Statewide LID Training Program

INSTRUCTORS

REBECCA DUGOPOLSKI, PE
Senior Engineer
Key project experience: Stormwater monitoring, design, and NPDES Permit compliance

KATHY GWILYM, PE
Senior Civil Engineer
Key project experience: Complete street design, LID and permeable pavements for public works and private projects

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
• 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

Introduction to LID for Inspection & Maintenance Staff (Intermediate)
Introduction to LID for Inspectors & Maintenance Staff (Intermediate)
Introduction to LID for Inspectors & Maintenance Staff (Intermediate)

Intermediate LID Design: Rainwater Collection Systems & Vegetated Roofs
Intermediate LID Design: Permeable Pavement
Intermediate LID Design: Hydrologic Modeling

Intermediate LID Topics: NPDES Phase I & II Requirements
Intermediate LID Topics: NPDES Phase I & II Requirements
Intermediate LID Topics: NPDES Phase I & II Requirements

Intermediate LID Design: Site Assessment, Planning & Layout
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Intermediate LID Design: Bioretention Media & Compost Amended Soils
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Advanced LID Design: Site Assessment, Planning & Layout
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Advanced LID Topics: NPDES Phase I & II Requirements
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Advanced LID Design: Bioretention Media & Compost Amended Soils
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Advanced LID Topics for Long-term LID Operations: Permeable Pavement
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Advanced LID Topics for Long-term LID Operations: Hydrologic Modeling
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LOGISTICS

SCHEDULE
• Classroom training (8 am – 12 pm)
• 1-hour lunch break (12 – 1 pm)
• Field exercises (1 – 4 pm)

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

1. Understand the structure and function of permeable pavement components.
2. Gain an in-depth understanding of the primary inspection activities and tools to maintain permeable pavement function over time.
3. Know the primary maintenance requirements for permeable pavement.
4. Identify maintenance problems and associated solutions necessary for long-term function of permeable pavement areas.

AGENDA

- introduction
- permeable pavement O&M
- O&M costs
- administrative tools
- wrap up & field exercises
TOPICS

INTRODUCTION

LOW IMPACT DEVELOPMENT (LID):
Introduction to Principles

- Site design & planning techniques emphasizing conservation
- Use of small-scale engineered controls to closely mimic pre-development hydrologic processes
- Careful assessment of site soils and strategic site planning to best use those soils for stormwater management

LID: Introduction to Principles: Pre-developed Forest Hydrology
LID: Introduction to Principles: Developed Condition Hydrology

INTRODUCTION

LID: Site Design and Planning Techniques

- Minimize disturbance
- Reduce impervious surface
- Protect and restore native soils and vegetation
- Manage stormwater close to the source

Traditional LID

INTRODUCTION

LID: Small-Scale Engineering Controls

- Infiltration
- Filtration
- Storage
- Evaporation
- Transpiration

Conserve or regain pre-developed hydrologic functions
INTRODUCTION

LID: Best Management Practices (BMPs)

- Rain Gardens (BMP T5.14A)
- Biotreatment (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)

INTRODUCTION

LID: Permeable Pavement

- Infiltration
- Filtration
- Storage
- Evaporation
- Transpiration

INTRODUCTION

TOPICS

Intro to LID  NPDES Permit  LID O&M Guidance Document
NPDES PERMIT LID O&M REQUIREMENTS:
Western WA NPDES Permit
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 Permittees</th>
<th>Western Washington Phase II Permittees</th>
<th>Eastern Washington Phase II Permittees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I Permittees</td>
<td>Seattle</td>
<td>82 Cities</td>
<td>18 Cities</td>
</tr>
<tr>
<td>Phase I Permitties</td>
<td>Tacoma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase I Permittees</td>
<td>Clark County</td>
<td>5 Counties</td>
<td></td>
</tr>
<tr>
<td>Phase I Permittees</td>
<td>King County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase I Permittees</td>
<td>Pierce County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase I Permittees</td>
<td>Snohomish County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase I Permittees</td>
<td>WSDOT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary Permittees: Approximately 45; such as ports and universities</td>
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<td></td>
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</tr>
</tbody>
</table>

To see a listing of permittees visit

INTRODUCTION
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.6.a of the Phase I Permit</td>
<td>Per Section S5.C.6.e of the Phase I Permit</td>
</tr>
<tr>
<td>Most Permittees</td>
<td>Lewis Co. and Snohomish Co.</td>
</tr>
<tr>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

INTRODUCTION
Requirements Vary By BMP Classification

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

**NPDES MUNICIPAL STORMWATER PERMIT:**

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

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**NPDES PERMIT LID O&M 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

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**NPDES PERMIT LID O&M 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 LID O&M 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

INTRODUCTION
On-site SW Management BMPs (LID BMP)

“Distributed stormwater management practices, integrated into a project design, that emphasize pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation and transpiration. LID BMPs include, but are not limited to, bioretention/rain gardens, permeable pavements, roof downspout controls, dispersion, soil quality and depth, vegetated roofs, minimum excavation foundations, and water re-use.”
DEFINITIONS

INTRODUCTION

- SW Treatment & Flow Control BMPs/Facilities (MR #6 and/or MR #7)
  - "Detention facilities, treatment BMPs/facilities, bioretention, vegetated roofs, and permeable pavements that help meet Appendix 1 Minimum Requirements #6 (treatment), #7 (flow control), or both"

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 Credit¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Amendment</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dispersion</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Retaining &amp; Planting Trees</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rainwater Harvesting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioretention*</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Permeable Pavement²</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Vegetated Roofs¹</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

¹Meets basic, enhanced and phosphorus treatment when infiltrating through soil per Ecology treatment requirements
²Where permeable pavement is over soils meeting the suitability criteria or a treatment layer is included
³Also considered SW Treatment & Flow Control BMPs/Facilities (additional requirements in regard to long term inspection, operations, and maintenance apply)

NPDES PERMIT LID O&M REQUIREMENTS:

O&M Standards

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMP</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>X</td>
<td></td>
</tr>
<tr>
<td>Implement practices, policies, &amp; procedures to reduce SW impacts associated with runoff*</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

*Requirements for O&M including (but not limited to): pipe cleaning, cleaning conveyance structures, sediment and erosion control, and vegetation management
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>X</td>
<td></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>X</td>
<td></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>

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>

NPDES PERMIT LID O&M REQUIREMENTS:

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></td>
</tr>
<tr>
<td>Conduct ongoing annual inspections</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Perform spot checks for potentially damaged BMPs owned/operated by Permittee after major storm events</td>
<td>X</td>
<td></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.
**NPDES PERMIT LID O&M REQUIREMENTS:**

### 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>X</td>
<td></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>

### 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>
INTRODUCTION

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

INTRODUCTION

TOPICS

Intro to LID NPDES Permit LID O&M Guidance Document

INTRODUCTION

LID O&M GUIDANCE DOCUMENT: Objective

• 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
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

Photos provided by MIG SvR
**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

- 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)
PERMEABLE PAVEMENT O&M

TOPICS

• Types
• How the system works
• Maintenance considerations for facility function
• General maintenance for all
• Routine maintenance activities specific to each type
• Corrective maintenance activities
• Equipment and material recommendations
• Skills

TYPES & TERMS

- Pervious Concrete
- Porous Asphalt
- Permeable Interlocking Concrete Pavers
- Open Celled Systems (Flexible & Rigid)

Photos provided by MIG SvR
**TYPES: Porous Asphalt**

- Flexible, non-proprietary
- Placement is similar to conventional asphalt but need large quantity
- Typically used for parking and light traffic loads; however, has been used for medium and heavy applications
- Initial infiltration rate: 200+ inches/hour

**TYPES: Pervious Concrete**

- Rigid, non-proprietary
- Placement differs from conventional. Small batches feasible.
- 3/8” typical (round or crushed) aggregate w/o to minimal fines. Admixtures (optional) to increase workability and strength.
- Initial Infiltration rate 200+ inches/hour

**TYPES: Permeable Interlocking Pavers**

- Flexible, proprietary
- Capable of high vehicle loads. Used for lower speeds
- High-density concrete that interlock and transfer vertical loads to surrounding pavers
- Clean aggregate (w/o fines) filled within the openings/gaps
- Initial infiltration rates can vary depending upon paver type
• Flexible, proprietary
• Plastic grid filled with clean gravel (w/o fines) or soil and planted with grass
• Trails, paths, maintenance access in a park, parking
• Highest percent voids

HOW THE FACILITY WORKS

• Sections vary – check as-builts
  • Top Wearing Course
  • Leveling Course?
  • Sub-base (storage)
  • Water quality treatment layer?
  • Geotextile?
  • Native soil
  • Storage within Sub-base
  • Slope conditions – check dams
  • Overflow (pipe or structure)
INTRODUCTION TO MAINTENANCE

• "The maintenance of LID facilities is essential to ensure that design stormwater management and other benefits continue over the full lifecycle of the installation."

• What to look for?
  • Drainage Function
  • Safety
  • Aesthetics

• What’s different vs same?

• Long term infiltration capacity can remain high however...............

O&M TRANSITION

• O&M starts at the Planning phase

• Transitioning from Construction to O&M
  • Purpose?
  • What are the regulatory reporting requirements?
  • Record/As-built?
  • Training new staff
  • Mapping
**PERMEABLE PAVEMENT O&M**

**GENERAL: Protection of Surface**
Inform crews about protecting permeable pavements
Use tarps/cover under stockpiles

**PERMEABLE PAVEMENT O&M**

**GENERAL: Adjacent Stabilization**
Maintain stabilization of adjacent areas to protect from sediment transport
• Proactive vs Reactive
• Address Source

**PERMEABLE PAVEMENT O&M**

**GENERAL: Vegetation Migration & Rooting**
• Ground Cover Migration
• Cover if Hydroseeding/Landscaping
• Options for Maintenance
  • Modify planting plan and remove invasive plants
  • Maintain adjacent landscaping
Ground cover migration happens even with conventional pavement

Photos provided by MIG SvR
GENERAL: Moss Growth

- Be careful with expectations
- Moss is present regardless of pavement type in PNW
- More prevalent in shady areas and under trees
- Monitor
- Remove if observed to affect drainage and impacts safety
- Some is okay
- Perception on Aesthetics can vary

If severe, options for removal:
- Pressure washing (concrete)
- Weed burner
- Sweeping (during dry periods)
- Vacuuming (effectiveness varies)

During planning & design, consider impacts of shade to maintenance frequency

Implement measures to minimize landscape clippings and debris onto porous.

Photos provided by MIG SvR
GENERAL: Moss Growth

*Installed ~10 years ago.*

Photo taken w/n 1 year of installation.

*Installed in 2010 — no routine maintenance.*

Photo July 2014.

*Installed in 2005 — no routine maintenance.*

Photo May 2014. Photos provided by MIG SvR.

GENERAL: Protection From Staining

- Applies to pavers, asphalt, cement concrete. Same as conventional pavements.
- During construction, keeping pervious concrete covered for curing & protection can lead to some discoloration but fades with time.
- Avoid placement of organic/compost material on pavement.

Staining from compost spilling onto pervious concrete.

Photos provided by MIG SvR.
**GENERAL: Snow Removal**

- Modify snow management procedures
- Avoid sanding since it will clog the system, except in cases of emergencies/safety issues (vacuum sediment as soon as possible after melt)
- Avoid sanding adjacent streets since tires will track it onto the porous pavement
- Avoid stockpiling snow on porous pavement

**GENERAL: Snow Removal**

- Adjust snow plow height to avoid scratching
- UNH reported up to 75% decrease in salt use but it will depend on site conditions (shade, location etc)
- Permeable sub-base provides drainage
- Voids in wearing course provides space for freeze thaw
- Installed in cold climates such as Iowa, Pennsylvania, Colorado, Ohio, Lake Tahoe

**Parking Lot, Denver, CO – Next AM Following 12” Snow**

- Photos courtesy of National Ready Mixed Concrete Association and slide courtesy of Center for Portland Cement Concrete Pavement Technology, 2005 via John Kevern at National Concrete Pavement Technology, Iowa State University
GENERAL: Drainage Function Inspection

- Inspect drainage function in the rain and identify areas for maintenance
  - Is there runoff from the surface?
  - Is water still ponding on the surface 1 hour after rain has stopped?
  - Is there ponding water in the observation port 24 hours after the rain has stopped?
  - If ponding, then corrective action required for cleaning surface.

GENERAL: Drainage Function Inspection

- Video/photos of overall area during rain event
  - If no ponding on the surface then it's flowing through top wearing course

VIDEO IN THE RAIN
PERMEABLE PAVEMENT O&M
VIDEO IN THE RAIN

2/10/2016

PERMEABLE PAVEMENT O&M
GENERAL: Drainage Function Inspection

• Inspect drainage function in dry weather
  • Cylinder test: ASTM C1701 results indicate an infiltration rate of 10 inches per hour or less then corrective action required.
  • Test the surface infiltration rate using ASTM C1701 (perform 1 test/installation but not < 1 test/2,500 sf)
  • Run cylinder tests over multiple areas
  • Turn on sprinklers/garden hose to test larger area?
  • Does water pool or drain out?

PERMEABLE PAVEMENT O&M
GENERAL: Corrective Action for Drainage

• If not draining through top wearing course then corrective maintenance options include:
  • Pressure wash and/or vacuum system
  • Hand held pressure wash or power wash with rotating brushes
  • Pure vacuum sweeper (calibrated to not dislodge wearing course aggregate)
  • Gravel grid and pavers – removing and replacing aggregate
**PERMEABLE PAVEMENT O&M**

**GENERAL: Under- and Elevated-Drains**

- Under-drain/Elevated drain is clogged:
  - Jet clean or rotary cut debris/roots from under-drain
  - Clean flow restrictor/orifice
  - Identify the source of the blockage and take actions to prevent future blockages

- If pipe daylights, check for erosion damage at discharge point:
  - Identify source of problem
  - Repair erosion and stabilize surface

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**GENERAL: Under- and Elevated-Drains**

- Water remains in storage aggregate longer than anticipated:
  - Inspect standpipes for under-drain
  - Inspect drains
  - If structural problems possible schedule investigation of subsurface materials or other potential causes of extended ponding

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**GENERAL: Inspect Overflow/Backup System**

- Check overflow drainage path
  - What is the flow path if water does not infiltrate?
  - If has under-drain pipes, verify they are draining
  - Verify that the overflow structure is not plugged.
**PERMEABLE PAVEMENT O&M**

**GENERAL NON-ROUTINE: Utility Cuts**
- Temporary Patch
- Protect adjacent porous to remain
- Permanent Panel replacement
- Permanent Restoration: Use same material as original, except use conventional asphalt for porous asphalt

**ROUTINE AND CORRECTIVE MAINTENANCE BY COMPONENT**
- Pavement surface
  - Porous Asphalt and Pervious Concrete
  - Permeable Interlocking Concrete Pavers
  - Open Celled Gravel grid
  - Open Celled Grass grid

**ROUTINE: Porous Asphalt & Pervious Concrete**
- Cleaning surface debris
  - Large areas: vacuum sweep (regenerative air or high efficiency vacuum)
  - Small areas: walk behind vacuums, shop vacs, hand held pressure washer or power washer with rotating brushes
  - Frequency: 1-2 times annually or as determined by site conditions
  - Consult with equipment manufacturer/rep for optimum operation
PERMEABLE PAVEMENT O&M

ROUTINE: Porous Asphalt & Pervious Concrete
- No Overlay
- No black topping/sealing
- May need to re-stripe parking lot more frequently

NON-ROUTINE: Pervious Concrete Structural
- Major cracks or trip hazards and concrete spalling and raveling
  - Determine cause
  - Replace panel with porous material if feasible
  - Modify operations?

NON-ROUTINE: Raveling at Construction Joints
- Consult with industry, engineer
- Patch?
  - Cut out and replace with new panel (pervious concrete)
  - Replace with conventional asphalt?
### PERMEABLE PAVEMENT O&M

#### NON-ROUTEINE: Drainage Function Rehabilitation
- Consult with industry, engineer
- Significant decline in infiltration when system is not routinely maintained

#### ROUTINE: PICP & Pavers

**ROUTINE: PICP & Pavers**

- Routine maintenance (cleaning surface debris)
  - Large areas: vacuum sweep (regenerative air or high efficiency vacuum)
  - Small areas: walk behind vacuums, shop vacs
  - Frequency: 1-2 times annually or as determined by site conditions
  - Consult with equipment manufacturer/rep for optimum operation
  - Vacuum settings may have to be adjusted to prevent excess uptake of aggregate from paver openings or joints
  - Vacuum surface openings in dry weather to remove dry, encrusted sediment

**ROUTINE: PICP & Pavers**

- Routine maintenance (vegetation)
  - Remove weeds if they start to affect drainage performance
  - Aesthetics
  - Do not use herbicides (this is a stormwater facility)
  - Weed burner
  - Larger gaps between pavers easier for removal of weeds (shovel)
CORRECTIVE: PICP & Pavers

- Clogged wearing course
  - Review overall performance of the facility
  - If water ponds or flows off pavement surface during rain event, corrective maintenance or testing is needed
  - Dry Weather: Test the surface infiltration rate using ASTM C1781 (perform 1 test/installation but not < 1 test/2,500 sf)

CORRECTIVE: PICP & Pavers

- Clogged wearing course
  - Corrective maintenance options include:
    - Pure vacuum sweeper
    - Pressure wash and vacuum system calibrated to remove all visible sediment (likely 2-3 cm of aggregate) in the joints or infiltration cells
  - Replace aggregate in joints or infiltration cells per manufacturer specifications

NON-ROUTINE: PICP & Pavers

- Utility work
  - Pavers can be removed individually and replaced after work is complete
  - Clean sub-base material (no to minimal fines)
**PERMEABLE PAVEMENT O&M**

**NON-ROUTINE: PICP & Pavers**
- Structural integrity
  - Loss of aggregate material between paver blocks: Refill per manufacturer’s recommendations
  - Paver block missing or damaged: Remove individual damaged paver blocks by hand and replace or repair per manufacturer’s recommendations
  - Surface settling: May require resetting

**NON-ROUTINE: PICP & Pavers**
- Structural integrity and snow
  - The structure of the top edge of the paver blocks reduces chipping from snowplows
  - Skids on the corner of plow blades are recommended

**ROUTINE: Gravel Grid**
- Cleaning surface debris
  - Large areas: vacuum sweep? (regenerative air or high efficiency vacuum)
  - Small areas: walk behind vacuums, shop vacs, rake, leaf blower
  - Frequency: 1-2 times annually or as determined by site conditions
  - Consult with equipment manufacturer/rep for optimum operation
  - Vacuum settings may have to be adjusted to prevent excess uptake of aggregate from paver openings or joints
  - Vacuum surface openings in dry weather to remove dry, encrusted sediment
  - Maintain aggregate 0.25 inches above grid structure
CORRECTIVE: Gravel Grid

- Clogged wearing course
  - Observe the pavement system after a rain event (testing infiltration rate using ASTM C1701 likely not applicable)
  - Corrective action needed, if ponding on surface or water flows off aggregate surface during rain event

CORRECTIVE: Gravel Grid

- Clogged wearing course
  - Use vacuum system calibrated to remove all visible sediment (likely 2-3 cm of aggregate)
  - Replace aggregate per manufacturer specifications (usually 0.25 inches above grid structure)

NON-Routine: Gravel Grid

- Structural integrity
  - Grid damaged:
    - Remove pins (if present), pry up grid segments, and replace grid, pins and gravel
    - Replace grid segments where three or more adjacent rings are broken or damaged
  - Loss of aggregate material: Refill per manufacturer’s recommendations (usually 0.25 inches above grid structure)
PERMEABLE PAVEMENT O&M

ROUTINE: Grass Grid

- Cleaning surface debris
  - Large and small areas: rakes, leaf blowers
  - Consult manufacturer guidelines
  - Frequency: 1-2 times annually or as determined by site conditions
  - Maintain soil/sand slightly below grid structure

CORRECTIVE: Grass Grid

- Clogged wearing course
  - Observe the grass pavement system after a rain event (testing infiltration rate using ASTM C1701 likely not applicable)
  - Corrective action needed if ponding on surface or water flows off grass surface during rain event
  - Follow manufacturer’s guidelines for repairing surface

NON-ROUTINE: Grass Grid

- Structural integrity
  - Grid damaged:
    - Remove pins (if present), pry up grid segments, and replace grid, pins and grass.
    - Replace grid segments where 3 or more adjacent rings are broken or damaged
  - Grass growth:
    - Mulch mower
    - Top dress with 0.5 inches of compost if nutrient deficient (do not use fertilizer)
  - Surface settling: May require resetting
PERMEABLE PAVEMENT O&M
NON-ROUTINE: Grass Grid

• Structural integrity
  • Poor grass coverage:
    - Restore growing medium, reseed or plant and/or amend vegetated area as needed
    - Traffic loading may be inhibiting grass growth, reconsider traffic loading if feasible
    - Growing media elevation should be maintained slightly below grid structure
    - Consult manufacturer/sales representative
    - May need occasional reseeding

PERMEABLE PAVEMENT O&M
NON-ROUTINE: Grid Systems

• Structural integrity and snow
  • Snow plows should use skids to elevate the blades to prevent loss of aggregate and damage to the grid

PERMEABLE PAVEMENT O&M
EQUIPMENT & MATERIALS
PERMEABLE PAVEMENT O&M
EQUIPMENT & MATERIALS: Routine Maintenance
Equipment to address clogging of wearing course, such as:
• Hand held pressure washer or power washer with rotating brushes
• Walk-behind vacuum
• Pure vacuum sweeper
• Brush broom
• Combined higher pressure wash and vacuum system

PERMEABLE PAVEMENT O&M
EQUIPMENT & MATERIALS: Routine Maintenance
Equipment to remove sediment, debris, and leaf litter, such as:
• High efficiency regenerative air or vacuum sweeper
• Push broom
• Brush broom
• Leaf blower

PERMEABLE PAVEMENT O&M
EQUIPMENT & MATERIALS: Routine Maintenance
Weed/vegetation removal equipment, such as:
• Weeding tools
• Weed burner
• Edging and trimming equipment control groundcover and other vegetation
Additional equipment for grass-filled open-celled grid systems, such as:
- Mower or mulch mower
- Topdress grass seed
- Compost
- Replacement grid segments

Additional equipment for gravel-filled open-celled grid systems, such as:
- Rakes and shovels
- Replacement grid segments
- Replacement aggregate
- Wheelbarrow (for transporting replacement aggregate)

Additional equipment for permeable paver systems, such as:
- Rakes and shovels
- Extra pavers and bedding material
- Replacement aggregate
- Wheelbarrow (for transporting replacement aggregate)
PERMEABLE PAVEMENT O&M

EQUIPMENT & MATERIALS: Routine Maintenance

Snow removal equipment, such as:
- Plow with skids to prevent damage to permeable pavement
- Snow blower

Pipe/structure inspection and maintenance equipment:
- Hand tools
- Wrench or manhole opener
- Flashlight
- Mirror
- Garden hose
- Plumbing snake
- Measuring tape or ruler

EQUIPMENT & MATERIALS: Corrective Maintenance

- Elgin’s Whirlwind (pure vacuum sweeper)
- Bunyan B.I.R.D. vacuum attached to vactor truck (10 gpm): $7,800 + power if not on vactor
- Paragon Industries
- Stay tuned … supply and demand affect technology
PERMEABLE PAVEMENT O&M
EQUIPMENT & MATERIALS: Corrective Maintenance

Timm Sowders with Paragon Industries

Video of the B.I.R.D. with vactor truck

PERMEABLE PAVEMENT O&M
EQUIPMENT & MATERIALS: Corrective Maintenance
PERMEABLE PAVEMENT O&M

EQUIPMENT & MATERIALS: Corrective Maintenance

Erosion control equipment:
- Erosion control matting
- Rocks
- Mulch
- Plants
- Landscaping tools
- Tarps (to protect pavement)

Photo provided by MIG SvR

PERMEABLE PAVEMENT O&M

EQUIPMENT & MATERIALS: City of Olympia

2006 Study Findings:
- Leaf/Litter vacuums are more effective than sweepers with dust control vacuum systems
- Vacuum machines had difficulty removing leaf piles when they were more than 2 to 3 inches thick

City of Olympia maintenance memo
PERMEABLE PAVEMENT O&M

EQUIPMENT & MATERIALS: City of Portland

N Gay Avenue & Westmoreland Projects:
• Pavers, porous asphalt and pervious concrete public streets
• 1X to 2X/year* - Vacuum sweepers used to collect fines:
  • Tymco's 500x, Schwarze's A7000, Elgin's Crosswind J-Plus
  • Infiltration testing with flusher truck
  • "Vegetation growth in pavers did not appear to hinder infiltration on Rex St." (~63 in/hr)
  • Information from 2008+/

SKILLS
• Sweeper and equipment operation
• Commercial driver's license (CDL)
• Landscaping skills (e.g., general plant care) for grass-filled open-celled grid systems
• Engineer and/or landscape architect for major maintenance

Q&A
### Break

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**introduction**

**permeable pavement O&M**

**O&M costs**

**administrative tools**

**wrap up & field exercises**

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**O&M COSTS**

**CONVENTIONAL VS LID O&M ACTIVITIES**

<table>
<thead>
<tr>
<th>Conventional</th>
<th>LID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweeping</td>
<td>Sweeping / clean surface debris</td>
</tr>
<tr>
<td>Repair structural damage</td>
<td>Repair structural damage</td>
</tr>
<tr>
<td>Typically Streets Department maintains roadways</td>
<td>Transportation or Drainage??</td>
</tr>
<tr>
<td>Run-on from adjacent landscaping</td>
<td></td>
</tr>
<tr>
<td>Traditional drainage infrastructure + storage and grey infrastructure</td>
<td>Unplug drain and inspect for damage</td>
</tr>
</tbody>
</table>

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**PERMEABLE PAVEMENT O&M SCHEDULE**

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Pervious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tacoma Residential</td>
<td>2 x/year</td>
<td>2x/year</td>
</tr>
<tr>
<td>Streets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tacoma Arterials</td>
<td>4x 6 weeks</td>
<td>4x 6 weeks</td>
</tr>
<tr>
<td>Streets</td>
<td>Monthly</td>
<td>Monthly</td>
</tr>
<tr>
<td>Puyallup Streets</td>
<td>Monthly</td>
<td>Monthly</td>
</tr>
<tr>
<td>Monroe Streets</td>
<td>Varies</td>
<td>Same as conventional + additional sweeping by new sweeper for pervious.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Jessica Knickerbocker, City of Tacoma; Mark Palmer, City of Puyallup; Vince Bertrand, City of Monroe, 360-863-4552

**PERMEABLE PAVEMENT O&M COST FACTORS**

- Current street sweeping practices for conventional
- Site Location and surrounding conditions
- Amount of run-on and source of run-on
- Equipment
- Level of service for aesthetics
- Quality of the initial installation
- Other

**PERMEABLE PAVEMENT RESOURCES**

Local Information Resources

- ROADMAP, Contact Luanne Coachman, email: [luanne.coachman@kingcounty.gov](mailto:luanne.coachman@kingcounty.gov)
- APWA Stormwater Managers Committee, Bruce Wulkan and Paul Fendt chairs, google group: [https://groups.google.com/forum/#!forum/apwa-stormwater](https://groups.google.com/forum/#!forum/apwa-stormwater)
- Permeable Pavements for Puget Sound [https://groups.google.com/forum/#!forum/permeable-pavements-for-puget-sound](https://groups.google.com/forum/#!forum/permeable-pavements-for-puget-sound)
- Industry Reps
- Other agencies
• Inspection checklist
• Record keeping and tracking
• Interpreting plans and as-builts
• Inspection programs
ADMINISTRATIVE TOOLS
INSPECTION CHECKLIST

Name(s) of inspection: ____________________________
Date of inspection: ____________________________
Location of the permeable pavement facility: ____________________________
Surface finish, course type: ____________________________
Address or Intersection: ____________________________
Age of permeable pavement facility: ____________________________
Permeable pavement facility area (ft x ft): ____________________________
Time since last rainfall (hrs): ____________________________
Quantity of last rainfall (in): ____________________________

Site sketch (include surbe, islands, trees, etc.): ____________________________

Notes:

ADMINISTRATIVE TOOLS
INSPECTION CHECKLIST

Based on visual assessment of the site, answer the following questions and take photographs of the site:

Surface/Finishing Course:
1. Are there indications of any of the following on the surface of the permeable pavement facility? (If yes, mark on site sketch)
   - Excessive sediment
   - Moss growth
   - Cracks, slip hazards, or concrete/Asphalt spalling
   - Trash and debris
   - Leaf accumulation
   - Settlement of surface
   - Other:
     - None
   If yes, describe the potential reasons for ponded water below (leaf or debris buildup, non-functional undrainage, groundwater input, IBSC connection, inadequate capacity in facility, etc.).

2. Is there ponding on the surface of the permeable pavement? Yes ☐ No ☐

   Notes:

ADMINISTRATIVE TOOLS
INSPECTION CHECKLIST

Inlet/Outlet/Drains:
3. How many inlet pipes are present? ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

4. Are any of the inlet pipes clogged? (If yes, mark the location on your site sketch and list in the boxes below with the cause of the clogging (e.g., debris, sediment, vegetation, etc.)) Yes ☐ Partially ☐ Completely ☐ NA ☐

5. Are any of the inlet pipes altered from the original design or otherwise in need of maintenance? (If yes, write in reasons: pipe breaks, washout, sediment, etc.)

<table>
<thead>
<tr>
<th>Partially clogged</th>
<th>Completely clogged</th>
<th>Reason for maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
Administrative Tools

Inspection Checklist

6. Are any overflow, underdrains, raised subsurface overflow pipes, or outlet structures clogged?
   - [ ] Yes
   - [ ] Partially
   - [ ] Completely
   - [ ] No
   a. If yes, mark the locations on your site sketch and fill in the boxes below with the cause of the clogging (e.g., debris, sediment, vegetation, roots, etc.)
   b. Are any of the overflow structures altered from the original design or otherwise in need of maintenance? (If yes, write in reason: frost heave, vandalism, unknown)

<table>
<thead>
<tr>
<th>Outlet</th>
<th>Outlet</th>
<th>Outlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partially clogged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completely clogged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reason for maintenance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observation Points:

7. Is water remaining in the storage aggregate longer than anticipated by design after the end of a storm?
   - [ ] Yes
   - [ ] No
   - [ ] Unknown
   a. If yes, identify potential cause of extended ponding and mark the location of observed extended ponding on your site sketch.

Summary:

8. Inspector’s Recommendations: When is maintenance needed?
   - [ ] Immediately
   - [ ] Within a month or two
   - [ ] Within a year
   - [ ] No sign that any maintenance is required

9. Summarize the results of this inspection and write any other observations in the box below:

Summary and other observations:

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)
ADMINISTRATIVE TOOLS

RECORD KEEPING & TRACKING

• 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

ADMINISTRATIVE TOOLS

INTERPRETING PLANS & AS-BUILTS

• How to interpret construction plans, installation photos, and as-builts

ADMINISTRATIVE TOOLS

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)
• 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)
Introduction to LID for Inspection & Maintenance Staff

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 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

Advanced Topics in LID Design:
- Bioretention

Advanced Topics in LID Design:
- Permeable Pavement

Advanced Topics in LID Design:
- Hydrologic Modeling

Advanced Topics for Long-term LID Operations:
- Bioretention

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

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
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• Sign up to follow and get Tweets

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

Lunch
Field Exercises
Site Inspection
Infiltration Tests