New Research Focusing on Emerging Wet Weather Flow Management Strategies

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The research carried out by our group at the University of Alabama has recently focused on sources and treatability of wet-weather flows and contaminants, and the development and testing of new treatment technologies. Some of these activities are listed below and will be briefly described during this presentation:

- The National Stormwater Quality Database
- Surveys and the identification of inappropriate discharges to stormwater drainage systems using source tracking and uncertainty analyses
- Bacteria sources and control options in the Lake Tuscaloosa watershed
- Urban pet and wildlife bacteria sources, survivability, and transport
- Pollutant releases during the initial aging of asphaltic pavements
- Degradation and pollutant releases from piping and gutter materials under different pH and salinity conditions (WEFTEC poster)
- Heavy metal leaching from treated wood ash and soil amendments
- PAH contamination of urban stream sediments by particle size and organic content, and the development of thermal extraction methods

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Management and treatment of wet weather flow discharges:

- Stormwater non-potable beneficial uses
- Development of biofiltration media designs to meet very low numeric effluent limits from an industrial site (WEFTEC presentation)
- Monitoring and modeling the interaction of green infrastructure practices for the control of combined sewer overflows
- Sources and treatment of emerging contaminants in wet weather flows
- Testing of alternative biofiltration underdrain systems and the effects of sand characteristics on treatment flow rates (WEFTEC poster)
- Development and testing of the upflow filter for critical source areas
- Scour of captured stormwater sediments from simple treatment devices
- The use of WinSLAMM at US naval facilities to identify sources and treatment options for critical heavy metals
- Development of monitoring program to evaluate the performance of green infrastructure components for the control of CSOs
- Soil characteristics and infiltration designs to assist the city of Tuscaloosa in its reconstruction efforts

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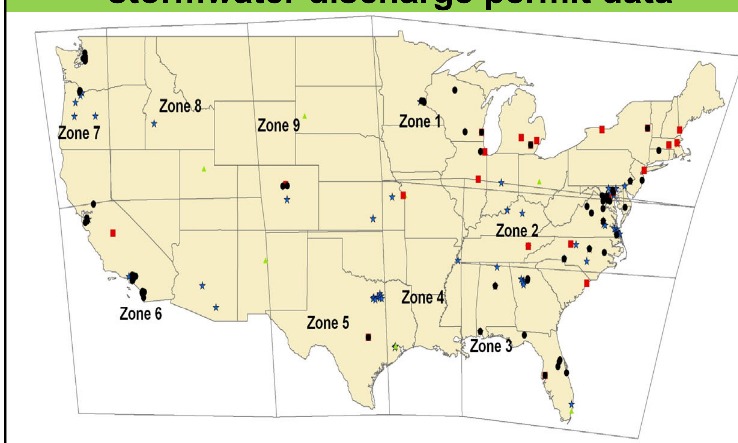
National Stormwater Quality Database, Developed for the EPA to compile existing stormwater discharge permit data



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Number of Events and Geographical Coverage in NSQD ver. 3		
Rain Zone	Number of Events	Percentage of Events
Zone 1- Great Lakes and Northeast	1,271	15
Zone 2- Mid Atlantic	3,984	46
Zone 3- Southeast	744	9
Zone 4- Lower Mississippi Valley	301	4
Zone 5- Texas	799	9
Zone 6- Southwest	417	5
Zone 7- Northwest	865	10
Zone 8- Rocky Mountains	24	0.3
Zone 9- Midwest	197	2
TOTAL	8,602	100

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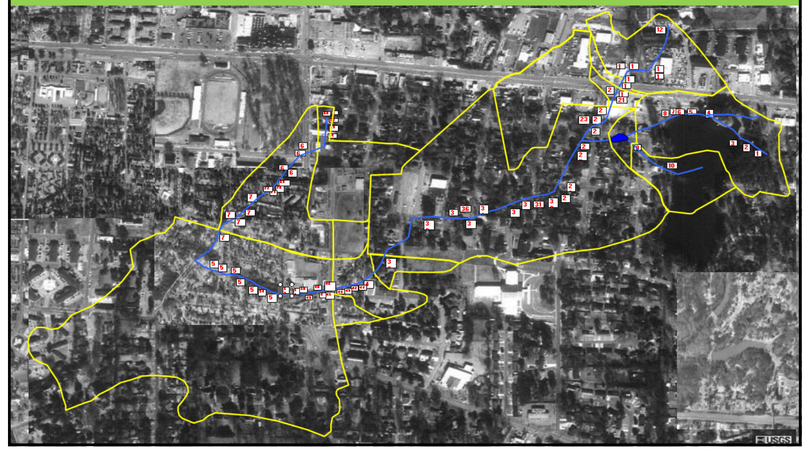
Storm drainage system in Tuscaloosa used to evaluate inappropriate discharge protocols developed for EPA



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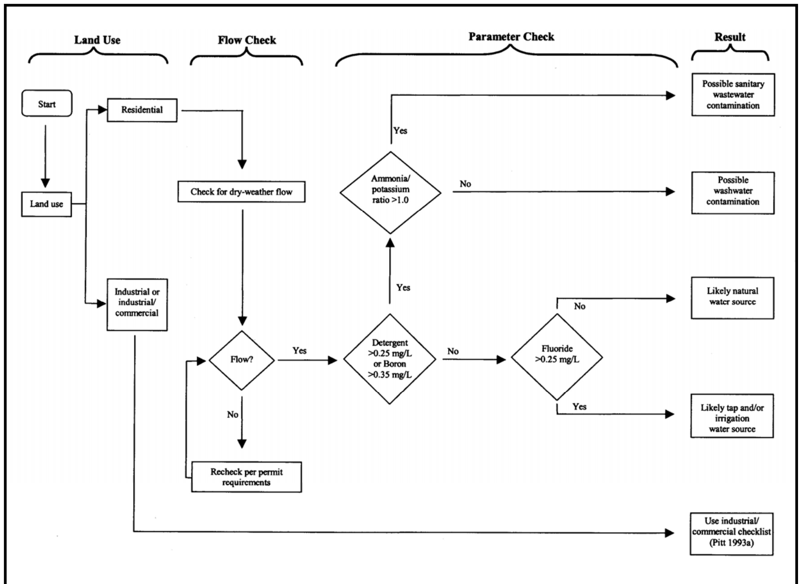

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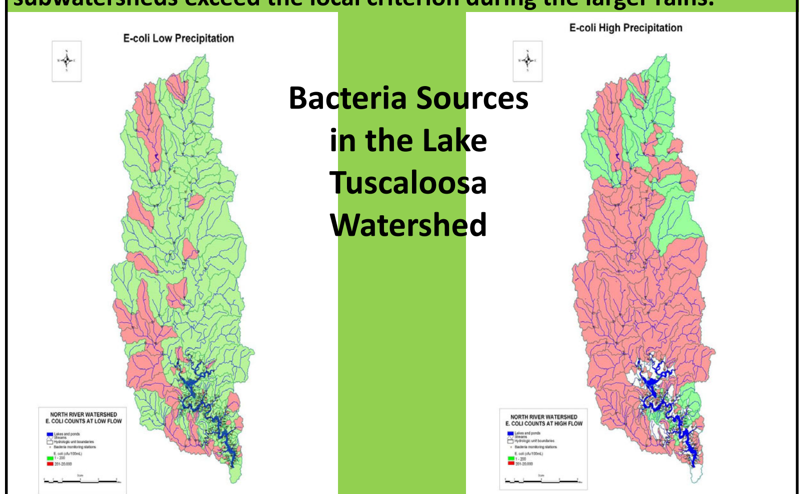
Higher *E. coli* levels were found in subwatersheds of Lake Tuscaloosa during large rains (>25 mm), compared to smaller rains, and more subwatersheds exceed the local criterion during the larger rains.



Bacteria Sources in the Lake Tuscaloosa Watershed

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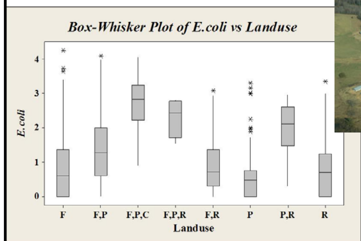
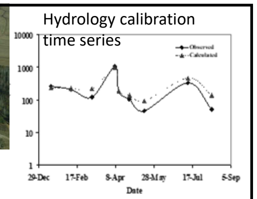
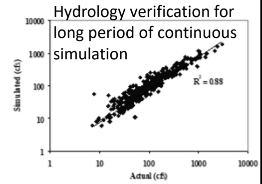
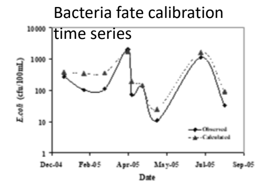


Watershed monitoring indicated that subwatersheds having chicken facilities had much greater levels of *E. coli* than subwatersheds having other land uses:
-forested land had the lowest, then residential areas, then pastures/cattle feedlots, then chicken facilities with the highest







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Survivability of Indicator Bacteria on Pervious and Impervious Surfaces

Warm (90° F) Dry (~30% RH)	Warm (90° F) Moist(~85% RH)
UV Shielded	UV Shielded
Cool (40° F) Dry (38% RH)	Cool (40° F) Moist(~85% RH)
UV Shielded	UV Shielded

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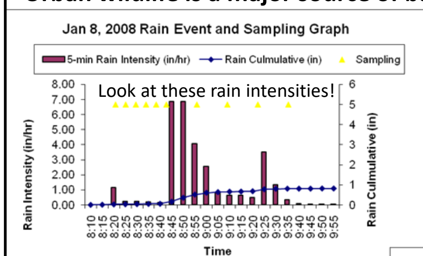
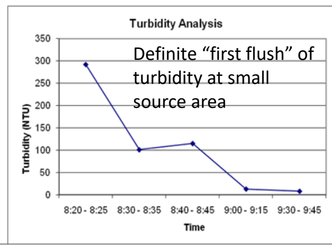
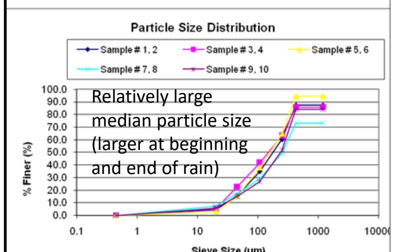
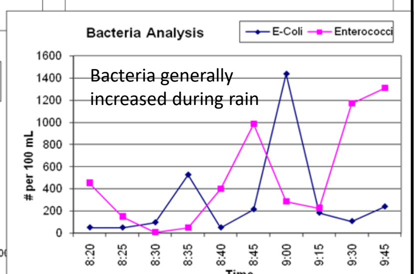
Monitoring of 0.4 ha parking lot and surrounding landscaped area – Urban wildlife is a major source of bacteria in urban areas.









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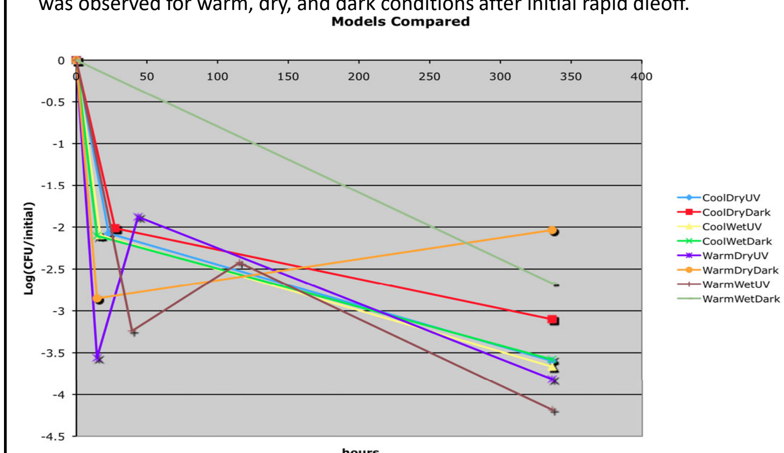
On concrete blocks, dog poop *E. coli* had rapid die-off for all conditions, except for warm, wet, and dark conditions. Die-off rate after one or two days decreased significantly and was similar to the persistent conditions. Three log removals (99.9% reductions) after about 10 days for most conditions. Re-growth was observed for warm, dry, and dark conditions after initial rapid dieoff.



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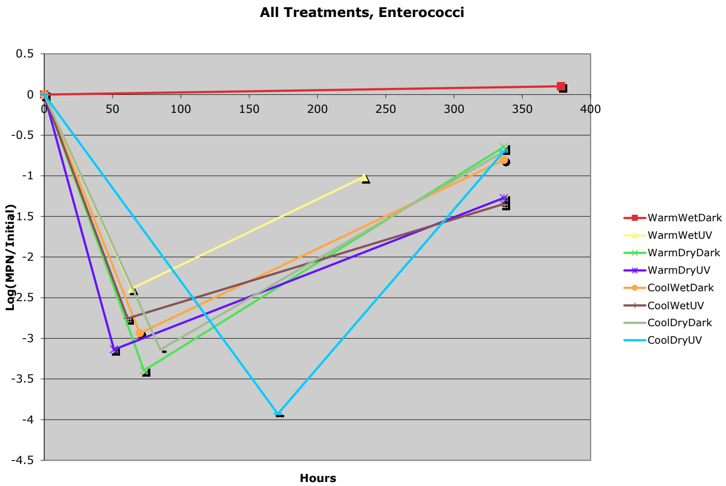
Enterococci was more persistent than *E. coli* with no removal noted for warm, wet, and dark conditions, with re-growth after the two day initial rapid die-off period for the other conditions.



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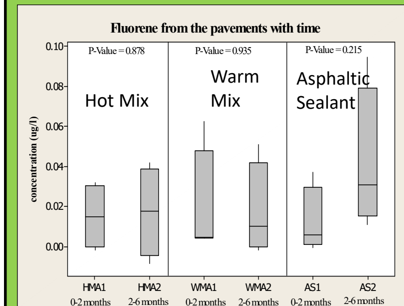
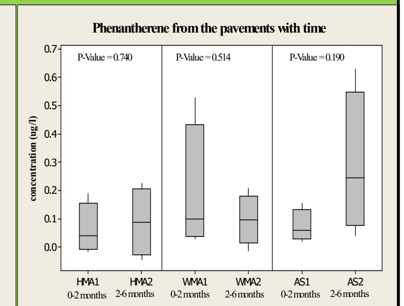
Pollutant Releases During the Initial Aging of Asphaltic Pavements

Fluorene, Anthracene, Pheneanthrene, Pyrene, and Benzo(a)pyrene from the pavement with the sealer indicated increasing concentrations with increasing exposure, while the hot mix and warm mix asphalt pavements showed little PAH concentration changes with time for these and other PAHs.





The PAH concentrations in the pavement runoff samples were very low (most less than 1 μg/L).

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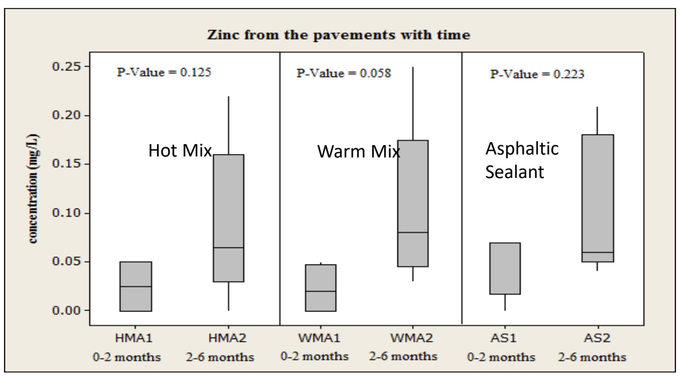
Zinc Concentrations in Pavement Runoff



- Pb, Cd and Cr always below the detection limits in all samples.
- Zinc showed an increasing trend with the aging of the pavement, with the highest concentrations being 210 to 250 μg/L after the 6 month aging period.

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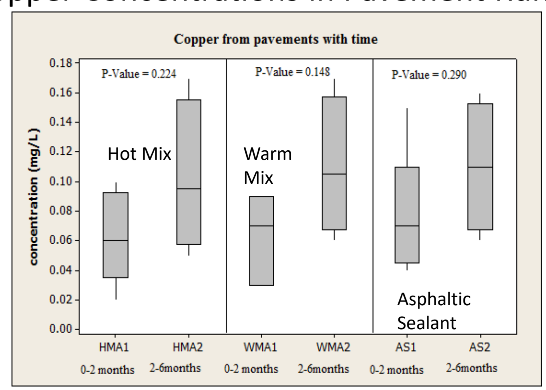
Copper Concentrations in Pavement Runoff



Cu release from the pavements showed a weak increasing trend with the highest concentrations being about 170 μg/L for the final sample at the end of 6 months of aging of the pavements.

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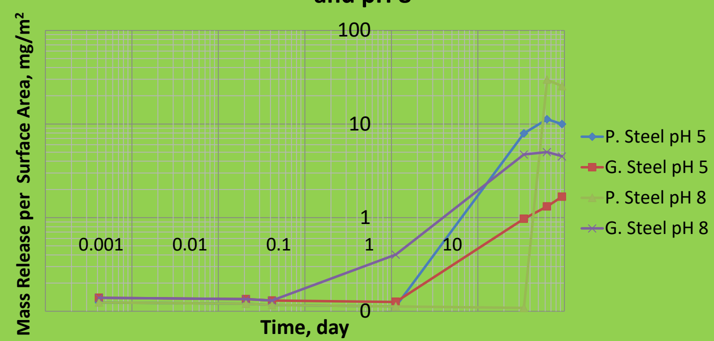
Lead Releases for Pipe/Gutter Materials at pH 5 and pH 8



- ❑ Lead release was observed only for galvanized steel.
- ❑ Lead losses occurred only after about several hours to one day of exposure.
- ❑ The highest lead release was about 0.7 mg/L (corresponding to about 30 mg/m²).

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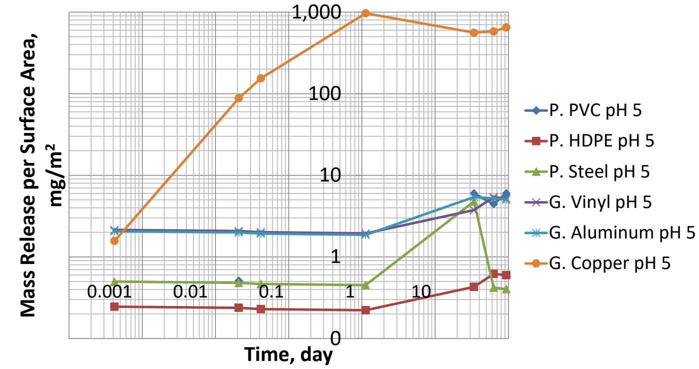
Copper Releases at pH 5



- ❑ The highest copper release was observed from copper materials at pH 5. After about one day of exposure, the copper concentration was more than 6 mg/L (970 mg/m²).
- ❑ Copper release was also found for the other materials, but at much lower concentrations.

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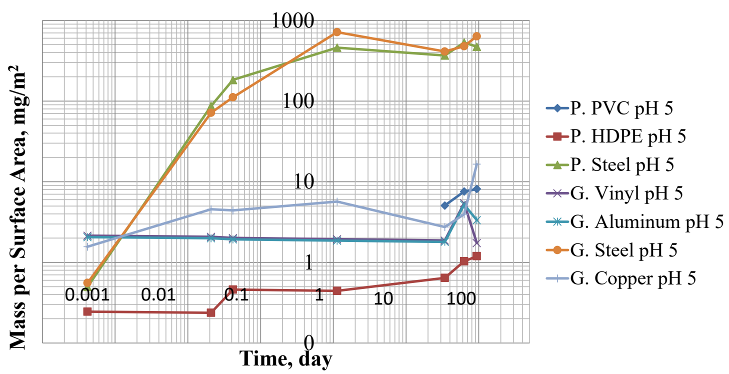
Zinc Releases at pH 5



- ❑ Zinc losses were the highest for galvanized steel materials (as high as 100 mg/L)
- ❑ Copper materials were the second highest source of Zinc release
- ❑ Concrete and Plastic materials were the lowest source of zinc

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Leaching of Heavy Metals from Treated Wood Ash with Different Amendments

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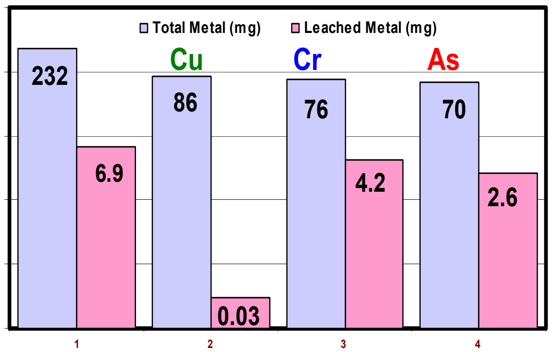
Metals Present and Leached from Soil/Ash Mixture (mg g^{-1} & %)



Leaching Trend : Cr>As>Cu

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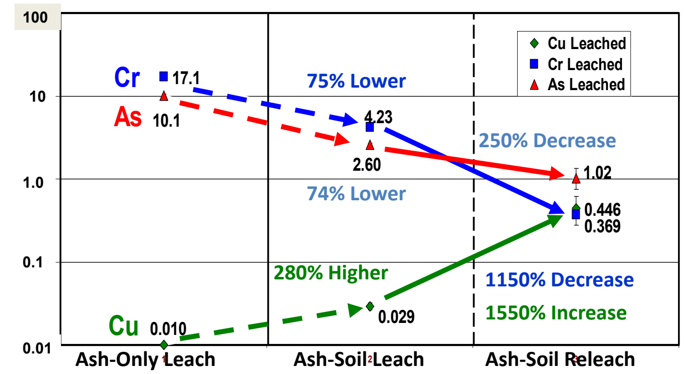
Batch Leaching of CCA-ash & Soil/CCA-ash Mixture



Therefore natural soil retards Cr & As mobility

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PAHs in Urban Stream Sediments

Site 1: Cribbs Mill Creek

- Source areas: medium density two story family home residential area
- No history of sanitary sewage contamination

Site 2: Hunter Creek

- Source areas: automobile service commercial areas, heavy traffic along McFarland Blvd., and runoff from trailer park residential areas

Site 3: Carroll Creek

- Source areas: A residential area on one side and forested lands on the other side of the creek
- Has a recent history (in 2006) of sanitary sewer overflows (SSOs) into the creek

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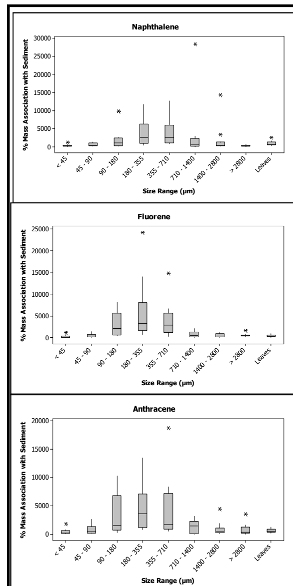
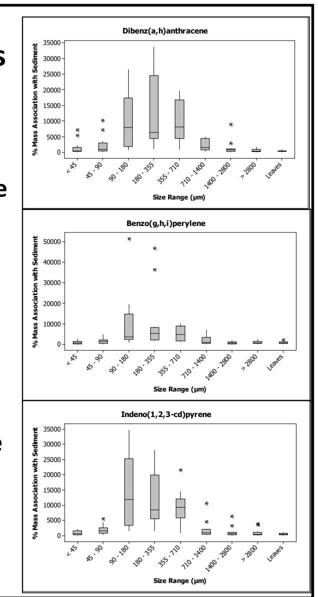


Mass of PAHs by Particle Sizes

Almost all of the sediment PAHs are associated, by mass, in the intermediate particle size fraction (90 to 710 µm), even though this size range had the lowest concentrations



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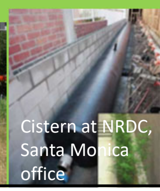
Stormwater Non-potable Beneficial Uses

Selected Case Studies Examined:

- Asia (Singapore, Japan, Thailand, Indonesia, Philippines, Bangladesh, China, South Korea, and India)
- Africa (South Africa, Kenya, and Tanzania)
- Europe (Germany and Ireland)
- Australia (South Australia, Queensland, Victoria, and New South Wales)
- North America (US Virgin Islands, Florida, Hawaii, Washington, New York, Maryland, California, Missouri, Oregon, Washington, D.C., and North Carolina)


Rainwater jars in Thailand


Park over stormwater harvesting tanks at Docklands, Melbourne


Cistern at NRDC, Santa Monica office


Cistern at Wash. U., St. Louis

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Comparison of East Coast vs. Central US Roof Runoff Harvesting Potential for Medium Density Residential Areas (can't use the same designs everywhere!)

Region	total roof area (%)	landscaped area (%)	study period annual rain fall (in) (1995 to 2000)	maximum roof runoff control (%), silty soil	storage tank size for max roof runoff control (ft^3 storage/ft^2 roof area), silty soil
Central	18.1	62.5	33.5	90.6	0.72
East Coast	15.9	54.5	53.0	60.1	2.00

✓The Central US area has a higher potential level of control compared to the East Coast because the ET demands better match the rain fall pattern.

✓The Southwest US area is challenging due to large mismatches in timing of ET/irrigation requirements and availability of rains (would need very large tanks for long-term storage).

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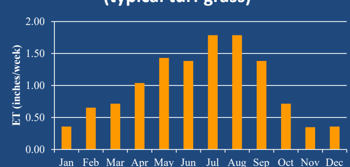
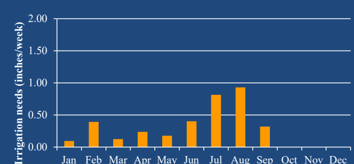
Kansas City Green Infrastructure Demonstration Project: Calculations of Water Harvesting Potential of Roof Runoff

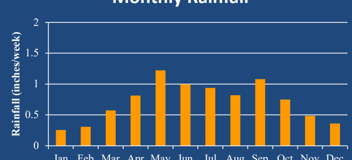
Evapotranspiration per Month (typical turf grass)



Supplemental Irrigation Needs per Month (typical turf grass)



Monthly Rainfall



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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Cistern/Storage Tank Sizing vs. Performance

Storage per house (ft^3 per ft^2 of roof area)	Reduction in annual roof runoff (%)	Number of 35 gallon rain barrels for 945 ft^2 roof	Tank height size required if 5 ft D (ft)	Tank height size required if 10 ft D (ft)
0.005	24	1	0.24	0.060
0.010	29	2	0.45	0.12
0.020	39	4	0.96	0.24
0.050	56	10	2.4	0.60
0.12	74	25	6.0	1.5
0.50	99	100	24	6.0

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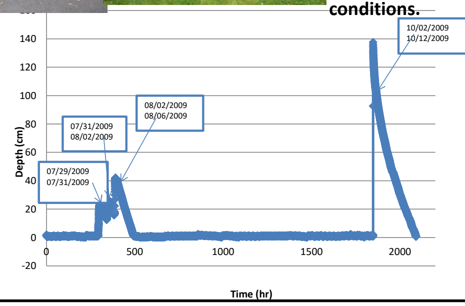
Nine dry wells are being monitored in Millburn, NJ as part of EPA project for long-term hydraulic performance, and six were monitored to examine surface and subsurface water quality conditions.

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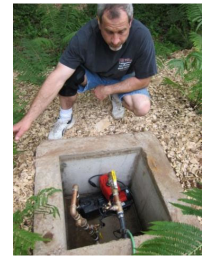

This major home restoration project included the installation of underground water storage tanks instead of dry wells. Homes in this neighborhood have summer water bills approaching $1k/month for landscape irrigation, so the economic benefits of irrigation using stormwater are very good.


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Designs and Evaluations to Support Biofiltration Systems in the Southwestern U.S.

- With very low numeric effluent limits, site requires designs refined to a much higher degree than in typical practice
- Need to optimize stormwater control performance through various design factors:
  - Treatment trains using combinations of sedimentation and media filtration
  - Long sedimentation pre-treatment drainage time
  - Sufficient media contact time to increase control of critical constituents
  - Specially-selected filtration media
- Bench-scale laboratory and pilot-scale media testing was therefore conducted to provide needed performance and design information.

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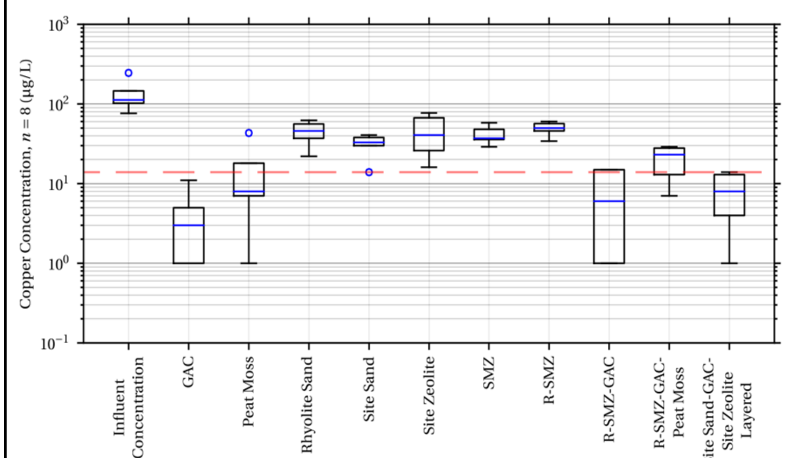
Media Performance Plots for Copper, Full-Depth Long-Term Column Tests



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Urban Runoff Quality and Treatability

Pollutants	Media Treatment Notes
NH_3-N	NH_4^+ removed by organic media with variety of removal sites. May be removed by ion-exchange resins/zeolites if limited competition from +2 ions.
NO_3-N	Uptake by plants. Limited removal below root zone. Leaches. (AEC)
PO_4-P	Removed in high AEC or high Al/Fe media. Leaches if excess P in soil. (use soil test for preliminary determination) (low P; low OM)
TSS	Removal excellent for particles greater than 1 – 2 µm.
Cu, Total	Particulate fraction removed to some extent; Limited physical removals for Cu bound to particles smaller than 1 – 2 µm.
Cu, Dissolved	Valence charges range from +3 to -2. Cations potentially removed in ion-exchange resin. Anions and small positive charges likely removed in organic media with variety of removal sites. (CEC/OM)
Zn, Total	Particulate fraction removed to some extent; Limited physical removals for Zn bound to particles smaller than 1 – 2 µm.
Zn, Dissolved	Valence charges range from +3 to -2. Cations potentially removed in ion-exchange resin. Anions and small positive charges likely removed in organic media with variety of removal sites. (CEC/OM)

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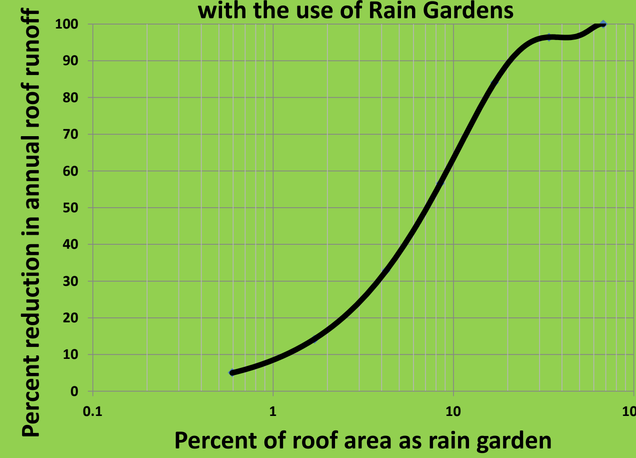
Green Infrastructure Controls in Kansas City CSO Study Area

Reductions in Annual Flow Quantity from Directly Connected Roofs with the use of Rain Gardens



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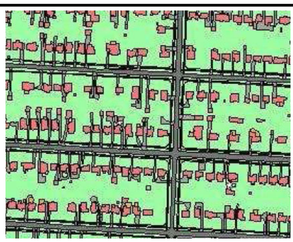
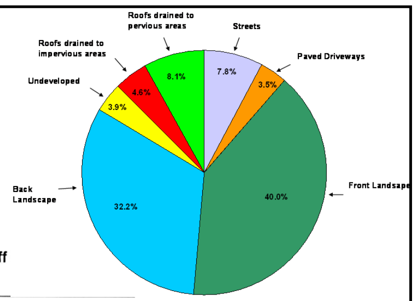
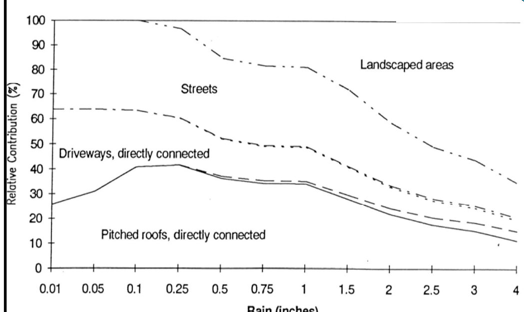


Medium Density Residential Area, Runoff





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

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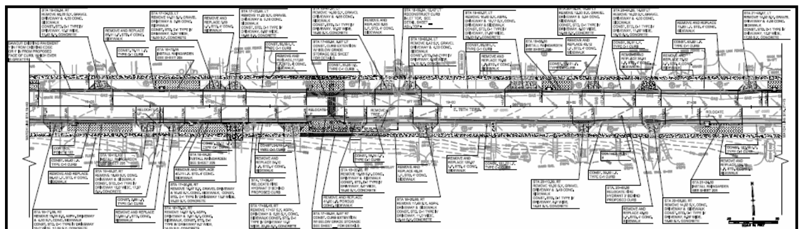
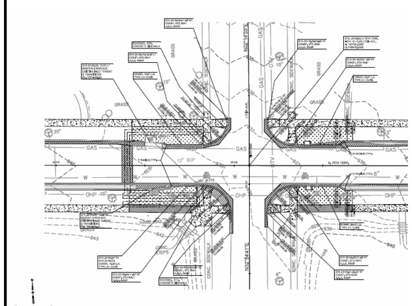
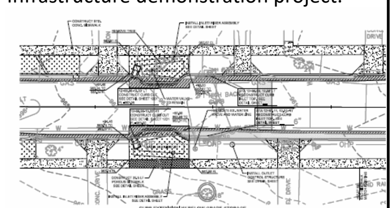




Examples from “65%” plans prepared by URS for project streets. Plans reviewed and modeled by project team, and construction will occur in spring and summer of 2011 in Kansas City for Green Infrastructure demonstration project.



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Stormwater Treatment Technologies that are Good Candidates for the Removal of Wet Weather Emerging Contaminants

- Biofiltration and bioinfiltration. We are conducting groundwater fate modeling to investigate potential groundwater contamination of ECs during infiltration through different soils
- Sedimentation. Our fugacity modeling indicates that many ECs are associated with particulates and can be trapped in wet detention ponds
- Other commonly used stormwater controls likely have less potential treatability of most emerging contaminants due to high flow rates and short contact periods
- Activated sludge and strong oxidation have been shown to be good treatment unit operations for emerging contaminants at wastewater treatment plants, but these processes are not common for stormwater control, but are used at treatment facilities receiving combined sewage.

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Some Targeted Compounds

- Acidic Pharmaceuticals
  - ❖Sulfamethoxazole
  - ❖Carbamazepine
  - ❖Trimethoprim
  - ❖Fluoxetine
  - ❖Ibuprofen
  - ❖Gemfibrozil
  - ❖Triclosan
- PAHs
  - ❖Naphthalene
  - ❖Acenaphthylene
  - ❖Acenaphthene
  - ❖Phenanthrene
  - ❖Fluorene
  - ❖Anthracene
  - ❖Flouranthene
  - ❖Pyrene

Basic pharmaceuticals and pesticides are also being studied

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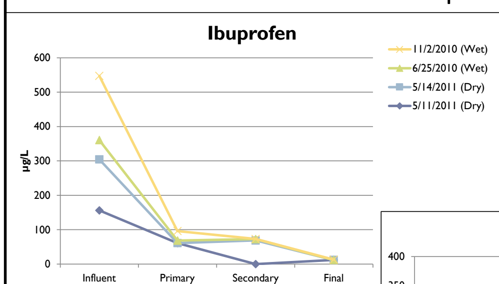
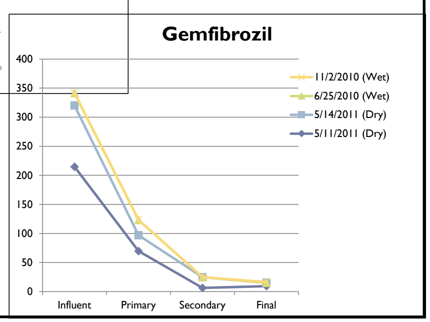
Comparison of wet and dry weather flow treatment at the Tuscaloosa wastewater treatment plant for pharmaceuticals



The wet weather flows generally have higher influent concentrations, but the effluent quality is similar. The treatment plant also shows excellent treatment during all flow conditions.



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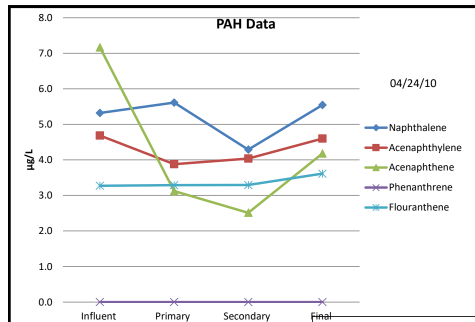
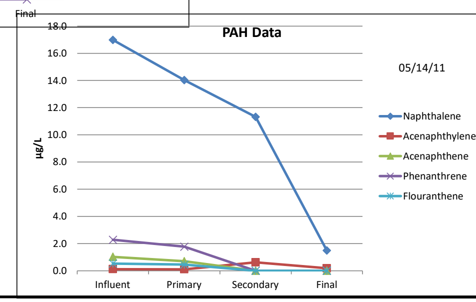


Treatment at the Tuscaloosa wastewater treatment plant for PAHs

PAHs have a more varied treatment performance, with some days having very low influent conditions.



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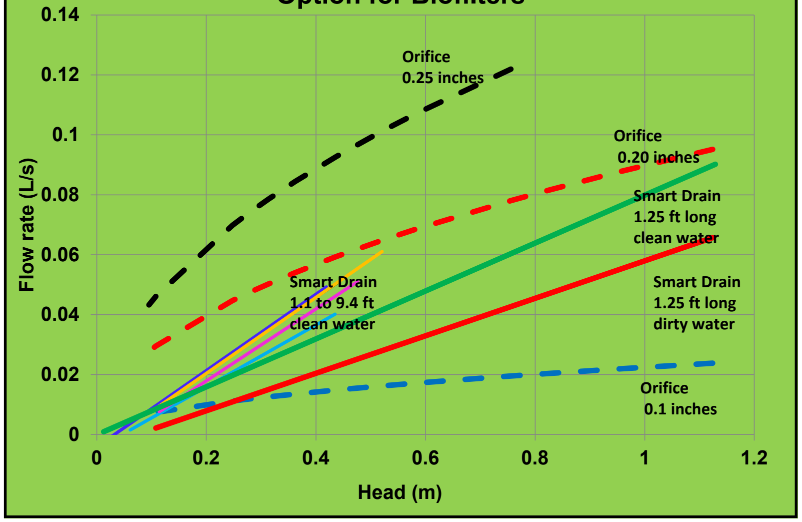
Testing of the SmartDrain™ as a More Effective Flow Control Option for Biofilters



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Biofouling Testing of SmartDrain™ Material

- The Formica-lined plywood box was also used to verify the head vs. discharge relationships for the biofouling tests.
- The SmartDrain™ was installed on top of a 4" layer of the drainage sand, and another 4" layer of the sand was placed on top of the SmartDrain™.
- The box was filled with tap water and left open to the sun for several weeks to promote the growth of algae. Two different species of algal and liquid fertilizer were added to the test

Trial No.	Drainage date	algae exposure period(days)
1	17-Jun-10	14
2	8-Jul-10	35
3	25-Jul-10	52
4	12-Aug-10	70
5	3-Sep-10	92
6	27-Sep-10	116
7	11-Oct-10	130

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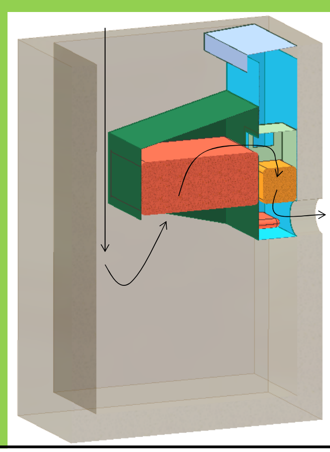
Full-Scale Testing of the Up-Flo™ Filter at Tuscaloosa, AL

From Prototype to Product



- Sump
- Screen
- Upflow Filter
  - Media Bags
- Weephole
- Bypass
- Floatables Trap
- *Secondary Media*

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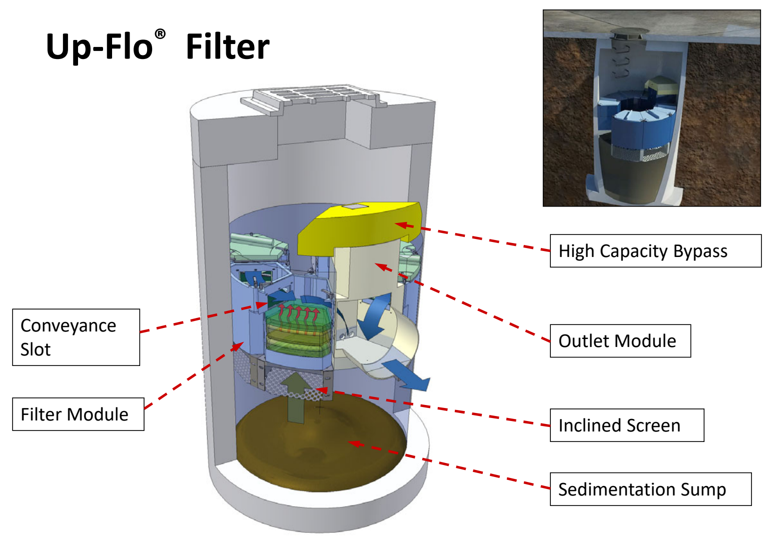
Up-Flo® Filter



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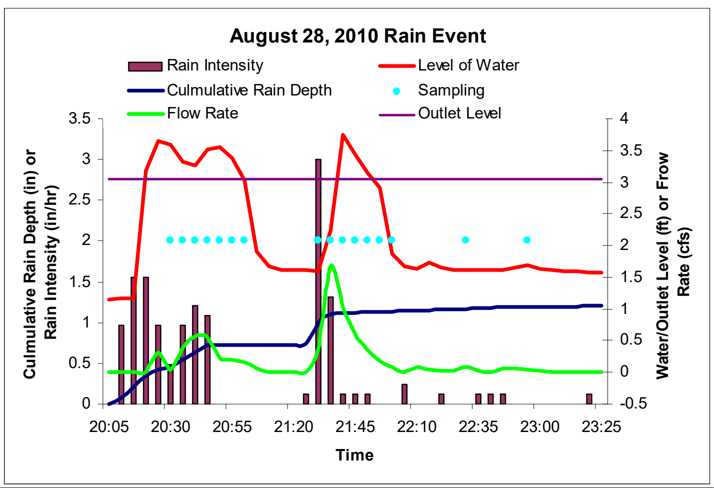
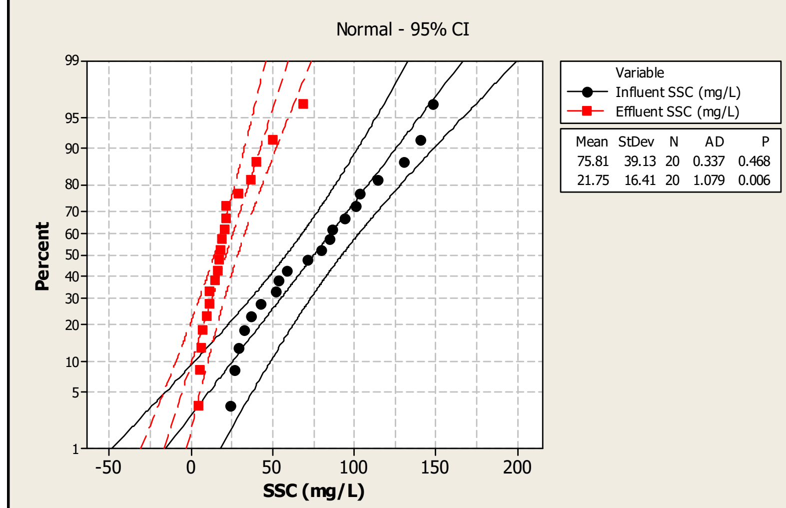
Up-Flo® Filter Installation in Vault for Large Flows

Current Full-Scale Test Setup in Tuscaloosa, AL

Hydrology Graph at BamaBelle Site



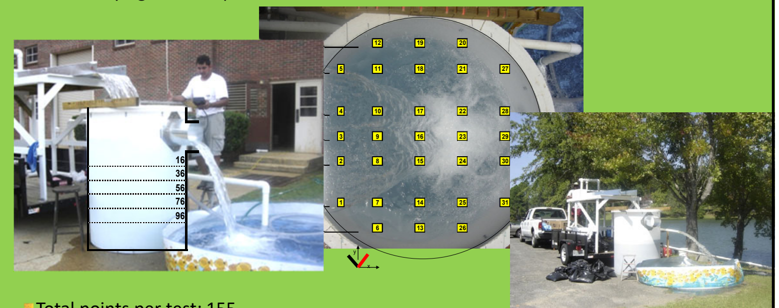
Influent and Effluent SSC (mg/L) Probability Plots



Particle size range (µm)	SS influent mass (lb)	SS effluent mass (lb)	% Reduction (%)
0.45-3	0.3	0.2	39
3-12	10.7	5.1	52
12-30	35.7	12.4	65
30-60	81.2	12.4	85
60-75	24.3	1.7	93
75-150	43.0	1.3	97
150-250	21.9	2.8	87
250-425	21.4	0.4	98
425-850	30.1	0	100
850-1400	21.2	0	100
1400-2000	15.7	0	100
2000-4760	17.6	0	100
>4760	10.9	0	100
Sum	334	36	86

CFD Calibration and Modeling of Scour of Captured Sediment in Storm Drain Catchbasin Inlets

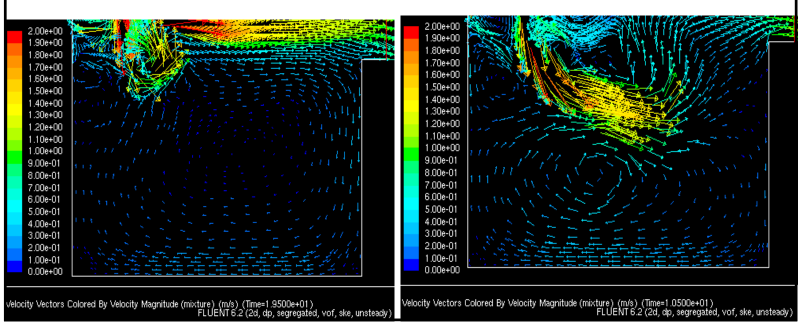
- Three flow rates: 10, 5, and 2.5 LPS (160, 80, and 40 GPM)
- Velocity measurements (Vx, Vy, and Vz)
- Five overlying water depths above the sediment: 16, 36, 56, 76, and 96 cm



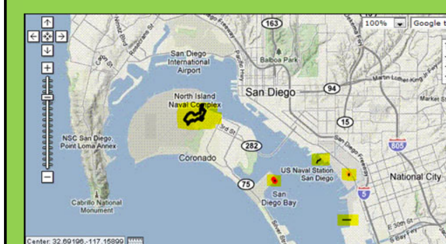
- Total points per test: 155
- 30 instantaneous velocity measurements at each point

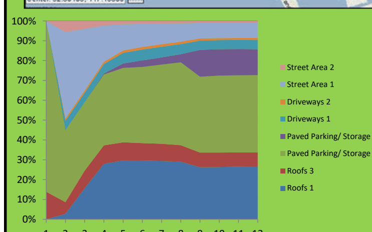
CFD Modeling to Calculate Scour/Design Variations

- Used CFD (Fluent 6.2 and Flow 3D) to determine scour from stormwater controls; results being used to expand WinSLAMM analyses after verification with full-scale physical model
- This is an example of the effects of the way that water enters a sump on the depth of the water jet and resulting scour



Naval Facilities use of WinSLAMM – Calibration and Source Evaluation of San Diego Test Watersheds





The model is being tested and calibrated against historical data for a number of drainages at Navy facilities and validated against an additional set data. The model will then be implemented Navy-wide for environmental managers to apply to their facilities.

The Use of WinSLAMM to Evaluate Stormwater Control Options for Controlling Bacteria and Nutrients in the Antelope Creek Watershed, Lincoln, NE

WinSLAMM identified stormwater pollutant sources and candidate control practices for the Antelope Creek watershed in Lincoln, NE. The controls examined included:

- Roof runoff controls: rain gardens, disconnections, rain barrels and larger water tanks
- Pavement controls: disconnections, biofiltration, and porous pavement
- Street side drainage controls: grass swales and curb-cut biofilters
- Public works practices: street cleaning and catchbasin cleaning
- Outfall controls: wet detention ponds

The project included calculated runoff characteristics and the estimated costs (capital costs, land costs, maintenance costs, total annual costs, and total present value cost) and the unit removal costs.

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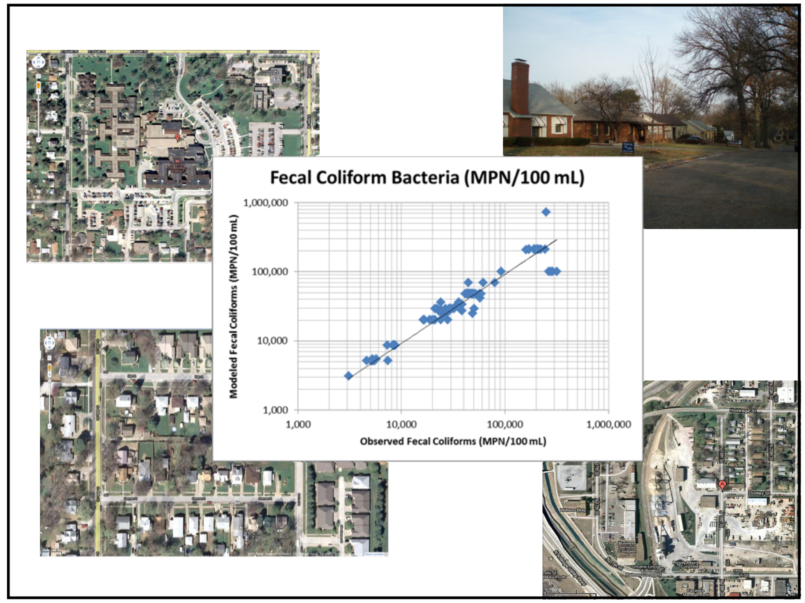

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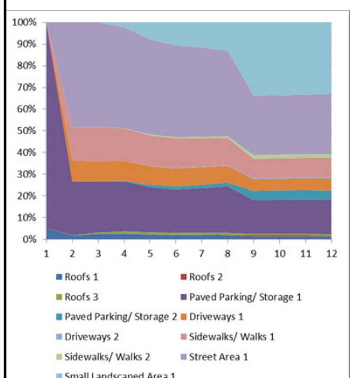
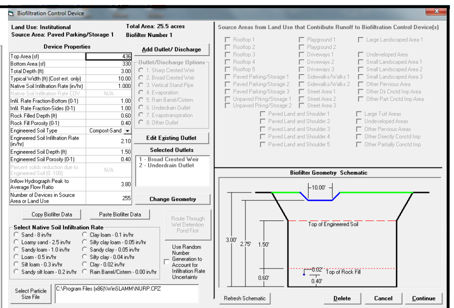
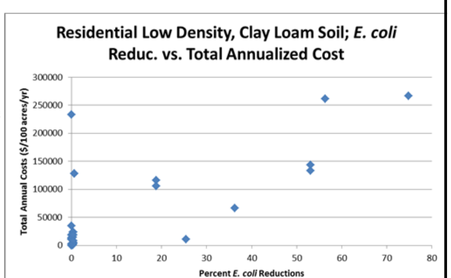


Residential Areas Fecal Coliform Contributions
Rains: 1: 0.01"; 2: 0.05"; 3: 0.1"; 4: 0.25"; 5: 0.5"; 6: 0.75"; 7: 1"; 8: 1.5"; 9: 2"; 10: 2.5"; 11: 3"; 12: 4"





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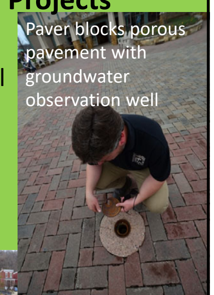
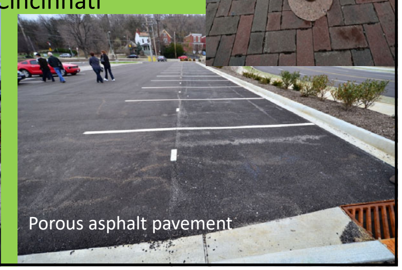
Strategies and Experimental Design for Monitoring the Performance of Various Green Infrastructure Controls for CSO Sites at Cincinnati Demonstration Projects

Cincinnati State Technology School

Cincinnati Zoo

University of Cincinnati





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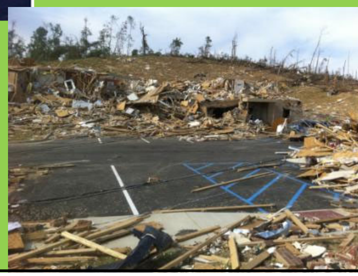
Chastain Manor, Tuscaloosa, AL, F5 Tornado Damage, April 27, 2011

We are working 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.



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We are developing a fast track design manual, doing site designs, and reviewing 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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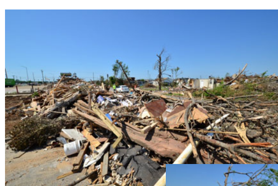
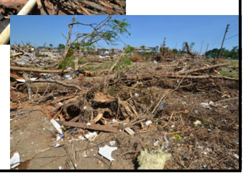
A clean slate at the Krispy Kreme location… total destruction of building, was totally impervious and will now have to meet new stormwater regulations with volume reductions. Surrounding destroyed neighborhoods will also receive attention, although individual homes are exempt from current stormwater regulations.





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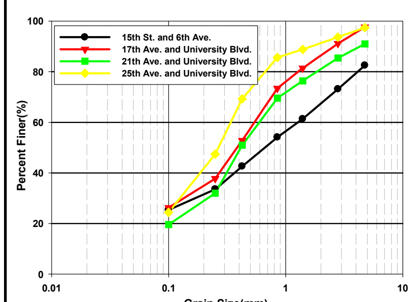
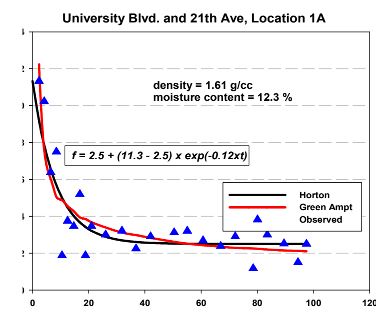
Soil and infiltration information being collected to aid in the design and evaluation of new controls

	initial infilt. rate (in/hr)	final infilt. rate (in/hr)	K (1/min)	dry density (g/cm^3)	moisture content (%)	median size(D_{50})
average	10.7	4.4	0.07	1.7	15.9	0.4
min	1.7	1.9	0.01	1.6	12.3	0.3
max	17.0	8.3	0.15	1.9	19.8	0.7
COV	0.4	0.5	0.69	0.1	0.2	0.4

Comparing large and small-scale infiltration test results





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