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.

PROJECT LEAD

CORE TEAM

ADDITIONAL TRAINING SUPPORT
Statewide LID Training Program

PROGRAM OVERVIEW

- Implement first phase of trainings (September 2014 through May 2015)
- 64 trainings offered in first phase
- Three levels: Introductory, Intermediate, and Advanced
- Train the Trainer program for service providers and LID topic experts

HIGHLIGHTS OF PROGRAM

**INTRODUCTORY**

- 9/22/2014
- Trainings through September
- Introductory trainings offered first phase

**INTERMEDIATE**

- 9/22/2014
- Introductory Phase 1 training
- Intermediate trainings first phase

**ADVANCED**

- 9/22/2014
- Advanced trainings first phase

TRAIN THE TRAINERS

- 9/22/2014
- Service Providers
- LID Experts

TODAY’S TRAINING

- 9/22/2014
- Intermediate topics
- Advanced topics
- Trainings through September
INSTRUCTORS

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

CURTIS HINMAN
Senior Scientist
Research specialist in the performance and design of LID applications

AGENDA

1. introduction & regulations
2. site assessment, planning, layout
3. BMP specifics
4. cost comparisons & resources
5. wrap up
LEARNING OBJECTIVES

1. Efficient application of LID BMPs.
2. New LID regulatory requirements.
3. How LID development process and cost compares with conventional stormwater practices.
4. The basic principles of site assessment, site layout and construction sequencing to improve the design and long-term, effective operation of LID best management practices (BMPs) and projects.
5. How to minimize construction impacts.
6. Minimum requirements for construction and protection of LID BMPs during construction.

Why LID?
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: Pre-developed forest

LID Principles: Developed condition
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

LID BMPs: Small-Scale Engineering Controls

- Infiltration
- Filtration
- Storage
- Evaporation
- Transpiration

Conserves or regains pre-developed hydrologic functions

Washington Municipal Stormwater Permits

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

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

Secondary Permits: Approximately 45, such as ports and universities

To see a listing of permits visit:

**NPDES PERMIT LID REQUIREMENTS:**

**Minimum Requirements**

1. Preparation of Stormwater Site Plans
2. Construction SWPP
3. Source Control of Pollution
4. Preservation of Natural Drainage Systems and Outfalls
5. On-Site Stormwater management
6. Runoff Treatment
7. Flow Control
8. Wetlands Protection
9. O&M

**NPDES PERMIT LID 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

---

**Western WA Phase I and II timeline for updating local codes**

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Section S5.C.5.a of the Phase I Permit</td>
<td>Per Section S5.C.5.a of the Phase II Permit</td>
</tr>
<tr>
<td>West Lewis Co. and Clark Co.</td>
<td>City of Aberdeen</td>
</tr>
<tr>
<td>June 2014</td>
<td>June 30, 2015</td>
</tr>
<tr>
<td>June 30, 2016*</td>
<td>Dec. 31, 2016*</td>
</tr>
<tr>
<td>June 30, 2017</td>
<td>June 30, 2018</td>
</tr>
</tbody>
</table>

* = Or GMA update deadline
NPDES PERMIT LID 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

NPDES PERMIT LID REQUIREMENTS: List #1 & 2 vs. LID Performance Standard

- List #1 (MR 1-5) and List #2 (MR 1-9)
  - For each surface, consider the BMPs in the order listed for that type of surface. Use the first BMP that is considered feasible
  - Example: Hard surfaces other than roof
    1. Full dispersion
    2. Permeable Pavement
    3. Dewatering
    4. Surface flow

- Achieve the LID Performance Standard (Duration Flow Control)

Note: achieving LID Performance Standard will require very large ponds that may significantly reduce buildable area without incorporating LID practices.

NPDES PERMIT LID REQUIREMENTS: On-Site Stormwater Management BMPs

- Used to help meet MR #5

- May be used to help meet MR #6 (Treatment) and/or MR #7 (Flow Control)

- “On-site Stormwater Management BMPs” = LID BMPs
INTRODUCTION & REGULATIONS

NPDES PERMIT LID REQUIREMENTS:
On-Site Stormwater Management BMPs

- Includes the following LID BMPs:
  - Rain Gardens (BMP T5.14A) Not “Engineered”
  - Bioretention (BMP T5.14B) “Engineered”
  - 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)

INTRODUCTION & REGULATIONS

NPDES PERMIT LID 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)

<table>
<thead>
<tr>
<th>BMP</th>
<th>Flow Control</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost Amended Soils (BMP T5.13)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bioretention (BMP T5.14A, T5.14B)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Retaining &amp; Planting Trees (BMP T5.14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rain Gardens (BMP T5.14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeable Pavement (BMP T5.15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeable Pavement (BMP T5.15)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Stormwater Harvesting (BMP T5.20)</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

1. Meets basic, enhanced and phosphorus treatment when infiltrating through soil meeting Ecology treatment requirements.
2. Bioretention (underdrain) systems where the underdrain is elevated within the underlying base course can have some peak flow reduction benefit.
3. Where permeable pavement is over soils meeting the suitability criteria or a treatment layer (sand or soil meeting criteria) is included, then permeable pavement can provide treatment.

Q&A
TRADITIONAL V. LID DEVELOPMENT

- 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 V. LID DEVELOPMENT

Typical grid road layout
- Impervious coverage: 27-36%
- Less adaptive to site features.
- Promotes transit and connectivity with more direct access to services.

Typical curvilinear road layout
- Impervious coverage: 15-29%
- More adaptive to site features.
- Generally discourages transit with longer, less connected system.

Hybrid or LID road layout
- Impervious coverage: similar percentage to other layouts.
- Adaptive to site features and uses site features (particularly water as an organizing theme).
- Can provide good connectivity and fire and safety access.
Hydrologic modeling comparing a conventional development and the flow reduction benefits from individual practices for a low impact development design. The 24-acre till-mantled site in southern Puget Sound has 103 lots and was modeled with Western Washington Hydrologic Model (adopted from AHBL, 2000).

<table>
<thead>
<tr>
<th></th>
<th>Detention storage reduced (ft³)</th>
<th>Detention storage required (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional development</td>
<td>270,000</td>
<td></td>
</tr>
<tr>
<td>Low impact development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• reduce development</td>
<td>-149,019</td>
<td></td>
</tr>
<tr>
<td>envelope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• and use bioretention</td>
<td>-40,061</td>
<td></td>
</tr>
<tr>
<td>• and use minimal</td>
<td>-7,432</td>
<td></td>
</tr>
<tr>
<td>excavation foundation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• and use 20’ wide</td>
<td>-29,988</td>
<td></td>
</tr>
<tr>
<td>permeable road</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-226,500</td>
<td>43,500</td>
</tr>
</tbody>
</table>

Hydrologic modeling comparing a conventional development and the flow reduction benefits from individual practices for a low impact development design. The 24-acre till-mantled site in southern Puget Sound has 103 lots and was modeled with Western Washington Hydrologic Model (adopted from AHBL, 2000).

General Layout Strategies

- Cluster development to preserve vegetation and protect soils
- Grade to create small basins
- Maximize infiltration potential by locating BMPS on best soils
Site Layout: New Suburban Development

- Roads, Driveways and Parking
  - Reduce TIA by reducing overall road network cover and minimize or eliminate EIA
  - Use stormwater BMPs to infiltrate, slow, and filter storm flows
  - Minimize overall site disturbance
  - Create connected walking, biking, vehicular, and transit services
  - Create and use open space as a community amenity and stormwater management area

- Site Assessment, Planning & Layout
  - Site Assessment, Planning & Layout: Traditional v. LID Development

- Statewide LID Training Program
  - Developers & Contractors
  - Introduction to LID
SITE ASSESSMENT, PLANNING & LAYOUT

SITE ASSESSMENT

Preliminary Site Analysis

- Collect information from existing analyses, inventories, and historic information
- Conduct site reconnaissance and characterization
  - Info needed varies depending on which Minimum Requirements are triggered

SITE ASSESSMENT, PLANNING & LAYOUT

SITE ASSESSMENT

Minimum Requirements for 1-5

- A survey prepared by a registered land surveyor
  - Include features from existing site conditions table
- Contour map
  - Intervals are dependent on site slopes and elevations
- Soils report
- Survey of native soil and vegetation areas
- Drainage report / Stormwater Site Plan

SITE ASSESSMENT, PLANNING & LAYOUT

SITE ASSESSMENT

Minimum Requirements for 1-9 (Larger projects)

- More in-depth Geotechnical assessment than conventional project
- Ideally in 2 phases
  1. Infiltration soils reconnaissance (similar to septic reconnaissance) for planning level design
  2. Infiltration soils testing for design level design information at the location of the BMP
- Geotechnical Report or Soils Report need to include infiltration feasibility and design discussion
SITE ASSESSMENT, PLANNING & LAYOUT

SITE ASSESSMENT

Critical sub-surface assessment for BMPs
- Bioretention
  - Infiltration test at proper depth
- Permeable Pavement
  - Staging and access
  - Subgrade protection and remediation
  - Infiltration test at proper depth
- Additional testing for Design
  - PIT tests
  - Depth to groundwater
  - Mounding Analysis (if required)

SITE ASSESSMENT, PLANNING & LAYOUT

ECOLOGY SMALL-SCALE PIT METHOD

- PIT Timing
  - Test between December 1 and April 1
- 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)

SITE ASSESSMENT, PLANNING & LAYOUT

SITING CONSIDERATIONS: Native Soils

- Important for infiltrating facilities ONLY
- Infiltrating facilities sized based on infiltration rates
- Minimum "feasible" initial infiltration rate of 0.3 in/hr
- Locate infiltrating BMPs in areas with best soils
Site Assessment, Planning & Layout

Siting Considerations: Soil Variability

Site 1: Loam

Site 2: Sand
SITE ASSESSMENT, PLANNING & LAYOUT
SITING CONSIDERATIONS: Soil Variability

Site 3: Glacial till (highly compacted with high clay content)

SITE ASSESSMENT, PLANNING & LAYOUT
SITING CONSIDERATIONS

- Tree and vegetation preservation
- Site Slopes
  - Cross & Longitudinal Slopes
  - Positive Drainage from drainage area to overflow
- Setbacks (e.g., utilities & other infrastructure)
- May require pre-settling
- Public acceptance/participation (retrofits)

SITE ASSESSMENT, PLANNING & LAYOUT
Site Layout: Urban Redevelopment & Infill

Roads, Driveways and Parking
- Reduce total impervious area (TIA) and minimize effective impervious areas (EIA)
- Use stormwater BMPs to infiltrate, slow, and filter storm flows
- Incorporate trees and adequate soil into planting galleries and streetscapes
- Connect walking, biking, and vehicular access to transit services
- Create and use open space as a community amenity and stormwater management area
SINGLE FAMILY: Rain Gardens

SINGLE FAMILY: Stormwater Planters

RIGHT OF WAY: Seattle SEAstreets
SITE ASSESSMENT, PLANNING & LAYOUT

MULTI-FAMILY DEVELOPMENTS: Block Level Design

- Conduct parking studies to establish min. and max. demand ratios
- Design parking to reduce impervious surface area
  - Diagonal parking stalls with one-way traffic lanes
  - Place parking under buildings or create multi-story parking structures
  - Use permeable surface materials
  - Utilize BMPs to capture, treat, and infiltrate stormwater
- Design parking lots to be multi-user and serve different users at different times
Site Layout: Commercial Development

Rooftops
- Create vegetated roofs to reduce EIA

COMMERCIAL PARCELS

COMMERCIAL PARCELS: Conveyance

Downtown CSO Demand Management, Seattle, WA
SITE ASSESSMENT, PLANNING & LAYOUT
COMMERCIAL PARCELS: Parking Lots

Lewis Creek Park, Bellevue, WA

Combining landscape requirements with bioretention

SITE ASSESSMENT, PLANNING & LAYOUT
COMMERCIAL PARCELS: Parking Lots

Combining conveyance with bioretention

Bagley Elementary, Seattle, WA

SITE ASSESSMENT, PLANNING & LAYOUT
COMMERCIAL PARCELS: Bioretention and Rain Gardens

YMCA Silverdale, WA

Villanova Campus
Site Assessment, Planning & Layout

Site Layout Example 1: Using List #2

- Forested 0.8 ac. Parcel
- 2012 Manual adopted by local jurisdiction
  - 7,000 sf building
  - 7,000 sf parking
  - 1,750 sf walks
  - 12,000 sf landscaping
- Till & perched groundwater at 1-2' depth

Site Assessment, Planning & Layout

Site Layout Example 1: Lawn and Roofs

<table>
<thead>
<tr>
<th>Lawn</th>
<th>Feasible (SELECTED)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Post-Construction Self-Drainage and Infiltration Requirements, 11-2 "Slopes, V, of the 1NBM/WM
- Flood Discharge in accordance with the 1NBM/WM, Chapter 2, Section 1.1 of Volume II of the 1NBM/WM
- Infiltration Described in Volume III of the 1NBM/WM
- No groundwater/saturated conditions must be no more than 12" from bottom of aggregate base

Site Assessment, Planning & Layout

Site Layout Example 1: Other hard Surfaces

<table>
<thead>
<tr>
<th>Other hard surfaces</th>
<th>Infeasible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feasible (selected for sidewalks*)</td>
</tr>
<tr>
<td></td>
<td>Infeasible for PGIS</td>
</tr>
<tr>
<td></td>
<td>Infeasible</td>
</tr>
<tr>
<td></td>
<td>Infeasible</td>
</tr>
</tbody>
</table>

* Groundwater/saturated conditions must be no more than 12" from bottom of aggregate base
SITE LAYOUT EXAMPLE 1: Resulting Site Plan

SITE LAYOUT EXAMPLE 2: Using List #2
- Forested 0.7 ac. Parcel
- 2012 Manual adopted by local jurisdiction
  - 12,000 sf building
  - 22 parking stalls
- Outwash soils (4” per hour long term)
- Groundwater at 15’

SITE LAYOUT EXAMPLE 2: Lawn and Roofs

Lawn
- Feasible (SELECTED)
- Infeasible due to lack of downstream flow path and site land coverages

Roof
- Feasible (SELECTED)
SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 2: Other hard Surfaces

<table>
<thead>
<tr>
<th>Other hard Surfaces</th>
<th>Infeasible</th>
<th>Feasible (SELECTED)</th>
<th>Feasible</th>
<th>Infeasible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full dispersion in accordance with BMP 73.10 in Chapter 5 of Volume V of the SWMWWA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeable pavement in accordance with BMP 73.15 in Chapter 5 of Volume V of the SWMWWA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roadway (per Chapter 7, Volume V of the SWMWWA) facilities that have a maximum horizontally projected surface area below the overflow which is at least 1% of the total surface area drained to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stormwater dispersion in accordance with BMP 73.12, or Concentrated Flow Dispersion in accordance with BMP 73.13 in Chapter 5 of Volume V of the SWMWWA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 2: Resulting Site Plan

SITE ASSESSMENT, PLANNING & LAYOUT

COMMERCIAL PARCELS: Stormwater Planters

Downtown CSO Demand Management, Seattle, WA
CONSTRUCTION CONSIDERATIONS: Access & Staging

- Staging Areas
- Temporary Access
- Subgrade protection and restoration procedures
- Element #13 of the SWPPP
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

CONSTRUCTION CONSIDERATIONS: Erosion & Sediment Control

- Inadequate protection of BMPs during construction can result in expensive mitigation

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
CONSTRUCTION CONSIDERATIONS: Over-compaction

Vehicular loading prism – some compaction is necessary

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

CONSTRUCTION CONSIDERATIONS: Subgrade Permeability

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

Smeared and sealed by bucket

Q&A
BMP SPECIFICS

BIORETENTION

• Bioretention and Rain Gardens (30 minutes)
  • Anatomy of bioretention and rain gardens
  • NPDES protection requirements for bioretention and rain gardens (MR #2 and MR #5-7)
  • Setbacks
  • Construction sequencing and protection during construction for bioretention and rain gardens
  • Case Study with lessons learned

OVERVIEW: 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**

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

**BMP SPECIFICS – BIORETENTION**

**Bioretention Cell**

**Bioretention Planter**

**Bioretention Planter**
### BMP SPECIFICS – BIORETENTION VS RAIN GARDENS

- **Structures/Underdrains:**
  - Bioretention: Yes
  - Rain Garden: Usually no

- **Soil mixes:**
  - Bioretention: Less restrictive
  - Rain Garden: Designed

### BMP SPECIFICS

- **PERMEABLE PAVEMENT**
  - Anatomy of a facility
  - NPDES protection requirements for permeable pavement (MR #2 and MR #5-7)
  - Construction sequencing and protection guidelines for permeable pavement
  - Case Studies with lessons learned
FACILITY ANATOMY: Porous Asphalt

- Flexible
- Similar to conventional asphalt, but fines < No. 30 sieve reduced
- Typically used for parking and light traffic loads; however, has been used for medium and heavy applications
- ~16% voids typical (2-3% for conventional)

FACILITY ANATOMY: Pervious Concrete

- Rigid
- 1/4 to 5/8 round or crushed aggregate typical, portland cement, and admixtures (optional) to increase workability and strength
- 15 to 20% voids typical

FACILITY ANATOMY: Permeable Pavers

- Flexible
- Capable of high vehicle loads. Used for lower speeds
- High-density concrete that interlock and transfer vertical loads to surrounding pavers
- 12% voids typical
FACILITY ANATOMY: Plastic Grids

- Flexible
- Plastic grid filled with gravel or soil and planted with grass
- Capable of high vehicle loads. Used for lower speeds
- Highest percent voids

HOW THE FACILITY WORKS

- Inlets
- Outlets
- Slopes
BMP specifics

**DISPERSION & INFILTRATION**

- Dispersion and Infiltration (20 minutes)
  - Downspout infiltration and dispersion
  - Concentrated and sheet flow dispersion
  - Soil quality and depth (composted amended soils)
  - Local jurisdiction and homeowner requirements
  - Q&A

**COMPONENTS: Downspout Dispersion**

- Splash block
- Dispersal area

Source: City of Seattle
COMPONENTS: Downspout Dispersion
- Dispersion trench
- Dispersal area

COMPONENTS: Sheet Flow and Concentrated Flow Dispersion
Sheet Flow Dispersion
- Transition zone
- Dispersal area
Concentrated Flow Dispersion
- Rock pad at discharge point
- Dispersal area

COMPONENTS: Downspout Full Infiltration
- Rock trench/well
- Inlet
- Storage sump
COMPONENTS: Compost Amended Soils

BMP specifics

CONSTRUCTION CONSIDERATIONS: Tree Protection
- Trees are valuable!
- Arborist evaluation
- Valuation posted on each significant 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

CRZ
Feeder Root Zone

BMP SPECIFICS – NEWLY PLANTED AND RETAINED TREES

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

CRZ
Feeder Root Zone

BMP SPECIFICS – NEWLY PLANTED AND RETAINED TREES

IMPERVIOUS SURFACE REDUCTION CREDITS

<table>
<thead>
<tr>
<th>Tree Type</th>
<th>Flow Control Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen</td>
<td>20% of canopy area (min of 100 sf/tree)</td>
</tr>
<tr>
<td>Deciduous</td>
<td>10% of canopy area (min of 50 sf/tree)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tree Type</th>
<th>Flow Control Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen</td>
<td>50 sf/tree</td>
</tr>
<tr>
<td>Deciduous</td>
<td>20 sf/tree</td>
</tr>
</tbody>
</table>
introduction & regulations

site assessment, planning, layout

BMP specifics

cost comparisons & resources

wrap up

CONSTRUCTION COST: Bioretention

• Cost Comparison – bioretention vs. filters for treatment only

Assumptions:
• Double-loaded parking lot with perpendicular stalls & landscape strip
• 22’ travel lane / 9’x18’ parking stalls
• Exclude reduced detention benefits
CONSTRUCTION COST: Bioretention

- Cost Comparison – bioretention vs. filters for treatment only

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Cost (cost per LF)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONVENTIONAL</td>
<td>1. 4’ wide landscape island between rows of stalls</td>
<td>$20/LF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Catch basins @ 150’/acre</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. 8” CPEP storm pipe continuous</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Stormwater treatment provided by filter vaults sized @ 5 cartridges per acre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LID</td>
<td>1. 4’ wide bioretention cell between rows of stalls</td>
<td>$169.17/LF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Standpipe overflow with beehive grate in each bioretention cell 1 @ 150’</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Reduced detention benefit in addition to the 15% savings shown for treatment only

CONSTRUCTION COST: Rain Gardens

<table>
<thead>
<tr>
<th>Location</th>
<th>Self Installation (cost per SF)</th>
<th>Professional Installation (cost per SF)</th>
<th>Average Size (SF)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wisconsin</td>
<td>$2.90 - 4.60</td>
<td>$12.70 - 15.00</td>
<td>NA</td>
<td>Edgewood College (2003)</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>$3.50 - 5.80</td>
<td>$11.50 - 13.90</td>
<td>300</td>
<td>Kassulke (2003)</td>
</tr>
<tr>
<td>General</td>
<td>$3.00 - 4.00</td>
<td>$10.00 - 40.00</td>
<td>NA</td>
<td>EPA (2008)</td>
</tr>
<tr>
<td>Virginia</td>
<td>$0.50 - 0.75</td>
<td>$10.00</td>
<td>150</td>
<td>James City County (2008)</td>
</tr>
<tr>
<td>Lincoln, NE</td>
<td>$2.00 - 8.00</td>
<td>$8.00 - 14.00</td>
<td>NA</td>
<td>Lincoln (2008)</td>
</tr>
<tr>
<td>Salt Lake City, UT</td>
<td>$8.83</td>
<td>$16.63</td>
<td>NA</td>
<td>RS Means 100 Estimate of Elaborate Garden</td>
</tr>
</tbody>
</table>

CONSTRUCTION COST: Rain Gardens

- Average cost for self installation = $5.15 per SF
- Average cost for professional installation = $16.05 per SF
PERMEABLE PAVEMENT

Pervious Hot Mix Asphalt Per WSDOT Bid Tabs:

- Pervious HMA: $105-$135/TON (2014)
- Pervious Base: $25/TON (2014)

Conventional Pavement:

- Dense Graded HMA Class ¾": $85-$100/TON (2014)
- Crushed Surfacing Base Course: $20-$25/TON (2014)

Note: In many instances using pervious HMA is considered cost neutral. If soils infiltrate, permeable is much less costly than conventional.

PERMEABLE PAVEMENT

Pervious Concrete Sidewalk Per Three City of Bellingham Bid Tabs:

- Say $5-$6/sf with base

Note: The 2013 values included some 8” thick bike lanes, bids from each same contractor basically same as solid sidewalk.

OTHER LID BMPS: Cisterns

- Approximate cistern costs per gallon stored by tank type

  - $0.50
  - $1
  - $2.00
  - $4-$6
  - $1.50
  - $2.00
  - $4-$6
  - $4-$6
### COST COMPARISONS & RESOURCES

#### OTHER LID BMPS: Vegetated Roof

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Green Roof Cost (s.f.)</th>
<th>Roofing Cost (s.f.)</th>
<th>Total Cost w/ Roofing (s.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensive Green Roof (3-4&quot; soil with sedums)</td>
<td>$5-8</td>
<td>$15-20</td>
<td>$20-28</td>
</tr>
<tr>
<td>Semi-Intensive Green Roof (4-8&quot; soil with sedums/wildflowers, perennials)</td>
<td>$10-15</td>
<td>$15-20</td>
<td>$25-35</td>
</tr>
<tr>
<td>Intensive Green Roof (8-12&quot; with groundcover, small shrubs)</td>
<td>$18-25</td>
<td>$15-20</td>
<td>$33-45</td>
</tr>
<tr>
<td>Roof Terrace (intensive with pavers, trees, planters, shrubs)</td>
<td>$50-80+</td>
<td>$15-20</td>
<td>$65-100+</td>
</tr>
</tbody>
</table>

### COST COMPARISONS & RESOURCES

#### MAINTENANCE

<table>
<thead>
<tr>
<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>
</tr>
<tr>
<td>Inlet/outlet protection</td>
<td>Inlet/outlet protection</td>
</tr>
<tr>
<td>Sediment removal</td>
<td>Ponding area maintenance</td>
</tr>
<tr>
<td>Check dam/weir sediment management and erosion repair</td>
<td>Protect bioretention soil from compaction</td>
</tr>
<tr>
<td>Maintain vegetation cover</td>
<td>Protect bioretention soil from compaction</td>
</tr>
<tr>
<td>Ponding area maintenance</td>
<td>Mulching</td>
</tr>
<tr>
<td>Flow spreader</td>
<td>Underdrain clog removal</td>
</tr>
<tr>
<td>Watering</td>
<td>Watering</td>
</tr>
</tbody>
</table>

### COST COMPARISONS & RESOURCES

#### MAINTENANCE: Bioretention

WERF LID Cost Calculator (last updated 5/9/2009)

<table>
<thead>
<tr>
<th>Item</th>
<th>Maintenance Frequency</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Annual O&amp;M Cost for 400 SF (Medium)</th>
<th>Cost/SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation management</td>
<td>Every 3 years</td>
<td>1/year</td>
<td>12/year</td>
<td>$134</td>
<td>$0.34</td>
<td></td>
</tr>
<tr>
<td>Replace mulch</td>
<td>Every 3 years</td>
<td>1/year</td>
<td>$224</td>
<td>$0.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Till soil</td>
<td>Every 10 years</td>
<td>Every 5 years</td>
<td>$90</td>
<td>$0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>$448</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Puget Sound Stormwater BMP Cost Database Technical Memorandum (Herrera 2013)
### Maintenance: Bioretention

#### 30-Year Cost Comparison

<table>
<thead>
<tr>
<th>BMP</th>
<th>30-Year O&amp;M Cost</th>
</tr>
</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>
</tr>
</tbody>
</table>


### Maintenance: Permeable Pavement

#### WERF LID Cost Calculator (Last updated 5/9/2009)

<table>
<thead>
<tr>
<th>Item</th>
<th>Maintenance Frequency</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Annual O&amp;M Cost for 5,000 SF (Medium)</th>
<th>Cost/SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection, reporting, and data management</td>
<td>Every 3 years</td>
<td></td>
<td></td>
<td></td>
<td>$47</td>
<td>$0.01</td>
</tr>
<tr>
<td></td>
<td>Every 3 years</td>
<td></td>
<td>1/year</td>
<td></td>
<td>$120</td>
<td>$0.03</td>
</tr>
<tr>
<td></td>
<td>Every 3 years</td>
<td></td>
<td>1/year</td>
<td></td>
<td>$80</td>
<td>$0.02</td>
</tr>
<tr>
<td>Litter &amp; minor debris removal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Every 3 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweeping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Every 3 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$247</td>
</tr>
</tbody>
</table>

### Maintenance: Permeable Pavement

#### Puget Sound Stormwater BMP Cost Database Technical Memorandum (Herrera 2013)

<table>
<thead>
<tr>
<th>O&amp;M Activities</th>
<th>Unit</th>
<th>n</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine sweeping (2X per year)</td>
<td>SF</td>
<td>1</td>
<td>$0.02</td>
<td>$0.02</td>
<td>$0.02</td>
</tr>
</tbody>
</table>

- Restorative maintenance (power washing followed by vactoring to unplug the upper layer and restore porosity) is estimated at $1/SF
LEARNING OBJECTIVE RECAP

1. Efficient application of LID BMPs.
2. New LID regulatory requirements.
3. How LID development process and cost compares with conventional stormwater practices.
4. The basic principles of site assessment, site layout and construction sequencing to improve the design and long-term, effective operation of LID best management practices (BMPs) and projects.
5. How to minimize construction impacts.
6. Minimum requirements for construction and protection of LID BMPs during construction.

RESOURCES

- 2012 Stormwater Management Manual for Western Washington
  

- Low Impact Development Technical Guidance Manual for Puget Sound
  

- Western Washington Low Impact Development (LID) Operations and Maintenance (O&M) Guidance Document,
  
  (Click on the "Maintain LID" tab)
ECOLOGY WEBINAR - LOW IMPACT DEVELOPMENT – RAIN GARDENS AND BIORETENTION

ECOSYSTEMS

WWHM 2012 Training Documents
www.ecy.wa.gov/programs/wq/stormwater/municipal/PrevWS.html

Rain Garden Handbook for Western Washington

Q&A

1. Introduction & Regulations
2. Site Assessment, Planning, Layout
3. BMP Specifics
4. Cost Comparisons & Resources
5. Wrap Up

DEVELOPERS & CONTRACTORS

INTEGRATING LOW IMPACT DEVELOPMENT (LID)

STATEWIDE LID TRAINING PROGRAM
Statewide LID Training Program

COURSE CATALOG

http://www.wastormwatercenter.org/lidwtrainingprogram/

INTRODUCTORY

1.0 Introduction to LID for Eastern Washington

INTERMEDIATE

3.1 Introduction to LID for Inspectors & Maintenance Staff

3.2 Introduction to LID for Developers, & Contractors for Green

3.3 Intermediate LID Topics: NPDES Phase I & II Requirements

3.4 Intermediate LID Topics: Design & Maintenance

3.5 Intermediate LID Topics: Permeable Pavement

3.6 Intermediate LID Topics: Site Assessment, Planning & Layout

ADVANCED

5.1 Advanced Topics in LID Design: Bioretention

5.2 Advanced Topics in LID Design: Permeable Pavement

5.3 Advanced Topics in LID Operations: Bioretention

5.4 Advanced Topics in LID Operations: Permeable Pavement

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

5.6 Advanced Topics in LID Operations: Bioretention Media

ADVANCED TOPICS IN LID DESIGN:

6.0 Advanced Topics in LID Design: Hydrologic Modeling

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

8.0 Advanced Topics in LID Design: Inspection, Maintenance & Vegetated Roofs

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

9.1 Intermediate LID Design: Hydrologic Modeling

9.2 Intermediate LID Design: Site Assessment, Planning & Layout

TRAIN THE TRAINERS

LID Topic Experts

ONLINE EVALUATION

- An on-line evaluation will be sent to you within 5 days following this training.
Statewide LID Training Program

CERTIFICATE

Two certificates:
• Stay tuned for decisions on certificate
• 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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Statewide LID Training Program

QUESTIONS

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