Meeting CSO Management Goals Using Green Infrastructure: Kansas City EPA National Demonstration Project (with some comments from other projects)

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PV & Associates LLC

WinSLAMM ver. 10 Workshop
StormCon 2012
August 20, 2012, Denver, CO

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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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Grass Filter Strips Ver. 10 Input Screen

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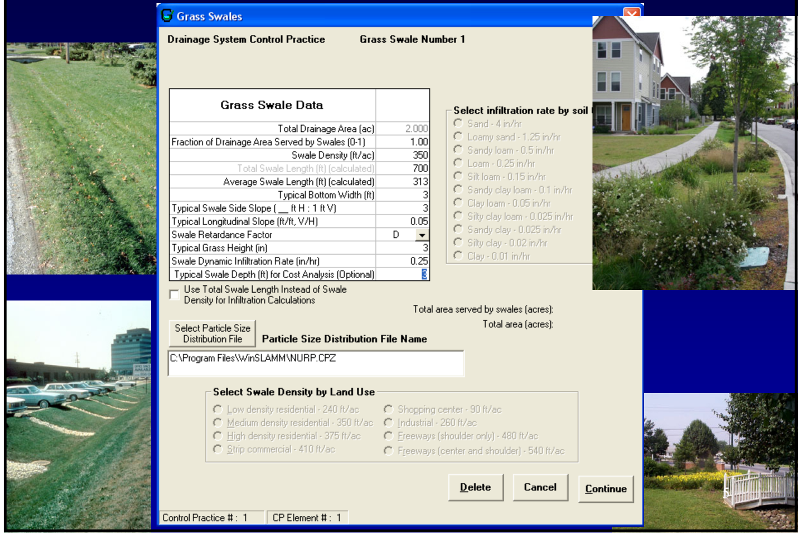
Grass Swales Ver. 10 Input Screen


Grass Swales

Drainage System Control Practice — Grass Swale Number 1

Grass Swale Data	
Total Drainage Area (ac)	2.000
Fraction of Drainage Area Served by Swales (0-1)	1.00
Swale Density (ft/ac)	350
Total Swale Length (ft) (calculated)	700
Average Swale Length (ft) (calculated)	313
Typical Bottom Width (ft)	3
Typical Swale Side Slope (__ ft H : 1 ft V)	3
Typical Longitudinal Slope (ft/ft, V/H)	0.05
Swale Retardance Factor	D
Typical Grass Height (in)	3
Swale Dynamic Infiltration Rate (in/hr)	0.25
Typical Swale Depth (ft) for Cost Analysis (Optional)	3

Select infiltration rate by soil
- 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 clay 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

Use Total Swale Length Instead of Swale Density for Infiltration Calculations

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

Select Particle Size Distribution File — Particle Size Distribution File Name
C:\Program Files\WinSLAMM\NURP.CPZ

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

Delete | Cancel | Continue

Control Practice # : 1 — CP Element # : 1

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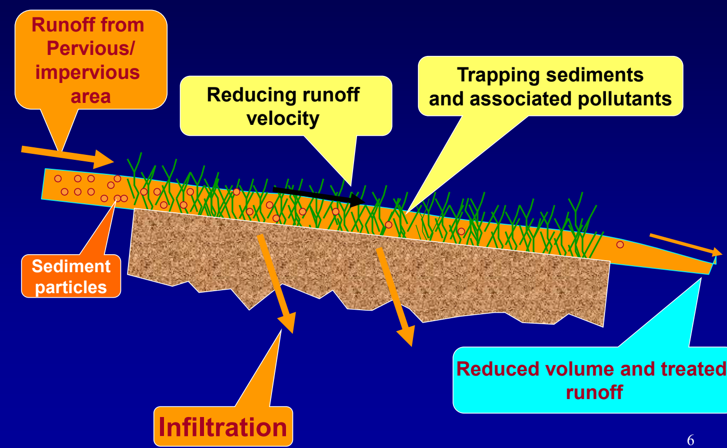
Pollutant Control in Grass Swales and Grass Filters



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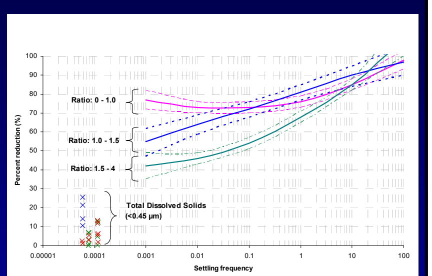
Particulate Removal Calculations

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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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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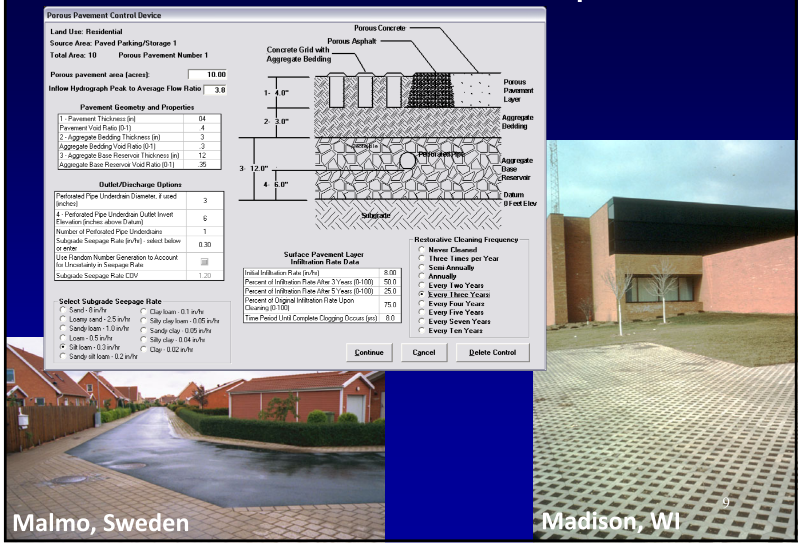
Porous Pavement Ver. 9.4 Input Screen



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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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Modeling Findings for Porous Pavements in Central Alabama Area

- Soils having at least 2.5 mm/hr infiltration rates can totally remove the runoff from porous pavement areas, assuming about 10 cm 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 12 mm/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 (about 4.2 inches in depth).
- 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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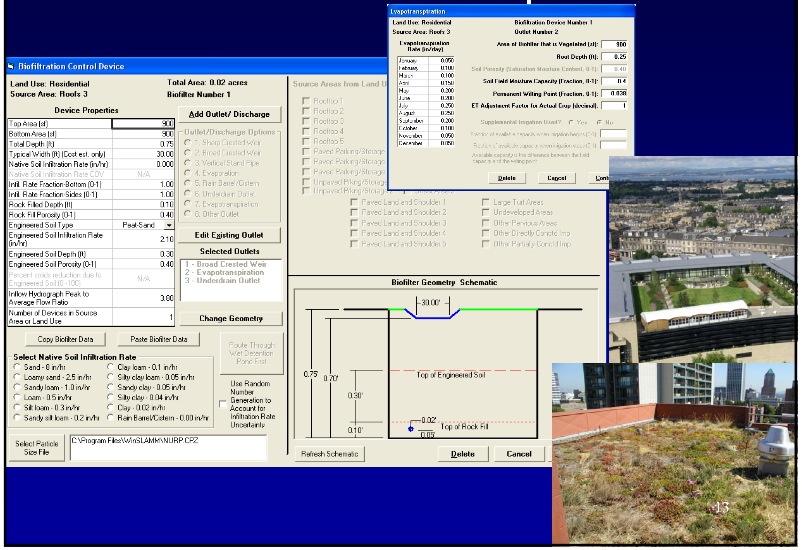
Green Roofs Ver. 9.5 Input Screen



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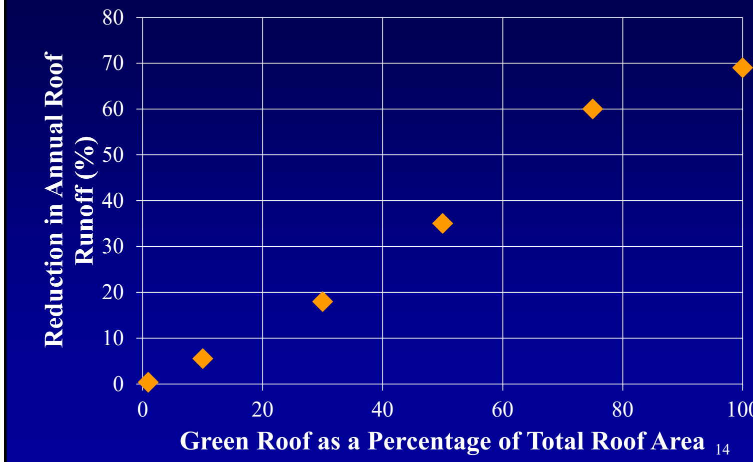
Annual Roof Runoff Reductions for Local Green Roofs



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Rain Gardens for Roof and Paved Area Runoff

- Simple rain gardens without 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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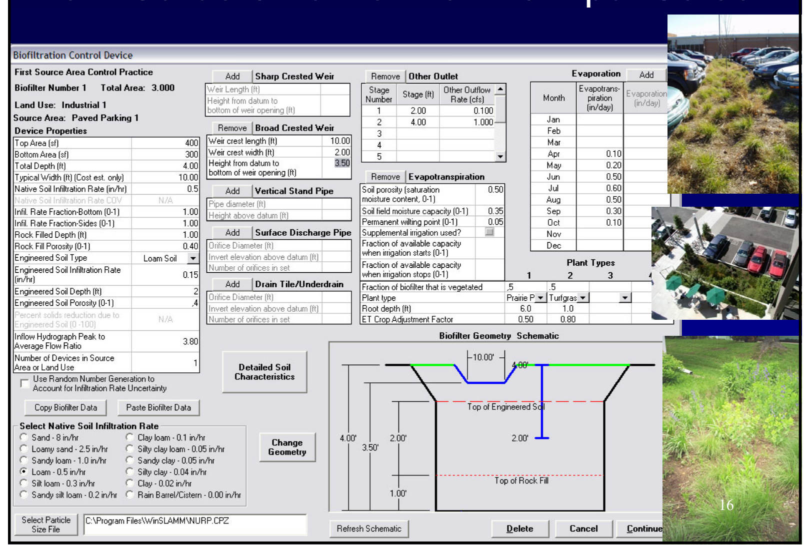
Rain Garden/Biofilter Ver. 10 Input Screen



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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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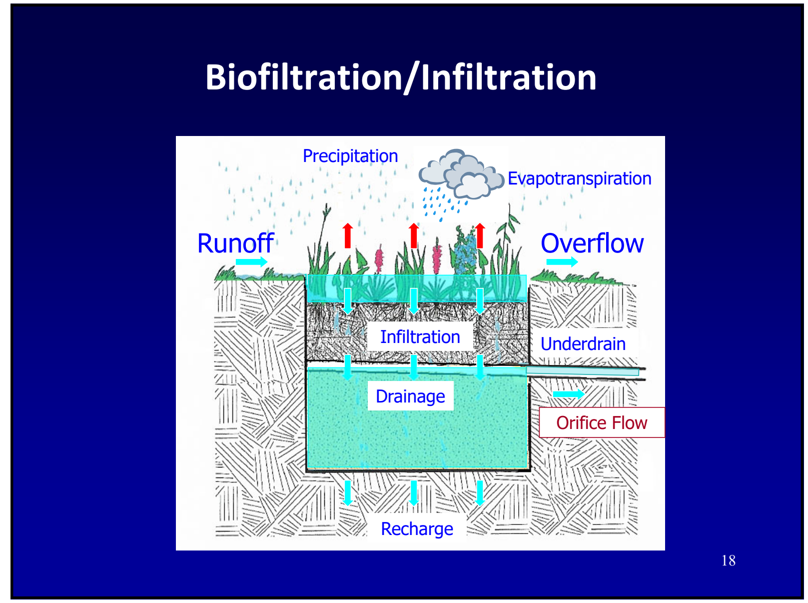
Biofiltration/Infiltration
Precipitation
Evapotranspiration
Runoff
Overflow
Infiltration
Underdrain
Drainage
Orifice Flow
Recharge
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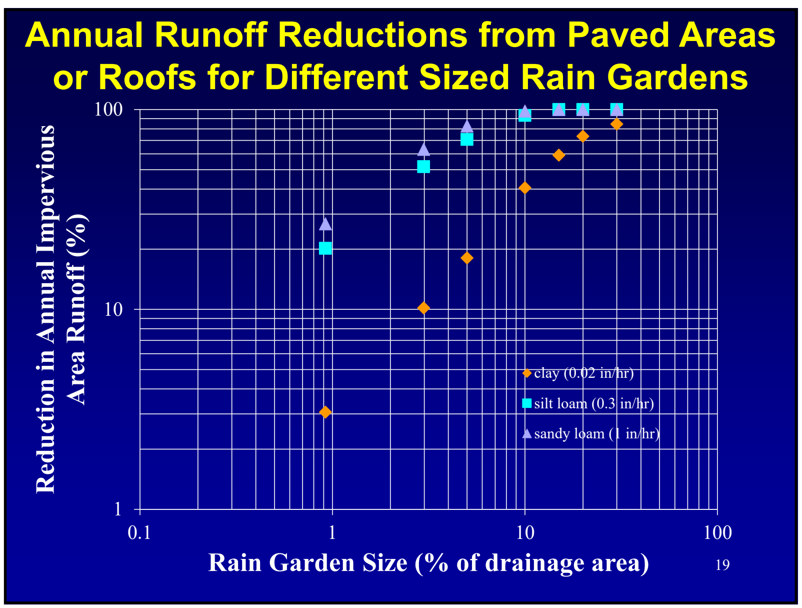
Annual Runoff Reductions from Paved Areas or Roofs for Different Sized Rain Gardens
Reduction in Annual Impervious Area Runoff (%)
100
10
1
0.1
1
10
100
clay (0.02 in/hr)
silt loam (0.3 in/hr)
sandy loam (1 in/hr)
Rain Garden Size (% of drainage area)
19

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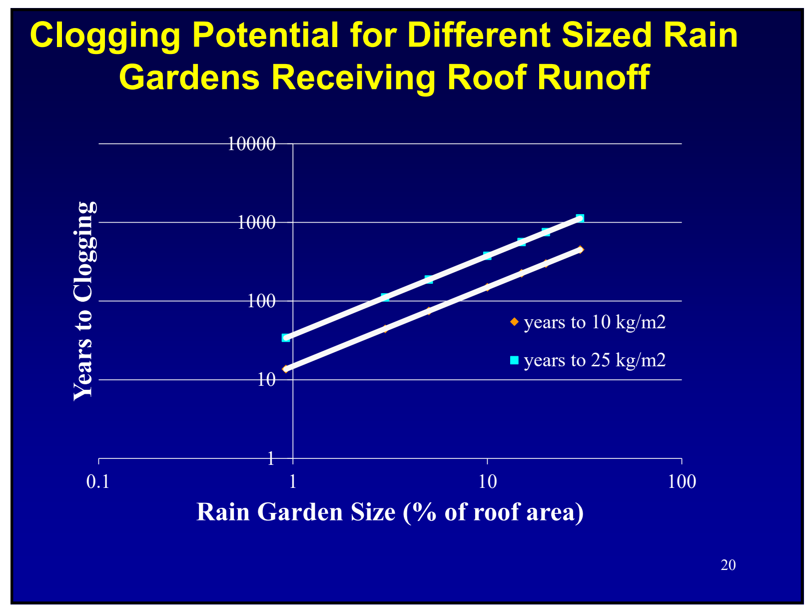
Clogging Potential for Different Sized Rain Gardens Receiving Roof Runoff
Years to Clogging
10000
1000
100
10
1
0.1
1
10
100
years to 10 kg/m2
years to 25 kg/m2
Rain Garden Size (% of roof area)
20

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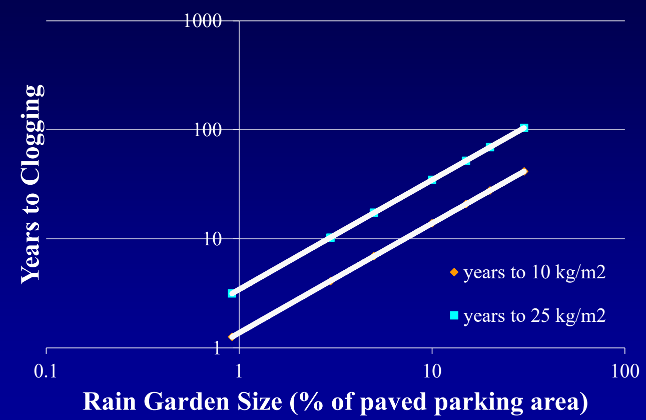
Clogging Potential for Different Sized Rain Gardens Receiving Paved Parking Area Runoff



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Results from Modeling Local Birmingham Rain Gardens

- Local rain gardens should be located in areas having soil infiltration rates of at least 8 mm/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 a large 100 mm 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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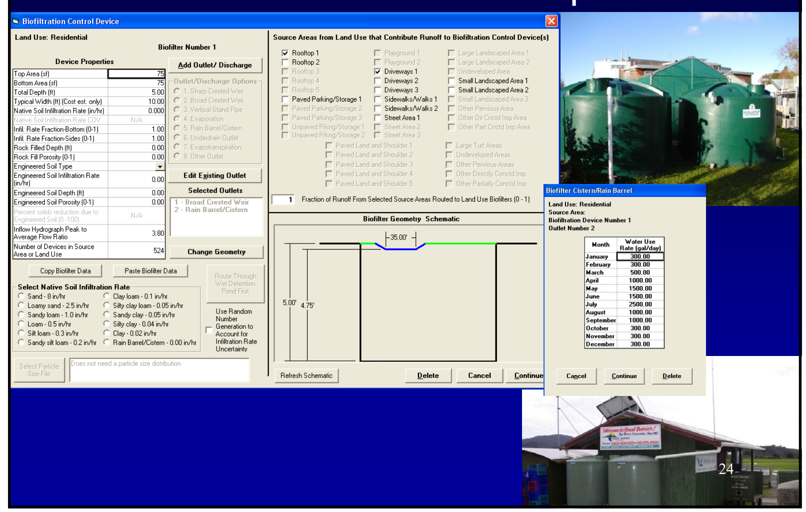
Water Tank/Cistern/Rain Barrel Beneficial Use of Stormwater Ver. 9.5 Input Screen



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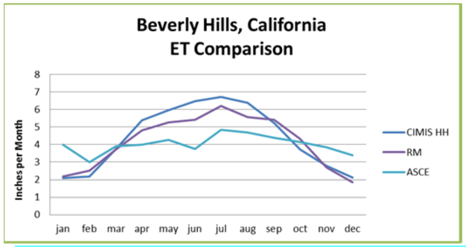
Evapotranspiration (ET) data sources are from agricultural and wildland environments which differ greatly from urban settings. The few projects that have examined urban ET values indicate large differences. Therefore, further research applying the available ET rates to disturbed urban environments is required to confirm the applicability of these rates in urban stormwater management practices.

Evapotranspiration (ET) as a Major Factor in Calculating Irrigation Needs



k values	Observed Site Conditions	Assessed Category	Estimated Coefficient
Species Factor	cool season grasses	High	.9*/.95
Density Factor	Low density groundcover	Low	0.75
Microclimate	Shaded with wind protection	Low	0.65
	$K_L=k_S*k_d*k_{mc}$		.43*/.46

*Slight reduction in species factor to account for early spring growing season

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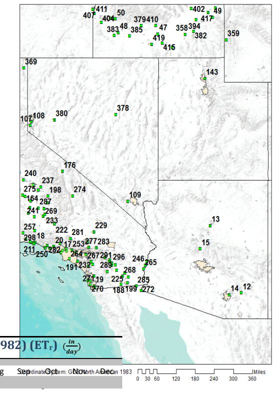
ET Rates can Vary Greatly Over Small Distances, Especially in the West

Our recent WERF report has compilations of various ET databases showing monthly ET values for many regions in the US that can be used to estimate the irrigation needs for stormwater beneficial uses. Some areas have large amounts of ET data (such as CA and FL), while the data is more sparse for other locations.



Lat	Long	Elev	Station Name	Years of Data	Kimberly Penman Equation (1982) (ET_r) $(\frac{in}{day})$ Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
64.84	-147.62	454	Fairbanks Alaska		Unavailable at this time											
61.08	-149.73	1480	Rabbit Creek Alaska		Unavailable at this time											
57.8	-135.13	450	Hoonah Alaska		Unavailable at this time											
33.44	-86.081	600	Talladega Alabama	5	0.07	0.13	0.18	0.24	0.26	0.26	0.25	0.24	0.23	0.21	0.13	0.09
32.96	-87.171	363	Oakmulgee Alabama	7	0.08	0.09	0.13	0.20	0.22	0.25	0.24	0.22	0.21	0.17	0.13	0.08
34.14	-87.362	804	Bankhead Alabama	7	0.06	0.12	0.17	0.24	0.25	0.26	0.25	0.25	0.23	0.20	0.13	0.09
32.45	-85.641	283	Tuskegee Alabama	5	0.08	0.13	0.17	0.24	0.26	0.27	0.27	0.25	0.23	0.19	0.13	0.07
34.76	-90.722	253	Marianna Arkansas	3	0.06	0.07	0.13	0.18	0.21	0.27	0.26	0.25	0.20	0.16	0.11	0.06
34.27	-92.393	270	Sheridan Arkansas	6	0.07	0.12	0.19	0.08	0.32	0.31	0.20	0.30	0.28	0.21	0.15	0.08
36.07	-93.357	2365	Compton Arkansas	2	0.06	0.10	0.15	0.21	0.32	0.38	0.35	0.30	0.24	0.22	0.11	0.08
35.87	-94.297	1633	Strickler Arkansas	6	0.06	0.07	0.12	0.16	0.19	0.23	0.24	0.24	0.20	0.15	0.11	0.07
32.4	-110.27	4175	Muleshoe Ranch AZ	13	0.09	0.15	0.22	0.29	0.35	0.37	0.29	0.29	0.31	0.25	0.16	0.11
35.15	-111.68	7000	Flagstaff Arizona	10	0.06	0.10	0.14	0.18	0.24	0.28	0.28	0.24	0.23	0.18	0.10	0.06
32.32	-110.81	3100	Saguaro Arizona	8	0.12	0.18	0.21	0.29	0.35	0.36	0.30	0.29	0.31	0.26	0.17	0.11

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Example Irrigation Needs Calculated for Silty Soil-East Coast Conditions

Calculated using continuous simulations and long-term rain records

	ET for site conditions (in/month)	Rainfall infiltration adding to soil moisture, from model (in/month)	Irrigation deficit (ET minus soil moisture addition from rain) (in/month)	irrigation deficit (gal/day/house)
Jan	0	3.44	n/a	0
Feb	0	2.67	n/a	0
Mar	2.79	3.67	n/a	0
Apr	4.20	3.38	0.82	102
May	4.96	4.16	0.80	96
Jun	5.10	3.18	1.92	240
Jul	5.27	4.36	0.92	109
Aug	4.65	3.44	1.21	140
Sep	3.90	3.84	0.06	7
Oct	3.10	3.00	0.11	13
Nov	1.80	3.79	n/a	0
Dec	1.24	3.35	n/a	0

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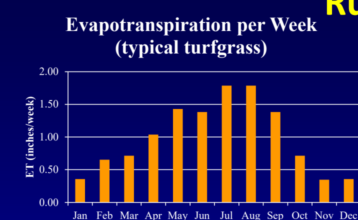
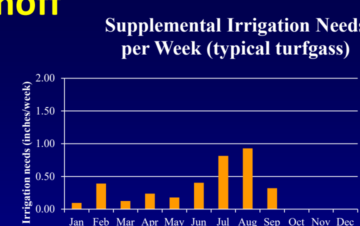
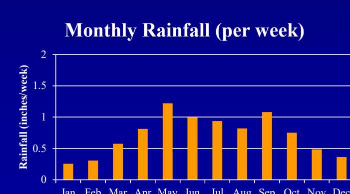
Kansas City Water Harvesting Potential of Roof Runoff







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

January	160	July	1350
February	650	August	1570
March	208	September	529
April	393	October	0
May	295	November	0
June	670	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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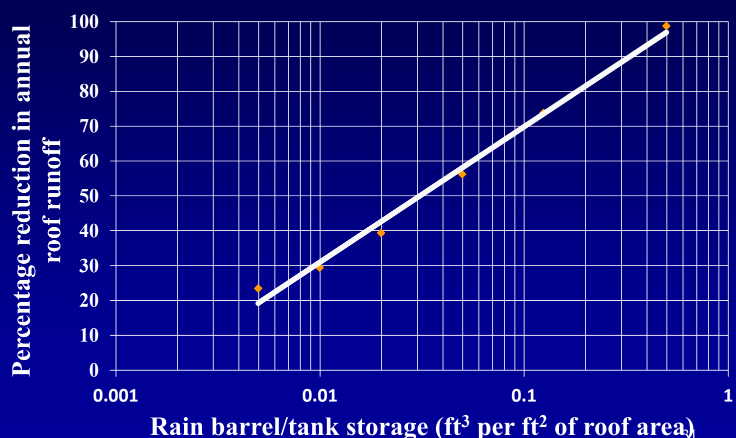
Reductions in Annual Flow Quantity from Directly Connected Roofs with the use of Rain Barrels and Water Tanks (Kansas City CSO Study Area)



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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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Kansas City's CSO Challenge

- Combined sewer area: 58 mi^2
- Fully developed
- Rainfall: 37 in./yr
- 36 sewer overflows/yr by rain > 0.6 in; reduce frequency by 65%.
- 6.4 billion gal overflow/yr, reduce to 1.4 billion gal/yr
- Aging wastewater infrastructure
- Sewer backups
- Poor receiving-water quality

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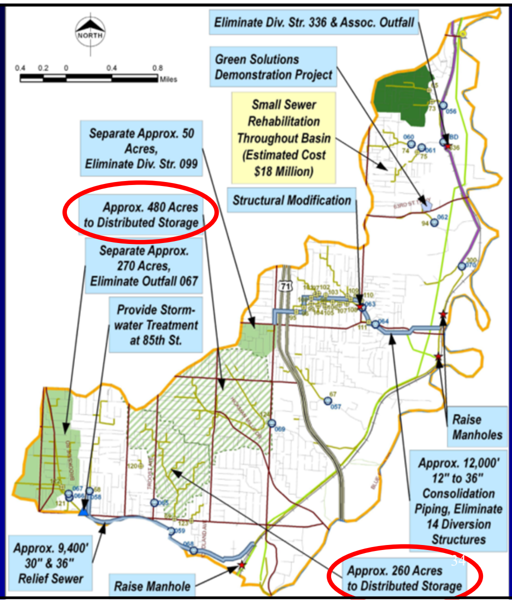
Kansas City's Revised Middle Blue River Plan with Distributed Storage and Green Infrastructure



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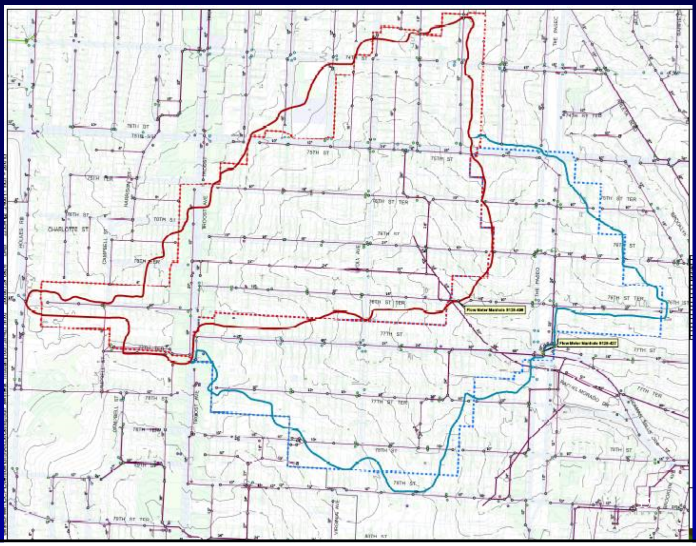
Adjacent Test and Control Watersheds



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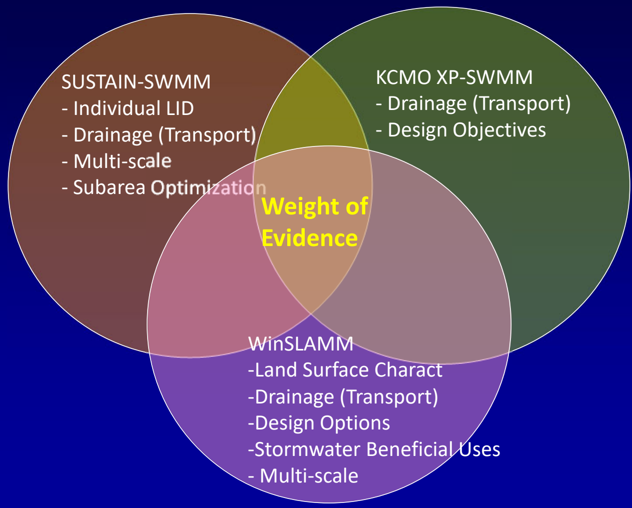
KC's Modeling Connections



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Major Land Use Components in Residential Portion of Study Area (% of area and % of total annual flow contributions)

	Roofs	Drive-ways	Side-walks	Park-ing	Streets	Land-scaped	Total
Directly connected	2 (6)	4 (9)	1 (3)	2 (5)	9 (21)		18 (44)
Disconnected	11 (7)	4 (3)	1 (1)				16 (11)
Landscaped						66 (45)	66 (45)
Total area	13 (13)	8 (12)	2 (4)	2 (5)	9 (21)	66 (45)	100

Based on KCMO GIS mapping and detailed site surveys, along with WinSLAMM calculations.

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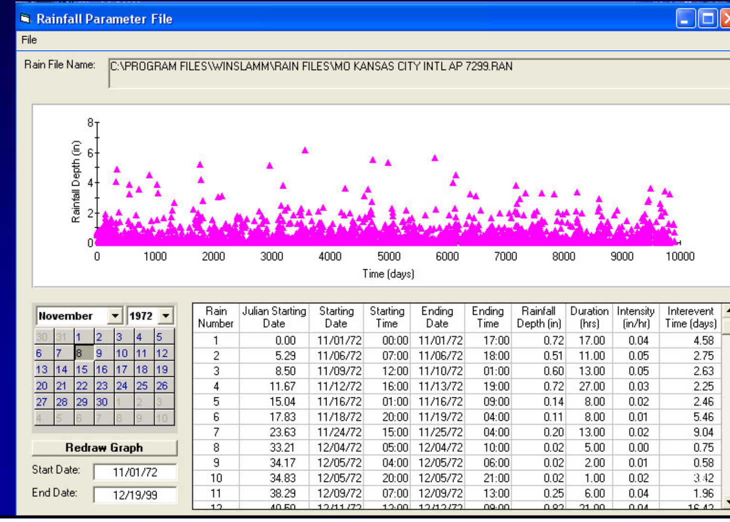
Continuous Simulations using Kansas City 1972 to 1999 Rain Series to Evaluate Roof Runoff Controls in Combined Sewer Area



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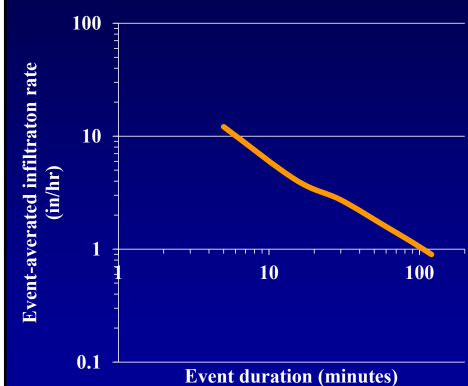
Varying-duration Site Infiltration Rates



This plot shows the time-averaged infiltration rates based on the individual incremental values. The surface infiltration rates are less than 25 mm/hr for rains about 2 hrs long and longer.

Additional site measurements and deep soil profiles have indicated that infiltration rates are quite low for most of the area during the large and long-duration critical events for overflows. 39

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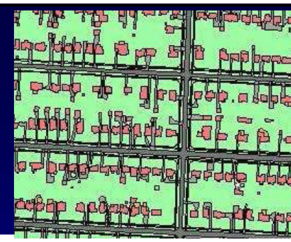

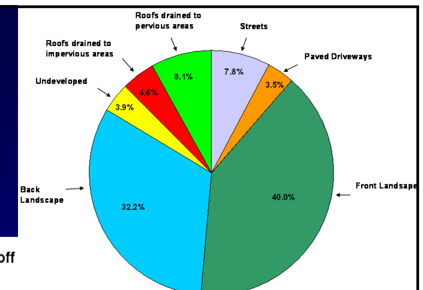

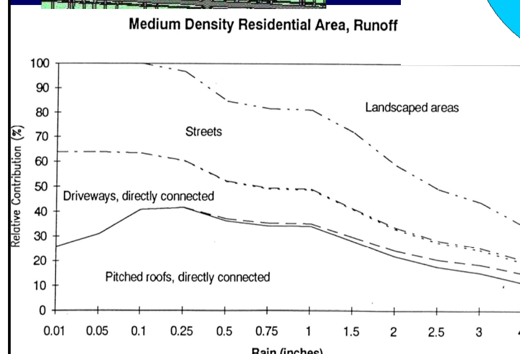

Surveys were conducted for each house and lot in the study area. This information was used with the GIS data and WinSLAMM to determine the sources of the runoff during different rain conditions 40

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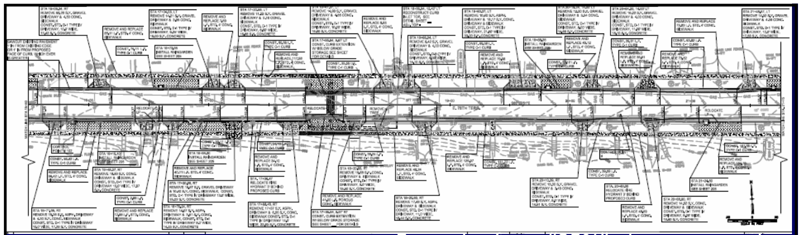
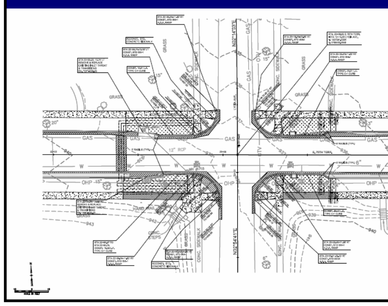
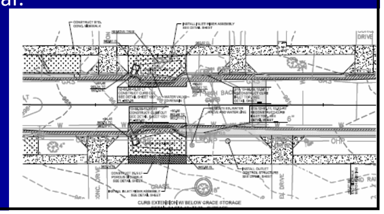


Examples from "95%" plans prepared by URS for project streets. Plans reviewed and modeled by project team, and construction completed in Summer 2012. Monitoring until end of year.





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Interactions of Controls being Evaluated in Kansas City

The curb-side biofilters are modeled as a cascading swale system where the site runoff is filtered and allowed to infiltrate. If the runoff volume is greater than the capacity of the biofilters, the excessive water is discharged into the combined sewer.

When evaluated together, cisterns treat the roof runoff first, the excess water is discharged to household rain gardens, then to the curbside biofilters. Continuous simulations drain the devices between events, depending on the interevent conditions and water demand.

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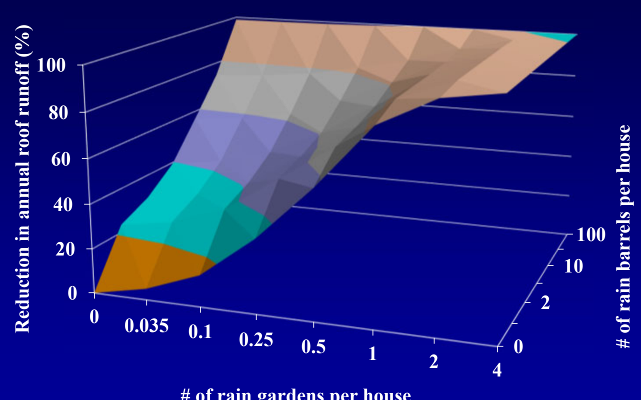
Interaction Benefits of Rain Barrels and Rain Gardens in the Kansas City CSO Study Area



Two 130 L rain barrels plus one 15 m^2 rain garden per house can reduce the total annual runoff quantity from directly connected roofs by about 90%

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NORTH HUNTSVILLE CONSERVATION DESIGN INDUSTRIAL PARK

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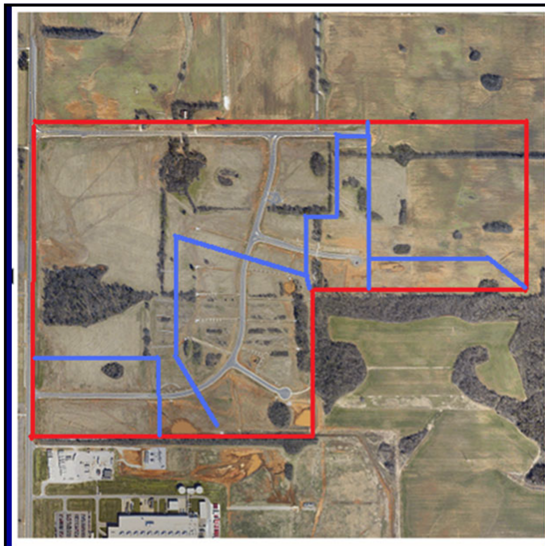

Aerial Photo of Site under Construction (Google Earth)

- 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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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.
- Trail system throughout area.

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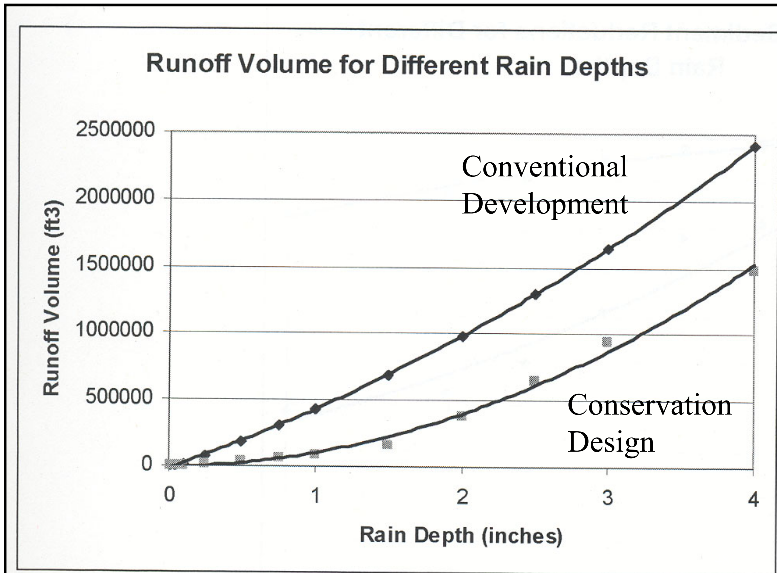

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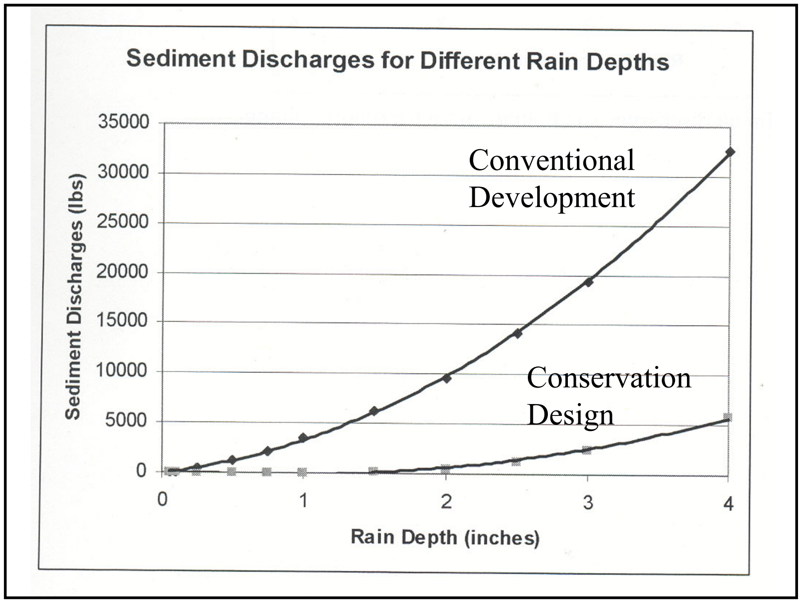

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Millburn, NJ

Dry well disposal of stormwater for groundwater recharge in conjunction with irrigation beneficial use

- For the past several years, the city of Millburn has required dry wells to infiltrate increased flows from newly developed areas.
- There are some underground water storage tanks now being installed to use stormwater for irrigation.
- Our recent project, supported by the Wet Weather Flow Research Program of the US EPA, is investigating the performance of this shallow groundwater recharge (including groundwater contamination potential) in conjunction with irrigation beneficial uses of the stormwater.

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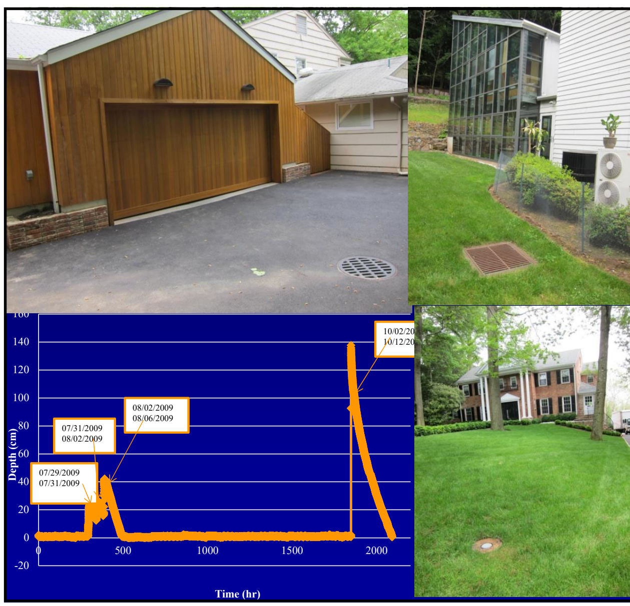

Nine dry wells were monitored in Millburn, NJ as part of EPA project for long-term hydraulic performance, and six were monitored to examine surface and subsurface water quality conditions.

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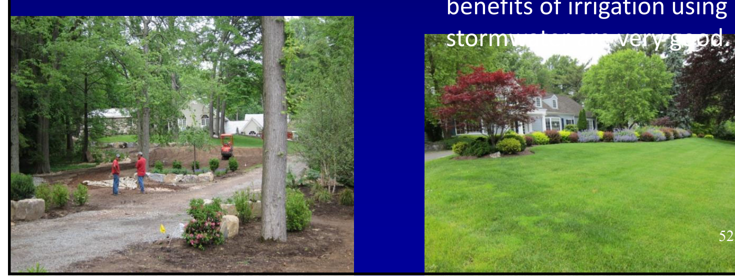
This major home restoration project included the installation of underground water storage tanks instead of dry wells. Homes in this neighborhood have summer water bills approaching $1k/month for landscape irrigation, so the economic benefits of irrigation using stormwater are very good.



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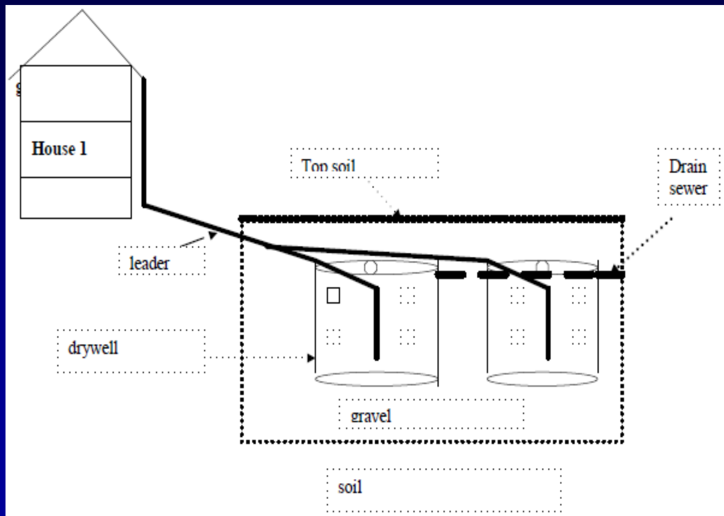
Schematic of Millburn Dry Wells



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Millburn Township Land Covers for Study Sites (Area, as a percentage)

Monitoring Location	Roofs	Driveways	Parking	Side walks	Street	Landscape	Paved Patio	Rear Walkway and Steps	Shed	Deck
8 South Beechcroft	9.3	6.7	0.0	1.3	10.6	70.2	1.3	0.1	0.0	0.5
11 Fox Hill	13.4	6.9	0.0	0.3	10.1	67.6	1.7	0.0	0.0	0.0
43 Browning Road S.H	14.2	5.9	0.0	0.7	13.2	63.2	2.9	0.0	0.0	0.0
1 Sinclair terrace	10.9	4.9	0.0	0.8	6.4	75.3	0.0	1.5	0.3	0.0
7 Fox Hill	14.3	6.3	0.0	2.2	10.6	64.4	2.2	0.0	0.0	0.0
9 Lancer	14.5	9.6	0.0	1.9	9.1	61.3	0.0	2.3	0.0	1.2
135 Tennyson Dr	5.7	5.2	4.2	1.4	17.0	66.5	0.0	0.0	0.0	0.0
79 Minnisink Rd	19.2	10.9	6.7	5.5	6.3	51.4	0.0	0.0	0.0	0.0
18 Slope Dr	15.4	11.7	5.8	0.0	24.9	42.1	0.0	0.0	0.0	0.0
139 Parsonage Hill Rd	13.3	6.6	7.9	0.8	16.9	54.5	0.0	0.0	0.0	0.0
Average	13.0	7.5	2.5	1.5	12.5	61.6	0.8	0.4	0.0	0.2

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Dry Well Drainage Observations

- Most of the dry wells were dry most of the time during the monitoring period (75 to 98% of the time)
- Standing water was observed at a few sites when sufficient time occurred to allow the water to reach a consistent minimum water level (about 3 ft deep); likely due to a high water table condition. The slow drainage rate may have been caused by saturated conditions from groundwater mounding
- Several sites experienced periodic slowly draining conditions, mainly in the spring, that could have been associated with SAR problems. The slow infiltration rates could be due to poor soils (with the clays resulting in SAR problems), or saturated soil conditions

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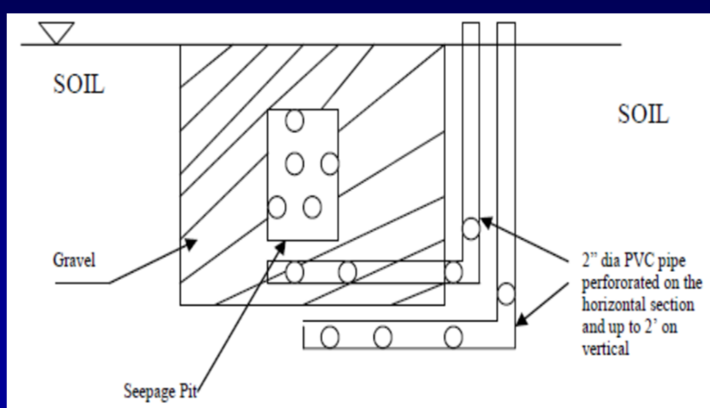
PVC Pipe pan lysimeters for dry wells (Shallow sampler next to bottom of dry bottom and deep sampler at least 2 ft below bottom of lower crushed stone layer).



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Monitored Water Quality below Dry Wells

- Ten rains (0.1 to 9 inches in depth, including Hurricane Irene); median depth 0.15 inches.
- Three dry wells were monitored (along with one cistern).
- TN, NO_3, TP, COD, Cu, Pb, Zn, enterococci, *E. coli* for all events and pesticides/herbicides for one event.
- No significant differences in the paired sample concentrations for the dry wells.
- Bacteria and lead may exceed New Jersey groundwater disposal guidelines.

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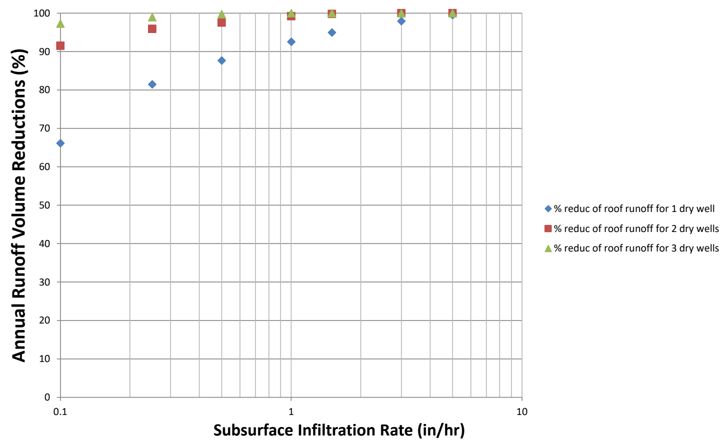
Roof runoff volume reductions using dry wells in Millburn, NJ.



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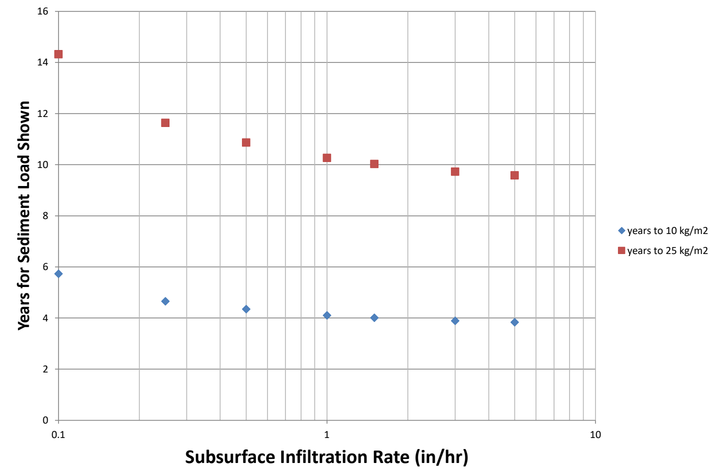
Clogging potential of dry wells in Millburn, NJ.



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Irrigation Beneficial Uses of Stormwater

	New Middlesex County New Jersey (in/day)	Ringwood New Jersey (in/day)	Average ET_o (in/day)
January	0.02	0.01	0.015
February	0.03	0.03	0.03
March	0.09	0.12	0.105
April	0.14	0.12	0.13
May	0.17	0.14	0.155
June	0.17	0.14	0.155
July	0.18	0.13	0.155
August	0.16	0.11	0.135
September	0.14	0.10	0.12
October	0.10	0.13	0.115
November	0.09	0.11	0.10
December	0.04	0.05	0.045

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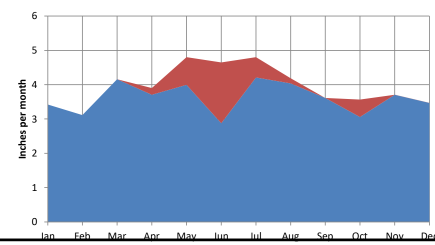
Irrigation Needs to Satisfy Evapotranspiration Requirements for Essex County, NJ

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average monthly rain (in/mo)	3.42	3.11	4.16	3.71	3.99	2.88	4.21	4.04	3.61	3.06	3.70	3.47
Average monthly ET (in/mo)	0.47	0.85	3.26	3.90	4.81	4.65	4.81	4.19	3.60	3.57	3.00	1.40
deficit for ET needs (in/mo)	0.00	0.00	0.00	0.19	0.81	1.77	0.60	0.15	0.00	0.51	0.00	0.00
Deficit ET needed (gal/day/house) 0.36 acres	0	0	0	63	256	577	188	47	0	160	0	0



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For a "healthy" lawn, total water applied (including rain) is generally about 1" of water per week, or 4" per month. Excessive watering is harmful to plants, so indiscriminate over-watering is to be avoided.

Some plants can accommodate additional water. As an example, Kentucky Bluegrass, the most common lawn plant in the US, needs about 2.5 in/week, or more, during the heat of the summer, and should receive some moisture during the winter.

The following table therefore calculates supplemental irrigation for 0.5 inches per week in the dormant season and up to 2.5 inches per week in the hot months

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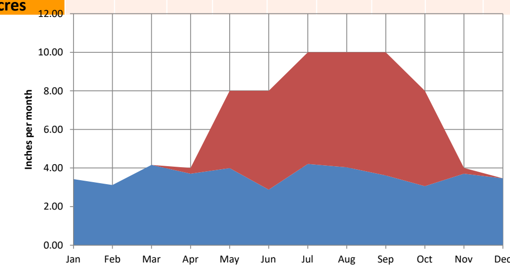
Irrigation Needs to Satisfy Heavily Irrigated Lawn for Essex County, NJ

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average monthly rain (in/mo)	3.42	3.11	4.16	3.71	3.99	2.88	4.21	4.04	3.61	3.06	3.70	3.47
Lawn moisture needs (in/mo)	2.00	2.00	4.00	4.00	8.00	8.00	10.00	10.00	10.00	8.00	4.00	2.00
Deficit irrigation need (in/mo)	0.00	0.00	0.00	0.29	4.01	5.12	5.79	5.96	6.39	4.94	0.30	0.00
Deficit irrigation needed (gallons/day/house) 0.36 acres	0	0	0	96	1263	1669	1826	1880	2081	1558	96	0



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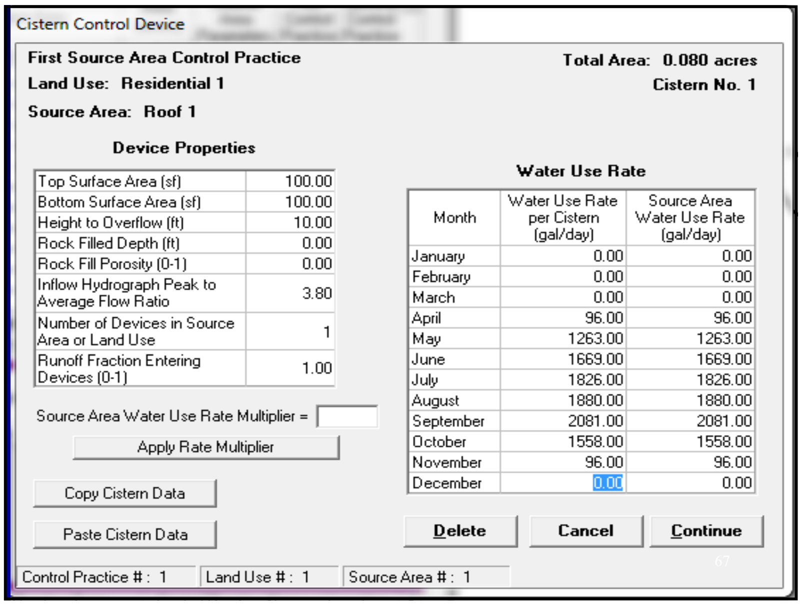
Cistern Control Device

First Source Area Control Practice

Land Use: Residential 1

Source Area: Roof 1

Total Area: 0.080 acres

Cistern No. 1

Device Properties

Top Surface Area (sf)	100.00
Bottom Surface Area (sf)	100.00
Height to Overflow (ft)	10.00
Rock Filled Depth (ft)	0.00
Rock Fill Porosity (0-1)	0.00
Inflow Hydrograph Peak to Average Flow Ratio	3.80
Number of Devices in Source Area or Land Use	1
Runoff Fraction Entering Devices (0-1)	1.00

Source Area Water Use Rate Multiplier =

Apply Rate Multiplier

Copy Cistern Data

Paste Cistern Data

Water Use Rate

Month	Water Use Rate per Cistern (gal/day)	Source Area Water Use Rate (gal/day)
January	0.00	0.00
February	0.00	0.00
March	0.00	0.00
April	96.00	96.00
May	1263.00	1263.00
June	1669.00	1669.00
July	1826.00	1826.00
August	1880.00	1880.00
September	2081.00	2081.00
October	1558.00	1558.00
November	96.00	96.00
December	0.00	0.00

Delete Cancel Continue

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

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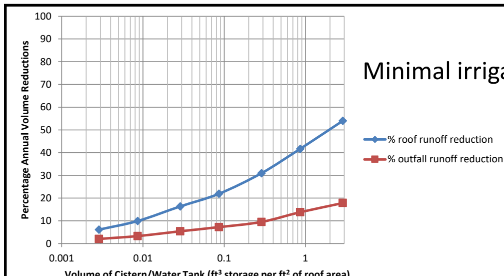
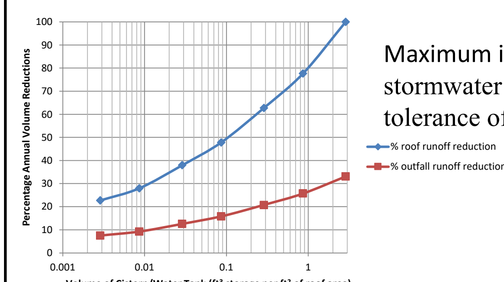


Minimal irrigation to meet ET



Maximum irrigation to dispose of stormwater but within expected tolerance of Kentucky Bluegrass

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Conclusions

- There are a large number of infiltration-based stormwater controls that can be applied to a variety of land uses to reduce the volume and rates of stormwater discharged to combined sewers.
- Beneficial uses of stormwater can also be a useful tool to reduce these discharges, while still conserving important resources.
- Continuous WinSLAMM simulations can calculate the benefits of these controls in many combinations for an area.

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