Hydrologic Design of Vegetated Roofs

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20 June 2016
MWEA Annual Conference

LAWRENCE TECH
GREAT LAKES
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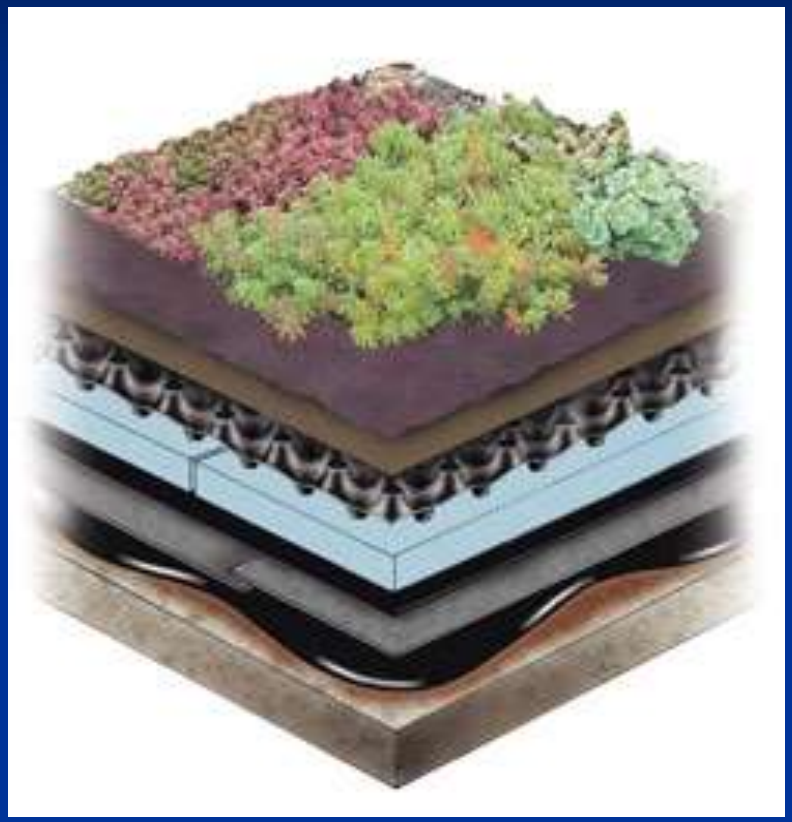
Session Overview

- (Very) Brief Introduction to Vegetated Roofs
- Hydrologic Performance
- Monitoring Data
- Hydrologic Design Parameters

Fun Vegetated

Types of Vegetated Roofs



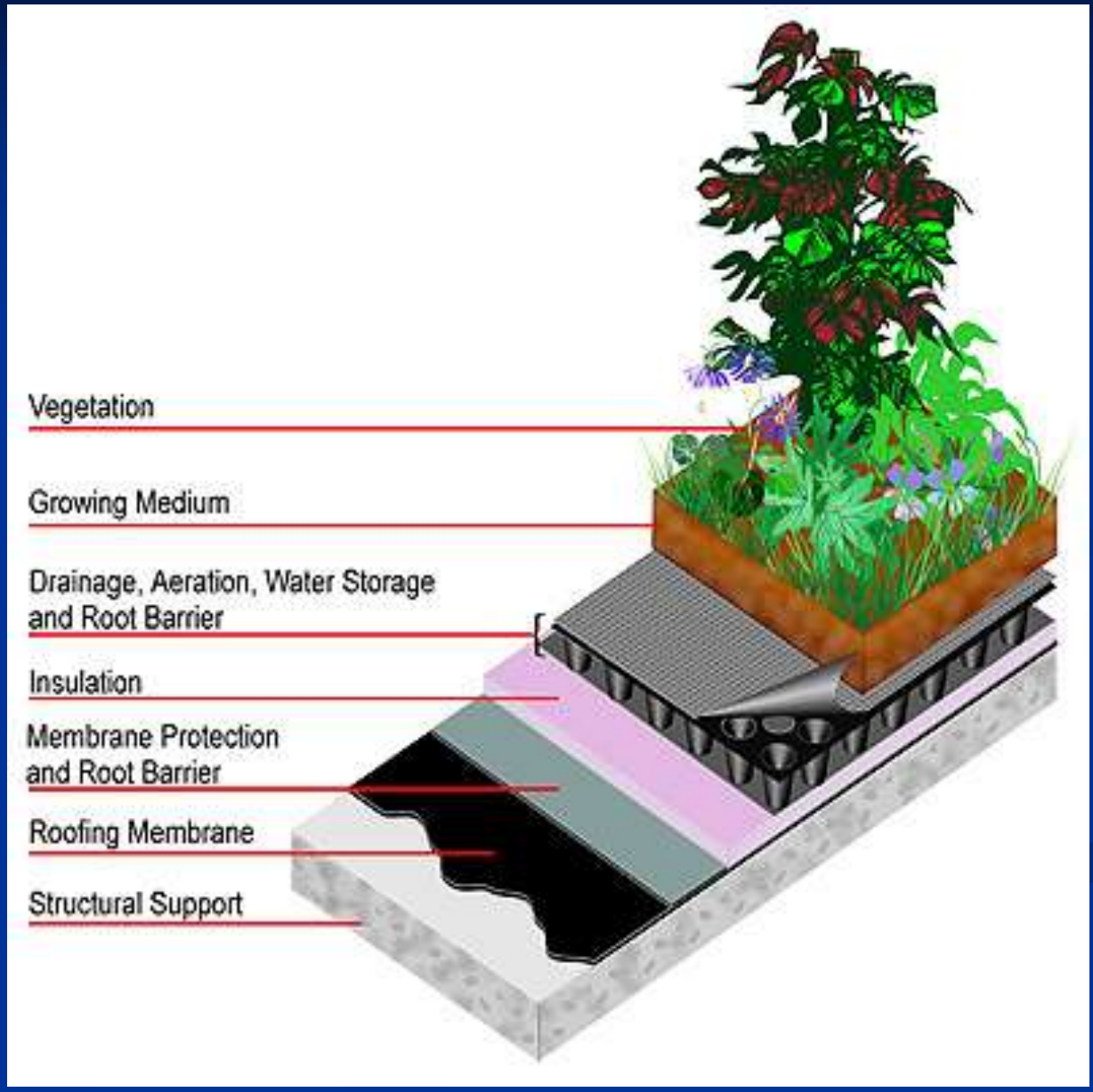
Extensive

Intensive

Intensive Roof

SC4 Extensive Roofs

Typical Cross Section



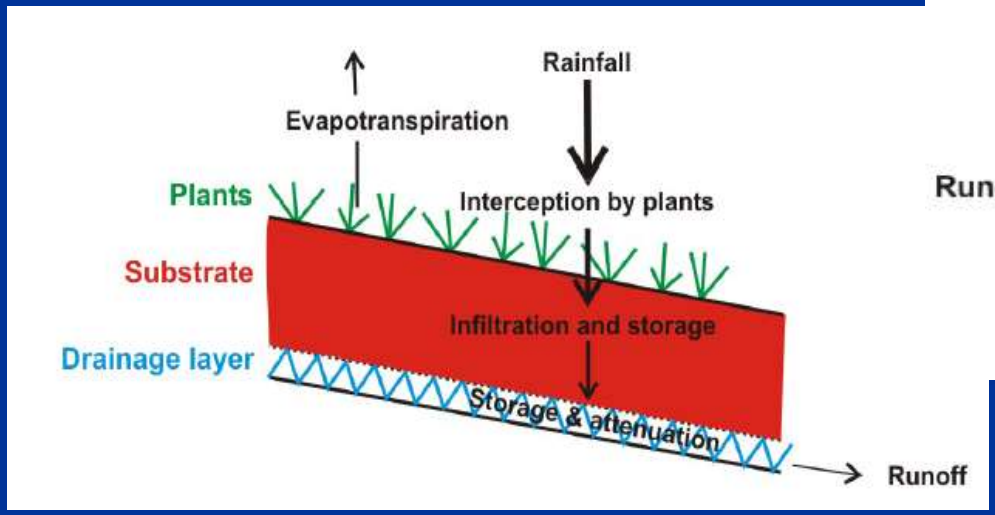
Vegetation

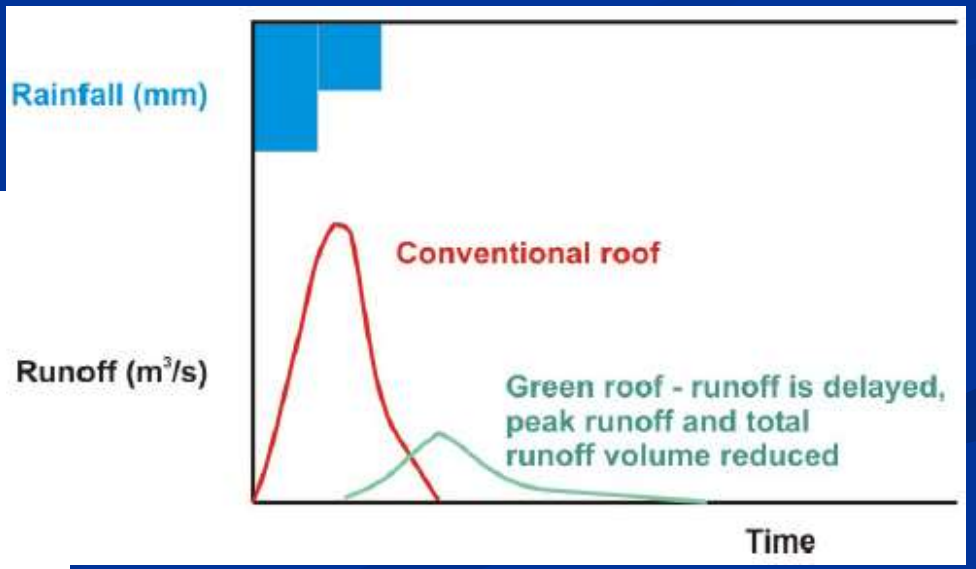
Comparing the Two Roofs

Characteristics	Intensive	Extensive
Soil	Typically one foot or more of soil depth	Requires only 1 to 5 inches of soil depth
Vegetation	Accommodates large trees, shrubs, and gardens	Various vegetative ground cover, sedums, and grasses
Load	Adds 80-150 pounds per square foot of load	Adds only 12-50 pounds per square foot
Access	Regular access accommodated & encouraged	Usually not designed for public accessibility
Maintenance	Significant maintenance required	Annual maintenance walks are performed
Drainage	Complex drainage systems	Simple drainage system

Vegetated Roof Performance

- Hydrologic response is diverse due to:
  - variation in the physical properties of the media
  - layered structure of the various proprietary systems
  - local climatic conditions





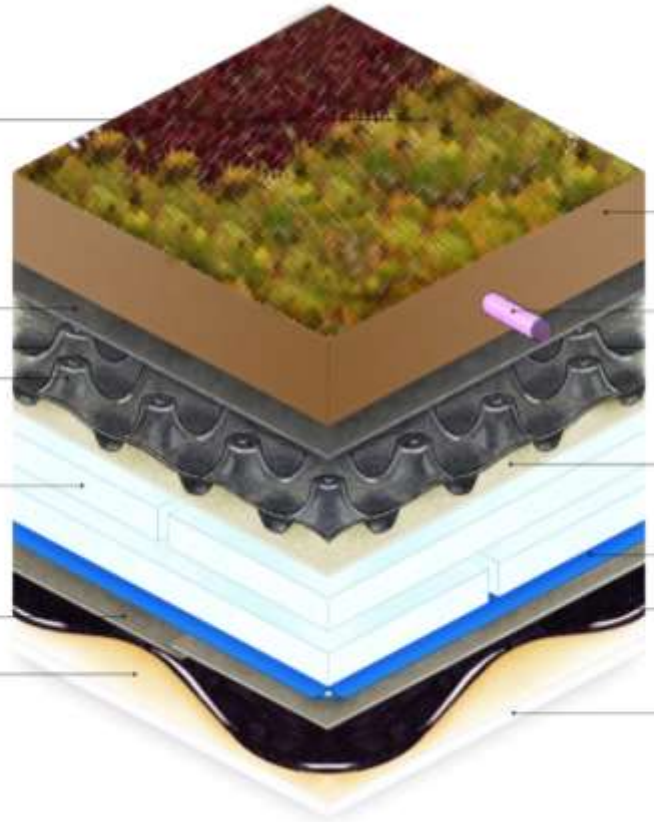
Vegetated Roof Design

- Many roof companies only report annual retention values – not helpful for storm design
- CN and C_v will vary for each storm – need site specific information or modeling
- Hydrologic modeling is preferred (and is an option for some proprietary systems)

Lawrence Tech Vegetated Roof

- 10,000 sq ft HydroTech Extensive Garden Roof Assembly
- Research project to determine effectiveness - water quality and quantity (USEPA and LTU COE).

HydroTech Garden Roof Cross-Section



DROUGHT TOLERANT PLANTS
INCLUDING SEDUM VARIETIES
& DIANTHUS

FILTER FABRIC

FLORADRAIN FD25

2 LAYERS OF 1 1/2"
POLYSTYRENE INSULATION

ROOF PROTECTION COURSE

PRIMER

4" EXPANDED SHALE BLEND
PLANTING MEDIUM

DRIP IRRIGATION TUBING
USED DURING INITIAL 2 SEASONS
OF PLANT ESTABLISHMENT

WATER RETENTION LAYER

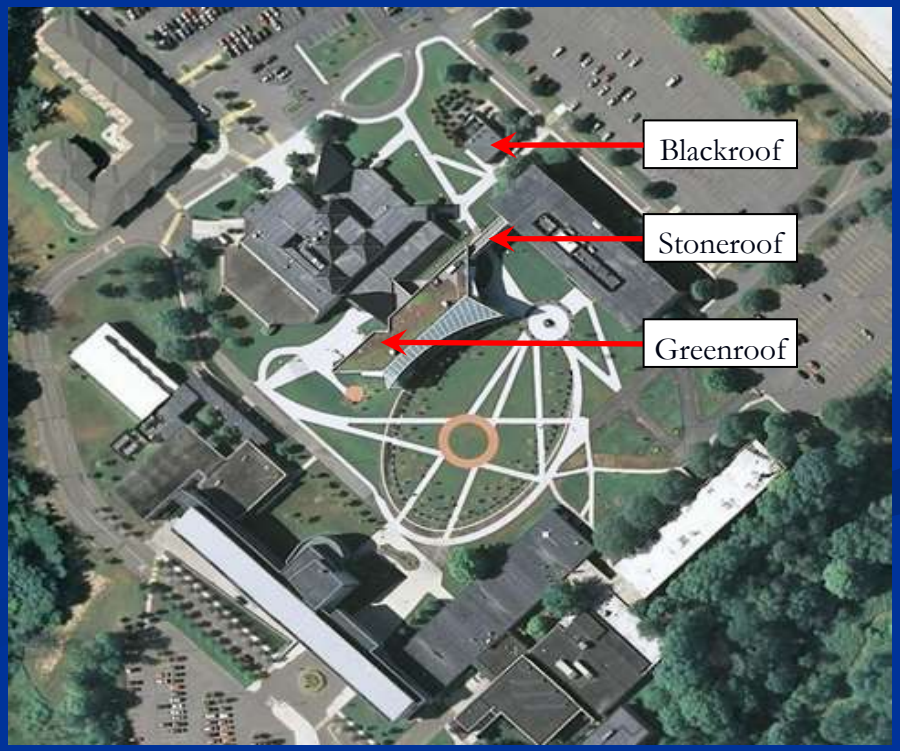
ROOT BARRIER

WATERPROOF ROOF MEMBRANE

ROOF DECK
- FIRE RATED GYPSUM DECK BOARD
- METAL DECK

Experimental Set-Up

- Performance monitoring equipment was set up on three full scale roof systems on campus:
  - 3496 sq ft section of HydroTech Extensive Garden Roof
  - 912 sq ft new rock ballast roof
  - 1647 sq ft existing asphalt roof

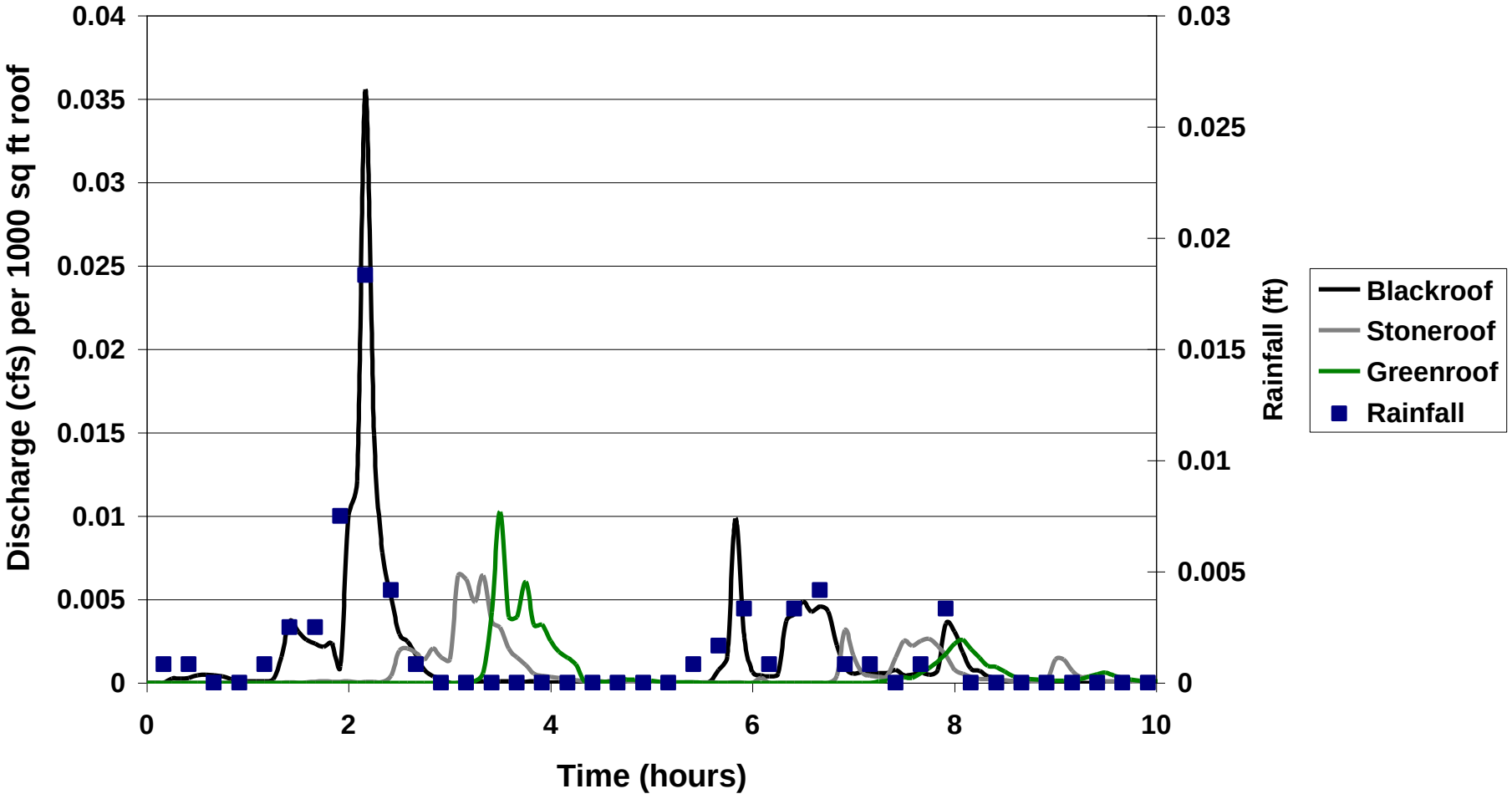


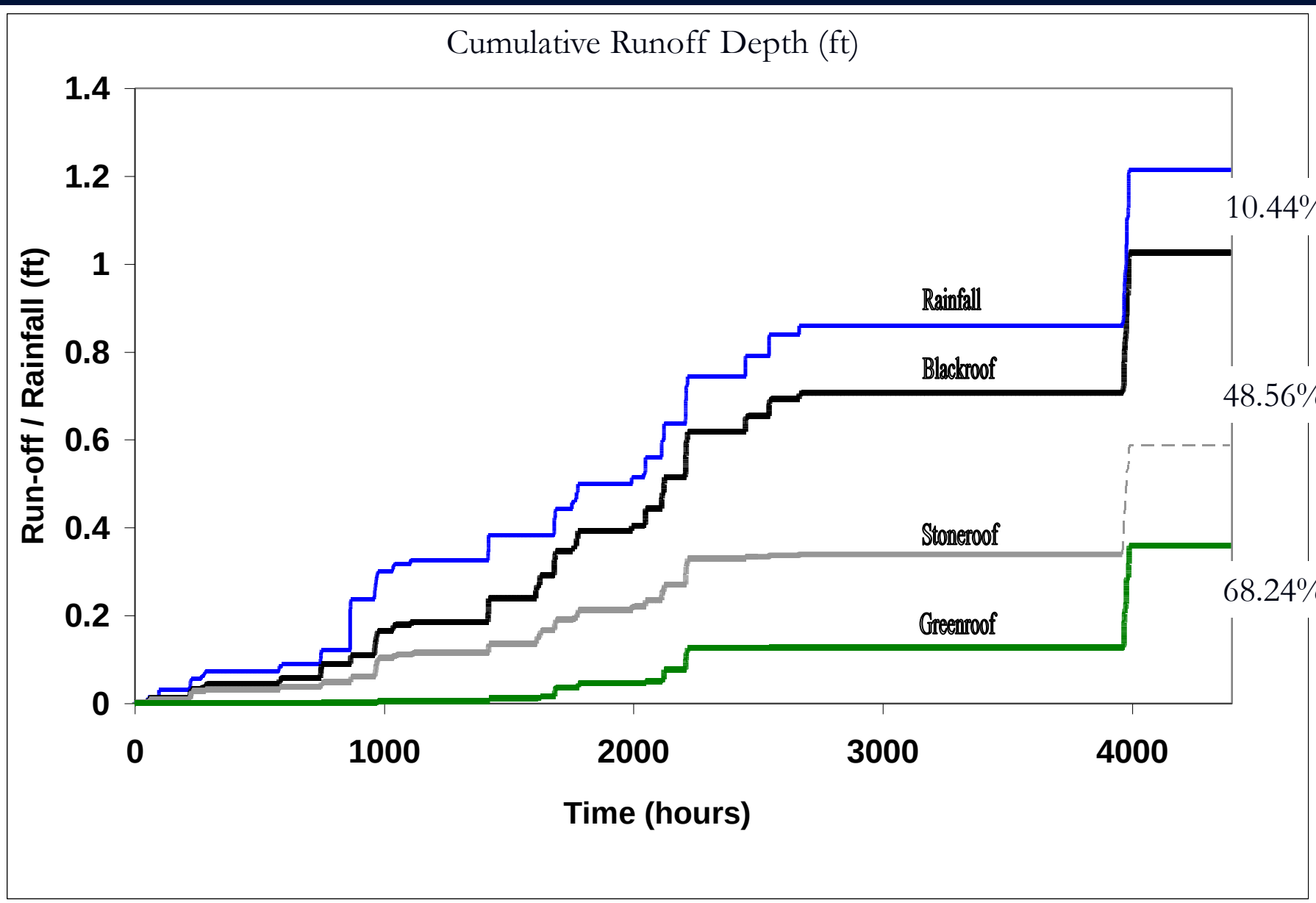
Monitoring Equipment

- Teledyne ISCO Avalanche Samplers
- Teledyne ISCO 730 Bubbler Flowmeter
- Teledyne ISCO 674 Rain Gauge
- 4" Palmer-Bowlus Flumes
- Microdaq USB Temperature sensors

Flow Monitoring Equipment

Normalized Hydrographs - June 10, 2008

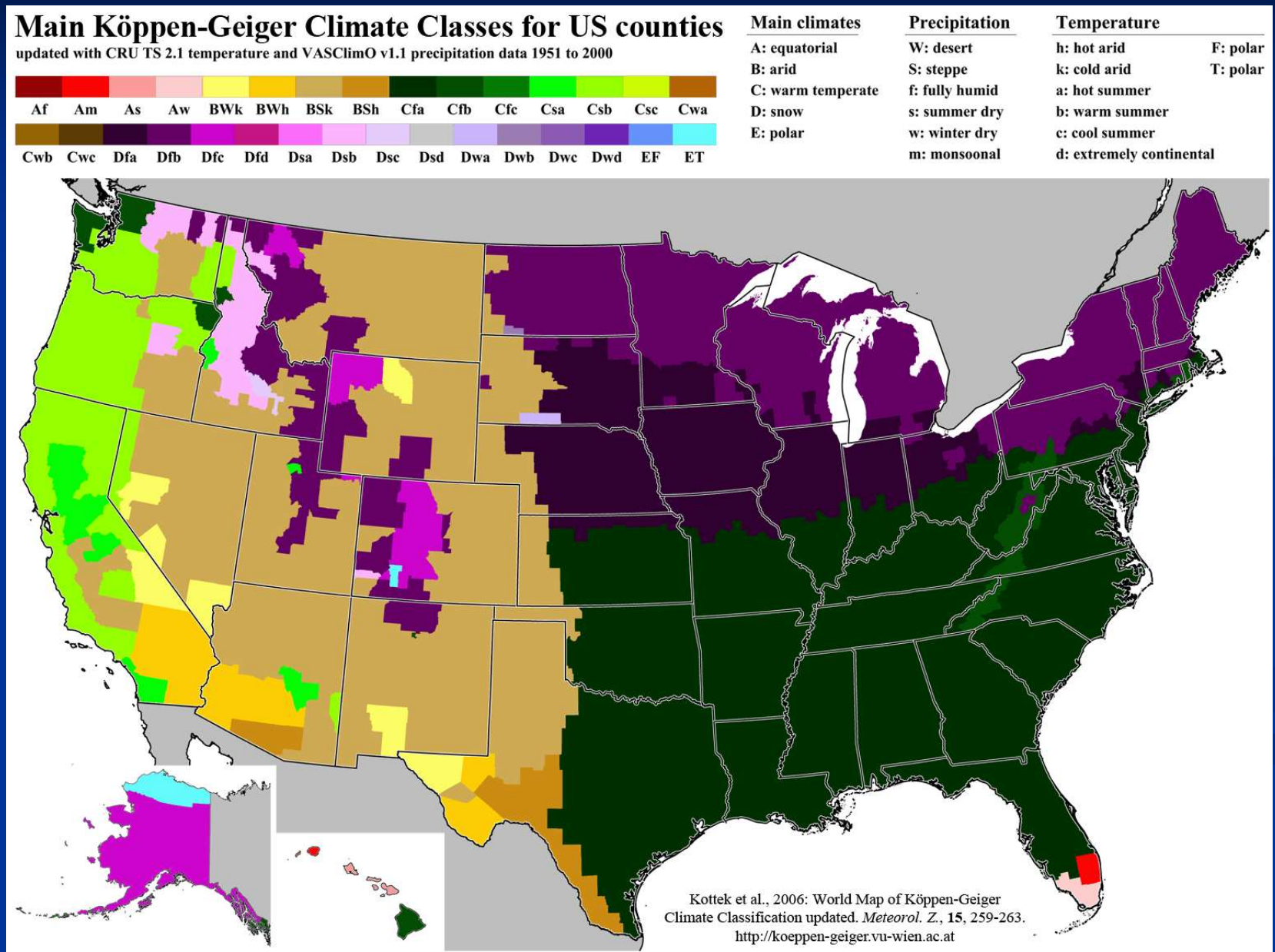



Cumulative Runoff Depth (ft)
Run-off / Rainfall (ft)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1000
2000
3000
4000
Time (hours)
Rainfall
Blackroof
Stoneroof
Greenroof
10.44%
48.56%
68.24%

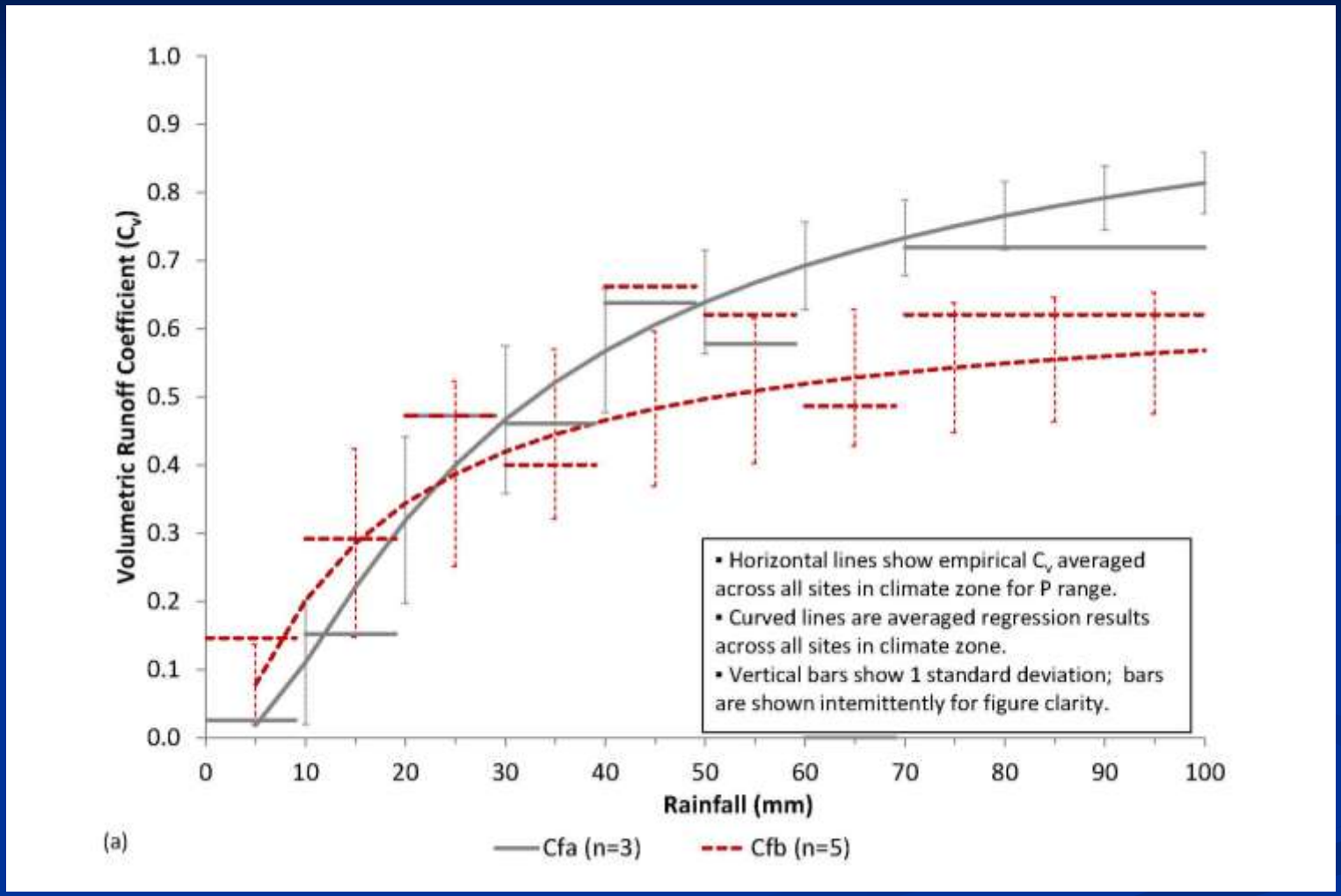
ASCE Green Roof TC

- "Curve Number and Runoff Coefficients for Extensive Living Roofs" by Elizabeth Fassman-Beck, William Hunt, Donald D. Carpenter, Robert Berghage, Timothy Kurtz, Virginia Stovin, and Bridget Wadzuk
  - Journal of Hydrologic Engineering (2015)
- Meta-analysis of 21 sites in five countries
  - Brownstown and Lawrence Tech

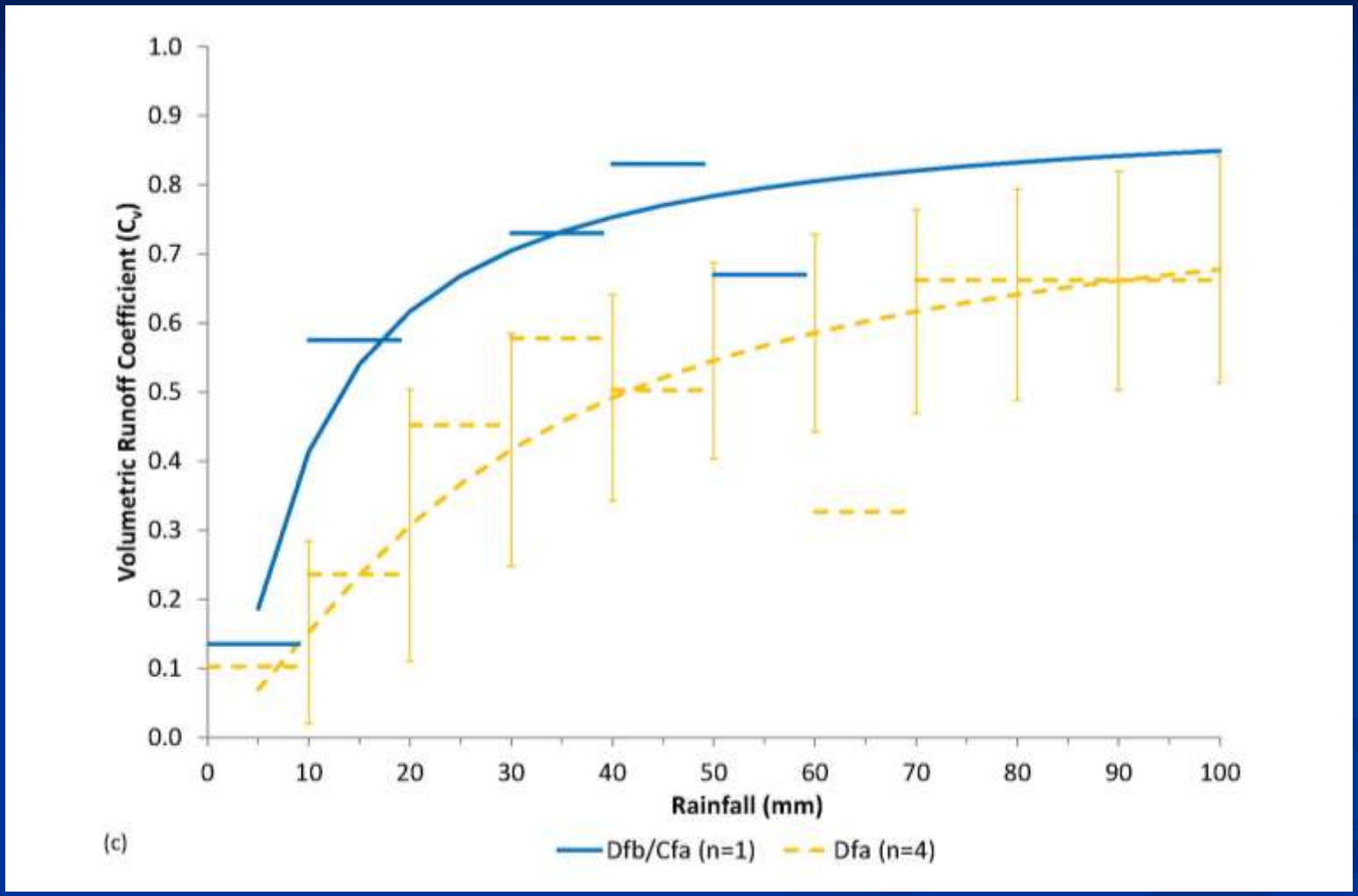
Climate Classification



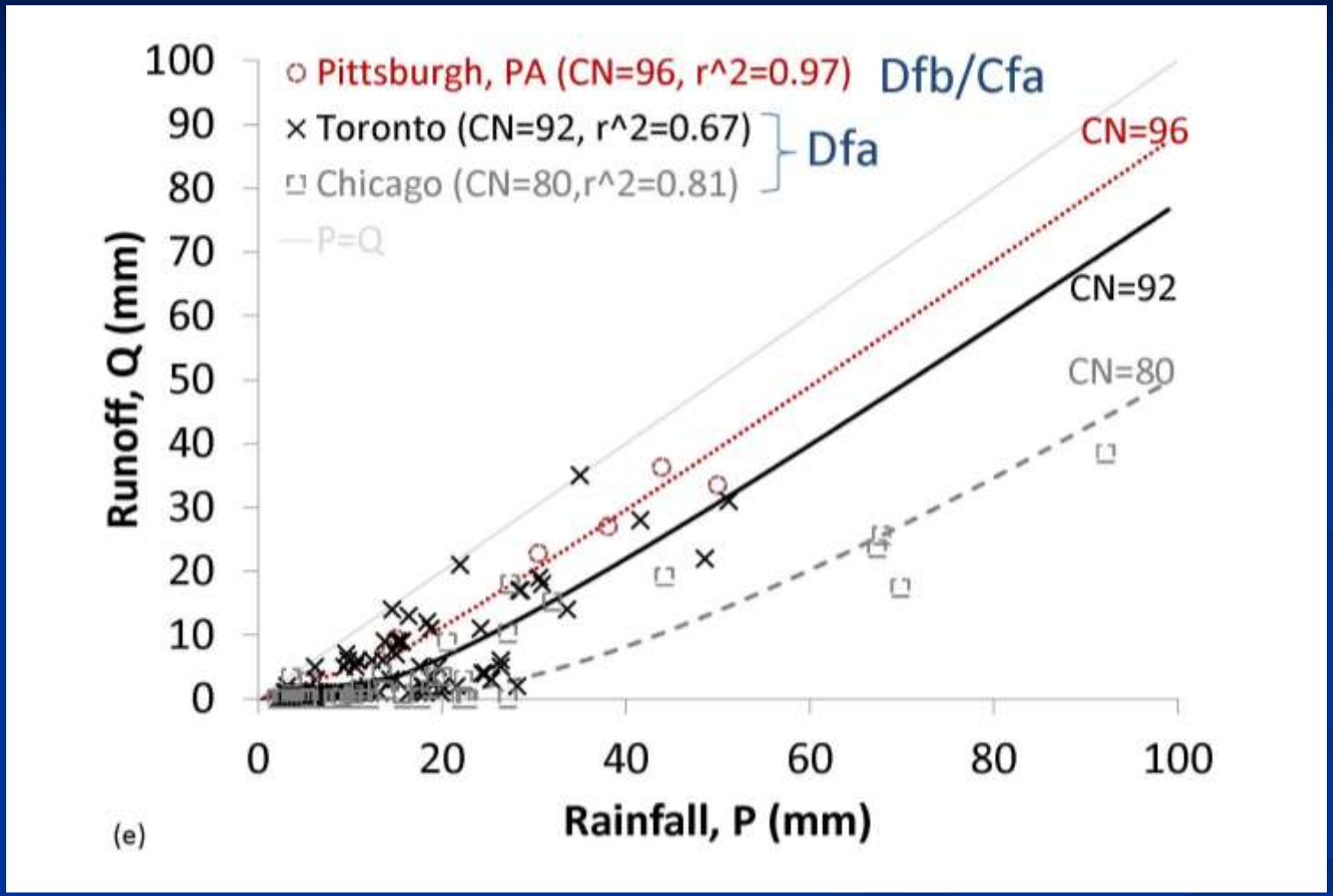
Cv – Warm Temperate Climates



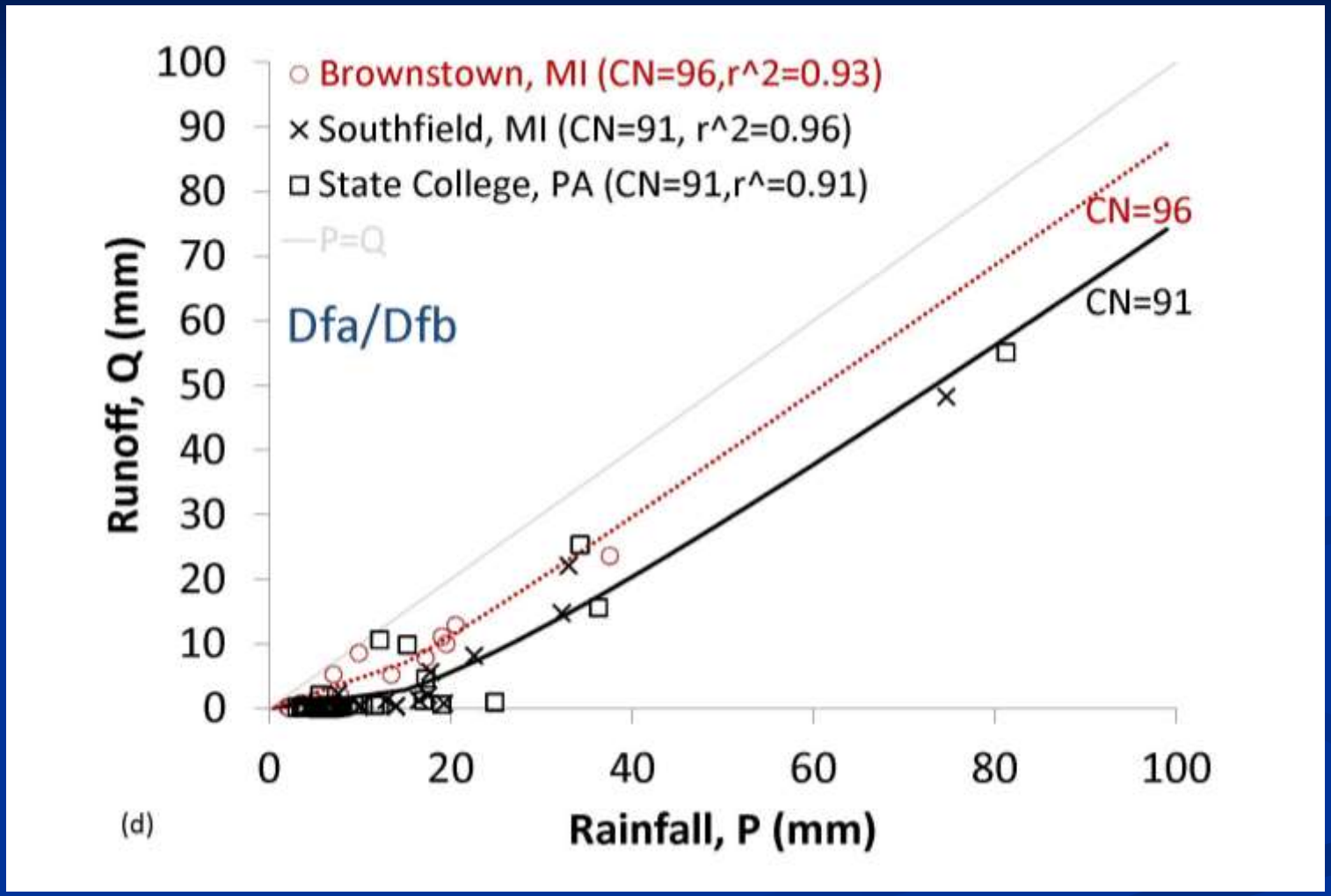
Cv – Snow/Humid Hot Summer



CN – Regional


Pittsburgh, PA (CN=96, r^2=0.97)
Toronto (CN=92, r^2=0.67)
Chicago (CN=80,r^2=0.81)
P=Q
Dfb/Cfa
Dfa
CN=96
CN=92
CN=80
Runoff, Q (mm)
Rainfall, P (mm)
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
(e)

CN – Regional

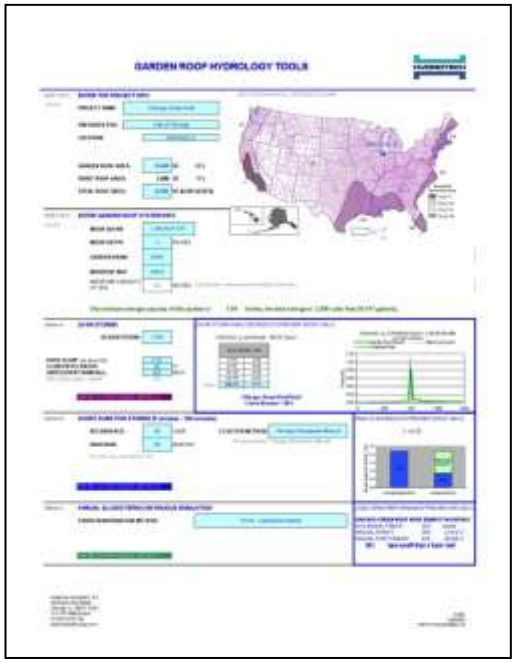

Brownstown, MI (CN=96,r^2=0.93)
Southfield, MI (CN=91, r^2=0.96)
State College, PA (CN=91,r^=0.91)
P=Q
Dfa/Dfb
CN=96
CN=91
Runoff, Q (mm)
Rainfall, P (mm)
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
(d)

Extensive Vegetated Roofs Design Parameters

- Recommend Modeling for Performance BUT…
- Runoff Volume Coefficient
  - $0 < Cv < 0.8$
- Curve Numbers
  - CN = 85 for events greater than moisture holding capacity (ASCE Green Roof TC)
  - CN = 65 for rain events 3 x's depth of media (MI LID Manual)
  - CN > 90 for several regional vegetated roofs

HydroTech Hydrology Tool (HHT)

- Manufacturer specific calculation
- Utilizes known performance of HydroTech specific green roof materials
  - Lawrence Tech was one of many monitoring programs used to calibrate the HHT



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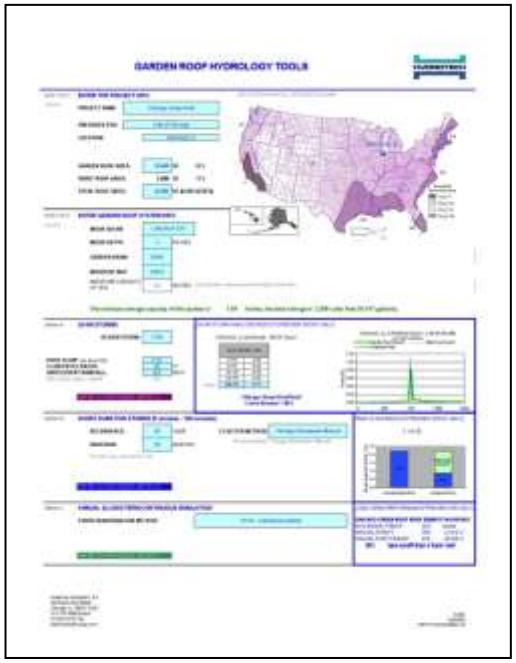
DESIGNING | BUILDING | GROWING

HydroTech Hydrology Tool (HHT)

- **24 hour storm event evaluations**
  - How much water is retained within the Garden Roof Assembly?
- **Short duration storms events (Rational Method)**
  - How fast water is leaving the roof?
- **Long term storm evaluations**
  - How much water is leaving roof over a season?
- **Establish LEED compliance**
  - Does the roof help the projects LEED goals?



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Summary

- Vegetated roof systems must be designed according to local climatic conditions.
- Performance expectations must be based on vegetated roof system and the climatic conditions for which published performance data was collected.
- Important to understand performance in the region of application and preferably from full-scale monitoring or performance modeling results.


Thanks!
Questions?
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http://www.ltu.edu/water/