

# Extensive Vegetated Roofs

Beautiful and practical additions to the Urban Landscape

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# Presentation Overview

- The roof in sustainable building
- Extensive green roof types
- How good green roofs are created
- Case Studies
  - Meadow style extensive green roofs
  - Sloped green roofs
  - Publicly accessible green roofs
- Summary

# Sustainable Building

## How green roofs fit in

- Sustainable Site
- Energy Use
- Environmentally preferable materials
- Enhanced indoor environmental quality
- Optimize operational and maintenance practices
- Water conservation and protection



# Rooftop Temperature



# Enhanced indoor environmental quality

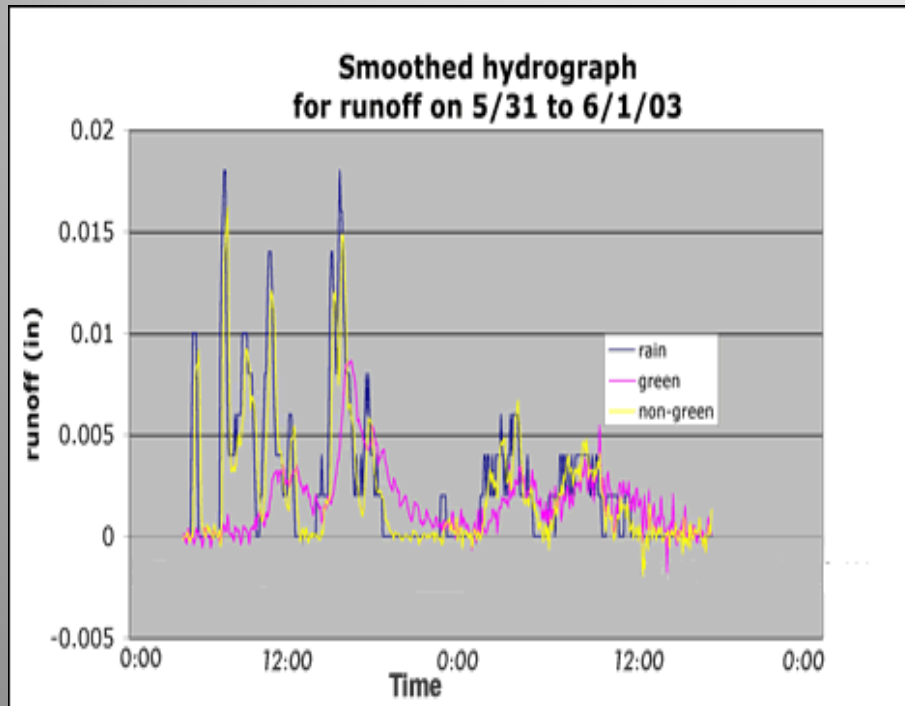
- Optimize aesthetics of visible roofs
  - Green improves people's well being and performance



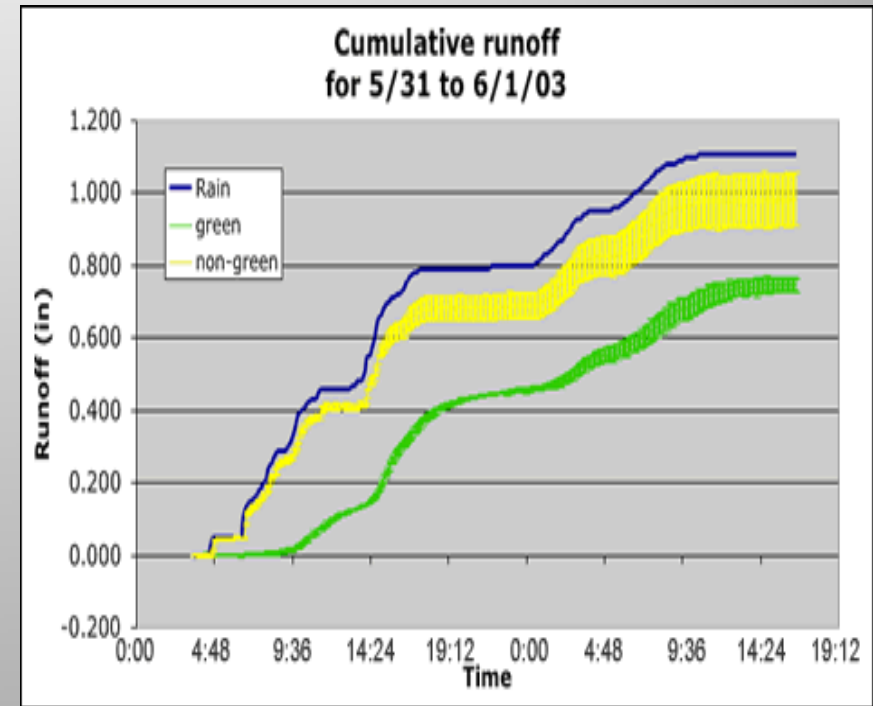
# Water conservation and protection

- Capture storm water
  - Up to 30 mm captured in 4" deep medium
    - A 4" green roof reduces annual run-off by 60-70%
- Detain storm water run-off
  - Can delay water run-off by several hours depending on rain intensity
  - More effective than controlled flow drains

# Water conservation and protection



Run-off Delay



Run-off Reduction



# Water conservation and protection



## Storm Water Quality



# How do green roofs perform

- Plants utilise solar radiation
  - Create carbohydrates and  $O_2$  from  $H_2O$  and  $CO_2$
  - Respiration turns carbohydrates and  $O_2$  into growth
  - Respiration and photosynthesis create need for transpiration
  - Transpiration draws  $H_2O$  and  $O_2$  from soil along with nutrients
  - Growing medium absorbs and holds  $H_2O$  and  $O_2$  until transpired
  - Filtration and buffering takes place in the process

# Extensive Green Roof Systems

- Three critical factors
  - Drainage
  - Growing medium
  - Plants

Nothing else matters

- A stressed green roof doesn't function properly!
- A dead green roof doesn't function !!!!

# Extensive Green Roof Systems

- Built in place systems
- Pre-grown blankets
- Conventional trays
- Hybrid modules

# Built in Place Systems



Typical built in place





# Built in Place Systems



Grand Rapids, MI 1 year old



1 season old

Ottawa, ON

# Built in Place Systems



Erosion control matting Chicago, IL



# Built in Place Systems



Toronto, ON



Grand Rapids, MI

# Blanket Systems



Blanket system assembly





# Blanket Systems



Blankets over built in place

# Blanket Systems



A mature blanket system



# Conventional Trays



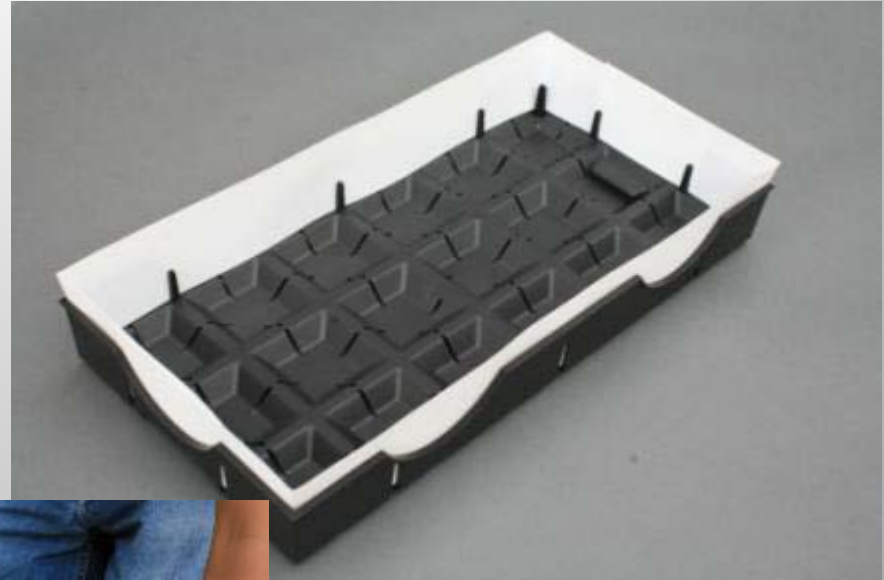
# Conventional modules





# Hybrid modules

Pre-vegetated  
Interconnected



# Efficient Handling



# Hybrid modules





# Hybrid modules



# How good green roofs are created

- Specifications (if you are a designer)
  - Choose an appropriate roofing system
    - Appropriate for the building
    - Compatible with a green roof
  - Choose the green roof system type
  - Specify a named product.
    - Decide whether to allow alternates
    - Check out the chosen product
      - At installation time
      - 1 year old
      - 4 years old
    - If alternates are proposed on the RFI, check them out before approving. Give yourself at least two weeks
    - Don't mix and match specifications

# How good green roofs are created

- Specifications (if you are an installer)
  - Read the specifications and look at the drawings
  - Are you a certified installer for the product?
  - Can you become a certified installer?
  - Price the specified product
  - Price the design
  - Propose and price alternates if appropriate
  - Do not violate your licensing agreements



# Green roof design

- Roofing Design
  - Always check your specifications with roofing system manufacturer and green roof manufacturer
  - Conventional roofing assembly
    - Typical assembly on Steel Deck
      - Vapour barrier
      - Cover board
      - 2 layers of polyisocyanurate, seams off-set, screwed or glued to deck
      - Cover board glued to iso insulation
      - Membrane fully adhered to cover board
      - EFVM leak detection (optional)
      - Loose laid root barrier (compatible with EFVM if used)
      - Green roof system

# Green roof design

- Roofing Design
  - Protected Membrane Assembly
    - Typical on a concrete deck
    - Modular green roof system
      - Fully adhered membrane system
      - Root barrier (optional location)
      - 2 layers of Extruded Polystyrene seams off set (lower layer with drainage channels)
      - Green roof system layers
  - Note: insulation layer has to have vapour diffusion space. No more than 35% can be sealed.

# Green roof design

- Drainage
  - Good drainage is essential.
  - No water holding in the drainage layer unless designed as a reservoir.
  - No perched water table in the growing medium
  - Leave space around drains
  - Leave overflow space around perimeter
  - Do not block drainage flow with
    - Irrigation lines
    - Pavers
    - Edging materials without drainage slots
    - Filter cloth
    - Layers of fabric



# Drainage



# Drainage



# Green roof design

- Growing medium
  - Proper growing medium is essential
    - As light weight as practical
    - Supports long term plant growth
    - Retains water
    - Has good aeration, even when saturated
    - Durable and stable
      - Low in organic matter
      - No unstable fillers such as vermiculite, horticultural foam
  - conforms to FLL granulometric standards
    - Include a mandatory growing medium test in specifications
      - Agricultural Analytical Services Laboratory, Penn State University




# Growing Medium



# Growing medium

- Growing medium Test



**PENN STATE**

(814) 863-0841 Fax: (814) 863-4540  
 Agricultural Analytical Services Laboratory  
 The Pennsylvania State University  
 University Park, PA 16802  
 www.aasl.psu.edu

ANALYSIS FOR:			ADDITIONAL COPY TO:		
LAB ID	SAMPLE ID	SAMPLE TYPE	DATE SAMPLED	DATE RECEIVED	DATE COMPLETED
SM03530		Multi-layer extensive		7/9/2010	7/27/2010

**Green Roof Media Analysis**  
Results on dry weight basis unless specified otherwise

Analysis	Units	Result	FLL Guidelines for Multi Course Extensive Sites <sup>1</sup>
<i>Particle Size Distribution (See accompanying report)</i>			
≤ 0.05 mm (FI reference value based on < 0.06 mm)	mass %	7.5	≤ 15
<i>Density Measurements</i>			
Bulk Density (dry weight basis)	g/cm <sup>3</sup>	1.07	—
Bulk Density (dry weight basis)	lb/ft <sup>3</sup>	67.05	—
Bulk Density (at max. water-holding capacity)	g/cm <sup>3</sup>	1.55	—
Bulk Density (at max. water-holding capacity)	lb/ft <sup>3</sup>	97.06	—
<i>Water/Air Measurements</i>			
Moisture	mass %	11.5	—
Total Pore Volume <sup>2</sup>	Vol. %	54.3	—
Maximum water-holding Capacity	Vol. %	49.4	35 - 65
Air-Filled Porosity (at max water-holding capacity)	Vol. %	4.9	≥ 10
Water permeability (saturated hydraulic conductivity)	cm/s	0.01	0.001 - 0.12
Water permeability (saturated hydraulic conductivity)	in/min	0.31	0.024 - 2.83
<i>pH and Salt Content</i>			
pH (CaCl <sub>2</sub> )		7.4	6.0 - 8.5
Soluble salts (water, 1:10, m.v)	mmhos/cm	0.21	—
Soluble salts (water, 1:10, m.v)	g (KCl)/L	1.34	≤ 3.5
<i>Organic Measurements</i>			
Organic matter content	mass %	5.8	—
Organic matter content	g/L	62.8	≤ 65
<i>Nutrients</i>			
Phosphorus, P <sub>2</sub> O <sub>5</sub> (CAL)	mg/L	24.7	≤ 200
Potassium, K <sub>2</sub> O (CAL)	mg/L	217.1	≤ 700
Magnesium, Mg (CaCl <sub>2</sub> )	mg/L	301.5	≤ 200
Nitrate + Ammonium (CaCl <sub>2</sub> )	mg/L	19.2	≤ 80

<sup>1</sup>Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL). 2008. Guidelines for the Planning Execution and Upkeep of Green-Roof Sites  
<sup>2</sup>Total pore volume determined using measured particle density instead of assumed particle density as specified in FLL.

page 1





# Growing medium



- Too coarse
- Too little organic matter

# Growing medium



Too much organic matter



# Growing medium



Too much organic matter  
Lovely lamb's quarters, pigweed and clover



# Growing medium



FLL Standard Growing medium

# Green roof design

- Plants
  - Adaptive plants
  - Select plants according to
    - Media depth
    - Hardiness Zone
    - Elevation and exposure of the roof
    - Irrigation intent
    - Potential ecological impact on surrounding vegetation in sensitive areas

# Green Roof Plants

- Plant choices in Great Lakes Basin
  - Growing media depth: 2.5"
    - Shallowest practical growing medium depth
      - Hardy succulents (CAM)
      - Small flowering Allium
      - Ephemeral spring bulbs
      - May still need periodic irrigation
      - 10-18 psf depending on growing medium

# Green Roof Plants

- Plant choices in Great Lakes Basin
  - Growing media depth: 4"
    - Best practical growing medium depth
      - Succulents and related plants (CAM)
      - Alliums
      - Ephemeral bulbs
      - A few drought tolerant grasses if irrigated
      - Some drought tolerant perennials if irrigated
      - Most efficient stormwater control on annual basis
      - 23-30 psf depending on growing medium



# Green Roof Plants

- Plant choices in Great Lakes Basin
  - Growing media depth: 6"
    - Designer's Choice: 6" and up
      - Succulents, hardy perennials, sedges and grasses
      - Irrigation required if planted with more than succulents
      - 40-50 psf depending on growing medium and plants

# Green roof design

- Other factors to consider
  - Irrigation Design
  - Irrigation for overhangs
  - South facing glass walls
  - Exposed vs ballasted perimeters
  - Roof access points
  - Air vents
  - Edge stress due to thermal bridging
  - Material handling safety

# Irrigation design

- Sprinklers
  - Design for wind
  - Operate intelligently
- Drip Irrigation
  - Poorly suited to thin systems
  - Stripes
- Sub-irrigation
  - Can lead to waterlogging and poor drainage
  - Difficult to design and install properly

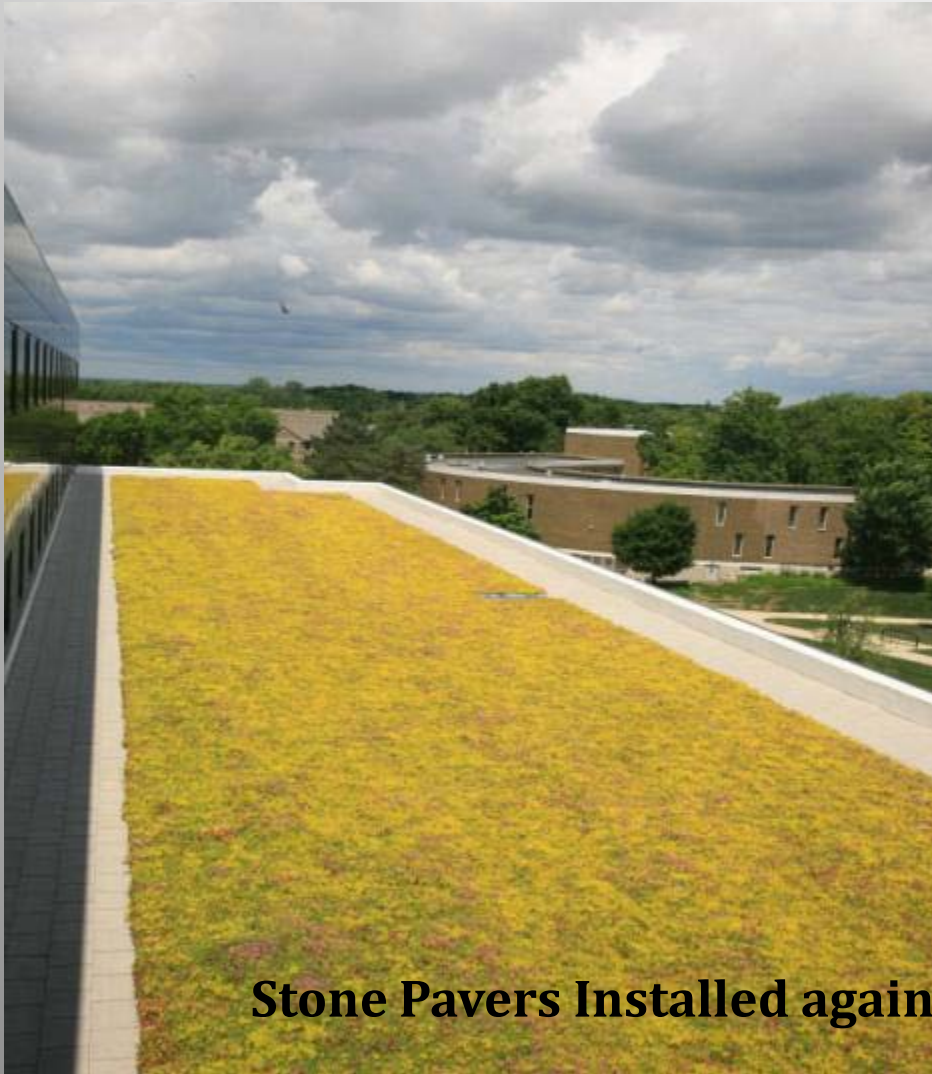
# Overhangs



**Overhanging roofs require irrigation**



# Glass Walls



**Stone Pavers Installed against a South Facing Wall**

# Exposed vs Ballasted



**Roof with Exposed Membrane**



**Roof without Exposed Membrane**



# Access Points



**Distressed and Dead Plants Due to Excessive Foot Traffic**



# Access Points



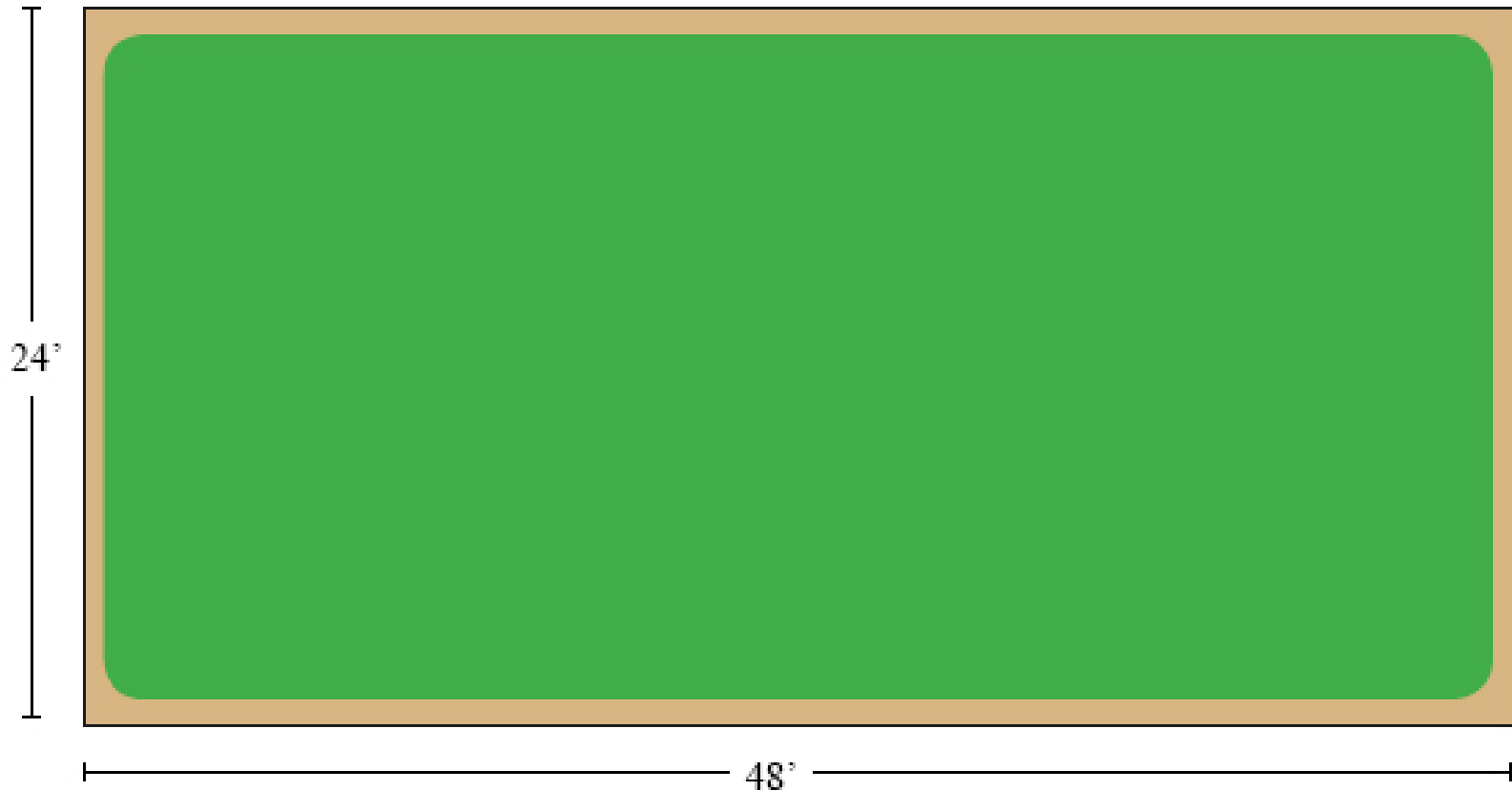
**Roof Access Point with Stone Pavers**

# Air vents



**Plant Death Caused by Roof Vent Air stream**

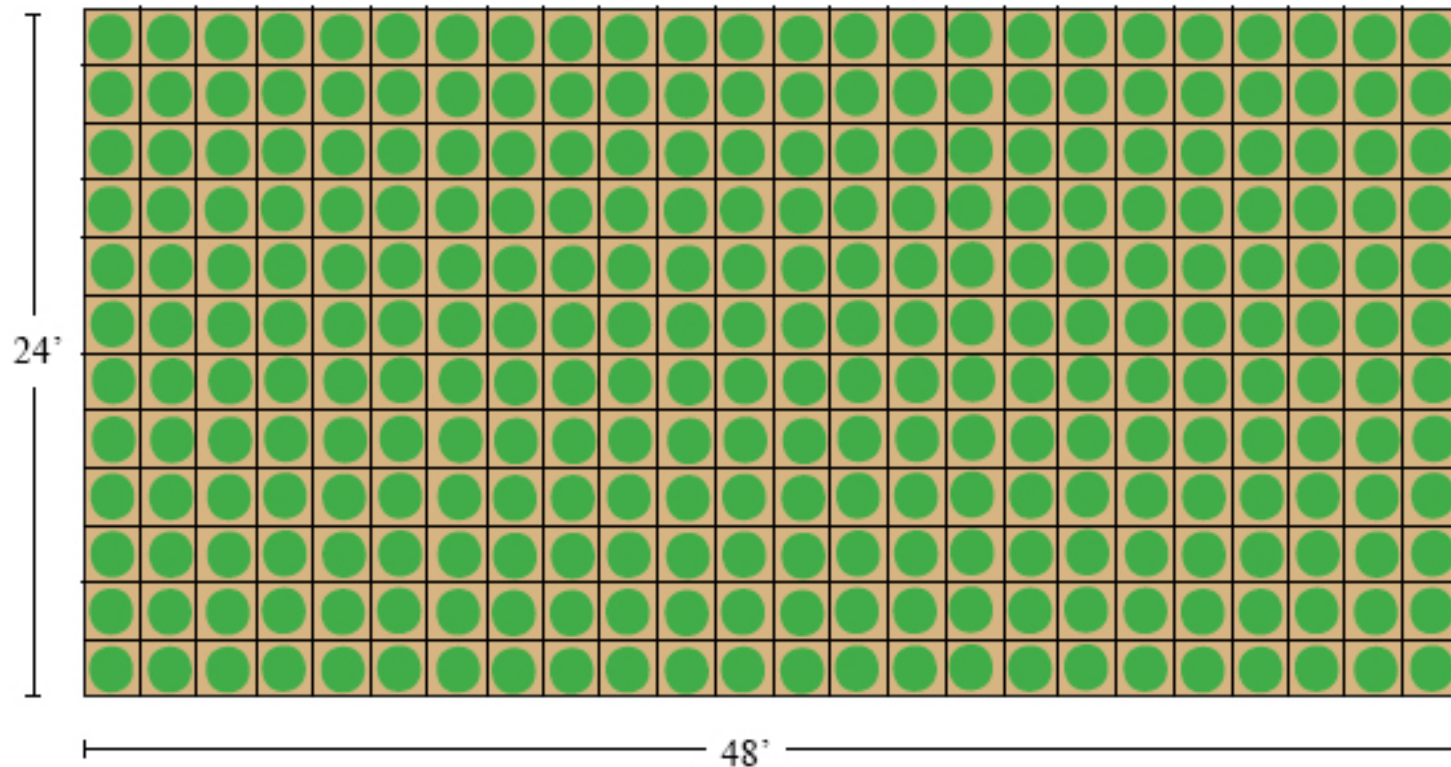
# Edge Stress



Monolythic = 144' of Edge



# Edge Stress



2' x 2' Modular Grid = 1248' of edge (*conservative*) 8+ times more !  
= 2304' of edge (*counting all four sides of each tray*) 16 times more !



# Material Handling Safety



# Meadow Style green roofs

## Toronto Transit Commission

- Eglinton West Station
  - Existing building opened in 1978
  - Active subway and bus station
  - TTC Pilot Project
    - First of potentially many green roofs on TTC facilities
- Similar projects:
  - Toronto Public Service Building
  - Victoria Park Station

# TTC Eglinton West Station



Summer 2008

# TTC Eglinton West Station

- Green Roof Design
  - System choice
    - Active subway station: installation to be fast
    - Very meticulous client
    - High profile: Instant green roof
    - Exposed: station open to the north
    - Allowable saturated weight: 23 psf
    - Pre-grown hybrid modular 3.5" deep



# TTC Eglinton West Station

- Plant Choices:
  - System Depth: 3.5"
  - Mixture of 8 varieties of Sedums
  - Custom selection for site conditions
    - USDA Hardiness Zone 3 and 4 plants
  - Selection for visual impact
    - Matched plant selections to optimize long term visual appeal

# TTC Eglinton West Station



The green roof in production  
4 weeks prior to installation

# TTC Eglinton West Station

## The Blank Canvas

- membrane replaced
- EFVM installed
- Asphalt flood coat applied



# TTC Eglinton West Station



Transport to Site



# TTC Eglinton West Station



## Challenge # 1

How to get six 18 wheelers and a crane past this slope

# TTC Eglinton West Station



Solution

Back up 1.6 km from the next station

# TTC Eglinton West Station

- Installation Day 1





# TTC Eglinton West Station



Installation End of Day 2



# TTC Eglinton West Station



Installation End of Day 4

# TTC Eglinton West Station



3 Months Later



# TTC Eglinton West Station



11 Months later

# TTC Eglinton West Station

- Total Roofing Project Size: 30,000 sq ft
- Green roof project size: 9,950 sq ft
- Installation time:
  - Re-roofing: 2 months
  - Green Roof: 5 days including stone & irrigation
- Plant Mix:
  - Sedum acre 'Aureum'
  - Sedum album 'Coral Carpet'
  - Sedum floriferum 'Weihestephaner Gold'
  - Sedum hybridum 'Immergrunnen'
  - Sedum reflexum
  - Sedum rupestre 'Angelina'
  - Sedum sexangulare
  - Sedum spurium 'Dragon's Blood'
  - Sedum spurium 'Voodoo'



# Toronto Public Service Building



# Victoria Park Station



# Sloped Green Roofs

- North London Community Centre
  - New building in London, ON suburbs
  - Combination pool, library, community centre
  - First community green roof in London
  - Green roof visible from road
- Other sloped green roofs
  - JKLA, Buffalo, NY
  - 1 Haworth Circle, Holland, MI
  - Vancouver Convention Centre, BC

# North London Library

- Green Roof Design considerations
  - Brand new building
    - TPO 60 mil fully adhered roofing
    - Green roof with 22 degree slope
    - Curbs integrated into structure
    - Non-irrigated
  - Root barrier
    - TPO
    - Heat welded at seams



# North London Library



Green roof in production

# North London Library



The roof to be greened  
Slope: 22 degrees

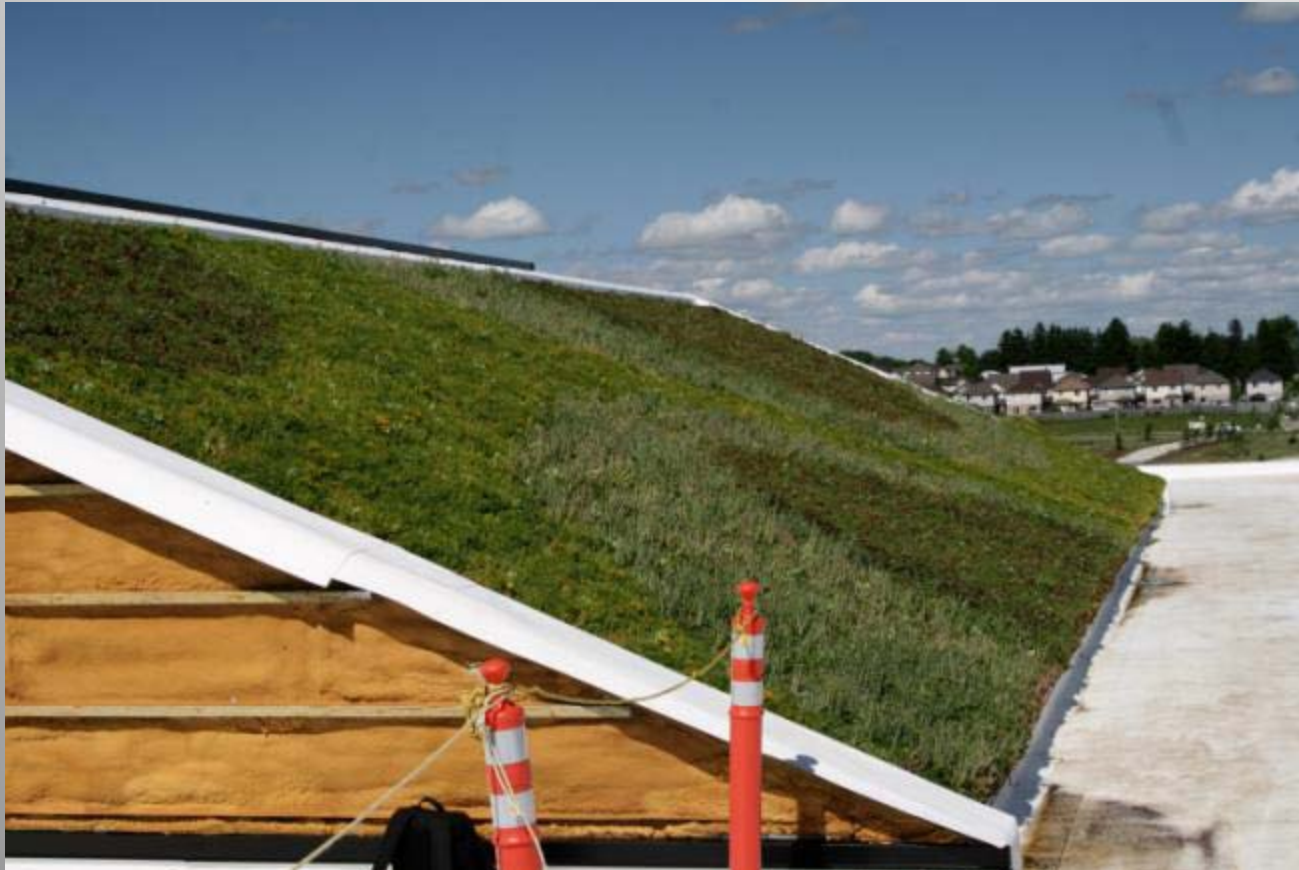
# North London Library



A day later



# North London Library





# North London Library



Two Months later

# North London Library



View from the road



# JKLA Studio

The blank canvas



Fully adhered EPDM

# JKLA Studio

Suspending the drainage layer



Installing the layers



# JKLA Studio

Planting the roof



First summer

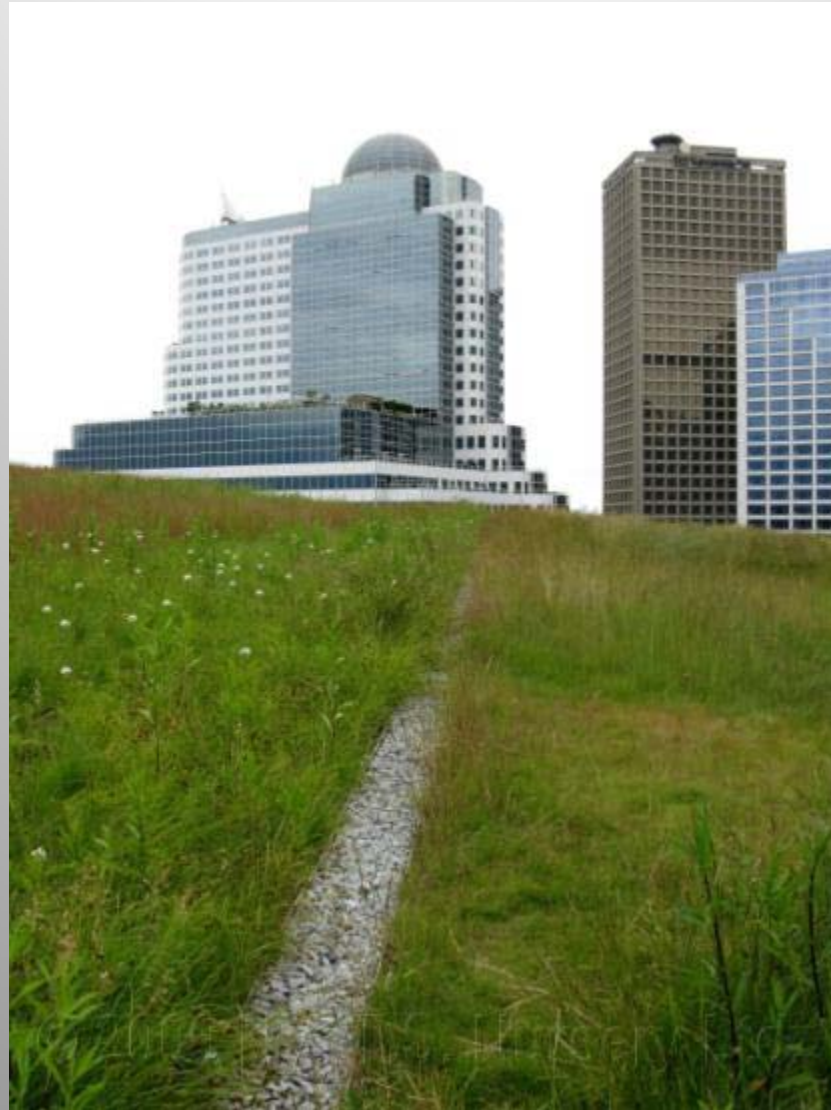




# 1 Haworth Circle



# Vancouver Convention Centre





# Vancouver Convention Centre



Images courtesy of NATS Nursery

# Vancouver Convention Centre



Images courtesy of NATS Nursery

# Vancouver Convention Centre





# Publicly Accessible Green Roofs

- Podium Green Roof Nathan Phillips Square
  - Part of Toronto City Hall Complex
  - Publicly accessible sunrise to sunset
  - 3<sup>rd</sup> floor of City Hall
  - Visible from all buildings around
- Other accessible green roofs
  - Hamilton City Hall, Hamilton, ON
  - St Ignatius of Loyola School Guelph

# Publicly Accessible Green Roofs

## City of Toronto

- City Hall Podium
  - Existing building opened in 1965
  - Second roof replacement
  - Entirely closed to the public since mid-90's
  - First phase of revitalisation project

# Nathan Phillips Square



**Toronto's main gathering place**

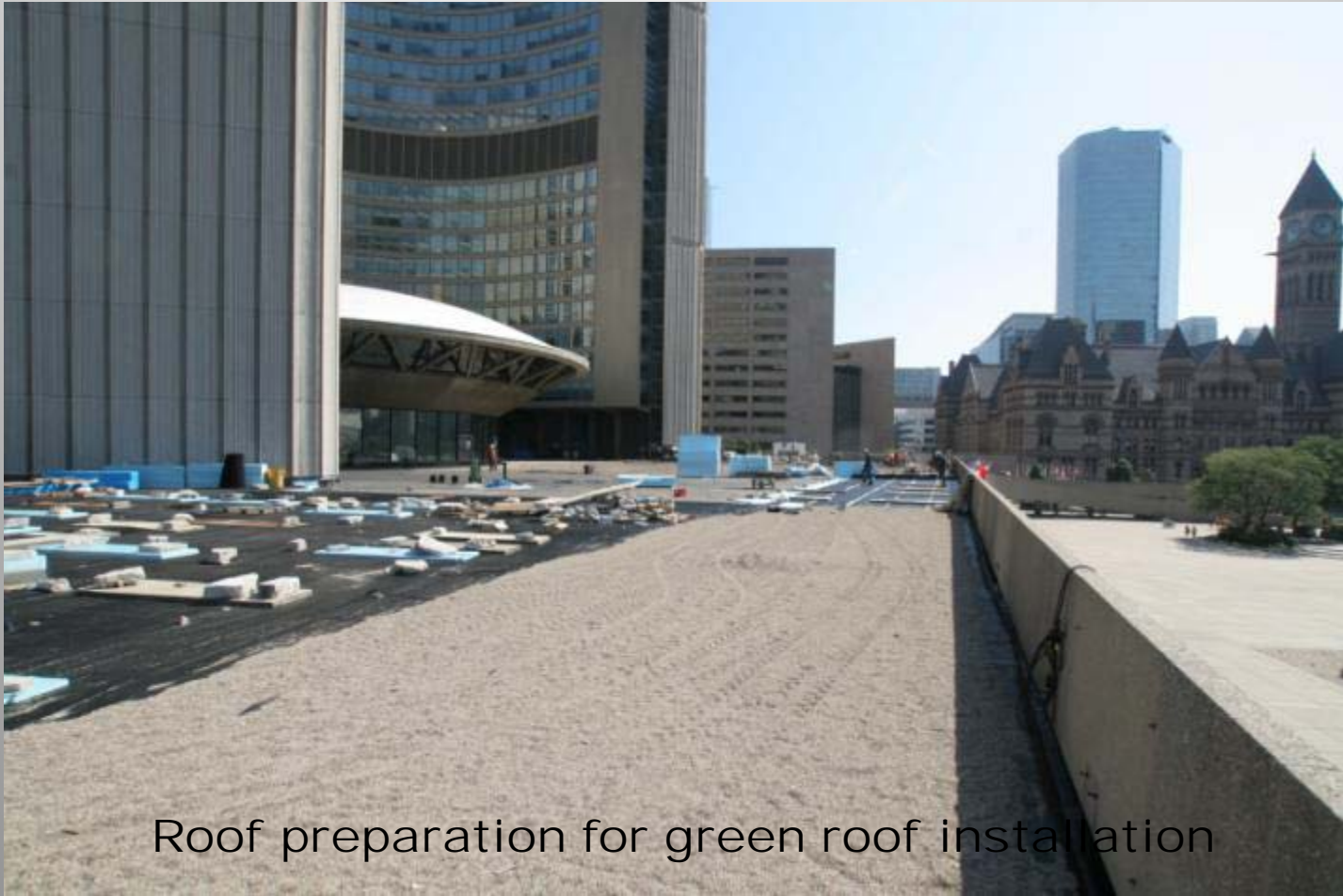


# Nathan Phillips Square



Roofing removal, May 2009

# Nathan Phillips Square



Roof preparation for green roof installation

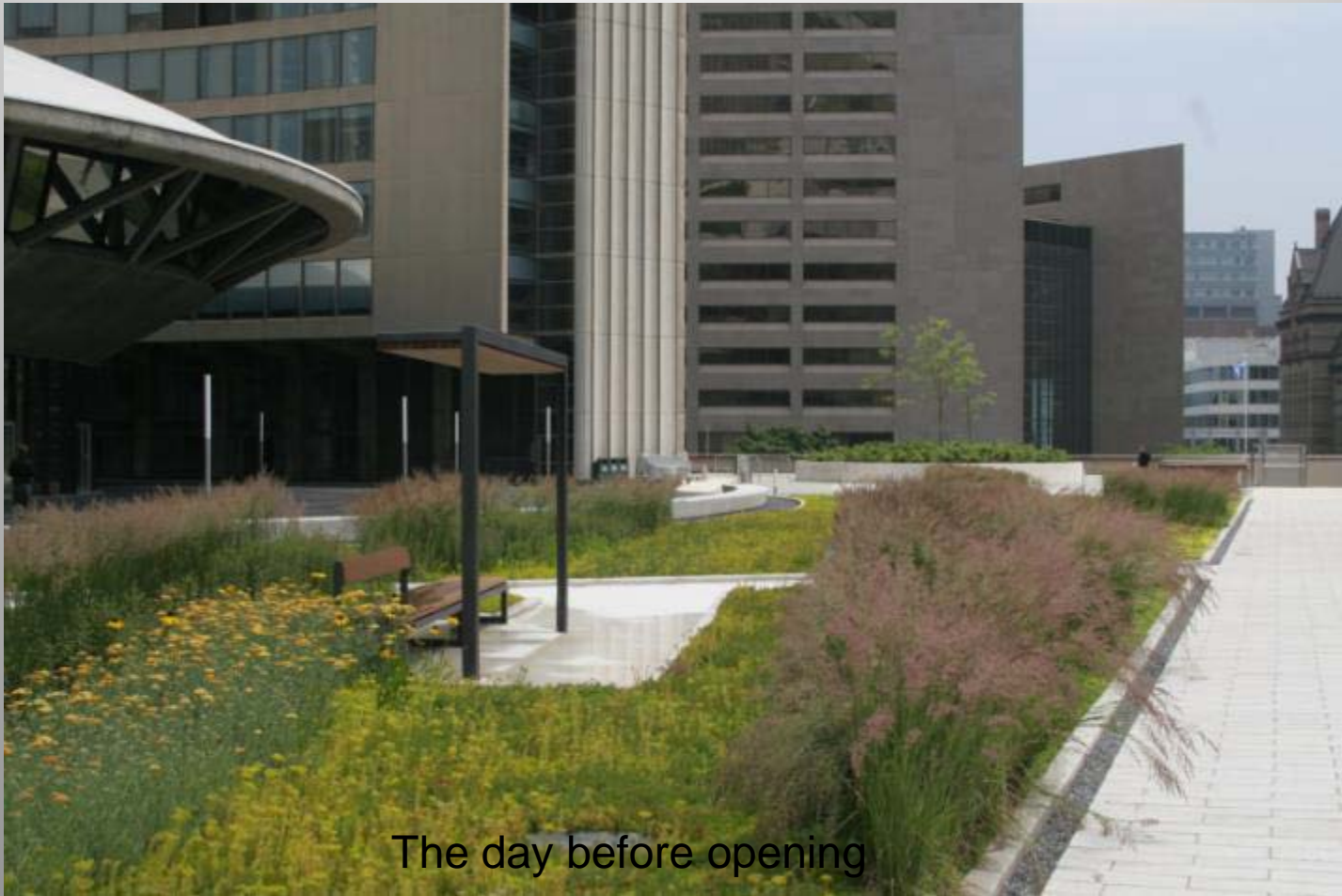
# Nathan Phillips Square



Plant installation nearing completion



# Nathan Phillips Square



The day before opening



# Nathan Phillips Square



Opening Day

# Nathan Phillips Square









# Hamilton City Hall



# St Ignatius High School, Guelph, ON



# Summary

- Careful specification is important
- Ensure good drainage of
  - The roof
  - The green roof system
  - The growing medium
- Ensure water availability on the roof
- Design for durability, instead of cost
- Make proper plant selections
- Keep the aesthetics of the green roof in context
- Ensure everything is installed according to specification



# Summary

- Remember:

It is all about the plants

Green roofs perform because of healthy plants

# What should be in you library?

- Guideline for the planning, execution and upkeep of Green-roof sites. Release 2008 [www.FLL.DE](http://www.FLL.DE)
- The Green Roof Manual: A professional guide to the Design, Installation and Maintenance.  
[www.Timberpress.com](http://www.Timberpress.com)
- Green Roof Plants: A resource and planting guide.  
[www.Timberpress.com](http://www.Timberpress.com)

# Extensive Vegetated Roofs

- Improving the environment one roof at a time

## Contact Information

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