Evaluating Stormwater Solutions in Ohio’s Lake Erie Basin

Collaborative Learning Group meeting

July 17th, 2013
Welcome

1. Introductions
2. Meeting objectives
3. Site visit wrap up
Meeting Objectives

• Visit Pepper Pike site.
• Discuss updated monitoring data from Perkins and learn about monitoring of all sites.
• Discuss and given input on project plans for tool development for 2014.
• Review model codes checklist and explore ways to strengthen and use the checklist.
• Hear about modeling and parameters.
Pepper Pike Infiltration Tests
Pepper Pike Infiltration Tests

- Soil: mapped Mahoning Urban Complex; 15-18” below original grade; silty clay loam texture
- Four valid SRI tests completed 7/9/13
- Test results: 0.01, 0.01, 0.02, 0.05 in/hr
Site Visit Wrap Up

• Final thoughts?
• Infiltration test results
• Lessons learned?
Monitoring Data at Perkins & Monitoring Site Updates

Ryan Winston, North Carolina State University
Perkins Township

• Outcome of concrete inspection
• Status of swale stabilization
• Monitoring ongoing
Perkins Township: Data Collection

- Data collection began on April 3, 2013
- Rain gauge & weather station recording climatic data
- 3 monitoring locations
  - Western permeable pavement application
    - Underlying soils very tight (0.01 in/hr in two infiltration tests)
  - Eastern permeable pavement application
  - Western permeable pavement monitoring well
    - Logging water level on a two minute interval
Perkins Township: Revisited

- Standard Concrete Drive Lanes
- Permeable Concrete Parking Stalls
2\textsuperscript{nd} Monitoring Site
Perkins Township Monitoring Equipment Installation

- Completed over 1.5 days (April 2-3)
- Four parts to installation:
  - Two weir boxes in catch basins
  - Rain gauge and weather station
  - Sensors to monitor flow depth and salinity
  - Technology transfer to Biohabitats
Weather Data Collection

• Capturing the following data on a 1-minute interval:
  • Wind speed (mph)
  • Gust wind speed (mph)
  • Temperature (°F)
  • Relative Humidity (%)
  • Wind direction (φ)
  • Solar Radiation (W/m²)
Perkins Township Rainfall Data

Perkins Rainfall

04/01/13 to 05/23/13

Rainfall (inches)
## Rainfall Data Analysis

<table>
<thead>
<tr>
<th>Storm Event Date</th>
<th>Event No</th>
<th>Rainfall Depth (in)</th>
<th>Rainfall Duration (days)</th>
<th>Average Intensity (in/hr)</th>
<th>Antecedent Dry Period (days)</th>
<th>Peak 5-min Intensity (in/hr)</th>
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<tbody>
<tr>
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<td>1</td>
<td>2.58</td>
<td>1.976</td>
<td>0.054</td>
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<td>3.24</td>
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<td>4.035</td>
<td>0.48</td>
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<td>2.759</td>
<td>0.84</td>
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<td>4/28/2013</td>
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<td>0.26</td>
<td>0.320</td>
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<td>6</td>
<td>0.19</td>
<td>0.153</td>
<td>0.052</td>
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<td>0.027</td>
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<td>1.32</td>
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<td>0.304</td>
<td>0.015</td>
<td>0.834</td>
<td>0.36</td>
</tr>
</tbody>
</table>
Flow Monitoring at Perkins

- Monitoring data from two water level loggers in each weir box is very similar
Comparing Effluent Volume

- East PP application has a 0.57 acre watershed
- West PP application has a 0.43 acre watershed
  - Except for 2 largest storms (2.58 and 1.24 inches), West PP had less outflow than East PP application
- Five storms at West application had zero outflow, while all storms produced outflow from the East application
Peak Flow Rate Results

[Graph showing peak flow rates for different events and locations, with annotations indicating key values and trends.]
Comparing Against Predicted Peak Flow from Standard Asphalt

- Calculated using Rational Method \( Q_p = C \times i \times A \)
Water Level Measurement within Underlying Aggregate
Water Level Response to Rainfall
## Calculation of Drawdown Rate

<table>
<thead>
<tr>
<th>Begin Date</th>
<th>End Date</th>
<th>Beginning Stage (ft)</th>
<th>Ending Stage (ft)</th>
<th>Delta Stage (ft)</th>
<th>Delta time (days)</th>
<th>Drawdown Rate (ft/day)</th>
<th>Drawdown Rate (in/hr)</th>
</tr>
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<tbody>
<tr>
<td>4/3/2013</td>
<td>4/6/2013</td>
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<td>4/19/2013</td>
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<td>0.737</td>
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<td>4.56</td>
<td>0.027</td>
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<tr>
<td>4/25/2013</td>
<td>4/28/2013</td>
<td>0.954</td>
<td>0.819</td>
<td>0.135</td>
<td>3.36</td>
<td>0.040</td>
<td>0.020</td>
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<tr>
<td>4/29/2013</td>
<td>5/10/2013</td>
<td>0.887</td>
<td>0.615</td>
<td>0.272</td>
<td>11.46</td>
<td>0.024</td>
<td>0.012</td>
</tr>
<tr>
<td>5/11/2013</td>
<td>5/15/2013</td>
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<td>0.135</td>
<td>4.40</td>
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<td>5/15/2013</td>
<td>5/21/2013</td>
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<td>0.262</td>
<td>6.16</td>
<td>0.043</td>
<td>0.021</td>
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<td>5/24/2013</td>
<td>5/27/2013</td>
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<td>5/29/2013</td>
<td>5/31/2013</td>
<td>0.717</td>
<td>0.644</td>
<td>0.073</td>
<td>2.51</td>
<td>0.029</td>
<td>0.015</td>
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<td>6/1/2013</td>
<td>6/5/2013</td>
<td>0.905</td>
<td>0.762</td>
<td>0.143</td>
<td>4.13</td>
<td>0.035</td>
<td>0.017</td>
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<tr>
<td>Measured Drawdown Rates (in/hr)</td>
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</tr>
</tbody>
</table>

- Jay’s measured drawdown rates for two single ring infiltrometer tests (pre-construction) were 0.01 in/hr.

- Average measured drawdown/exfiltration/infiltration rate was 0.016 in/hr with a standard deviation of 0.0046 in/hr.

- This suggests that Jay’s pre-development single ring tests are accurate for design of permeable pavement.
Total Exfiltration to Date

- West PP application 6,100 ft² in surface area.
- Assuming a 33% porosity for the underlying gravel, we can use the change in stage (water height) to calculate exfiltration volume.
- Total of 3,123 ft³ of water exfiltrated from West PP application in first two months.

<table>
<thead>
<tr>
<th>Change in Stage during Inter-Event Period (ft)</th>
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<tbody>
<tr>
<td>0.144</td>
</tr>
<tr>
<td>0.165</td>
</tr>
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<tr>
<td>0.073</td>
</tr>
<tr>
<td>0.143</td>
</tr>
</tbody>
</table>
What Reporters Would Say...

- 3.5% of an Olympic swimming pool
- 23,300 gallons of milk
- Approximating my two dogs, Ali (the larger) and Grayson (smaller) as cylinders:
  - 1326 Grayson’s
  - 690 Ali’s
Perkins Monitoring Data Discussion

• It all makes sense, right?

Any Questions?
Monitoring Permeable Pavement for Clogging & Maintenance

• Ryan Winston, North Carolina State University
Permeable Pavement Maintenance

• One of biggest questions with PP is maintenance
  • How frequently must I maintain?
  • How much does annual maintenance cost?
• What type of test do you perform?
  • Single ring test (ASTM C1701)
  • Bucket test
  • Visual methods
  • NCSU simple infiltration test
Permeable Pavement Maintenance

• How quickly do permeable pavements clog as a function of drainage area (i.e. run-on from impermeable pavement)?
• What percentage of pavement needs to be clogged before maintenance is needed?
Monitoring for Progression of Clogging Front

Monitoring Locations

Run-on from Impermeable Asphalt

10 ft

5 ft

3 ft

1 ft
Monitoring for Clogging & Maintenance

• Utilize soil moisture sensors (bottom left) or time domain reflectometers (bottom right) to measure relative water content in gravel underlying the permeable pavement
### Hypothetical Results

#### Sensor Locations

<table>
<thead>
<tr>
<th>Sensor Location</th>
<th>Amount of Flow</th>
</tr>
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<tbody>
<tr>
<td>1 ft</td>
<td>High</td>
</tr>
<tr>
<td>3 ft</td>
<td>Low</td>
</tr>
<tr>
<td>5 ft</td>
<td>None</td>
</tr>
<tr>
<td>10 ft</td>
<td>None</td>
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</table>
Hypothetical Results

<table>
<thead>
<tr>
<th>Sensor Location</th>
<th>Amount of Flow</th>
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<tbody>
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<tr>
<td>3 ft</td>
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</tr>
<tr>
<td>5 ft</td>
<td>None</td>
</tr>
<tr>
<td>10 ft</td>
<td>None</td>
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### Hypothetical Results

#### Sensor Locations

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<td>Low</td>
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<tr>
<td>3 ft</td>
<td>High</td>
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<tr>
<td>5 ft</td>
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<tr>
<td>10 ft</td>
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**1 Year Post-Installation**
## Hypothetical Results

### Sensor Locations

<table>
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<th>Sensor Location</th>
<th>Amount of Flow</th>
</tr>
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<td>1 ft</td>
<td>None</td>
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<tr>
<td>3 ft</td>
<td>Moderate</td>
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<tr>
<td>5 ft</td>
<td>Moderate</td>
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**1.5 Years Post-Installation**
# Hypothetical Results

<table>
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<th>2 Years Post-Installation</th>
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<td>Sensor Location</td>
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<td></td>
<td>3 ft</td>
</tr>
<tr>
<td></td>
<td>5 ft</td>
</tr>
<tr>
<td></td>
<td>10 ft</td>
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</tbody>
</table>
Plan of Work for Maintenance Study

- Will install sensors below pavement at:
  - NC Central University Law School (Completed)
  - Willoughby Hills Community Center
  - Old Woman Creek NERR
- Various hydraulic loading ratios will be observed at each site to see how that affects clogging progression
- Water quality monitoring for TSS (inlet vs. outlet) at each site to determine TSS loading rate
- Will complete single ring and simple infiltration tests ~3-4 times per year at each site
If Clogging Occurs Quickly

• i.e. in <1 year, may be able to maintain site to compare against initial monitoring results
Questions?
Updates on Monitoring Sites

- Pepper Pike: Permeable Pavers
- Perkins Township: Pervious Concrete
- Old Woman Creek NERR: Porous Asphalt
- Orange Village: Permeable Pavers & Bioretention
- Willoughby Hills: Permeable Pavers
- Holden Arboretum: Bioretention
Old Woman Creek NERR

- Technical advice
  - Binders
  - Surface and base course thickness
- Bidding and construction schedule
- Install TDRs to predict clogging rates & understand maintenance requirements
Orange Village

- Final design specifies washed stone for sub-grade
- Contractor selection process complete
- Pre-construction meeting held 6/21/13
- Construction currently underway
Willoughby Hills

- Amy presented to city council on 6/13/13
  - Aesthetic concerns with monitoring equipment
  - New city engineer involvement
- Bid awarded on 6/27/13
- Construction starting in August 20
Holden Arboretum

- Survey completed
- Meeting held to discuss draft design
- 2 bioretention cells with:
  - Drainage Areas of 0.7 and 0.5 Acres
  - 58% Impervious Area
- August Construction by Holden Staff
Tools & Outreach for 2014

- Amy Brennan, Chagrin River Watershed Partners
- Heather Elmer, Old Woman Creek NERR
Training & Technical Assistance

A. Monitoring training and working session
B. Technical assistance on community codes (Ongoing)
C. Design, maintenance and construction training (Fall 2014/Spring 2015)

Which of these is most useful to you?
What else should we be producing?
Are these approaches the most effective?
Technical Tools

A. Updated Rainwater manual
B. Report on runoff reduction credits
C. Codes checklist
D. Model codes
E. Project lessons learned
F. Site-based case studies

Which of these is most useful to you?
What else should we be producing?
Site-Based Case Studies

• Do the case study products sound useful?
• What information do they need to contain?
• What would be the most effective format?
Lunch
Model Code Updates & Codes Checklist

- Amy Brennan, Chagrin River Watershed Partners
July 2012 CLG Policy Needs Discussion

Barriers
• Time
• Cost
• Lack of knowledge

Needs & Opportunities
• Regulations and credits that work together
• Education and training
• Regional consistency and coordination
• Effective administrative processes
• Elevated standards
• AG review of model codes
• Require code review every 2-3 years (OEPA)
• Key topics: Downspouts and off-street parking
Codes Checklist

• Supplement to the Ohio Balanced Growth Program’s Best Local Land Use Practices
• Development Regulations
• Parking Lot Design
• Flood Damage Reduction
• Stream and Wetland Setbacks
• Flexible Subdivision Design
• Compact Development
• Tree and Woodland Protection
• Natural Areas
Parking Lot Design

• Evaluate:
  - Number of required parking spaces
  - Use of parking maximums
  - Width of parking stalls and aisles

• Allow:
  - Pervious paving materials
  - Shared parking and land banking
  - Landscaping to be used as stormwater management.
City of Mentor Parking Code

- Minimum and Maximum parking rates for each use
  - Allow Planning Commission to vary based on published data or parking study
- Shared parking
- Size of Parking Spaces:
  - 9 x 18 size spaces
  - Compact parking spaces (9 x 16) for 10% of lots over 100 spaces
- Require interior landscaping for lots with over 20 spaces
- Allow flexibility based on acceptable industry publication or parking study
- Bicycle parking for all new non-residential development with schedule
- Allow permeable paving for residential and non-residential
Small Group Discussion

Please review the codes checklist

• Which elements of the checklist are useful?
• How might it be improved?

Plan to share your key insights with the larger group
Large Group Discussion

• Key insights from small group discussion?
• Does the checklist address problems and barriers that CLG members with local codes?
• What guidance do you have for improving the checklist?

• What suggestions do you have for enhancing model codes?
• How essential are model codes to your community and will they make a practical difference?
Modeling and Parameters

- Michelle LaRose, Cardno JFNew
- Scott Isenberg, Cardno JFNew
Modeling Presentation Outline

• Project Goals and Overview
• Phase 1 Results
• Phase 2 Results
• Conclusions
• Next Steps
• Questions
Project Goals

• Develop a practical range of BMP parameters to model
  – Utilize Ohio Rainwater & Land Development Manual for guidance
  – Use other resources as needed
    • Michigan LID Manual
    • SWMM Users Manual
    • Monitoring Data/Literature

• Determine which parameters have the greatest impact on BMP performance for various soil types
PHASE 1 - Define default parameters for each BMP

- Bioretention
- Porous Pavement
- Grass swales
- Dry detention basin
- Soil Renovation

- Evaluate BMP performance with varied BMP-to-watershed ratio
- Evaluate A, B, C, D soils

<table>
<thead>
<tr>
<th>$A_{BMP}/A_w$</th>
<th>BMP Area (ft$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>436</td>
</tr>
<tr>
<td>2%</td>
<td>871</td>
</tr>
<tr>
<td>5%</td>
<td>2,178</td>
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<tr>
<td>10%</td>
<td>4,356</td>
</tr>
<tr>
<td>25%</td>
<td>10,890</td>
</tr>
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</table>

PHASE 2 - Determine sensitivity of BMP parameters
Modeling Flow Chart

1-ac Undeveloped

Agriculture
P Pasteur
Forest

Development

0.5-ac imp
0.5-ac grass

\[
\frac{\text{Area}_{BMP}}{\text{Area}_{IMP}}
\]

Vary BMP parameters for each combination of soil type & BMP size

Vary BMP parameters

PPT
0.25-in
0.50-in
0.75-in
1.00-in
1.25-in
1.50-in
2.00-in
2.50-in
3.00-in
3.50-in

LEGEND
Un-developed
Developed
# Pre-Development Conditions

<table>
<thead>
<tr>
<th>Subcatchment Properties</th>
<th>Pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (acres)</td>
<td>1</td>
</tr>
<tr>
<td>Width (feet)</td>
<td>200</td>
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<tr>
<td>% Slope</td>
<td>2</td>
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<tr>
<td>% Impervious area</td>
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</tr>
<tr>
<td>N-Pervious</td>
<td>0.3</td>
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<tr>
<td>Detention Store - Impervious (ft)</td>
<td>0.05</td>
</tr>
<tr>
<td>Detention Store - Pervious (ft)</td>
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<tr>
<td>Subarea Routing</td>
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<tr>
<td>Percent Routed</td>
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<td>Infiltration Parameters</td>
<td>GREEN_AMPT</td>
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</tbody>
</table>

## Underlying (existing) Soil Ksat in Model

- **A Soils**: 2.35 in/hr
- **B Soils**: 0.52 in/hr
- **C Soils**: 0.12 in/hr
- **D Soils**: 0.04 in/hr
Bioretention

- Surface ponding
- Soil thickness
- Soil type
- Gravel storage depth
- Underdrain offset
Porous Pavement

- Surface roughness
- Permeability
- Storage depth
- Underdrain offset
### Bioretention

<table>
<thead>
<tr>
<th>SURFACE</th>
<th>Variable</th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
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</thead>
<tbody>
<tr>
<td>Storage Depth (in)</td>
<td>6</td>
<td>12</td>
<td>18</td>
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<tr>
<td>Vegetative Fraction</td>
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<tr>
<td>Surface Roughness</td>
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<tr>
<td>Surface Slope</td>
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### Porous Pavement

<table>
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<th>SOIL</th>
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<th>Median</th>
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<tbody>
<tr>
<td>Thickness (in)</td>
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<td>-</td>
<td>48</td>
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<tr>
<td>Soil Type</td>
<td>loamy sand</td>
<td>loamy sand/sandy loam</td>
<td>sandy loam</td>
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<tr>
<td>Porosity</td>
<td>0.437</td>
<td>0.445</td>
<td>0.453</td>
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<tr>
<td>Field Capacity</td>
<td>0.105</td>
<td>0.145</td>
<td>0.19</td>
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<tr>
<td>Wilting Point</td>
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<td>0.066</td>
<td>0.085</td>
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<tr>
<td>Conductivity</td>
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<td>1</td>
<td>2</td>
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</tr>
<tr>
<td>Conductivity Slope</td>
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<td>6.5</td>
<td>7</td>
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<tr>
<td>Suction Head</td>
<td>2.41</td>
<td>3.37</td>
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### Storage

<table>
<thead>
<tr>
<th>STORAGE</th>
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</thead>
<tbody>
<tr>
<td>Height (in)</td>
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<td>21</td>
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<tr>
<td>Void Ratio</td>
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<td>Conductivity</td>
<td>varies with HSG of existing soils</td>
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<tr>
<td>Clogging Factor</td>
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### Underdrain

<table>
<thead>
<tr>
<th>UNDERDRAIN</th>
<th>Variable</th>
<th>Min</th>
</tr>
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<tbody>
<tr>
<td>Coefficient</td>
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</tr>
<tr>
<td>Drain Exponent</td>
<td>Set to represent orifice scenario</td>
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</tr>
<tr>
<td>Drain Offset (in)</td>
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### PAVEMENT

<table>
<thead>
<tr>
<th>PAVEMENT</th>
<th>Variable</th>
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<tbody>
<tr>
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<td>Void Ratio</td>
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<td>Impervious Surface Fraction</td>
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<tr>
<td>Permeability (in/hr)</td>
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<td>100</td>
<td>1000</td>
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<tr>
<td>Clogging Factor</td>
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### Storage (PAVEMENT)

<table>
<thead>
<tr>
<th>STORAGE</th>
<th>Variable</th>
<th>Min</th>
<th>Median</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Height (in)</td>
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<tr>
<td>Void Ratio</td>
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<tr>
<td>Conductivity</td>
<td>varies with HSG of existing soils</td>
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<tr>
<td>Clogging Factor</td>
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### UNDERDRAIN (PAVEMENT)

<table>
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<tr>
<th>UNDERDRAIN</th>
<th>Variable</th>
<th>Min</th>
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</thead>
<tbody>
<tr>
<td>Coefficient</td>
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</tr>
<tr>
<td>Drain Exponent</td>
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<tr>
<td>Drain Offset (in)</td>
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<td>3</td>
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</tbody>
</table>
Other BMP Parameters & Challenges

• Grass swales – typical slopes/dimensions
• Dry detention – outlet size to meet water quality volume
• Soil renovation – still researching
• Grass filter strip – slope, roughness
• Underground detention – outlet size to meet water quality volume, sump depth
• Infiltration trench – clogging factor
• Green roof – typical soil medium
Phase 1 Bioretention Results C-soils

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**Peak Flows**

![Graph showing peak flows for different soil types and percentages.]

**Surface Ponding + Infiltration Volumes**

![Graph showing surface ponding and infiltration volumes for different soil types and percentages.]

- Storage ponding volume @ 10% ratio
Phase 1
Porous Pavement Results
C-soils
Combined BMP Graphs

**Peak Flows on C Soils (1 inch Storm Event)**

- Bioretention
- Porous Pavers
- Grass Swale
- Existing Condition: Agriculture
- Existing Condition: Pasture
- Existing Condition: Forest

**Outflow Volume on C Soils (1 inch Storm Event)**

- Bioretention
- Porous Pavers
- Grass Swale
- Existing Condition: Agriculture
- Existing Condition: Pasture
- Existing Condition: Forest
Combined BMP Graphs (cont.)

Infiltration and Storage losses on C Soils (1 inch Storm Event)

- Bioretention
- Porous Pavers
- Grass Swale
- Water Quality Volume

Infiltration and Storage Losses (ft³)

AreaBMP / AreaWatershed (%)
Conclusion

Which BMP parameters have the greatest impact on BMP performance (the “big knobs”)?

Which BMP parameters minimally affect BMP performance (the “small knobs”)?
Conclusion (cont.)

For Bio-Retention...
- Surface Ponding Depth – major knob
- Soil Type – moderate knob
- Soil Thickness – negligible
- Storage Depth / Underdrain Offset – negligible

For Porous Pavement...
- Underdrain Offset – moderate knob
- Pavement Permeability – minor knob
- Storage Height – negligible
Next Steps

• Finish Phase 1 & 2 for remaining BMPs
• Determine strategy for Phase 3 implementation
  – Integrate BMPs at site level
  – Incorporate real rainfall data
  – Consider combinations of BMPs
General Project Business

• Heather Elmer, Old Woman Creek NERR
• Amy Brennan, Chagrin River Watershed Partners
General Project Business

- September 18th CLG meeting
  - Bill Hunt visiting- Ideas for meeting topics?
- Upcoming Trainings & Conference
  - October 1st Landscaper Community BMP Maintenance at Cleveland Metroparks West Creek Stewardship Center
  - Stormwater and Climate Change Workshop, Monroe, MI
  - National Nonpoint Source Monitoring Conference; Cleveland October 28-30, 2013
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  - bhohman or cdymond @eriecounty.oh.gov 419-626-5211