OVERVIEW OF PROGRAM

• 2012: Public and private partners engage state legislature to fund program

• June 2012: LID Training Steering Committee

• 2012-2013: Washington State LID Training Plan developed: www.wastormwatercenter.org/statewide-lid-training-program-plan

• Training program built from state LID Training Plan
### Statewide LID Training Program

#### OVERVIEW OF PROGRAM

<table>
<thead>
<tr>
<th>PROJECT LEAD</th>
<th>CORE TEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="#">HERRERA</a></td>
<td><a href="#">CASCADIA</a></td>
</tr>
</tbody>
</table>

#### ADDITIONAL TRAINING SUPPORT

- [CH2M HILL](#)
- [Washington Stormwater](#)
- [SvR Design Company](#)
- [Kindred Hydro](#)
- [MITHÜN](#)
- [Leaping Frog Films](#)
- [Mutual Materials](#)
- [StormwaterONE](#)
Statewide LID Training Program

PROGRAM OVERVIEW

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

## Overview of Program

<table>
<thead>
<tr>
<th><strong>Introductory</strong></th>
<th><strong>Intermediate</strong></th>
<th><strong>Advanced</strong></th>
</tr>
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<tbody>
<tr>
<td><strong>2.1</strong></td>
<td>Intermediate LID Topics: NPDES Phase I &amp; II Requirements</td>
<td>Advanced Topics for Long-term LID Operations: Bioretention</td>
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<tr>
<td><strong>2.1</strong></td>
<td>Intermediate LID Design: Bioretention</td>
<td>Advanced Topics for Long-term LID Operations: Permeable Pavement</td>
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<td><strong>2.2</strong></td>
<td>Introduction to LID Design: Permeable Pavement</td>
<td>Advanced Topics in LID Design: Bioretention</td>
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<tr>
<td><strong>3.1</strong></td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
<td>Advanced Topics in LID Design: Permeable Pavement</td>
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<tr>
<td><strong>3.2</strong></td>
<td>Intermediate LID Design: Rainwater Collection Systems &amp; Vegetated Roofs</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
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<td><strong>3.3</strong></td>
<td>Intermediate LID Design: Hydrologic Modelling</td>
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- Advanced Topics for Long-term LID Operations: Bioretention
- Advanced Topics in LID Design: Bioretention
- Advanced Topics for Long-term LID Operations: Permeable Pavement
- Advanced Topics in LID Design: Permeable Pavement
- Advanced Topics in LID Design: Site Assessment, Planning & Layout
- Advanced Topics in LID Design: Rainwater Collection Systems & Vegetated Roofs
# Statewide LID Training Program

## Overview of Program

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<td>5.6 Advanced Topics in LID Design: Hydrologic Modeling</td>
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Advanced Topics for Long-term LID Operations:
- Bioretention
- Permeable Pavement
- Site Assessment, Planning & Layout
- Rainwater Collection Systems & Vegetated Roofs

Advanced Topics in LID Design:
- Hydrologic Modeling
- Bioretention Media and Compost Amended Soils
Rainwater Collection Systems & Vegetated Roofs

WESTERN WASHINGTON

Statewide LID Training Program

DEPARTMENT OF ECOLOGY
State of Washington
JASON KING, RLA  
ASLA LEED AP  
Senior Landscape Architect  
Key project experience:  
Stormwater design for development, site design, green roofs, stormwater art, ecological planning

MITHÜN

CHRIS WEBB, PE  
LEED FELLOW  
Associate Engineer  
Key project experience: permeable pavement, bioretention, rainwater harvesting
AGENDA

1. introduction
2. rainwater collection systems
3. vegetated roofs
4. wrap up
AGENDA

1 introduction

2 rainwater collection systems

3 vegetated roofs

4 wrap up
LEARNING OBJECTIVES

• Participants gain an intermediate level knowledge necessary to coordinate activities for entry level design and implementation of rainwater collection systems and vegetated roofs in residential and commercial settings (new and retrofit).

• Participants learn basic entry level design and implementation approaches for rainwater collection systems and vegetated roofs in residential and commercial settings.

• Participants learn practical skills necessary for construction of basic rainwater collection systems and vegetated roofs.
INTRODUCTION & REGULATIONS

LID Principles: Pre-developed forest
INTRODUCTION & REGULATIONS

LID Principles: Developed condition

2012 LID Technical Guidance Manual for Puget Sound
INTRODUCTION & REGULATIONS

LOW IMPACT DEVELOPMENT (LID): Stormwater Management Strategy

• Site design & planning techniques emphasizing conservation

• Use of small-scale & distributed engineered controls to closely mimic pre-development hydrologic processes

• Minimizing the concentration of stormwater

• Careful assessment of site soils and strategic site planning to best use those soils for stormwater management
LID Principles: Site Design And Planning

- Minimize disturbance
- Reduce impervious surface
- Protect and restore native soils and vegetation
- Manage stormwater close to the source in a system of distributed practices
- Disconnect impervious surfaces

**Traditional**

**LID**
INTRODUCTION & REGULATIONS

LID BMPs: Small-Scale Engineering Controls

• Infiltration
• Filtration
• Storage
• Evaporation
• Transpiration

Conserve or regain pre-developed hydrologic functions

Synonyms for LID BMPs:

Green Stormwater Infrastructure (GSI), Integrated Management Practices (IMPs), and On-Site Stormwater Management BMPs
**Western WA NPDES Permit**

National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Permits (2013-2018 permit cycle)

<table>
<thead>
<tr>
<th>Phase 1 Permittees</th>
<th>Western Washington Phase II Permittees</th>
<th>Eastern Washington Phase II Permittees</th>
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<tr>
<td>Seattle</td>
<td>82 Cities</td>
<td>18 Cities</td>
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<td>Tacoma</td>
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<td>5 Counties</td>
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<td>Clark County</td>
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<tr>
<td>King County</td>
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<tr>
<td>Pierce County</td>
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<tr>
<td>Snohomish County</td>
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</tbody>
</table>

*Secondary Permittees:* Approximately 45; such as ports and universities

To see a listing of permittees visit [http://www.ecy.wa.gov/programs/wq/stormwater/municipal/MuniStrmWtrPermList.html](http://www.ecy.wa.gov/programs/wq/stormwater/municipal/MuniStrmWtrPermList.html)
NPDES PERMIT LID REQUIREMENTS: Implementation Timeline Varies By Permittee

Review and revise development related codes, rules & standards (i.e. adopt the 2012 Stormwater Manual)

Timeline for updating local codes

**Phase I**

- Per Section S5.C.5.b of the Phase I Permit
- June 2014

**Phase II**

- Per Section S5.C.4 of the Phase II Permit
- June 30, 2015
- Dec. 31, 2016*
- June 30, 2017
- June 30, 2018

* = Or GMA update deadline

Permittees in Lewis & Cowlitz Counties

City of Aberdeen

Most Permittees

Permittees in Lewis & Cowlitz Counties

City of Aberdeen
INTRODUCTION & REGULATIONS

NPDES MUNICIPAL STORMWATER PERMIT:
Minimum Requirements (MRs)

1. Preparation of Stormwater Site Plans
2. Construction Stormwater Pollution Prevention Plan (SWPPP)
3. Source Control of Pollution
4. Preservation of Natural Drainage Systems and Outfalls
5. On-Site Stormwater Management
6. Run-off Treatment
7. Flow Control
8. Wetlands Protection
9. Operations and Maintenance
### DEFINITIONS

Subset of On-site Stormwater Management BMPs used to meet MR #6 or MR #7 (may also be used to meet MR #5)

<table>
<thead>
<tr>
<th>Onsite SW Management BMP</th>
<th>Flow Control Credit</th>
<th>Treatment Credit&lt;sup&gt;1&lt;/sup&gt;</th>
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<tr>
<td>Soil Amendment</td>
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<tr>
<td>Retaining &amp; Planting Trees</td>
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<tr>
<td>Rainwater Harvesting</td>
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<tr>
<td><strong>Bioretention</strong>&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>X</td>
</tr>
<tr>
<td><strong>Permeable Pavement</strong>&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>X&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Vegetated Roofs</strong>&lt;sup&gt;3&lt;/sup&gt;</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Meets basic, enhanced and phosphorus treatment when infiltrating through soil per Ecology treatment requirements

<sup>2</sup> Where permeable pavement is over soils meeting the suitability criteria or a treatment layer is included

<sup>3</sup> Also considered SW Treatment & Flow Control BMPs/Facilities (additional requirements in regard to long term inspection, operations, and maintenance apply)
AGENDA

1. introduction

2. rainwater collection systems

3. vegetated roofs

4. wrap up
Introduction

• What is Rainwater Collection
• History of Rainwater Collection
• Definitions
  • Reclaimed water
  • Greywater
  • Rainwater
• Benefits of Rainwater Harvesting
Introduction

RAINWATER COLLECTION SYSTEMS
System Types

• Non-Potable
  • toilets
  • urinals
  • trap primers for floor drains and floor sinks
  • irrigation
  • industrial processes
  • water features
  • cooling tower makeup
System Types

• Potable
  • Sole Source
  • Redundant

• Gravity or Pumped

• Commercial / Residential

• Single Building or Community Scale

• Simple

• Complex

• Hybrid Stormwater Systems
System Components

Roofing

- For potable systems powder coated metal roofing is preferred
- Others can be considered
- Ecology water quality testing results
- Potable source control (UPC Appendix K)
  - Wood Roofing Materials
  - Lead Flashing
  - Roof paints and coatings with lead, chromium, or zinc
System Components

Collection

- Gutters
- Screens
- Wet vs. dry conveyance
- Sumps & relay pumping
- Freeze protection
System Components

Pre-Filtration

- Filter Examples
- Pre-filtration vs. roof washer
- 100 micron per UPC 1709.9.11

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System Components

Storage (Cistern)

Design requirements

• Structural
• Access
• Overflow
• Isolate and drain for maintenance
• Screen all penetrations for vermin and insects
• Freeze protection
System Components

Storage (Cistern) – Above Grade Metal

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RAINWATER COLLECTION SYSTEMS

System Components

Storage (Cistern) – Recycled

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System Components

Storage (Cistern) – Above Grade Plastic

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System Components
Storage (Cistern) – Below Grade Plastic
System Components

Storage (Cistern) – Below Grade Concrete (cast in place)

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System Components

Storage (Cistern) – Below Grade Concrete (Pre-Cast)

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Storage options with costs

Approximate cistern costs per gallon stored by tank type

- $0.50
- $1.00
- $2.00
- $4-$6
- $1.50
- $2.00
- $4-$6
- $4-$6
System Components

Pumping & Distribution

- Freeze protection
- Suctions
  - Floating
  - Static
- Float Switches
System Components

Pumping & Distribution

- Controls
- Variable Speed vs. single speed with pressure tank
- Jet pumps
- Submersible pumps
RAINWATER COLLECTION SYSTEMS

System Components

Filtration: Non-potable

- Depends on use
- Typically 20-50µ
System Components

Filtration: SF Residential Non-Potable Filter example

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System Components

Filtration: community Non-Potable Filter example

Mithun
System Components

Filtration: community Non-Potable Filter example

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System Components

Filtration: community Non-Potable Filter example

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System Components

Filtration: Potable

- Pollutants of Concern
- Filtration
- Disinfection
RAINWATER COLLECTION SYSTEMS

System Components

Filtration: Potable Filter example

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System Components

Back-up

- Direct Connection
  - DCVA / RP Device
  - Level Control
- Cistern top off
  - Air Gap

Typical RP - For Reference Only
RAINWATER COLLECTION SYSTEMS

Codes and Permitting

Plumbing Code

Governs the piping of water inside and outside of a building

Enforced by health / building departments

• Chapter 17 - Nonpotable RW Catchment Systems

• Appendix K - Potable RW Systems

• WAC 51-56-1700 WA Amendments

Exceptions:

1. A permit is not required for exterior rainwater catchment systems used for outdoor drip and subsurface irrigation with a maximum storage capacity of 360 gallons (1363 L).

2. A plumbing permit is not required for rainwater catchment systems for single family dwellings where outlets, piping, and system components are located on the exterior of the building. This does not exempt the need for permits where required for electrical connections, tank supports, or enclosures.
Codes and Permitting

Plumbing Code – Cross Connection

• Located on back-up line
• Most important code issue
• Necessary to protect potable supply
• Need to isolate premises or within a premises
• Covered by WAC 246-290-490
• EPA Cross Connection Control Manual (816-R-03-002)
• Local code may vary
Codes and Permitting

Plumbing Code – Cross Connection – Air Gap
RAINWATER COLLECTION SYSTEMS

Codes and Permitting

Plumbing Code – Cross Connection – RP Device / DCVA

Typical DCVA - For Reference Only

Typical RP - For Reference Only
RAINWATER COLLECTION SYSTEMS

Codes and Permitting

Plumbing Code – Pipe Labeling

• Requirements vary by jurisdiction
• Label per ASME 13.1
• Black Lettering on yellow background 4’ o/c
• Purple pipe can be allowed

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RAINWATER COLLECTION SYSTEMS

Codes and Permitting

Plumbing Code – Fixture Labeling

• Label all plumbing fixtures ““CAUTION: NONPOTABLE WATER, DO NOT DRINK”

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RAINWATER COLLECTION SYSTEMS
Codes and Permitting

Plumbing Code – Equipment Room Signs

• Equipment Room Signs per code:

“CAUTION NONPOTABLE RAINWATER, DO NOT DRINK. DO NOT CONNECT TO DRINKING WATER SYSTEM. NOTICE: CONTACT BUILDING MANAGEMENT BEFORE PERFORMING ANY WORK ON THIS WATER SYSTEM.”
RAINWATER COLLECTION SYSTEMS

Codes and Permitting

Plumbing Code – Building Signs

• Building Signs per code:

“TO CONSERVE WATER, THIS BUILDING USES RAINWATER TO FLUSH TOILETS AND URINALS.”
RAINWATER COLLECTION SYSTEMS
Codes and Permitting
Plumbing Code – Tank Labeling

• Tank Signs per code:
  “NONPOTABLE RAINWATER.”
  “DANGER-CONFINED SPACE.”
RAINWATER COLLECTION SYSTEMS

Codes and Permitting

ANSI/NSF P151

- NSF P151 - Health Effects from Rainwater Catchment System Components
- Plumbing Code Appendix K, 103.1
RAINWATER COLLECTION SYSTEMS

Codes and Permitting

Water Rights

- Water Law / Water Rights
- WSDOE POL 107 (Oct. 9, 2009)
- Limitations and requirements
Codes and Permitting

ARCSA/ASPE/ANSI 63-2013: Rainwater Catchment Systems

Design and Installation Requirements

• Collection Parameters
• Conveyance System
• Pre-filtration
• Cisterns / Storage
• Pump
• Filtration
• Piping
• System Inspection and Maintenance
• Potable Water Applications
• Operation and Water Quality Maintenance
• Labeling
RAINWATER COLLECTION SYSTEMS

Codes and Permitting

Local Codes & Guides

- Varies by jurisdiction
- Rainwater as sole source
- Sizing guidance
- ARCSA Accredited Professional
- Other requirements
## Modelling

### Cistern Sizing (monthly vs. daily)

#### Model Inputs
- **Academic Toilet Demand:** 1,945 gallons per day

#### Rainwater Collection System

<table>
<thead>
<tr>
<th>Date</th>
<th>Month</th>
<th>Year</th>
<th>Rainfall (inches)</th>
<th>Rainfall (corrected)</th>
<th>Total Demand</th>
<th>Available Water</th>
<th>Net to Cistern</th>
<th>Shares</th>
<th>Adds</th>
<th>Cistern Storage</th>
<th>Overflow</th>
<th>Back-up</th>
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</table>

#### Average Monthly Precipitation

**Seattle Sea-Tac Airport, Washington**

- **Average Precipitation:**
  - January: 1.0 inches
  - February: 1.5 inches
  - March: 2.0 inches
  - April: 2.5 inches
  - May: 3.0 inches
  - June: 3.5 inches
  - July: 4.0 inches
  - August: 4.5 inches
  - September: 5.0 inches
  - October: 5.5 inches
  - November: 6.0 inches
  - December: 6.5 inches

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**Statewide LID Training Program**

**Western Washington**

**Rainwater Collection Systems & Vegetated Roofs**
Modelling

Cistern Sizing (monthly vs. daily)
Modeling

Stormwater (BMP T5.20: Rainwater Harvesting)

**BMP T5.20: Rainwater Harvesting**

**Purpose and Definition**
Rainwater harvesting is the capture and storage of rainwater for beneficial use. Roof runoff may be routed to cisterns for storage and nonpotable uses such as irrigation, toilet flushing, and cold water laundry. Rainwater harvesting can help reduce peak stormwater flows, durations, and volumes. The amount of reduction achieved with cistern storage is a function of contributing area, storage volume, and rainwater use rate.

**Design Criteria**
- 100% reuse of the annual average runoff volume (use continuous runoff model to get annual average for drainage area).
- System designs involving interior uses must have a monthly water balance that demonstrates adequate capacity for each month and reuse of all stored water annually.

**Runoff Model Representation**
- Do not enter drainage area into the runoff model.

**Other Criteria**
- Restrict use to 4 homes/acre housing and lower densities when the captured water is solely for outdoor use.
Modeling

Stormwater (BMP T5.20: Rainwater Harvesting)

- Instances where BMP T5.20 applies is very limited
- **Recommendation**: Model daily demand as an infiltration rate in a vault
- Stacked hybrid vault or in-line cistern
Operations and Maintenance

• Inspect and clean filters and screens
• Inspect cisterns and clean accumulated sediment
• Inspect pump & controls
• Backflow prevention device inspection
• Water quality testing as required for potable systems
• Document and log all maintenance and testing
RAINWATER COLLECTION SYSTEMS

Potable Example

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**Potable Example**

- Sole Source
- Retrofit
- 3 bedroom / 5 occupants (183 gpd)
- 200sf irrigated garden
- 2,500sf roof
- High rainfall site (119”/year)
- 13,500 gallon cistern meets 95% of days in the model
- Sump pumps required for collection
NOTES:

1. ALL EQUIPMENT TO BE INSTALLED PER MANUFACTURER’S INSTRUCTIONS AND LOCAL PLUMBING CODE.
2. TANK TO BE INSTALLED PER MANUFACTURER’S INSTRUCTIONS.
3. ALL TANK INLETS/OUTLETS SHALL BE SCREENED WITH ⅛” SS MESH.
4. FREEZE PROTECT ALL ABOVE GRADE PIPING.
5. THE TANK SHOULD BE PROVIDED WITH AN OVERFLOW TO THE A DISPERSION TRENCH BY OTHERS.
6. BURY ALL BELOW GRADE PRESSURIZED OR SUCTION WATER LINES PER DETAIL 1 ON SHEET C1.2.

Chris Webb & Associates, Inc.

Statewide LID Training Program

WESTERN WASHINGTON

RAINWATER COLLECTION SYSTEMS & VEGETATED ROOFS 67
Potable Example

RainBank Rainwater Systems
Potable Example

RainBank Rainwater Systems
Potable Example

RainBank Rainwater Systems
Hybrid Example

Legend:
1. Roof water collection
2. Downspout to raingarden
3. Demonstration raingarden
4. Conveyance to cistern
5. Rainwater cistern
6. Recycle rainwater for water closets
7. Recycle rainwater for irrigation
8. Sheet flow to raingarden
9. Raingarden in right-of-way
10. Sheet flow to previous pervious
11. Collect and daylight to raingarden
12. Infiltration zone

- Collected rainwater
- Recycled rainwater
Hybrid Example

RAINWATER COLLECTION SYSTEMS
Hybrid Rainwater / Green Roof?

- Not recommended to collect and re-use rainwater collected from Green Roof areas for potable reuse
- Toilet flushing in some cases/irrigation ok
- Aesthetic issues (i.e. discoloration / tannins)
- Some leaching of nutrients possible with some media
AGENDA

1. introduction
2. rainwater collection systems
3. vegetated roofs
4. wrap up
Types, Functions & Performance

Vegetated Roof?
VEGETATED ROOFS
Types, Functions & Performance

A Range of Benefits

• Improved Stormwater Management
• Urban Heat Island Reduction
• Usable Green Space
• Energy Efficiency/Thermal Insulation
• Roof Longevity
• Biodiversity/Habitat
• Reduction of Noise
• Reduction of Dust & Smog Particles
• Integrated Design Opportunities
• Aesthetics/Views
VEGETATED ROOFS
Types, Functions & Performance

**Extensive**
Thin, lightweight soil profile for with low maintenance vegetation such as succulents, grasses and perennials for stormwater management. Access paths usually for maintenance only.

**Semi-Intensive**
Hybrid system with slightly more soil, capable of supporting more vegetation including small trees and shrubs. Can include small areas for seating and paths.

**Intensive**
Thicker soil profile with more robust vegetation including trees and shrubs. Includes paving, structures and other roof terrace elements.
VEGETATED ROOFS

Types, Functions & Performance

Extensive
VEGETATED ROOFS

Types, Functions & Performance

Extensive
VEGETATED ROOFS

Types, Functions & Performance

Extensive
VEGETATED ROOFS

Types, Functions & Performance

Semi-Intensive
VEGETATED ROOFS

Types, Functions & Performance

Semi-Intensive
VEGETATED ROOFS

Types, Functions & Performance

Semi-Intensive
VEGETATED ROOFS

Types, Functions & Performance

Intensive (Roof Terrace)
VEGETATED ROOFS

Types, Functions & Performance

Intensive (Roof Terrace)
VEGETATED ROOFS

Types, Functions & Performance

Intensive (Roof Terrace)
VEGETATED ROOFS

Types, Functions & Performance

Rooftop Agriculture
VEGETATED ROOFS

Types, Functions & Performance

Rooftop Agriculture
VEGETATED ROOFS
Types, Functions & Performance
Part of an Integrated System – LID Design

The water system in Berlin’s Potsdamer Platz

Overall plan of the Potsdamer Platz site with urban water features.
# VEGETATED ROOFS

## Types, Functions & Performance

### Performance

<table>
<thead>
<tr>
<th>Project</th>
<th>Completed</th>
<th>GM Depth</th>
<th>Area</th>
<th>Volume Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSU Broadway Building</td>
<td>2005-present</td>
<td>15 cm</td>
<td>500 m²</td>
<td>41-48%</td>
</tr>
<tr>
<td>BCIT</td>
<td>2005</td>
<td>75, 150 mm</td>
<td>33 m²</td>
<td>29%(75mm) 26%(150mm)</td>
</tr>
<tr>
<td>Multnomah</td>
<td>2004-2005</td>
<td>6 in</td>
<td>11,900 ft²</td>
<td>30%</td>
</tr>
<tr>
<td>Hamilton (west roof)</td>
<td>2002-2005</td>
<td>5 in (~4”)</td>
<td>2,520 ft²</td>
<td>56%</td>
</tr>
<tr>
<td>Zoonazium</td>
<td>2-4/2007</td>
<td>6 in</td>
<td>8,000 ft²</td>
<td>38%</td>
</tr>
</tbody>
</table>
VEGETATED ROOFS
Types, Functions & Performance
Performance

- Peak flows reduced by up to 53.3%
- Total runoff reduction of up to 70%
- Reductions of peak flows due to increased travel time of runoff

VEGETATED ROOFS

Types, Functions & Performance

Factors Influencing Performance

- Size, shape and configuration of vegetated roof
- Soil depth
- Soil moisture conditions
- Magnitude and distribution of rainfall events
- Vegetative Conditions
- Runoff travel path
VEGETATED ROOFS
Types, Functions & Performance
Additional Performance Values

- 10% reduction in energy use
- Double lifespan of roof (50 years)
- Reduced UV degradation and fluctuation of temperatures
- Reduction of urban heat island (local and modelled cumulative benefit)
- Reduction in particulate matter
VEGETATED ROOFS
Types, Functions & Performance
Additional Performance Values

- Improved performance of solar due to cooling from vegetated roof
VEGETATED ROOFS

Design Process

BASE COMPONENTS
• Waterproof Membrane
• Protection Layer
• Root Barrier
• Drainage Layer
• Edging/Curbs
• Maintenance Paths
• Ballast/Gravel
• Filter Fabric
• Growth Media (soil)
• Vegetation/Plants

• **Irrigation System**

OPTIONAL COMPONENTS
• Insulation
• Moisture Retention Mat
• Leak Detection System
• Rainwater Detention
• Ponds/Detention
• Railings
• Paving
• Lighting

Essential for our climate!
VEGETATED ROOFS

Design Process

Exploded Axonometric

- plantings
- gravel streams
- berms
- growing media
- irrigation
- trays
- edging
- furniture
- protective roof barrier
- rigid insulation (blue foam)
- new waterproofing

pump to irrigation
rainwater cisterns (36,000 gallons)

from roof drains
VEGETATED ROOFS

Design Process

Extensive Roof – Typical Layers

- a. existing structural roof support
- b. existing 5-ply roofing system
- c. ¼” protection board
- d. ½” drainage mat with root barrier
- e. stainless steel edging
- f. 6” growth medium
- g. green roof vegetation
- h. drip irrigation system
- i. gravel ballast
- j. roof drain
- k. monitoring equipment
- l. concrete pavers
VEGETATED ROOFS

Design Process

Different Systems
**VEGETATED ROOFS**

**Design Process**

**Growing Media**

- **standard topsoil**
  - 120-160 pounds per square foot (saturated)

- **lightweight aggregate**
  - 40-80 pounds per square foot (saturated)

- **polymers**
Growing Media

- Light weight (saturated)
- Maintain structure/Limited fines
- Retain moisture
- Environment for plant growth
Design Process

Growing Media

- Grain Size Distribution
- Density
- Water & Air Management
- pH, Lime & Salt Content
- Organics
- Nutrients
- CEC Capacity
VEGETATED ROOFS

Design Process

Varying Depths of Growing Media

ECO-ROOF A
- Sedums & Grasses
- 3-6’ (75-150mm)
- Drainage Mat
- Root Barrier/Protection
- Waterproof Membrane

ECO-ROOF B
- Sedums & Grasses
- 3-6’ (75-150mm)
- Root Permeable Separation Fabric
- 1-2’ (25-50mm) Tephradren Drainage
- Root Barrier/Protection
- Waterproof Membrane

ECO-ROOF C
- Wildflowers/Groundcovers
- 6’+ (150+mm)
- Filter Fabric
- Water Retention/Drainage Mat
- Root Barrier/Protection
- Waterproof Membrane

URBAN AGRICULTURE
- Vegetables, Herbs, & Flowers
- Composted Mulch
- Drainage
- Water Retention
- Filter Fabric
- Waterproof Membrane
- Planter or Module
### Design Process

#### Structural Considerations

<table>
<thead>
<tr>
<th>Type of Vegetated Roof</th>
<th>Range of Loading (pounds per square foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensive</td>
<td>12-40 p.s.f.</td>
</tr>
<tr>
<td>Semi-Intensive</td>
<td>40-80 p.s.f.</td>
</tr>
<tr>
<td>Intensive (Roof Terrace)</td>
<td>80-250 p.s.f. (can be higher depending on use of larger trees)</td>
</tr>
<tr>
<td>Rooftop Agriculture</td>
<td>40-150 p.s.f.</td>
</tr>
</tbody>
</table>
VEGETATED ROOFS

Design Process

Plantings
Non-Sedums breath through stomata during the day to photosynthesize, thus lose water in large amounts...

CAM plants keep stomata closed during the day and open during the night to absorb CO2, cutting down on transpiration and increasing the ability to survive arid conditions.
VEGETATED ROOFS

Design Process

Plantings: Got CAM?*

Native / Adaptive (without irrigation)

Native / Adaptive (with irrigation)

Ornamental (without irrigation)

Ornamentals (with irrigation)
Design Process

Plantings: Pots
VEGETATED ROOFS

Design Process

Plantings: Cuttings
### Design Process

#### Plantings: Seasonality

<table>
<thead>
<tr>
<th>Plant Palette</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
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<th>O</th>
<th>N</th>
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</tr>
</thead>
<tbody>
<tr>
<td><em>cerci scirpendalis</em></td>
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<td><em>acer circinatum</em></td>
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<td><em>begonia masoniana</em></td>
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<tr>
<td><em>rubus sanguineus</em></td>
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<td><em>hemerocallis</em></td>
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<tr>
<td><em>mahonia repens</em></td>
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<tr>
<td><em>daphne bukweo</em></td>
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<tr>
<td><em>penstemon 'little bunny'</em></td>
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<tr>
<td><em>salvia spp.</em></td>
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<tr>
<td><em>veronica 'anemone'</em></td>
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<tr>
<td><em>polydichium multiflorum</em></td>
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<tr>
<td><em>lavandula angustifolia</em></td>
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<tr>
<td><em>sedum spp.</em></td>
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</tbody>
</table>
VEGETATED ROOFS

Design Process

Plantings: Diversity

Sedum oreganum (Oregon Stonecrop)

Sedum spatifolium ‘Coral Carpet’ (Coral Carpet Stonecrop)
VEGETATED ROOFS

Design Process

Plantings: Diversity

Sedum acre (Biting Stonecrop)

Sedum kamtschaticum 'Variegatum' (Variegated Stonecrop)
VEGETATED ROOFS

Design Process

Plantings: Diversity

Delosperma cooperi
(Hardy Iceplant)

Sempervivum spp
(Hens and Chicks)
VEGETATED ROOFS

Design Process

Plantings: Diversity

Lewisia Columbiana (Columbia Lewisia)

Hemerocallis spp. (Daylilies)
VEGETATED ROOFS
Design Process
Plantings: Diversity

Festuca glauca ‘Elijah’s Blue’
(Elijah’s Blue Fescue)

Fragaria chiloensis
(Coast Strawberry)
VEGETATED ROOFS

Design Process

Plantings: Diversity
VEGETATED ROOFS

Design Process

Irrigation: Precipitation - Seattle vs. European Cities
VEGETATED ROOFS
Design Process

Irrigation: Precipitation - Seattle vs. other US Cities (East)
VEGETATED ROOFS

Design Process

Irrigation: Precipitation Seattle vs. other US Cities (West)
VEGETATED ROOFS

Design Process

Irrigation: Seattle - Precipitation v. Evapotranspiration
VEGETATED ROOFS

Design Process

Irrigation: Demand

• 30-40 day spans without even a trace of precipitation

• When trace precipitation (less than 0.01 inches) is factored in, the dry spells increase even greater, up to 71 days with only a trace of precipitation.

• There are a number of recorded 40-60 day spans with only a trace of precipitation, mostly occurring from mid-June to late August
VEGETATED ROOFS

Design Process

Irrigation: Spray Rotors
VEGETATED ROOFS

Design Process

Irrigation: Capillary Drip System

The EPIC system can utilize 40%-80% less water for irrigation while removing nutrients. The EPIC profile stays moist as water wicks upward by capillary action from the chamber.

Illustration Courtesy: Firestone Specialty Products
VEGETATED ROOFS

Design Process

Irrigation: Issues with Traditional Spray
VEGETATED ROOFS

Design Process

Irrigation: Issues with Traditional Drip

![Image of irrigation system]

**Large Pore Space**
Gravitational Pull
Sandy Soil

- 15 min: Depth 12"
- 40 min: Depth 24"
- 1 hour: Depth 36"
- 24 hours: Depth 48"

**Small Pore Space**
Capillary Action
Clayey Soil

- 4 hours: Depth 24"
- 24 hours: Depth 48"
- 48 hours: Depth 72"

---

Statewide LID Training Program

WESTERN WASHINGTON

RAINWATER COLLECTION SYSTEMS & VEGETATED ROOFS
VEGETATED ROOFS

**Design Process**

**Irrigation: Et Controllers/Weather Stations**
VEGETATED ROOFS

Layout Complexity of Rooftop Equipment /Access
VEGETATED ROOFS

Layout Complexity of Rooftop Equipment/Access
VEGETATED ROOFS

Layout Parapet Height
VEGETATED ROOFS
Layout  Safety
VEGETATED ROOFS

Layout Views from Above
VEGETATED ROOFS

Layout  Views from Adjacent Spaces
VEGETATED ROOFS

Access & Interpretive Elements

Green roof plants were specifically selected for a number of factors, including appropriateness to roofing conditions, improvement of water retention, cost, low maintenance, aesthetic value, and ecologic function.

Plants

1. Lavender
2. Fountain Grass
3. Purple-Eyed Grass
4. Pampas Grass
5a. Red Wildflower Area
5b. Yellow Wildflower Area
5c. Wild Blue and Beeswax
6. Redbrick
7. Purple Mix
8. Bower Green Mix
9a. White-Seta Mix
9b. Red Sedum Mix
9c. Purple Sedum Mix
10. 1st and Daffodil Bulbs

Components:
A. Gazebo Area
B. Navo Area
C. Seating Area and Planter
D. Nursery
E. Interpretive Kiosk
F. Bed Drain
G. Premier Walk

Multnomah County

Statewide LID Training Program

Rainwater Collection Systems & Vegetated Roofs
VEGETATED ROOFS

Layout Preliminary Sketches
VEGETATED ROOFS

Layout  Design Concept
VEGETATED ROOFS
Layout Construction Documents

LEVEL 4 - HRC & C-WING IRRIGATION PLANS

IRRIGATION LEGEND

NOTES

Statewide LID Training Program
RAINWATER COLLECTION SYSTEMS & VEGETATED ROOFS
VEGETATED ROOFS

Construction Process

Roofing & Protection
VEGETATED ROOFS

Construction Process

Edging/Access
VEGETATED ROOFS

Construction Process

Soil Loading & Placement
VEGETATED ROOFS

Construction Process

Irrigation
VEGETATED ROOFS

Construction Process

Planting
VEGETATED ROOFS

Construction Process

Inspections

• Pre Construction
• Roofing/Waterproofing
• Plumbing/Mechanical/Electrical (as governed by permitting)
• Initial Layout/Edging (design)
• Growing Media (depth)
• Planting (correct plants/density)
• Irrigation (proper operation)
• Final Walkthrough/Punchlist
• Periodic O&M Reviews
VEGETATED ROOFS

Operations & Maintenance

O&M Planning

General Operations & Maintenance

O&M Contacts

Operations and Maintenance Requirements

- Irrigation
- Vegetation Management
- Soil Substrate/Growing Medium
- Aesthetics
- Insect Control
- Structural Components
- Debris & Litter
- Spill Prevention
- Training/Written Guidance
- Access & Safety

O&M Schedule & Documentation

- Activity Matrix
- Maintenance Calendar
- O&M Form
VEGETATED ROOFS

Operations & Maintenance

O&M Planning: Detailed Specs

2c. Soil Substrate/Growing Medium

- Inspection should be conducted for evidence of erosion from wind or water.
  - Any erosion should be stabilized with additional substrate and/or growing medium similar in nature to the original material (not to exceed 4" soil depth)
  - Areas should be planted immediately with appropriate material to hold soils in place; use erosion control netting and/or sterile straw mulch if necessary to provide immediate coverage of areas.
  - Sources of erosion damage (shedding from other roofs, channeling of surface runoff, obstructions) should be identified and corrected immediately.

2d. Aesthetics

- The desired aesthetic of the green roof is to maintain a healthy mix of succulent vegetation, perennials, and herbs per plans, that is free of weeds and that each band is not dominated by a single species.
- Irrigation is for maintenance of plant health, and should allow for seasonal variation of plants, not to maintain a lush surface year round.
- Weeding and litter control should be done to maintain a neat appearance of vegetation and common areas and to avoid colonization by non-sedum species.
# VEGEATED ROOFS

## Operations & Maintenance

### O&M Planning: Activity Matrix

#### 3a. Activity Matrix

The following table summarizes operations and maintenance activities. Each section is divided by the component or area that is addressed. Specific activities are listed, each including a routine schedule for regular maintenance, as well as possible triggers that will necessitate unscheduled checks. All activities should be recorded in an O&M manual for a complete record of adjustments, upkeep, repairs, and water usage.

<table>
<thead>
<tr>
<th>Area</th>
<th>Activity</th>
<th>Unscheduled Trigger</th>
<th>Schedule First 2 years</th>
<th>Schedule Long Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>Inspect system for correct operation, water coverage and/or broken lines;</td>
<td>Noticeable dry or brown patches/de-back of vegetation</td>
<td>Every month during irrigation season; Once weekly during hot, dry periods</td>
<td>Twice yearly (once all system startup in spring); spot check during hot, dry periods</td>
</tr>
<tr>
<td></td>
<td>Evaluate irrigation timing with plant water needs. Record schedule</td>
<td>Noticeable dry or brown patches/de-back of vegetation</td>
<td>Every month during irrigation season</td>
<td>3 times yearly during irrigation season</td>
</tr>
<tr>
<td></td>
<td>Check point of connection</td>
<td>Reduced pressure or flow</td>
<td>One monthly during irrigation season</td>
<td>Once monthly during irrigation season</td>
</tr>
<tr>
<td></td>
<td>Check valves</td>
<td>Reduced system performance</td>
<td>Twice yearly during irrigation season</td>
<td>Twice yearly during irrigation season</td>
</tr>
<tr>
<td></td>
<td>Replace damaged connections, pipe accessories and emitters</td>
<td>as needed</td>
<td>as needed</td>
<td>as needed</td>
</tr>
<tr>
<td></td>
<td>Flush irrigation system and winterize system; insulate live supply lines</td>
<td>n/a</td>
<td>End of irrigation season (Nov 1)</td>
<td>End of irrigation season (Nov 1)</td>
</tr>
</tbody>
</table>
VEGETATED ROOFS
Operations & Maintenance
O&M Planning: Maintenance Calendar

3b. Maintenance Calendar

The following is recommended schedule for O&M for the first two years (augment annually based on site observations and project maturity) and long term, to focus on the primary maintenance issues that will arise at different times of the year. While this outlines scheduled required activities, there should be regular visits and observation (monthly walk through) to observe unscheduled triggers and identify potential problems before they escalate. Every visit should include review for access/safety, litter removal, and updating O&M logs accordingly.

<table>
<thead>
<tr>
<th>MONTH</th>
<th>ESTABLISHMENT (2 YEARS)</th>
<th>LONG TERM</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>Check for Erosion/Exposed Soil/Standing Water</td>
<td>Spot Check for Erosion Issues, Standing Water, Drain Function &amp; Litter Removal</td>
</tr>
<tr>
<td>February</td>
<td>Check drains for obstructions</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>Litter Removal</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>Spring Cleaning/Heavy Weeding</td>
<td>Spring Cleaning/Light Weeding</td>
</tr>
<tr>
<td></td>
<td>Survey for Nuisance Vegetation &amp; Remove</td>
<td>Survey for Nuisance Vegetation &amp; Remove</td>
</tr>
<tr>
<td></td>
<td>Provide Additional Sedum Cuttings in Exposed Areas</td>
<td>Add sedum cuttings (if needed)</td>
</tr>
<tr>
<td></td>
<td>Mow Sedum areas to promote colonization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fill any soil areas that settled more than 1&quot;</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>Startup Irrigation System, Set Timer &amp; Test</td>
<td>Startup Irrigation System, Set Timer &amp; Test</td>
</tr>
<tr>
<td></td>
<td>Moderate Weeding</td>
<td>Light Weeding as needed</td>
</tr>
<tr>
<td>June</td>
<td>Monitor and Adjust Irrigation Timing</td>
<td>Light Weeding as needed</td>
</tr>
<tr>
<td></td>
<td>Moderate Weeding</td>
<td></td>
</tr>
</tbody>
</table>
VEGETATED ROOFS

Operations & Maintenance

O&M Planning: O&M Forms/Documentation

3c. O&M Form

Maintenance: Record date, description, and contractor (if applicable) for all structural repairs, landscape maintenance, and facility cleanout activities.

<table>
<thead>
<tr>
<th>Log #:</th>
<th>Date:</th>
<th>Work Performed By:</th>
<th>Initials:</th>
</tr>
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Description of Work Performed:

<table>
<thead>
<tr>
<th>Scheduled? (Y/N)</th>
<th>Required Follow-up Activities and Date:</th>
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<tbody>
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VEGETATED ROOFS

Codes & Permitting

Ecology Guidelines

• Vegetated Roofs in the 2013-2018 Western Washington Phase II Stormwater Permit

  • Defined as a “Hard Surface”
  • Flow control and on-site stormwater management option
  • Not an option in List #1 or List #2 for meeting Minimum Requirement #2
  • Need to use LID Performance Standard to receive on-site stormwater management (Minimum Requirement #5) or flow control (Minimum Requirement #7) credit
VEGETATED ROOFS

Codes & Permitting

Ecology Guidelines

• Vegetated Roofs in the 2012 Stormwater Management Manual for Western Washington (SWMMWW)

  • BMP T5.17 (Volume V)
  • Consist of four basic components: waterproof membrane, drainage layer, light-weight growing medium, and vegetation
  • Install on roofs with slopes between 5 and 20 degrees. Roofs with slopes greater than 10 degrees require an analysis of engineered slope stability
  • Refer to LID Technical Guidance Manual for Puget Sound (2012) for additional design guidance, and Appendix III-C of the SWMMWW for modeling guidance
AGENDA

1. introduction
2. rainwater collection systems
3. vegetated roofs
4. wrap up
## Statewide LID Training Program

### Overview of Program

<table>
<thead>
<tr>
<th>Introductory</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Introduction to LID for Inspection &amp; Maintenance Staff</td>
<td>3.1 Intermediate LID Topics: NPDES Phase I &amp; II Requirements</td>
<td>5.0 Advanced Topics for Long-term LID Operations: Bioretention</td>
</tr>
<tr>
<td>2.1 Introduction to LID for Inspection &amp; Maintenance Staff</td>
<td>3.2 Intermediate LID Design: Bioretention</td>
<td>5.6 Advanced Topics in LID Design: Hydrologic Modeling</td>
</tr>
<tr>
<td>2.2 Introduction to LID for Developers &amp; Contractors: Make Money be Green</td>
<td>3.3 Intermediate LID Design: Permeable Pavement</td>
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<td>3.4 Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
<td>6.2 Advanced Topics in LID Design: Bioretention Media and Compost Amended Soils</td>
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<td>3.5 Intermediate LID Design: Rainwater Collection Systems &amp; Vegetated Roofs</td>
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Statewide LID Training Program

COURSE CATALOG

http://www.wastormwatercenter.org/lidswtrainingprogram/
ONLINE EVALUATION

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

http://www.wastormwatercenter.org

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Statewide LID Training Program

QUESTIONS

Further questions? Contact:
training@cascadiaconsulting.com
(206) 449-1163