INSTRUCTORS

DUSTIN ATCHISON, PE
Water Resources Project Manager
Key project experience: LID design, stormwater master planning, stream and wetland restoration design, hydrologic and hydraulic modeling

Curtis Hinman
Senior Scientist
Key project experience: Research specialist in the performance and design of LID applications.

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
Program Overview

- Implement first phase of trainings (September 2014 through May 2015)
- 49 trainings offered in western and eastern WA first year
- 45 trainings offered in western and eastern WA in current phase (through June 2016)
- Three levels: Introductory, Intermediate, and Advanced
- Statewide LID Certificate now available

Program Overview

<table>
<thead>
<tr>
<th>Introductory</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Introduction to LID for Inspectors &amp; Maintenance Staff</td>
<td>3.1 Introductory LID Topics: NPDES Phase I &amp; II Requirements</td>
<td>5.0 Advanced Topics for Long-term LID Operations: Bioretention</td>
</tr>
<tr>
<td>2.2 Introduction to LID for Inspectors &amp; Maintenance Staff</td>
<td>3.2 Intermediate LID Design: Permeable Pavement</td>
<td>5.1 Advanced Topics for Long-term LID Operations: Permeable Pavement</td>
</tr>
<tr>
<td>2.3 Introduction to LID for Developers &amp; Contractors, Make Money be Green</td>
<td>3.3 Intermediate LID Design: Vegetated Roofs</td>
<td>5.2 Advanced Topics in LID Design: Permeable Pavement</td>
</tr>
<tr>
<td>3.4 Intermediate LID Design: Bioretention, Planning &amp; Layout</td>
<td>3.5 Intermediate LID Design: Rainwater Harvesting &amp; Site Assessment</td>
<td>5.3 Advanced Topics in LID Design - Bioretention Planning &amp; Layout</td>
</tr>
<tr>
<td>3.6 Intermediate LID Design: Stormwater Management Modeling</td>
<td>5.4 Advanced Topics in LID Design: Rainwater Collection Systems &amp; Vegetated Roofs</td>
<td>5.5 Advanced Topics in LID Design: Bioretention Media and Compost Amended Soils</td>
</tr>
<tr>
<td>5.6 Advanced Topics in LID Design: Hydrologic Modeling</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LEARNING OBJECTIVES

1. Gain an intermediate level knowledge necessary for proper entry level design of bioretention systems.
2. Learn skills necessary for basic site assessment and locating bioretention areas in residential and commercial settings.
3. Learn practical skills necessary for construction of basic bioretention systems.
AGENDA

Statewide LID Training Program

1. Introduction to course and bioretention
2. Water quality treatment
3. Bioretention sitting, design and construction
4. Inspection & verification
5. Wrap-up

TOPICS

INTRODUCTION

Intro to LID

NPDES Permit

Bioretention Basics
• A land use development strategy that emphasizes protection and use of on-site natural features to manage stormwater.
• Careful assessment of site soils and strategic site planning to best use those soils for stormwater management.
• Integrates engineered and non-engineered, small scale stormwater controls into the site design to closely mimic pre-development hydrologic processes.

INTRODUCTION
WHAT IS LOW IMPACT DEVELOPMENT?

• Used at the parcel and subdivision scale. Site scale necessary but not sufficient. Regional land use planning critical for effective stormwater management.
• Primary goal: no measurable impacts to receiving waters by maintaining or approximating pre-development surface flow volumes and durations.

Undeveloped - Forest
• During winter months evaporation continues to be active while the transpiration component is minimal.
• Storm events moderated by infiltration, evaporation, and transpiration.
• Water is available in substrates to sustain stream base flows during summer months.
• As winter progresses, the interflow component of stream flow increases.
• During the Summer and Fall streams are maintained priming by glacial meltwater and/or groundwater flow.
WHAT IS LOW IMPACT DEVELOPMENT?

Objectives

- Protect and restore native soils/vegetation
- Reduce development envelope
- Reduce impervious surfaces and eliminate effective impervious areas
- Manage stormwater as close to its origin as possible
- Integrate stormwater controls into the design—create a multifunctional landscape

INTRODUCTION

TOPICS

Intro to LID

NPDES Permit

Bioretention Basics
NPDES PERMIT REQUIREMENTS

INTRODUCTION
- Phase I*
  - Populations ≥ 100,000
- Phase II
  - Generally populations > 10,000
- Issuance date: August 1, 2012
- Effective date: August 1, 2014
- Permit term: 5 years (through July 31, 2019)

* No Phase I jurisdictions in Eastern WA

Phase II Cities
- Asotin
- Clarkston
- East Wenatchee
- Ellensburg
- Kennewick
- Moses Lake
- Pasco
- Pullman
- Richland
- Selah
- Spokane
- Spokane Valley
- Sunnyside
- Union Gap
- Walla Walla
- Wenatchee
- West Richland
- Yakima

Phase II Counties
- Asotin
- Chelan
- Douglas
- Spokane
- Walla Walla
- Yakima

#1 Preparation of a Stormwater Site Plan
#2 Construction Stormwater Pollution Prevention
#3 Source Control of Pollution
#4 Preservation of Natural Drainage Systems and Outfalls
#5 Runoff Treatment
#6 Flow Control
#7 Operations and Maintenance
#8 Local Requirements
### NPDES PERMIT REQUIREMENTS:

**Core Element 5 – Runoff Treatment**
- New: ≥ 5,000 sq. ft. pollutant-generating impervious surface (PGIS)
- Redevelopment: ≥ 5,000 sq. ft. PGIS for specific industrial, commercial, high-use, and high traffic sites

**Core Elements 6 – Flow Control**
- New: > 10,000 sq. ft. new impervious surfaces
- Redevelopment: Not required for redevelopment unless required under a basin plan or other federal, state, or local requirement

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### INTRODUCTION

**TOPICS**

- Introduction to LID
- NPDES Permit
- Bioretention Basics

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**BIORETENTION: Definition and Types**

- Shallow landscaped depressions that are engineered (bioretention) or non-engineered (rain gardens) to receive stormwater from small contributing areas
- Small scale, dispersed facilities
- Types:
  - Bioretention cells
  - Bioretention swales
  - Infiltration planters
  - Flow-through planters
BIORETENTION: Components

- Pre-Settling/Flow Entrance
- Bioretention Soil/Amended Soil
- Mulch/Compost
- Native Vegetation
- Ponding Area (earthen depression or permeable reservoir)
- Underdrain (optional)
- Overflow

BIORETENTION vs. RAIN GARDENS

- Bioretention:
  - Often includes surface and subsurface infrastructure
  - Designed soil mix

- Rain gardens:
  - Usually do not include under-drains
  - May use less restrictive soil mix guidelines (e.g., existing soil augmented with compost and sand)

INTRODUCTION

- Primary functions
- Hydrologic benefits
- Water quality treatment
- Aesthetic amenity
Introduction to course and bioretention

Water quality treatment

Bioretention siting, design and construction

Inspection & verification

Wrap-up

**WATER QUALITY TREATMENT**

Primary pathways for removing pollutants from storm flows active in bioretention

- Stormwater volume reduction
- Sedimentation
- Filtration
- Phytoremediation
- Thermal attenuation
- Adsorption
- Volatilization

Note: rain gardens can also provide these pollutant capture pathways, but should only be used for small projects that do not trigger Core Elements #5 or #6.
### VOLUME REDUCTION

<table>
<thead>
<tr>
<th>Project</th>
<th>Completed</th>
<th>Infiltration</th>
<th>Sizing</th>
<th>Volume Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siskiyou Green Street</td>
<td>Oct 2003</td>
<td>1.5 - 2.0 in/hr</td>
<td>6%</td>
<td>*(1/04 – 12/05) 83%</td>
</tr>
<tr>
<td>Glencoe Rain Garden</td>
<td>Oct 2003</td>
<td>1.8 - 3.0 in/hr</td>
<td>6%</td>
<td>*(1/04 – 12/05) 94%</td>
</tr>
<tr>
<td>Greensboro NC</td>
<td>2001</td>
<td>0.2 - 0.6 in/hr</td>
<td>5%</td>
<td>*(2002) 78%</td>
</tr>
<tr>
<td>110th Cascade</td>
<td>2003</td>
<td>variable</td>
<td>~2%</td>
<td>*(2001 – present) 98%</td>
</tr>
<tr>
<td>Meadow on the Hylebos</td>
<td>2006</td>
<td>0.0 - 0.8 in/hr</td>
<td>15%</td>
<td>*(10/07 – 5/08) 99.99%</td>
</tr>
</tbody>
</table>

### SOIL CONTAMINANT LEVELS

<table>
<thead>
<tr>
<th>Project</th>
<th>0-6&quot; (MPN/g)</th>
<th>6-12&quot; (MPN/g)</th>
<th>12-18&quot; (MPN/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siskiyou Green Street</td>
<td>280</td>
<td>34.4</td>
<td>170</td>
</tr>
<tr>
<td>SW 12th &amp; Montgomery</td>
<td>--</td>
<td>17.0</td>
<td>12.2</td>
</tr>
<tr>
<td></td>
<td>17.6</td>
<td>10.9</td>
<td>0.054</td>
</tr>
</tbody>
</table>

### WATER QUALITY TREATMENT

**Percent Removal of Nutrients**

<table>
<thead>
<tr>
<th></th>
<th>TKN (mg/L)</th>
<th>NO3 (mg/L)</th>
<th>TP (mg/L)</th>
<th>Hydrocarbons (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis et al 2006*</td>
<td>88% (u) 68% (l)</td>
<td>48% (u) 34% (l)</td>
<td>1% (u) 81% (l)</td>
<td></td>
</tr>
<tr>
<td>Greenbelt</td>
<td>57%</td>
<td>16%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Largo</td>
<td>67%</td>
<td>15%</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>Mass removal</td>
<td>97%</td>
<td>97%</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>Hunt et al 2006</td>
<td>-3.6%</td>
<td>75%</td>
<td>-240%</td>
<td></td>
</tr>
<tr>
<td>Chapel Hill</td>
<td>45%</td>
<td>13%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Hunt 2005</td>
<td>&gt;97%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PNW Bioswales (Herrera 2006)</td>
<td>18%</td>
<td>-20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nat’l Bioswales**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Event mean concentrations

* Percent reduction at 18 cm (upper) and 61 cm (lower) depths (lab) ** Herrera from Barrett
## PERCENT REMOVAL OF TSS & METALS

<table>
<thead>
<tr>
<th>Event</th>
<th>TSS (%)</th>
<th>Cu (µg/L)</th>
<th>Pb (µg/L)</th>
<th>Zn (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis et al 2003*</td>
<td>89% (u) 92% (l)</td>
<td>&gt;98% (u) &gt;98% (l)</td>
<td>&gt;98% (u) &gt;98% (l)</td>
<td></td>
</tr>
<tr>
<td>Davis et al 2003**</td>
<td>&gt;99%</td>
<td>&gt;99%</td>
<td>&gt;99%</td>
<td></td>
</tr>
<tr>
<td>Greenbriar</td>
<td>97%</td>
<td>&gt;95%</td>
<td>&gt;95%</td>
<td></td>
</tr>
<tr>
<td>Largo</td>
<td>93%</td>
<td>70%</td>
<td>64%</td>
<td></td>
</tr>
<tr>
<td>Hunt et al 2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greensboro</td>
<td>-180%</td>
<td>99%</td>
<td>81%</td>
<td>98%</td>
</tr>
<tr>
<td>Chapel Hill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hsieh, Davis 2005</td>
<td></td>
<td></td>
<td>91%</td>
<td></td>
</tr>
<tr>
<td>PNW Bioswales (Herrera 2005)</td>
<td>64%</td>
<td></td>
<td></td>
<td>47%</td>
</tr>
<tr>
<td>National Bioswales (Herrera from Barrett)</td>
<td>43%</td>
<td></td>
<td></td>
<td>53%</td>
</tr>
</tbody>
</table>

Event mean concentrations
* Percent reduction at 18 cm (upper) and 61 cm (lower) depths (lab)
** Percent mass removal (lab)

## WATER QUALITY TREATMENT

### BIORETENTION FLUSHING

<table>
<thead>
<tr>
<th>Date</th>
<th>Total Phosphorus (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar-12</td>
<td>6.0</td>
</tr>
<tr>
<td>Apr-12</td>
<td>2.5</td>
</tr>
<tr>
<td>May-12</td>
<td>2.0</td>
</tr>
<tr>
<td>Jun-12</td>
<td>1.5</td>
</tr>
<tr>
<td>Jul-12</td>
<td>1.0</td>
</tr>
<tr>
<td>Aug-12</td>
<td>0.5</td>
</tr>
<tr>
<td>Sep-12</td>
<td>0.0</td>
</tr>
<tr>
<td>Oct-12</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**IN** | **OUT**

- Rainfall exclusion (6-15-13)
- Rainfall exclusion (7-13-13)
- Increased retention (10-13-13)
- High rainfall (11-13-13)
- Rainfall exclusion (12-13-13)
- High rainfall (11-13-13)
- Added conditioned water (12-13-13)

## WATER QUALITY TREATMENT

### BIORETENTION FLUSHING

<table>
<thead>
<tr>
<th>Date</th>
<th>Dissolved Copper (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar-12</td>
<td>30.0</td>
</tr>
<tr>
<td>Apr-12</td>
<td>25.0</td>
</tr>
<tr>
<td>May-12</td>
<td>15.0</td>
</tr>
<tr>
<td>Jun-12</td>
<td>10.0</td>
</tr>
<tr>
<td>Jul-12</td>
<td>5.0</td>
</tr>
<tr>
<td>Aug-12</td>
<td>0.5</td>
</tr>
<tr>
<td>Sep-12</td>
<td>0.0</td>
</tr>
<tr>
<td>Oct-12</td>
<td>0.0</td>
</tr>
<tr>
<td>Nov-12</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**IN** | **OUT**

- Rainfall exclusion (6-15-13)
- Rainfall exclusion (7-13-13)
- Increased retention (10-13-13)
- High rainfall (11-13-13)
- Rainfall exclusion (12-13-13)
- High rainfall (11-13-13)
- Added conditioned water (12-13-13)
BIORETENTION FLUSHING EXPERIMENTS

<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>
<th>Sand Result</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>
<td></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>
<td></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>
<td></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>
<td></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>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>CFU/100mL</td>
<td>229</td>
<td>5</td>
<td>22.5</td>
<td>65</td>
<td>32</td>
<td></td>
</tr>
</tbody>
</table>

Filtration: bioretention provides excellent sediment filtration...

Does not appear to be concentration dependent.

WATER QUALITY TREATMENT

DISSOLVED COPPER CAPTURE

WSU large-scale lysimeter study (unpublished)
SUMMARY

- Initial flushing of nitrogen, phosphorus and copper (all studies).
- Excellent zinc capture at installation (most studies).
- Reasonable TN capture at typical influent concentrations after flushing (WSU).
- Very good TSS capture (WSU).
- Cu and Ni initial flushing and TP and PO4 longer-term remain challenges for compost-based media.
SITE SUITABILITY CRITERIA:
Infiltration Setbacks

<table>
<thead>
<tr>
<th>Feature</th>
<th>Setback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking water well</td>
<td>100 feet</td>
</tr>
<tr>
<td>Spring used for drinking water</td>
<td>100 feet</td>
</tr>
<tr>
<td>Known deep soil contamination</td>
<td>100 feet</td>
</tr>
<tr>
<td>Closed or active landfill</td>
<td>100 feet</td>
</tr>
<tr>
<td>Small on-site septic drainfield</td>
<td>10 feet</td>
</tr>
<tr>
<td>Wellheads, on-site septic systems, basements, utilities, slopes,</td>
<td></td>
</tr>
<tr>
<td>contaminated areas, and property lines</td>
<td>Consult local jurisdiction guidelines</td>
</tr>
</tbody>
</table>

SITE SUITABILITY CRITERIA:
Infiltration Setbacks

<table>
<thead>
<tr>
<th>Feature</th>
<th>Setback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building foundations</td>
<td></td>
</tr>
<tr>
<td>Downslope</td>
<td>≥ 20 feet</td>
</tr>
<tr>
<td>Upslope</td>
<td>100 feet</td>
</tr>
<tr>
<td>Native Growth Protection Easement</td>
<td>≥ 20 feet</td>
</tr>
<tr>
<td>Top of slopes &gt;15%</td>
<td>≥ 50 feet</td>
</tr>
</tbody>
</table>

SITE SUITABILITY CRITERIA

- Groundwater Protection Areas
  - Not allowed if it will cause a violation of GW quality stds.
- Depth to bedrock, seasonal high-water mark, or impermeable layer
  - ≥ 5 feet from facility base
  - ≥ 3 feet on case-to-case basis
- Infiltration rate/Drawdown time
  - 0.5 in/hr to 2.4 in/hr
  - Soil groups B & C
  - 72 hr drawdown
**BIORETENTION SITING, DESIGN & CONSTRUCTION**

**SITING CONSIDERATIONS**

- Understand the fate of infiltrated water
  - Intent is to infiltrate to native underlying soil
  - Arterial ROW with dense underground infrastructure (preferential pathway → utility trenches)
  - Potential for excessive shallow interflow emerging at slopes, development cuts, or in basements
  - Use engineering controls
    - Ex. trench water stops to prevent re-infiltration to pipes
    - Ex. liners to protect adjacent infrastructure

---

**SITING CONSIDERATIONS**

- Native soil and vegetation preservation
- Site Slopes
- Cross & longitudinal slopes
- Positive drainage from drainage area to bioretention to overflow
- Setbacks (e.g., utilities & other infrastructure, wetland and streams)
- May require pre-settling
- Public acceptance/participation (retrofits)

---

**BIORETENTION SITING, DESIGN & CONSTRUCTION**

**SITING CONSIDERATIONS: Soils**

- Why soils affect siting
- Soil variability
- Initial infiltration rates
- Design infiltration rates
• Important for infiltrating facilities ONLY
• Infiltrating facilities sized based on infiltration rates
• Locate infiltrating BMPs in areas with best soils

BIORETENTION SITING, DESIGN & CONSTRUCTION
SITING CONSIDERATIONS: Native Soils

Statewide LID Training Program

ECOLOGY
INTERMEDIATE LID DESIGN 52

SITING CONSIDERATIONS: Soil Variability

Broadview Green Grid, Seattle, WA

Site 1: Loam

Site 2

Site 3

BIORETENTION SITING, DESIGN & CONSTRUCTION
SITING CONSIDERATIONS: Soil Variability

Statewide LID Training Program

ECOLOGY
INTERMEDIATE LID DESIGN 54
SITING CONSIDERATIONS: Soil Variability

Site 2: SAND

Broadview Green Grid, Seattle, WA

SITING CONSIDERATIONS: Soil Variability

Site 3: Glacial till

Broadview Green Grid, Seattle, WA

INFILTRATION RATES: Overview

Measure or estimate initial saturated hydraulic conductivity

Apply correction factor

Long-term (design) infiltration rate
INfiltration Rates: Methods

- Estimate based on soil properties
  - Soil grain analysis*
  - Atterberg limits and ASTM D4318-84 visual/manual procedure
- In-situ field measurements
  - Small-scale PIT methods*
  - Large-scale PIT methods*
  - Borehole methods
  - Single-ring infiltrometer
  - Constant head conditions

* Included in SWMMEW and in the Eastern WA LID Guidance Manual

ECOLOGY SMALL-SCALE PIT METHOD

- Excavate pit
  - Depth ~ surface elevation of native soil (before BSM placement)
  - Horizontal bottom area ~ 12 to 32 sf
  - Side slopes laid back, but vertical to test ponding depth (6 – 12in)
- Install vertical measuring rod
- Install splash plate
  - Reduce side wall erosion and disturbance of bottom (clogging)

ECOLOGY SMALL-SCALE PIT METHOD

- Fill pit for pre-soak period
  - Standing water (at least 12 inches) for 6 hours
- Adjust flow rate for steady state period
  - Constant water depth (6 – 12 inches) for 1 hour
- Turn off water and record rate of infiltration every 30–60 minutes until one hour after the flow has stabilized
- Lowest hourly flow rate is the initial (measured) infiltration rate
BIORETENTION SITING, DESIGN & CONSTRUCTION
ECOLOGY SMALL-SCALE PIT METHOD

• Depth to groundwater
  - Over excavate below pit bottom to check for hydraulic restrictive layers (e.g., bed rock, till/clay lenses) or groundwater

• Number of PITs
  - Recommend one PIT at each bioretention site
  - For larger site, one PIT every 5,000 sf
  - For long narrow facilities, one PIT every 200 lineal feet (unless borings indicate consistent soil characteristics)

Regulate flow (Ex. Ball Valve)
Flow Meter
Fire Hose
Garden Hose
To Pit
**Vertical measuring rod**

- Pit (lay back side slopes)
- 5 gal. bucket (energy dissipation)

Water level recorded every 15 minutes

---

**ECOLOGY SMALL-SCALE PIT METHOD**

Initial rate = 0.25 in/hr

1.5 in/hr
**DESIGN INFILTRATION RATES**

- Correction factors applied to initial rate to estimate long-term rate for design.
- Partial Correction factors:
  - $CF_v$ (Site variability and number of locations tested) = 0.33 to 1
  - $CF_t$ (Test method) = 0.4 to 0.75
  - $CF_m$ (Degree of influent control to prevent siltation and bio-buildup) = 1 (overlying BSM provides excellent protection)
- Total Correction Factor ($CF$) = $CF_v \times CF_t \times CF_m$
- Design rate = Initial Rate $\times CF$

**APPLICABILITY**

- **Residential Parcels**
  - Landscaped areas
  - Planters
- **Right-of-Way**
  - Planting strip
  - Curb bulbs
  - Medians
- **Commercial Parcels**
  - Landscaped areas
  - Planters
  - Parking Lots

Note: rain gardens should only be used for small projects that do not trigger Core Elements #5 or #6.
BIORETENTION SITING, DESIGN & CONSTRUCTION
SINGLE FAMILY: Stormwater Planters

Inflow

Conveyance

Overflow

BIORETENTION SITING, DESIGN & CONSTRUCTION
RIGHT OF WAY: Seattle SEA Street

Before

After

BIORETENTION SITING, DESIGN & CONSTRUCTION
RIGHT OF WAY: Seattle SEA Street

Before

After
BIORETENTION SITING, DESIGN & CONSTRUCTION
COMMERCIAL PARCELS: Parking Lots
Northgate Mall, Seattle, WA

Curb Cut Inflow

Beehive Structure Overflow

Combining landscape requirements with bioretention

Lewis Creek Park, Bellevue, WA

Combining conveyance with bioretention

Bagley Elementary, Seattle, WA
BIORETENTION SITING, DESIGN & CONSTRUCTION

COMMERCIAL PARCELS: Bioretention and Rain Gardens

YMCA Silverdale, WA

Villanova Campus

COMMERCIAL PARCELS: Stormwater Planters

Taylor 28 Apartments
Seattle, WA

SNOW STORAGE

• Can be used for snow storage in cold climates

• If used for snow storage or to treat parking lot runoff:
  - Plant with salt tolerant and non-woody plant species
  - Minimize use of sand, cinders, and other winter abrasives

City of Spokane
BIORETENTION SITING, DESIGN & CONSTRUCTION
PERFORMANCE STANDARDS

• Runoff Treatment (MR #5)
  • Treat 90% of annual runoff
  • Specific treatment required depending on site type and/or location:
    - Basic (TSS)
    - Metals (dissolved Cu and Zn)
    - Phosphorus
    - Oil

• Flow Control (MR #6)
  • Based on a pre-developed condition (prior to settlement) or existing condition

LAYOUT OPTIONS

Series of Connected Cells

Single Cell

Broadview Green Grid, Seattle, WA
FLOW ENTRANCE: Design Criteria

- Flow entering should be non-erosive
  - Velocity less than 1.0 fps
- Dispersed flow entrance → Preferred!
  - Vegetated buffer strip
  - Sheet flow across pavement/gravel
  - Sheet flow b/t wide wheel stops
- Concentrated flow entrance → Requires erosion protection (e.g., rock)
  - Piped flow
  - Curb cuts
  - Trench drains

Wheel stops prevent vehicle entry and restrict vehicle loading at edge while allowing sheet flow to bioretention.
FLOW ENTRANCE

Finish grade should be 2-3” lower than curb line to allow for settling. Armor flow entrance with concrete pad or stone.

Armor flow entrance with concrete pad or stone.

Depressed gutter at inlet

Curb Cut

Trench Drain Curb Cut

Yakima LID Manual

Do not use woody plants at inlet (can restrict or concentrate flows)

For higher/surface elevation inlets

Trench Drain

2012 LID Technical Guidance Manual for Puget Sound

Portland BES

Minimum of 18-inches wide

2012 LID Technical Guidance Manual for Puget Sound
Armored flow entrance with curb cut

- For roadside, driveway, or parking lot area curb cuts
- Finish grade is 2-3” lower than curb line to allow for settling
- Minimum curb cut width is 12-inches; 18-inches preferred
- Armored flow entrance with concrete pad and stone

Trench Drain
PRE-SETTLING

To capture debris/sediment and reduce potential for clogging of BSM

May be required for:
- For concentrated flow entrances
- For larger drainage areas
- Where sediment loading is expected (e.g., high-use parking lots and roadways)

Pre-settling methods:
- Open forebay
- Catch basin

Rockery Walls

Earthen Depression

PONDING AREA
PONDING AREA: Design/Performance

**Without Underdrain**
- Earthen depression (w/o liner) or open-bottomed planter
- Relies on infiltration to native soil
- Can provide effective on-site stormwater management, flow control and WQ treatment

**With Underdrain**
- Some infiltration to native soil (w/out liner)
- Can provide on-site stormwater management
- Can provide effective WQ treatment for some pollutants
- Cannot meet flow control goals alone, but can contribute as part of a system to achieve flow control goals (orifice improves performance)

PONDING AREA: Sizing Criteria

- Size to meet performance standards
- Use single event modeling to size for runoff treatment (CE #5) or flow control (CE #6)
- Max. surface pool drawdown time (24-48 hours)
- Soil allowed to dry out periodically
- Restore hydraulic capacity of system
- Maintain adequate soil oxygen levels
- Prevent conditions supportive of mosquito breeding

\[ \text{Surface Pool Drawdown} = \frac{\text{Ponding Depth}}{\text{Design Infiltration Rate}} \]
**PONDING AREA: Sizing Criteria**

- **Size to meet performance standards**
  - Use single event modeling to size for runoff treatment (CE #5) or flow control (CE #6)
- **Max. surface pool drawdown time (24-48 hours)**
  - Soil allowed to dry out periodically
  - Restore hydraulic capacity of system
  - Maintain adequate soil oxygen levels
  - Prevent conditions supportive of mosquito breeding

*Surface Pool Drawdown*  
Example: 6 inch ÷ 0.25 inch/hour = 24 hours

---

**PONDING AREA: Footprint Area**

- Larger footprint area for:
  - Larger contributing area
  - Higher site precipitation
  - Lower native soil infiltration rate
  - Shallower ponding depth
  - Shallower BSM depth

---

**PONDING AREA: Cross-Section Criteria**

- Max ponding depth (12 inches)
- Min bottom width (1 foot)
- Max planted side slope (2.5:1)  
  (for depth ≥ 3 ft)
- Min freeboard?
- Max contributing area or bottom area?

*Seattle requirements provided for example design criteria*

Max contributing area to single cell is 5,000 sf impervious.
PONDING AREA: Roadway Facility Criteria*

- 2-foot shoulder
- Grade at 3H:1V
- Grade at 4H:1V for intersections (Seattle)
- Compact shoulder to 90 percent standard proctor

*Seattle requirements provided for example design criteria

PONDING AREA: Roadway Facility Criteria*

- Rockery >1’ high, min 10’ from curb/edge of road
- Rockery <1’ high min 5’ from curb/edge of road

*Seattle requirements provided for example design criteria

Max 4’ drop from vehicular lane

*Seattle requirements provided for example design criteria
PONDING AREA: Design Resources

UNDERDRAINS: Purpose

- Near sensitive infrastructure with high flood potential
- Filtering storm flows from gas stations and pollutant hotspots
- Areas with contaminated groundwater/soils
- Minimum infiltration rate allowed by local jurisdiction is not adequate to meet drawdown requirements
- Route outflow around phosphorus sensitive water body
**UNDERDRAINS: Types of Pipes**

- **Slotted, thick-walled plastic pipe**
  - Minimum 4” diameter Schedule 40 PVC

- **Slot openings**
  - Smaller than smallest aggregate gradation of filter material
  - Slots perpendicular to long axis of pipe

- **Slotted PVC Pipe with Aggregate Filter/bedding material**
  - Aggregate filter/bedding material
    - Prevent migration of fine material into drain
    - WSDOT Standard Specification 9-03.12(4)
  - Do not wrap in filter fabric

**UNDERDRAINS: Slotted Pipe Placement**

- Slotted pipe placement within aggregate filter/bedding material (Seattle)
  - 6” under pipe
  - 12” on top of pipe
  - 12” each side
UNDERDRAINS: Slotted Pipe Benefits

- Increased media area provides better filtering
  - Reduced potential for clogging (versus perforated pipe wrapped in filter fabric)
- More durable and easier to clean (rotary root cutter or water jet)
  - Versus perforated PVC or flexible slotted HDPE

UNDERDRAINS: Slotted Pipe Guidance

- Observation pipe/clean out
  - 6" rigid non-perforated
  - Every 250 to 300 feet
  - Clean out port
  - Observation well for dewatering rates
- Raised under-drain
  - Maximize infiltration
  - Fluctuating aerobic/anaerobic conditions → Denitrification

- Minimum underdrain slope = 0.5%
- Orifice/control structures
  - Improve flow control performance
  - Minimum 0.5" orifice diameter
  - Maintenance access to orifice required
- Design with access for future modification
  - "Adaptive management"
  - Cap drain pipe
  - Throttle flows with orifice

Photo courtesy of Seattle Public Utilities
UNDERDRAINS: Design Resources

Seattle Standard Details

Bioretention with curb

OVERFLOW: Design Criteria/Types

- Necessary to safely convey flows that exceed capacity
  - Protect downstream property and resources
  - Overflow configuration depends on design objectives
- Overflow elevation set at max. ponding depth
- Directed to downstream BMP or approved discharge point

OVERFLOW: Surface Overflow

- Sizing
  - Minimum 6-inches of freeboard
- Vertical stand pipe
  - Can be connected to underdrain system
- Horizontal pipe
- Armored overflow channels

Walla Walla, WA

Vertical stand pipe with beehive grate

Broadview Green Grid, Seattle, WA
ELEVATIONS AND GRADE: Considerations

- Cross Slope
- Longitudinal Slope
- Positive Grade
- Series of Cells
- Check Dams

BIORETENTION SITING, DESIGN & CONSTRUCTION

ELEVATIONS AND GRADE: Cross Slope

- Larger footprint area and berming or wall(s) to achieve ponding area

ELEVATIONS AND GRADE: Cross Slope

- Required width on flat area
- Required width on slope
- Berm
- Zero Cross Slope
ELEVATIONS AND GRADE: Longitudinal Slope

- For long, linear configurations, create series of flat-bottomed cells
- Optimum slope is 2% Maximum slope = 8%
- Steep slopes: control gradient with intermittent weirs or berms or standpipe overflow to provide ponding and dissipate energy
- Flat slopes: may need weir to create ponding

Photo courtesy of Seattle Public Utilities

ELEVATIONS AND GRADE: Positive Grade

- Need positive grade for gravity flow
  - Inflow from contributing area to bioretention cell
  - Overflow from bioretention cell

ELEVATIONS AND GRADE: Series of Cells

- Check dams/weirs or vertical stand pipe overflow
- Reduce flow velocities & erosion potential/dissipates energy
- Create ponding to promote infiltration

Photo courtesy of Seattle Public Utilities
ELEVATIONS AND GRADE: Series of Cells

- **Types of check dams / weirs**
  - Compacted earthen berms covered with vegetation
  - Vegetated hedgerows
  - Rock
  - Wood
  - Concrete

- **Optimum spacing determined by longitudinal slope, performance goals and cost**

**Photo courtesy of Seattle Public Utilities**

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ELEVATIONS AND GRADE: Mild Longitudinal Slope

- Earthen berms
- Rock berms
- Wood berms

**High Point, Seattle, WA**

---

ELEVATIONS AND GRADE: Mild Longitudinal Slope

- Rock berms
- Wood berms
**ELEVATIONS AND GRADE:**

- **Moderate**
  - Longitudinal Slope
  - BIORETENTION SITING, DESIGN & CONSTRUCTION
  - Portland, OR
  - Photo: Curtis Hinman

- **Steeper**
  - Longitudinal Slope
  - BIORETENTION SITING, DESIGN & CONSTRUCTION
  - 110th Street Cascade, Seattle, WA
  - Concrete weirs for longitudinal slopes
  - Walls for cross slopes

- **ELEVATIONS AND GRADE:**
  - Steeper
  - Longitudinal Slope
  - Beehive grate over vertical pipe/structure
  - Broadview Green Grid, Seattle, WA
  - Eastern WA LID Manual
ELEVATIONS AND GRADE: Design Resources

Check Dams

2014 San Francisco Typical Details

BIORETENTION SITING, DESIGN & CONSTRUCTION

CONSTRUCTION CONSIDERATIONS

• Minimize site disturbance
• Tree protection
• Preventing over compaction
• Erosion and sediment control
• Construction sequencing (next section)
CONSTRUCTION CONSIDERATIONS: Minimize Site Disturbance

- Stream biota significantly reduced at SS levels of 50-80 mg/L (Corish 1995).
- Schueler reported median TSS concentrations of 4,145 mg/L leaving construction sites with no TESC and 283 mg/L with TESC.

CONSTRUCTION CONSIDERATIONS: Minimize Site Disturbance

- Site design
- Construction Planning
- Training
- Equipment

CONSTRUCTION CONSIDERATIONS: Tree Protection

- Trees are valuable!
- Arborist evaluation
- Valuation posted on each tree
- Vegetation protection in TESC
CONSTRUCTION CONSIDERATIONS: Tree Protection
- Critical Root Zone (CRZ)
  - No disturbance
  - Arborist present for construction in CRZ
- Dripline
  - Fence during construction

CONSTRUCTION CONSIDERATIONS: Tree Protection
- Feeder Root Zone
  - Limit heavy equipment/stockpiling
  - Limit Trenching
- Utility Boring
  - Tunnel/bore under trees to avoid open cut trench through CRZ and dripline

CONSTRUCTION CONSIDERATIONS: Native Soil Variability
- Do cells look like test pit?
- If lower permeability:
  - Increase size
  - Over-ex and add more BR soil
  - Increase ponding depth (if drawdown can be maintained)
  - Add underdrain

Broadview Green Grid, Seattle, WA
CONSTRUCTION CONSIDERATIONS: Over-compaction

- Prevent over compaction (CRITICAL FOR PERFORMANCE)
- No excavation, soil placement, or soil amendment during wet or saturated conditions
- Operate equipment adjacent to (not in) the facility
- If machinery must operate in the facility, use light weight, low ground-contact pressure equipment

Soils for Salmon

Vehicular loading prism – some compaction is necessary

For road or parking lot stability, need heavy compaction from road prism-2H:1V from edge

Target compaction for BSM in cell: 85% of max dry density

CONSTRUCTION CONSIDERATIONS: Subgrade permeability

Scarify subgrade to re-fRACTURE soil and till in BSM at interface

Smeared and sealed by bucket
CONSTRUCTION CONSIDERATIONS: Erosion & Sediment Control

- Protect adjacent properties
- Protect public waterways and storm systems
- Protect installed work
- Protect infiltration systems including swales, soils and permeable pavement

Bioretention Media

MEDIA: Media for Optimum Performance

- High enough infiltration rates to meet desired surface water drawdown and system dewatering
- Infiltration rates that are not too high in order to optimize pollutant removal capability
- A growth media to support long-term plant and soil health and water quality treatment capability
- Balance nutrient availability and retention and copper retention at low effluent levels
**MEDIA: Common Soil Media Guidelines**

- 40% topsoil, 30% sand, 30% compost common recommendation nationally and in (in the past) this region
- Issues with this and other guidelines
  - Fines (< 5% passing the #200 sieve)
  - Minimum organic matter content 10% by dry weight per ASTM D 2974
  - Material control
  - Contaminant flushing

**MEDIA: Developing New Soil Media Guidelines**

Driver:
- Top soil specifications can be difficult to apply consistently.
- The need for relatively consistent materials that are readily available, affordable and meet necessary criteria.

**MEDIA: Initial Soil Media Investigations**

Hydraulic conductivity strongly related to percent fines (passing #200 sieve)
Sands collected from suppliers—typically stocked "natural" or minimally processed sands to meet common specifications.

Hydraulic conductivity strongly related to coefficient of uniformity.

**MEDIA: Existing Soil Media Guidelines**

- Current guideline is 60% sand and 40% compost (this will likely be changing).
- For default media blend, use 12"/hr initial infiltration rate.
- 18" minimum soil depth for metals treatment. Minimum of 24" for improved nitrogen or phosphorus removal.

**MEDIA: Mineral Aggregate Specification**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
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<tbody>
<tr>
<td>3/8&quot;</td>
<td>100</td>
</tr>
<tr>
<td>#4</td>
<td>95-100</td>
</tr>
<tr>
<td>#10</td>
<td>75-90</td>
</tr>
<tr>
<td>#40</td>
<td>25-40</td>
</tr>
<tr>
<td>#100</td>
<td>4-10</td>
</tr>
<tr>
<td>#200</td>
<td>2-5</td>
</tr>
</tbody>
</table>

The following gradation provides a relatively consistent Ksat and coefficient of uniformity for bioretention soil mixes. This is the mineral aggregate spec included in the Eastern WA LID Guidance Manual.
If not using the default media blend determine long-term infiltration rate for sizing and flow control capacity:

- 1 in/hr minimum for acceptable ponding and system de-watering in typical setting (long-term hydraulic conductivity per ASTM D 2434 at 85% compaction per ASTM D 1557)
- If contributing area has <5,000 sf of PGS; and <10,000 sf TIA; and < ¾ acre landscaping then use correction factor of 2
- If over the above thresholds use correction factor of 4

• 2.4 in/hr was maximum rate...guideline likely established for existing native soils not designed soil mixes
• Research indicates that higher infiltration rates provide performance necessary to meet metals treatment requirements
• Ecology now accepts maximum measured (initial) WQ treatment rate of 12 in/hr with an OM content of 5-8% by weight, CEC ≥ 5 milliequivalents/100 grams dry soil, 2-5% mineral fines content, and 18” minimum soil depth
• Apply same correction factor as for flow control capacity

Recommended modifications to permeability testing (ASTM 2434) for bioretention soil media:

- If 60% aggregate/40% compost specification is followed, then use a measured Ksat of 12”/hr (3” to 6”/hr depending on correction factor)
- Previous recommendation of 10% OM content too high. Current recommendation 4% or 5% to 8% max
**Media Summary: What Do We Think We Know**

**BIORETENTION SITING, DESIGN & CONSTRUCTION**

- Sandy bioretention soil mixes should provide excellent water quality performance for Zn, hydrocarbon and bacteria removal. Design with caution for systems with under-drains in P and N sensitive basins.
- 2 to 4 percent passing the 200 sieve ideal. Fines should not be above 5 percent for a proper functioning specification.
- Also important: coefficient of Uniformity (Cu) ≥ 4. Cu is the measure of variation in particle sizes of mineral aggregate ($D_{60}/D_{10}$).
- Small variations in grain size distributions and uniformity can result in large variations in K values.

**BIORETENTION SITING, DESIGN & CONSTRUCTION**

- Monitor carefully if topsoil used for mineral component.
- Sandy soil mixes are very well drained...select plants carefully.
- New soil mixes for improved retention of bio-available P in progress.
- New soil mixes for improved retention of N in progress. Saturated zone improves nitrate removal.
- New soil mixes for improved retention of Cu in progress.
- Very likely that current compost guidelines in WAC did not consider use in stormwater filters. More research needed, and in progress, on compost in stormwater treatment applications.

**Media Summary: What Do We Think We Know**

**Bioretention Plants**
PLANTS: Selection

- Soil moisture conditions
- Sun exposure
- Above and below ground infrastructure
- Site distances and setbacks along roadways

BIORETENTION SITING, DESIGN & CONSTRUCTION

- Pedestrian use
- Adjacent plant communities and potential invasive species control
- Visual buffering
- Aesthetics
• Agricultural literature documents well the role of plants for building soil structure (Buckman and Brady 1969, Angers and Caron 1998)

• City of Portland OR documents increasing infiltration rates in 12-year old commercial parking bioretention areas. 1995~8”/hr, 2005~13”/hr (BES 2006)

• Lucas observes increased phosphate removal in vegetated vs non-vegetated bioretention... removal more than plant uptake
**BIORETENTION SITING, DESIGN & CONSTRUCTION**

**PLANTS: Mulch**

Mulch reduces weed establishment, regulates soil temperature and moisture, and adds OM to soil.

Mulch should be:
- 2-3 inches thick
- Chipped or shredded softwood or hardwood
- Coarse compost for bottom of facility
- Fine beauty bark not preferable

---

**CONSTRUCTION COSTS**

**BIORETENTION COST: Components**

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Estimated Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>CY</td>
<td>$8 – 10</td>
</tr>
<tr>
<td>Bioretention media</td>
<td>CY</td>
<td>$40 – 60</td>
</tr>
<tr>
<td>Filter fabric</td>
<td>SY</td>
<td>$1 – 5</td>
</tr>
<tr>
<td>Gravel</td>
<td>CY</td>
<td>$30 – 35</td>
</tr>
<tr>
<td>4-inch perforated underdrain pipe</td>
<td>LF</td>
<td>$8 – 15</td>
</tr>
<tr>
<td>Plants</td>
<td>each</td>
<td>$5 – 20</td>
</tr>
</tbody>
</table>

Source: [http://www.lowimpactdevelopment.org/fairfax.htm](http://www.lowimpactdevelopment.org/fairfax.htm)

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**BIORETENTION SITING, DESIGN & CONSTRUCTION**

**CONSTRUCTION COSTS**

Cost Comparison – bioretention vs. filters for treatment only

**CONVENTIONAL:**
1. 4' wide landscape island between rows of stalls
2. Catch basins @ 150' o/c
3. 8" CPEP storm pipe continuous
4. Stormwater treatment provided by filter vaults sized @ +/- 5% of tributary area for treatment only

**LID:**
1. 4' wide bioretention cell between rows of stalls, bioretention cells sized @ +/- 5% of tributary area for treatment only
2. Standpipe overflow with beehive grate in each bioretention cell 1 @ 150'

<table>
<thead>
<tr>
<th>CONVENTIONAL</th>
<th>LID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $5/ SF x 4 = $20/LF</td>
<td>1. $30/ LF x 4 = $120/LF</td>
</tr>
<tr>
<td>2. ($8.00/ $350) = $66.86/ LF</td>
<td>2. $1,000/ 150' = $6.67/LF</td>
</tr>
<tr>
<td>3. $50/LF</td>
<td>3. $1,000/LF</td>
</tr>
<tr>
<td>4. $1.25/ SF x (18'+2'+22') x $72.50</td>
<td>4. 150' x $72.50</td>
</tr>
</tbody>
</table>

**TOTAL:** $149.17 / LF  
**TOTAL:** ~ $126.67 / LF

**Notes**
- Reduced detention benefit in addition to the 15% savings shown for treatment only
No formal cost comparison, but contractor found LID project approximately 20% less than conventional.

Introduction

Water quality treatment

Bioretention siting, design and construction

Inspection & verification

Wrap-up

Inspection and verification timing and processes fall into three general phases of project:

- Pre-construction reviews
- Construction
- Verification/repair and final permit
CONSTRUCTION OVERSIGHT: Pre-Construction Reviews

- Set guidelines, expectations and timing for inspections
- Discuss construction sequencing
- Review checklists
- Determine training needs

Walla Walla, WA

CONSTRUCTION OVERSIGHT: Construction

First Visit: Pre-bioretention soil media (BSM) placement
- Certify native/existing soils comparable to design specs
- Temporary erosion and sediment control (TESC) correctly installed
- Rough grading to plans
- Under-drain(s) and overflow
- Field changes...process should have been covered at pre-construction
- Photo documentation?
CONSTRUCTION OVERSIGHT: Construction
Second Visit: Pre-mulch or planting
• Verify that BSM meets composition guidelines and depth
• For BSM composition: current lab report from physical submittal, truck ticket (no longer adequate), visual/texture. If questions on depth, expose to subgrade
• TESC still installed correctly and upslope areas managed properly

CONSTRUCTION OVERSIGHT: Post-Construction
Third Visit: Post-construction
• Verify final grade
• Verify contributing area as designed and stabilized
• Verify BSM not clogged and infiltration rate adequate
• Verify ponding depths, overflow, bottom swale area
• Verify plants (type and density)
• Verify mulch (type and depth)

CONSTRUCTION OVERSIGHT: Post-Construction
Third Visit: Post-construction (whole site)
• Final grades
• 30-45 day follow up to remove TESC
• Verify O&M plan in place
CONSTRUCTION SEQUENCING

- Site flat or sloping away from facility likely to:
  - Complete bioretention area with roads, utilities and storm infrastructure
  - Install conventional TESC and barriers

CONSTRUCTION SEQUENCING

- Construction activity sloping to bioretention facility
  - Divert flows around facility and treat during construction
  - Partially complete and allow storm flows through facility

CONSTRUCTION SEQUENCING

- Construction activity sloping to bioretention facility (w/o underdrain)
  - Delineate or partially grade to define facility. Keep construction traffic off area
  - Install TESC and stabilize upslope construction area as best as possible
  - Divert flows around facilities
  - If flows allowed through facility, leave at least 6" above final grade. Line or mulch?
  - Keep construction traffic off area
CONSTRUCTION SEQUENCING

- Construction activity sloping to bioretention facility (w/underdrain)
- Place infrastructure
- If possible leave rest of facility at least 6” above grade
- Install TESC and stabilize upslope construction area
- If flows allowed through facility, leave or backfill at least 6” above final grade
- Cover underdrain with plastic and fabric
- Line or mulch whole facility?
- Keep construction traffic off area

INSPECTION & VERIFICATION

CONSTRUCTION SEQUENCING

Partial excavation and completion of facility after homes are finished and landscaping stabilized requires clear agreement among developer, homebuilder and jurisdiction

REMEDIES FOR FAILING SITES

- Poor TESC and sediment to facility
  - Excavate to depth that sediment deposits and potential clogging not present (usually 6”)
  - Replace BSM, mulch, and plants
- Compaction of existing soils
  - Does the facility still infiltrate at design rate?
  - Perform infiltration test or verify pre-construction density
  - Remedy procedures if necessary
**Statewide LID Training Program**

**OVERVIEW OF PROGRAM**

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<th>INTERMEDIATE</th>
<th>ADVANCED</th>
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<td>Advanced Topics for Long-term LID Operations: Bioretention</td>
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</table>

**OVERVIEW OF PROGRAM**

- An on-line evaluation will be sent to you within 5 days following this training.
Two certificates:
- LID Design certificate
- Long-term LID Operations certificate

Sign out!

Statewide LID Training Program

ONLINE RESOURCES

For information on training and other resources, visit the Washington Stormwater Center website:
http://www.wastormwatercenter.org

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HERRERA

CORE TEAM

CH2M HILL
KINDRED HYDRO
MITHUN
MSM

PROJECT LEAD

ADDITIONAL TRAINING SUPPORT

OVERVIEW OF PROGRAM