Volume reduction in systems not designed for volume reduction

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Acknowledgements

- NOAA
- EPA
- Kristar
When to Design for Infiltration

• Volume reduction (hydrologic transparency)
• Load reduction

Constraints
• Nearby infrastructure receptors
• Existing soil/groundwater contamination
• Contamination hot spots
• Vertical setbacks
  • Groundwater
  • Bedrock
Need for Underdains

- Low infiltration rate
  - < 0.25 in/hr (Philadelphia)
  - < 0.5 in/hr (EPA, NJ, NY, NH, ME, VT)
  - < 0.52 in/hr (MD, Center for Watershed Protection)
  - < 0.17 in/hr (MA)

<table>
<thead>
<tr>
<th>Texture Class</th>
<th>Effective Water Capacity ($C_w$)</th>
<th>Minimum Infiltration Rate ($I$)</th>
<th>Hydrologic Soil Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(inch per inch)</td>
<td>(inches per hour)</td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>0.35</td>
<td>8.27</td>
<td>A</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>0.31</td>
<td>2.41</td>
<td>A</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>0.25</td>
<td>1.02</td>
<td>A</td>
</tr>
<tr>
<td>Loam</td>
<td>0.19</td>
<td>0.52</td>
<td>B</td>
</tr>
<tr>
<td>Silt Loam</td>
<td>0.17</td>
<td>0.27</td>
<td>B</td>
</tr>
<tr>
<td>Sandy Clay Loam</td>
<td>0.14</td>
<td>0.17</td>
<td>C</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>0.14</td>
<td>0.09</td>
<td>D</td>
</tr>
<tr>
<td>Silty Clay Loam</td>
<td>0.11</td>
<td>0.06</td>
<td>D</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>0.09</td>
<td>0.05</td>
<td>D</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>0.09</td>
<td>0.04</td>
<td>D</td>
</tr>
<tr>
<td>Clay</td>
<td>0.08</td>
<td>0.02</td>
<td>D</td>
</tr>
</tbody>
</table>

* Source: Rawls, Brakensiek and Saxton, 1982
Systems Presented Today

- Tree Filter
  - Design by water quality flow
- Tree Trench
  - Water quality volume design
  - Static sizing
The Kristar TreePod – Tree Filter

FIG. 4

72” x 48” I.D. Concrete Vault 24” Right Opening Shown. 24” Left Opening uses the same components.
Tree Box Filter
Site pic today
Not too Long Ago
Tree Box Watershed

Tree box
Tree box filter design

- Manufacturer sizing: 36 gpm (1 gpm/ft$^2$)
- NH water quality flow sizing – 198 gpm
- For media IC of 100 in/hr, capacity is 37 gpm
- 80% Sand : 20% UNH Compost
- Native soil infiltration capacity ~ 0.3 in/hr
Soil at the site

- WfB—Windsor loamy fine sand, clay subsoil variant, 0 to 8 percent slopes
- Slope: 0 to 8 percent
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
- Depth to water table: About 24 to 36 inches
## Site Characteristics

<table>
<thead>
<tr>
<th>System</th>
<th>Watershed area (acres)</th>
<th>System area (sq. feet)</th>
<th>Watershed area to filter area ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree box filter</td>
<td>0.477</td>
<td>36</td>
<td>577</td>
</tr>
<tr>
<td>Tree trench</td>
<td>0.58</td>
<td>2,550</td>
<td>9.9</td>
</tr>
</tbody>
</table>
Inflow (calibrated weir/orifice)
Outflow (calibrated weir/orifice)
Estimate from precipitation times watershed area times runoff coefficient
In system well

Monitoring period – 12 Jun 2012 – 5 June 2014
Overall Hydraulic Performance –
tree box filter all data

Volume Reduction - All events

\[ y = 0.0265x + 0.6071 \]
\[ R^2 = 0.0303 \]

Average 64%
Median 79%
n 146
Overall Hydraulic Performance –
tree box all data

Peak Flow Reduction - All events

\[ y = -0.2193x + 0.7066 \]
\[ R^2 = 0.0412 \]

Average  63%
Median  81%
n  146
Overall Hydraulic Performance – tree box filter snowmelt

Volume Reduction - Snowmelt events

Average 96%
Median 98%
n 21

$y = -0.0005x + 0.9599$
$R^2 = 0.0031$
Overall Hydraulic Performance –
tree box filter snowmelt

Peak Flow Reduction - Snowmelt events

\[ y = -0.0763x + 0.9723 \]
\[ R^2 = 0.3787 \]

- Average: 94%
- Median: 98%
- n: 21

Precipitation Depth (in)
Philadelphia Tree Trench

GREEN STREETS: STORMWATER TREE TRENCH

Street View

Evapotranspiration

Subgrade View

Rainfall

Stormwater Flow

NEW TREES
NEW STORMWATER INLET

Distributed through Tree Trench, then slow released into existing storm sewer, if necessary

Infiltration

DISTRIBUTION PIPE
STONE STORAGE
Tree Trench Design Components

• One inch water quality volume

• If design infiltration rates are found to be less than 0.25 inches per hour, or if system is not able to completely drain in 72 hours, the system should be designed for detention/slow-release.

• Detention/slow-release systems should be designed to release at a maximum rate of 0.05 cfs per acre of contributing impervious drainage area.

• Orifice diameters must not be less than 0.5”.
Static Sizing

Static Sizing Performance

- No Infiltration 0.75 in
- Infiltration 0.75 in
- No Infiltration 1 in
- Infiltration 1 in
- No Infiltration 1/2 in
- Infiltration 1/2 in

Water Storage (ft³)

Time (hours)
Dynamic Sizing

Dynamic Sizing Performance - 1/2 in orifice

- No Infiltration 1 in storm
- Infiltration 1 in storm
- No Infiltration 1.5 in storm
- Infiltration 1.5 in storm

Water Storage (ft³)

Time (hours)
Watershed
TREES TRENCH SYSTEM FOR AREA 02
PLAN VIEW

- 100' x 8" Ø DISTRIBUTION PIPE (PERFORATED)
- UNDERDRAIN CLEANOUT WITH VENTED CAP
- 8" Ø PERFORATED UNDERDRAIN
- 3" CALIPER TREES (TYP.)
- BOUNDARY OF NEW PAVEMENT

- 12" Ø HIGHFLOW BYPASS AND 12" Ø HDPE OUTLET
- EXISTING DMH
- EXISTING 2' x 2' GRATE
- 36' x 8" Ø DISTRIBUTION PIPE (PERFORATED)
- 2' x 4' DROP-IN GRATED INLET
- 12'L x 8' W x 6' H CONCRETE FLOW CONTROL STRUCTURE
- EXISTING 2' x 4' GRATE REPLACED WITH SOLID CAP
- 8" Ø PERFORATED UNDERDRAIN
- UNDERDRAIN CLEANOUT WITH VENTED CAP
Pre-Existing Site
Soil at the Site

• ScA—Scantic silt loam, 0 to 3 percent slopes
• Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.20 in/hr)
Infiltration Measurements

Turf-Tec Infiltrometer

Double Ring Infiltrometer
<table>
<thead>
<tr>
<th>Location</th>
<th>Turf Tec (in/hr)</th>
<th>Double Ring (in/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.13</td>
<td>0.03</td>
</tr>
<tr>
<td>2</td>
<td>1.27</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>0.36</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>1.98</td>
<td>-</td>
</tr>
</tbody>
</table>

Median = 0.8 in/hr
Site Today
Not Too Long Ago
Tree Trench Monitoring

- Inflow volume — precipitation times watershed area times runoff coefficient
- Outflow — well water level

Monitoring period — 31 October 2014 — 25 March 2015
Capacity at outflow pipe invert ~ 2,430 cu ft
Filling and Draining Rates
Filling and Draining Rates

The graph illustrates the non-exceedance probability of fill/infiltration rates over time. The x-axis represents the fill/infiltration rate (in/hr), while the y-axis shows the non-exceedance probability. The graph separates filling from draining, with filling occurring at lower rates and draining at higher rates. The data points indicate a higher probability of draining as the fill/infiltration rate increases.
Median water depth = 0.06 ft
Changing Infiltration Rate

![Graph showing the relationship between infiltration rate (in/hr) and water depth (ft).]
Recall median field-measured infiltration rate = 0.8 in/hr
Intermediate Depth Infiltration 0.75 ft > h > 0.025 ft

\[ y = 0.1637x + 0.0168 \]
\[ R^2 = 0.1988 \]
Low Water Infiltration < 0.025 ft

\[ y = 0.0684x + 0.0183 \]

\[ R^2 = 0.0007 \]
Infiltrated Volume

- For the 146 day period
  - 14.99 in. precip.
  - Precip. Volume = 31,560 ft$^3$
  - Runoff volume ($C = 0.92$) = 29,035 ft$^3$
  - Infiltrated volume = 25,091 ft$^3$
  - Volume reduction = 86%
Conclusions

• Infiltration systems yield higher infiltration rates than design rate presumably because most design methods
  • Use only bottom area
  • Use a fraction (1/2 to 1/3) of field measured rates.