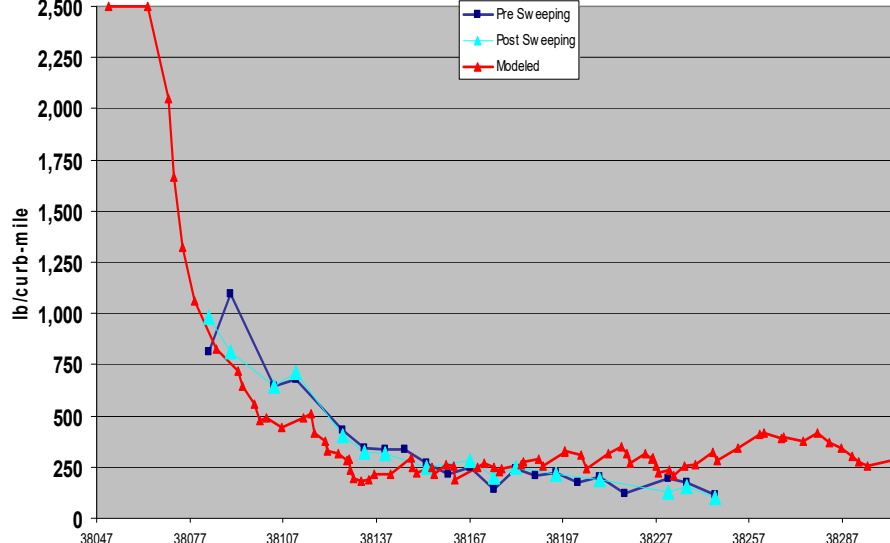
Parking Densities
 1. None
 2. Light
 3. Medium
 4. Extensive (short term)
 5. Extensive (long term)

Are Parking Controls Imposed?
 Yes No



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



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Hydrodynamic Device

First Source Area Control Practice
Hydrodynamic Device Number 2
 Land Use: Industrial 1
 Source Area: Paved Parking 1

Hydrodynamic Control Device General Information - Enter for Both Single Chamber and Proprietary Devices

Device Drainage Area (ac)	1.000
Fraction of Drainage Area Served by Device (0-1)	1.000
Number of Devices	1
Device Density (units/ac)	1.000

Model Hydrodynamic Device with Lamella Plates or Settling Tubes

Fraction of device area with plates or tubes	0.75
Average tube diameter or distance between plates (ft)	0.50
Number of plates or tubes a vertical line will intersect	3

For Device Cleaning, Select Either

Device Cleaning No.	Device Cleaning Date (mm/dd/yy)
1	
2	
3	
4	
5	

OR

Device Cleaning Frequency

Monthly
 Three Times per Year
 Semi-Annually
 Annually
 Every Two Years
 Every Three Years
 Every Four Years
 Every Five Years
 Never

Single Chamber Device Characteristics

1 - Average Sump Depth below Device Outlet Invert (ft)	3.00
Depth of Sediment in Device at Beginning of Study Period (ft)	0.00
2 - Typical Outlet Pipe Diameter (ft)	1.00
Typical Outlet Pipe Manning's n	0.012
3 - Typical Outlet Pipe Slope (ft/ft)	0.0100
Typical Device Sump Surface Area (sf)	50.0
4 - Device Depth from Sump Bottom to Street Level (ft)	10.00
Inflow Hydrograph Peak to Average Flow Ratio	3.8
5 - Minimum Allowable Scour Depth Below Outlet Invert (ft)	1.0
Maximum Flow to In-Line Sump (cfs)	N/A - Click to Activate
6 - Diameter of Orifice that Controls Flow to In-Line Sump (ft)	1.00
7 - Inflow Orifice Invert Elevation (ft)	6.00
9 - Length (ft) of Overflow Structure Acting as a Sharp-Crested Weir	5.00
9 - Elevation of Overflow Structure to Bypass In-Line Sump (ft above sump base)	8.00

Or Use Proprietary Hydrodynamic Control Device Information

Manufacturer - Model

Average Sump Depth below

Below Outlet Invert (ft)

Device Sump Surface Area (sf)

Copy Hydrodynamic Device Data Paste Hydrodynamic Device Data

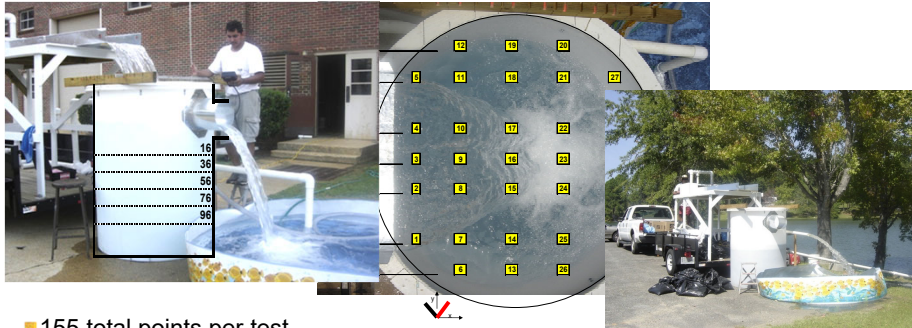
Delete Control Cancel Continue

Hydrodynamic Devices/Catchbasins with Lamella Plates or Settling Tubes

Control Practice #: 2
Land Use #: 1
Source Area #: 13

Scour of Captured Sediment in Storm Drain Catchbasin Inlets

- Three flow rates: 10, 5, and 2.5 LPS (160, 80, and 40 GPM)
- Velocity measurements (V_x , V_y , and V_z)
- Five overlying water depths above the sediment: 16, 36, 56, 76, and 96 cm

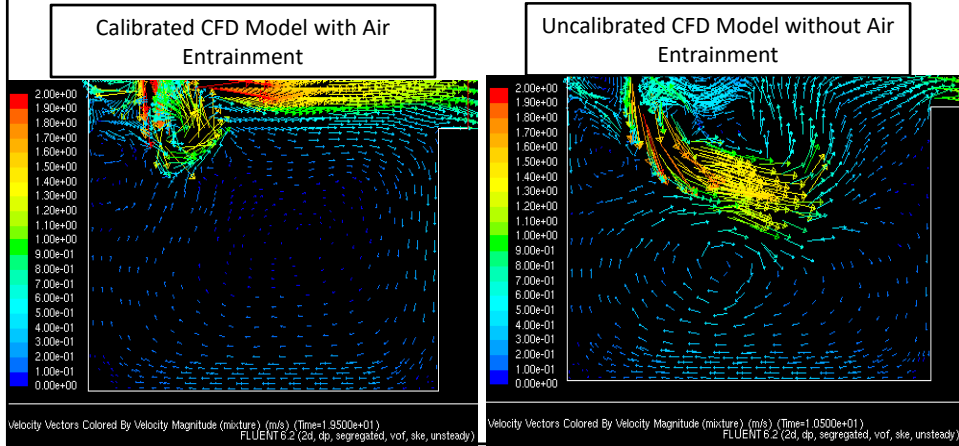


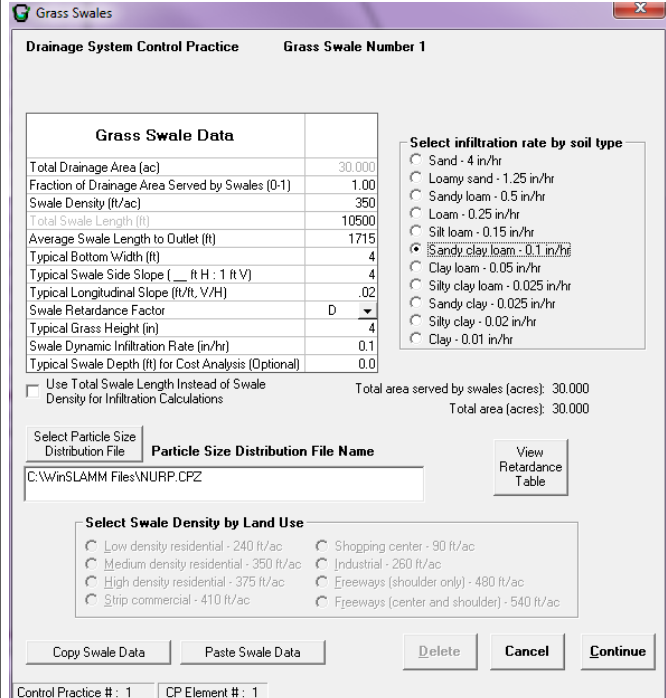
- 155 total points per test
- 30 velocity measurements at each point

CFD Modeling to Calculate Scour/Design Variations


■ Used CFD (Fluent 6.2 and Flow 3D) to determine scour from stormwater controls; results being used to expand WinSLAMM analyses after verification with full-scale physical model

■ This is an example of the effects of the way that water enters a sump on the depth of the water jet and resulting scour

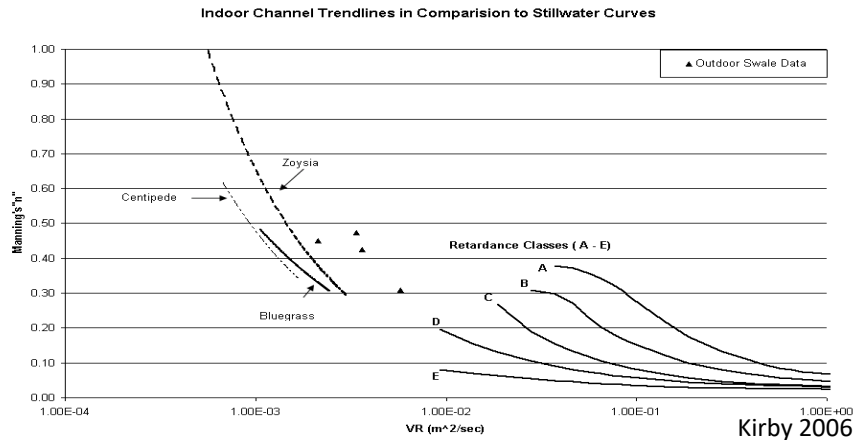




Grass Swale Data Entry Form



Low Flow vs. Historical Stillwater, OK, Retardance Curves (can't use conventional VR-n curves for small urban swales)



Swale and grass filter hydraulic characteristics can be predicted on the basis of flow rate, cross sectional geometry, slope, and vegetation type.

Grass Filter Strips

Assumptions:

- Flow over surface modeled as sheet flow
- All particle sizes are treated
- Effective treatment length reduced based upon slope
 - <0.02 ft/ft – 3 ft reduction
 - >0.05 ft/ft – 10 ft reduction
 - else – 6 ft reduction
- Irreducible concentration a function of particle size

Filter Strip Control Device

Land Use: Commercial 2 Total Area: 4.000 acres
 Source Area: Paved Parking 2 Filter Strip No. 1

First Source Area Control Practice

Device Properties	
Total Area in Source Area (ac)	4.000
Area Fraction Served by Filter Strips (0-1)	0.50
Total Filter Strip Width (ft)	400
Effective Flow Length (ft)	20
Infiltration Rate (in/hr)	0.050
Typical Longitudinal Slope (0-1)	0.100
Typical Grass Height (in)	4.0
Grass Retardance Factor	D
Use Stochastic Analysis to account for Infiltration Rate Uncertainty	<input type="checkbox"/>
Native Soil Infiltration Rate COV	
Surface Clogging Load (lbs/st)	3.50

Filter Strip Area to Drainage Area Ratio = 0.092
 This ratio must be greater than 0.05 to activate the filter strip.

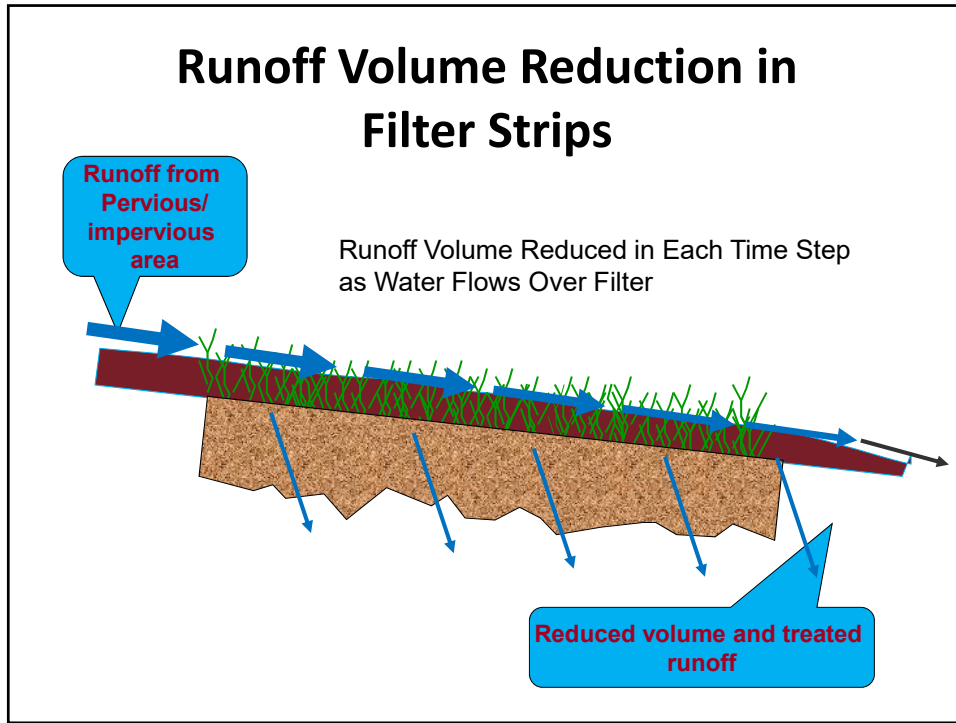
Select Particle Size File
 C:\Program Files (x86)\WinSLAMM v10\NURP.CPZ

Select Native Soil Infiltration Rate	
<input type="radio"/> Sand - 8 in/hr	<input type="radio"/> Clay loam - 0.1 in/hr
<input type="radio"/> Loamy sand - 2.5 in/hr	<input checked="" type="radio"/> Silty clay loam - 0.05 in/hr
<input type="radio"/> Sandy loam - 1.0 in/hr	<input type="radio"/> Sandy clay - 0.05 in/hr
<input type="radio"/> Loam - 0.5 in/hr	<input type="radio"/> Silty clay - 0.04 in/hr
<input type="radio"/> Silt loam - 0.3 in/hr	<input type="radio"/> Clay - 0.02 in/hr
<input type="radio"/> Sandy silt loam - 0.2 in/hr	

Copy Filter Strip Data Paste Filter Strip Data

Delete Cancel Continue

Control Practice #: 1 Land Use #: 3 Source Area #: 14



Biofilter Data Entry Form

First Source Area Control Practice

Top Area (sf)	120
Bottom Area (sf)	100
Total Depth (ft)	4.00
Typical Width (ft) (Cost est. only)	10.00
Native Soil Infiltration Rate (in/hr)	0.1
Native Soil Infiltration Rate CDV	N/A
Infil. Rate Fraction-Bottom (0-1)	1.00
Infil. Rate Fraction-Sides (0-1)	1.00
Rock Filled Depth (ft)	1.00
Rock Fill Porosity (0-1)	0.40
Engineered Soil Type	Soil Data
Engineered Soil Infiltration Rate (in/hr)	9.40
Engineered Soil Infiltration Rate CDV	N/A
Engineered Soil Depth (ft)	2
Engineered Soil Porosity (0-1)	0.39
Percent solids reduction due to Engineered Soil (0-100)	N/A
Inflow Hydrograph Peak to Average Flow Ratio	3.80
Number of Devices in Source Area or Land Use	1

Activate Pipe or Box Storage Pipe Box

Diameter (ft) _____
 Length (ft) _____
 Within Biofilter (check if Yes)
 Perforated (check if Yes)
 Bottom Elevation (ft above datum) _____
 Discharge Orifice Diameter (ft) _____

Select Native Soil Infiltration Rate

<input type="radio"/> Sand - 8 in/hr	<input type="radio"/> Clay loam - 0.1 in/hr
<input type="radio"/> Loamy sand - 2.5 in/hr	<input type="radio"/> Silty clay loam - 0.05 in/hr
<input type="radio"/> Sandy loam - 1.0 in/hr	<input type="radio"/> Sandy clay - 0.05 in/hr
<input type="radio"/> Loam - 0.5 in/hr	<input type="radio"/> Silty clay - 0.04 in/hr
<input type="radio"/> Silt loam - 0.3 in/hr	<input type="radio"/> Clay - 0.02 in/hr
<input type="radio"/> Sandy silt loam - 0.2 in/hr	<input type="radio"/> Rain Barrel/Cistern - 0.00 in/hr

Select Particle Size File: C:\Program Files\WinSLAMM\NURP\CPZ

Control Practice #: 1 Land Use #: 1 Source Area #: 5 Total Area: 4.000 acres Land Use: Residential 1 Source Area: Roof 5

Other Outlet

Stage Number	Stage (ft)	Other Outflow Rate (cfs)
1		
2		
3		
4		
5		

Evapotranspiration

Soil porosity (saturation moisture content, 0-1)	0.386
Soil field moisture capacity (0-1)	0.115
Permanent wilting point (0-1)	0.037
Supplemental irrigation used?	<input type="checkbox"/>
Fraction of available capacity when irrigation starts (0-1)	
Fraction of available capacity when irrigation stops (0-1)	

Plant Types

Month	Evapotranspiration (in/day)	Evaporation (in/day)
Jan		
Feb		
Mar		
Apr	0.2000	
May	0.4000	
Jun	0.6000	
Jul	0.8000	
Aug	0.8000	
Sep	0.6000	
Oct	0.4000	
Nov	0.2000	
Dec		

Biofilter Geometry Schematic

Up-flo® Filter Incorporated into WinSLAMM Based on Lab and Field Tests

Hydro International Up-Flo Filter

First Source Area Control Practice

Contact Hydro International Web Site

A 3.00'

B 3.00'

Device Geometry	
Area Fraction Served by Up-Flo Filters (0-1)	1.000
A - Height from Outlet Invert to Structure Top (ft)	3.00
B - Sump Depth (ft)	3.00
Peak to Average Flow Ratio	3.80
Total Basin Area: 0 acres	
Area Served by Upflow Filter (ac): 10.000	

Solve for Given Conditions
Number of Filter Modules: 5 Tank Area = 12.6 sf

OR

Solve Interatively for Desired Percent Reduction or Effluent Concentration

- Treatment Goal - Percent TSS (>0.45-75 um) Removed
- Treatment Goal - Percent SSC (>0.45 um) Removed
- Treatment Goal - Effluent TSS Concentration (mg/L)
- Treatment Goal - Effluent SSC Concentration (mg/L)

Select Particle Size Distribution File
Not needed - calculated by program

Copy Media Filter Data
Paste Media Filter Data

CPZ

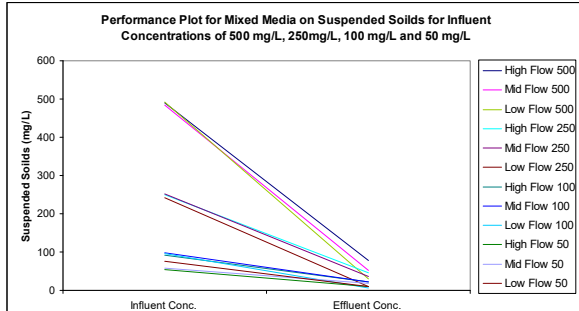
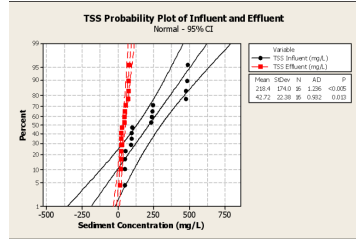
Delete Cancel Continue

Control Practice #: 1 Land Use #: 1 Source Area #: 13 Total Area: 10.000 acres Land Use: Commercial 1 Source Area: Paved Parking 1

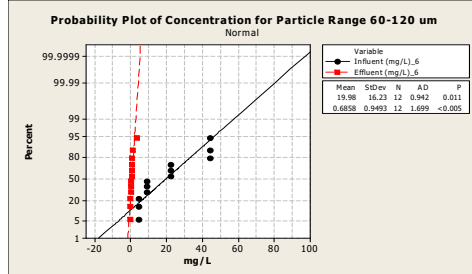
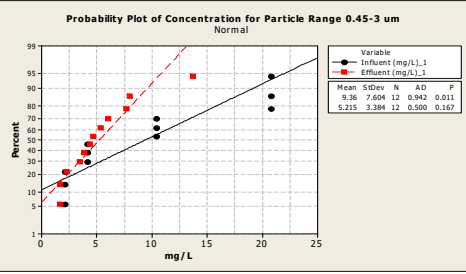


Flow rate has only a small effect on effluent quality. Effluent quality is relatively constant over broad range of influent concentrations and flows.

Pilot-Scale Tests, Controlled Tests and Three Years of Actual Runoff Events



Performance during actual rains over a 10 month monitoring period:



The Contech StormFilter is Incorporated into WinSLAMM based on Field and Lab Data

Stormwater Management StormFilter(R) (by Contech)

Drainage System Control Practice

Media Type: ZPG

Cartridge Height: 12 inches 18 inches 27 inches

Cartridge Specific Flow Rate: 1 gpm/sf 2 gpm/sf

Head Difference (ft) Between Inlet and Outlet Inverts (Minimum Difference = 2.3'): 3.00

Bypass Structure Location: Online - Within cartridge chamber Offline - Upstream of cartridge chamber

Activate Upstream Storage Gallery

Volume Based Chamber Size
Runoff Depth (ft):
Storage Chamber Depth (ft):

Pipe Storage
Storage Pipe Diameter (ft):
Storage Pipe Length (ft):
Chamber Sump Depth (ft):

Box Storage
Chamber Footprint Area (sf):
Chamber Depth (ft):
Chamber Sump Depth (ft):

Solve for Given Conditions

Number of Cartridges: 5 Chamber Dimension = 5' dia

OR

Solve Iteratively for Desired Percent Reduction of Effluent Concentration

Treatment Goal - Percent TSS (0.45-75 um) Removed

Treatment Goal - Percent SSC (>0.45 um) Removed

Treatment Goal - Effluent TSS Concentration (mg/L)

Treatment Goal - Effluent SSC Concentration (mg/L)

Select Particle Size Distribution File: Not needed - calculated by program

Have Model Determine Cleaning/Replacement Frequency:

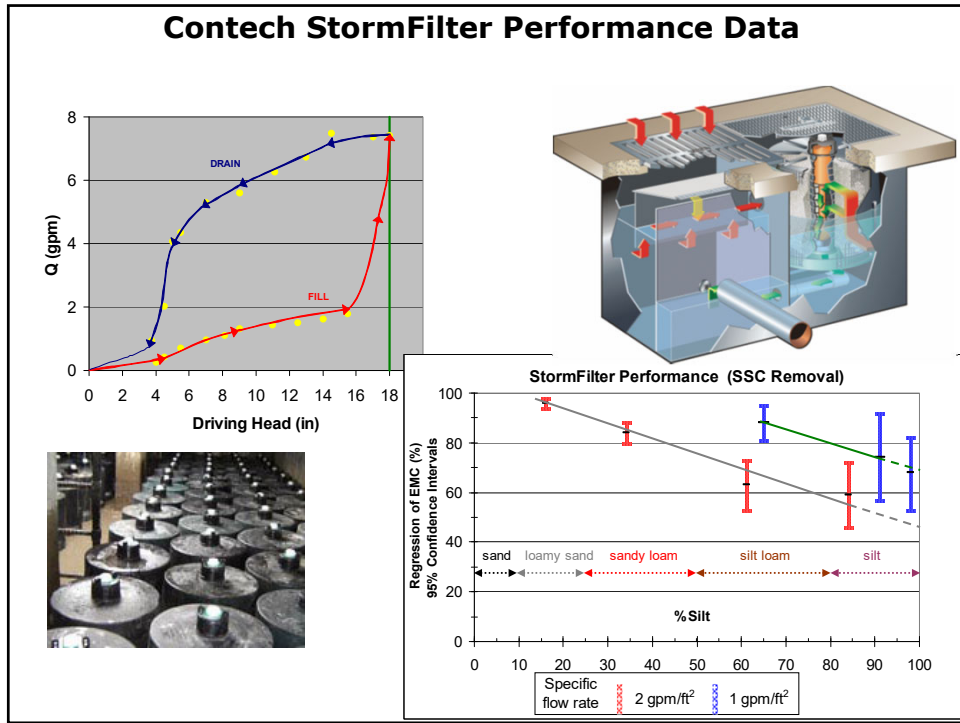
Copy Media Filter Data Delete Control

Paste Media Filter Data Cancel

Continue Contact Contech Web Site

Cartridge Flow Rate = 7.50 gpm External Bypass Weir Height = 4.5 ft. Tank Height = 5.5 ft.

Not To Scale



The ADS StormTech Isolator Row System is Incorporated into WinSLAMM based on Field and Lab Data

ADS StormTech Isolator Row

Drainage System Control Practice DS Isolator Row # 1

Total Available System Length (ft) Available Height from Chamber Base to Surface (ft) Native Soil Infiltration Rate (in/hr)

Total Available System Width (ft) Number of Isolator Rows Assumed Stone Porosity

Select Either of These Sizing Options

Use All Available Area Enter Required Storage Volume Enter Number of Rows and Row Length

Copy Data Paste Data

Update Graphics

Show Cross Section Detail

Chamber Segment Dimensions				Calculated System Size				Cross Section				
Product	Height (in)	Width (in)	Length (in)	Final Storage Volume (cf)	Number of Rows	Row Length (ft)	Total Chamber Length (ft)	Total System Width (ft)	Number of Chambers	Outlet	Invert Elevation (ft)	Orifice Diameter (ft)
<input type="radio"/> SC-150LP	12	25	85.4							Overflow Weir	1.00	N/A
<input type="radio"/> SC-310	16	34	85.4							Orifice 1	0.00	0.00
<input type="radio"/> SC-740	30	51	85.4							Orifice 2	0.00	0.00
<input type="radio"/> DC-780	30	51	85.4	9858	10	88.1	854.0	47.5	120			
<input type="radio"/> MC-3500	45	77	86									
<input type="radio"/> MC-4500	60	100	48.3									

Top of Pavement

Min. Req. Cover of 18.0"

5.00'

Approximate Pipe Configuration

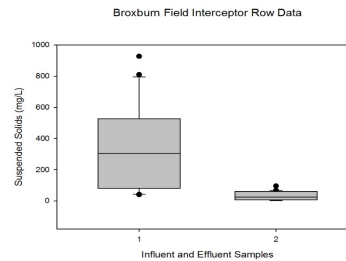
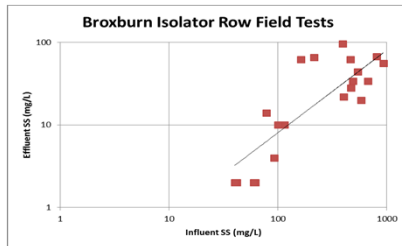
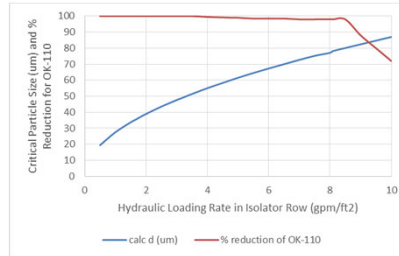
Press 'F1' for Help

Cancel Delete Control Continue

Control Practice #: 1 CP Index #: 1

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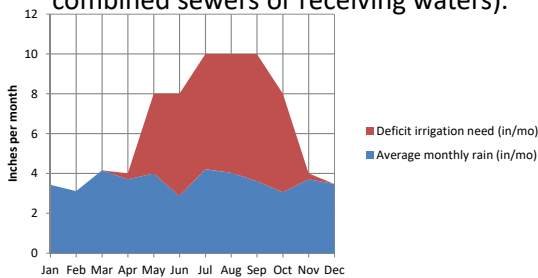
ADS Isolator Row Performance Data



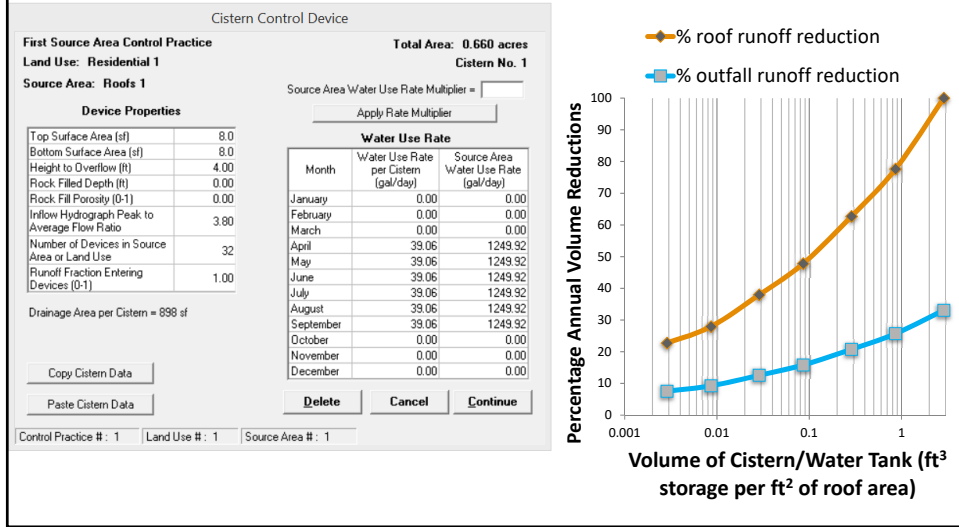
Cisterns and Beneficial Uses in WinSLAMM

Main Features of Cisterns/Water Tank Storage and Beneficial Use Calculations in WinSLAMM:

- Mass balance calculations using long-term rainfall data.
- Calculations for different tank volumes and source areas.
- Geographical location affects water needs (conservation approach to meet evapotranspiration (ET) requirements or maximum use to minimize discharges to combined sewers or receiving waters).



Cistern Data Entry Form and Example Modeled Production Function



One of the Most Important WinSLAMM Features is its' Ability to Route Hydrographs and Particle Size Distributions through Successive Control Practices

- Upgradient hydrograph modifications usually improve the performance of downgradient controls mostly due to decreased peak treatment flow rates.
- Particle size distribution routing through control practices provides more accurate overall performance calculations (e.g., errors associated with double counting due to removal of larger particles removed by preceding controls).
- These enhancements result in an improved ability to accurately model treatment trains and to select and size complementary control practices throughout an area.

We will cover . . .

- WinSLAMM Purpose, History and Unique Features
- Model Applications
- Small Storm Hydrology
- Basic Program Structure and Operation
- Model Calibration
- Treatment Practices
- **Model Output**



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Model Output

1. Output Summary
2. Receiving Water Impacts
3. Land Uses and Source Area Detail
4. Control Device Detail
5. Analyzed as a single file or in batch mode
6. Many output options
 - i. Control Device Detailed Output
 - ii. Hydrograph and Particle Size Distribution at each Control Practice, Land Use and Junction

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File Name: C:\WinSLAMM Files\Southwest\Navy\Feb. 2012 files\QF9NAB Cu all rains.mdb

Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total of All Land Uses without Controls	672284		0.45	416.0	17458	
Outfall Total with Controls	672289	0.00 %	0.45	340.7	14298	18.10 %

Current File Output: Annualized Total After Outfall Controls: 112459 Years in Model Run: 5.98 2392

Pollutant	Concentration - No Controls	Concentration - With Controls	Concentration Units	Pollutant Yield - No Controls	Pollutant Yield - With Controls	Pollutant Yield Units	Percent Yield Reduction
Particulate Copper	110.0	90.05	ug/L	4.617	3.779	lbs	18.15 %
Filterable Copper	80.04	80.04	ug/L	3.359	3.359	lbs	0 %
Total Copper	190.1	170.1	ug/L	7.976	7.138	lbs	10.51 %

Print Output Summary to Text File Total Area Modeled (ac): 5.334

Drainage System and Outfall Results:

Perform Outfall Flow Duration Curve Calculations

Receiving Water Impacts Due To Stormwater Runoff (CWP Impervious Cover Model)

	Calculated Rv	Approximate Urban Stream Classification
Without Controls	0.45	Poor
With Controls	0.45	Poor

Model Output Receiving Water Impacts

Flow Duration Curve for Current Model Run

Discharge Greater Than or Equal to (cfs)	Percent of Flow Area (Yield)	Without Controls	With Controls
10	0.10	0.00	0.00
20	0.20	0.00	0.00
30	0.30	0.00	0.00
40	0.40	0.00	0.00
50	0.50	0.00	0.00
60	0.60	0.00	0.00
70	0.70	0.00	0.00
80	0.80	0.00	0.00
90	0.90	0.00	0.00
100	1.00	0.00	0.00

Flow Duration Curve for Current Model Run Without Controls

Stream Quality vs Impervious Cover

Drainage System and Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Land Uses without Controls	795739		0.29	323.6	19671	
Outfall Total with Controls	628039	19.04 %	0.23	317.3	1244	92.06 %

Receiving Water Impacts Due To Stormwater Runoff (CWP Impervious Cover Model)

	Calculated Rv	Approximate Urban Stream Classification
Without Controls	0.29	Poor
With Controls	0.23	Poor

Model Output

Land Uses
Junctions
Control Practices
Outfall
Output Summary

File Name: C:\Files\SLAMM\WinSLAMM\v10\Current\Map Example for Documentation.mdb

Drainage System and Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg./l.)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total of All Land Uses without Controls	75739		0.29	323.6	15671	
Outfall Total with Controls	628039	19.04 %	0.23	31.73	1244	92.06 %
<hr/>						
Current File Output: Annualized Total After Outfall Controls	8.817E+06				17466	
Total Area Modeled (ac)	149.000					
Years in Model Run:	0.07					

Print Output Summary File

Detailed Output Information

Receiving Water Impacts Due To Stormwater Runoff

(CWP Impervious Cover Model)

	Calculated Rv	Approximate Urban Stream Classification
Without Controls	0.29	Poor
With Controls	0.23	Poor

Perform Outfall Flow Duration Curve Calculations

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Runoff Volume Tab Complete Output

Land Uses		Junctions		Control Practices		Outfall		Output Summary	
Runoff Volume				Particulate Solids				Pollutants	
Runoff Volume (cu. ft.)								Source Area Runoff Contribution (R)	
Data File: C:\Files\SLAMM\WinSLAMM\v10\Current\Map Example for Documentation.mdb									
Rain File: WinReg - Madison WI 1981.RAIN									
Date: 02/19/12 Time: 2:55:47 PM									
Site Description:									
Institutional 1 Areas - Runoff Volume (cu. ft.)									
Start Date	Rain Total	Roofs 1	Land Use Totals	Rv	Total Losses (in.)	Calculated CN*			
06/02/81	0.01	0	0	0.00	0.01	N/A			
06/03/81	0.01	0	0	0.00	0.01	N/A			
06/08/81	0.01	0	0	0.00	0.01	N/A			
06/08/81	0.33	972	972.0	0.73	0.09	99.1			
06/09/81	0.07	30	29.65	0.17	0.06	98.5			
06/12/81	0.43	218	1208	0.17	0.06	99.0			
06/15/81	2.59	864	864	0.92	0.20	99.1			
06/20/81	0.34	100	100	0.03	0.05	99.1			
06/21/81	0.32	839	837.9	0.72	0.09	99.1			
06/23/81	0.51	1447	1447	0.78	0.11	98.9			
06/25/81	0.13	582	225.9	0.46	0.07	99.1			
06/28/81	0.24	582	1477.3	0.08	0.09	99.1			
Summary for All Events									
Rain Total	Roofs 1	Land Use Totals	Rv	Total Losses (in.)	Calculated CN*				
Minimum:	0.01	0	0	0.00	0.01	N/A			
Maximum:	2.59	8664	8664	0.92	0.20	99.1			
Average:	0.42	1343	1343	0.82	0.08	99.6			
Total:	4.99	14774	14773	0.92					
Institutional 2 Areas - Runoff Volume (cu. ft.)									
Start Date	Rain Total	Paved Parking/Storage 1	Land Use Totals	Rv	Total Losses (in.)	Calculated CN*			
06/02/81	0.01	0	0	0.00	0.01	N/A			
06/03/81	0.01	0	0	0.00	0.01	N/A			
06/08/81	0.01	0	0	0.00	0.01	N/A			
06/08/81	0.33	0	0	0.00	0.33	N/A			
06/09/81	0.07	0	0	0.00	0.07	N/A			
06/12/81	0.43	0	0	0.00	0.43	N/A			
06/15/81	2.59	4104	4104	0.44	1.46	93.1			
06/20/81	0.34	0	0	0.00	0.34	N/A			
06/21/81	0.32	0	0	0.00	0.32	N/A			
06/23/81	0.51	0	0	0.00	0.51	N/A			
06/25/81	0.13	0	0	0.00	0.13	N/A			
06/28/81	0.24	0	0	0.00	0.24	N/A			
Summary for All Events									
Rain Total	Paved	Land	Rv	Total	Calculated				

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Control Practice Summary Table

Land Uses		Junctions	Control Practices		Outfall		Output Summary			
Runoff Volume		Part. Solids Yield (lbs)		Part. Solids Conc. (mg/L)		Summary Table				
Data File: C:\Files\SLAMM\WinSLAMM\v10\Current\Map Example for Documentation.mdb										
Rain File: WisReg - Madison WI 1981.RAN										
Date: 02-18-12 Time: 2:39:53 PM										
Site Description:										
Control Practice No.	Control Practice Type	Control Practice Name or Location	Total Inflow Volume (cf)	Total Outflow Volume (cf)	Percent Volume Reduction	Total Influent Load (lbs)	Total Effluent Load (lbs)	Percent Load Reduction	Flow Weighted Influent Conc (mg/L)	Conc (mg/L)
1	Catchbasin Cleaning	Catchbasins 1	4.834E+06	4.834E+06	0	6428	5798	9.792	21.30	21.30
2	Catchbasin Cleaning	SA Device, LU# 1, SA# 13	71678	71678	0	1119	936.3	16.31	250.0	250.0
3	Street Cleaning	SA Device, LU# 1, SA# 37	820200	820200	0	12895	5491	57.42	251.8	251.8
4	Wet Detention Pond	Wet Pond 1	5.878E+06	5.878E+06	0	25335	14548	42.58	69.04	69.04
5	Grass Swales	Grass Swales 1	4.834E+06	3.273E+06	32.29	5798	3727	35.72	19.21	19.21
6	Biorefilter	Biorefilters 1	2.631E+06	2.605E+06	0.9872	21825	21609	0.9916	132.9	132.9
7	Porous Pavement	SA Device, LU# 3, SA# 13	71678	0	100.0	581.7	0	100.0	130.0	130.0
8	Street Cleaning	SA Device, LU# 4, SA# 38	1.383E+06	1.383E+06	0	16912	13988	17.29	195.8	195.8
9	Catchbasin Cleaning	SA Device, LU# 4, SA# 38	1.383E+06	1.383E+06	0	13988	13522	3.332	162.0	162.0
10	Filter Strips	SA Device, LU# 4, SA# 25	163944	163944	0	1576	1576	0	154.0	154.0

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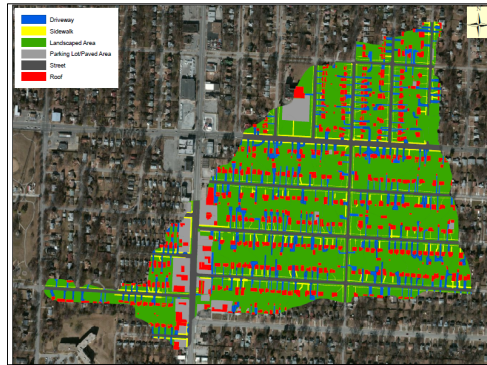
Model Output

Similar Output for -

- Particulate Solids Concentration
- Particulate Solids Yield
- Pollutant Concentration
- Pollutant Yield

The screenshot displays multiple overlapping windows from the WinSLAMM software. The primary window shows a detailed table of 'Particulate Solids' data, including columns for 'Concentration', 'Yield', 'Pollutant', and 'US Yield Concentration'. The data is organized by 'Runoff Volume' and 'Particulate Solids' sub-sections. The 'Yield' section includes columns for 'Runoff Volume', 'Particulate Solids Yield', 'Pollutant Yield', and 'US Yield Concentration'. The 'Pollutant' section includes columns for 'Pollutant Concentration', 'Pollutant Yield', and 'US Yield Concentration'. The 'US Yield Concentration' section includes columns for 'US Yield Concentration', 'US Yield Concentration', and 'US Yield Concentration'. The data is presented in a grid format with multiple columns and rows, showing various numerical values and units.

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For additional model information, go to www.winslamm.com

Remember to Press the "F1" to access the Help File