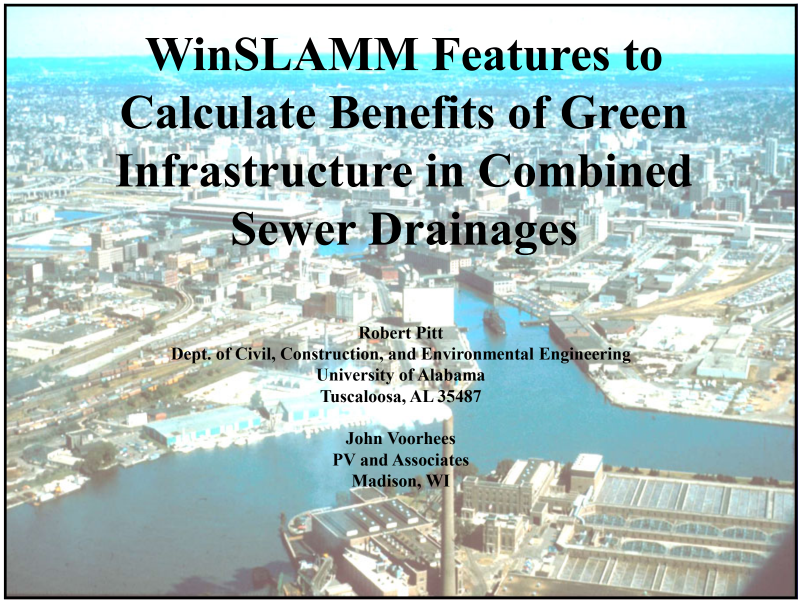
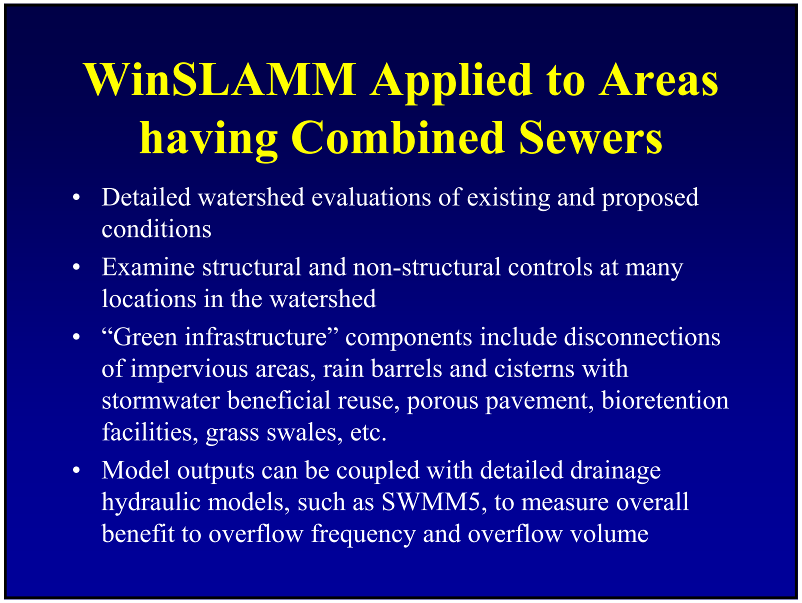


# WinSLAMM Features to Calculate Benefits of Green Infrastructure in Combined Sewer Drainages

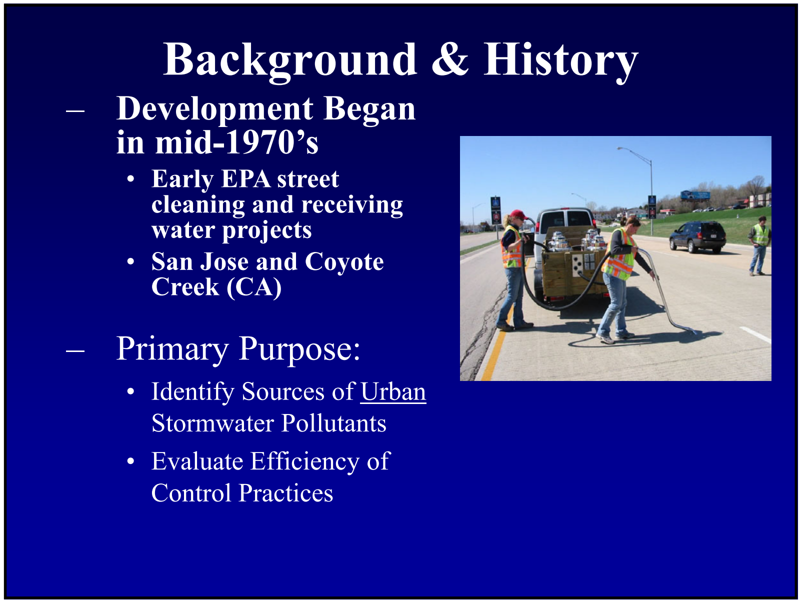
**Robert Pitt**
**Dept. of Civil, Construction, and Environmental Engineering**
**University of Alabama**
**Tuscaloosa, AL 35487**

**John Voorhees**
**PV and Associates**
**Madison, WI**



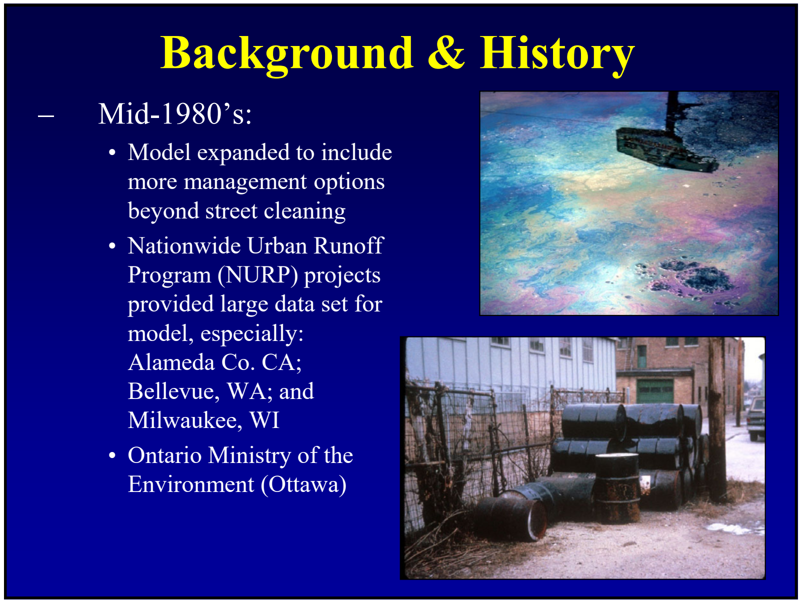
## WinSLAMM Applied to Areas having Combined Sewers

- Detailed watershed evaluations of existing and proposed conditions
- Examine structural and non-structural controls at many locations in the watershed
- “Green infrastructure” components include disconnections of impervious areas, rain barrels and cisterns with stormwater beneficial reuse, porous pavement, bioretention facilities, grass swales, etc.
- Model outputs can be coupled with detailed drainage hydraulic models, such as SWMM5, to measure overall benefit to overflow frequency and overflow volume



## Background & History

- **Development Began in mid-1970’s**
  - **Early EPA street cleaning and receiving water projects**
  - **San Jose and Coyote Creek (CA)**
- Primary Purpose:
  - Identify Sources of Urban Stormwater Pollutants
  - Evaluate Efficiency of Control Practices



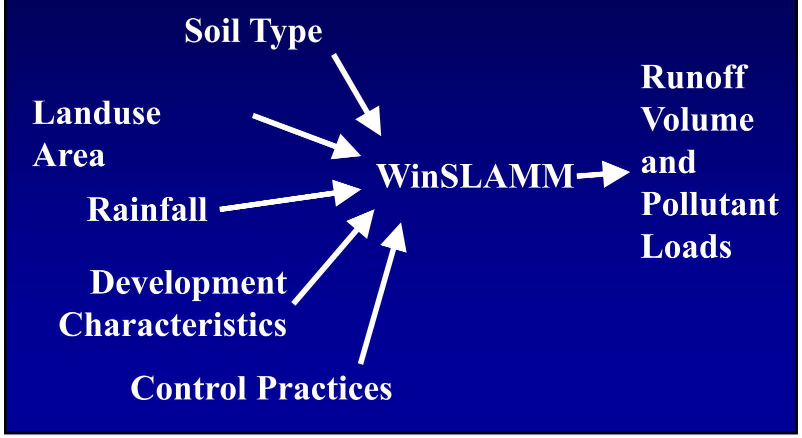
## Background & History

- Mid-1980’s:
  - Model expanded to include more management options beyond street cleaning
  - Nationwide Urban Runoff Program (NURP) projects provided large data set for model, especially: Alameda Co. CA; Bellevue, WA; and Milwaukee, WI
  - Ontario Ministry of the Environment (Ottawa)

# Background & History

- Mid-1980's - Model started to be used in Agency Programs:
  - Toronto Area Watershed Management Strategy
  - Wis. Dept. of Natural Resources: Priority Watershed Program
- First Windows Version Developed in 1995 (Currently developing Windows version 10)
- Continuously being updated based on user needs and new research (recent and current support from Stormwater Management Authority of Jefferson County, AL; the TVA, Economic Development group; WI DNR; and the USGS)
- Currently being used in the Kansas City national demonstration project of green infrastructure benefits in combined sewage area

# WinSLAMM integrates site and development information:



**Soil Type**

**Landuse Area**

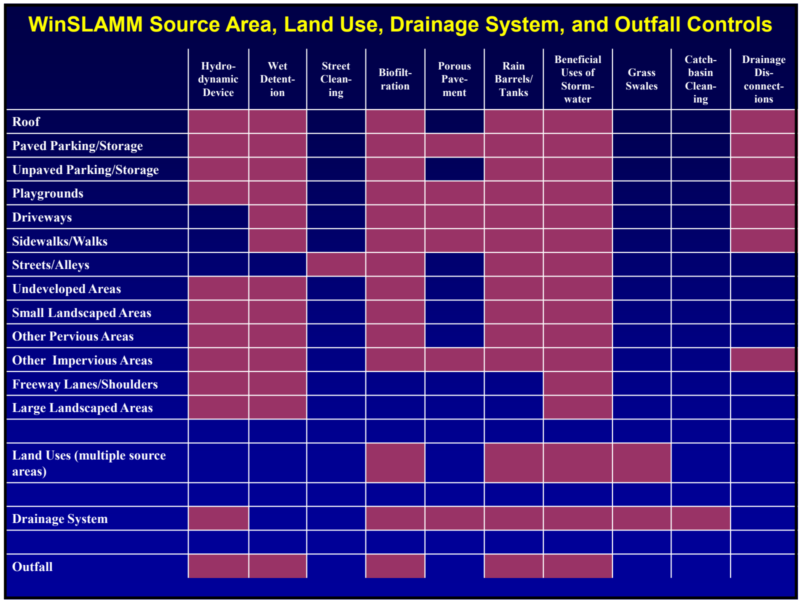
**Rainfall**

**Development Characteristics**

**Control Practices**

**WinSLAMM**

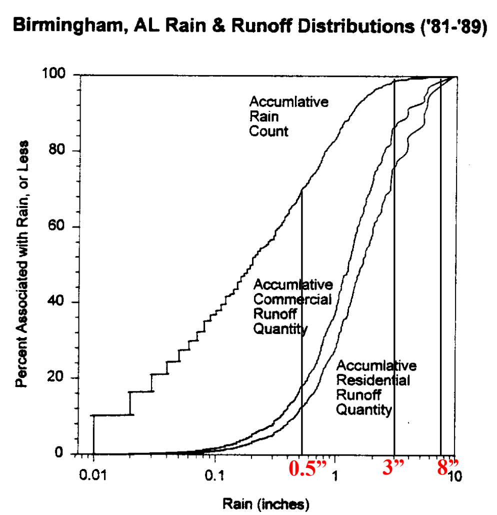
**Runoff Volume and Pollutant Loads**



## WinSLAMM Source Area, Land Use, Drainage System, and Outfall Controls

| | Hydro-dynamic Device | Wet Detent-ion | Street Clean-ing | Biofilt-ration | Porous Pave-ment | Rain Barrels/ Tanks | Beneficial Uses of Storm-water | Grass Swales | Catch-basin Clean-ing | Drainage Dis-connect-ions |
|---|---|---|---|---|---|---|---|---|---|---|
| Roof | 🟥 | 🟥 | | 🟥 | | 🟥 | 🟥 | | | 🟥 |
| Paved Parking/Storage | 🟥 | 🟥 | | 🟥 | 🟥 | 🟥 | 🟥 | | | 🟥 |
| Unpaved Parking/Storage | 🟥 | 🟥 | | 🟥 | | 🟥 | 🟥 | | | 🟥 |
| Playgrounds | 🟥 | 🟥 | | 🟥 | 🟥 | 🟥 | 🟥 | | | 🟥 |
| Driveways | | 🟥 | | 🟥 | 🟥 | 🟥 | 🟥 | | | 🟥 |
| Sidewalks/Walks | | 🟥 | | 🟥 | 🟥 | 🟥 | 🟥 | | | 🟥 |
| Streets/Alleys | | | 🟥 | 🟥 | | 🟥 | 🟥 | | | |
| Undeveloped Areas | 🟥 | 🟥 | | 🟥 | | 🟥 | 🟥 | | | |
| Small Landscaped Areas | 🟥 | 🟥 | | 🟥 | | 🟥 | 🟥 | | | |
| Other Pervious Areas | 🟥 | 🟥 | | 🟥 | | 🟥 | 🟥 | | | |
| Other Impervious Areas | 🟥 | 🟥 | | 🟥 | 🟥 | 🟥 | 🟥 | | | 🟥 |
| Freeway Lanes/Shoulders | 🟥 | 🟥 | | | | | 🟥 | | | |
| Large Landscaped Areas | 🟥 | 🟥 | | | | | 🟥 | | | |
| | | | | | | | | | | |
| Land Uses (multiple source areas) | | | | 🟥 | | 🟥 | 🟥 | 🟥 | | |
| | | | | | | | | | | |
| Drainage System | 🟥 | | | 🟥 | 🟥 | 🟥 | 🟥 | 🟥 | 🟥 | |
| | | | | | | | | | | |
| Outfall | 🟥 | 🟥 | | 🟥 | | 🟥 | 🟥 | | | |

**Probability distribution of rains (by count) and runoff (by depth).**



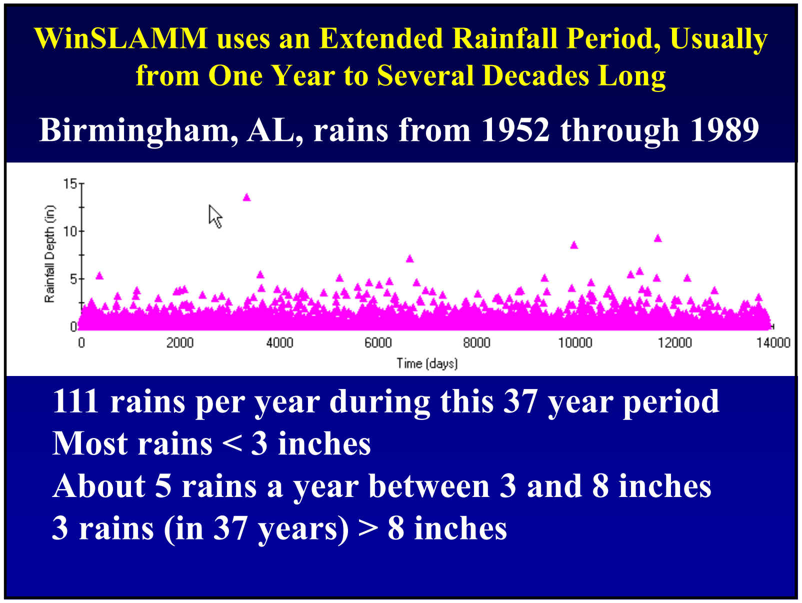
**Birmingham Rains:**

**<0.5": 65% of rains (10% of runoff)**

**0.5 to 3": 30% of rains (75% of runoff)**

**3 to 8": 4% of rains (13% of runoff)**

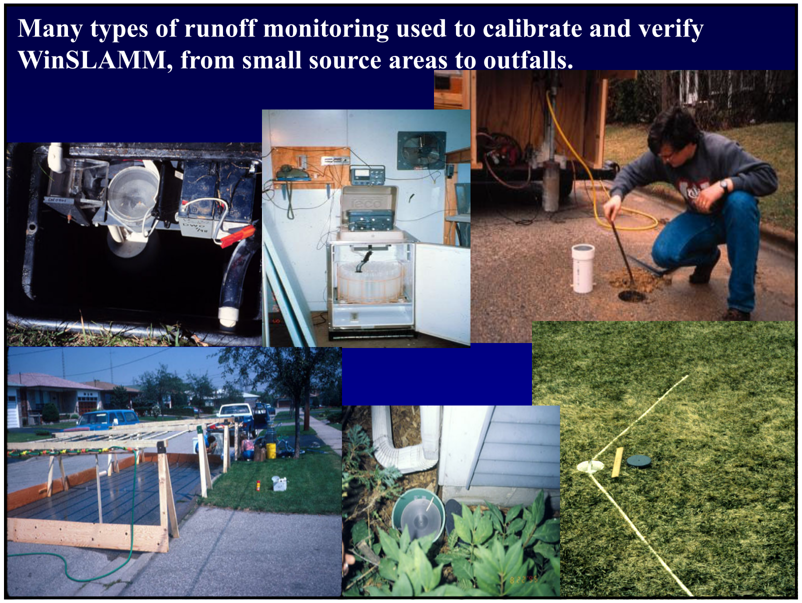
**>8": <0.1% of rains (2% of runoff)**



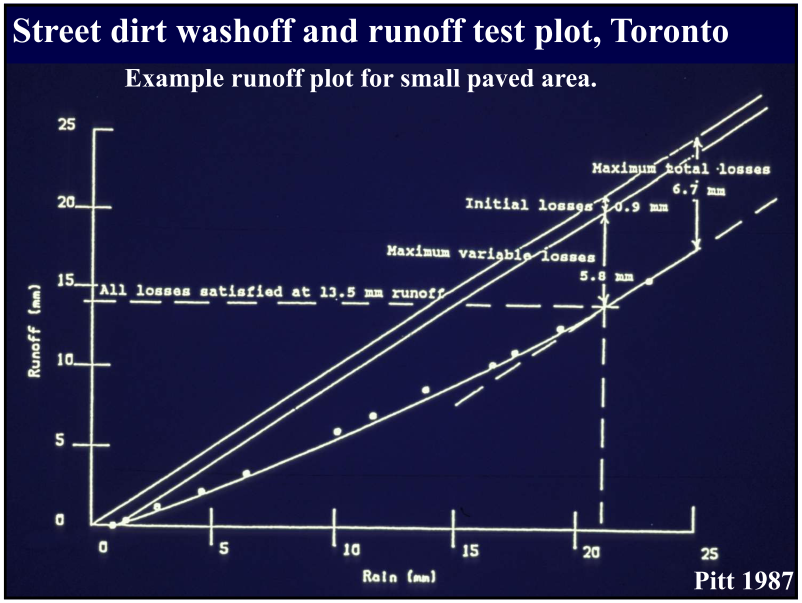
## WinSLAMM uses an Extended Rainfall Period, Usually from One Year to Several Decades Long

Birmingham, AL, rains from 1952 through 1989

111 rains per year during this 37 year period
Most rains < 3 inches
About 5 rains a year between 3 and 8 inches
3 rains (in 37 years) > 8 inches



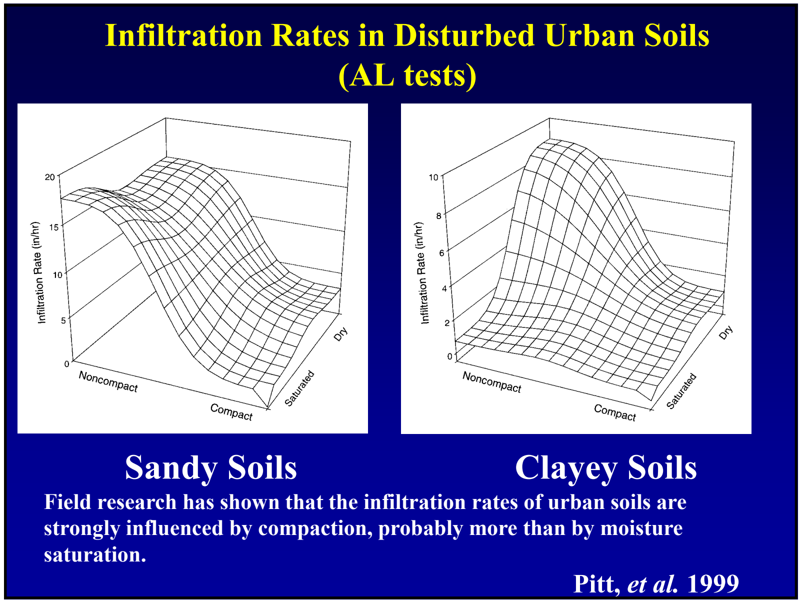
## Many types of runoff monitoring used to calibrate and verify WinSLAMM, from small source areas to outfalls.



## Street dirt washoff and runoff test plot, Toronto

Example runoff plot for small paved area.

Pitt 1987

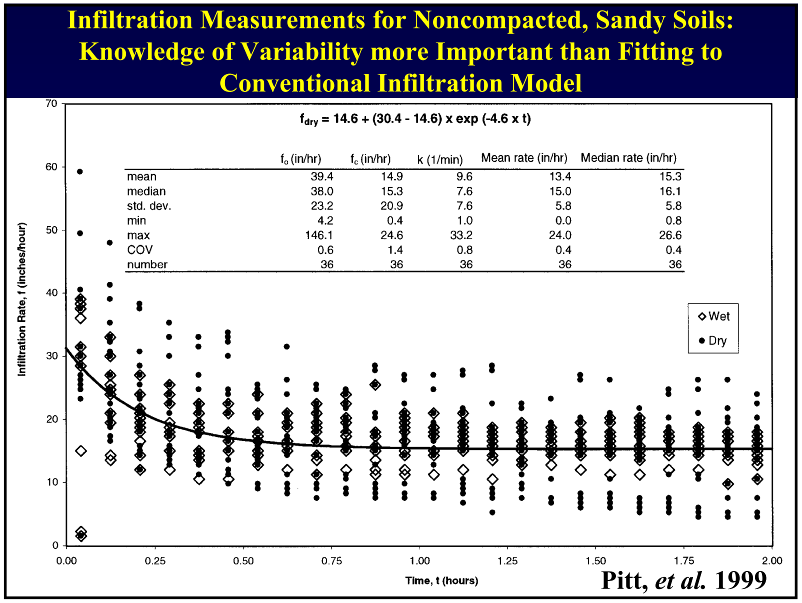


## Infiltration Rates in Disturbed Urban Soils (AL tests)

**Sandy Soils** **Clayey Soils**

Field research has shown that the infiltration rates of urban soils are strongly influenced by compaction, probably more than by moisture saturation.

Pitt, *et al.* 1999



## Infiltration Measurements for Noncompacted, Sandy Soils: Knowledge of Variability more Important than Fitting to Conventional Infiltration Model

$f_{dry} = 14.6 + (30.4 - 14.6) \times \exp(-4.6 \times t)$

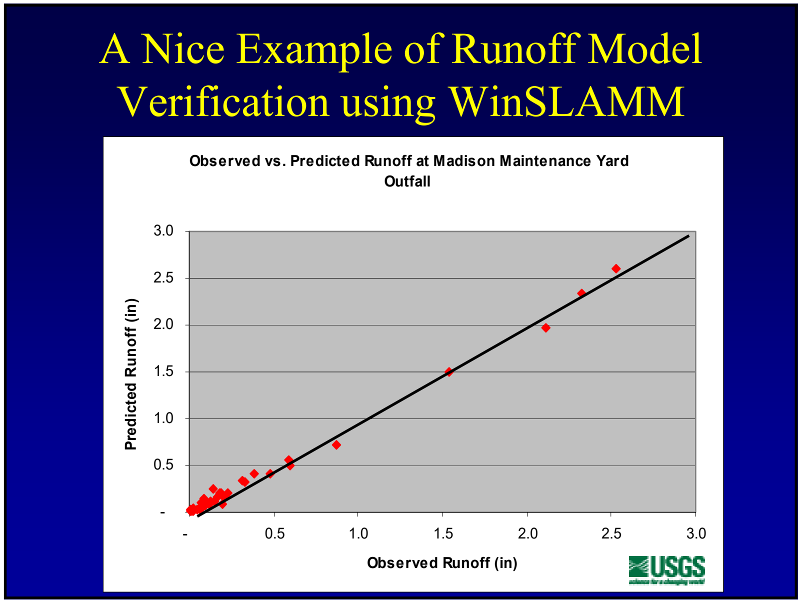
| | $f_o$ (in/hr) | $f_c$ (in/hr) | k (1/min) | Mean rate (in/hr) | Median rate (in/hr) |
|---|---|---|---|---|---|
| mean | 39.4 | 14.9 | 9.6 | 13.4 | 15.3 |
| median | 38.0 | 15.3 | 7.6 | 15.0 | 16.1 |
| std. dev. | 23.2 | 20.9 | 7.6 | 5.8 | 5.8 |
| min | 4.2 | 0.4 | 1.0 | 0.0 | 0.8 |
| max | 146.1 | 24.6 | 33.2 | 24.0 | 26.6 |
| COV | 0.6 | 1.4 | 0.8 | 0.4 | 0.4 |
| number | 36 | 36 | 36 | 36 | 36 |

Pitt, *et al.* 1999

## Long-Term Sustainable Average Infiltration Rates

| Soil Texture | Compaction Method | Dry Bulk Density (g/cc) | Long-term Average Infilt. Rate (in/hr) |
|---|---|---|---|
| Sandy Loam | Hand | 1.595 | 35 |
| | Standard | 1.653 | 9 |
| | Modified | 1.992 | 1.5 |
| Silt Loam | Hand | 1.504 | 1.3 |
| | Standard | 1.593 | 0.027 |
| | Modified | 1.690 | 0.0017 |
| Clay Loam | Hand | 1.502 | 0.29 |
| | Standard | 1.703 | 0.015 |
| | Modified | 1.911 | <0.001 |

**Compaction, especially when a small amount of clay is present, causes a large loss in infiltration capacity.**

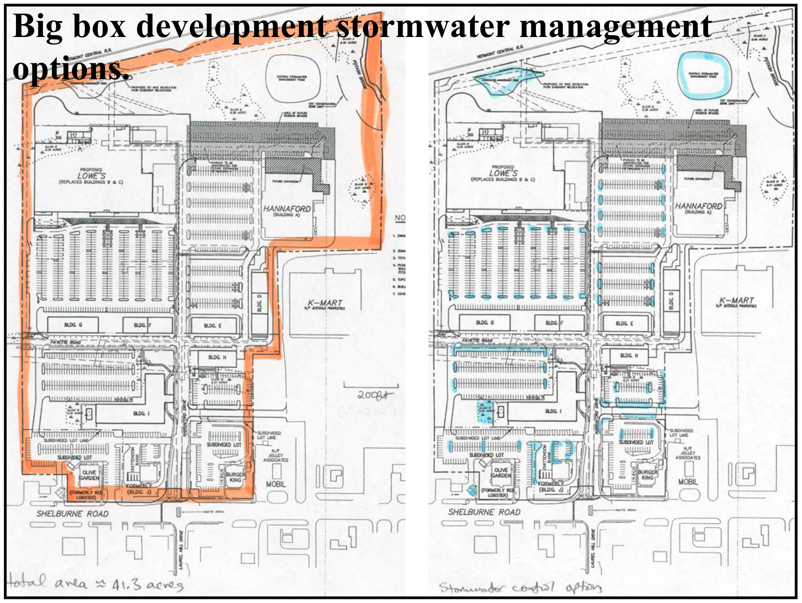


## A Nice Example of Runoff Model Verification using WinSLAMM

## Conservation Design Approach for New Development

- **Better site planning to maximize resources of site**
- **Emphasize water conservation and water reuse on site**
- **Encourage infiltration of runoff at site but prevent groundwater contamination**
- **Treat water at critical source areas and encourage pollution prevention (no zinc coatings and copper, for example)**
- **Treat runoff that cannot be infiltrated at site**

## Big box development stormwater management options.



## Summary of Measured Areas

- Totally connected impervious areas: 25.9 acres
  - parking 15.3 acres
  - roofs (flat) 8.2 acres
  - streets (1.2 curb-miles and 33 ft wide) 2.4 acres

- Landscaped/open space 15.4 acres

- Total Area 41.3 acres

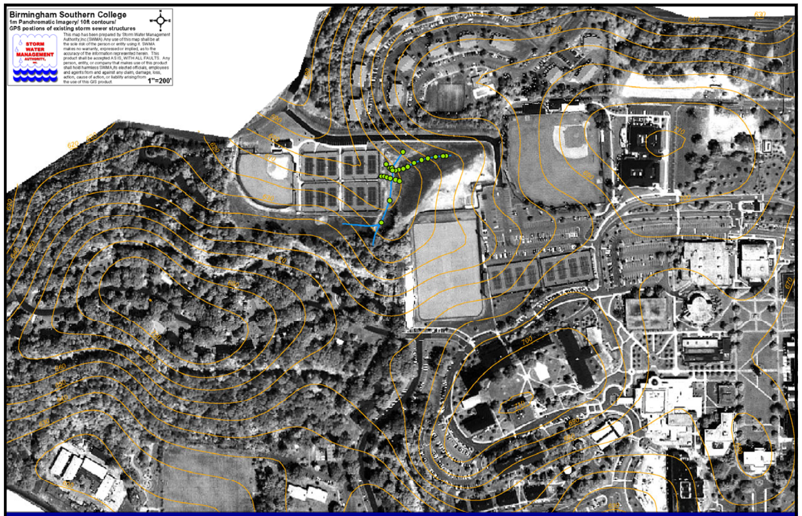
## Stormwater Controls

- Biofiltration areas (parking lot islands)
  - 52 units of 40 ft by 8 ft
  - Surface area: 320 ft$^2$
  - Bottom area: 300 ft$^2$
  - Depth: 1 ft
  - Vertical stand pipe: 0.5 ft. dia. 0.75 ft high
  - Broad-crested weir overflow: 8 ft long, 0.25 ft wide and 0.9 ft high
  - Amended soil: sandy loam

- Also examined wet detention ponds

## Runoff Volume Changes

| | **Base conditions** | **With biofiltration** |
|---|---|---|
| **Runoff volume ($10^6$ ft$^3$/yr)** | **2.85** | **1.67** |
| **Flow-weighted average Rv** | **0.59** | **0.35** |
| **% reduction in volume** | **n/a** | **41%** |



Birmingham Southern College Campus (map by Jefferson County Stormwater Management Authority)

## Birmingham Southern College Fraternity Row

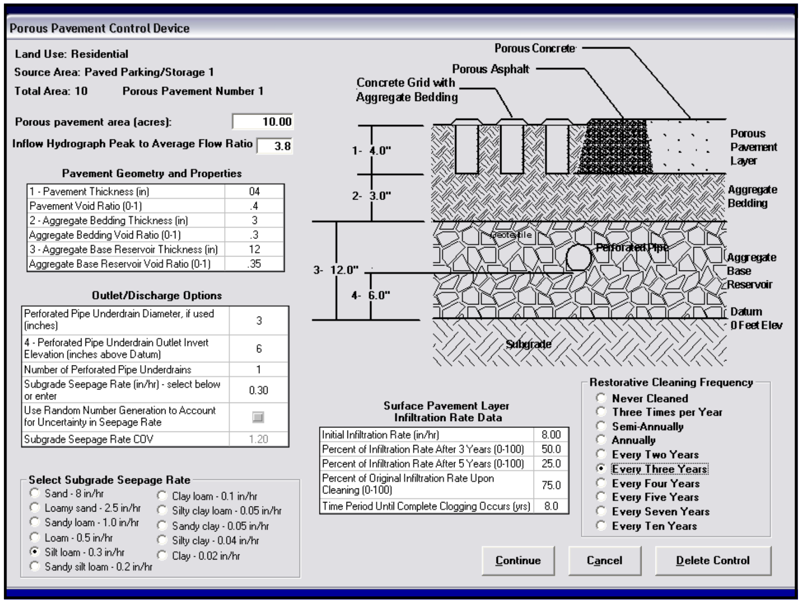
| | Acres | % of Total |
|---|---|---|
| Roadways | 0.24 | 6.6% |
| Parking | 0.89 | 24.5 |
| Walks | 0.25 | 6.9 |
| Roofs | 0.58 | 16.0 |
| Landscaping | 1.67 | 46.0 |
| Total: | 3.63 | 100.0 |

## Supplemental Irrigation

| | Inches per month (example) | Average Use for 1/2 acre (gal/day) |
|---|---|---|
| Late Fall and Winter (Nov-March) | 1 to 1-1/2 | 230 - 340 |
| Spring (April-May) | 2 to 3 | 460 - 680 |
| Summer (June-August) | 4 | 910 |
| Fall (Sept-Oct) | 2 to 3 | 460 - 680 |
| Total: | 28 (added to 54 inches of rain) | |

## Capture and Reuse of Roof Runoff for Supplemental Irrigation

| Tankage Volume (ft$^3$) per 4,000 ft$^2$ Building | Percentage of Annual Roof Runoff used for Irrigation |
|---|---|
| 1,000 | 56% |
| 2,000 | 56 |
| 4,000 | 74 |
| 8,000 | 90 |
| 16,000 | 98 |



**Porous Pavement Control Device**

Land Use: Residential
Source Area: Paved Parking/Storage 1
Total Area: 10 Porous Pavement Number 1

Porous pavement area (acres): 10.00
Inflow Hydrograph Peak to Average Flow Ratio 3.8

**Pavement Geometry and Properties**

| | |
|---|---|
| 1 - Pavement Thickness (in) | 04 |
| Pavement Void Ratio (0-1) | .4 |
| 2 - Aggregate Bedding Thickness (in) | 3 |
| Aggregate Bedding Void Ratio (0-1) | .3 |
| 3 - Aggregate Base Reservoir Thickness (in) | 12 |
| Aggregate Base Reservoir Void Ratio (0-1) | .35 |

**Outlet/Discharge Options**

| | |
|---|---|
| Perforated Pipe Underdrain Diameter, if used (inches) | 3 |
| 4 - Perforated Pipe Underdrain Outlet Invert Elevation (inches above Datum) | 6 |
| Number of Perforated Pipe Underdrains | 1 |
| Subgrade Seepage Rate (in/hr) - select below or enter | 0.30 |
| Use Random Number Generation to Account for Uncertainty in Seepage Rate | ☐ |
| Subgrade Seepage Rate COV | 1.20 |

**Select Subgrade Seepage Rate**

○ Sand - 8 in/hr
○ Loamy sand - 2.5 in/hr
○ Sandy loam - 1.0 in/hr
○ Loam - 0.5 in/hr
● Silt loam - 0.3 in/hr
○ Sandy silt loam - 0.2 in/hr
○ Clay loam - 0.1 in/hr
○ Silty clay loam - 0.05 in/hr
○ Sandy clay - 0.05 in/hr
○ Silty clay - 0.04 in/hr
○ Clay - 0.02 in/hr

**Surface Pavement Layer Infiltration Rate Data**

| | |
|---|---|
| Initial Infiltration Rate (in/hr) | 8.00 |
| Percent of Infiltration Rate After 3 Years (0-100) | 50.0 |
| Percent of Infiltration Rate After 5 Years (0-100) | 25.0 |
| Percent of Original Infiltration Rate Upon Cleaning (0-100) | 75.0 |
| Time Period Until Complete Clogging Occurs (yrs) | 8.0 |

**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

# Combinations of Controls to Reduce Runoff Volume

| | Total Annual Runoff ($ft^3$/year) | Increase Compared to Undeveloped Conditions |
|---|---|---|
| Undeveloped | 46,000 | -- |
| Conventional development | 380,000 | 8.3X |
| Grass swales and walkway porous pavers | 260,000 | 5.7 |
| Grass swales and walkway porous pavers, plus roof runoff disconnections | 170,000 | 3.7 |
| Grass swales and walkway porous pavers, plus bioretention for roof and parking area runoff | 66,000 | 1.4 |

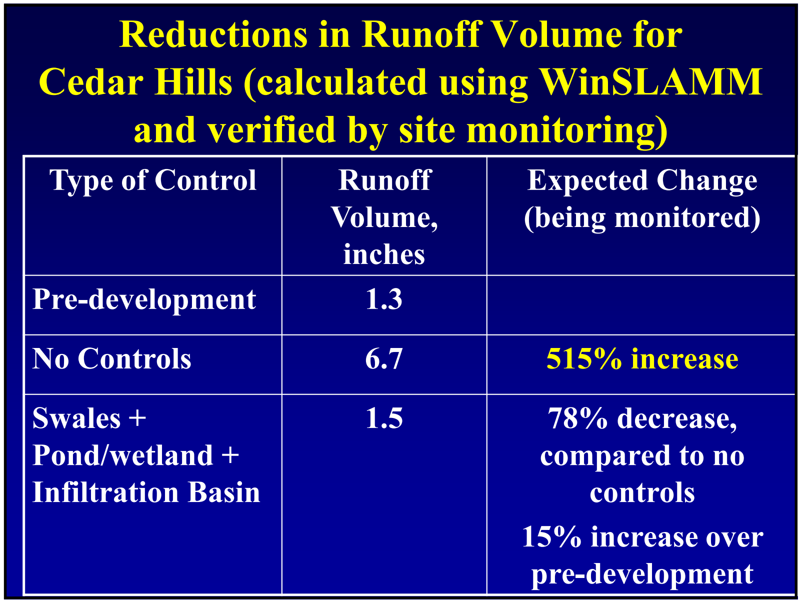
# Elements of Conservation Design for Cedar Hills Development

## (near Madison, WI, project conducted by Roger Bannerman, WI DNR and Bill Selbig, USGS)

- Grass Swales
- Wet Detention Pond
- Infiltration Basin/Wetland
- Reduced Street Width

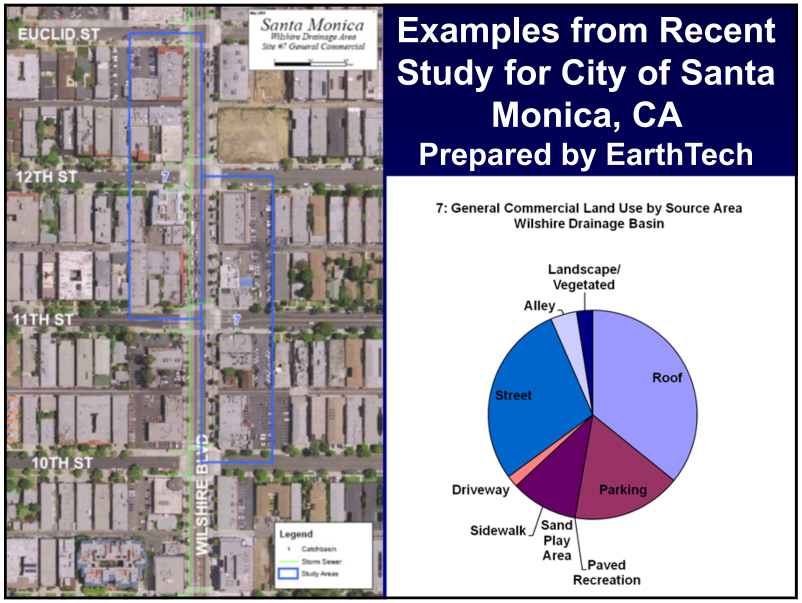
## Cedar Hill Site Design, Crossplains WI

WI DNR photos



## Reductions in Runoff Volume for Cedar Hills (calculated using WinSLAMM and verified by site monitoring)

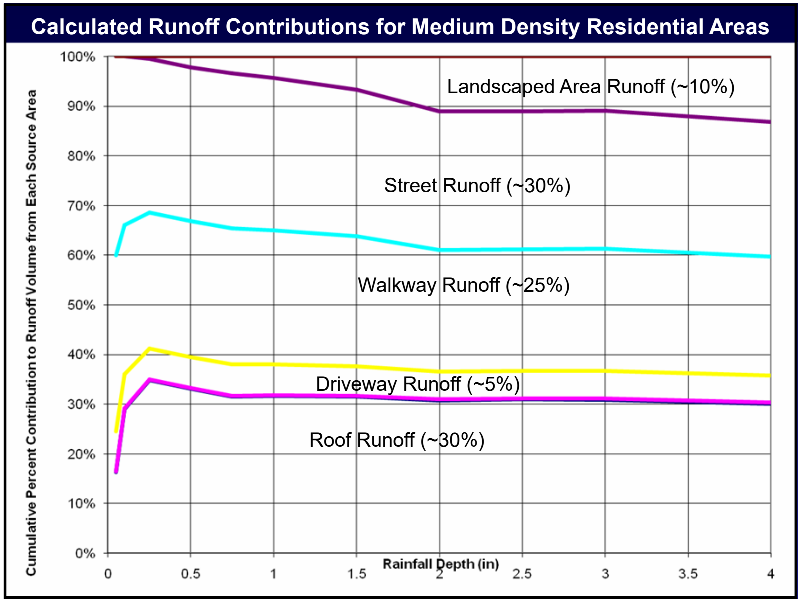
| Type of Control | Runoff Volume, inches | Expected Change (being monitored) |
|---|---|---|
| Pre-development | 1.3 | |
| No Controls | 6.7 | 515% increase |
| Swales + Pond/wetland + Infiltration Basin | 1.5 | 78% decrease, compared to no controls<br>15% increase over pre-development |



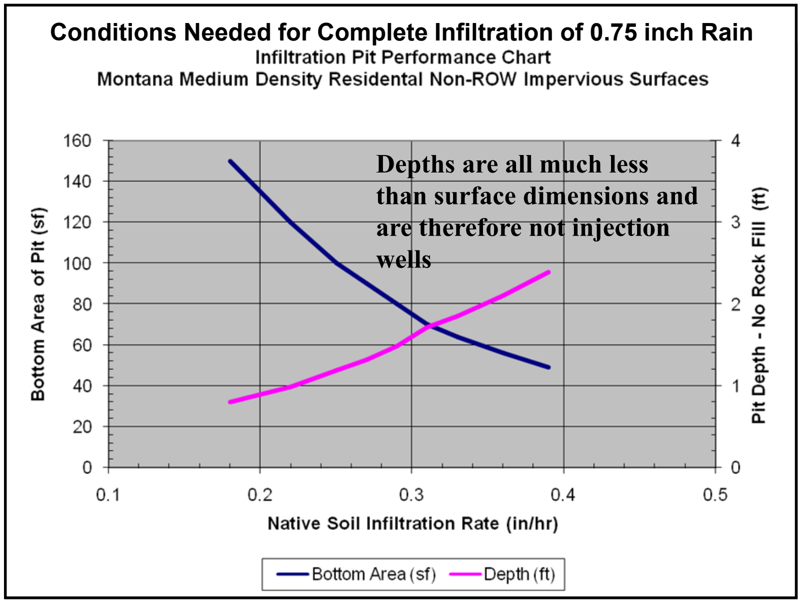
## Examples from Recent Study for City of Santa Monica, CA

### Prepared by EarthTech

7: General Commercial Land Use by Source Area
Wilshire Drainage Basin



## Calculated Runoff Contributions for Medium Density Residential Areas

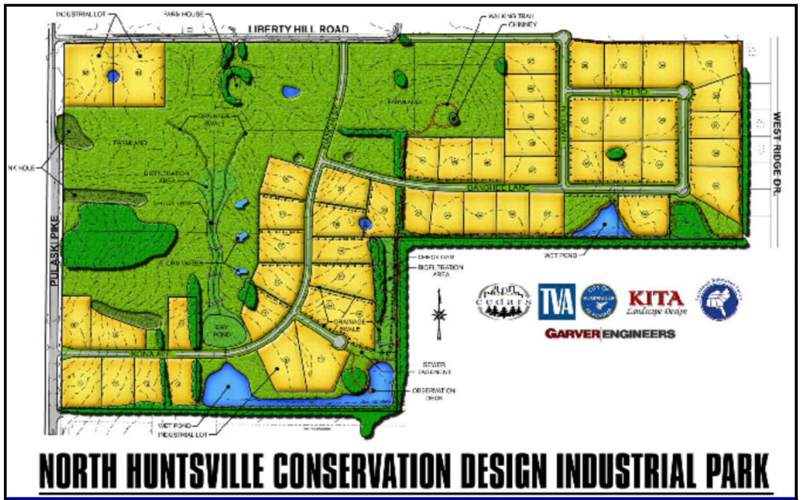


## Conditions Needed for Complete Infiltration of 0.75 inch Rain

Infiltration Pit Performance Chart

Montana Medium Density Residental Non-ROW Impervious Surfaces

Depths are all much less than surface dimensions and are therefore not injection wells

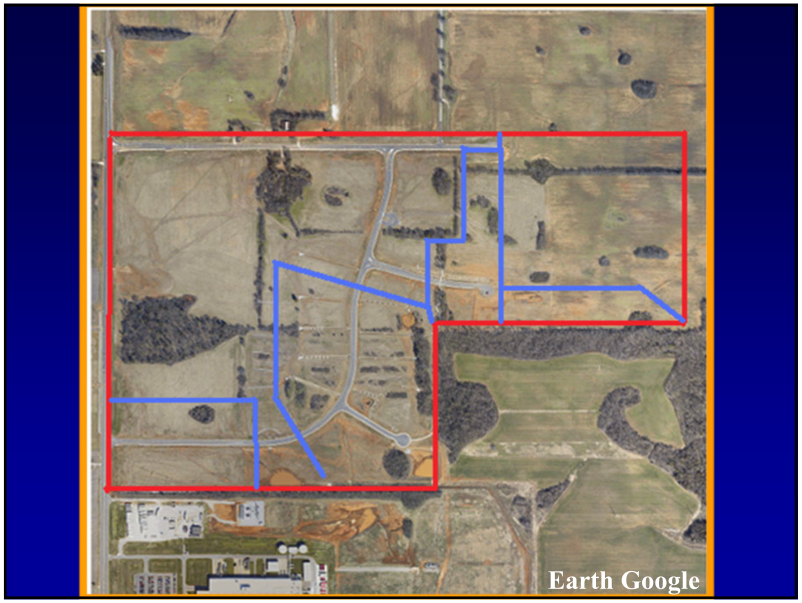


## NORTH HUNTSVILLE CONSERVATION DESIGN INDUSTRIAL PARK

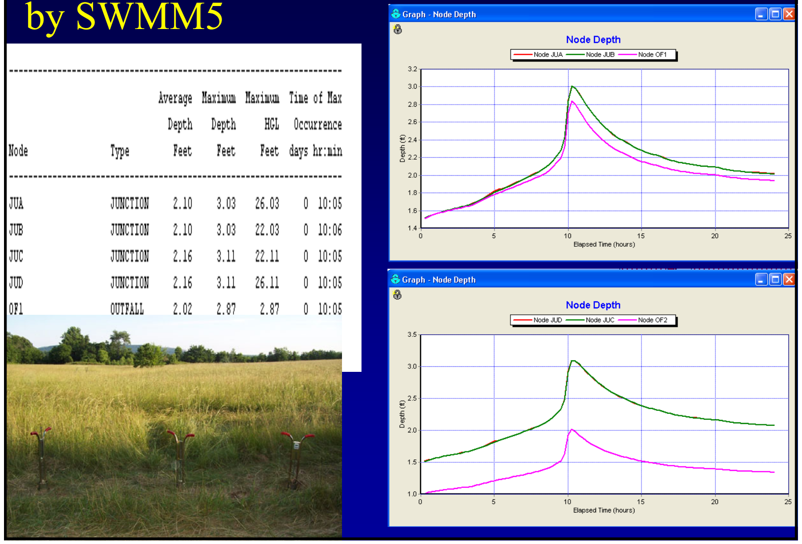
**Example of WinSLAMM and SWMM5 Integration to Evaluate Benefits of Green Infrastructure**

## Conservation Design Elements for North Huntsville, AL, Industrial Park

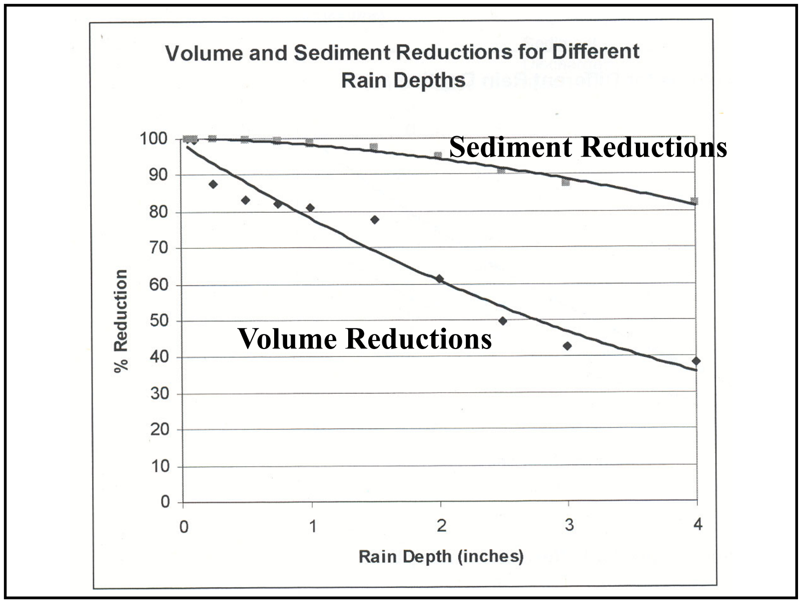
- Grass filtering and swale drainages
- Modified soils to protect groundwater
- Wet detention ponds
- Bioretention and site infiltration devices
- Critical source area controls at loading docks, etc.
- Pollution prevention through material selection (no exposed galvanized metal, for example) and no exposure of materials and products.



## Flow Rate Reductions in Drainage Calculated by SWMM5



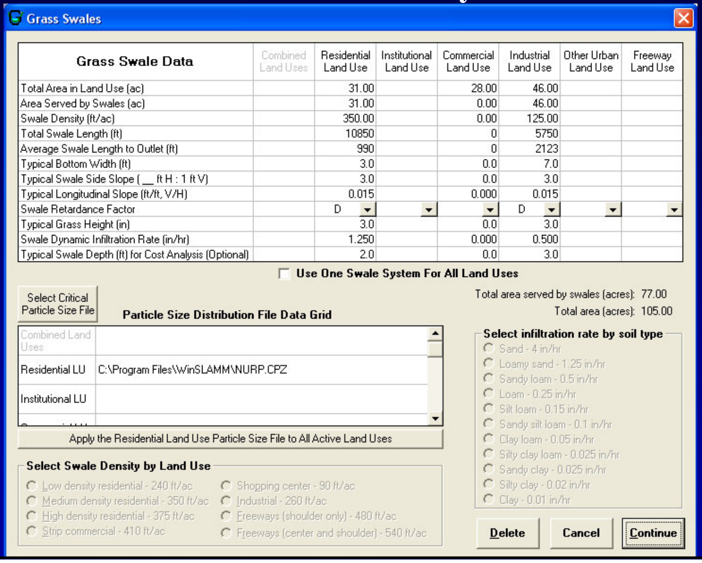
```
-----------------------------------------------------------------
                          Average  Maximum  Maximum  Time of Max
                            Depth    Depth      HGL   Occurrence
Node                Type     Feet     Feet     Feet  days hr:min
-----------------------------------------------------------------
JUA                 JUNCTION     2.10     3.03    26.03     0  10:05
JUB                 JUNCTION     2.10     3.03    22.03     0  10:06
JUC                 JUNCTION     2.16     3.11    22.11     0  10:05
JUD                 JUNCTION     2.16     3.11    26.11     0  10:05
OF1                 OUTFALL      2.02     2.87     2.87     0  10:05
```



Volume and Sediment Reductions for Different Rain Depths

## Conventional curbs with inlets directed to site swales

# Grass Swale Data Entry Form



| Grass Swale Data | Combined Land Uses | Residential Land Use | Institutional Land Use | Commercial Land Use | Industrial Land Use | Other Urban Land Use | Freeway Land Use |
|---|---|---|---|---|---|---|---|
| Total Area in Land Use (ac) | | 31.00 | | 28.00 | 46.00 | | |
| Area Served by Swales (ac) | | 31.00 | | 0.00 | 46.00 | | |
| Swale Density (ft/ac) | | 350.00 | | 0.00 | 125.00 | | |
| Total Swale Length (ft) | | 10850 | | 0 | 5750 | | |
| Average Swale Length to Outlet (ft) | | 990 | | 0 | 2123 | | |
| Typical Bottom Width (ft) | | 3.0 | | 0.0 | 7.0 | | |
| Typical Swale Side Slope ( __ ft H : 1 ft V) | | 3.0 | | 0.0 | 3.0 | | |
| Typical Longitudinal Slope (ft/ft, V/H) | | 0.015 | | 0.000 | 0.015 | | |
| Swale Retardance Factor | | D | | | D | | |
| Typical Grass Height (in) | | 3.0 | | 0.0 | 3.0 | | |
| Swale Dynamic Infiltration Rate (in/hr) | | 1.250 | | 0.000 | 0.500 | | |
| Typical Swale Depth (ft) for Cost Analysis (Optional) | | 2.0 | | 0.0 | 3.0 | | |

☐ Use One Swale System For All Land Uses

Total area served by swales (acres): 77.00
Total area (acres): 105.00

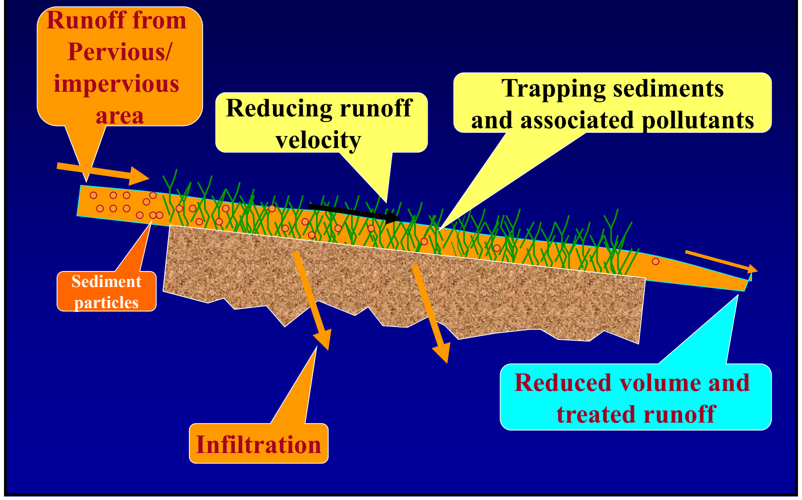
**Particle Size Distribution File Data Grid**

| | |
|---|---|
| Combined Land Uses | |
| Residential LU | C:\Program Files\WinSLAMM\NURP.CPZ |
| Institutional LU | |

**Select infiltration rate by soil type**
○ Sand - 4 in/hr
○ Loamy sand - 1.25 in/hr
○ Sandy loam - 0.5 in/hr
○ Loam - 0.25 in/hr
○ Silt loam - 0.15 in/hr
○ Sandy silt loam - 0.1 in/hr
○ Clay loam - 0.05 in/hr
○ Silty clay loam - 0.025 in/hr
○ Sandy clay - 0.025 in/hr
○ Silty clay - 0.02 in/hr
○ Clay - 0.01 in/hr

**Select Swale Density by Land Use**
○ Low density residential - 240 ft/ac
○ Medium density residential - 350 ft/ac
○ High density residential - 375 ft/ac
○ Strip commercial - 410 ft/ac
○ Shopping center - 90 ft/ac
○ Industrial - 260 ft/ac
○ Freeways (shoulder only) - 480 ft/ac
○ Freeways (center and shoulder) - 540 ft/ac

# Pollutant Control in Grass Swales



Runoff from Pervious/ impervious area

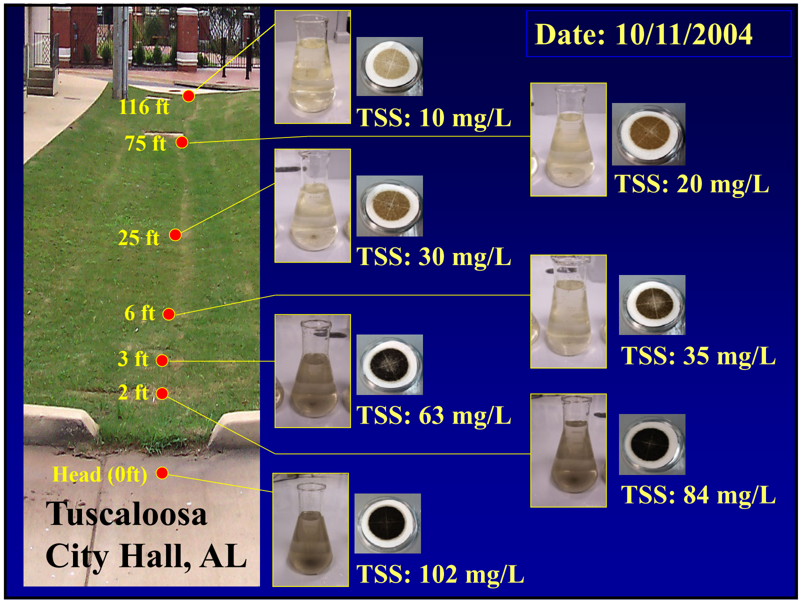
Reducing runoff velocity

Trapping sediments and associated pollutants

Sediment particles

Reduced volume and treated runoff

Infiltration



Date: 10/11/2004

TSS: 10 mg/L

TSS: 20 mg/L

TSS: 30 mg/L

TSS: 35 mg/L

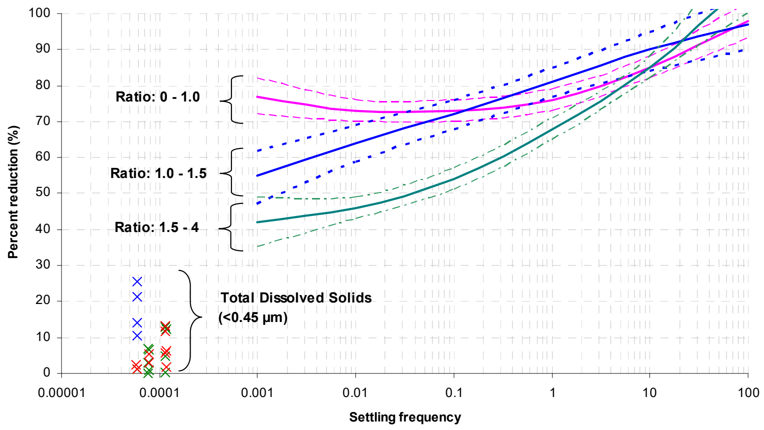
TSS: 63 mg/L

TSS: 84 mg/L

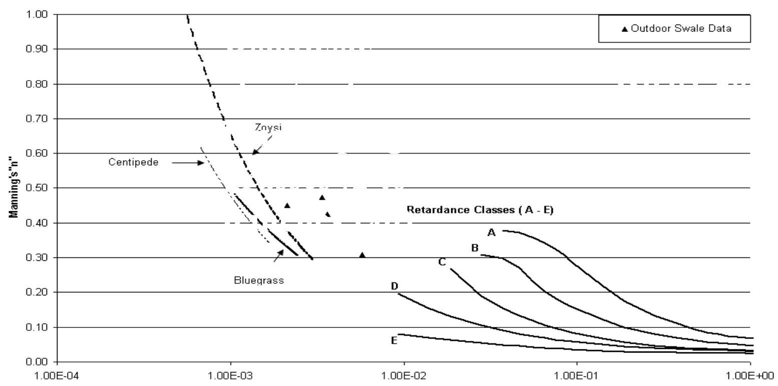
TSS: 102 mg/L

Tuscaloosa City Hall, AL

# Settling of Different Sized Particulates as a Function of Flow Characteristics (depth and velocity), Particle Settling Characteristics and Grass Type and Height

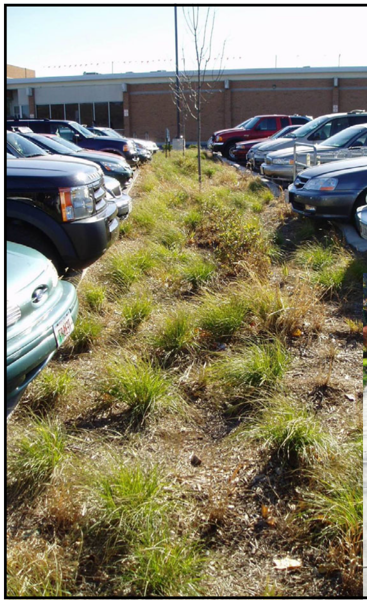


## Low Flow vs. Historical Stillwater, OK, Retardance Curves



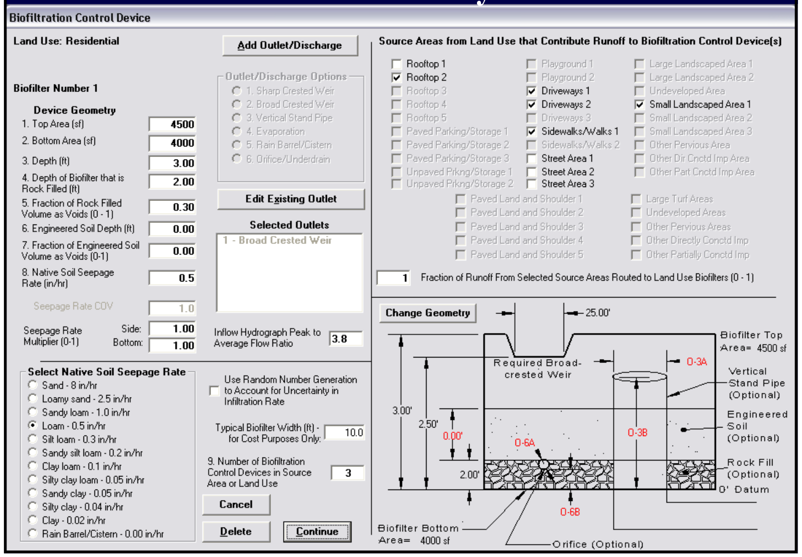
Kirby 2005

From such graphs swale hydraulic characteristics can be predicted on the basis of flow rate, cross sectional geometry, slope, and vegetation type.



## Recent Bioretention Retrofit Projects in Commercial and Residential Areas in Madison, WI

## Biofilter Data Entry Form



**Biofiltration Control Device**

**Land Use: Residential**

**Biofilter Number 1**

**Device Geometry**

1. Top Area (sf): 4500
2. Bottom Area (sf): 4000
3. Depth (ft): 3.00
4. Depth of Biofilter that is Rock Filled (ft): 2.00
5. Fraction of Rock Filled Volume as Voids (0 - 1): 0.30
6. Engineered Soil Depth (ft): 0.00
7. Fraction of Engineered Soil Volume as Voids (0-1): 0.00
8. Native Soil Seepage Rate (in/hr): 0.5

Seepage Rate COV: 1.0

Seepage Rate Multiplier (0-1) Side: 1.00 Bottom: 1.00

**Select Native Soil Seepage Rate**
- ○ Sand - 8 in/hr
- ○ Loamy sand - 2.5 in/hr
- ○ Sandy loam - 1.0 in/hr
- ● Loam - 0.5 in/hr
- ○ Silt loam - 0.3 in/hr
- ○ Sandy silt loam - 0.2 in/hr
- ○ Clay loam - 0.1 in/hr
- ○ Silty clay loam - 0.05 in/hr
- ○ Sandy clay - 0.05 in/hr
- ○ Silty clay - 0.04 in/hr
- ○ Clay - 0.02 in/hr
- ○ Rain Barrel/Cistern - 0.00 in/hr

**Outlet/Discharge Options**
- ○ 1. Sharp Crested Weir
- ○ 2. Broad Crested Weir
- ○ 3. Vertical Stand Pipe
- ○ 4. Evaporation
- ○ 5. Rain Barrel/Cistern
- ○ 6. Orifice/Underdrain

**Selected Outlets**

1 - Broad Crested Weir

Inflow Hydrograph Peak to Average Flow Ratio: 3.8

☐ Use Random Number Generation to Account for Uncertainty in Infiltration Rate

Typical Biofilter Width (ft) - for Cost Purposes Only: 10.0

9. Number of Biofiltration Control Devices in Source Area or Land Use: 3

**Source Areas from Land Use that Contribute Runoff to Biofiltration Control Device(s)**

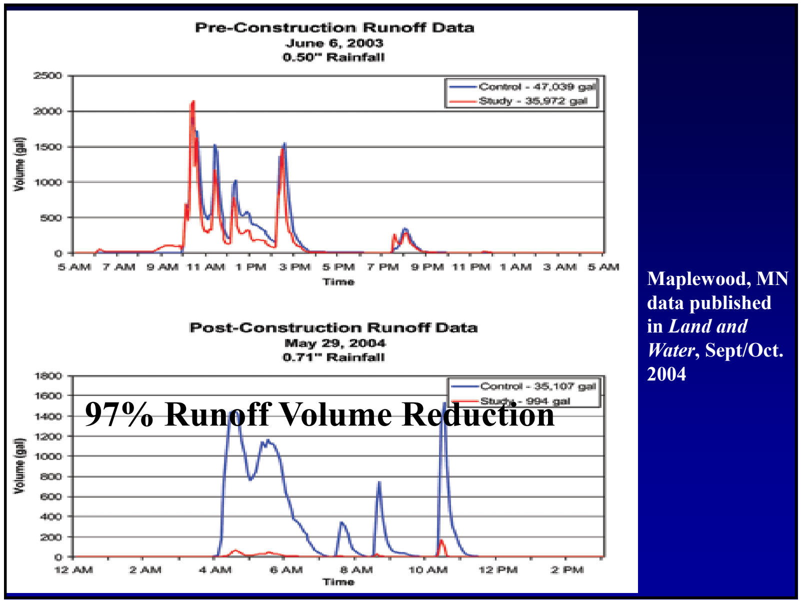
☐ Rooftop 1
☑ Rooftop 2
☐ Rooftop 3
☐ Rooftop 4
☐ Rooftop 5
☐ Paved Parking/Storage 1
☐ Paved Parking/Storage 2
☐ Paved Parking/Storage 3
☐ Unpaved Prkng/Storage 1
☐ Unpaved Prkng/Storage 2
☐ Playground 1
☐ Playground 2
☑ Driveways 1
☑ Driveways 2
☐ Driveways 3
☑ Sidewalks/Walks 1
☐ Sidewalks/Walks 2
☐ Street Area 1
☐ Street Area 2
☐ Street Area 3
☐ Paved Land and Shoulder 1
☐ Paved Land and Shoulder 2
☐ Paved Land and Shoulder 3
☐ Paved Land and Shoulder 4
☐ Paved Land and Shoulder 5
☐ Large Landscaped Area 1
☐ Large Landscaped Area 2
☐ Undeveloped Area
☑ Small Landscaped Area 1
☐ Small Landscaped Area 2
☐ Small Landscaped Area 3
☐ Other Pervious Area
☐ Other Dir Cnctd Imp Area
☐ Other Part Cnctd Imp Area
☐ Large Turf Areas
☐ Undeveloped Areas
☐ Other Pervious Areas
☐ Other Directly Conctd Imp
☐ Other Partially Conctd Imp

1 Fraction of Runoff From Selected Source Areas Routed to Land Use Biofilters (0 - 1)

Biofilter for highway runoff, Lodi, WI

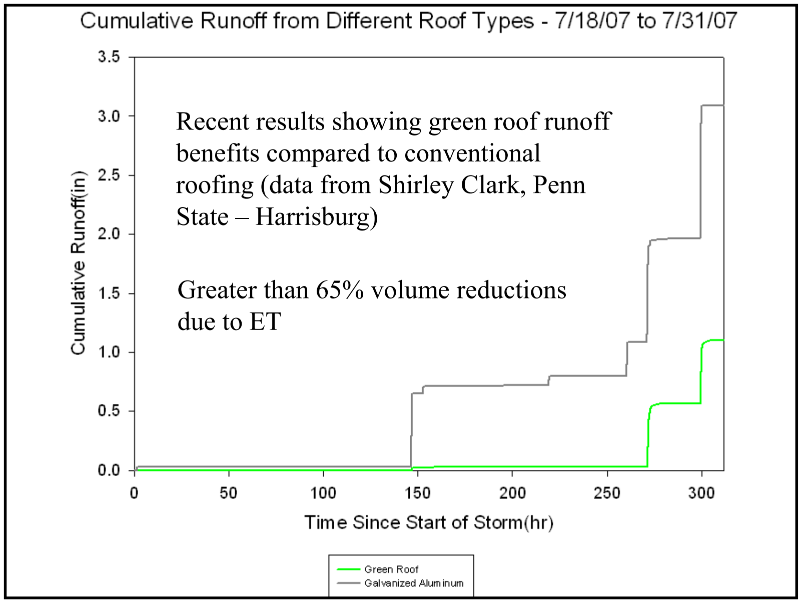
Biofilter for employee parking lot at industrial facility, WI (part of a treatment train that also uses wet pond with lamella separator pretreatment units in manufacturing area)

## Rain Garden Designed for Complete Infiltration of Roof Runoff



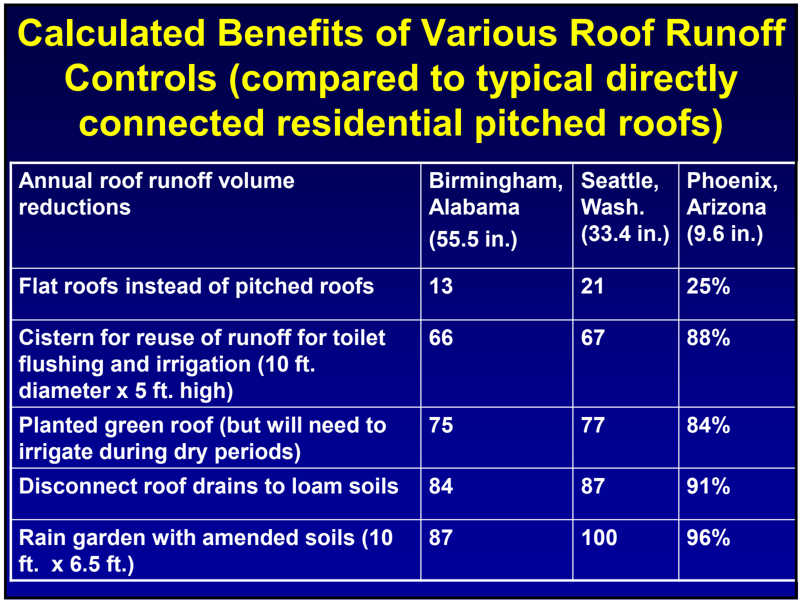
97% Runoff Volume Reduction

Maplewood, MN data published in *Land and Water*, Sept/Oct. 2004



Recent results showing green roof runoff benefits compared to conventional roofing (data from Shirley Clark, Penn State – Harrisburg)

Greater than 65% volume reductions due to ET



## Calculated Benefits of Various Roof Runoff Controls (compared to typical directly connected residential pitched roofs)

| Annual roof runoff volume reductions | Birmingham, Alabama (55.5 in.) | Seattle, Wash. (33.4 in.) | Phoenix, Arizona (9.6 in.) |
|---|---|---|---|
| Flat roofs instead of pitched roofs | 13 | 21 | 25% |
| Cistern for reuse of runoff for toilet flushing and irrigation (10 ft. diameter x 5 ft. high) | 66 | 67 | 88% |
| Planted green roof (but will need to irrigate during dry periods) | 75 | 77 | 84% |
| Disconnect roof drains to loam soils | 84 | 87 | 91% |
| Rain garden with amended soils (10 ft. x 6.5 ft.) | 87 | 100 | 96% |

## Soil Modifications for rain gardens and other biofiltration areas can significantly increase treatment and infiltration capacity compared to native soils.

Rob Harrison ,Univ. of Wash., and Bob Pitt, Univ. of Alabama examined the benefits of adding large amounts of compost to glacial till soils at the time of land development (4” of compost for 8” of soil)

## Enhanced Infiltration with Amendments

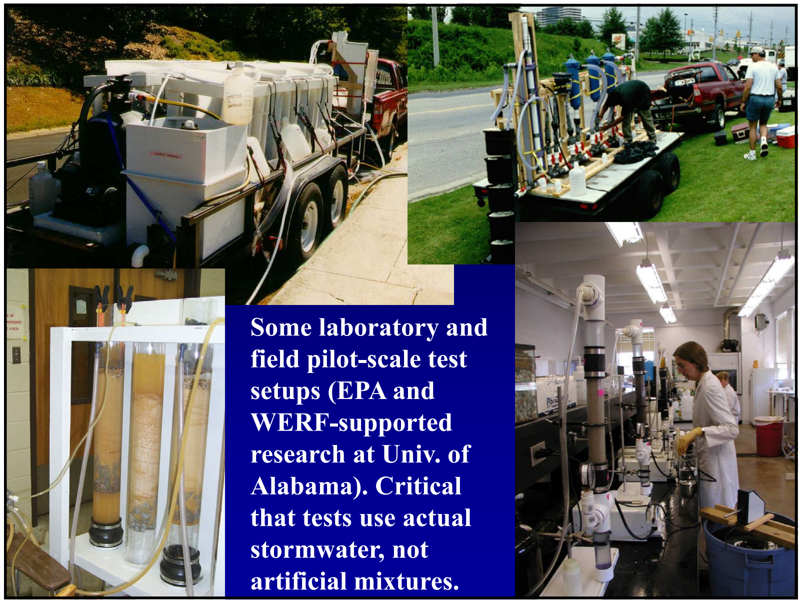
| | Average Infiltration Rate (in/h) |
|---|---|
| UW test plot 1 Alderwood soil alone | 0.5 |
| UW test plot 2 Alderwood soil with Ceder Grove compost (old site) | 3.0 |
| UW test plot 5 Alderwood soil alone | 0.3 |
| UW test plot 6 Alderwood soil with GroCo compost (old site) | 3.3 |

Six to eleven times increased infiltration rates using compost-amended soils measured during long-term tests using large test plots and actual rains (these plots were 3 years old).

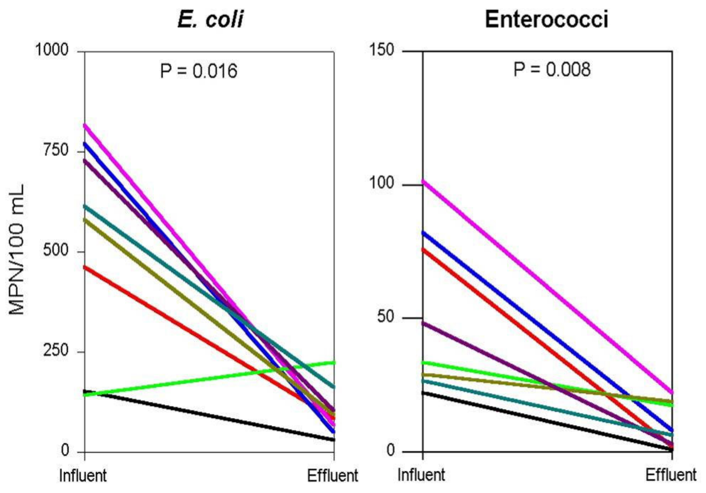
## Changes in Mass Discharges for Plots having Amended Soil Compared to Unamended Soil

| Constituent | Surface Runoff Mass Discharges | Subsurface Flow Mass Discharges |
|---|---|---|
| Runoff Volume | 0.09 | 0.29 (due to ET) |
| Phosphate | 0.62 | 3.0 |
| Ammonia | 0.56 | 4.4 |
| Nitrate | 0.28 | 1.5 |
| Copper | 0.33 | 1.2 |
| Zinc | 0.061 | 0.18 |

Increased mass discharges in subsurface water pollutants observed for many constituents (new plots).



Some laboratory and field pilot-scale test setups (EPA and WERF-supported research at Univ. of Alabama). Critical that tests use actual stormwater, not artificial mixtures.



PEAT-SAND FILTER: Pilot-Scale Testing, Fall 1999

## Capture of Stormwater Particulates by Different Soils and Filtering Media

### (moderate influent SSC of about 100 mg/L)

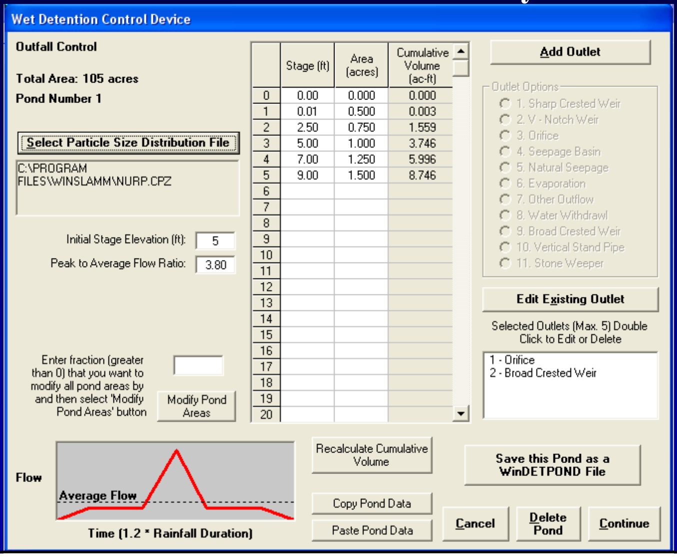
| | 0.45 to 3µm | 3 to 12µm | 12 to 30µm | 30 to 60µm | 60 to 120µm | 120 to 250µm | >250 µm |
|---|---|---|---|---|---|---|---|
| Porous pavement surface (asphalt or concrete) | 0% | 0% | 0% | 10% | 25% | 50% | 100% |
| Coarse gravel | 0% | 0% | 0% | 0% | 0% | 0% | 10% |
| Fine sand | 10% | 33% | 85% | 90% | 100% | 100% | 100% |
| Loam soil | 0% | 0% | 0% | 0% | 25% | 50% | 100% |
| Activated carbon, peat, and fine sand | 40% | 45% | 80% | 100% | 100% | 100% | 100% |

## Wet Detention Ponds

Typical Wet Pond Performance Reported in Literature

- Suspended solids: 70-95%
- COD: 60-70%
- BOD5: 35-70%
- Total Kjeldahl Nitrogen: 25-60%
- Total Phosphorus: 35-85%
- Bacteria: 50-95%
- Copper: 60-95%
- Lead: 60-95%
- Zinc: 60-95%

## Wet Detention Pond Data Entry Form



Wet Detention Control Device

**Outfall Control**

**Total Area: 105 acres**

**Pond Number 1**

C:\PROGRAM FILES\WINSLAMM\NURP.CPZ

Initial Stage Elevation (ft): 5

Peak to Average Flow Ratio: 3.80

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

| | Stage (ft) | Area (acres) | Cumulative Volume (ac-ft) |
|---|---|---|---|
| 0 | 0.00 | 0.000 | 0.000 |
| 1 | 0.01 | 0.500 | 0.003 |
| 2 | 2.50 | 0.750 | 1.559 |
| 3 | 5.00 | 1.000 | 3.746 |
| 4 | 7.00 | 1.250 | 5.996 |
| 5 | 9.00 | 1.500 | 8.746 |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |

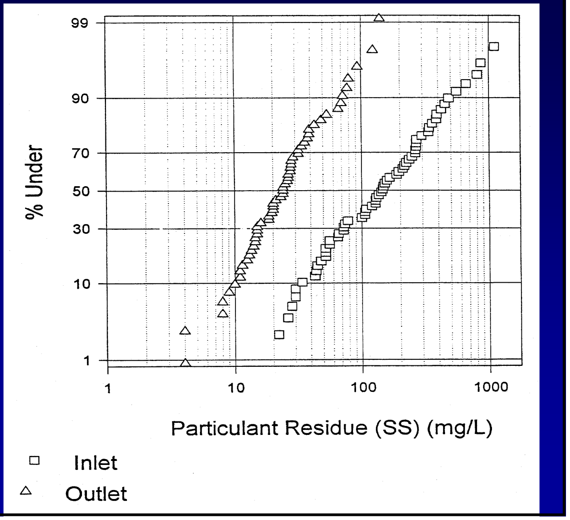
Outlet Options
- ○ 1. Sharp Crested Weir
- ○ 2. V - Notch Weir
- ○ 3. Orifice
- ○ 4. Seepage Basin
- ○ 5. Natural Seepage
- ○ 6. Evaporation
- ○ 7. Other Outflow
- ○ 8. Water Withdrawl
- ○ 9. Broad Crested Weir
- ○ 10. Vertical Stand Pipe
- ○ 11. Stone Weeper

Selected Outlets (Max. 5) Double Click to Edit or Delete

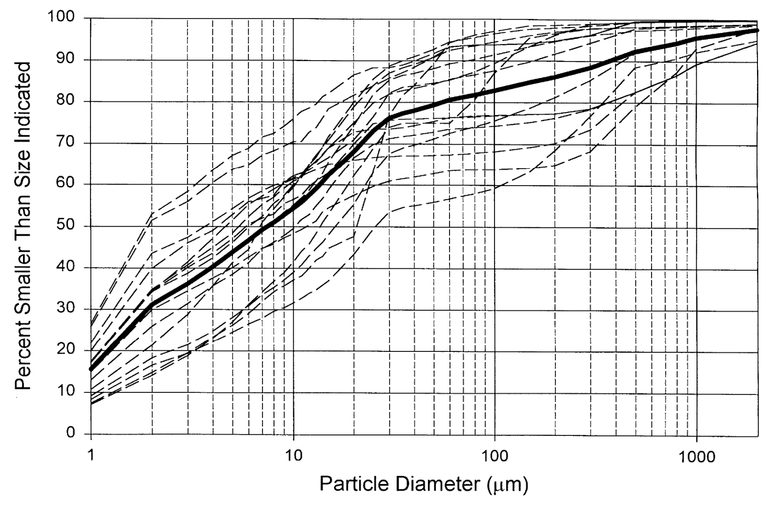
1 - Orifice
2 - Broad Crested Weir

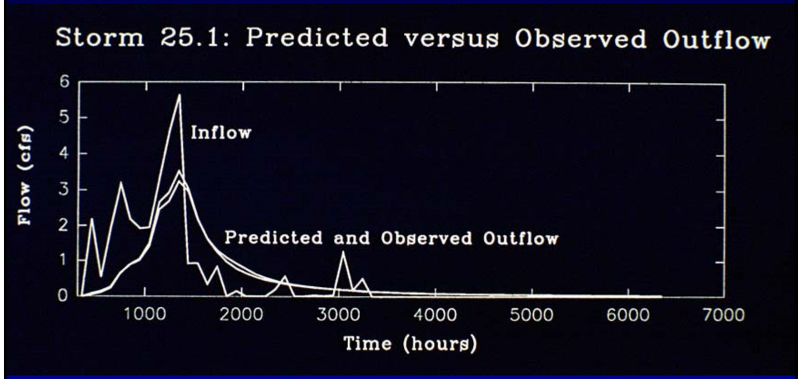
## Suspended Solids Control at Monroe St. Detention Pond, Madison, WI (USGS and WI DNR data)

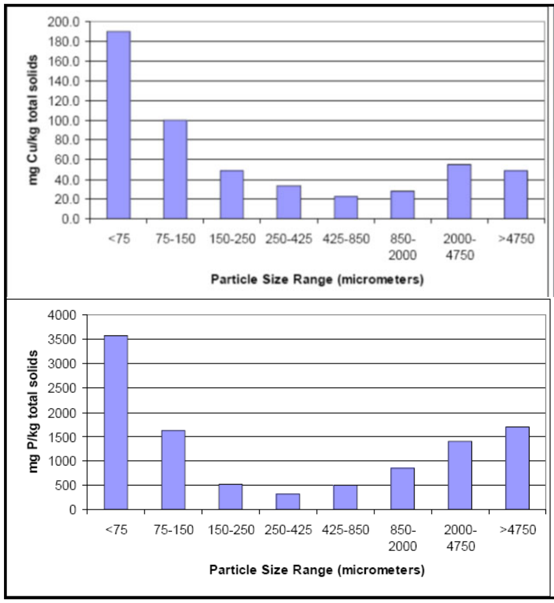
Consistently high TSS removals for all influent concentrations (but better at higher concentrations, as expected)



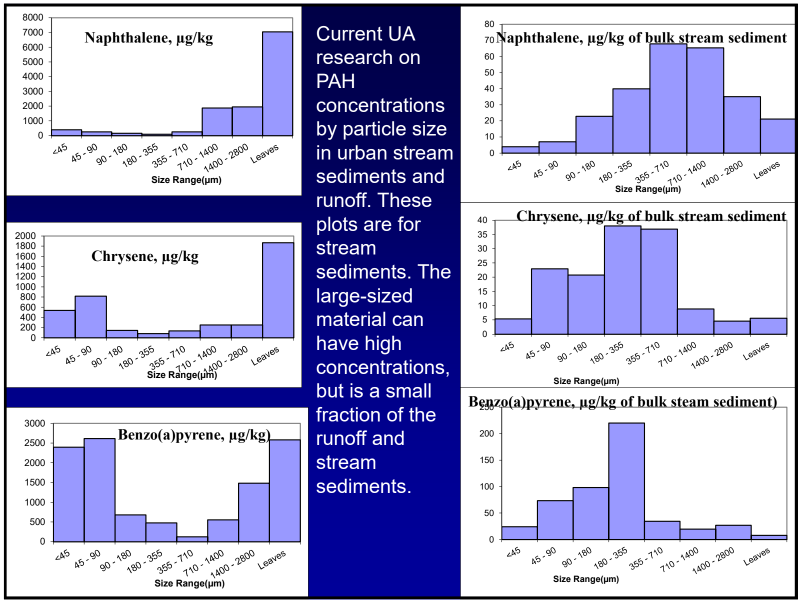
## Measured Particle Sizes, Including Bed Load Component, at Monroe St. Detention Pond, Madison, WI



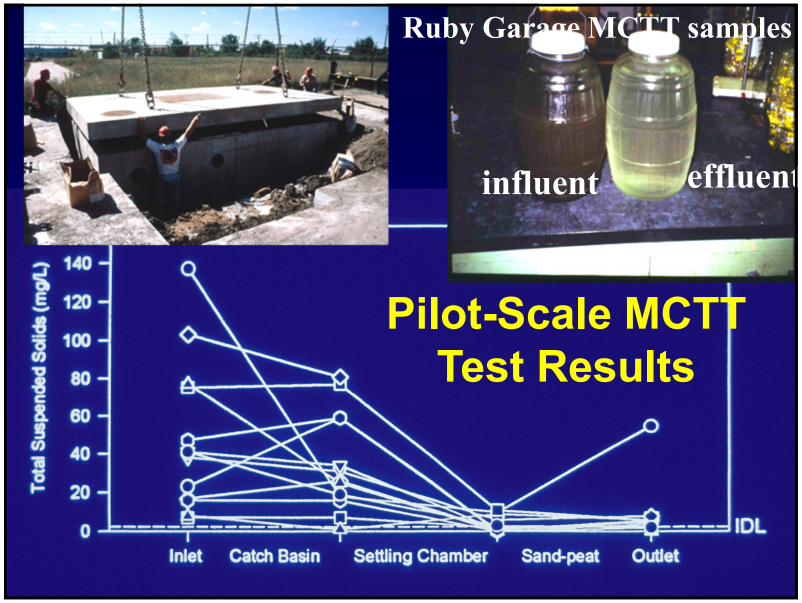




Example copper and phosphorus concentrations as a function of particle size, showing typically higher concentrations with smaller particles

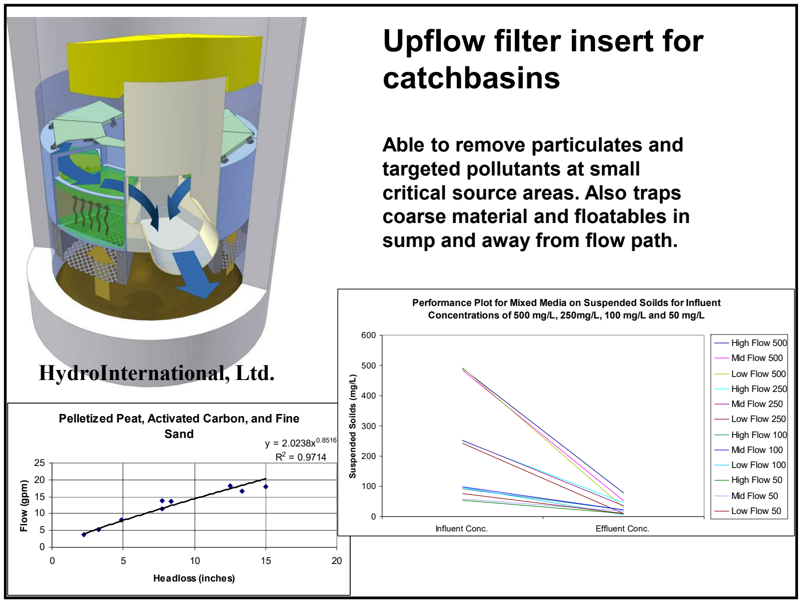


Current UA research on PAH concentrations by particle size in urban stream sediments and runoff. These plots are for stream sediments. The large-sized material can have high concentrations, but is a small fraction of the runoff and stream sediments.



## Pilot-Scale MCTT Test Results

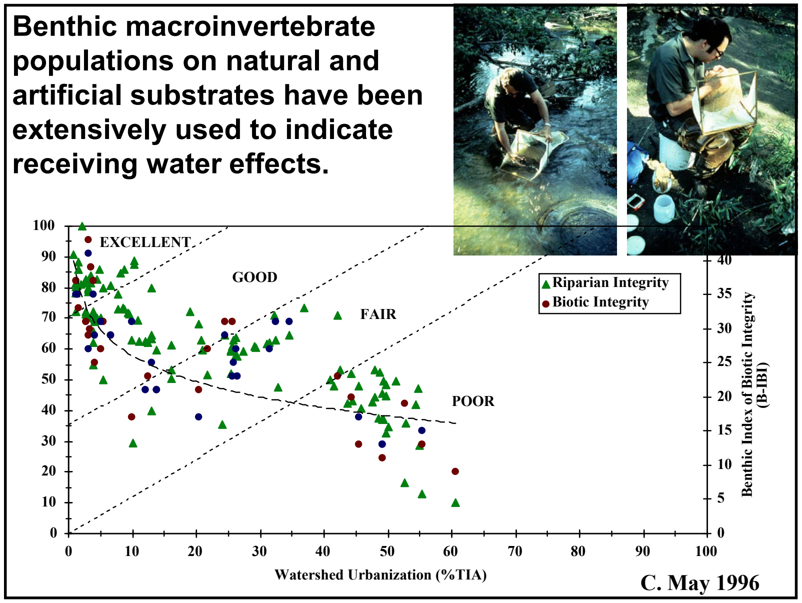
Ruby Garage MCTT samples



## Upflow filter insert for catchbasins

Able to remove particulates and targeted pollutants at small critical source areas. Also traps coarse material and floatables in sump and away from flow path.

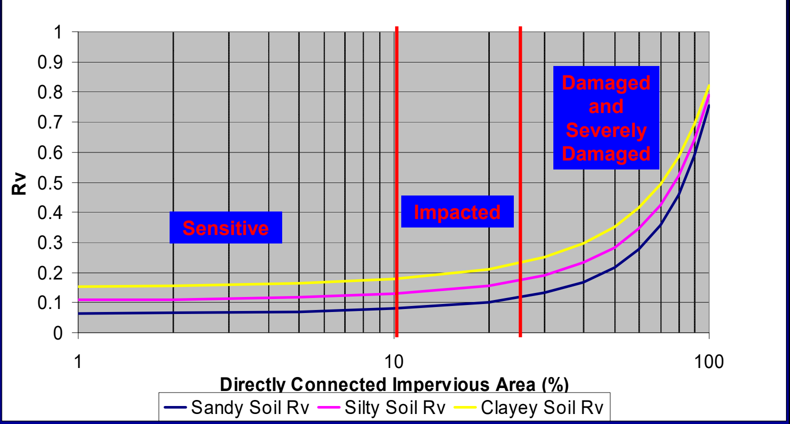
HydroInternational, Ltd.



Benthic macroinvertebrate populations on natural and artificial substrates have been extensively used to indicate receiving water effects.

C. May 1996

## Volumetric Runoff Coefficients and Expected Urban Stream Classification



Based on modeling several hundred neighborhoods representing many land uses in Jefferson Co, AL. Can now calculate the expected effects and magnitude of needed changes to achieve targeted conditions.

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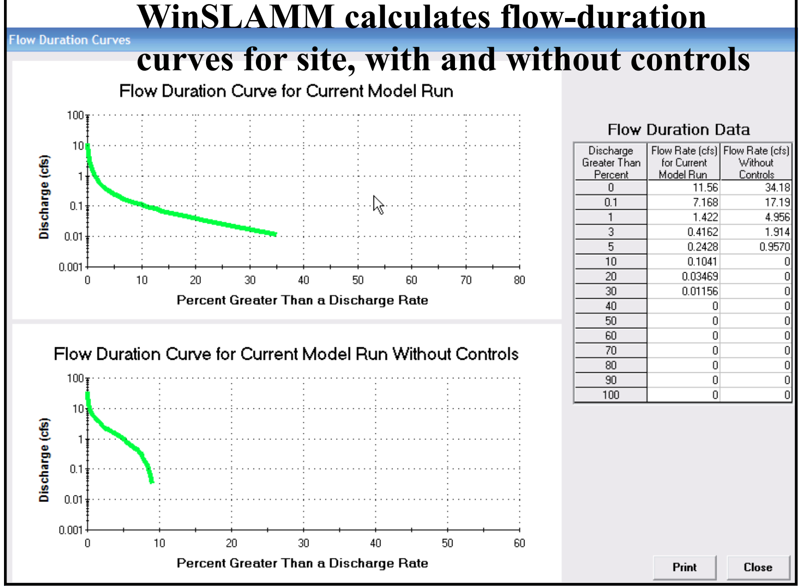
## WinSLAMM calculates flow-duration curves for site, with and without controls



Flow Duration Data

| Discharge Greater Than Percent | Flow Rate (cfs) for Current Model Run | Flow Rate (cfs) Without Controls |
|---|---|---|
| 0 | 11.56 | 34.18 |
| 0.1 | 7.168 | 17.19 |
| 1 | 1.422 | 4.956 |
| 3 | 0.4162 | 1.914 |
| 5 | 0.2428 | 0.9570 |
| 10 | 0.1041 | 0 |
| 20 | 0.03469 | 0 |
| 30 | 0.01156 | 0 |
| 40 | 0 | 0 |
| 50 | 0 | 0 |
| 60 | 0 | 0 |
| 70 | 0 | 0 |
| 80 | 0 | 0 |
| 90 | 0 | 0 |
| 100 | 0 | 0 |

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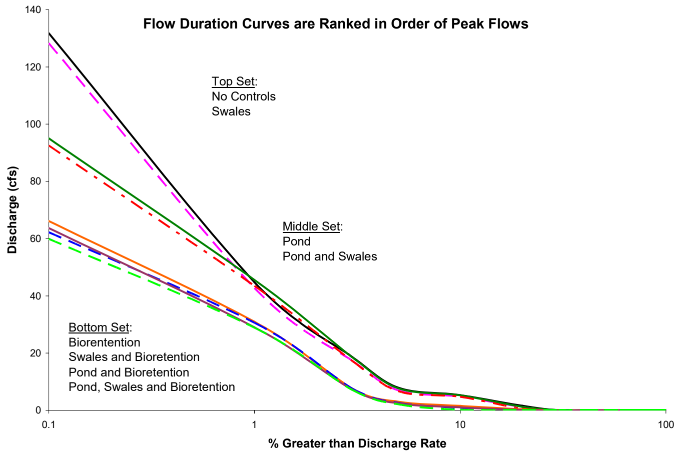
## Flow-Duration Curves for Different Stormwater Conservation Design Practices



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## Appropriate Combinations of Controls

- No single control is adequate for all problems
- Only infiltration reduces water flows, along with soluble and particulate pollutants. Only applicable in conditions having minimal groundwater contamination potential.
- Wet detention ponds reduce particulate pollutants and may help control dry weather flows. They do not consistently reduce concentrations of soluble pollutants, nor do they generally solve regional drainage and flooding problems.
- A combination of bioretention and sedimentation practices is usually needed, at both critical source areas and at critical outfalls.