My Soil Won’t Drain, Can I Still Use LID?

Rob Buchert, John Knutson, Erik Pruneda
Presentation Topics

- Background information
- Designing LID for cold and snow prone conditions
- Applying LID in Pullman’s low permeability soils
- How the soil and BMP type affect the feasibility of retention
- Options to improve Bioretention in low permeability soils
- Benefits of using LID even if under-drains are necessary
Background

- Ecology LID Project Grant Funded, City Match
- Designed 4 sites - three parking lot retrofits, one new lot
  1. Neill Public Library - *Direct Discharge to SF Palouse River*
  2. Sims Parking Lot - *Direct Discharge to Dry Fork Creek*
  3. Fire Station 1 - *Direct Discharge to Dry Fork Creek*
  4. South Street Parking Lot - *Direct Discharge to SF Palouse River*
- Built two sites - Neill Library and South Street
Background

- E. WA Climatic Region 4 (NE & Blue Mountains)
- 21.2 inches of mean annual precipitation
- 29.1 inches mean annual snowfall

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Max. Temperature (F)</td>
<td>35.0</td>
<td>40.7</td>
<td>47.4</td>
<td>55.9</td>
<td>64.5</td>
<td>71.3</td>
<td>82.0</td>
<td>82.3</td>
<td>73.2</td>
<td>59.9</td>
<td>43.9</td>
<td>36.1</td>
<td>57.7</td>
</tr>
<tr>
<td>Average Min. Temperature (F)</td>
<td>23.0</td>
<td>27.1</td>
<td>30.8</td>
<td>35.5</td>
<td>41.3</td>
<td>46.3</td>
<td>49.8</td>
<td>49.7</td>
<td>44.2</td>
<td>37.1</td>
<td>30.4</td>
<td>24.9</td>
<td>36.7</td>
</tr>
<tr>
<td>Average Total Precipitation (in.)</td>
<td>2.76</td>
<td>2.00</td>
<td>2.06</td>
<td>1.65</td>
<td>1.69</td>
<td>1.44</td>
<td>0.56</td>
<td>0.75</td>
<td>0.93</td>
<td>1.68</td>
<td>2.84</td>
<td>2.84</td>
<td>21.20</td>
</tr>
<tr>
<td>Average Total Snowfall (in.)</td>
<td>9.5</td>
<td>4.4</td>
<td>2.9</td>
<td>0.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
<td>3.5</td>
<td>7.9</td>
<td>29.1</td>
</tr>
<tr>
<td>Avg. Snow Depth (in.)</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Western Region Climate Center (2013)
Background

Geotechnical Investigation

- Neill Public Library
  - Asphalt (0-2 in.), Silty Gravel Fill (2-9 in.), Silty Clay Fill (9-96 in.)
  - Measured \( i = 1.3 \text{ in/hr} \) (approx. 6.5 ft BGS)
  - Req’d subgrade compaction under Permeable Pavers and Asphalt

- South Street Parking Lot
  - Silty Gravel Fill & Topsoil (0-12 in.), Silt Alluvium (12-120 in.)
  - Measured infiltration rate 0.4 in/hr (approx. 6.5 ft BGS)
  - Did not require subgrade compaction
**Background**

**BMPs Selected at Each Site**

- **Neill Library**
  - Permeable Pavers
  - Bioretention
  - Filterra Tree Box Filter
  - Contech CDS

- **South Street**
  - Permeable Pavers
  - Porous Asphalt
  - Bioretention

- **Contech CDS** - pretreatment for large off-site commercial drainage area.

- **South Street bioretention** - enhanced treatment for off-site roadway area.
Background

Neill Library

Asphalt
Permeable Pavers
Contech CDS
Filterra Tree Box
Bioretention

Neill Library
Background

South Street

Permeable Pavers
Porous Asphalt
Bioretention
Designing LID for Cold and Snow Prone Conditions

South Street Off-Site Roadway to be Treated - December 5th 2013, 10 Degrees
Designing LID for Cold and Snow Prone Conditions

Response to Pullman Cold and Snow Prone Issues

- Well drained BMPs to protect from frost depths
- Consider deicer & traction sand impacts - deicer concerns, O&M
- Adequate sump volume to capture traction grit
- Avoid edges that catch plow blades, flush curbs must be flush, markers
- Right pavement section for loading, geotextile separation
- Bioretention double as snow storage, ID other storage areas
- Plants selected to handle cold, some deicer, snow storage

A little careful thought and collaboration with maintenance staff will save a lot of headaches
Applying LID in Pullman’s Low Permeability Soils

Neill Library Clayey
Fill 8/23/16
Applying LID in Pullman’s Low Permeability Soils

Liners and Underdrains

- **Impermeable Liners** - Considered over clayey subgrade to prevent wetting, but only used under bioretention near steep slope due to stability concerns

- **Geotextile Separation** - Used above subgrades to improve strength and prevent subbase migration

- **Underdrains** - Used to provide positive drainage and avoid prolonged wetting of clayey fill soils at Library site
Applying LID in Pullman’s Low Permeability Soils

Underdrain Elevation ($H$)

- Can be selected to foster some stormwater retention if subgrade soils:
  - Are not compacted
  - When under permeable pavements, remain structurally stable when wet
Example Underdrain Elevation Calculation

- Assume infiltration over entire subgrade surface area
- Assumed constant (or average) infiltration rate = $i$, in/hr
- Max allowable draindown time = 72 hrs (E. WA)
- Storage reservoir gravel porosity = $n\%$
- Max height to underdrain perforation = $H$, inches above subgrade soil

$$H = \frac{(i \times 72)}{(n/100)}$$

Example: $i = 0.05$ in/hr, subbase gravel porosity = 30% $\rightarrow H = 12$ inches

*Can infiltrate equivalent of 3.6 inches of stored depth in 72 hrs*
Applying LID in Pullman’s Low Permeability Soils

For Proper Underdrain Function

► ALWAYS REMEMBER - water flows downhill, even in LID subbase reservoir layers

► Keep subgrade level when possible, confine at the edges to build water depth up to underdrains

► Carefully consider underdrain layout and need for subsurface check dams when working with sloped subgrades
How the Soil and Type of BMP Affect the Feasibility of Retaining Stormwater

South Street Parking Lot Porous Asphalt and Permeable Pavers
10/28/16
How the Soil and Specific BMP Affect the Feasibility of Retaining Stormwater

Common Misconceptions

- Retention/infiltration is impossible or insignificant in fine grained soils with low permeability
- Receiving water flow control benefit is greatly reduced when using underdrains

Let's take a closer look
How the Soil and Specific BMP Affect the Feasibility of Retaining Stormwater

Two main types of retention BMPs:

- **Type A** - Infiltration BMPs that concentrate runoff into a small footprint relative to the drainage area (bioretention, infiltration basins, drywells)

- **Type B** - BMPs that provide about the same area for infiltration as the overall drainage area (permeable pavements without run-on)

The ability of Type A BMPs to retain and infiltrate significant rainfall is more restricted by low permeability soils than Type B BMPs
How the Soil and Specific BMP Affect the Feasibility of Retaining Stormwater

Consider:

- Soil with measured $i = 0.4\ \text{in/hr}$ (South Street Park Site)
- Permeable pavements over un-compacted subgrade
- Low plugging concerns, assume long term low head $i = 0.2\ \text{in/hr}$
- Pullman 6 month, 24 hr Type 1A Storm - 1.05 in.
- Pullman 10 yr, 24 hr Type 1A Storm - 2.10 in.
- 6 inch diameter underdrains, perforations three inch above subgrade
How the Soil and Specific BMP Affect the Feasibility of Retaining Stormwater

Permeable Pavement
No Run-On, 6 Mo. Storm

To infiltrate entire 6 month storm requires storage of:

- About \((0.66 \text{ hr}) \times (0.06 \text{ in/hr})/2 = 0.02 \text{ in. of rain}\)
- Accounting for porosity of reservoir gravel, \(0.02/0.3 = 0.07 \text{ inches of ponding}\)
- Neglects abstractions, evaporation, etc.
How the Soil and Specific BMP Affect the Feasibility of Retaining Stormwater

Permeable Pavement
No Run-On, 10 Yr. Storm

To infiltrate entire 10 year storm requires storage of:

- About \((1.2 \text{ hr}) \times (0.3 \text{ in/hr})/2 = 0.18 \text{ in. of rain}\)
- Accounting for porosity of reservoir gravel, \(0.18/0.3 = 0.6 \text{ inches of ponding in storage layer}\)
How the Soil and Specific BMP Affect the Feasibility of Retaining Stormwater

Clearly Permeable Pavements can retain larger storm events even when used in soils with low infiltration rates

- Water Quality Benefits
- Flow Control Benefits

Some Key Issues

- Traffic loading/structural stability
- Compaction of subgrade
- Shrink-swell potential
- Geotextile/geogrid reinforcement
- Underdrain elevation
- Run-on
How the Soil and Specific BMP Affect the Feasibility of Retaining Stormwater

Now Let’s Look at South Street Site Bioretention Facility

- Contributing Drainage Area of 0.29 ac., 100% Impervious
- 6 month storm: \( Q_p = 0.06 \text{ cfs}, \ Vol = 870 \text{ cf} \)
- Active Bioretention Facility Footprint = 500 sf
- Max Ponding Depth = 3 inches, but underdrain provides free drainage
- Footprint has approx. available infiltration rate = 0.2 in/hr
- Approximate infiltration outflow rate = 0.002 cfs
How the Soil and Specific BMP Affect the Feasibility of Retaining Stormwater

**Bioretention, 6 Mo. Storm**

- Up to 160 cf infiltrates during storm, 710 cf of excess treated runoff
- Excess treated runoff removed by underdrains
- Only minor flow control benefit

Options to Improve Flow Control Benefit?
Options to Improve Bioretention in Low Permeability Soils
Options to Improve Bioretention in Low Permeability Soils

Bioretention: Options to Improve Flow Control Benefit

- **Option 1** - Keep same geometry and cross-section but remove underdrain and force use of available storage before accessing overflow drainage

- **Option 2** - Remove underdrain and add more subsurface storage and infiltration area

- **Option 3** - Restrict underdrain outflow to promote more infiltration and provide detention effect for released water

We’ll look at Options 1 and 2
Options to Improve Bioretention in Low Permeability Soils

Bioretention Flow Control Improvement Option 1

Same geometry, remove (or raise) underdrain, use available storage

- Storage Volume = ponding + saturated mulch + saturated media + saturated gravel storage = Approx. 520 cf (accounts for geometry and porosity of granular materials)

- Volume infiltrated during the storm = 160 cf

- Est. total volume retained = 520 + 160 = 680 cf = 78% of WQ Volume!

- Max Draindown = (520 cf)/(500 sf x (0.2 in/hr)/(12 in/ft)) = 62.4 hr (ok E WA)
Options to Improve Bioretention in Low Permeability Soils

Bioretention Flow Control Improvement **Option 2**
Remove or raise underdrain, add subsurface storage and infiltration area

- Add 150 ft infiltration trench 18 in. wide, 21 in. tall, 1 ft dia. perf. pipe, gravel \( n = 30\% \) → adds 200 cf storage plus 0.001 cfs infiltration outflow rate
- New volume infiltrated during the storm = 160 cf + 79 cf = **239 cf**
- New Storage Volume = 520 cf + 200 cf = **720 cf**
- Est. total volume retained = 720 + 239 = **959 cf = 110% of WQ Volume!**
- Max draindown = \( \frac{720 \text{ cf}}{725 \text{ sf} \times (0.2 \text{ in/hr})/(12 \text{ in/ft})} \) = **59.6 hr (ok E WA)**
Benefits of Using LID Even if Underdrains are Necessary

- Permeable pavements in low permeability soils can provide major retention and flow control when:
  - Run-on is minimal
  - Subgrade is not compacted

- Bioretention in low permeability soils can provide moderate retention and flow control when:
  - The full storage volume is used prior to accessing drainage
  - Extra subsurface storage volume and infiltration area is added
  - Draindown times are acceptable
Thank You!