Re-Defining LID in Terms of Cost Benefits as Incentives for Mitigating Impacts of Climate Change

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Impacts of Land Use Change
Altered Hydrology

1.) Increase in pollutants in runoff from impervious surfaces

2.) Stress to natural and man-made infrastructure from increases in runoff from impervious surfaces
Top causes of stream depletion are:

• Extensive instream withdrawals and groundwater withdrawals in the watershed

• Land-use change – addition of impervious surface

http://www.waterencyclopedia.com/St-Ts/Streamflow-Variability.html
Impact of Development

Bank Full Return Intervals with build-out

- Existing: 1.8
- Future: 13.5

650% Increase

Courtesy of L. Coffman
The Primary Cause of WQ and Stream Channel Degradation is Altered Hydrology

This Can be Corrected By LID Design Through:

- **Storm volume reduction through** *infiltration* thereby replacing lost hydrologic functions from impervious surfaces by reducing hydrologic footprint

- **Water quality treatment by filtration** of stormwater through engineered soil media which replaces the lost treatment benefits of natural soils.
What is Low Impact Development?

Systems and practices that use or mimic natural processes to:

- Filtrate
- Evaporate
- Infiltrate

Stormwater or runoff as close to where it is generated as possible.
How are municipalities dealing with the increasing runoff volumes resulting in CSO?

- NBC RI has begun construction of six miles of underground storage tunnels at a projected cost of $467 million (1992 dollars).

- Tunnels will store the sewage overflows during intense rain events for later treatment.
New York City chose LID ordinances

NYC needs to eliminate 460 CSO discharge points by 2030. They chosen to disconnect impervious areas from the sewer system and treat the runoff through infiltration practices.

City of Philadelphia chose the LID ordinance

- Cost for building additional in-line storage for the sewers systems = $4.5/gallon of storage, no treatment (Montalto et al., 2007)

- Alternative LID cost between $4 and $6 dollars per gallon (capital cost per storage/treatment capacity)

www.phila.gov/OHCD/government.htm
Has the Stormwater Management Community Practically Considered Climate Change?

- Recent research examining impacts of climate change on rainfall depths showed a 28-60% increase in Q25-Q100.
- Existing urban infrastructure primarily culverts will be under-capacity by 35%.
- This in addition to stressed stormwater infrastructure from land use change (Guo, 2006).

Design standards are static ➔ our infrastructure is obsolete from the first day after construction.
Changing Trends

Trend in the Frequency of Storms with Extreme Precipitation, 1948-2006

-75% to -90%
-60% to -75%
-45% to -60%
-15% to -30%
0% to -15%
15% to 30%
30% to 45%
45% to 60%
60% to 75%
75% to 90%
90% to 105%
105% to 120%

Statistically Significant
Estimated impact of climate change on intensity/return-period relationship
Keene, NH, *point process* model

<table>
<thead>
<tr>
<th>Return period (years)</th>
<th>Precipitation (cm)</th>
<th>Late-20th century</th>
<th>Mid-21st century</th>
<th>Δ%</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>3.23</td>
<td>3.36</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>5.42</td>
<td>5.66</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6.56</td>
<td>7.08</td>
<td>8%</td>
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<tr>
<td>7.5</td>
<td>7.15</td>
<td>7.89</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>7.55</td>
<td>8.47</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>8.75</td>
<td>10.38</td>
<td>19%</td>
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</tr>
<tr>
<td>50</td>
<td>9.60</td>
<td>11.91</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>10.09</td>
<td>12.86</td>
<td>27%</td>
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<tr>
<td>100</td>
<td>10.46</td>
<td>13.55</td>
<td>30%</td>
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<tr>
<td>250</td>
<td>11.46</td>
<td>15.88</td>
<td>39%</td>
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</tr>
<tr>
<td>500</td>
<td>12.22</td>
<td>17.78</td>
<td>46%</td>
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</tr>
<tr>
<td>750</td>
<td>12.65</td>
<td>18.96</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>12.95</td>
<td>19.82</td>
<td>53%</td>
<td></td>
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Source: Stack et al. (2008)
<table>
<thead>
<tr>
<th>Type</th>
<th>Old Regs</th>
<th>New Regs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Quality</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Sensitive Sites</td>
<td>Large Sensitive Sites - 80% TSS (or sliding scale)</td>
<td>Most Sites Effective BMPs targeting TSS, NO3, TP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensitive Sites Meet TMDL or Anti-degradation</td>
</tr>
<tr>
<td><strong>Water Quantity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Sites</td>
<td>All Sites Flow Match 2, 10, 25-year storms</td>
<td>Most Sites Infiltration and volume reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large Sites Volume Reduction and Peak Flow Match 2, 10, 25-year storms</td>
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</tbody>
</table>
LID Ordinances requirements for recharge:

<table>
<thead>
<tr>
<th>Hydrologic Soil Type/State</th>
<th>NHDES</th>
<th>MADEP</th>
<th>Philadelphia/for CSO-sheds</th>
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</thead>
<tbody>
<tr>
<td>Type A</td>
<td>1cm (0.40 in)</td>
<td>1.5 cm (0.60 in)</td>
<td>2.5 cm (1in)</td>
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<tr>
<td>Type B</td>
<td>0.6 cm (0.25 in)</td>
<td>0.9 cm (0.35 in)</td>
<td>2.5 cm (1in)</td>
</tr>
<tr>
<td>Type C</td>
<td>0.3 cm (0.1 in)</td>
<td>0.6 cm (0.25 in)</td>
<td>2.5 cm (1in)</td>
</tr>
<tr>
<td>Type D</td>
<td>Not required</td>
<td>0.3 cm (0.10 in)</td>
<td>2.5 cm (1in)</td>
</tr>
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</table>

Are LID system able to infiltrate these amounts?

Can LID practices attenuate impacts from Climate Change?
Predevelopment LAND USE
4 hectares of grass and woods combination

Numerical modeling of Conventional and LID designed sites:
- 10 acre residential site
- 10 x 1 acre lots in watershed at 5% slope
- Type A and C soils

LAND USE for ten 1- acre residential lots
Conventional Design

- Lawns 86.8%
  (CN=98)
- Roads 5%
  (CN=98)
- Driveways 3.6%
  (CN=98)
- Roof tops 4.6%
  (CN=98)

LAND USE for ten 0.4 hectares (1- acre) residential lots
LID Design

- Lawns 21.8%
  (CN=43(typeA), 76(typeC))
- Roads 5%
- Driveways 3.6%
- Roof tops 4.6%

Conserve 65%
(CN=49(typeA), 79(typeC))

• 10 acre residential site
• 10 x 1 acre lots in watershed at 5% slope
• Type A and C soils
Conventional design

- Connected impervious surfaces

LID Site:
- Disconnected imperviousness
  - Rooftop to bioretention 1" WQV, overflow to PA driveway
  - Driveway and Roadways as PA
  - Lawns to PA
  - 65% UDC, <10% EIC (NHDES requirements)
LID design

- 65% Conservation
- Rooftop
- Lawn
- Porous Pavement
- Bioretention
Analyses for 2-, 10-, and 100-year design storms and 2-, 10-, and 100-year storms adjusted for climate change
Total runoff Volumes for Each Scenario per 1 Acre of Development in Type C Soil
Distribution of Storm Volumes

Total Storm Volumes per 1 Acre for Type C Soils

Runoff Volume (cf)

PRE Conv LID

Runoff

Infiltration
Volumes Retained on the Site per 1 acre

Changes in Volumes Retained on The Site After Development for Type A Soils

Changes in Volumes Retained on the Site After Development for Type C Soil

- Conventional
- LID
Did we obtain 10% impervious cover required by NHDES?

Initial impervious cover = 13.2%

Effective Impervious Cover = 0%

Porous pavement for driveway and road runoff

Bioretention for rooftop runoff

What about developments with greater density?
Annual groundwater recharge from storms of 5.5 inches or smaller on type A soils

Recharge From Precipitation Events of 75 mm and Smaller - Type A soil
Annual groundwater recharge from storms of 5.5 inches or smaller on C soils

Recharge From Precipitation Events of 75 mm and Smaller - Type C Soil

Cumulative Precipitation Depth (centimeters)

- Pre: 77.8
- Conv: 68.2
- LID: 81.9
Results

- Compared to undeveloped conditions, the LID Site retained 15% more precipitation on site for the type A soil, and 22% for the type C soil under extreme storms.

- For the LID Site, peak flow rates were reduced by 86% for the type A soil and 84% for the type C soil compared to the peak flow values of the Conventional design site.

- The LID design can retain on the site the first 13 cm of rainfall for the type A soil and 2.5 cm for the type C soil.
Summary and Conclusions:

- LID system benefits extend beyond Water Quality
- LID systems and planning can reduce volume and peak flow for extreme storms
- LID can contribute to community resiliency to climate change
- LID design results in more water stored in the watershed and therefore more beneficial uses
Funding

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QUESTIONS???