WinSLAMM Support for Green Infrastructure in Combined Sewer Areas: Kansas City, EPA National Demonstration Project

Workshop presentation

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Water Tank/Cistern/Rain Barrel Beneficial Use of Stormwater Ver. 9.5 Input Screen
Grass Filter Strips Ver. 10 Input Screen

Filter Strip Control Device

Land Use: Institutional 1
Source Area: Paved Parking 1
Filter Strip No. 1
First Source Area Control Practice

Device Properties
- Total Area in Source Area (ac): 2.000
- Area Fraction Served by Filter Strips (0-1): 1.00
- Total Filter Strip Length (ft): 0
- Effective Width (ft): 0
- Infiltration Rate (in/hr): 0.000
- Typical Longitudinal Slope (0-1): 0.000
- Typical Grass Height (in): 0.0
- Grass Retardance Factor
- Use Stochastic Analysis to account for Infiltration Rate Uncertainty
- Native Soil Infiltration Rate CV

Select Particle Size File
C:\Program Files\WinSLAMM\NURP.CFZ

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

Copy Filter Strip Data
Paste Filter Strip Data
Delete
Cancel
Continue
Porous Pavement Ver. 9.4 Input Screen

### Porous Pavement Control Device

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

<table>
<thead>
<tr>
<th>Porous pavement area (acres)</th>
<th>10.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflow Hydrograph Peak to Average Flow Ratio</td>
<td>3.8</td>
</tr>
</tbody>
</table>

#### Pavement Geometry and Properties

<table>
<thead>
<tr>
<th>1 - Pavement Thickness (in)</th>
<th>04</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - Aggregate Bedding Thickness (in)</td>
<td>3</td>
</tr>
<tr>
<td>3 - Aggregate Base Reservoir Thickness (in)</td>
<td>12</td>
</tr>
<tr>
<td>Aggregate Void Ratio (V)</td>
<td>0.3</td>
</tr>
<tr>
<td>Aggregate Void Ratio (V) (D)</td>
<td>35</td>
</tr>
</tbody>
</table>

#### Outlet/Discharge Options

<table>
<thead>
<tr>
<th>Perforated Pipe Undrained Diameter (inches)</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Perforated Pipe Undrains</td>
<td>1</td>
</tr>
<tr>
<td>Subgrade Seepage Rate (in/hr)</td>
<td>0.30</td>
</tr>
</tbody>
</table>

#### Surface Pavement Layers

<table>
<thead>
<tr>
<th>Infiltration Rate Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Infiltration Rate (in/hr)</td>
</tr>
<tr>
<td>Percent of Infiltration Rate After 3 Years (0.100)</td>
</tr>
<tr>
<td>Percent of Infiltration Rate After 5 Years (0.100)</td>
</tr>
<tr>
<td>Percent of Original Infiltration Rate Upon Dewatering (0.100)</td>
</tr>
<tr>
<td>Time Period Until Complete Clogging Occurs (yr)</td>
</tr>
</tbody>
</table>

#### 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

### Select Subgrade Seepage Rate

- Sand - 3 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

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[Image of Porous Pavement Diagram]
Grass Swales Ver. 10 Input Screen

Grass Swale Data

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

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 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

Select Particle Size Distribution File:
- Particle Size Distribution File Name: C:\Program Files\WinSLAMM\NURP.CFZ

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

Control Practice #: 1
CP Element #: 1

Options:
- Delete
- Cancel
- Continue
Kansas City’s CSO Challenge

- Combined sewer area: 58 mi²
- 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
Kansas City Project Team

- EPA ORD: Rich Field, Tom O’Connor, Tony Tafuri
- EPA R7: Kerry Herndon
- Tetra Tech: Scott Struck
- Mid-America Regional Council: Tom Jacobs & Ginny Moore
- University of Missouri, Kansas City: Deb O’Bannon
- University of Alabama, Tuscaloosa: Bob Pitt
- Independent Contractor: Mike Ports
- Partnerships with KCMO WSD & neighborhood, watershed, & regional levels
Kansas City Middle Blue River Outfalls

- 744 acres
- Distributed storage with “green infrastructure” vs. storage tanks
- Need 3 Mgal storage
- Goal: < 6 CSOs/yr
Kansas City’s Original Middle Blue River Plan with CSO Storage Tanks
Kansas City’s Revised Middle Blue River Plan with Green Solutions
Adjacent Test and Control Watersheds
Project Strategy and Modeling

- Conventional CSO evaluations were conducted using XP_SWMM in order to identify the design storm for the demonstration area that will comply with the discharge permits.

- XP_SWMM was also used by KCMO Water Services Department, Overflow Control Program, to examine different biofiltration and porous pavement locations and storage options in the test.
Project Strategy and Modeling (cont.)

- WinSLAMM is being used to quantify benefits for different applications of many stormwater controls in the test watershed with continuous simulations. It is also being used to examine capital and maintenance costs, along with quantify the maintenance schedules needed for the different alternatives. Decision analysis considering many project objectives is also being supported by WinSLAMM.
KC’s Modeling Connections

SUSTAIN-SWMM
- Individual LID
- Drainage (Transport)
- Multi-scale
- Subarea Optimization

KCMO XP-SWMM
- Drainage (Transport)
- Design Objectives

WinSLAMM
- Land Surface Characteristics
- Drainage (Transport)
- Design Options
- Stormwater Beneficial Uses
- Multi-scale

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

<table>
<thead>
<tr>
<th></th>
<th>Roofs</th>
<th>Driveways</th>
<th>Sidewalks</th>
<th>Parking</th>
<th>Streets</th>
<th>Landscaped</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directly connected</td>
<td>2 (6)</td>
<td>4 (9)</td>
<td>1 (3)</td>
<td>2 (5)</td>
<td>9 (21)</td>
<td>18 (44)</td>
<td></td>
</tr>
<tr>
<td>Disconnected</td>
<td>11 (7)</td>
<td>4 (3)</td>
<td>1 (1)</td>
<td></td>
<td></td>
<td>16 (11)</td>
<td></td>
</tr>
<tr>
<td>Landscaped</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>66 (45)</td>
<td>66 (45)</td>
<td></td>
</tr>
<tr>
<td>Total area</td>
<td>13 (13)</td>
<td>8 (12)</td>
<td>2 (4)</td>
<td>2 (5)</td>
<td>9 (21)</td>
<td>66 (45)</td>
<td>100</td>
</tr>
</tbody>
</table>

Based on KCMO GIS mapping and detailed site surveys, along with WinSLAMM calculations.
Continuous Simulations using Kansas City 1972 to 1999 Rain Series to Evaluate Roof Runoff Controls in Combined Sewer Area
This plot shows the time-averaged infiltration rates based on the individual incremental values. The surface infiltration rates are less than 1 in/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.
Reductions in Annual Flow Quantity from Directly Connected Roofs with the use of Rain Gardens (Kansas City CSO Study Area)
Water Harvesting Potential of Roof Runoff

Evapotranspiration per Week (typical turfgrass)

Monthly Rainfall (per week)

Supplemental Irrigation Needs per Week (typical turfgrass)

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

<table>
<thead>
<tr>
<th>Month</th>
<th>Gallons/Day/House</th>
<th>Month</th>
<th>Gallons/Day/House</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>42</td>
<td>July</td>
<td>357</td>
</tr>
<tr>
<td>February</td>
<td>172</td>
<td>August</td>
<td>408</td>
</tr>
<tr>
<td>March</td>
<td>55</td>
<td>September</td>
<td>140</td>
</tr>
<tr>
<td>April</td>
<td>104</td>
<td>October</td>
<td>0</td>
</tr>
<tr>
<td>May</td>
<td>78</td>
<td>November</td>
<td>0</td>
</tr>
<tr>
<td>June</td>
<td>177</td>
<td>December</td>
<td>0</td>
</tr>
</tbody>
</table>

Warrabungles National Park, Australia
Siding Springs Observatory, Australia
Winery, Heathcote, Australia
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.
Reductions in Annual Flow Quantity from Directly Connected Roofs with the use of Rain Barrels and Water Tanks (Kansas City CSO Study Area)
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.

<table>
<thead>
<tr>
<th>rain barrel/tank storage per house (ft(^3))</th>
<th>percentage reduction in annual roof runoff</th>
<th># of 35 gallon rain barrels</th>
<th>tank height size required if 5 ft D (ft)</th>
<th>tank height size required if 10 ft D (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4.7</td>
<td>20</td>
<td>1</td>
<td>0.24</td>
<td>0.060</td>
</tr>
<tr>
<td>9.4</td>
<td>31</td>
<td>2</td>
<td>0.45</td>
<td>0.12</td>
</tr>
<tr>
<td>19</td>
<td>43</td>
<td>4</td>
<td>0.96</td>
<td>0.24</td>
</tr>
<tr>
<td>47</td>
<td>58</td>
<td>10</td>
<td>2.4</td>
<td>0.60</td>
</tr>
<tr>
<td>118</td>
<td>75</td>
<td>25</td>
<td>6.0</td>
<td>1.5</td>
</tr>
<tr>
<td>470</td>
<td>98</td>
<td>100</td>
<td>24</td>
<td>6.0</td>
</tr>
</tbody>
</table>
Interaction Benefits of Rain Barrels and Rain Gardens in the Kansas City CSO Study Area

Two 35 gal. rain barrels plus one 160 ft² rain garden per house can reduce the total annual runoff quantity from directly connected roofs by about 90%.
Annual Runoff Reductions from Paved Areas or Roofs for Different Sized Rain Gardens for Various Soils

Rain Garden Size (% of drainage area) vs. Reduction in Annual Impervious Area Runoff (%)

- Clay (0.02 in/hr)
- Silt loam (0.3 in/hr)
- Sandy loam (1 in/hr)
Clogging Potential for Different Sized Rain Gardens Receiving Roof Runoff

Clogging not likely a problem with rain gardens from roofs
Proposed Bioretention/Filtration Profile

- 9" Ponding (61 CF) + Saturated Slopes (8 CF)
- Curb Cut, Forebay and Rock Chute Inlet
- 24" Engineered Soil w/20% Voids (64 CF)
- Infiltration 0.2"/hr (24 CF/6 hr and 96 CF/24)

PROFILE VIEW
Not to Scale

4" Underdrain

Note:
4" Underdrain is optional when sewer connection is available.
Rain gardens should be at least 10% of the paved drainage area, or receive significant pre-treatment (such as with long grass filters or swales, or media filters) to prevent premature clogging.
Conclusions

- WinSLAMM considers specialized urban hydrology and pollutant transport processes that consider the unique features of urban surfaces and soils.
- These are especially critical when considering water quality evaluations that are heavily influenced by smaller and intermediate-sized runoff events.
- Field measurements are needed for calibration and verification for all stormwater models, and are the basis for most of the processes included in WinSLAMM.
- WinSLAMM considers a wide range of historical and newly emerging stormwater control practices, and routes flows, particulates, and pollutants considering interactions of these controls and site conditions.