Disclaimer

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GI Evaluation in Urban Areas: Strategies and Challenges

This research has been supported by a grant from the U.S. Environmental Protection Agency's Science to Achieve Results (STAR) program.
The goal of monitoring is to evaluate the performance of GI

- Stormwater capture
- Infiltration
- Sustainability / maintenance
- Impact (CSO reduction, groundwater mounding, surface ponding, neighborhood)
What do we monitor?

- Rainfall
- Topography
- Inflows
- Outflows
- Storage
- Infiltration rates
- Water table
- Soil properties
- Plant health
What are the monitoring costs?

- Rain gauges $
- Water level loggers $
- Communication $ to $$
- Soil moisture loggers $$
- Flow meters $$
- Calibration $ to $$
- Construction $$ to $$$
- Drilling$$$$
- LiDAR (airborne or surface) $$$
- Geophysics $$ to $$$
- Infiltration surveys $
- Compaction surveys $
- Maintenance $$
- Technical support $$$
- $ 100’s $$ 1000’s $$$ 10000’s
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Monitoring presents challenges

- Equipment failure
- Power
- Communication
- Cost
- Reliability
- Seasonal variation
- Heterogeneity

And more...

Data gaps

All-weather monitoring
Some challenges are unique to urban settings

- Permits
- Infrastructure
- Community acceptance
- Equipment disturbance
- By pass
- Clogging
- Heterogeneity
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If It Doesn’t Get In, We Can’t Measure It

Surface flow bypassing trench drain

Effects of post-construction enhancements

Inflow backing up due to debris and clogging
What are we learning from monitoring?

- Comparison of design strategies
- Modeling input
- Old versus new design
- Oversizing
Comparison of upflow and downflow design

- Rainwater enters the garden (through a roof leader).
- Rainfall enters the rain garden and soaks into the soil.
- Rain gardens should be planted with native shrubs and flowers that don’t mind being wet.

Soil / Compost Mix (9” – 18” deep)
Downflow design treats more water than expected
Upflow design creates stormwater bypass
Wakefield raingarden instrumentation

- Tensiometers (red dots)
- Wells and water level loggers (yellow dots)
Tensiometer data used to calibrate model
Oversized trench keeps stormwater from pits

Stormwater tree trench

\[ y = 9.4311x^2 - 1.6462x + 3.1562 \]

\[ R^2 = 0.7653 \]

\[ R^2 = 0.64 \]
Old versus new stormwater control

Infiltration trench: 82 m by 2.4 m
The trench responded only to big storms.

The old pipe design responded to every storm.
Monitoring helps assess what happens when GI isn’t working

- Groundwater mounding
- Bypassing
- No storage
- Season variations
- Infiltration difficult to predict
Infiltration basin received water from roof of new science building.
Stormwater mounding should not be within 0.6 m of trench.
Storm with and without mounding in tree trench
Seasonality affects results

- Event rainfall depth is related to peak water level, but only Apr-Sept
- Long term monitoring is needed
Bypassing means storm isn’t fully captured.
Ground-based LiDAR may determine capture areas better.
Trim the trees & delineate capture areas
Football field basin designed to capture street overflow
Football field basin designed to capture street overflow, but doesn’t
Blue roof was not storing water
Retrofit with $5 supplies from hardware store

- Reduce size of overflow holes on one roof
- Leave the other roof as original size
Success! Now need to watch out for clogging

10 months later
Can geophysics help?

- Finding infrastructure: yes, but it adds to the cost
- Monitoring infiltration: mixed results
GPR did not predict infiltration rate in urban soil.
Electrical resistivity was tried next

- If it doesn’t rain, use a sprinkler
- EM profiler survey in rows
Results are promising using an inversion model to calculate infiltration.

\[
\begin{align*}
\sigma_{\text{dry}} &= 9.4 \, \text{mS} \\
\sigma_{\text{wet}} &= 15.0 \, \text{mS} \\
\text{Thickness} &= 1.0 \, \text{m} \\
\text{Velocity} &= 0.37 \, \text{m/hour}
\end{align*}
\]
Long term monitoring should include

- Community driven
- Inspection & maintenance
- Vegetation surveys

CHECKLIST FOR INSPECTION OF BIORETENTION SYSTEM / TREE FILTERS

<table>
<thead>
<tr>
<th>Inspection Items</th>
<th>Satisfactory (S) or Unsatisfactory (U)</th>
<th>Comments/Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Initial Inspection After Planting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plants are stable, roots not exposed</td>
<td>$ U</td>
<td></td>
</tr>
<tr>
<td>Surface is at design level, no evidence of preferential flow/shoving</td>
<td>$ U</td>
<td></td>
</tr>
<tr>
<td>Inlet and outlet/bypass are functional</td>
<td>$ U</td>
<td></td>
</tr>
<tr>
<td><strong>2. Debris Cleanup (1 time/year minimum, Spring/Fall)</strong></td>
<td></td>
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<tr>
<td>Litter, leaves, and dead vegetation removed from the system</td>
<td>$ U</td>
<td></td>
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<tr>
<td>Prune/mow vegetation</td>
<td>$ U</td>
<td></td>
</tr>
<tr>
<td><strong>3. Standing Water (1 time/year and/or after large storm events)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of standing water after 24-48 hours since rainfall</td>
<td>$ U</td>
<td></td>
</tr>
<tr>
<td><strong>4. Vegetation Condition and Coverage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation condition good with good coverage (typically &gt; 75%)</td>
<td>$ U</td>
<td></td>
</tr>
<tr>
<td><strong>5. Other Issues</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Note any additional issues not previously covered</td>
<td>$ U</td>
<td></td>
</tr>
</tbody>
</table>

Corrective Action Needed

1. 
2. 
3. 

Due Date

Inspector Signature

Date
Some maintenance requires technical support (PWD program)
Long term monitoring should include

- Performance effectiveness
  - Sensor installation
  - Solar panels
  - Routine data collection & synthesis
  - Updates on land use

Low cost solar panel data loggers
GI Evaluation in Urban Areas

We’ve come a long way, but questions remain

Blue roof

Clogged drain

This research has been supported by a grant from the U.S. Environmental Protection Agency's Science to Achieve Results (STAR) program.
FUTURE MONITORING ISSUES

- What is the scalability and transferability of our approaches?
- Effectiveness is not constant. How do we account for changing variables such as plants, ET, seasons, land use?
- How can our results be used to improve designs from a maintenance perspective? Leads to greater acceptability in GI installation.
- How are monitoring for operation, maintenance and design linked?
QUESTIONS continued

- How can we use monitoring information to inform future design?
- How can we use monitoring to better calibrate models?
- What are key characterization strategies to recommend?
- Do we have a “minimum effective” monitoring strategy?
- How would that vary from site to site?
- What is a good way to convey the lessons learned to practitioners?