Statewide LID Training Program
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Senior Scientist
Key project experience: Research specialist in the performance and design of LID practices.
ADVANCED TOPICS IN LID DESIGN:
BIORETENTION MEDIA AND COMPOST
AMENDED SOILS
Statewide LID Training Program

LOGISTICS

SCHEDULE
8-hour training
Lunch on your own

OTHER LOGISTICS
• Restrooms
• Food
• Turn off cell phones
• Sign in and sign out
LEARNING OBJECTIVES

1. Gain an advanced level understanding of the physical and chemical characteristics of bioretention media components and blends necessary to meet specific performance objectives.

2. Understand the flow control and water quality treatment performance of current bioretention media specifications.

3. Know the options for meeting BMP T5.13, and strategies for determining site soil conditions and developing a soil management plan.
Statewide LID Training Program

PROGRAM OVERVIEW

- 2012: Public and private partners engage state legislature to fund program
- June 2012: LID Training Steering Committee convened
- 2012-2013: Washington State LID Training Plan developed: www.wastormwatercenter.org/statewide-lid-training-program-plan
- 2014: Training program built from state LID Training Plan
Statewide LID Training Program

PROGRAM OVERVIEW

• Implement first phase of trainings (September 2014 through May 2015)
• 64 trainings offered in first phase
• Three levels: Introductory, Intermediate, and Advanced
## Statewide LID Training Program

**TEAM**

<table>
<thead>
<tr>
<th>PROJECT LEAD</th>
<th>CORE TEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Herrera Logo" /></td>
<td><img src="image2" alt="Cascadia Consulting Group" /> <img src="image3" alt="Veda Environmental" /></td>
</tr>
</tbody>
</table>

### ADDITIONAL TRAINING SUPPORT

- ![CH2M HILL Logo](image4)
- ![Associated Earth Sciences Incorporated](image5)
- ![Leaping Frog Films](image6)
- ![Kindred Hydro](image7)
- ![SvR Design Company](image8)
- ![StormwaterONE](image9)
## Statewide LID Training Program

### TRAINING SEQUENCE

<table>
<thead>
<tr>
<th>INTRODUCTORY</th>
<th>INTERMEDIATE</th>
<th>ADVANCED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0</strong></td>
<td><strong>3.1</strong></td>
<td><strong>5.1</strong></td>
</tr>
<tr>
<td>Introduction to LID for Eastern Washington</td>
<td>Intermediate LID – NPDES Phase I &amp; II Requirements</td>
<td>Advanced Topics in LID Design: Bioretention</td>
</tr>
<tr>
<td><strong>2.1</strong></td>
<td><strong>3.2</strong></td>
<td><strong>5.2</strong></td>
</tr>
<tr>
<td>Introduction to LID for Inspection &amp; Maintenance Staff</td>
<td>Intermediate LID Design: Bioretention</td>
<td>Advanced Topics in LID Design: Permeable Pavement</td>
</tr>
<tr>
<td><strong>2.2</strong></td>
<td><strong>3.3</strong></td>
<td><strong>5.3</strong></td>
</tr>
<tr>
<td>Introduction to LID for Developers &amp; Contractors: Make Money be Green</td>
<td>Intermediate LID Design: Permeable Pavement</td>
<td>Advanced Topics for LID Operations: Bioretention</td>
</tr>
<tr>
<td><strong>3.4</strong></td>
<td><strong>5.4</strong></td>
<td><strong>5.4</strong></td>
</tr>
<tr>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
<td>Advanced Topics for LID Operations: Permeable Pavement</td>
<td>Advanced Topics in LID Design: Bioretention Media</td>
</tr>
<tr>
<td><strong>4.1</strong></td>
<td><strong>4.2</strong></td>
<td><strong>6.0</strong></td>
</tr>
<tr>
<td><strong>4.1</strong></td>
<td><strong>9.1</strong></td>
<td><strong>9.2</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Service Providers</td>
</tr>
<tr>
<td><strong>4.2</strong></td>
<td></td>
<td>LID Topic Experts</td>
</tr>
</tbody>
</table>

**TRAIN THE TRAINERS**
## INTRODUCTORY

| 1.0 | Introduction to LID for Eastern Washington |
| 2.1 | Introduction to LID for Inspection & Maintenance Staff |
| 2.2 | Introduction to LID for Developers & Contractors: Make Money be Green |

## INTERMEDIATE

| 3.1 | Intermediate LID – NPDES Phase I & II Requirements |
| 3.2 | Intermediate LID Design: Bioretention |
| 3.3 | Intermediate LID Design: Permeable Pavement |
| 3.4 | Intermediate LID Design: Site Assessment, Planning & Layout |
| 4.1 | Intermediate LID Design: Rainwater Collection Systems & Vegetated Roofs |
| 4.2 | Intermediate LID Design: Hydrologic Modeling |

## ADVANCED

| 5.1 | Advanced Topics in LID Design: Bioretention |
| 5.2 | Advanced Topics in LID Design: Permeable Pavement |
| 5.3 | Advanced Topics for LID Operations: Bioretention |
| 5.4 | Advanced Topics for LID Operations: Permeable Pavement |
| 6.0 | Advanced Topics in LID Design: Hydrologic Modeling |
| 7.0 | Advanced Topics in LID Design: Site Assessment, Planning & Layout |
| 8.1 | Advanced Topics in LID Design: Rainwater Collection Systems & Vegetated Roofs |
| 8.2 | Advanced Topics in LID Design: Bioretention Media |

## TRAIN THE TRAINERS

| 9.1 | Service Providers |
| 9.2 | LID Topic Experts |
introduction

media primer

water quality treatment strategies

performance

wrap-up
In the beginning there wasn’t much...

**2002**
- First bioretention applications with monitoring (Seattle SEA Street).
- Primarily topsoil based media.

**2009**
- Issues with BSM consistency using topsoil emerge.
- PSAT funds small project through WSU to ID alternative and potentially more consistent materials for BSM. Flow focused. Sand- and compost-based media guideline developed.
- Sand spec well-tested and performs well hydraulically. OM content spec too high.

**2011**
- WSU LID research facility comes online. Media blend research focus (no funding to conduct fundamental media component characterization).
Statewide LID Training Program

2012

• Export of N, P and Cu identified at WSU facility and City of Redmond swale monitoring.
• Individual BSM component characterization studies begin at Port of Olympia (Herrera), City of Redmond (Herrera) and at WSU (primarily compost).

2013

• Ecology funds approximately $1 million in media study projects through Kitsap County (Herrera technical lead), City of Tacoma (UWT technical lead) and City of Redmond (Herrera technical lead).
• Kitsap County project examining a broad range of individual media components.
• City of Tacoma project focused on WTRs.
• Redmond focused on full-scale monitoring of swales (component characterization included).

2015

• Significant new data coming available to hopefully improve BSM performance and consistency.
• We may be a few years from developing a reliable, affordable and non-proprietary BSM to treat a broad suite of pollutants.
Today’s focus:

- Bioretention media for advanced water quality treatment (direct release to receiving waters, over shallow drinking water aquifers, industrial sites, remedial sites...)

- There are many applications where a conventional sand and compost or topsoil-based media will perform well
Introduccion

Background

Context

- For advance treatment media we are opening a complex black box...
- And attempting to reliably replicate a dynamic biological system with complex structures and processes to treat a broad range of contaminants to very low levels...a worthy challenge!
INTRODUCTION
BACKGROUND

- Flow Entrance
- Pre-Settling
- Ponding Area
- Bioretention Soil
- Mulch/Compost
- Vegetation
- Filter Fabric (?)
- Liner (optional)
- Underdrain (optional)
- Overflow
1. Introduction

2. Media Primer

3. Water Quality Treatment Strategies

4. Performance

5. Wrap-up
Factors influencing hydraulic conductivity

- Percent fines
- Particle size distribution
Hydraulic conductivity strongly related to percent fines (passing #200 sieve)
Hydraulic conductivity strongly related to coefficient of uniformity
Factors influencing hydraulic conductivity

- Percent fines
- Particle size distribution
- Compaction
- Organic material
- Plants
Control structures
**MEDIA BASICS**

**BIORETENTION HYDRAULICS PRIMER**

- ASTM D2434
All primary pathways for removing pollutants from storm flows are active in bioretention

- Stormwater volume reduction
- Sedimentation
- Filtration
- Phytoremediation
- Thermal attenuation
- Sorption
- Complexation
- Volatilzation
Factors influencing water quality treatment

- pH
- Temperature
- Hydraulic residence time
- Media (organic material, particle size, porosity, chemistry)
- Competing ions, ionic chemistry
- Soil water condition
- Influent concentration
Is the following statement correct?

- If an influent concentration of 5 µg/L into a bioretention area results in an effluent concentration of 10 µg/L
  
  then

- an influent concentration of 50 µg/L will result in an effluent concentration of 100 µg/L.
Sorption

- Ionic charge and speciation
- Functional groups (moiety)
- Organic material (TOC and DOC)
- Competing ions and ion exchange
- Clay (particle size)

<table>
<thead>
<tr>
<th>Metal Fraction</th>
<th>Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchangeable Fraction</td>
<td>High. Changes in major cationic compositions may cause release due to ion exchange</td>
</tr>
<tr>
<td>Fe-Mn Oxides Bound</td>
<td>Medium. Changes in redox conditions may cause release</td>
</tr>
<tr>
<td>Carbonate Bound</td>
<td></td>
</tr>
<tr>
<td>OM Bound</td>
<td>Medium/high. Decomposition/oxidation with time.</td>
</tr>
<tr>
<td>Residual Fraction</td>
<td>Low. Available after weathering.</td>
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</tbody>
</table>
Sorption

<table>
<thead>
<tr>
<th>System</th>
<th>Copper, $\mu$g/L</th>
<th>Lead, $\mu$g/L</th>
<th>Zinc, $\mu$g/L</th>
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</thead>
<tbody>
<tr>
<td>Small system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input</td>
<td>140 ± 32</td>
<td>61 ± 3</td>
<td>600 ± 8</td>
</tr>
<tr>
<td>Average ± standard deviation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>12 ± 3.4</td>
<td>2.9 ± 1.4</td>
<td>43 ± 15</td>
</tr>
<tr>
<td>L</td>
<td>3.4 ± 1.6</td>
<td>&lt;2</td>
<td>&lt;25</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>3.2–18</td>
<td>&lt;2–6.7</td>
<td>&lt;25–70</td>
</tr>
<tr>
<td>L</td>
<td>&lt;2–7.7</td>
<td>&lt;2–4.5</td>
<td>&lt;25–130</td>
</tr>
<tr>
<td>Reduction, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>91 ± 2</td>
<td>95 ± 2</td>
<td>93 ± 3</td>
</tr>
<tr>
<td>L</td>
<td>98 ± 1</td>
<td>&gt;98</td>
<td>&gt;97</td>
</tr>
</tbody>
</table>
TREATMENT STRATEGIES

• Sorption and metal complexes
  • Metal atom associated with group of molecules or anions
  • Organically bound Cu often dominant fraction in soils

“Cu however, has a high affinity for soluble organic ligands and the formation of these complexes may greatly increase Cu mobility in soils.” (EPA 1992)
TREATMENT STRATEGIES

• Implications for copper
  • To best manage Cu we will likely have to manage DOC
  • Fe and Ca may be (likely), important for DOC capture
  • Identify aggregate and organic materials with low Cu content and flushing potential
MEDIA BASICS

TREATMENT STRATEGIES

• Primary mechanisms for P management
  • Plant and microbial uptake
  • Sorption and precipitation. Sorption materials include Al and Fe hydroxides and Ca
  • Reactions are pH dependent. Calcium likely not a reliable material for binding P (higher pH best for precipitation)

Methods for retaining phosphate

Organic matter, fertilizers

Adsorbed P inorganic

Plant uptake

Available P

Microbial P organic

Precipitation

Mineral P
MEDIA BASICS
TREATMENT STRATEGIES

PO4 Effluent Concentration

mg/L

Influent 60/15/15/10 60/30/10 60/40 80/20

Treatment

Statewide LID Training Program

8.2 BIORETENTION MEDIA
ADVANCED LID DESIGN
• **P removal efficiency v input concentration**

![Graph showing phosphorus removal efficiency vs concentration.](image)

- During initial loadings with tap water (< 0.06mg/l) there was export of P.
- Stormwater loadings commenced after 18 months.
**TREATMENT STRATEGIES**

**Implications for phosphorus**

- Design with lower organic material content and upper range for C/N ratio (i.e. 35/1)
- Use organic material that is refractory (probably the older the better)
- Bind P with Al or Fe hydroxides
- Identify aggregate material with little to no P flushing
- Likely will need a polishing layer/filter if using compost
- Above design considerations likely most important for at least three years of installation
Methods for managing nitrate (biological transformations)

- **Denitrification** ($N_2$, $N_2O$)
- **Ammonium** ($NH_4^+$)
- **Nitrites** ($NO_2^-$)
- **Nitrates** ($NO_3^-$)

**MEDIA BASICS**

NO3- electron acceptor not O2 in anaerobic conditions

$$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_2O$$

Electron donor may be sugar, hydrocarbon (simple) or complex (mulch).
MEDIA BASICS

TREATMENT STRATEGIES
MEDIA BASICS

TREATMENT STRATEGIES

Methods for managing nitrate (60-15-15-10 columns)
TREATMENT STRATEGIES

Implications

- Design with an elevated under-drain (multiple advantages to this approach)
- Caution: we don’t fully understand the potential for metal and P desorption in the anoxic zone
PERFORMANCE

TREATMENT STRATEGIES

Nitrate-nitrite (mg/L)

<table>
<thead>
<tr>
<th>Date</th>
<th>influent</th>
<th>70vs/20cp/10gac</th>
<th>70ws/20cp/10ash</th>
<th>70vs/20cp/10ash</th>
<th>90vs/10comp/player</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/16/2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.75</td>
<td>0.028</td>
<td>0.327</td>
<td>0.362</td>
<td>1.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.028</td>
<td>0.083</td>
<td>0.339</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.037</td>
<td>0.194</td>
<td>0.366</td>
<td>1.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.031</td>
<td>0.201</td>
<td>0.356</td>
<td>1.573</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.028</td>
<td>0.194</td>
<td>0.362</td>
<td>1.570</td>
</tr>
<tr>
<td></td>
<td>98</td>
<td>89</td>
<td>79</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>10/30/2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.561</td>
<td>0.016</td>
<td>0.216</td>
<td>no sample</td>
<td>0.842</td>
</tr>
<tr>
<td></td>
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<td>0.019</td>
<td>0.097</td>
<td>0.201</td>
<td>0.851</td>
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<td></td>
<td></td>
<td>0.025</td>
<td>0.164</td>
<td>0.198</td>
<td>0.88</td>
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<td></td>
<td></td>
<td>0.020</td>
<td>0.159</td>
<td>0.200</td>
<td>0.858</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.019</td>
<td>0.164</td>
<td>0.200</td>
<td>0.851</td>
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<tr>
<td></td>
<td>97</td>
<td>71</td>
<td>64</td>
<td>-52</td>
<td></td>
</tr>
</tbody>
</table>
Filtration: 60/40 bioretention media provides excellent filtration of TSS (depending on PSD and permeability)...

Does not appear to be concentration dependent
HYDRAULIC PERFORMANCE

ASTM D2434 tests performed 2011 as part of a project to standardize test methods across regional labs (60/40 media)

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Dry Density (pcf)</th>
<th>% Compaction</th>
<th>Mold Diameter (in.)</th>
<th>Day 1 (in./hr)</th>
<th>Day 2 (in./hr)</th>
<th>Day 3 (in./hr)</th>
<th>Day 4 (in./hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AESI</td>
<td>94.8</td>
<td>85.0%</td>
<td>6</td>
<td>3.4</td>
<td>3.8</td>
<td>4.1</td>
<td>4.7</td>
</tr>
<tr>
<td>GeoTest</td>
<td>91.5</td>
<td>84.3%</td>
<td>6</td>
<td>10</td>
<td>13</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>GeoEngineers (85% of MDD)</td>
<td>96.9</td>
<td>85.3%</td>
<td>6</td>
<td>3.8</td>
<td>3.7</td>
<td>3.7</td>
<td>3.8</td>
</tr>
<tr>
<td>GeoEngineers (90% of MDD)</td>
<td>102.6</td>
<td>90.3%</td>
<td>6</td>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HWA</td>
<td>93.1</td>
<td>84.9%</td>
<td>6</td>
<td>19</td>
<td>25</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Shannon &amp; Wilson</td>
<td>95.0</td>
<td>84.1%</td>
<td>6</td>
<td>6.2</td>
<td>5.4</td>
<td>5.2</td>
<td>5.5</td>
</tr>
<tr>
<td>HWA</td>
<td>93.1</td>
<td>84.9%</td>
<td>4</td>
<td>17</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPU</td>
<td>95.9</td>
<td>86.4%</td>
<td>4</td>
<td>39</td>
<td>39</td>
<td>40</td>
<td>42</td>
</tr>
</tbody>
</table>
HYDRAULIC PERFORMANCE

• Soil treatments
  • 60% sand – 40% compost
  • 80% sand – 20% compost
  • 60% sand – 30% compost – 10% WTRs
  • 60% sand – 15% compost – 15% shredded bark – 10% WTRs
  • 60% sand – 10% biosolids – 15% – shredded bark – 5% sawdust – 10% WTRs
HYDRAULIC PERFORMANCE

- Mesocosm Falling Head Permeability Test (May-June 2011)
PERFORMANCE

HYDRAULIC PERFORMANCE

• Mesocosm Falling Head Permeability Test (June 2012)
HYDRAULIC PERFORMANCE

- Mesocosm Falling Head Permeability Test (June 2013)
PERFORMANCE

HYDRAULIC PERFORMANCE

ASTM D2434 tests performed 2015 as part of a project to develop a high performance water quality treatment media

Mean Ksat Rates per ASTM 2434

- 90vs/10comp/player: 148
- 70vs/20cp/10ash: 91
- 70ws/20cp/10ash: 32
- 70vs/20cp/10gac: 138
- 70vs/20cp/10de: 81
- 70vs/20fe/10ash: 69
- 70vs/20fe/10de: 51

Ksat (in/hr)
HYDRAULIC PERFORMANCE

Implications

- Consider carefully acceptance/verification requirements....the system may be hydraulically functional, but not meet specific guidelines at that time
- Consider how to size and operate a system that may be evolving over time

Side note

- The region may becoming more accepting of high flow media with control structures
Lunch
PERFORMANCE

HYDRAULIC PERFORMANCE

Compost-based media
WATER QUALITY TREATMENT PERFORMANCE

TSS Effluent Concentration

Influent  60/15/15/10  60/30/10  60/40  80/20

mg/L

Treatment

Statewide LID Training Program

8.2 BIORETENTION MEDIA

ADVANCED LID DESIGN
PERFORMANCE
WATER QUALITY TREATMENT PERFORMANCE

NO$_3$–NO$_2$ Effluent Concentration

anything interesting

mg/L

Influent  60/15/15/10  60/30/10  60/40  80/20

Treatment
PERFORMANCE
WATER QUALITY TREATMENT PERFORMANCE

NO\textsubscript{3}–NO\textsubscript{2} Effluent Concentration

mg/L

Influent 60/15/15/10 60/30/10 60/40 80/20

Treatment
PERFORMANCE
WATER QUALITY TREATMENT PERFORMANCE

PO4 Effluent Concentration

mg/L

Influent 60/15/15/10 60/30/10 60/40 80/20

Treatment
PERFORMANCE
WATER QUALITY TREATMENT PERFORMANCE

PO4 Effluent Concentration

mg/L

Influent 60/15/15/10 60/30/10 60/40 80/20

Treatment
PERFORMANCE
WATER QUALITY TREATMENT PERFORMANCE

Dissolved Cu Effluent Concentration

Treatment
Influent 60/15/15/10 60/30/10 60/40 80/20

µg/L
15
10
5
PERFORMANCE
WATER QUALITY TREATMENT PERFORMANCE

Dissolved Cu Effluent Concentration

Treatment

Influent  60/15/15/10  60/30/10  60/40  80/20

µg/L

4  6  8  10  12
WATER QUALITY TREATMENT PERFORMANCE

Fecal Effluent Concentration

CFU/100ml

Influent 60/15/15/10 60/30/10 60/40 80/20

Treatment

Statewide LID Training Program

8.2 BIORETENTION MEDIA
ADVANCED LID DESIGN 62
PERFORMANCE
WATER QUALITY TREATMENT PERFORMANCE

Fecal coliform Data Distribution (4-10-13 Storm)

Statewide LID Training Program
8.2 BIORETENTION MEDIA
ADVANCED LID DESIGN 63
**PERFORMANCE**

**WATER QUALITY TREATMENT PERFORMANCE**

- All mesocosms (Phase 1 flushing regime)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Units</th>
<th>Median Influent</th>
<th>Min</th>
<th>Median Effluent</th>
<th>Max</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>4.9</td>
<td>1</td>
<td>5.3</td>
<td>22.5</td>
<td>36</td>
</tr>
<tr>
<td>Diss Zn</td>
<td>µg/L</td>
<td>71</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Diss Cu</td>
<td>µg/L</td>
<td>3</td>
<td>1.7</td>
<td>8.6</td>
<td>15.9</td>
<td>40</td>
</tr>
<tr>
<td>PO4</td>
<td>mg/L</td>
<td>0.016</td>
<td>0.086</td>
<td>0.236</td>
<td>0.461</td>
<td>40</td>
</tr>
<tr>
<td>NO3-NO2</td>
<td>mg/L</td>
<td>0.361</td>
<td>0.05</td>
<td>0.145</td>
<td>1.03</td>
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<td>Fecal coliform</td>
<td>CFU/100mL</td>
<td>229</td>
<td>5</td>
<td>22.5</td>
<td>65</td>
<td>32</td>
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</table>
PERFORMANCE
WATER QUALITY TREATMENT PERFORMANCE

Developing a high-performance WQ treatment media
Media treatments

- 60% sand/40% compost (control).
- 70% volcanic sand/20% iron-fused wood chips/10% diatomaceous earth.
- 70% volcanic sand/20% iron-fused wood chips/10% high carbon wood ash.
- 70% volcanic sand/20% coco coir/10% diatomaceous earth.
- 70% volcanic sand/20% coco coir/10% granulated activated charcoal.
- 70% washed sand/20% coco coir/10% high carbon wood ash.
- 70% volcanic sand/20% coco coir/10% high carbon wood ash.
- 90% volcanic sand/10% compost/polishing drainage layer (volcanic sand, activated alumina and bone char).
**Effluent Concentration by Percent Water Year**

- **Dissolved Copper**

  - **Effluent Concentration by Treatment**

  - Two-Way ANOVA
    - Treatment p-value: $2.05e-08^{	ext{***}}$
    - Sample Event p-value: $7.21e-57^{	ext{***}}$
    - Interaction p-value: $2.23e-06^{	ext{***}}$
PERFORMANCE
WATER QUALITY TREATMENT PERFORMANCE

Flushing findings

• 60% sand/40% compost (control) flushing concentrations 1-2 orders of magnitude greater than treatments.

• All treatments exhibit a standard flushing pattern for N and Cu; however, ortho-P flushing increases before decreasing in 60/40. Other research showing extended flushing of ortho-P in compost medias.

• In general, the coco coir pith and GAC or high carbon wood ash best performers for minimal flushing.
## PERFORMANCE
### WATER QUALITY TREATMENT PERFORMANCE

### TSS (mg/L)

<table>
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<td>15.3</td>
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<td>15.3</td>
<td>24.3</td>
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<td>24.3</td>
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<td>Mean</td>
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<td>34.2</td>
<td>4.1</td>
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<tr>
<td></td>
<td>Median</td>
<td>48.8</td>
<td>23.9</td>
<td>37.1</td>
<td>4.1</td>
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<td></td>
<td>Percent Reduction</td>
<td>3</td>
<td>53</td>
<td>27</td>
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### Ortho-P (mg/L)

#### 12/11/2014

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<td>0.094</td>
<td>0.019</td>
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<tr>
<td>Percent Reduction</td>
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<td>98</td>
<td>81</td>
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#### 12/11/2014

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<td>0.094</td>
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<tr>
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<td>0.098</td>
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<tr>
<td>Percent Reduction</td>
<td>58</td>
<td>85</td>
<td>54</td>
<td>32</td>
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</table>
Nitrate + Nitrite

Effluent Concentration by Treatment

Two-Way ANOVA
- Treatment p-value: 2.5e-08 ***
- Influent Concentration p-value: 0.0149 *
- Interaction p-value: 2.4e-05 ***

mg-N/L
Dissolved Copper

Effluent Concentration by Treatment

Two-Way ANOVA
Treatment p-value: 1.06e-13 ***
Influent Concentration p-value: 1.09e-08 ***
Interaction p-value: 0.00362 **
### WATER QUALITY TREATMENT PERFORMANCE

#### Dissolved Cu (μg/L)

**10/30/2014**

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<table>
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<th>Sample Type</th>
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<th>Percent Reduction</th>
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**12/11/2014**

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<td>7.3</td>
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</table>

<table>
<thead>
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<th>Sample Type</th>
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<th>Median</th>
<th>Percent Reduction</th>
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</thead>
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<tr>
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<td>3.7</td>
<td>3.1</td>
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</tr>
<tr>
<td></td>
<td>5.5</td>
<td>29</td>
<td>-5</td>
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Dosing findings

- 60% sand/40% compost (control) effluent concentrations 1-2 orders of magnitude greater for N and P than treatments.

- Significant release of dissolved Cu in treatments with iron coated wood chips during dosing.

- Very good dissolved Cu management at low and high influent concentrations for coco coir pith and GAC or high carbon wood ash treatments.

- Good N and P management at low and high influent concentrations for coco coir pith and GAC or high carbon wood ash.

- Coco coir and GAC or high carbon wood ash best performers for N, P and Cu capture.
PERFORMANCE

BIOLOGICAL EFFECTIVENESS
PERFORMANCE

BIOLOGICAL EFFECTIVENESS

- More context...

% Reduction in Dissolved Metals

- Zn: 99%
- Cu: 72%
- Ni: 31%
- Pb: 91%
- Cd: 100%
### PERFORMANCE BIOLOGICAL EFFECTIVENESS

<table>
<thead>
<tr>
<th>Animal Model</th>
<th>Effect</th>
<th>Exposure</th>
<th>Reduced</th>
<th>Eliminated</th>
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<tbody>
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<td>Juv. coho</td>
<td>Mortality</td>
<td>96 h</td>
<td>100%</td>
<td>✓</td>
</tr>
<tr>
<td>Mayfly nymph</td>
<td>Mortality</td>
<td>48 h</td>
<td>100%</td>
<td>✓</td>
</tr>
<tr>
<td>Zebrafish</td>
<td>Mortality</td>
<td>96 h</td>
<td>100%</td>
<td>✓</td>
</tr>
<tr>
<td>Daphnid</td>
<td>Mortality</td>
<td>48 h</td>
<td>100%</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Reproductive Impairment</td>
<td>7 d</td>
<td>100%</td>
<td>✓</td>
</tr>
<tr>
<td>Zebrafish</td>
<td>Cardiac dysfunction</td>
<td>48 h</td>
<td>100%</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Growth impairment</td>
<td>96 h</td>
<td>100%</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Cardiac edema</td>
<td>96 h</td>
<td>100%</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Swim bladder</td>
<td>96 h</td>
<td>100%</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Microphthalmia</td>
<td>96 h</td>
<td>81%</td>
<td></td>
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<tr>
<td></td>
<td>CYP1a induction</td>
<td>48 h</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>Cardiac genes</td>
<td>48 h</td>
<td>TBD</td>
<td>TBD</td>
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## Statewide LID Training Program

### Other Course Offerings

<table>
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<tr>
<th><strong>Introductory</strong></th>
<th><strong>Intermediate</strong></th>
<th><strong>Advanced</strong></th>
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<tbody>
<tr>
<td><strong>1.0</strong></td>
<td>Introduction to LID for Eastern Washington</td>
<td><strong>5.1</strong> Advanced Topics in LID Design: Bioretention</td>
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<tr>
<td><strong>2.1</strong></td>
<td>Introduction to LID for Inspection &amp; Maintenance Staff</td>
<td><strong>5.2</strong> Advanced Topics in LID Design: Permeable Pavement</td>
</tr>
<tr>
<td><strong>2.2</strong></td>
<td>Introduction to LID for Developers &amp; Contractors: Make Money be Green</td>
<td><strong>5.3</strong> Advanced Topics for LID Operations: Bioretention</td>
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<td><strong>5.4</strong> Advanced Topics for LID Operations: Permeable Pavement</td>
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<td><strong>3.1</strong> Intermediate LID Topics: NPDES Phase I &amp; II Requirements</td>
<td><strong>6.0</strong> Advanced Topics in LID Design: Hydrologic Modeling</td>
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<td><strong>3.2</strong> Intermediate LID Design: Bioretention</td>
<td><strong>7.0</strong> Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
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<td><strong>4.2</strong> Intermediate LID Design: Hydrologic Modeling</td>
<td><strong>9.2</strong> LID Topic Experts</td>
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</table>

**Train the Trainers**

- **9.1** Service Providers
- **9.2** LID Topic Experts
ONLINE EVALUATION

• An on-line evaluation will be sent to you within 5 days following this training
• Feedback will help to refine future trainings
• Feedback is also important to pursue funding to support a long-term statewide LID training program
Two certificates:

• LID Design certificate
• Long-term LID Operations certificate
• Stay tuned for developing certificate policies

Sign out!
For information on training and other resources, visit the Washington Stormwater Center website:

http://www.wastormwatercenter.org

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- Sign up to follow and get Tweets
Further questions? Contact:
training@cascadiaconsulting.com
(206) 449-1163