Stormwater Management Research and Applications

Bits and Pieces from 50 Years of Stormwater Research

excerpts from 2021 Julian Hinds Award Presentation

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Multi-Facet Monitoring Needed to Understand Stormwater Effects, Sources, and Treatment

- Receiving waters (water quality, sediment quality, flows, benthos, fish, aquatic plants, etc.)
- Outfall discharges from many land uses for different seasons (usually for "all" events over long periods of time)
- Source areas (pavements, roofs, landscaped areas, etc.)
- Treatability and development of stormwater controls

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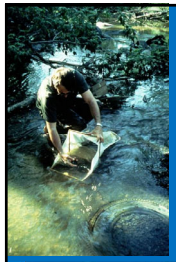
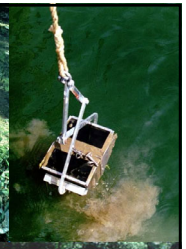
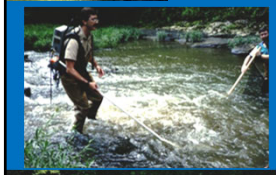
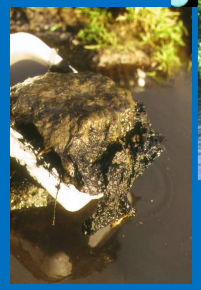
Fate and effects of stormwater pollutants and actual receiving water effects need to be directly monitored

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Stormwater Effects

- **Sediment (amount and quality)**
- **Habitat destruction (mostly through high flows [energy] and sedimentation)**
- **Eutrophication (nutrient enrichment)**
- **Low dissolved oxygen (from organic materials)**
- **Pathogens (urban wildlife vs. human wastes)**
- **Toxicants (heavy metals and organic toxicants)**
- **Temperature**
- **Debris and unsafe conditions**
- **etc.**

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A lot of stormwater flow and quality data have been collected over many years






It is important to compare these observations with model assumptions and to use these data for calibration and verification

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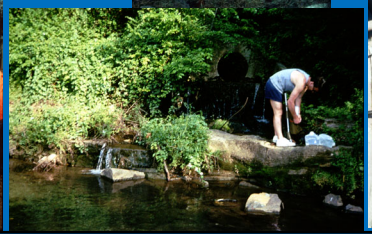
Many types of runoff monitoring have been used to understand stormwater pollutant transport and fate, from small source areas to outfalls.








When studying urban drainage systems, failing infrastructure also becomes obvious:

- Transportation accidents (vehicles and pipelines) can affect storm drainage systems
- Sanitary Sewer Overflows
- Inappropriate Discharges

Photo from Bellingham Herald

Photo from Birmingham News

Urban Hydrology Considerations for Stormwater Quality Analyses are Quite Different than for Drainage Design

- Pavement runoff during small and intermediate storms
- Runoff from other impervious areas
- Disturbed urban soils affected by cut and fill operations and by compaction
- Evapotranspiration of landscaped areas and beneficial uses of stormwater for irrigation
- Interception of rainfall by urban trees

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Urban Soils Compacted during and after Development

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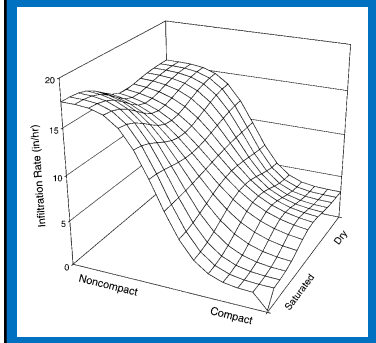
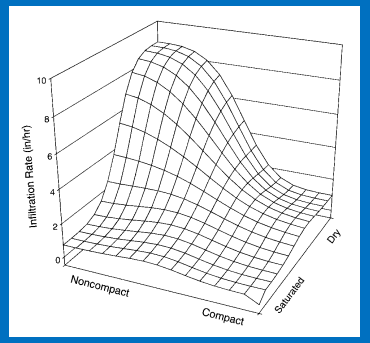
Infiltration Rates in Disturbed Urban Soils





Sandy Soils **Clayey Soils**

Infiltration rates of disturbed urban soils are more strongly influenced by compaction than by moisture for sandy soils and by both compaction and moisture in clayey soils.

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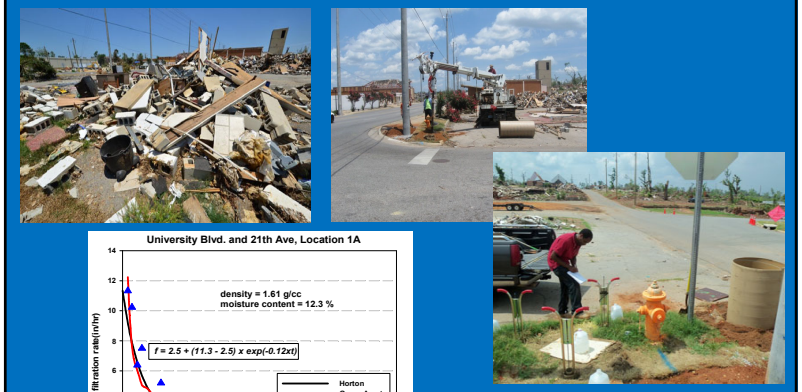
Stormwater Bioinfiltration Site Studies in Tuscaloosa Areas Devastated by Tornado



Bore Hole Drilling, Double-ring and Bore Hole Infiltration Measurement Installations

Sileshi 2013 11

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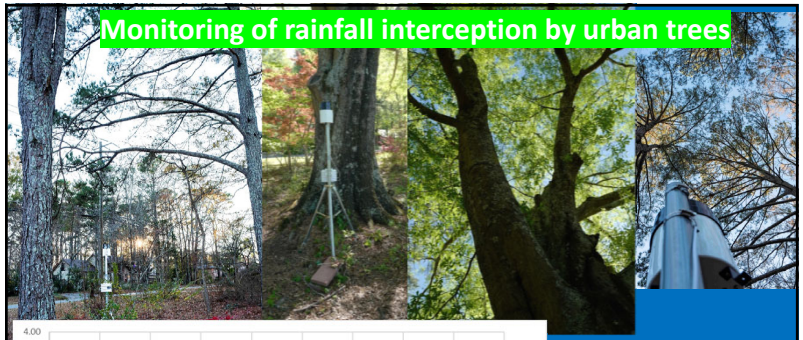
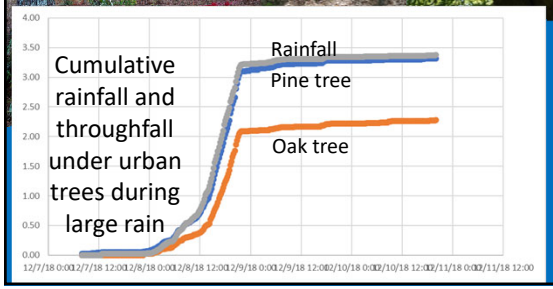
Monitoring of rainfall interception by urban trees





Interception mostly affected by tree species and is much less in urban areas compared to dense stands of trees in forest environments. Major benefit is when covering directly connected impervious areas.

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Potential Contamination of Groundwater and other Effects due to Stormwater Infiltration

- Groundwater contamination potential from infiltrating stormwater is decreased with treatment before discharge to the groundwater, proper media selection, or located in an area having little contamination potential.
- Mounding below infiltration sites can severely reduce infiltration rates
- Increased groundwater recharge may increase groundwater flows to adjacent urban streams.

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Direct Surface Water Connections to Groundwater in Karst Areas (rarely so obvious)

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Potential Problem Stormwater Pollutants Identified using a Weak-Link Model Having the Following Components:

- Their abundance in stormwater,
- Their mobility through the unsaturated zone above the groundwater, and
- Their treatability before discharge.

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Example Weak-Link Model Influencing Factors

Constituent	Abundance in Stormwater	Mobility (sandy/low organic soils)	Filterable Fraction (treatability)
Nitrates	low/moderate	mobile	high
Chlordane	moderate	intermediate	very low
Anthracene	low	intermediate	moderate
Pyrene	high	intermediate	high
Lead	low/moderate	very low	very low

Pretty obvious: Best to infiltrate stormwater having low concentrations of problem pollutants through surface soils having high organic content. Potential problems with contaminated stormwater infiltrated in injection systems or dry wells without adequate treatment before discharge.

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Need Combinations of Stormwater Control Unit Processes (such as incorporating storage, sedimentation and infiltration)

- Infiltration alone can be effective in reducing most stormwater pollutants and flows.
- Sedimentation before infiltration offers advantages of pre-treatment and protection of infiltration controls.
- Storage before infiltration enhances treatment at low treatment flows and reduces high flows to treatment flow rates.

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Significant Issues

- Are source area distributed controls effective in reducing outfall discharges?
- Can results from small-scale laboratory and pilot-scale field experiments be up-scaled to large, long-term installations?
- How robust are stormwater controls for extended periods?

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Development and Testing of Treatment Methods

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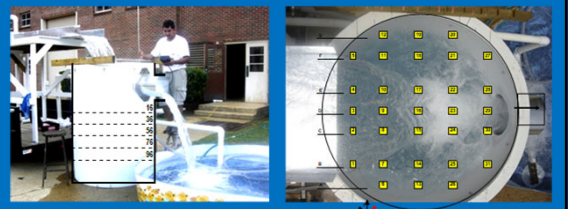
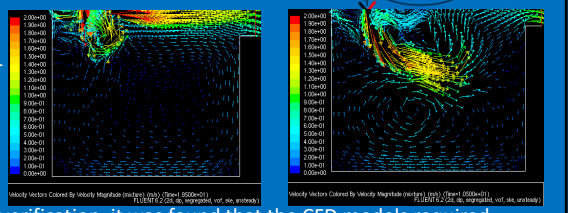
The Simplest System but Still with Surprises: Hydrodynamic Tests on Catchbasin with Sump

Calibrated CFD models (Fluent and Flow 3D) with 3D flow tests using acoustic doppler velocity meter along with scour tests.



The way water enters the sump and the amount of entrained air in the stormwater affects the depth of the water jet and resulting scour velocities.



During calibration and verification, it was found that the CFD models required modifications (air entrainment plus sediment transport) to duplicate the field observations.

Avila 2008

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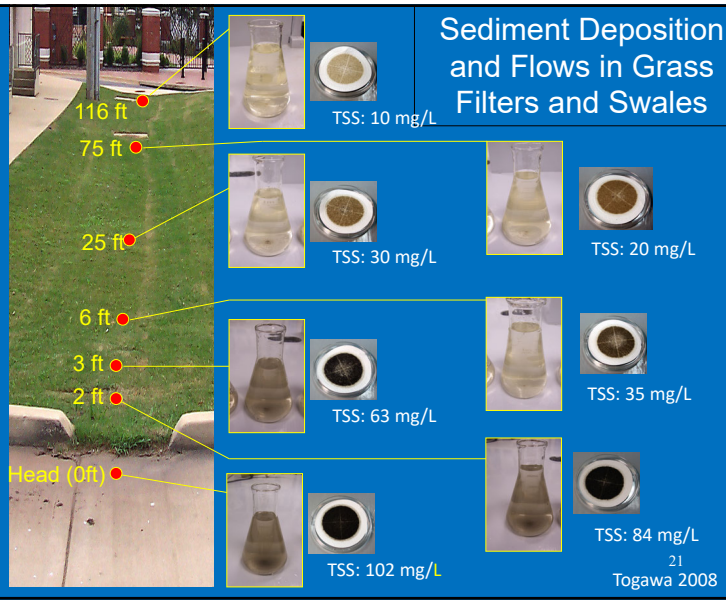
Sediment Deposition and Flows in Grass Filters and Swales



Togawa 2008

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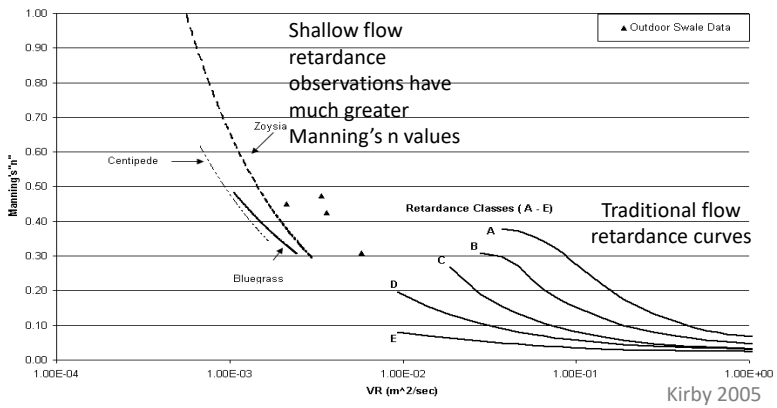
Shallow Flow Retardance in Grass Swales vs. Conventional Stillwater, OK, Retardance Curves



Kirby 2005

Flow retardance in small urban drainage systems with shallow flows is quite different than for flows in larger systems.

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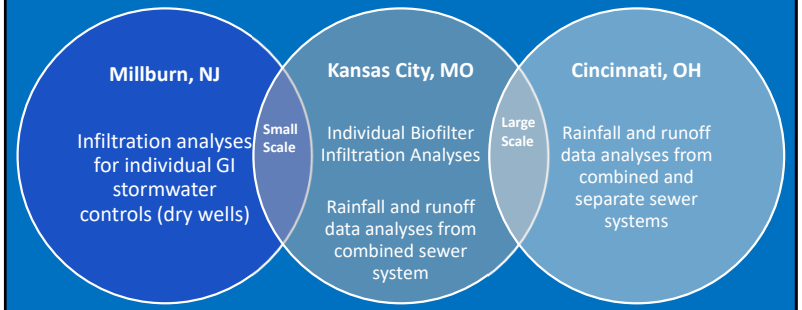
Comparing Small-scale Test Results to Large System Responses



Talebi 2014

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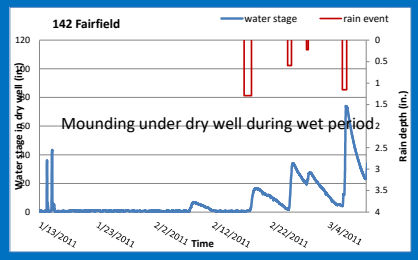
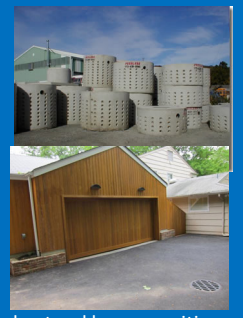
Small-Scale Monitoring

- Dry wells required to infiltrate increased flows from newly developed impervious areas.
- There is increasing use of underground water storage tanks to use stormwater for irrigation.





Water table elevation and subsurface soils poorly understood by many cities and expected performance may not be achieved.

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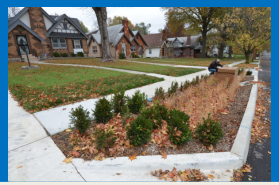
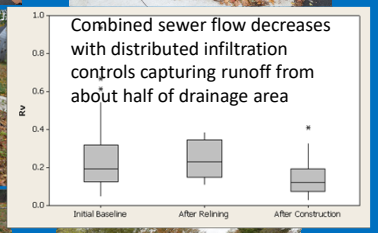
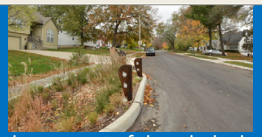
Small and large-scale performance monitoring at Kansas City, MO






Retrofitted controls are limited in the amount of the whole drainage area served.

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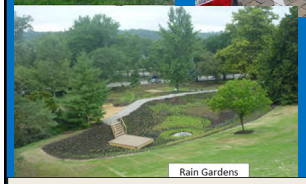
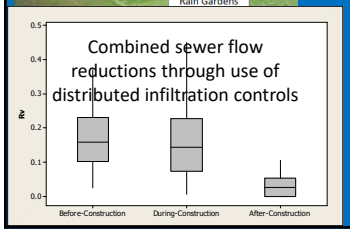
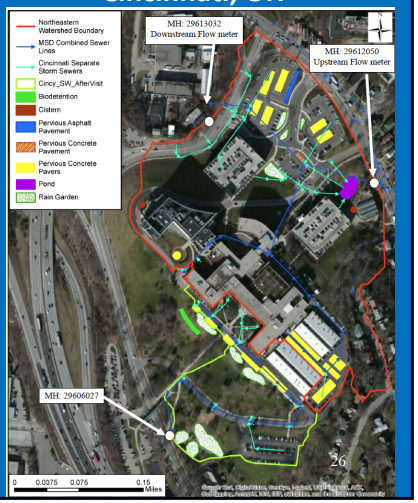




Distributed controls at combined sewer demonstration projects in Cincinnati, OH



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Laboratory Tests to Develop Media to Treat a Broad Range of Stormwater Contaminants

How well do these work when used at large-scale installations?

- Long-term column tests using actual stormwater:
  - Clogging, breakthrough, and pollutant removal
  - Effects of contact time and media depth on removal
- Batch tests:
  - Media uptake capacity and removal kinetics
  - Aerobic and anaerobic effects on pollutant mass removed



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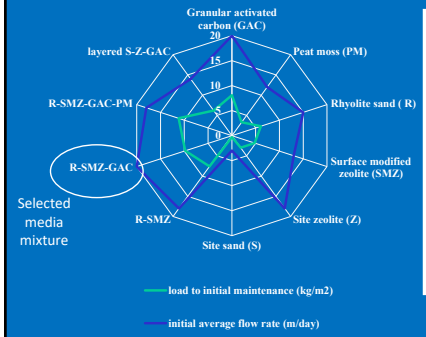
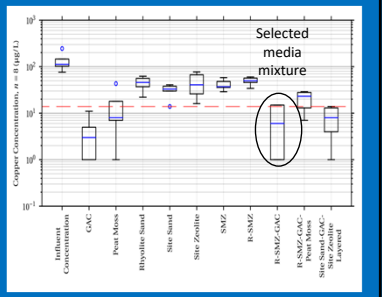
Column Tests for Flow Rates, Clogging Load, and Pollutant Removal





Selected media (mixture of Rhyolite sand, granular activated carbon, and surface modified zeolite had best combination of hydraulic attributes and pollutant removal performance and was therefore used at full-sized media treatment facilities on site.

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Preparing Media for Large Biofilters

Filling individual media bags prior to mixing

Loading media bags into mixer for blending media mixture

Finished mixed media loaded into final bags

Mixed media ready for placement into biofilters

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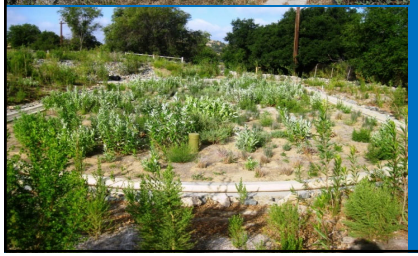
Some of the Santa Susana Field Lab (SSFL) distributed stormwater controls using media selected during laboratory studies



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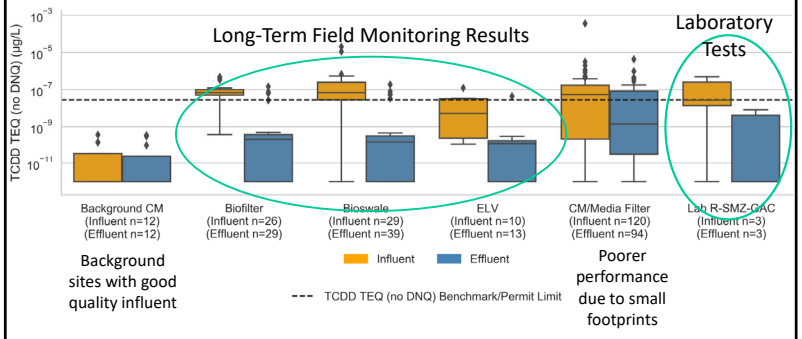
Comparisons of Lab Performance Tests with Six to Nine years of Full-scale Field Performance Monitoring Results



Background sites with good quality influent

Poorer performance due to small footprints

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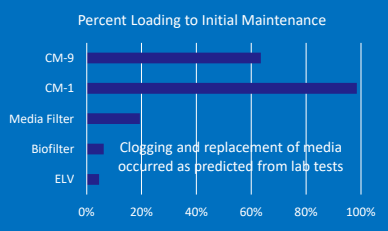
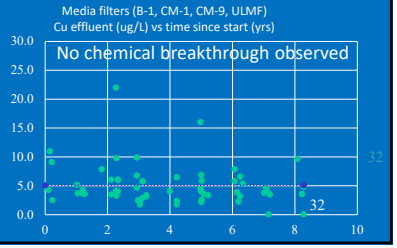
Long-Term Field-Scale Performance Evaluations

- Long-term hydraulic performance was evaluated using several metrics
  - Cumulative solids load used to assess remaining time until clogging
  - Temporal trends to evaluate treatment performance and signs of breakthrough
    - Influent and effluent concentrations
    - Influent and effluent particulate strengths
    - Lab studies showed clogging to precede chemical breakthrough





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Study Design Recommendations

Important factors to allow lab studies to provide accurate predictions of field-scale performance

- Use real stormwater
  - similar in overall composition, both influent concentrations of target pollutants and other water quality parameters (major ions and fine sediment) (consider effects of storage)
- Use representative flow rates and durations
  - mimic design conditions
- Collect sufficient data
  - enables statistically rigorous evaluations
- Measure cumulative solids loading until clogging
  - allows estimation of media lifetime for full-scale system
  - The media can be selected and sized so clogging would occur before breakthrough

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  - TetraTech
  - Geosyntec
  - HydroInternational
  - Institute of Scrap Recycling Industries
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Many of our research reports, student's theses, and dissertations are available at my teaching and research web site at:

- http://rpitt.eng.ua.edu/index.shtml

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