INSTRUCTORS

KATE FORESTER
Landscape Architect
Key project experience: Stormwater design, maintenance, and manual development

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.
• 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
Introduction to LID for Inspection & Maintenance Staff

OVERVIEW OF PROGRAM

INTRODUCTORY INTERMEDIATE ADVANCED

Intermediate LID Design: Rainwater Collection Systems & Vegetated Roofs

Intermediate LID Topics: NPDES Phase I & II Requirements

Intermediate LID Design: Permeable Pavement

Intermediate LID Design: Hydrologic Modeling

Advanced Topics in LID Design: Bioretention Media and Compost Amended Soils

Advanced Topics for Long-term LID Operations: Bioretention

Advanced Topics for Long-term LID Operations: Permeable Pavement

Advanced Topics for Long-term LID Operations: Hydrologic Modeling

Advanced Topics for Long-term LID Operations: Site Assessment, Planning & Layout

Advanced Topics for Long-term LID Operations: Rainwater Collection Systems & Vegetated Roofs

OVERVIEW OF PROGRAM

Intermediate LID Design: Bioretention

Intermediate LID Design: Permeable Pavement

Intermediate LID Design: Site Assessment, Planning & Layout

Intermediate LID Design: Hydrologic Modeling

Advanced Topics in LID Design: Rainwater Collection Systems & Vegetated Roofs

Advanced Topics in LID Design: Bioretention

Advanced Topics in LID Design: Permeable Pavement

Advanced Topics in LID Design: Hydrologic Modeling

Advanced Topics in LID Design: Site Assessment, Planning & Layout

Advanced Topics in LID Design: Rainwater Collection Systems & Vegetated Roofs

LEARNING OBJECTIVES

1. Gain an understanding of the structure and function of bioretention components
2. Develop an in-depth understanding of inspection activities to track and guide long-term facility maintenance
3. Know the requirements for primary preventative and intensive maintenance of bioretention facilities
4. Understand how to adaptively manage bioretention facilities by tracking trends in facility conditions and outcomes of maintenance activities
LOGISTICS

SCHEDULE

- Full day training
- Classroom training (8:30-12:30)
- 1-hour lunch (12:30-1:30)
- Field exercises (1:30-4:30)

OTHER LOGISTICS

- Restroom location
- Turn off cell phones
- Sign in and sign out

AGENDA

1. Introduction
2. Bioretention O&M
   - Plants
3. O&M costs
4. Administrative tools
5. Wrap up
INTRODUCTION

LOW IMPACT DEVELOPMENT (LID): Stormwater Management Strategy

- Site design & planning techniques emphasizing conservation
- Use of small-scale engineered controls to closely mimic pre-development hydrologic processes
### INTRODUCTION

**LID: Small-Scale Engineering Controls**

- Infiltration
- Filtration
- Storage
- Evaporation
- Transpiration

Synonyms for LID BMPs:
- Green Stormwater Infrastructure (GSI), Integrated Management Practices (IMPs), and On-Site Stormwater Management BMPs

---

### INTRODUCTION

**TOPICS**

- Intro to LID
- NPDES Permit
- LID O&M Overview

---

### INTRODUCTION

**NPDES PERMIT REQUIREMENTS**

National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Permits

<table>
<thead>
<tr>
<th>Municipal Stormwater Permits in Washington State</th>
<th>Western Washington Phase II Permits</th>
<th>Eastern Washington Phase II Permits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I Permits</td>
<td>82 Cities</td>
<td>18 Cities</td>
</tr>
<tr>
<td>Seattle</td>
<td>5 Cities</td>
<td>5 Counties</td>
</tr>
<tr>
<td>Tacoma</td>
<td>5 Counties</td>
<td>5 Counties</td>
</tr>
<tr>
<td>Clark County</td>
<td>5 Counties</td>
<td>5 Counties</td>
</tr>
<tr>
<td>King County</td>
<td>5 Counties</td>
<td>5 Counties</td>
</tr>
<tr>
<td>Pierce County</td>
<td>5 Counties</td>
<td>5 Counties</td>
</tr>
<tr>
<td>Snohomish County</td>
<td>5 Counties</td>
<td>5 Counties</td>
</tr>
</tbody>
</table>

Secondary Permitters: Approximately 45, such as ports and universities

To see a listing of permittees visit [http://www.ecy.wa.gov/programs/wq/stormwater/municipal/MuniStrmWtrPermitList.html](http://www.ecy.wa.gov/programs/wq/stormwater/municipal/MuniStrmWtrPermitList.html)
INTRODUCTION

NPDES PERMIT REQUIREMENTS:
Requirements Vary By Permittee

- Phase II requirements are somewhat less extensive
- Secondary permittee requirements vary

Timeline for updating maintenance standards

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Section S5.C.9.a of the Phase I Permit</td>
<td>Per Section S5.C.9.a of the Phase II Permit</td>
</tr>
<tr>
<td>West Pts</td>
<td>Lewis Co. and Cowlitz Co.</td>
</tr>
<tr>
<td>June 30, 2015</td>
<td>June 30, 2016</td>
</tr>
<tr>
<td>June 30, 2016</td>
<td>June 30, 2017</td>
</tr>
</tbody>
</table>

INTRODUCTION

NPDES PERMIT REQUIREMENTS:
Requirements Vary By BMP Classification

- On-site Stormwater Management BMPs
- Stormwater Treatment and Flow Control BMPs/Facilities

INTRODUCTION

NPDES PERMIT REQUIREMENTS: Minimum Requirements (MRs)

1. Preparation of Stormwater Site Plans
2. Construction SWPPP
3. Source Control
4. Preserve natural Drainage
5. On-Site Stormwater management
6. Run-off Treatment
7. Flow Control
8. Wetlands Protection
9. O&M
NPDES PERMIT REQUIREMENTS: Minimum Requirements (MRs)

- MR #2 – Construction Stormwater Pollution Prevention Plan (SWPPP)
  - Protect LID BMPs from sediment and compaction

- MR #5 – On-site Stormwater Management
  - Infiltrate, disperse, and retain runoff on-site to the extent feasible

NPDES PERMIT REQUIREMENTS: Minimum Requirements (MRs)

- MR #6 – Runoff Treatment
  - Water quality treatment for pollution generating areas

- MR #7 – Flow Control
  - Control of flow peaks and flow durations

- MR #9 – O&M
  - Require an O&M manual for proposed stormwater facilities and BMPs

NPDES PERMIT REQUIREMENTS: On-site Stormwater Management BMPs

- Used to help meet MR #5

- May be used to help meet MR #6 and/or MR #7

- "On-site Stormwater Management BMPs" = LID BMPs
NPDES PERMIT REQUIREMENTS: On-site Stormwater Management BMPs

- Includes the following LID BMPs:
  - Rain Gardens (BMP T5.14A)
  - Bioretention (BMP T5.14B)
  - Permeable Pavement (BMP T5.15)
  - Vegetated Roofs (BMP T5.17)
  - Downspout Full Infiltration (BMP T5.10A)
  - Downspout Dispersion (BMP T5.10B)
  - Concentrated Flow Dispersion (BMP T5.11)
  - Sheet Flow Dispersion (BMP T5.12)
  - Compost-amended soils (BMP T5.13)

NPDES PERMIT REQUIREMENTS: Treatment and Flow Control BMPs/Facilities

- Subset of On-site Stormwater Management BMPs
- Used to meet MR #6 or MR #7
- May also be used to meet MR #5
- Includes the following BMPs:
  - Bioretention (BMP T5.14B)
  - Permeable Pavement (BMP T5.15)
  - Vegetated Roofs (BMP T5.17)
  - Detention facilities
  - Standard infiltration facilities
  - Treatment BMPs/facilities

TOPICS

- Intro to LID
- LID O&M Overview
**INTRODUCTION**

**NPDES PERMIT LID O&M REQUIREMENTS:**

**O&M Standards**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implement maintenance standards</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Adopt or update ordinance or other enforceable documents</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Implement practices, policies, &amp; procedures to reduce stormwater impacts associated with runoff</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

**INTRODUCTION**

**NPDES PERMIT LID O&M REQUIREMENTS:**

**Plan Review**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify maintenance plan completed &amp; O&amp;M responsibility assigned</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Verify submission of maintenance instructions</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Verify that O&amp;M manual is complete</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Review and approve declaration of covenant (including design details, figures and maintenance instructions) and grant of easement</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**INTRODUCTION**

**NPDES PERMIT LID O&M REQUIREMENTS:**

**Inspection**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal authority to inspect private stormwater facilities and enforce maintenance standards</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Conduct post-construction inspections to ensure proper installation</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
### Inspection (continued)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduct inspections during construction in new residential developments*</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Conduct ongoing annual inspections</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Perform spot checks for potentially damaged BMPs owned/operated by Permittee after major storm events</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Every 6 months until 90% of the lots are constructed or when construction is stopped and the site is fully stabilized.

### Enforcement

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enforce compliance with maintenance standards, as needed, based on inspection</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

### Training

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train staff involved in plan review, permitting, construction site inspections, &amp; enforcement</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Implement an ongoing training program for employees who have primary O&amp;M job functions that may impact SW quality</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
NPDES PERMIT LID O&M REQUIREMENTS:
Record Keeping

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep records of inspections and enforcement actions (e.g., inspection reports, notices of violations)</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

NPDES PERMIT LID O&M REQUIREMENTS:
Mapping

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale drawing of the lot(s) and public ROW that show BMP locations</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Map BMPs owned/operated by Permittee</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Map connections between BMPs and tributary conveyances*</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Phase I Only

LID O&M GUIDANCE DOCUMENT: Objectives

- Support permittees in implementing LID maintenance programs
- Provide specific O&M guidance so permittees can create maintenance standards that preserve facility function
- Note: Jurisdictions may want to tailor the tables in the O&M guidance document to address varying levels-of-service
INTRODUCTION

LID O&M GUIDANCE DOCUMENT: Development

- Two advisory committees
  - LID Maintenance Advisory Committee
  - LID Maintenance Administrative Issues Advisory Committee
- Best available information
  - Advisory committee input
  - Literature review
  - Targeted surveys sent to jurisdictions, contractors/landscapers, and vendors
- Guidance will evolve over time

INTRODUCTION

LID O&M GUIDANCE DOCUMENT: Content

- Summary of NPDES Permit Requirements
- Maintaining LID BMPs
  - Bioretention facilities
  - Rain gardens
  - Permeable pavement
  - Vegetated roofs
  - Downspout infiltration systems
  - Downspout, sheet flow, and conc. dispersion systems
  - Compost amended soils
  - Programmatic & Administrative Guidance

INTRODUCTION

LID O&M GUIDANCE DOCUMENT: Content

- BMP description
  - How water moves through facility
- Key maintenance considerations to ensure facility function
  - Function by BMP component
  - Key maintenance by BMP component
- Key operations to preserve facility function
INTRODUCTION

LID O&M GUIDANCE DOCUMENT:
Maintenance Standard and Procedures

INTRODUCTION

LID O&M GUIDANCE DOCUMENT:
Equipment and Materials List

INTRODUCTION

LID O&M GUIDANCE DOCUMENT:
Skills and Staffing

Skills Needed for Maintenance of Bioretention Facilities
- Landscaping skills (e.g., general plant care)
- Plant identification skills (weeds vs. perennials, invasive vs. non-native weeds, how to distinguish native weeds, timing of weed seed dispersal)
- Erosion control knowledge
- General drainage system maintenance skills (e.g., interceptor underdrain cleaning experience)

• List of general skills required
• List of additional specialized skills
• Staffing survey estimates (e.g., crew hours per facility, per linear foot, or per square foot)
INTRODUCTION

BIORETENTION O&M

PLANTS

O&M COSTS

ADMINISTRATIVE TOOLS

WRAP UP

BIORETENTION O&M

OVERVIEW

- Definition and Types
- Components
- How the facility works
- Bioretention vs. rain gardens
- Maintenance standards & procedures by component
- Equipment and materials
- SKILLS

DEFINITION AND TYPES

- Shallow landscaped depressions that receive stormwater from small contributing areas
- Small scale, dispersed facilities
- Types:
  - Bioretention cells
  - Bioretention swales
  - Infiltration planters
  - Flow-through planters
**COMPONENTS**

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

---

**HOW THE FACILITY WORKS**

**Bioretention Cell**

- Water enters facility
- Ponds
- Infiltrates through bioretention soil/gravel bed
- Infiltrates into underlying soil
- Ponded water exceeding max. depth overflows

---

**Bioretention Planter**

- Water enters facility
- Ponds
- Infiltrates through bioretention soil/gravel bed
- Infiltrates into underlying soil
- Ponded water exceeding max. depth overflows
HOW THE FACILITY WORKS

- Water enters facility
- Ponds
- Infiltrates through bioretention soil/gravel bed
- Infiltrates into underlying soil
- Ponded water exceeding max. depth overflows
- Underdrain collects water in gravel layer and routes to overflow

BIORETENTION VS RAIN GARDENS

- Bioretention:
  - Often includes surface and subsurface infrastructure
  - Designed soil mix
  - Meets requirements for MR #6 and #7 and required for MR #5 if MR #1.9 required
- Rain gardens
  - Usually do not include under-drains
  - May use less restrictive soil mix guidelines (e.g., existing soil augmented with compost and sand)
  - Meets MR #5 requirements.

Maintenance Standards & Procedures By Component

- Inlets
- Ponding area
- Check dams/weirs
- Bioretention soil
- Outlets
- Underdrains
- Mulch
INLETS: Types

Sheet flow from sidewalk and roadway

Sheet flow from parking lot

INLETS: Types

Curb cut

Curb cut with grate

INLETS: Types

Trench drain from roadway

Trench drain from upslope BMP
INLETS: Types

- Piped inlet from roadway/parking lot
- Piped inlet from upslope BMP

INLETS: Maintenance Considerations

- Stormwater must freely enter facility (no obstructions)
- Water entering facility should not cause erosion

INLETS: Maintenance

- Maintain erosion control at concentrated flow inlets (e.g., rock pad)
- Ensure pipe is not damaged or clogged
INLETS: Maintenance

- Remove accumulated sediment, debris, leaves
- Clear/move vegetation inhibiting flow into facility

Catch basin inlets

BIORETENTION O&M

PONDING AREA: Types

Earthen depression

Rockery walls

In ground concrete planter

Aboveground metal planter
**PONDING AREA: Maintenance Considerations**

- Ponding area provides temporary surface storage before infiltration
- Must infiltrate within 48 hour “drawdown” time after the end of a storm
  - Restores hydraulic capacity of system
  - Prevent mosquito breeding conditions

---

**PONDING AREA: Maintenance**

**Integrity**

- Concrete or metal planter: ensure integrity (e.g., cracks, leaks)
- Rockery: ensure rockery sidewalls are secure
- Earthen side slopes/berms:
  - Erosion: stabilize and address cause of erosion, if feasible
  - Settlement: restore to design height
  - Leaks/seeps on face of berm: repair/compact
- Consult with an engineer when any major structural instability occurs

---

**PONDING AREA: Maintenance**

**Material Accumulation**

- Remove trash and debris
- Remove leaves if impacting facility function
- Accumulated sediment to extent that infiltration rate is reduced (see “excessive ponded water”) or storage capacity reduced
  - Remove excess sediment
  - Replace any vegetation damaged or destroyed by sediment accumulation and removal
  - Identify and control the sediment source, if feasible
PONDING AREA: Maintenance

Excessive Ponded Water

- Overflows during small storms or
- Does not fully infiltrate within 48 hours of end of storm

  - Determine cause:
    - Leaves/debris in bottom impeding infiltration?
    - Underdrain, if present, is clogged?
    - Water inputs (e.g., groundwater, illicit connections)
    - Verify sized for contributing area (and area has not increased)

  - If Steps 1-4 do not solve problem: bioretention soil is likely clogged
    - Consult with an engineer or facility designer (May need to remove/replace bioretention soil)

CHECK DAMS/WEIRS: Purpose

- Provides ponding on sloped facilities
- Provides detention/some water quality (settling)

CHECK DAMS/WEIRS: Types

Concrete
**CHECK DAMS/WEIRS: Other Types**

- Log/Abutment
- Gravel

**CHECK DAMS/WEIRS: Maintenance**

- Remove accumulated sediment, debris, leaves blocking flow
- Repair any erosion/undercutting and take preventative measures

**BIORETENTION SOIL: Maintenance**

- Infiltration through soil mix provides water quality treatment
- Stormwater must infiltrate freely into bioretention soil
- Infiltration rate may be reduced by compaction or clogging with fine sediment
BIORETENTION &
O&M
BIORETENTION SOIL: Maintenance

• Remove and replace, if clogged (see “excessive ponded water”)
• Minimize loading in cell to protect bioretention soil from compaction during maintenance
• Check for spills, replace spill areas if contaminated

BIORETENTION &
O&M
OUTLETS: Types and Maintenance
Considerations

• Stormwater must freely exit facility once capacity exceeded (above maximum ponding depth)
• Overflows must be conveyed to safe discharge point (e.g., storm drain system)

BIORETENTION &
O&M
OUTLETS: Maintenance

• Remove accumulated sediment, debris, leaves at outlet/grate/trash rack
• Clear/move vegetation within 1 foot of outlet to maintain access
• Clear pipes of accumulated material
UNDERDRAINS:

**Types**
- Perforated or slotted pipe wrapped in an aggregate blanket (or filter fabric)
- May have flow restrictor (e.g., orifice) to detain flow
- Can be included to collect treated water under the bioretention soil (e.g., where infiltration to native soil is not feasible)

**Prolonged Surface Ponding**
- Jet clean or rotary cut debris/roots from underdrain
- If equipped with flow restrictor (orifice), clean regularly
**BIORETENTION O&M**

**EQUIPMENT AND MATERIALS**

- Garden and mulch blower
- Treadle spade or other maintenance tool to prevent soil compaction if maintenance is necessary during periods when bioretention needs it.
- Sprinklerhead filter
- Soaker hose
- Watering bags
- Buckets
- Rolls of irrigation hoses
- Water sources (e.g., watering truck), if necessary
- Items not required for routine maintenance

**BIORETENTION O&M**

**SKILLS**

- Landscaping skills (e.g., general plant care)
- Plant identification skills
- Erosion control knowledge
- General drainage system maintenance skills
- Operation of specialized equipment
- Engineer and/or landscape architect for major maintenance
- Certified arborist (or equivalently trained staff) for pruning of mature trees

**Break**
PLANTS

OVERVIEW
- Plants and bioretention
  - Function
  - Performance goals
  - Maintenance issues
- Maintenance tools
  - Pruning
  - Plant thinning and replacement
  - Watering
- Species examples
- The weeds
  - Common and invasive
  - Identification resources
  - Species examples
- Plant health
  - Strategies supporting plant health
  - Common pest or disease symptoms

PLANTS AND BIORETENTION: Functions
- Groundcovers, shrubs and trees:
  - Intercept rain before it hits the soil and facilitates evaporation
  - Uptakes water from the soil and transpires it to the atmosphere
- Improves soil structure and increases infiltration capacity
- Promotes water quality treatment
PLANTS AND BIORETENTION: Performance Goals

- Maintain healthy vegetation that has 75% or greater survival rate so that it can support proper facility functions
- Vegetation that follows public safety guidelines
  - Does not interfere with vehicular or pedestrian sight distance triangles
  - Does not create pedestrian or vehicular hazards

PLANTS AND BIORETENTION: Maintenance Issues

- Poor plant health (low vigor)
  - Compaction of soil
  - Improper care, handling, or planting
    - Excessive or inappropriate pruning
    - Planted too shallow
    - Planted too deep
    - Improper watering
  - Chemical or herbicide injury
- 30 days to replace dead or dying vegetation (as weather and planting season allow)
MAINTENANCE TOOLS: Pruning

Trees and shrubs

- Prune trees and shrubs at the right time of year
  - Deciduous trees: November–February
  - Hazardous trees should be pruned any time of the year to avoid risk or injury
  - Do not prune with thick bark in the summer to reduce sun scald injury (e.g., birch (Betula spp.) cherry (Prunus spp.) and crabapple (Malus spp.))
  - Pine (Pinus spp.) or Elm (Ulmus spp.): Do not prune May – October to reduce possible exposure to bark beetle (pine) or Dutch Elm Disease (elm)
  - Avoid pruning during spring growth flush

Refer to Seattle Street Tree Manual or ISA website for more information.

MAINTENANCE TOOLS: Pruning

Emergent vegetation and grasses

Hand rake with small rake or fingers to remove dead foliage in spring or earlier only if foliage is blocking water flow

- Emergent vegetation: Sedges and rushes do not like continuous pruning.

- Perennial ornamental grasses: Leave dry foliage for winter interest (e.g., switchgrass (Panicum) and Karl Forester grass (Calamagrostis acutiflora ‘Karl Forester’)

- Evergreen ornamental grasses: Clean, rake, and comb grasses when they become too tall. Cut back to the ground or thin every 2 to 3 years.

MAINTENANCE TOOLS: Plant Thinning and Replacement

- Edge or trim groundcovers that grow beyond the facility edge onto sidewalks, paths, or street edges when they create pedestrian safety hazards or clog adjacent permeable pavement surfaces

- Prune, trim, or if necessary, replace plants when vegetation density negatively impacts facility function OR becomes a safety hazard

- Divide and replant when grasses die back in the center

Refer to Seattle Street Tree Manual or ISA website for more information.
PLANTS

MAINTENANCE TOOLS: Watering

Summer watering - first year

Once every 1-2 weeks or as needed during prolonged dry periods

- Trees: 10-15 gallons
- Shrubs: 3-5 gallons
- Groundcovers: 2 gallons/square foot

Summer watering - second and third year

Once every 2-4 weeks or as needed during prolonged dry periods

- Trees: 10-15 gallons
- Shrubs: 3-5 gallons
- Groundcovers: 2 gallons/square foot

After 3-year establishment period

- Trees may take up to 5 years to become fully established
- Identify trigger mechanisms for drought-stress of different species and water immediately after initial signs of stress appear
  - Leaf wilt
  - Rapid increase in life-cycle development (e.g. leaf and flower drop)
- Water during drought conditions

Q & A
**SPECIES EXAMPLES: Planting Zones**

- **Zone A:** Wet zone. For plants that can withstand temporarily high water levels.
- **Zone B:** Intermediate zone. Side slope plants that can withstand occasional standing water and are resilient from wet to dry conditions.
- **Zone C:** Upland zone. For plants that tolerate drier conditions.

---

**SPECIES EXAMPLES: Zone A**

**Sedges: Carex**

- *Carex stipata* (Sawbeak sedge, Native)
- *Carex testacea* (Orange New Zealand sedge)
- *Carex obnupta* (Slough sedge, Native)

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**SPECIES EXAMPLES: Zone A**

**Rushes and Bulrushes: Juncus and Schoenoplectus/Scirpus**

- *Juncus ensifolius* (Dagger-leaf rush, Native)
- *Juncus acutellus* (Tapertip rush, Native)
- *Scirpus microcarpus* (Small-fruited bulrush, Native)
PLANTS

SPECIES EXAMPLES: Zone A

**Flowering Herbs**

- Sidalcea spp. (Checkermallow, Native)
- Camassia quamash (Common camas, Native)
- Iris douglasiana (Douglas iris, Native)
- Mimulus guttatus (Yellow monkey flower, Native)

**Shrubs and ferns**

- Spiraea douglasii (Douglas' spiraea, Native)
- Blechnum spicant (Deer fern, Native)
- Cornus sericea (Red-twig dogwood, Native)
- Athyrium filix-femina (Lady fern, Native)

**Trees**

- Amelanchier alnifolia (Saskatoon, Native)
- Oemleria cerasiformis (Indian plum, Native)
- Acer circinatum (Vine maple, Native)
**SPECIES EXAMPLES: Zone B**

**Shrubs**

- Symphoricarpus albus  
  Snowberry, Native
- Gaultheria shallon  
  Salal, Native
- Arctostaphylos uva-ursi  
  Kinnikinnick, Native

**Herbaceous**

- Fragaria chiloensis  
  Coastal strawberry, Native
- Hemerocallis spp.  
  Day lily
- Heuchera spp.  
  Alumroot
- Aquilegia formosa  
  Western columbine, Native

**Trees**

- Arbutus unedo  
  Strawberry tree
- Quercus garryana  
  White oak
- Pinus sylvestris  
  Scots pine
- Populus tremuloides  
  Quaking aspen
SPECIES EXAMPLES: Zone C

Herbaceous

Panicum virgatum
Switchgrass

Miscanthus spp.
Silver grass

Lavendula spp.
Lavender

Rudbeckia hirta
Black-eyed susan, Native

Q & A

WEEDS: Common vs. Listed

Common species
- Remove at facility performance threshold

Washington State Noxious Weed Lists
- Identify weed species, reproductive strategies, and control methods
- When in doubt, get help!
- Create Management Plan

Taraxacum officinale
Dandelion
**WEEDS: Noxious Weed Classes**

Washington State Noxious Weed Lists

**Class A Noxious Weeds:** Non-native species that are limited in distribution in WA and state law requires their eradication.

**Class B Noxious Weeds:** Target species must be controlled in areas where they have not already spread. County or local jurisdiction may require removal.

**Class C Noxious Weeds:** Non-native species that are already widespread. WA counties can enforce control or educate residents about control.

---

**WEEDS: Identify Noxious Weeds**

Washington State Noxious Weed Control Board

Website Identification and Control Steps

2. Click on Noxious Weed List Tab and select the weed class you think your weed might be in
   - Example (right): 37 species on Washington's 2014 Class A list
3. Click on the details link to learn more about a plant
4. If searching the weed lists does not help positively identify a species:
   1. Email photos
   2. Mail in a specimen
   3. Call to set up a site visit

---

**WEEDS: Example Identification**

You think you may have found garlic mustard, but you are not completely sure:

1. Click on “details” link under garlic mustard
2. Review photos and information
3. If you want further verification:
   1. Email photos
   2. Mail in a specimen
   3. Call to set up a site visit
WEEDS: Control Methods

• Vary by species
  • Review reproductive strategies and control methods for target weed species.

• Example for Class A Species: Garlic Mustard

  Reproductive Strategy
  • Self-fertile and cross-pollinates
  • Disperses via seed

  Control Method
  • Hand pulling, but remove all roots. Bag all plant material and dispose of in landfill. Do not compost!

WEEDS: Control Methods

• Example for Class B Species: Polygonum cuspidatum (Japanese knotweed)

  Reproductive Strategy
  • Spreads by rhizome and seed, but large colonies are from rhizomatous spread (even a small fraction of the plant can produce another plant!)

  Control Method
  • Small populations: Remove ENTIRE root system. Be thorough and leave no fragments. Place vegetation on tarps or other impervious surface protected from wind and upsetting, and allow to dry out. Or, burn all plant fragments.
  • Large population: Cut or mow, spray low regrowth. Repeat cycle for several years.

WEEDS: Examples of Class B Weeds

- Buddleja davidii
- Butterfly bush
- Cynoglossum officinale
- Spotted knapweed
- Lythrum salicaria
- Purple loosestrife
- Cytisus scoparius
- Scotch broom
- Lythrum salicaria
- Butterfly bush
- Buddleja davidii
- Spotted knapweed
WEEDS: References

Washington State Noxious Weed Control Board
http://www.nwcb.wa.gov/

USDA Plants Database
http://plants.usda.gov/java/noxious?rptType=State&statefips=53

Washington State University Integrated Weed Management Project
http://invasives.wsu.edu/iwmanagement.htm

King County Weed Program
E-mail photos, mail in specimens, call to set up a site visit, or report a weed site

Q & A
PLANT HEALTH

Proper maintenance to ensure plant health

• Know maintenance needs of species
• Use integrated pest management (IPM) and adaptive management
• Protect and nourish healthy soils
• Remove diseased or dying plant material
• Attract beneficial insects and birds

The best way to fight disease and pests is to support healthy living conditions for plants. Thriving plants can overcome most pests and diseases.

PLANT HEALTH

Plant Problem Diagnosis Steps

From Landscape Plant Problems: A Pictorial Diagnostic Manual

1. Identify the host plant
2. Examine affected plants
3. Look for patterns of damage
4. Note signs and symptoms
5. Determine cause

The best way to fight disease and pests is to support healthy living conditions for plants. Thriving plants can overcome most pests and diseases.

PLANT HEALTH: Common Symptoms

Wilting or Withering

Causes
• Heat stress
• Lack of water
• Too much water

Remedies
• Water plants
• Shade plants
• Apply mulch

Sun burn

Causes
• Intense sun exposure

Prevention Methods
• Wrap or paint thin-barked trees
• Avoid watering plant foliage and water during the morning and evening
Fungal diseases

Causes
- Over 1,000 species of fungus
- Wet, cool conditions with poor air circulation
- Susceptible host plant

Remedies
- Reduce plant stress
- Sanitation
- Improve air circulation
- Be patient and wait for drier days
- Plant resistant species and cultivars

Yellowing and Discolored Leaves

Causes
- Nutrient deficiency
- Plant is unable to make chlorophyll
- Moisture stress

Remedies
- Nutrient deficiencies
- Pests
- Chemical or herbicide-induced

Herbicide damage

Causes
- Residual herbicide in soil
- Direct herbicide application
- Herbicide drift or over-application
- Misapplication, etc.

Remedies
- May need to conduct soil analysis to confirm chemical and intensity of soil contamination
- Remediation will depend on the toxin and level of contamination
PLANT HEALTH: References

The Garden Hotline
Call or e-mail for help
http://gardenhotline.org/natural-pest- weed-disease-control/

Washington State Pest Management Association
Call or e-mail
http://www.wpsa.org/

Washington State University Plant & Insect Diagnostic Laboratory
Reference the Pest Leaflet Series
http://puyallup.wsu.edu/plantclinic/resources/pls-res.html

Q & A

- introduction
- bioretention O&M
- plants
- O&M costs
- administrative tools
- wrap up
**CONVENTIONAL VS LID O&M ACTIVITIES**

<table>
<thead>
<tr>
<th></th>
<th>Conventional (Biofiltration swale/pond)</th>
<th>LID (Bioretention/Rain gardens)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mowing</td>
<td>Weeding &amp; vegetation management</td>
<td></td>
</tr>
<tr>
<td>Inlet/outlet protection</td>
<td>Inlet/outlet protection</td>
<td></td>
</tr>
<tr>
<td>Sediment removal</td>
<td>Ponding area maintenance</td>
<td></td>
</tr>
<tr>
<td>Flow spreader/check dam/weir sediment management and erosion repair</td>
<td>Check dam/weir sediment management and erosion repair</td>
<td></td>
</tr>
<tr>
<td>Poor vegetation coverage</td>
<td>Protect bioretention soil from compaction</td>
<td></td>
</tr>
<tr>
<td>Mulching</td>
<td>Mulching</td>
<td></td>
</tr>
<tr>
<td>Underdrain clog removal</td>
<td>Underdrain clog removal</td>
<td>Watering</td>
</tr>
</tbody>
</table>

**30-YEAR COST COMPARISON**

<table>
<thead>
<tr>
<th>BMP</th>
<th>30-year O&amp;M Cost</th>
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</thead>
<tbody>
<tr>
<td>Bioretention</td>
<td>$21.84 / SF</td>
</tr>
<tr>
<td>Wet Pond</td>
<td>$9.01 / SF</td>
</tr>
<tr>
<td>Combined Detention and Wetpool</td>
<td>$9.01 / SF</td>
</tr>
<tr>
<td>Stormwater Treatment Planter Vault</td>
<td>$27,903 / PV</td>
</tr>
<tr>
<td>Infiltration Basin</td>
<td>$3.36 / SF</td>
</tr>
<tr>
<td>Catch Basin</td>
<td>$1,331 / CB</td>
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</tbody>
</table>


**CASE STUDY: Seattle Public Utilities**

<table>
<thead>
<tr>
<th></th>
<th>HC</th>
<th>SW</th>
<th>LA</th>
<th>Other</th>
<th>Cost/SF</th>
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</thead>
<tbody>
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<td>Simple – A</td>
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<td>$2.86</td>
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<td>Simple – C</td>
<td>15</td>
<td>2</td>
<td>13</td>
<td>0</td>
<td>$2.94</td>
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</tbody>
</table>

*197 sites; estimated field operations and maintenance costs

Source: Drena Donofrio
CASE STUDY: Seattle Public Utilities

- **Total Cost = Vegetation + Hardscape**
- **Initial Vegetation – 3 years**
  - SPU cost: $2.21/SF
  - Watering method and frequency increase cost up to 4X
- **Established Vegetation – 4 plus**
  - SPU cost: $1.66/SF
  - 25% reduction
- **Replacement costs - $0.50/SF**
- **Hardscape - $0.31/SF**

**Source:** Diana Benakis

**ADMINISTRATIVE TOOLS**

**TOPICS**

- Resource list
- Record keeping and tracking
- Inspection programs
- Inspection challenges
ADMINISTRATIVE TOOLS

RESOURCE LIST

- Western WA LID O&M Guidance Document

ADMINISTRATIVE TOOLS

RECORD KEEPING & TRACKING

- Parcel information
- City/County permit (ROW and/or building permit)
- Relevant sections of the Stormwater Site Plan
- “As-builts” or “record drawings” (individual lots and public ROW)
- Legal agreements (covenants, easements)
- Location information (GPS data, digital maps)
- Project O&M manual (where applicable)
- Maintenance logs (typically included in a Project O&M Manual)
- Inspection forms
- Enforcement documents
**Inspection Programs**

- **Immediately post-construction** for all LID BMPs - installed per plan and functioning properly
- **Every 6 months** (until 90% of lots are constructed) for permanent Stormwater Treatment and Flow Control BMPs/Facilities in new residential developments - identify maintenance needs and enforce maintenance standards
- **Ongoing annual inspections** for all Stormwater Treatment and Flow Control BMPs/Facilities (MR #6 and/or MR #7)

**Discussion**
INTRODUCTORY

2.1 Introduction to LID for Inspection & Maintenance Staff

INTERMEDIATE

3.1 Intermediate LID Topics: NPDES Phase II Requirements

3.2 Intermediate LID Design: Rainwater Collection Systems & Vegetated Roofs

3.3 Intermediate LID Design: Permeable Pavement

ADVANCED

5.0 Advanced Topics for Long-term LID Operations: Bioretention

5.1 Advanced Topics for Long-term LID Operations: Permeable Pavement

5.2 Advanced Topics in LID Design: Hydrologic Modeling

5.3 Advanced Topics in LID Design: Permeable Pavement

5.4 Advanced Topics in LID Design: Site Design, Planning & Layout

5.5 Advanced Topics in LID Design: Rainwater Collection Systems & Vegetated Roofs

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

Stay connected through Social Media
• Come “Like” our Page
• Sign up to follow and get Tweets

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

SCHEDULE

• 1-hour lunch break (12:30-1:30)
• Field exercises (1:30-4:30)
  • Bioretention inspections
  • Watering techniques
  • Plants
  • Infiltration testing
  • Lessons learned
• You will need to sign in and sign out to receive credit for the Long-term LID Operations certificate