Green vs. Gray Infrastructure Cost

Rosa A. Fernández
R.R. Dupont
Civil and Environmental Engineering
Utah State University
Outline

• Introduction
  ▫ Gray infrastructure
  ▫ Green infrastructure
  ▫ Types of green infrastructure
  ▫ Cost Analysis
• Cost estimation tool
• Case studies
• Summary and Conclusion
• Questions
INTRODUCTION
Gray Infrastructure

General

Stormwater Management
Gray Infrastructure

Advantages

Quick transport of water
Flood control

Disadvantages

Erosion
Pollutes waterways
Inhibits recharge
High capital cost
Does not add beauty

Source: USGS Water Science School
Green Infrastructure

CNT’s Definition:

• “A network of **decentralized** storm-water management practices that can capture and infiltrate rain **where it falls**, reducing stormwater runoff and **improving** the health of surrounding waterways.”

EPA’s Definition:

• “[...] An approach to wet weather management that is **cost effective, sustainable** and environmentally friendly [...]”
Green Infrastructure

Advantages

- **Reduces** runoff volume
- **Improves** water quality
- **Recharges** aquifers.
- Landscape and cultural benefits
- Stormwater as resource
- Can **reduce** capital costs
- **Adds** beauty
- Can **increase** property values

Disadvantages

- risk of contaminating groundwater
- May require irrigation during dry season
Types of GI

- Vegetated swales
- Bioretention
- Gravel Wetland
- Porous Asphalt

Source: dottarchitecture.com
Types of Green Infrastructure

- Vegetated swales

Source: dottarchitecture.com
Types of Green Infrastructure

- Bioretention

Source: Bluegrasslawn.com
Types of Green Infrastructure

- Gravel Wetland

Source: stormwater.wef.org
Types of Green Infrastructure

- Porous Asphalt

Source: asphaltpavement.org
Cost analysis

- Key points
- Types of cost
Welcome to the Green Values® Stormwater Toolbox

Learn what green infrastructure is and does.

Learn how the use of green infrastructure saves money.

Understand the costs and benefits of using green infrastructure to mitigate the need for different types of built water infrastructure, such as sewers and detention basins.

Search our comprehensive bibliography for more information.

The Green Values® Stormwater Toolbox was originally developed primarily for use by planners, engineers and other municipal staff. As a result, we've tried to err on the side of giving too much technical information. However, we recognize that individuals are also interested in the benefits of green infrastructure, both for individual sites and to influence public policy.

Green Values Calculators
CASE STUDIES
CASE STUDY #1

New high density urban development
Residential Development
1709 East Murray Holladay Road,
Millcreek, UT
<table>
<thead>
<tr>
<th>Description</th>
<th>Area (acres)</th>
<th>% of total area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings</td>
<td>0.48</td>
<td>17%</td>
</tr>
<tr>
<td>Paved Parking</td>
<td>1.17</td>
<td>41%</td>
</tr>
<tr>
<td>Other impervious</td>
<td>0.21</td>
<td>7%</td>
</tr>
<tr>
<td>Landscaped areas</td>
<td>0.98</td>
<td>35%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2.84</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

**Impervious: 1.86 acres = 65%**

Legend:
- Parking lot
- Building
Design Specifications

- Storm: 24-hr 10 years: 1.89 inches of rainfall
- For impervious area = Building + Parking Lot + other impervious = 1.86 acres
- Rainfall volume = 12,764.27 ft^3
- Runoff volume = 9309 ft^3 (curve number method)
Bioretention Design
Area = 4052 ft²
Depth = 2.3 ft

Parking lot
Length = 288 ft
Width = 8 ft
Area = 2304 ft²

Sidewalk
Length = 116 ft
Width = 15 ft
Area = 1740 ft²
Cost

Excavation
Volume: 595 yard\(^3\)
Unit Price: $53.42/ yard\(^3\)
Subtotal: $31,751.93

Sandy/loam filling
20 inches
Weight: 350 ton
Unit Price: $25.00/ ton
Subtotal: $8,750.00

Curb and Gutter
Length: 576 ft
Unit Price: $35.16/ft
Subtotal: $20,252.16

$40,501.93
$20,252.16

$10.02/ft\(^2\) of bioretention
### OFFICE OF TOWNSHIP SERVICES
Engineering Services
2001 South State Street Suite N3-600
Salt Lake City, Utah 84190
(385) 468-6600

#### URBAN HYDROLOGY BOND

<table>
<thead>
<tr>
<th>Project Name:</th>
<th>1700 On the Park</th>
<th>Date Approved:</th>
<th>July 28, 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Address:</td>
<td>1717 E Murray Holladay Road</td>
<td>A/P #:</td>
<td>29091</td>
</tr>
<tr>
<td>Applicant:</td>
<td>Ken Keller</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>UNITS</th>
<th>DESCRIPTION</th>
<th>UNIT COST</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STORM DRAINAGE - PRIVATE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 EA</td>
<td>Storm Drain Curv Inlet Box</td>
<td>$3,225.00</td>
<td>$12,940.00</td>
<td></td>
</tr>
<tr>
<td>313 LN FT</td>
<td>12 inch SDR-35 PVC</td>
<td>$25.00</td>
<td>$7,825.00</td>
<td></td>
</tr>
<tr>
<td>366 LN FT</td>
<td>6 inch SDR-35 PVC</td>
<td>$15.00</td>
<td>$5,490.00</td>
<td></td>
</tr>
<tr>
<td>1 LS</td>
<td>Storm Tech System</td>
<td>$24,000.00</td>
<td>$24,000.00</td>
<td></td>
</tr>
<tr>
<td>2 EA</td>
<td>Snot</td>
<td>$1,600.00</td>
<td>$3,200.00</td>
<td></td>
</tr>
<tr>
<td>2 EA</td>
<td>5 foot Manhole</td>
<td>$3,800.00</td>
<td>$7,600.00</td>
<td></td>
</tr>
<tr>
<td>9 EA</td>
<td>Yard Box</td>
<td>$400.00</td>
<td>$3,600.00</td>
<td></td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td></td>
<td></td>
<td><strong>$47,765.00</strong></td>
<td></td>
</tr>
</tbody>
</table>

| **IRRIGATION - PRIVATE** | | | |
| 1 EA | Irrigation Access Structure | $2,500.00 | $2,500.00 |
| **SUBTOTAL** | | | **$27,515.23** |

**Total Costs:**
- **$40,501.93**
- **$27,515.23**
Green Values Calculator

Conventional Development

Impervious Area

- Roof size (ft^2): 21054.5
- Or give dimensions:
  - Roof Length (ft):
  - Roof Width (ft):
- Number of Parking Spots:
  - Number of Parking Spots: 0
  - Parking Lot Size (ft^2): 50778
- Sidewalk:
  - Length (ft): 1842
  - Width (ft): 5

Vegetation Filter Strips

- Length (ft): 404
- Width (ft): 10
- Depth of Prepared Soil (in): 20
- Porosity of Prepared Soil: 0.35

Average Annual Rainfall by Zip Code

- Zip Code: 84117
- Annual Rainfall (In): 15.05
- Storm Type (in): 99%
- Storm Rainfall (In): 1.58
- Size of Lot (acres): 2.84
- Soil Type: C

* Required fields.
+ Must have at least one of these fields filled in.
Unit Cost

<table>
<thead>
<tr>
<th>Method</th>
<th>Conventional</th>
<th>GI</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVC</td>
<td>0.62</td>
<td>0.35</td>
</tr>
<tr>
<td>Other</td>
<td>0.79</td>
<td>0.45</td>
</tr>
</tbody>
</table>
CASE STUDY #2

Stormwater Management Costs
(Jaffe, 2010)
Description and Methodology

- a suburban residential subdivision on 20 acres,
- A urban townhouse project on a 3-acre site,
- a renovated urban commercial project on a 3.5-acre site

- Objective: comparing the economic savings and the volume of storm water diverted from conventional sewers by green infrastructure practices over a 30-year life cycle.

- Methodology: The life-cycle costs were calculated using the net present value of the construction cost and the estimated annual maintenance costs of the practice.
Case Study 2

GI practices:
- Downspouts disconnection.
- Replacement of 50% of lawn area
- Porous Pavement
- Green Roofs
- +25% tree cover
- Vegetated Swales

## Table 2. Estimated costs, savings, and hydrologic benefits for use of green infrastructure in three development scenarios

<table>
<thead>
<tr>
<th>Case study</th>
<th>Description</th>
<th>Green components</th>
<th>Construction cost savings for green scenario</th>
<th>Green construction savings as % of conventional</th>
<th>30-Year life-cycle savings for green scenario</th>
<th>Green life-cycle savings as % of conventional</th>
<th>Green scenario annual hydrologic benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exurban development</td>
<td>A 20-acre site with 14 homes on undeveloped land</td>
<td>Rain gardens, native vegetation, trees, and roadside swales</td>
<td>$190,800</td>
<td>31%</td>
<td>$507,800</td>
<td>24%</td>
<td>1,411,000 gallons increase groundwater recharge</td>
</tr>
<tr>
<td>Blue Island river-front</td>
<td>A 3.0-acre site with 59 town houses on a former parking lot</td>
<td>Rain gardens, permeable pavement, trees, and streetside swales</td>
<td>$91,900</td>
<td>23%</td>
<td>$168,600</td>
<td>29%</td>
<td>2,409,000 gallons reduced runoff to sewers</td>
</tr>
<tr>
<td>Chicago Center for Green Technology</td>
<td>A 3.3-acre site with office building, parking, and wetland on former industrial land</td>
<td>Partial green roof, cisterns, vegetated swales, gravel parking lot, wetland, and native vegetation</td>
<td>$18,100</td>
<td>4%</td>
<td>$161,500</td>
<td>20%</td>
<td>2,468,000 gallons reduced runoff</td>
</tr>
</tbody>
</table>
Results

- GI 24% more cost-effective than gray infrastructure over a 30-year period.
- More cost-effective than gray infrastructure at all scales and time periods, with the possible exception of green roofs.
- Not only are these green practices initially more economical than conventional infrastructure in terms of their construction costs, but the practices are also able to divert millions of gallons of storm water from conventional storm-water conveyance systems over their useful lives, thus also avoiding the indirect costs of providing additional detention capacity and, in the case of combined sewer systems, dealing with potential sewage overflow problems.
CASE STUDY #3

University of New Hampshire
Stormwater Center (Houle et al., 2013)
Case Study #3

- Vegetated swale
- Wet pond
- Dry pond
- Sand filter
- Subsurface gravel wetland
- Bioretention systems
- Porous asphalt pavement
# Case Study #3

## Table 1. UNHSC SCM Design Data (SI Units)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Vegetated swale&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Wet pond&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Dry pond&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Sand filter</th>
<th>Gravel wetland</th>
<th>Bioretention #1</th>
<th>Bioretention #2 &amp; #3</th>
<th>Porous asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device class</td>
<td>Conventional</td>
<td>Conventional</td>
<td>Conventional</td>
<td>LID</td>
<td>LID</td>
<td>LID</td>
<td>LID</td>
<td>LID</td>
</tr>
<tr>
<td>Filter length (m)</td>
<td>85.3</td>
<td>21.3</td>
<td>21.3</td>
<td>6.1</td>
<td>15.8</td>
<td>20.4</td>
<td>10.4</td>
<td>26.8</td>
</tr>
<tr>
<td>Width (m)</td>
<td>3.0</td>
<td>14.0</td>
<td>14.0</td>
<td>2.4</td>
<td>11.3</td>
<td>10.7</td>
<td>2.4</td>
<td>19.5</td>
</tr>
<tr>
<td>Area (m²)</td>
<td>260</td>
<td>299</td>
<td>299</td>
<td>15</td>
<td>179</td>
<td>218</td>
<td>25</td>
<td>523</td>
</tr>
<tr>
<td>Depth (ft)</td>
<td>0.0</td>
<td>0.5</td>
<td>0.0</td>
<td>0.6</td>
<td>0.6</td>
<td>1.1</td>
<td>0.8</td>
<td>1.3</td>
</tr>
<tr>
<td>Ponding depth (ft)</td>
<td>0.6</td>
<td>0.5</td>
<td>0.9</td>
<td>1.5</td>
<td>0.4</td>
<td>0.2</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Catchment area (ha)</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.05</td>
</tr>
<tr>
<td>Water quality volume (m³)</td>
<td>97.7</td>
<td>97.7</td>
<td>97.7</td>
<td>97.7</td>
<td>97.7</td>
<td>97.7</td>
<td>97.7</td>
<td>13.3</td>
</tr>
<tr>
<td>Water quality flow (m³/s)</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>N/A</td>
</tr>
<tr>
<td>Watershed area/filter area</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>272</td>
<td>22.6</td>
<td>18.6</td>
<td>160</td>
<td>1.00</td>
</tr>
<tr>
<td>HLR (m/s)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>6.57</td>
<td>14.2</td>
<td>0.45</td>
<td>3.86</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<sup>a</sup>HLR and FA/WA ratios are not calculated for nonfiltration systems.
Maintenance cost

- Designs based on manuals from (NYSDEC), NHDES and Federal Highway Administration
- NYS manual: inspection checklists for operation, maintenance and management.
- Guideline were utilized on a monthly basis to track observations and maintenance activities for all SCMs
Results

• If maintenance activities are simple, periodic and routine maintenance costs are kept at a minimum.
• The type of maintenance affects the cost. Reactive, Periodic and predictive, proactive-adaptive
2. Annualized maintenance costs per system per hectare of IC treated per maintenance activity classification.
Results

**Table 2. UNHSC SCM Installation and Maintenance Cost Data, with Normalization per Hectare of IC Treated**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Vegetated swale</th>
<th>Wet pond</th>
<th>Dry pond</th>
<th>Sand filter</th>
<th>Gravel wetland</th>
<th>Bioretention</th>
<th>Porous asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original capital cost ($)</td>
<td>29,700</td>
<td>33,400</td>
<td>33,400</td>
<td>30,900</td>
<td>55,600</td>
<td>53,300</td>
<td>53,900</td>
</tr>
<tr>
<td>Inflated 2012 capital cost ($)</td>
<td>36,200</td>
<td>40,700</td>
<td>40,700</td>
<td>37,700</td>
<td>67,800</td>
<td>63,200</td>
<td>65,700</td>
</tr>
<tr>
<td>Maintenance-capital cost comparison (year)(^a)</td>
<td>15.9</td>
<td>5.2</td>
<td>6.6</td>
<td>5.2</td>
<td>12.2</td>
<td>12.8</td>
<td>24.6</td>
</tr>
<tr>
<td>Personnel (h/year)</td>
<td>23.5</td>
<td>69.2</td>
<td>59.3</td>
<td>70.4</td>
<td>53.6</td>
<td>51.1</td>
<td>14.8</td>
</tr>
<tr>
<td>Personnel ($/year)</td>
<td>2,030</td>
<td>7,560</td>
<td>5,880</td>
<td>6,940</td>
<td>5,280</td>
<td>4,670</td>
<td>939</td>
</tr>
<tr>
<td>Materials ($/year)</td>
<td>247</td>
<td>272</td>
<td>272</td>
<td>272</td>
<td>272</td>
<td>272</td>
<td>0</td>
</tr>
<tr>
<td>Subcontractor Cost ($/year)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,730</td>
</tr>
<tr>
<td>Annual O&amp;M Cost ($/year)</td>
<td>2,280</td>
<td>7,830</td>
<td>6,150</td>
<td>7,210</td>
<td>5,550</td>
<td>4,940</td>
<td>2,670</td>
</tr>
<tr>
<td>Annual maintenance/capital cost (%)</td>
<td>6</td>
<td>19</td>
<td>15</td>
<td>19</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Calculations based on original data with BGS units of $/acre and h/acre.

\(^a\)Number of years at which amortized maintenance costs equal capital construction costs.
Summary

• Following recommended O&M guidelines
• Properly designed GI systems can be more cost-effective than conventional infrastructure
• Type of maintenance affects costs
• A lot of research opportunities in the O&M costs area.
References

Questions?
### Concrete Curb And Gutter Installation Calculator

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Linear Feet</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Curb And Gutter Cost</td>
<td>608</td>
<td>576 feet</td>
<td>$3,445.55</td>
<td>$3,945.88</td>
</tr>
<tr>
<td>Concrete Curb And Gutter Labor, Basic</td>
<td>280.6 hrs</td>
<td>$16,804.91</td>
<td>$20,369.59</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Linear Feet</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Curb And Gutter Job Supplies</td>
<td>608</td>
<td>576 feet</td>
<td>$125.32</td>
<td>$142.56</td>
</tr>
</tbody>
</table>

### Cost to Excavate Land

Updated: August 2017

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Cubic Yards</th>
<th>Zip Code</th>
<th>Low</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Excavation Labor, Basic</td>
<td>659.6 hrs</td>
<td>$10,764.49</td>
<td>84117</td>
<td>$10,764.49</td>
<td></td>
</tr>
<tr>
<td>Land Excavation Equipment Allowance</td>
<td>1 job</td>
<td>$161.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Excavation Debris Disposal</td>
<td>473 cubic yards</td>
<td>$15,085.77</td>
<td>84117</td>
<td>$15,085.77</td>
<td></td>
</tr>
</tbody>
</table>

### Totals - Cost To Install Concrete Curb And Gutter

576 linear feet | $20,250.46 | $24,315.47

Average Cost per Linear Foot

$37.16 | $42.21