“Low Impact Development” Calculations using the Source Loading and Management Model (WinSLAMM)

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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 results in the 1970s did not conform to typical stormwater assumptions (especially rainfall-runoff relationships and sources of pollutants; way before we had long lists of control practices too!).
- Initial versions of the model therefore focused on site hydrology and particulate sources and transport (and public works practices). Other control practices added as they were developed and data become available.

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Stormwater Infiltration Controls Included in WinSLAMM

- Bioretention/biofiltration areas
- Rain gardens
- Porous pavement
- Grass swales and grass filters
- Infiltration basins
- Infiltration trenches
- Green (and blue) roofs
- Disconnections of paved areas and roofs from the drainage system
- Also considers evapotranspiration and stormwater beneficial uses

“SEA” (Street Edge Alternative) Street, Seattle, WA

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Grass Swales

Hybrid grass swales in Cross Plains, WI

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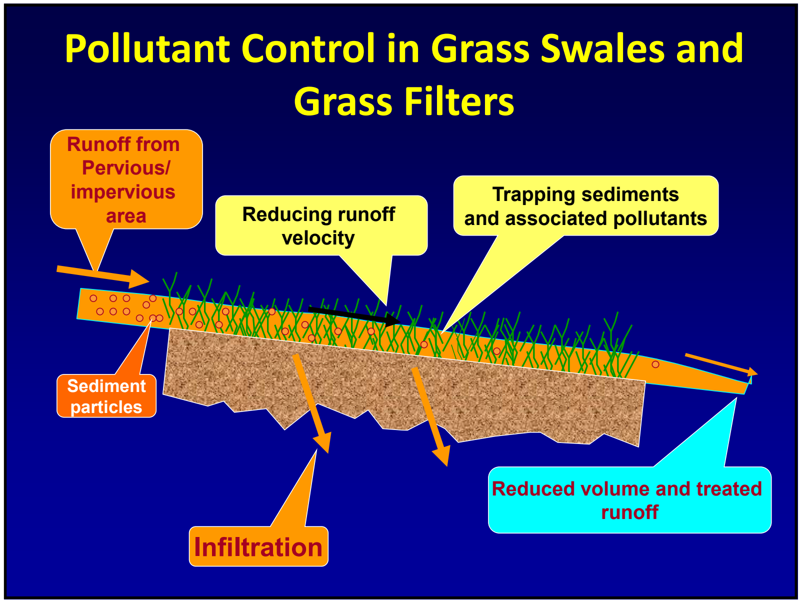

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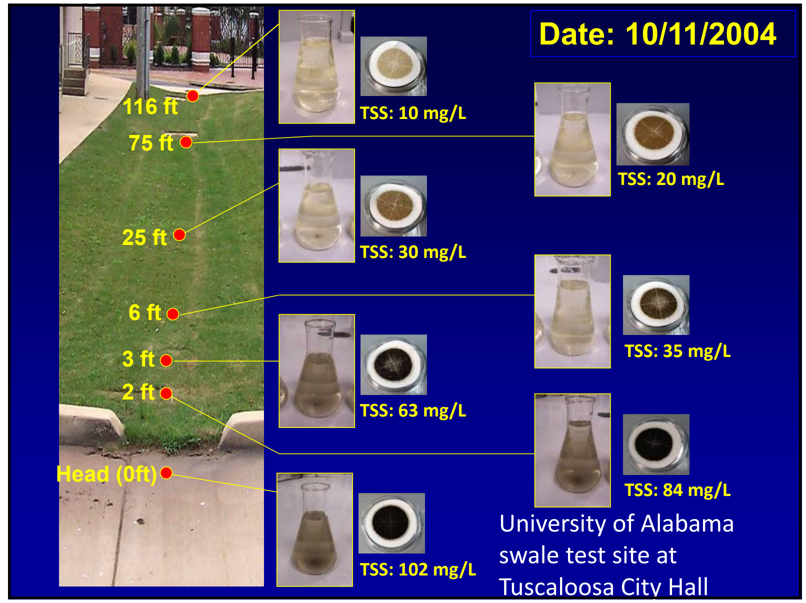

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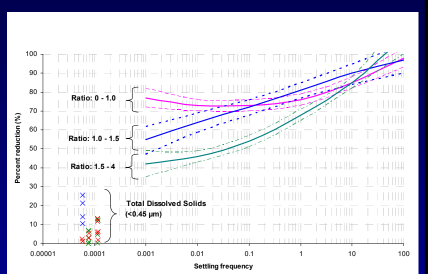
Particulate Removal Calculations

For each time step -

- Calculate flow velocity, settling velocity and flow depth
- Determine flow depth to grass height, for particulate reduction for each particle size increment using Nara & Pitt research



- Check particle size group limits
  - Not exceed irreducible concentration value by particle size
- Scour adjustment by
  - Flow velocity
  - Impervious area

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WinSLAMM Road Swale Description:

Grass Swales

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)		43.20					
Area Served by Swales (ac)		43.20					
Swale Density (ft/ac)		230.00					
Total Swale Length (ft)		9936					
Average Swale Length to Outlet (ft)		2058					
Typical Bottom Width (ft)		3.0					
Typical Swale Side Slope (__ ft H : 1 ft V)		3.0					
Typical Longitudinal Slope (ft/ft, V/H)		0.040					
Swale Retardance Factor		D					
Typical Grass Height (in)		4.0					
Swale Dynamic Infiltration Rate (in/hr)		0.250					
Typical Swale Depth (ft) for Cost Analysis (Optional)		1.0					

☐ Use One Swale System For All Land Uses

Total area served by swales (acres): 43.20
Total area (acres): 43.20

Select Critical Particle Size File

Particle Size Distribution File Data Grid

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

Apply the Residential Land Use Particle Size File to All Active Land Uses

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

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

Delete | Cancel | Continue

8

Porous Pavement

- Use for walkways and overflow parking areas, and service roads (alleys); not used in areas of material storage or for extensive parking or traffic to minimize groundwater contamination potential.

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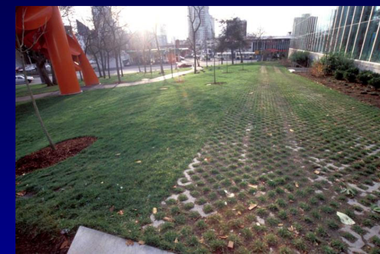
Temporary parking or access roads supported by geogrids, turf meshes, or paver blocks



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Recommendations to Reduce Groundwater Contamination Potential when using Infiltration in Urban Areas

- Infiltration devices should not be used in most industrial areas without adequate pretreatment.
- Runoff from critical source areas (mostly in commercial areas) need to receive adequate pretreatment prior to infiltration.
- Runoff from residential areas (the largest component of urban runoff in most cities) is generally the least polluted and should be considered for infiltration.

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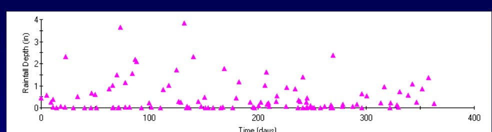
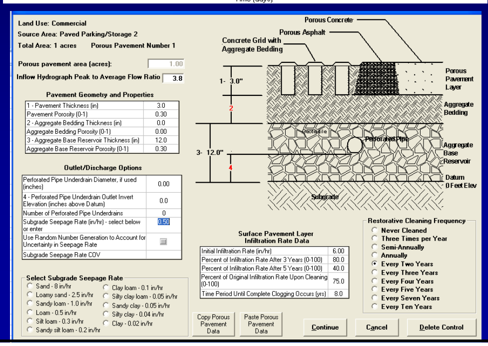
Continuous Simulations of Porous Pavement Installations using the 1976 Birmingham rain record (a typical rain period)

About 100 rains, 55 inches total, maximum rain depths of about 4 inches.



Input screen of the Source Loading and Management Model (WinSLAMM) for porous pavement



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Modeling Findings for Porous Pavements in Central Alabama Area

- Soils having at least 0.1 in/hr infiltration rates can totally remove the runoff from porous pavement areas, assuming about 1 ft coarse rock storage layer. Porous pavement areas can effectively contribute zero runoff, if well maintained.
- However, slow infiltrating soils can result in slow drainage times of several days. Soils having infiltration rates of at least 0.5 in/hr can drain the pavement structure and storage area within a day, a generally accepted goal.
- These porous pavements can totally reduce the runoff during the intense 2-year rains.
- Good design and construction practice is necessary to prolong the life of the porous pavements, including restricting runon, prohibiting dirt and debris tracking, and suitable intensive cleaning.

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Green Roofs

- Green roofs can contribute to energy savings in operation of a building, can prolong the life of the roof structure, and can reduce the amount of roof runoff.
- They can be costly. However, they may be one of the few options for stormwater volume control in ultra urban areas where ground–level options are not available.
- Irrigation of the plants is likely necessary to prevent wilting and death during dry periods.

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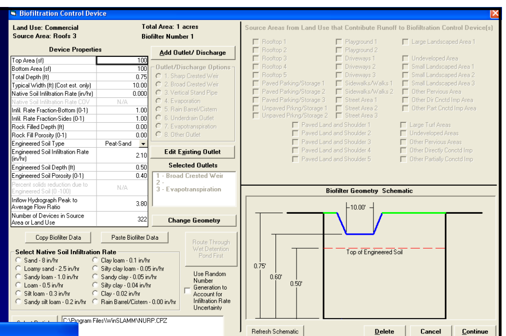
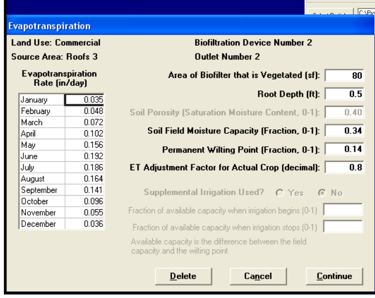
Continuous simulations were also conducted for green roofs and Birmingham conditions, using WinSLAMM





The main roof runoff removal mechanism for green roofs is evapotranspiration. These are central Alabama monthly ET values and the plant and substrate characteristics used in these analyses.

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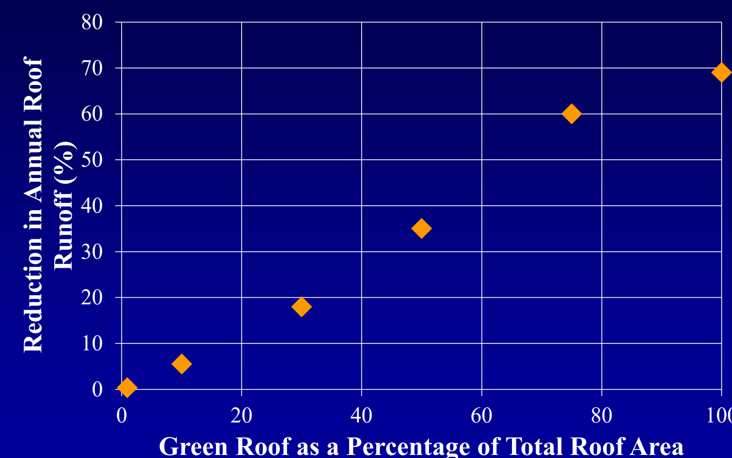
Annual Roof Runoff Reductions for Local Green Roofs



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Rain Gardens for Roof and Paved Area Runoff

- Simple rain gardens with extensive excavations or underdrains can be used near buildings for the control of roof runoff, or can be placed in or around the edges of parking areas for the control of runoff from parking areas.
- Rain gardens provide greater groundwater contamination protection compared to porous pavements as the engineered soil fill material should contain significant organic material that hinders migration of many stormwater pollutants. This material also provides much better control of fine sediment found in the stormwater.
- Rain gardens can be sized to control large fractions of the runoff, but maintenance to prevent clogging and to remove contaminated soils is also necessary.

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Different types of rain gardens for a residential roof, a commercial parking lot, and a curb-cut biofilter.

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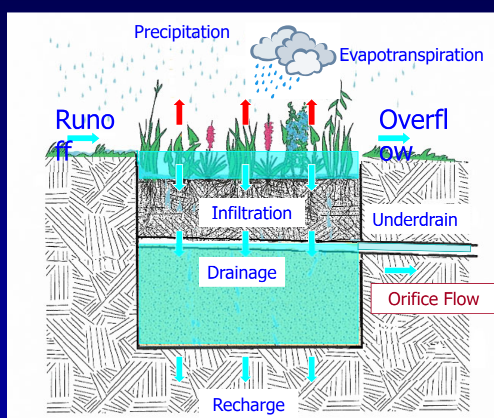
Biofiltration/Infiltration



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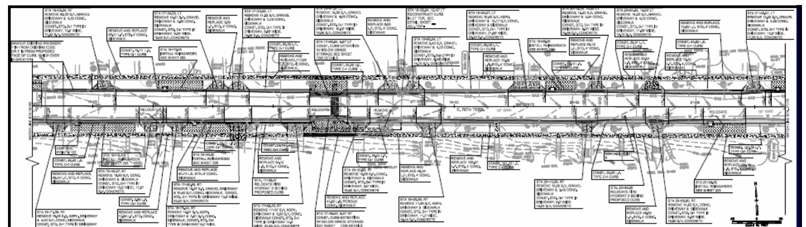
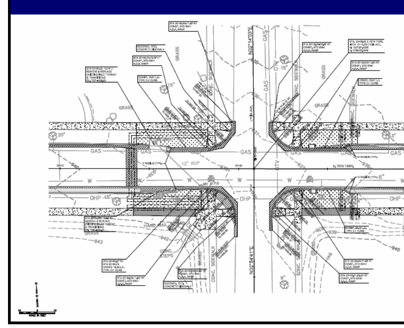
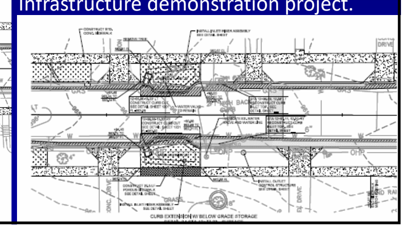


Examples from "65%" plans prepared by URS for project streets. Plans reviewed and modeled by project team, and construction will occur in spring and summer of 2011 in Kansas City for Green Infrastructure demonstration project.





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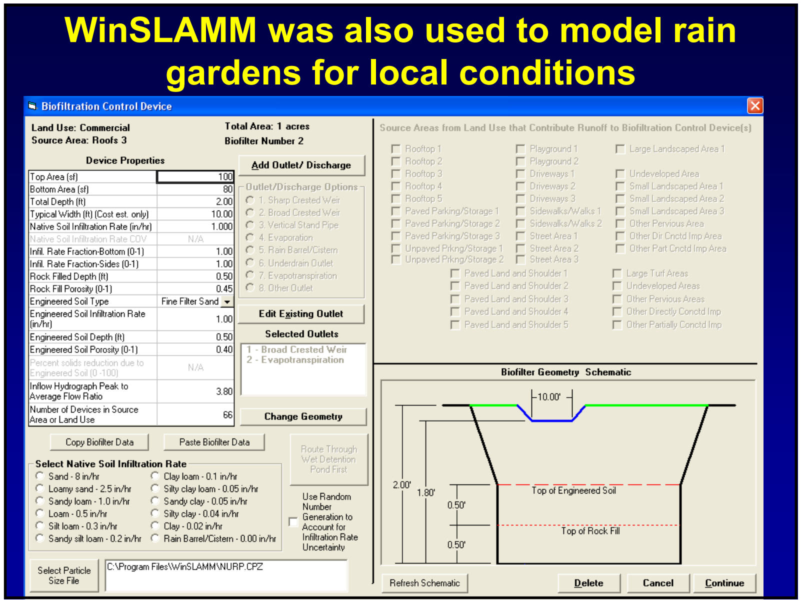
WinSLAMM was also used to model rain gardens for local conditions
Biofiltration Control Device
Land Use: Commercial
Source Area: Roofs 3
Total Area: 1 acres
Biofilter Number 2
Device Properties
Add Outlet/ Discharge
Top Area (sf) 100
Bottom Area (sf) 80
Total Depth (ft) 2.00
Typical Width (ft) (Cost est. only) 10.00
Native Soil Infiltration Rate (in/hr) 1.000
Infil. Rate Fraction-Bottom (0-1) 1.00
Infil. Rate Fraction-Sides (0-1) 1.00
Rock Filled Depth (ft) 0.50
Rock Fill Porosity (0-1) 0.45
Engineered Soil Type Fine Filter Sand
Engineered Soil Infiltration Rate (in/hr) 1.00
Engineered Soil Depth (ft) 0.50
Engineered Soil Porosity (0-1) 0.40
Inflow Hydrograph Peak to Average Flow Ratio 3.80
Number of Devices in Source Area or Land Use 66
Edit Existing Outlet
Selected Outlets
1 - Broad Crested Weir
2 - Evapotranspiration
Change Geometry
Copy Biofilter Data
Paste Biofilter Data
Select Native Soil Infiltration 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
Use Random Number Generation to Account for Infiltration Rate Uncertainty
Select Particle Size File
C:\Program Files\WinSLAMM\NURP.CPZ
Source Areas from Land Use that Contribute Runoff to Biofiltration Control Device(s)
Biofilter Geometry Schematic
10.00'
2.00'
1.80'
0.50'
0.50'
Top of Engineered Soil
Top of Rock Fill
Refresh Schematic
Delete
Cancel
Continue

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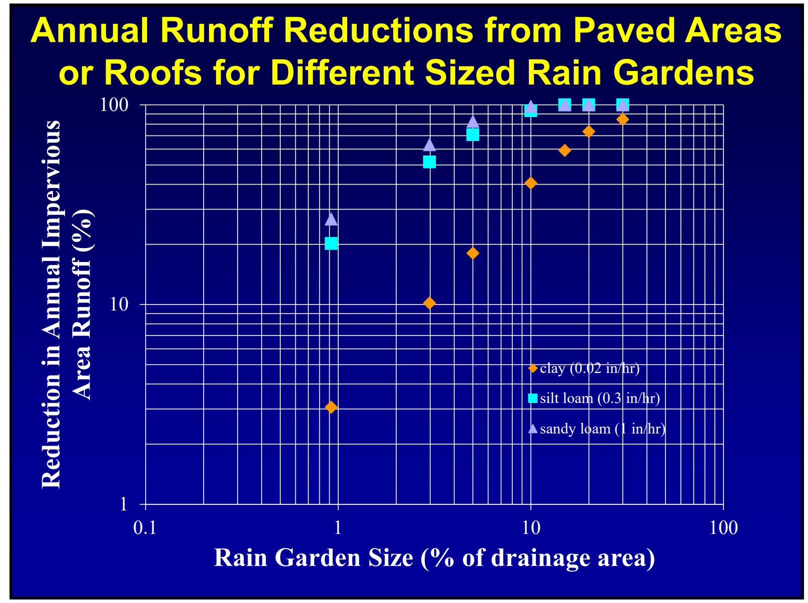
Annual Runoff Reductions from Paved Areas or Roofs for Different Sized Rain Gardens
Reduction in Annual Impervious Area Runoff (%)
100
10
1
0.1
1
10
100
Rain Garden Size (% of drainage area)
clay (0.02 in/hr)
silt loam (0.3 in/hr)
sandy loam (1 in/hr)

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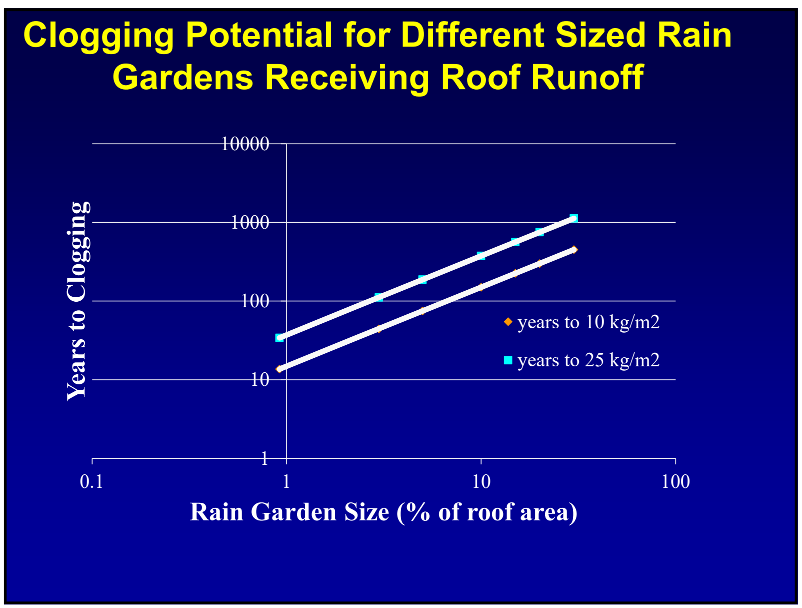
Clogging Potential for Different Sized Rain Gardens Receiving Roof Runoff
Years to Clogging
10000
1000
100
10
1
0.1
1
10
100
Rain Garden Size (% of roof area)
years to 10 kg/m2
years to 25 kg/m2

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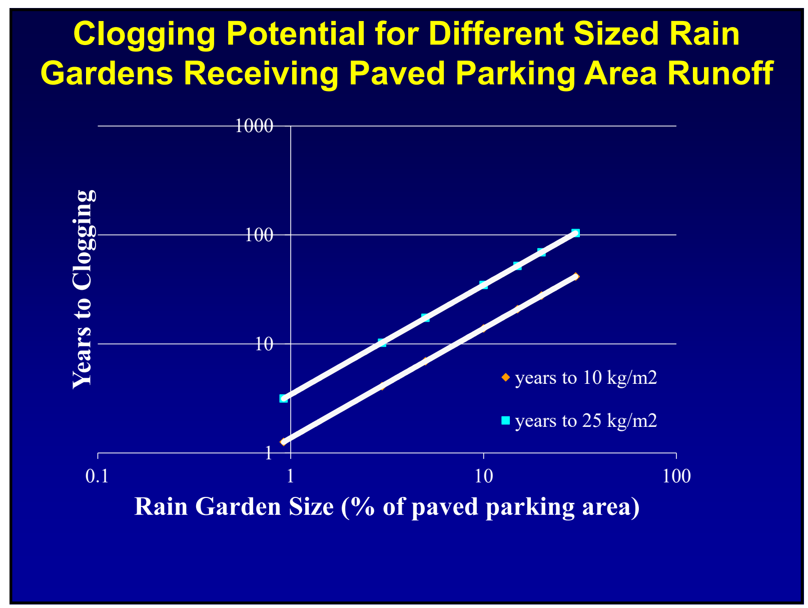
Clogging Potential for Different Sized Rain Gardens Receiving Paved Parking Area Runoff
Years to Clogging
1000
100
10
1
0.1
1
10
100
Rain Garden Size (% of paved parking area)
years to 10 kg/m2
years to 25 kg/m2

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Results from Modeling Local Rain Gardens

- Local rain gardens should be located in areas having soil infiltration rates of at least 0.3 in/hr. Lower rates result in very large and much less effective rain gardens, and the likely clay content of the soil likely will result in premature clogging.
- Rain gardens should be from 5 to 10 percent of the drainage area to provide significant runoff reductions (75+%).
- Rain gardens of this size will result in about 40 to 60% reductions in runoff volume from the large 4 inch rain. Rain gardens would need to be about 20% of the drainage area in order to approach complete control of these large rains.

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Rain Garden Results (cont.)

- Clogging of the rain garden may occur from particulates entering the device, or from clay in the engineered soil mix.
- Roof runoff contains relatively little particulate matter and rain gardens at least 1% of the roof area are not likely to clog (estimated 20 to 50 years).
- Paved area runoff contains a much greater amount of particulate matter and would need to be at least 10% of the paved area to have an extended life (>10 years).

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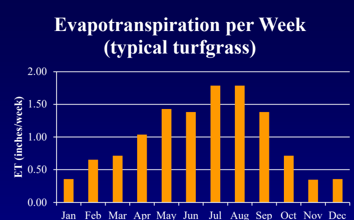
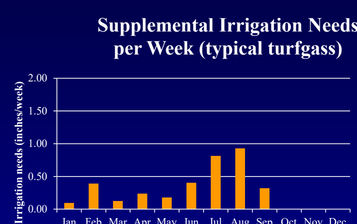
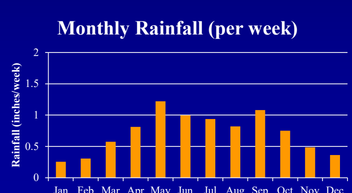
Water Harvesting Potential of Roof Runoff







Irrigation needs for the landscaped areas surrounding the homes were calculated by subtracting long-term monthly rainfall from the regional evapotranspiration demands for turf grass.

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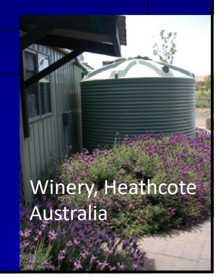
Household water use (gallons/day/house) from rain barrels or water tanks for outside irrigation to meet ET requirements:

January	42	July	357
February	172	August	408
March	55	September	140
April	104	October	0
May	78	November	0
June	177	December	0

Warrabungles National Park Australia

Siding Springs Observatory, Australia



Winery, Heathcote Australia

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Water Use Calculations in WinSLAMM

WinSLAMM conducts a continuous water mass balance for every storm in the study period.

For rain barrels/tanks, the model fills the tanks during rains (up to the maximum amount of runoff from the roofs, or to the maximum available volume of the tank).

Between rains, the tank is drained according to the water demand rate. If the tank is almost full from a recent rain (and not enough time was available to use all of the water in the tank), excess water from the event would be discharged to the ground or rain gardens after the tank fills.

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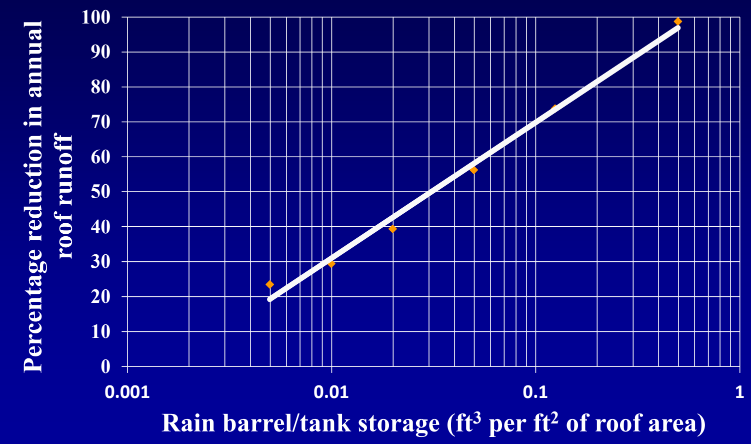
Reductions in Annual Flow Quantity from Directly Connected Roofs with the use of Rain Barrels and Water Tanks (Kansas City CSO Study Area)



30

0.125 ft of storage is needed for use of 75% of the total annual runoff from these roofs for irrigation. With 945 ft^2 roofs, the total storage is therefore 118 ft^3, which would require 25 typical rain barrels, way too many! However, a relatively small water tank (5 ft D and 6 ft H) can be used instead.

rain barrel/tank storage per house (ft^3)	percentage reduction in annual roof runoff	# of 35 gallon rain barrels	tank height size required if 5 ft D (ft)	tank height size required if 10 ft D (ft)
0	0	0	0	0
4.7	20	1	0.24	0.060
9.4	31	2	0.45	0.12
19	43	4	0.96	0.24
47	58	10	2.4	0.60
118	75	25	6.0	1.5
470	98	100	24	6.0

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On-going Millburn, NJ, Monitoring Project to Evaluate Performance and Groundwater Problems Associated with Required Dry Wells

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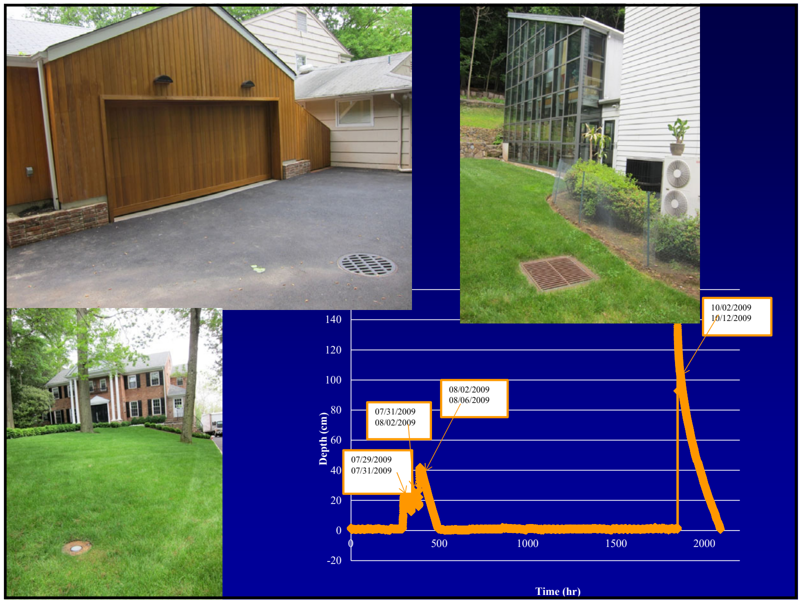

33


Home restoration using underground water storage tanks for landscaping irrigation instead of dry wells


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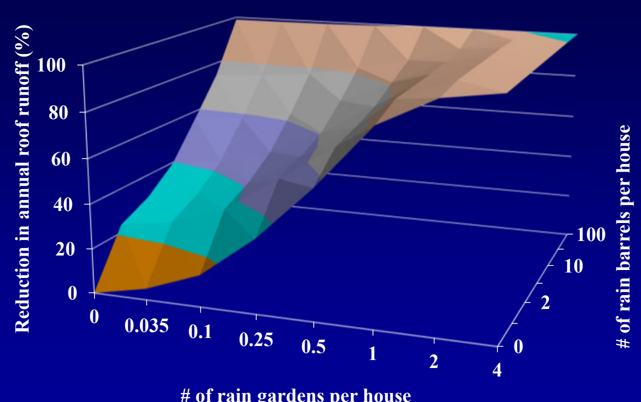
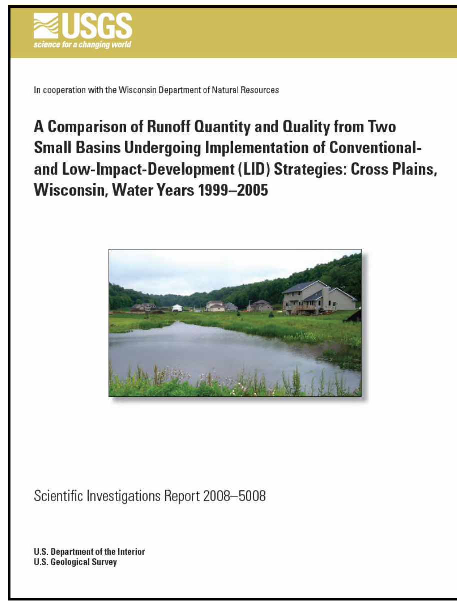
Interaction Benefits of Rain Barrels and Rain Gardens in the Kansas City CSO Study Area



Two 35 gal. rain barrels plus one 160 ft^2 rain garden per house can reduce the total annual runoff quantity from directly connected roofs by about 90%

35


USGS
science for a changing world

In cooperation with the Wisconsin Department of Natural Resources

A Comparison of Runoff Quantity and Quality from Two Small Basins Undergoing Implementation of Conventional- and Low-Impact-Development (LID) Strategies: Cross Plains, Wisconsin, Water Years 1999–2005

Scientific Investigations Report 2008–5008

U.S. Department of the Interior
U.S. Geological Survey

One of the most comprehensive full-scale studies comparing advanced stormwater controls available.

Available at: http://pubs.usgs.gov/sir/2008/5008/pdf/sir_2008-5008.pdf

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Parallel study areas, comparing test with control site

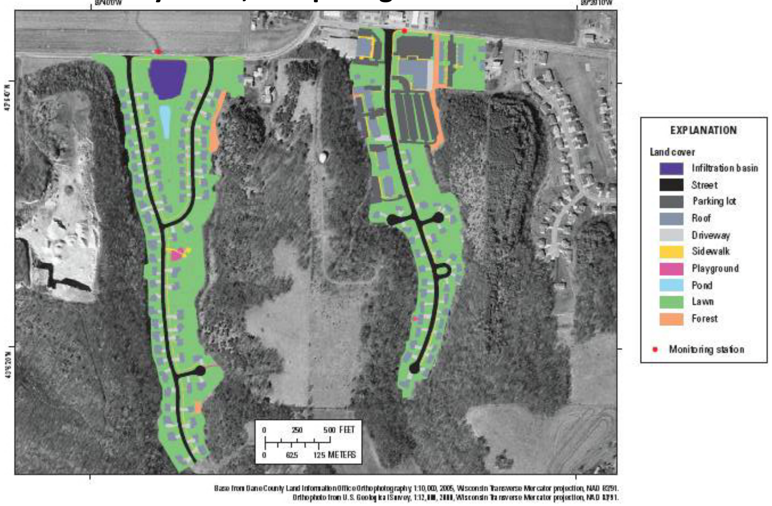

Figure 2. Land use in the low-impact-development (left) and conventional-development (right) basins and location of water-quality monitoring stations, Cross Plains, Wis.

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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 15% increase over pre-development

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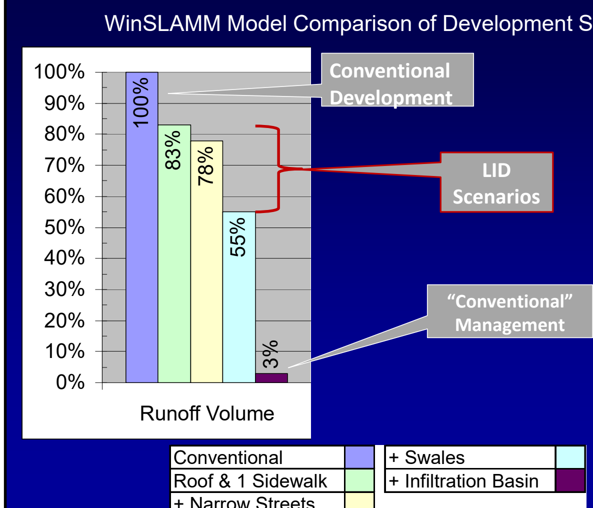
WinSLAMM Modeling Results



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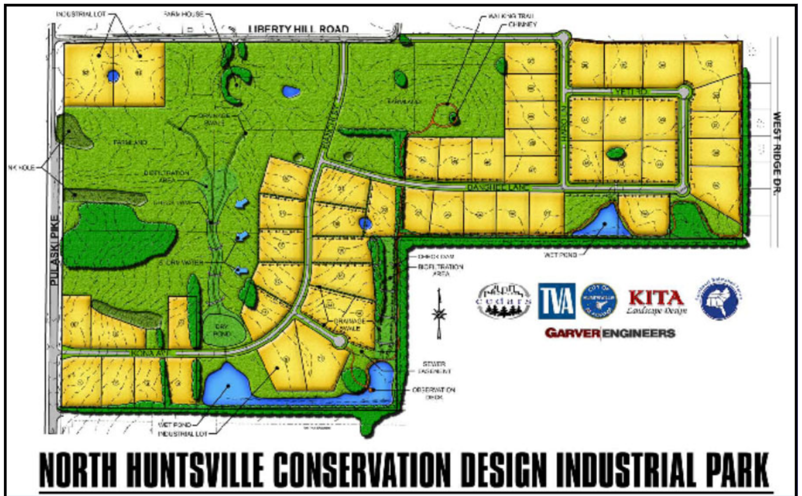
Monitored Performance of Controls at Cross Plains Conservation Design Development

Water Year	Construction Phase	Rainfall (inches)	Volume Leaving Basin (inches)	Percent of Volume Retained (%)
1999	Pre-construction	33.3	0.46	99%
2000	Active construction	33.9	4.27	87%
2001	Active construction	38.3	3.68	90%
2002	Active construction (site is approximately 75% built-out)	29.4	0.96	97%

WI DNR and USGS data

40



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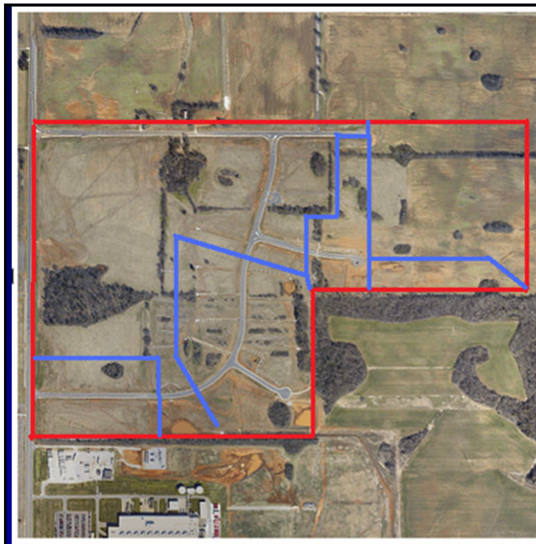

Aerial Photo of Site under Construction (Google Earth)

- On-site bioretention swales
- Level spreaders
- Large regional swales
- Wet detention ponds
- Critical source area controls
- Pollution prevention (no Zn!)
- Buffers around sinkholes
- Extensive trail system linking water features and open space

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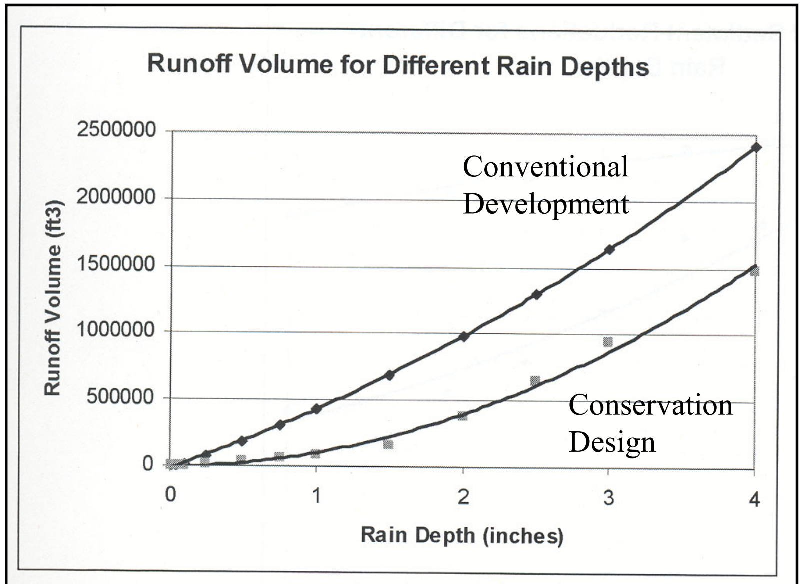

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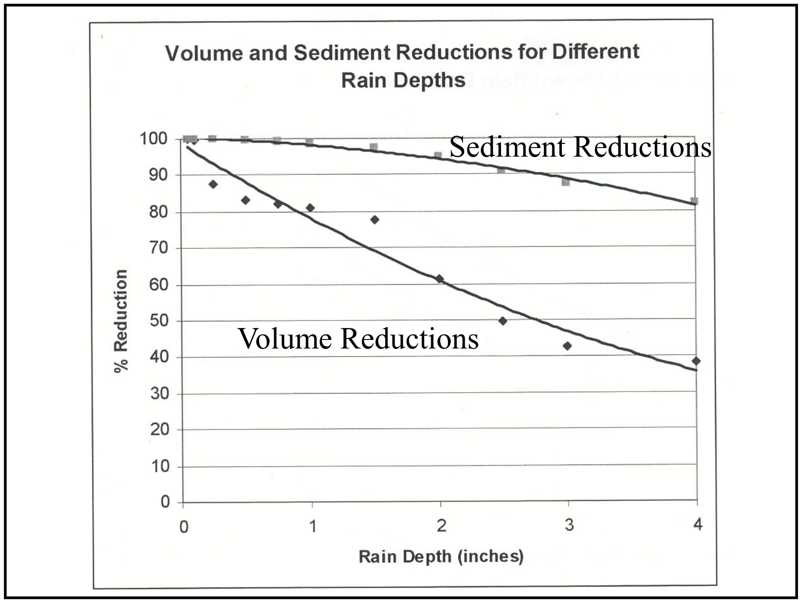

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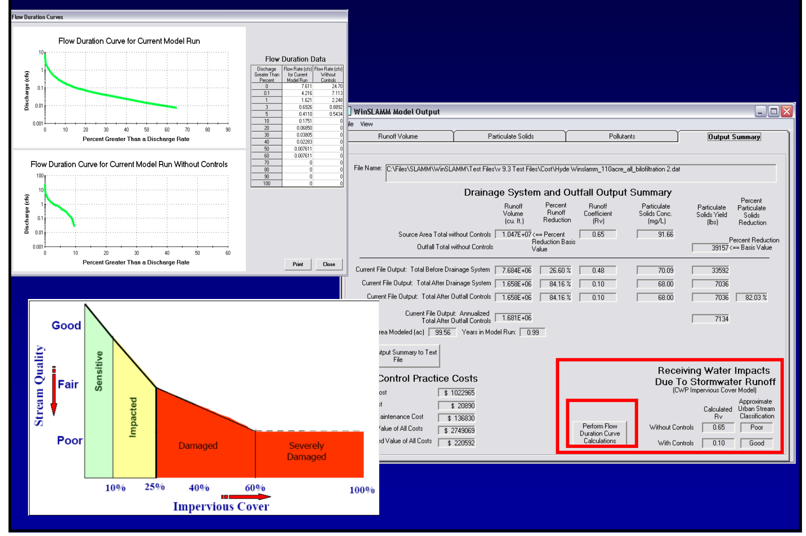
Receiving Water Impacts



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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 biofiltration and sedimentation practices is usually needed, at both critical source areas and at critical outfalls.

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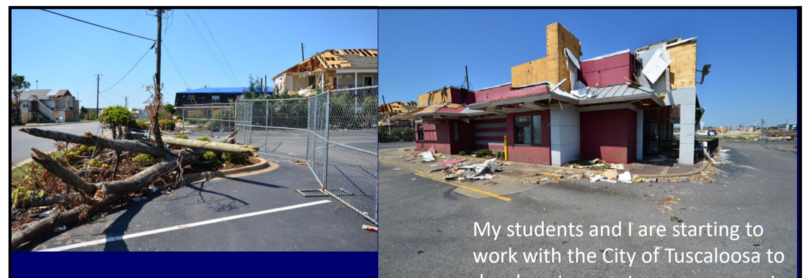

My students and I are starting to work with the City of Tuscaloosa to develop stormwater management options that meet the new city and state regulations for commercial sites that require re-building. Will develop fast track design manual, do site designs, and review plans. Starting with commercial buildings to maximize volume reductions; most all were not in compliance and City will not allow them to duplicate what was there before the tornadoes.

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A clean slate at the Krispy Crème location… total destruction of building, was totally impervious and will now have to meet new stormwater regulations with volume reductions. Surrounding destroyed neighborhoods will also receive attention, although individual homes are exempt from current stormwater regulations.
Krispy

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