Sustainable Green Roofs for Texas

BEC Spring Seminar
Austin, Texas
April 4, 2012

Overview

• Urban sprawl
• Green roof technology
• Green roof research
• Application
• Guidance for sustainable green roofs
• Green Roofs in Texas
• Ecoregion approach
Urban Sprawl

Sprawl in the U.S.

Bonn at 1:10.15 scale
Bonn, Germany population over 300,000

College Station at 1:10.15 scale
Bryan/College Station, TX 120,000
Sprawl by Design

Bonn at 1:3.4 scale

College Station at 1:3.4 scale

How many cars can park in the Bonn area?
http://www.jahreswagenpool.de/parken-BN-Bonn.html [4,268]

How many cars can park on the Texas A&M campus? [30,000]

Contemporary Site Drainage

Typically, if between only 10 and 25 percent of a watershed is impervious, its channels and pools begin to degrade. Impervious development in a watershed at rates above 25 percent usually produces degraded streams, silted waters and deteriorates them into a state of chaos.
“2. **The roof gardens.** The flat roof demands in the first place systematic utilization for domestic purposes: roof terrace, roof garden. The roof terrace satisfies both demands (a rain-dampened layer of sand covered with concrete slabs with lawns in the interstices; the earth of the flowerbeds in direct contact with the layer of sand). **In this way the rain water will flow off extremely slowly.** Waste pipes in the interior of the building. Thus a latent humidity will remain continually on the roof skin. The roof gardens will display highly luxuriant vegetation. Shrubs and even small trees up to 3 or 4 metres tall can be planted. **In this way the roof garden will become the most favored place in the building. In general, roof gardens mean to a city the recovery of all the built-up area.**”

**Le Corbusier- Five Points of Architecture-1926**

His ideas for vegetating rooftops under the modern movement were not well received by many. **His ideas were outright rejected by his peers, because nature was not part of the modern paradigm.** Only a small group of architects followed the ideas in the development of extensive green roofs elsewhere.

**Le Corbusier- La Tourette-1953**

2012 Texas Population: 26.4 million
2012 Texas urban population: 23.2 million
2015 Texas Population: 28.0 million
2015 Texas urban population: 24.7 million

Texas Dept. of State Health Services
Natural Systems are Irreplaceable

Houston toad (*Bufo houstonensis*)

- Only Bastrop County has been surveyed consistently from year to year since the 1970s (Table 1 in Forstner and Dixon 2011).
- In the 1980s, surveyors reported observing 30 to 1,000 Houston toads per breeding pond (Jacobsen 1983; Hillis et al. 1984).
- Thereafter, estimates of 2,000 Houston toads in all of Bastrop County were reported (Seal 1994).
- By 2003, Forstner (2003) estimated the number of Houston toads in Bastrop County to be between 100 and 200 individuals.

Habitat Destruction & Climate Change

Houston toad (*Bufo houstonensis*)

- The 2011 Houston toad breeding/survey season ended May 2011 with only a total of **12** Houston toads detected from extensive surveys in Austin, Bastrop, Burleson, Colorado, Lavaca, Lee, and Milam counties, as well as limited survey attempts in Leon and Robertson counties (Forstner and Dixon 2011; Dr. Michael Forstner, Texas State University, pers. comm. 2011, From Report *Bufo houstonensis*, 5-Year Review Summary and Evaluation, 11-2011).
Habitat Preservation with Green Roofs

- Moos Water Filtration Plant, built on Lake Zurich in 1914
- 7.4 acre green roof installed to moderate water temp.
- Since its initial installation, 170 species of plants have migrated to the roof including 9 orchid species of which 1 is listed as an endangered species.

In their report, Lincoln et al. (2011) cite three factors that appear to have contributed to reduce monarch abundance:
1) degradation of the forest in the overwintering areas;
2) the loss of breeding habitat in the United States due to the expansion of GM herbicide-resistant crops, with consequent loss of milkweed host plants, as well as continued land development;
3) and severe weather.
MLA student’s vision for wildlife habitat at Texas A&M campus.
Texas Chapter ASLA Honor Award

Green Roof Technology
A Green Roof

Vegetation varies (design program, regional & micro-climate, growth media depth & composition, maintenance, irrigation, elevation above grade)

Growth media (35%-60% LWA, 25%-50% course sand, up to 15% silt, 4%-12% organic content, per FLL 2002)

Media separator (nonwoven polypropylene fabric)

Drainage (expanded clay, shale, slate, or plastic sheets)

Protective/water mgmt. layer, nonwoven poly fabric

Water proofing/root barrier (Single Ply or built up)

Insulation Extruded Polystyrene (IRMA above waterproofing)

Roof slab-concrete, wood, steel (used with dense deck below)

Application
Urban Agriculture

In New York, homeless people maintain and eat rooftop produce.

Rooftop Farms, 6,000 s.f. organic vegetable farm Brooklyn, NY.

Wildlife Habitat

Habitat for the endangered Black Redstart
Vary Substrate Thickness for Biodiversity

Beam Beam

Industrial Wastewater Processing

John Deere Works, Mannheim, Germany
• Constructed 450 s.f. rooftop wetland to manage industrial waste
• 2” deep hydroponic system to remove carbon, nitrogen, phosphates and heavy metals.
Green Roofs and Green Building

Green Mall Osaka, Japan

Guidance for Sustainable Green Roofs
Two Green Roof Typologies

Sedum-roof: intended to maximize vegetative cover with fertilizer, irrigation, etc. High maintenance.

Two Green Roof Typologies

Ecoroof: intended to mimic natural systems via minimal human intervention. Low-input
### Not all green roofs remain green

<table>
<thead>
<tr>
<th>Type of failure</th>
<th>Design</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media slumping, drainage and plant failures</td>
<td>Custom</td>
<td>(Osmundson, 1999)</td>
</tr>
<tr>
<td><strong>Structural issues</strong>: cracking deck from excessive loads, collapsed roof deck.</td>
<td>Vendor</td>
<td>(Dvorak, 2003)</td>
</tr>
<tr>
<td>Plant failures</td>
<td>Vendor</td>
<td>(Carey, 2005)</td>
</tr>
<tr>
<td>Plant failures, clogged drainages (several projects)</td>
<td>Custom</td>
<td>(Paladino, 2006)</td>
</tr>
<tr>
<td><strong>Plant failures due to media blend</strong></td>
<td>Custom</td>
<td>(Carey, 2005)</td>
</tr>
<tr>
<td>Plant failures: media with excessive organics, slumping, excess watering</td>
<td>Custom</td>
<td>(Dvorak, 2008)</td>
</tr>
<tr>
<td><strong>Plant failures due to media, irrigation and maintenance problems</strong></td>
<td>Vendor</td>
<td>(Shackford, 2008)</td>
</tr>
</tbody>
</table>

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### Sustainable Green Roofs

- The concept of self-reliant green roofs was articulated in **Germany**, where the word *extensive* was used for green roofs to connote a widespread practice or application that can become ubiquitous with natural vegetation which requires hardly any external input for either maintenance or development (FLL, 2008 p.16, Werthmann, 2008 p.24).
Germany and the Development of Green Roof Technology

- Late 1800’s German named H. Koch developed gravel and sand ballast roof to prevent the spread of fire across dense urban areas in Berlin, Germany.
- Spontaneous (voluntary) vegetation established on gravel roofs.
- Botanist Reinhard Bornkamm’s office overlooked one of these spontaneous “greened” roofs (Green Roofs, Earth Pledge p 108).

German FLL Guidelines

- In 2002, English version of German based FLL Guidelines was released for the first time, now revised in 2008.
Table 2. Domains of Green Roof Knowledge Covered in the FLL Green Roofing Guidelines

<table>
<thead>
<tr>
<th>Knowledge Domain</th>
<th>Content</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Systems design</td>
<td>Application, interactions of and compatibility of components.</td>
<td>Chapters 1, 2, 5, 6, 7, 16</td>
</tr>
<tr>
<td>2. Structural</td>
<td>Dead and live load considerations</td>
<td>Chapters 1, 2, 5, 16, App. 1</td>
</tr>
<tr>
<td>3. Waterproofing/root</td>
<td>Membrane standards, application and testing</td>
<td>Chapters 2, 5, 6, 7, App. 3</td>
</tr>
<tr>
<td>4. Drainage</td>
<td>Materials, properties, application and testing</td>
<td>Chapters 7, 8, 16, App. 2</td>
</tr>
<tr>
<td>5. Growth media</td>
<td>Materials, properties application and testing</td>
<td>Chapters 2, 7, 10, 16, App. 2</td>
</tr>
<tr>
<td>6. Vegetation</td>
<td>Forms of, application and installation</td>
<td>Chapters 2, 3, 7, 11, 12</td>
</tr>
<tr>
<td>7. Maintenance</td>
<td>Types of and required activities</td>
<td>Chapters 7, 11, 12, 13, 16</td>
</tr>
</tbody>
</table>


FLL-Fig. 2: Granulometric distribution range for vegetation substrates at multiple-course extensive greening sites

Shaded area shows range of productive media for extensive green roofs.
For mesic or xeric designs, drainage layers should exceed the drainage capacity of growth media drainage characteristics.

**FLL Tab. 2: Standard course depths for different types of roof-greening**

<table>
<thead>
<tr>
<th>Type of Vegetation Support Course</th>
<th>1.5”</th>
<th>4.7”</th>
<th>7”</th>
<th>13.8”</th>
<th>23.6”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mosses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedum, moss, and herbaceous plants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedum, herbaceous-grass plants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass and herbaceous plants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-bush shrubs and vines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tall shrubs and vines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large bushes and small trees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mature size trees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large trees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Green Roof Research

Are Green Roofs Sustainable?

1. Reduction of stormwater runoff from 50% to 86%
2. Reduction of water temperature of roof runoff**
3. Reduction of peak discharge (CFS), delays run-off
4. Can improve water quality draining from rooftops
5. Reduction of building energy needs from 10% to 30%
6. Reduction of roof temperatures by 45°C, which in turn helps reduce the urban heat island effect
7. 40-50 decibel reduction of noise pollution**
8. Extends life of roof membrane 2 to 3 times
9. Carbon sequestration and reduction of air pollution**
10. Creates urban wildlife habitat**
11. Engages people with the environment

*Assembled from a diversity of sources
**very little research to document these findings.
Green Roofs in Texas

City of Austin, Green Roof Advisory Group, at least 27 green roofs in the Austin area. Performance Standards currently being written for City code part of the Density Bonus Program approved December 2011.

Research Site

Texas A&M University, College Station, Texas

College Station averages over 100 days a year with high daily temperatures above 90°F and receives 39 inches (99 cm) of precipitation annually.
Planted April 3rd, 2009, three plant species were investigated: *Talinum calycinum*, *Delosperma cooperi* and *Sedum kamtschaticum*.

### Materials

<table>
<thead>
<tr>
<th>Species</th>
<th>PI</th>
<th>PS</th>
<th>SR</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>D. cooperi</em></td>
<td>27</td>
<td>0</td>
<td>0%</td>
<td>All plants survived the first growing season. Plants were damaged in January, 2010 when temperatures dropped to -7.2°C, (19°F). <em>D. cooperi</em> is hardy in USDA zone 5. Spring of 2010 all plants continued living, but began to fade during the summer heat and drought, and none survived through August 2010.</td>
</tr>
<tr>
<td><em>S. Kamtschaticum</em></td>
<td>27</td>
<td>7</td>
<td>26%</td>
<td>Drought and heat tolerant once established. May need irrigation to establish and may need more than 8.9 cm of growth media.</td>
</tr>
</tbody>
</table>
2011 Climate

• 2011 was the warmest year on record in College Station since 1882, and third driest year. College Station was under an exceptional drought conditions from April 5, 2011 through the writing of this paper.
Lampranthus 'Red Shift' spectabilis
Malephora lutea
Graptopetalum paraguayense
Talinum calycinum
Sedum Album Murale
Lupinus texensis
Manfreda maculosa
Stipa tenuissima
Talinum calycinum
Stormwater managements

![Module Cross Section with Tipping Bucket (Xin Yang, 2010)](image)

June precipitation, 2010.

2010 Monthly precipitation totals at the research site and Easterwood Field for the period of investigation.

<table>
<thead>
<tr>
<th></th>
<th>Research site* Precipitation (mm)</th>
<th>Easterwood Field Precipitation (mm)</th>
<th>Easterwood Field Long-term mean (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>23.6</td>
<td>21.1</td>
<td>67.6</td>
</tr>
<tr>
<td>May</td>
<td>75.2</td>
<td>50.8</td>
<td>110.0</td>
</tr>
<tr>
<td>June</td>
<td>183.6</td>
<td>185.7</td>
<td>113.0</td>
</tr>
<tr>
<td>July</td>
<td>48.5</td>
<td>31.2</td>
<td>54.4</td>
</tr>
<tr>
<td>August</td>
<td>0.0</td>
<td>8.6</td>
<td>50.8</td>
</tr>
<tr>
<td>September</td>
<td>104.4</td>
<td>146.3</td>
<td>80.8</td>
</tr>
<tr>
<td>Totals</td>
<td>435.3</td>
<td>443.7</td>
<td>476.6</td>
</tr>
</tbody>
</table>

91% of normal
## Effect of all Species

<table>
<thead>
<tr>
<th>Date</th>
<th>Rainfall Depth (mm/in)</th>
<th>Duration (hrs)</th>
<th>Preceding Rainfall (days)</th>
<th>Green Roof Runoff (mm)</th>
<th>Green Roof Retention (mm)</th>
<th>Percent Retained by Green Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/18/2010</td>
<td>23.87 (0.92)</td>
<td>6.25</td>
<td>24</td>
<td>5.26</td>
<td>18.61</td>
<td>77.9</td>
</tr>
<tr>
<td>5/14/2010</td>
<td>58.42 (2.3)</td>
<td>9.5</td>
<td>27</td>
<td>28.25</td>
<td>30.17</td>
<td>51.6</td>
</tr>
<tr>
<td>5/17/2010</td>
<td>12.19 (0.48)</td>
<td>2</td>
<td>3</td>
<td>1.20</td>
<td>10.98</td>
<td>88.1</td>
</tr>
<tr>
<td>5/30/2010</td>
<td>4.57 (0.18)</td>
<td>0.75</td>
<td>12</td>
<td>0.00</td>
<td>4.57</td>
<td>100.0</td>
</tr>
<tr>
<td>6/2/2010</td>
<td>76.70 (3.02)</td>
<td>12.75</td>
<td>2</td>
<td>44.51</td>
<td>32.20</td>
<td>42.0</td>
</tr>
<tr>
<td>6/9/2010</td>
<td>102.87 (4.05)</td>
<td>6.75</td>
<td>6</td>
<td>65.05</td>
<td>37.92</td>
<td>36.9</td>
</tr>
<tr>
<td>6/24/2010</td>
<td>4.06 (0.16)</td>
<td>1.5</td>
<td>15</td>
<td>0.00</td>
<td>4.06</td>
<td>99.9</td>
</tr>
<tr>
<td>7/1/2010</td>
<td>10.41 (0.39)</td>
<td>1.75</td>
<td>6</td>
<td>0.21</td>
<td>10.20</td>
<td>98.1</td>
</tr>
<tr>
<td>7/2/2010</td>
<td>25.14 (0.99)</td>
<td>4.5</td>
<td>1</td>
<td>7.83</td>
<td>17.27</td>
<td>68.7</td>
</tr>
<tr>
<td>7/6/2010</td>
<td>7.36 (0.29)</td>
<td>1</td>
<td>24</td>
<td>0.01</td>
<td>7.35</td>
<td>99.9</td>
</tr>
<tr>
<td>7/28/2010</td>
<td>6.60 (0.26)</td>
<td>2.5</td>
<td>2</td>
<td>0.02</td>
<td>6.58</td>
<td>99.7</td>
</tr>
<tr>
<td>9/7/2010</td>
<td>72.39 (2.85)</td>
<td>10.5</td>
<td>40</td>
<td>34.58</td>
<td>37.81</td>
<td>52.2</td>
</tr>
<tr>
<td>9/9/2010</td>
<td>4.57 (0.18)</td>
<td>0.75</td>
<td>2</td>
<td>1.60</td>
<td>2.92</td>
<td>64.0</td>
</tr>
<tr>
<td>9/24/2010</td>
<td>6.85 (0.27)</td>
<td>0.25</td>
<td>14</td>
<td>0.00</td>
<td>6.81</td>
<td>99.3</td>
</tr>
<tr>
<td>9/25/2010</td>
<td>20.57 (0.81)</td>
<td>1.5</td>
<td>1</td>
<td>4.20</td>
<td>16.37</td>
<td>79.6</td>
</tr>
</tbody>
</table>

### 75% reduction during study

## Green Roof Effectiveness

**Relationship between percent retention and rainfall depth**

\[ y = -0.6468x + 96.15 \]

\[ R^2 = 0.80 \]

25 mm (1"")
Summary of May, 2010 rooftop temperatures in degrees Celsius

- Average cooling of 18 °C at the surface and 27.5 °C at the membrane.
- No irrigation.

Temperature difference between the green roofs and the conventional roof surface as affected by plant species and measurement location. a) difference between media surface and conventional roof surface and.
Temperature difference between the green roofs and the conventional roof surface as affected by plant species and measurement location. a) difference between media surface and conventional roof surface and, 

b) difference between temperature below the media and conventional roof surface temperature. The dotted line indicates the average temperature reduction achieved by the green roof surfaces over the time period (1 May 2010 – 31 Aug 2010).

Texas A&M Langford Building
Horace’s Duskywing - *Erynnis horatius* on Delosperma cooperi 10 AM May 7 2010
Ecoregion Strategies

- Work with interdisciplinary groups and industry
- Investigate multiple forms of plants i.e. succulents, graminoids, forbs, bulbs.
- Work with FLL or ASTM guidelines as a point of reference for media granulometric distribution, drainage and chemical properties and depth.
- Consult local codes and peer-reviewed research.

Questions?


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