LID Design for SW Management

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Lawrence Tech University

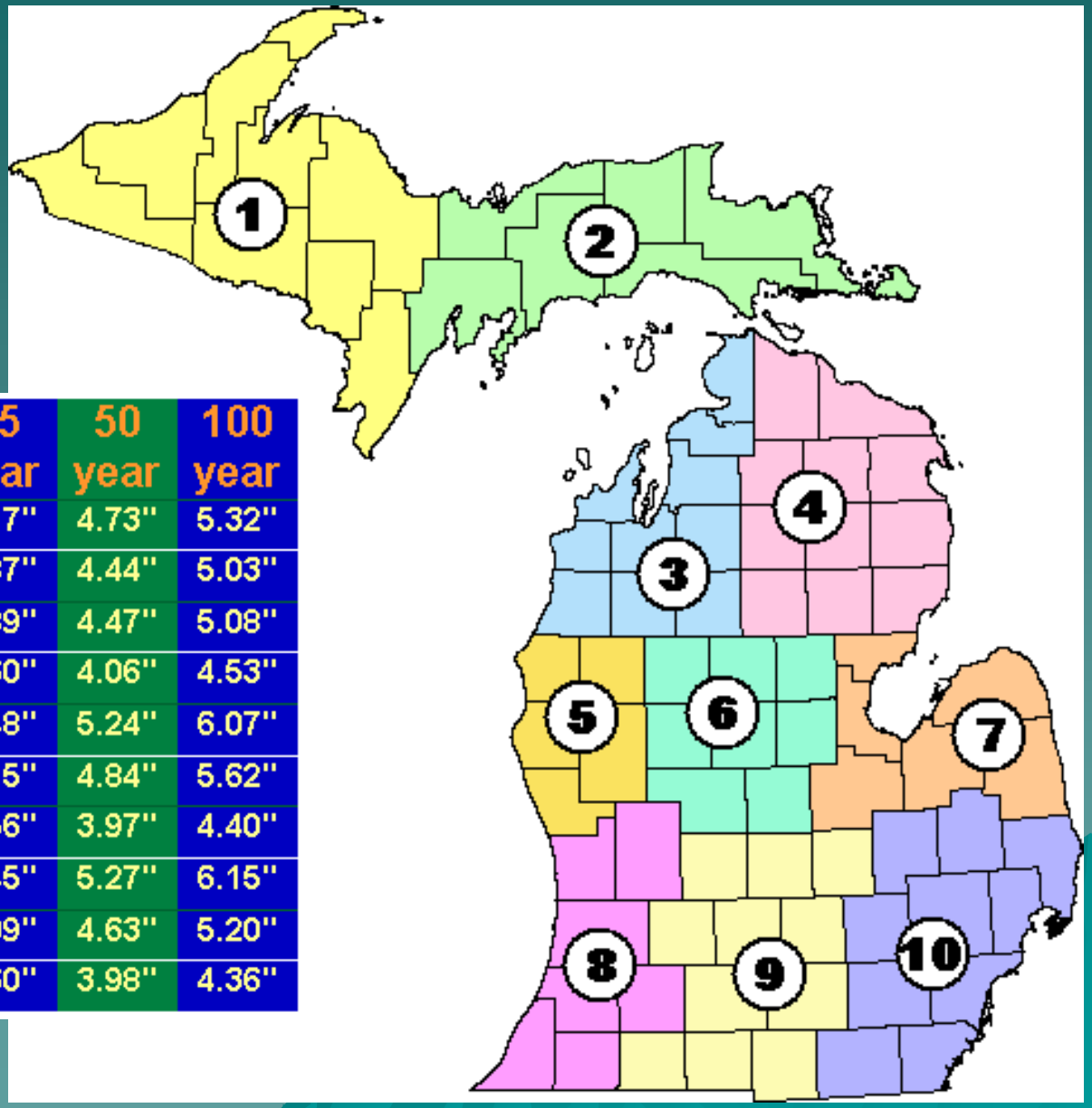
Overview

- Intro to LID Hydrologic Principles
- LID Modeling and Design Concepts
- Applied to Example BMPs
  - Vegetated Roofs
  - Porous Pavement
  - Bioretention (time pending)

Twenty Four Hour Rainfall

Rainfall Frequency Atlas of the Midwest, Bulletin 71, Midwestern Climate Center, 1992

Section	2 year	5 year	10 year	25 year	50 year	100 year
1	2.39"	3.00"	3.48"	4.17"	4.73"	5.32"
2	2.09"	2.71"	3.19"	3.87"	4.44"	5.03"
3	2.09"	2.70"	3.21"	3.89"	4.47"	5.08"
4	2.11"	2.62"	3.04"	3.60"	4.06"	4.53"
5	2.28"	3.00"	3.60"	4.48"	5.24"	6.07"
6	2.27"	2.85"	3.34"	4.15"	4.84"	5.62"
7	2.14"	2.65"	3.05"	3.56"	3.97"	4.40"
8	2.37"	3.00"	3.52"	4.45"	5.27"	6.15"
9	2.42"	2.98"	3.43"	4.09"	4.63"	5.20"
10	2.26"	2.75"	3.13"	3.60"	3.98"	4.36"



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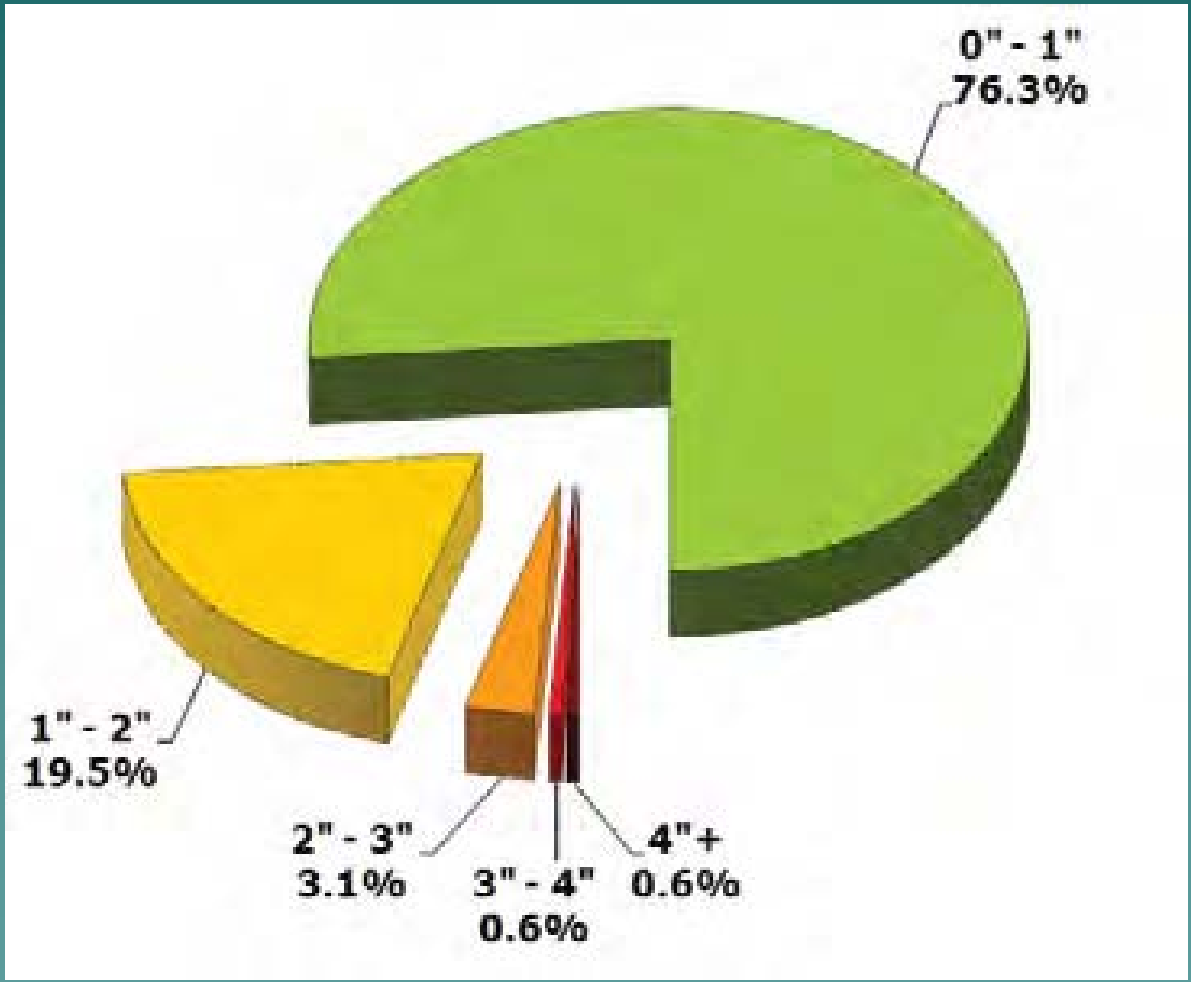
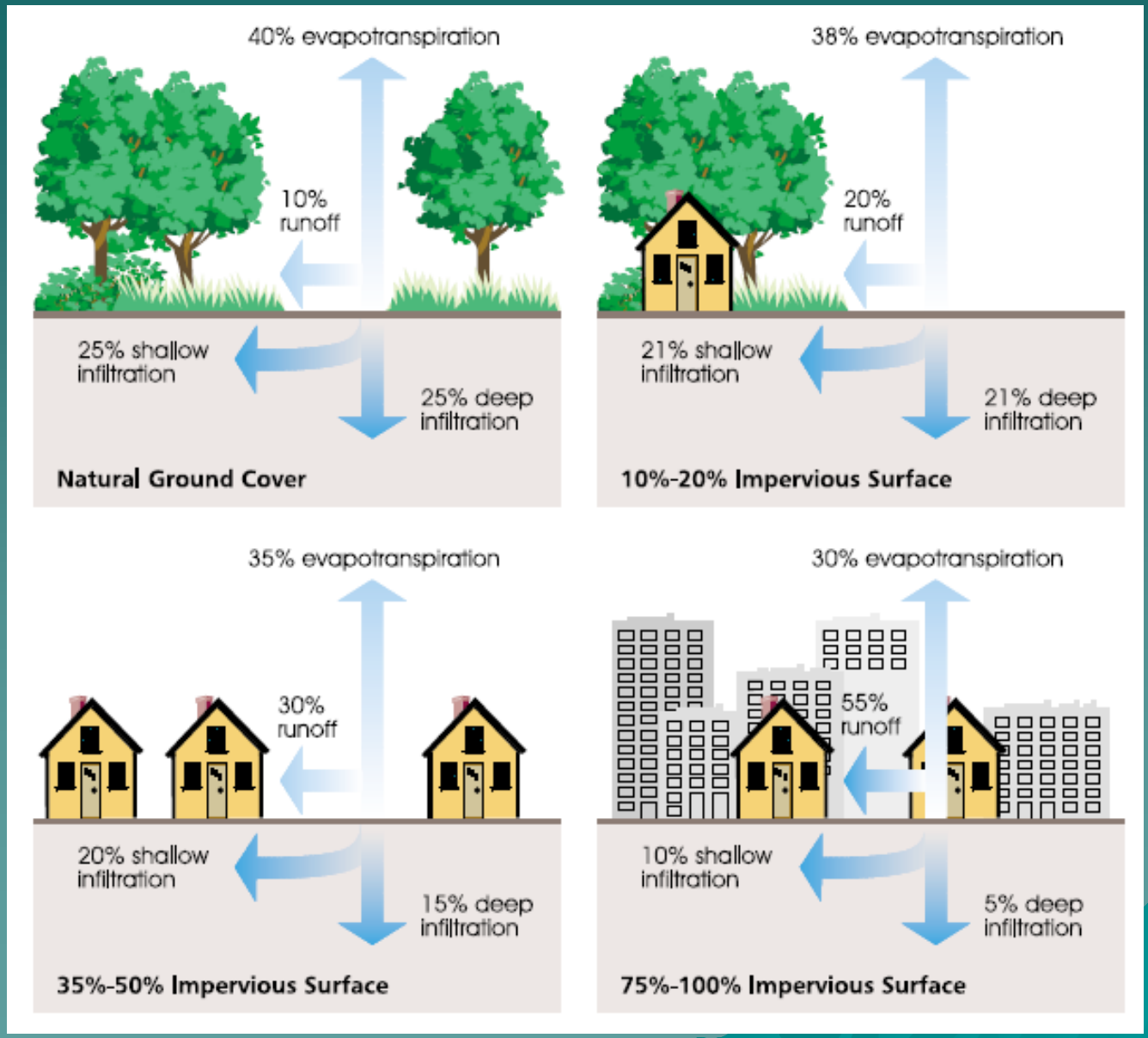
Rainfall Amount Frequency



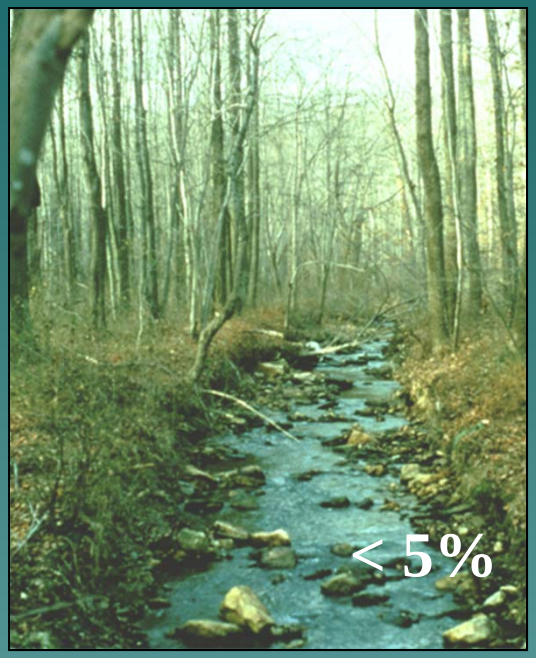
Site Hydrology



FISRWG

Urban Flooding

Stream Condition Related to Impervious Cover



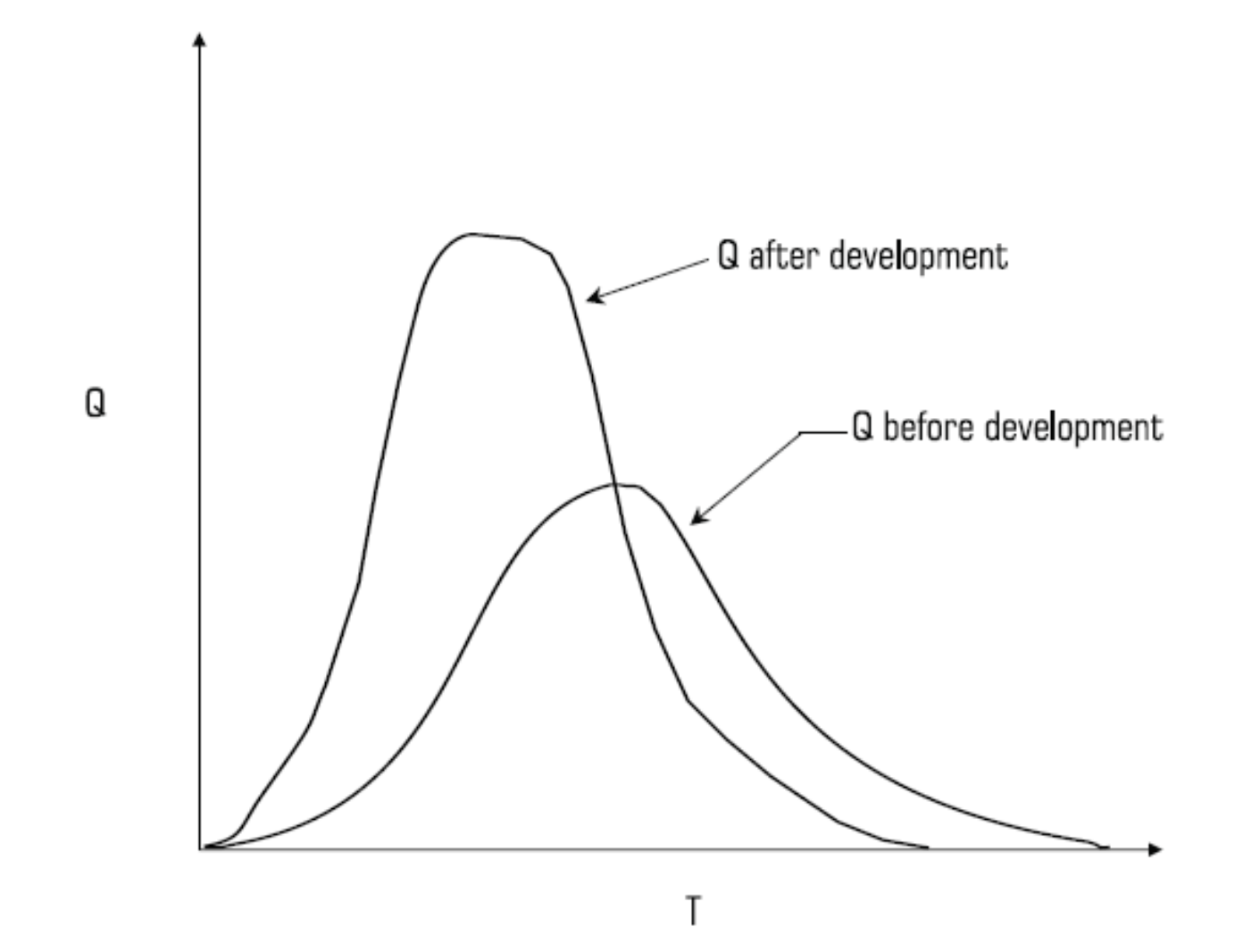
Impervious Cover

Pollutants in Urban Runoff

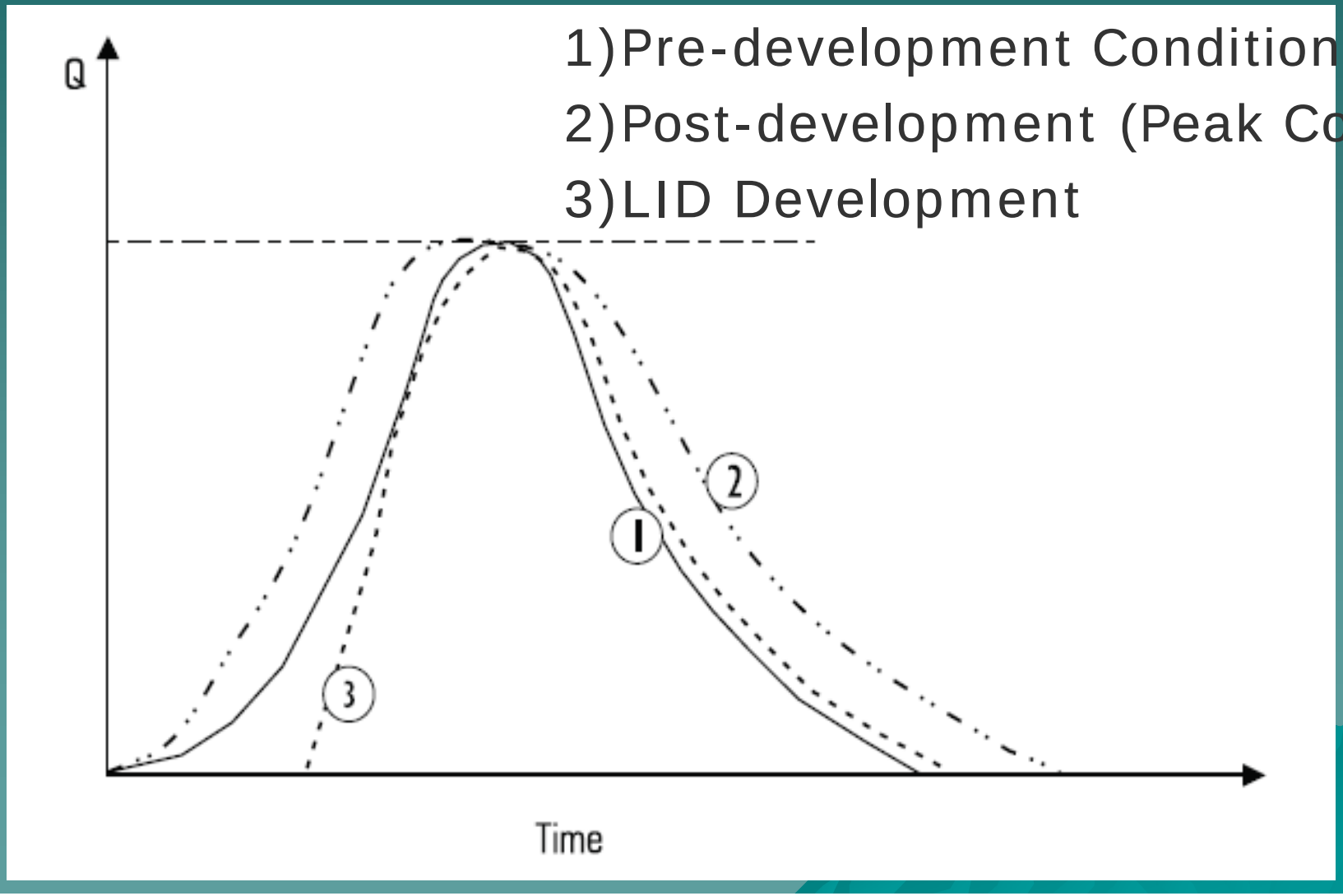
- Suspended Sediment
- Nutrients (phosphoru gen)
- Pesticides/herbici
- Heavy Metals
- Hydrocarb soline/grease)
- Bacteri
- Tras
- S

Non-Point Source Pollution

Site Runoff Hydrograph



LID Site Runoff

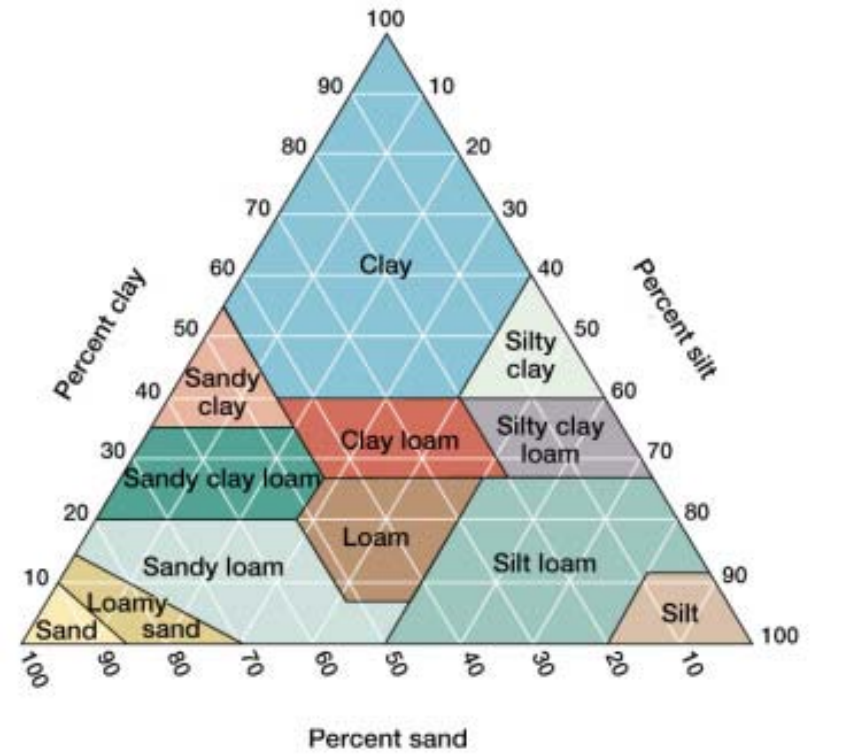


Runoff Factors

- Rainfall
- Land Use Cover
- Soil Type & Condition

Hydrologic Soil Groups

Soil Group	Soil Type	Drainage Capacity
A	sand, loamy sand, sandy loam	very well drained and highly permeable
B	silt loam, loam	good
C	sandy clay loam	fair
D	clay loam, silty clay loam, sandy clay, silty clay, clay	poorly drained and generally situated in a valley bottom or floodplain



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HSG	Infiltration Rate (in/hr)
A	2.0+
B	0.5
C	0.2
D	<0.1

“A” Soils

Photos courtesy of Steven Trinkaus, Trinkaus Engineering, LLC

“B” and “C” Soils

Photos courtesy of Steven Trinkaus, Trinkaus Engineering, LLC

“D” Soils

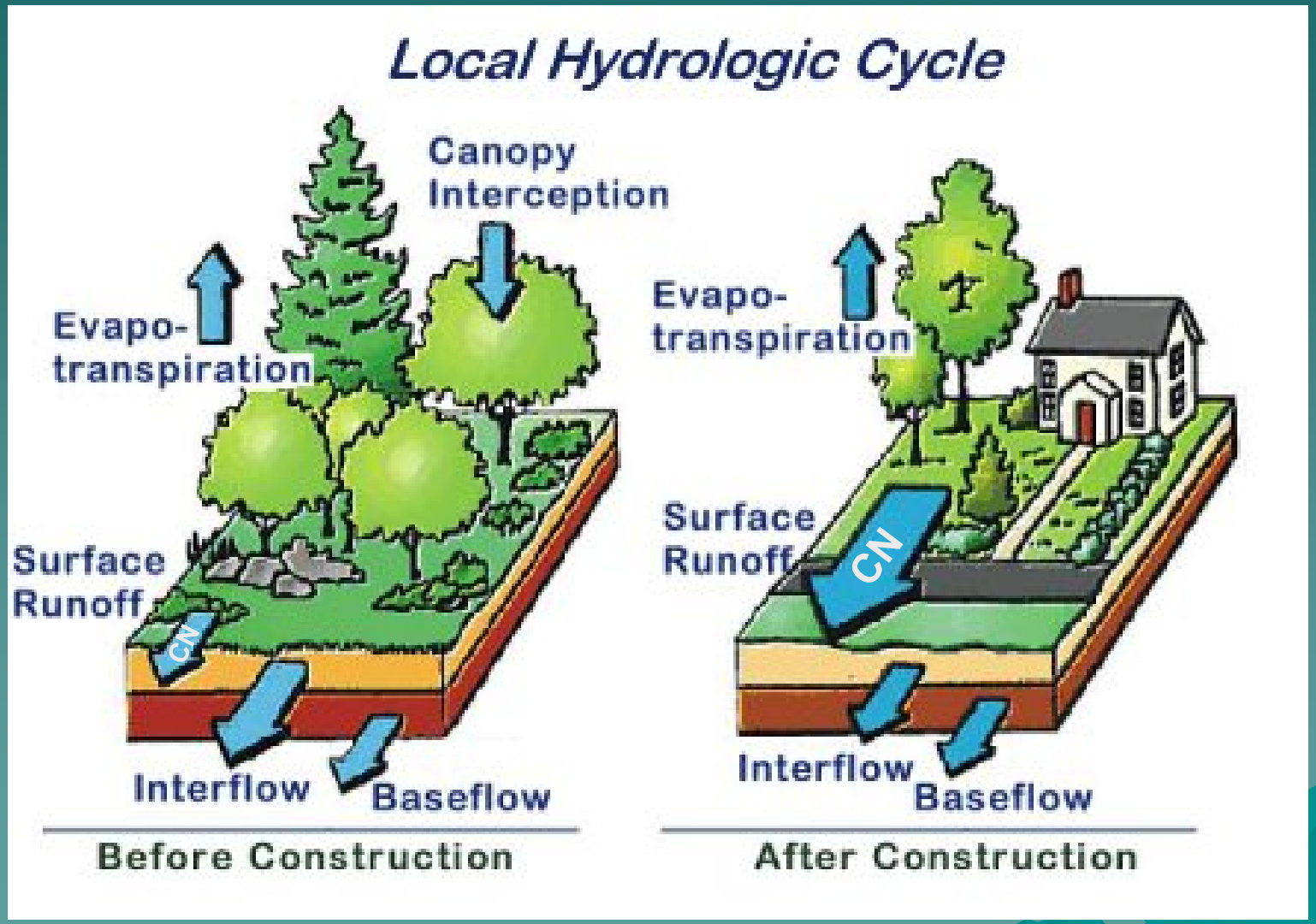
Photos courtesy of Steven Trinkaus, Trinkaus Engineering, LLC

Hydrologic Modeling Tools

Method	Hydrologic/Hydraulic Analysis	Acceptance
Rational Method	Event Based (Q_{peak} only) Simple Hydrology/Hydraulics Easy to Apply	Widely accepted by regulators for small sites.
Small Storm Hydrology Method (SSHM)	Event Based (Volume only) Simple Hydrology/Hydraulics Easy to Apply	Marginally accepted by regulators for small sites and small storms.
NRCS Curve Number (CN) Method	Event Based Moderate Hydrology/Hydraulics Easy to Apply	Widely accepted by regulators.
TR-55	Event Based Moderate Hydrology/Hydraulics Moderate to Apply	Widely accepted by regulators.
Source Loading and Management Model (SLAMM)	Continuous Simulation Complex Hydrology/Hydraulics Complex to Apply	Occasionally accepted by regulators.
Stormwater Management Model (SWMM) v.5	Continuous Simulation Complex Hydrology/Hydraulics Complex to Apply	Widely accepted by regulators
Western Washington Hydrology Model (WWHM v.3)	Continuous Simulation Complex Hydrology/Hydraulics Moderate to Apply	Locally accepted by regulators in WA.
Recarga Model	Continuous Simulation Moderate Hydrology/Hydraulics Moderate to Apply	Locally accepted by regulators in WI.

Runoff Curve Number (CN)

- Developed by the Natural Resource Conservation Service (NRCS)
- Based on land cover and soil type
- Commonly used as the rainfall to runoff transformation for small watershed hydrology
- Development and urbanization increases CN value thereby increasing runoff


Local Hydrologic Cycle
Canopy Interception
Evapo-transpiration
Surface Runoff
CN
Interflow
Baseflow
Before Construction
Evapo-transpiration
Surface Runoff
CN
Interflow
Baseflow
After Construction

Reznick

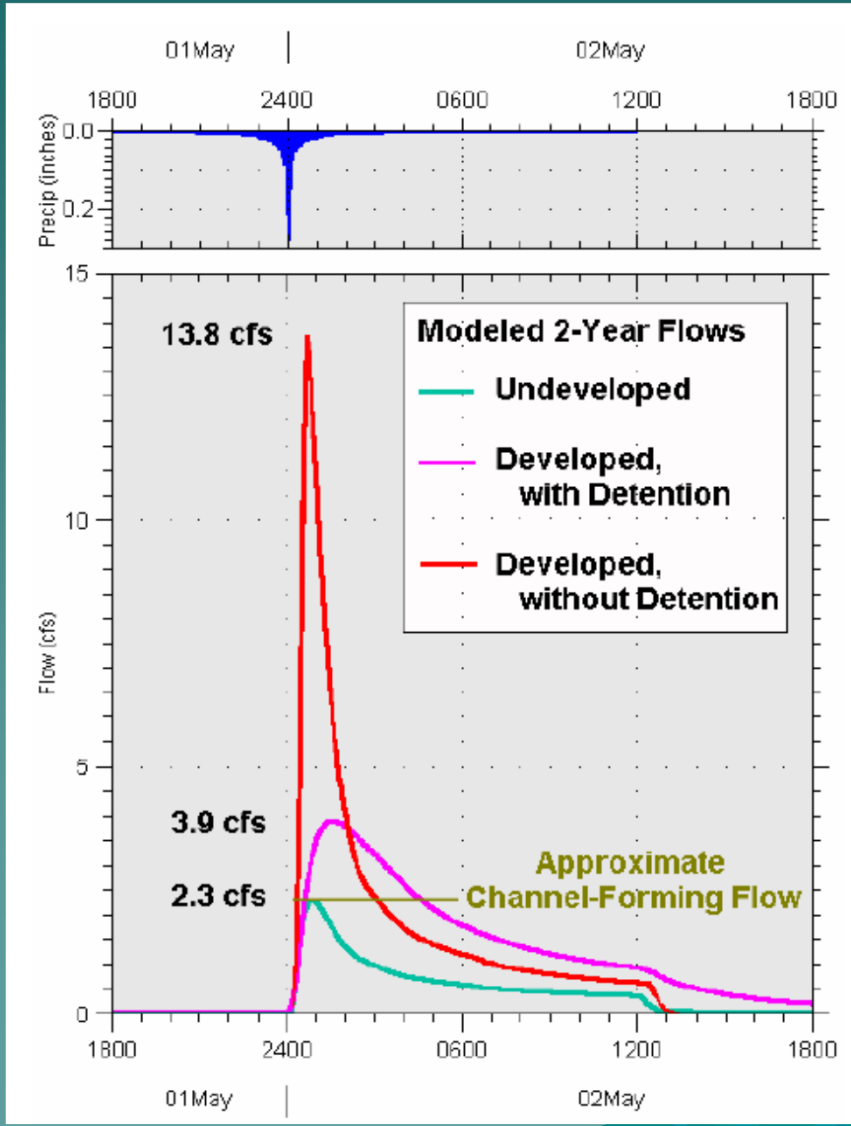
Curve Numbers

	Hydrologic Soil Group			
	A	B	C	D
Meadow	30	58	71	78
Woods (Fair)	36	60	73	79
Park/Golf Course	39	61	74	80
¼ Ac. Residential	61	75	83	87
Paved Surface	98	98	98	98

Runoff from 2” Storm

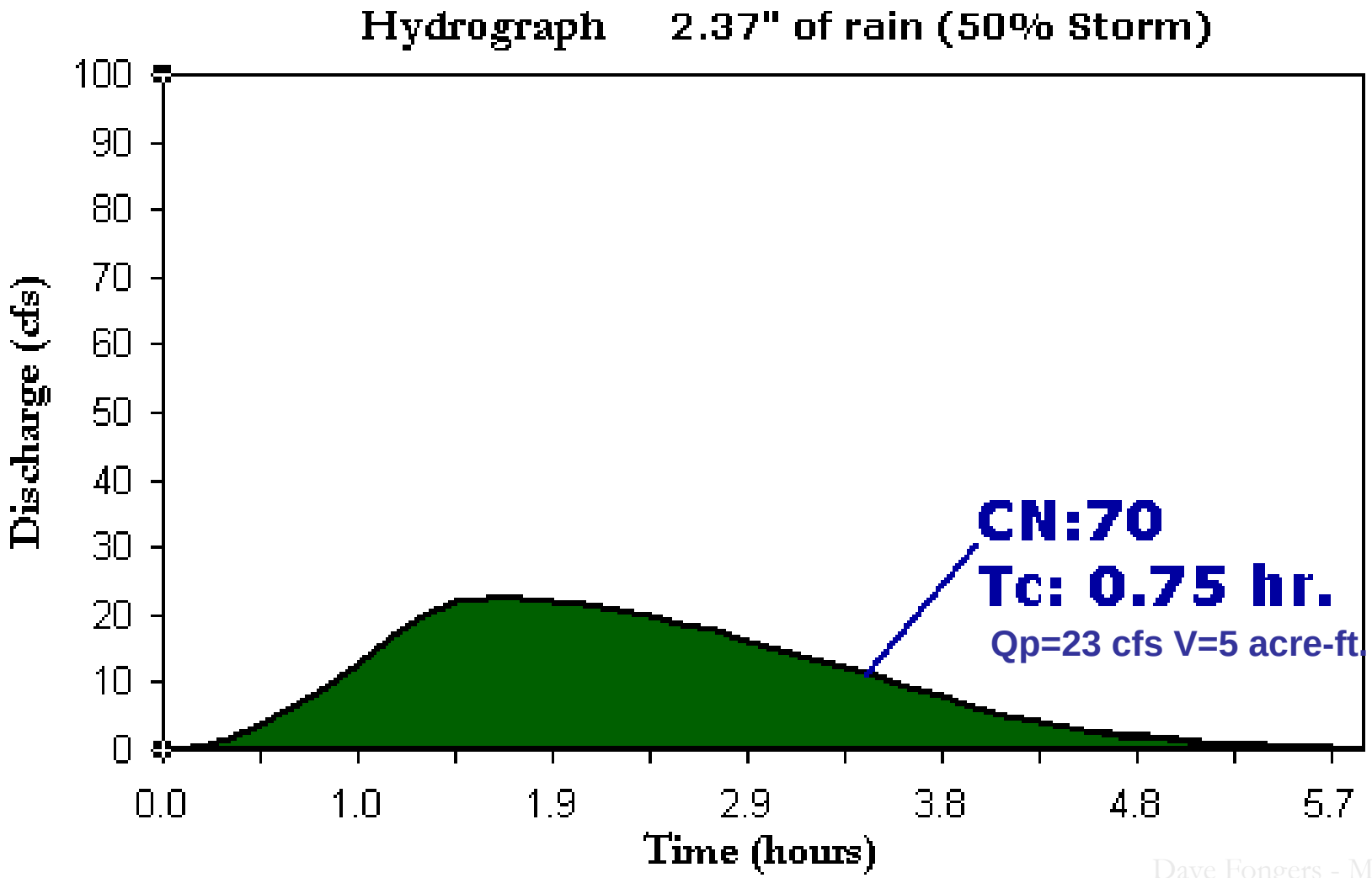
	Hydrologic Soil Group			
	A	B	C	D
Meadow	0.0”	0.0”	0.3”	0.5”
Woods	0.0”	0.0”	0.2”	0.4”
Park/Golf Course	0.0”	0.1”	0.3”	0.6”
¼ Ac. Residential	0.1”	0.4”	0.7”	0.9”
~~Paved Surface~~	~~1.8”~~	~~1.8”~~	~~1.8”~~	~~1.8”~~

Model Hydrograph Results



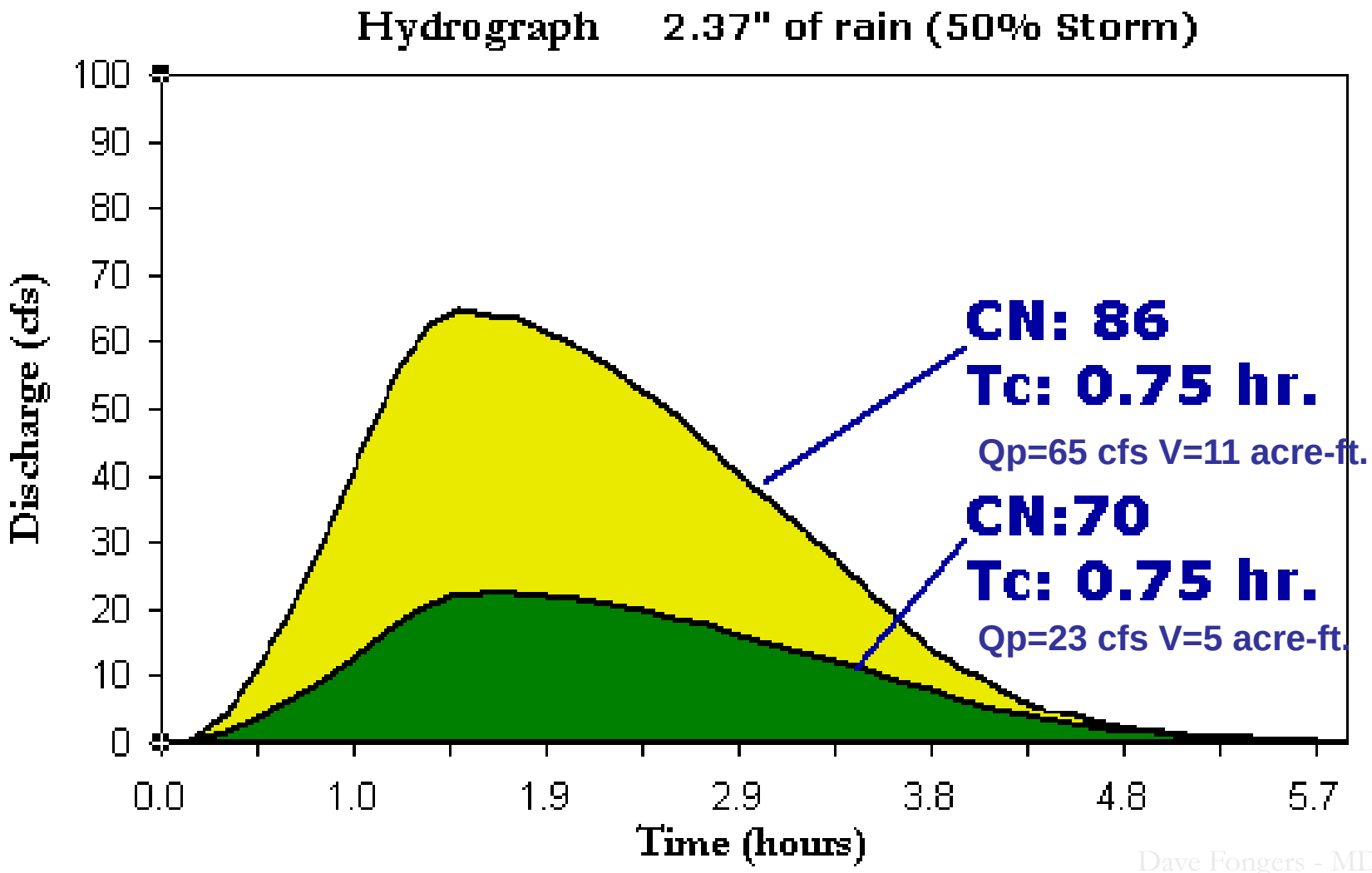
Reznick

Woods on C Soils or Farm on B Soils



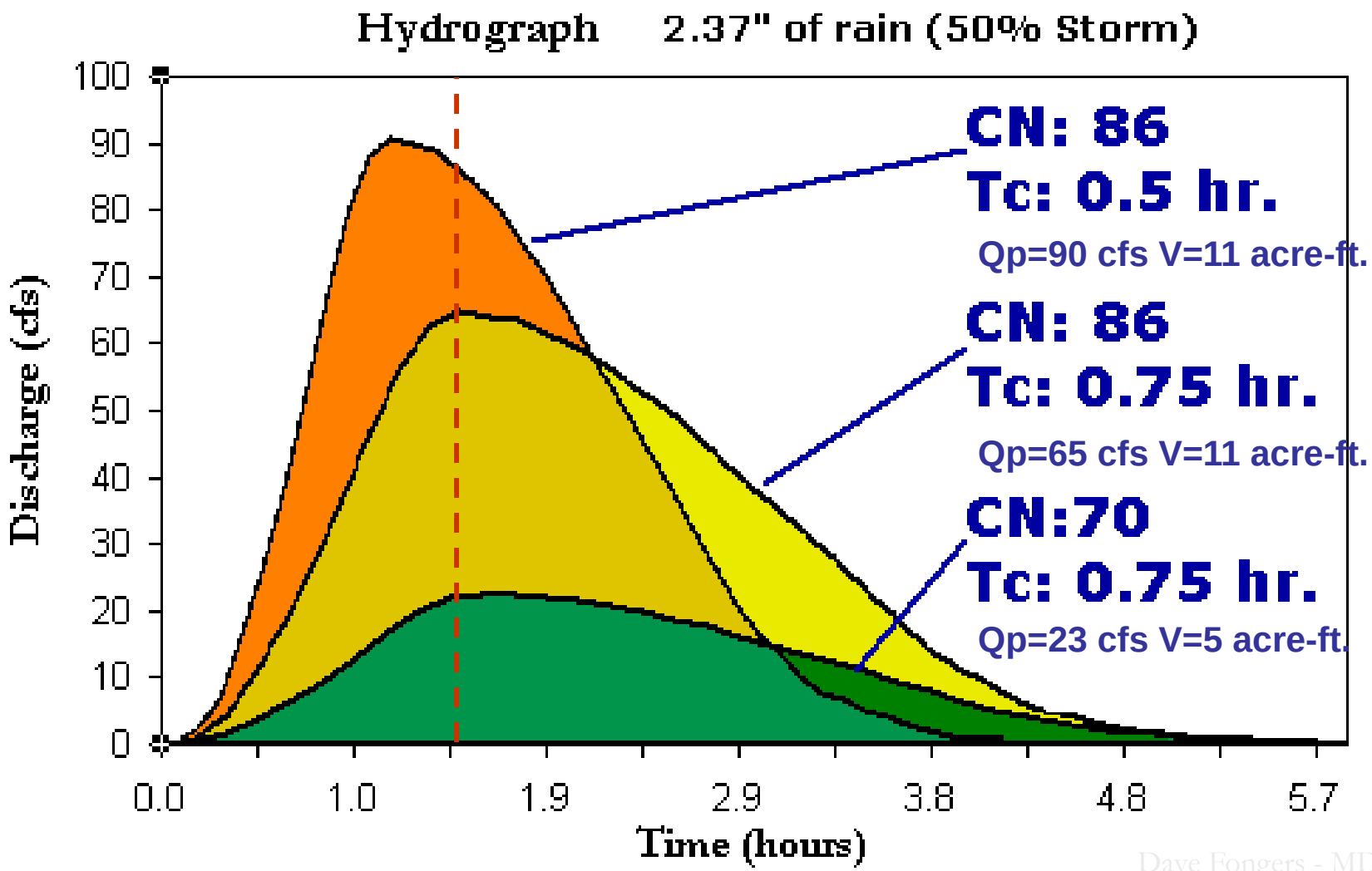
Dave Fongers - MDEQ

Development



Dave Fongers - MDEQ

Development with lower Tc



T_c (Time of Concentration)

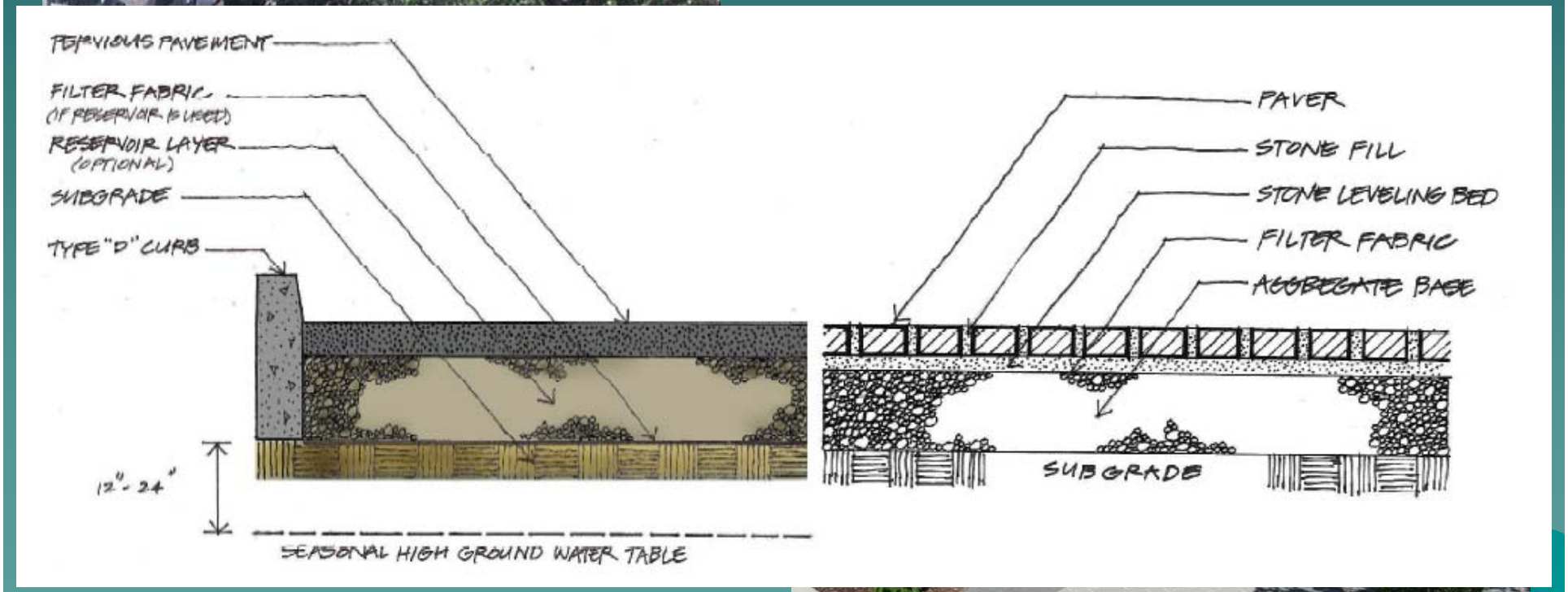
- Runoff travel time from the hydraulically most distant point of the watershed to the "outlet")
- Influences the shape and peak of runoff hydrograph
- Development usually decreases T_c
  - thereby increasing the peak runoff
- Goal is to match T_c and CN

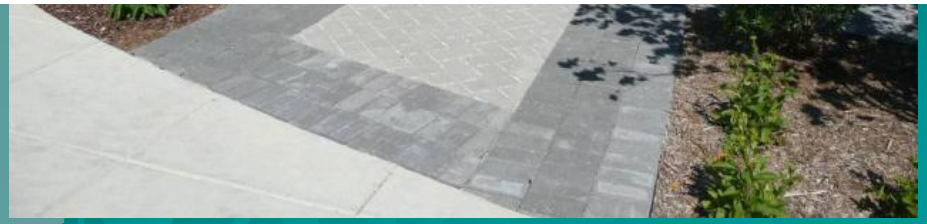
Hydrologic Principles for LID

- Groundwater Recharge Volume
  - Annual pre-development recharge rate for site specific soils, rainfall, and natural cover
- Water Quality Protection
  - Protect quality of watersheds
  - “First flush”, 1” rainfall, 0.5” run-off, 90% exceedence, etc.
- Channel Protection
  - Protect channel morphology and stability
  - Bankfull condition, 1.5-yr 24-hour event, etc.
- Flood Protection
  - Protect life and property from extreme events
  - 10-year to 100-year volume control
  - Focus on peak discharge

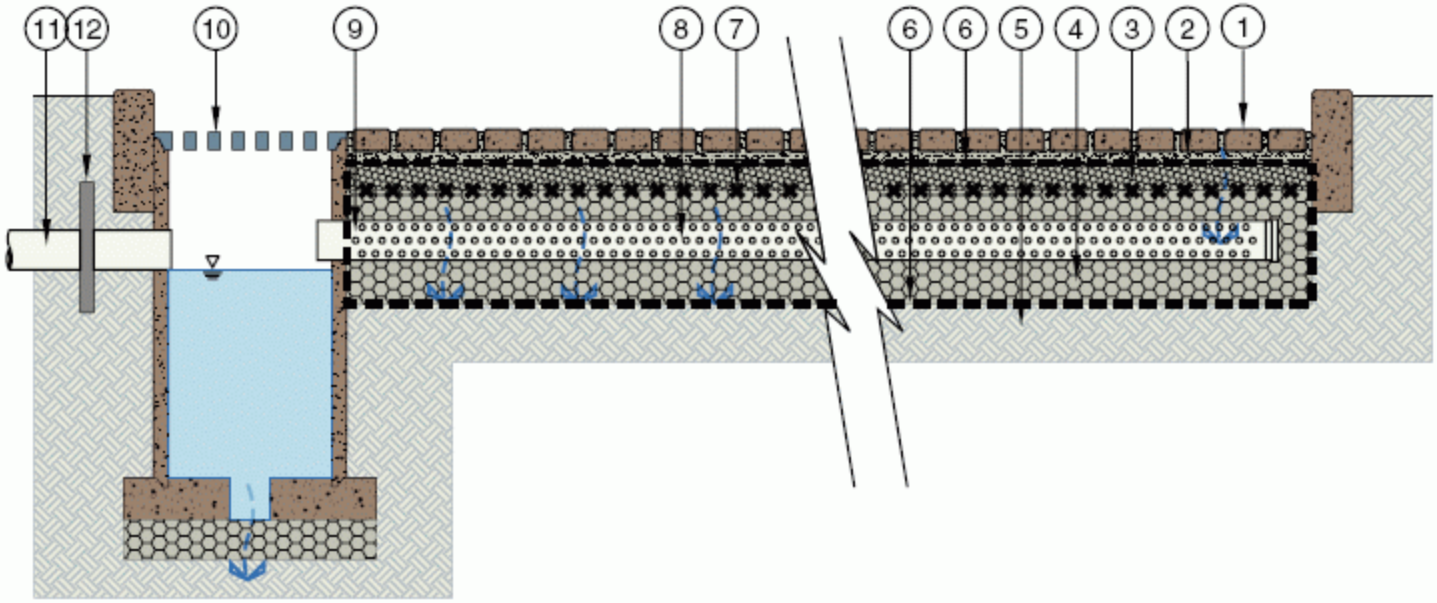
Permeable Pavement and Green Streets

Permeable Pavement





1. PERMEABLE PAVERS (MIN. 80mm THICKNESS)
2. AGGREGATE BEDDING COURSE -NOT SAND (50mm DEPTH)
3. OPEN GRADED BASE (DEPTH VARIES BY DESIGN APPLICATION)
4. OPEN GRADED SUB-BASE (DEPTH VARIES BY DESIGN APPLICATION)
5. SUBSOIL - FLAT AND SCARIFIED IN INFILTRATION DESIGNS
6. GEOTEXTILE ON ALL SIDES OF RESERVOIR
7. OPTIONAL REINFORCING GRID FOR HEAVY LOADS
8. PERFORATED DRAIN PIPE 150mm DIA MIN.
9. GEOTEXTILE ADHERED TO DRAIN AT OPENING
10. OVERFLOW INLET AT CATCH BASIN
11. OUTLET PIPE TO STORM DRAIN OR SWALE SYSTEM. LOCATE CROWN OF PIPE BELOW OPEN GRADED BASE (NO. 3) TO PREVENT HEAVING DURING FREEZE/THAW CYCLE
12. TRENCH DAMS AT ALL UTILITY CROSSINGS



4
B

PERVIOUS PAVING - PARTIAL INFILTRATION

Not To Scale

Section

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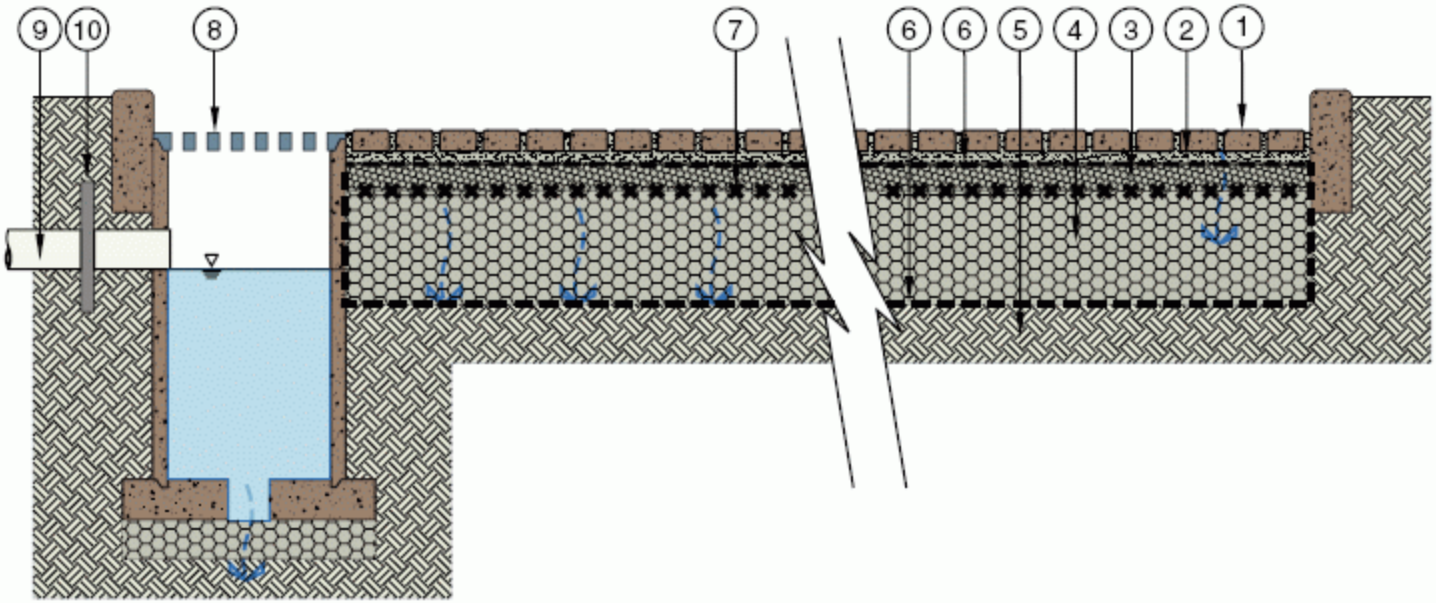


4/A PERVIOUS PAVING - FULL INFILTRATION

Not To Scale

Section

Permeable Pavers

Permeable Asphalt

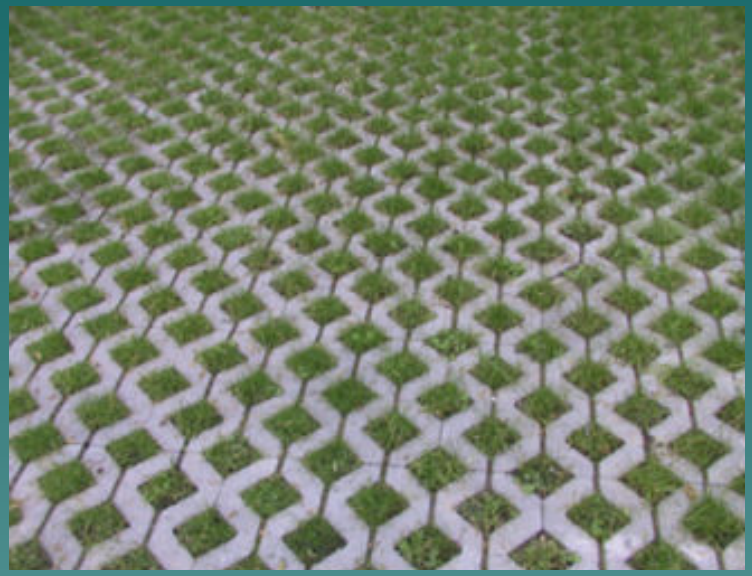
Porous Concrete

Mary's Kitchen TC – U'Ren

Flexible Pavement

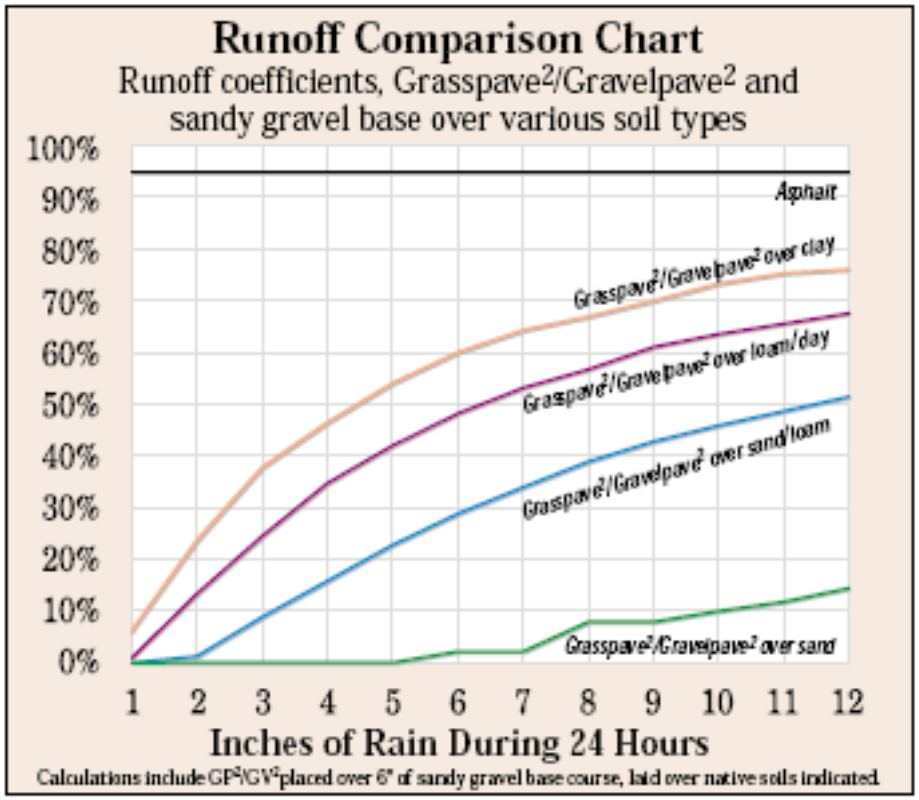
Concrete Block (CGP) Parking Lot

Martin County

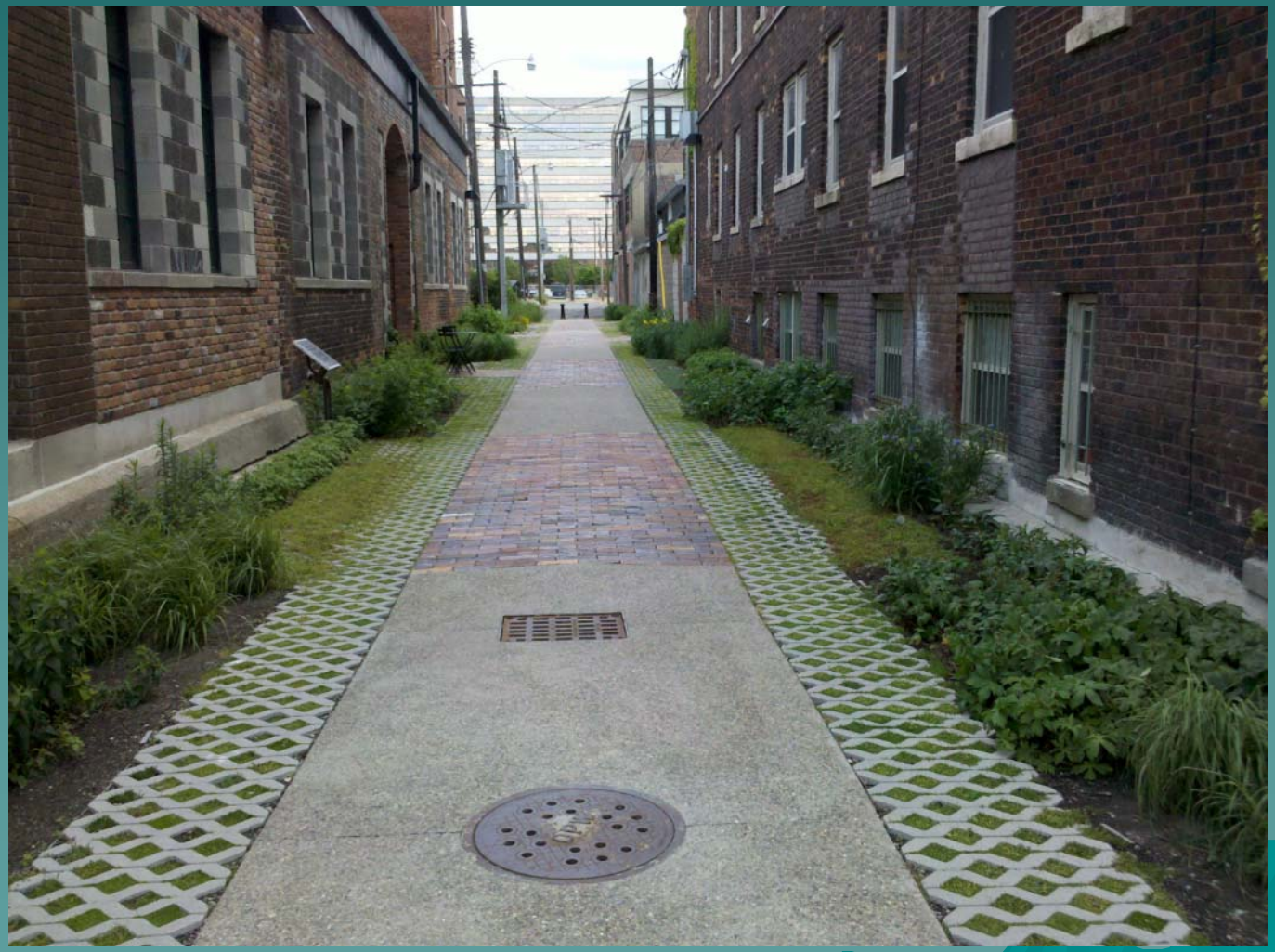


Concrete Block Parking

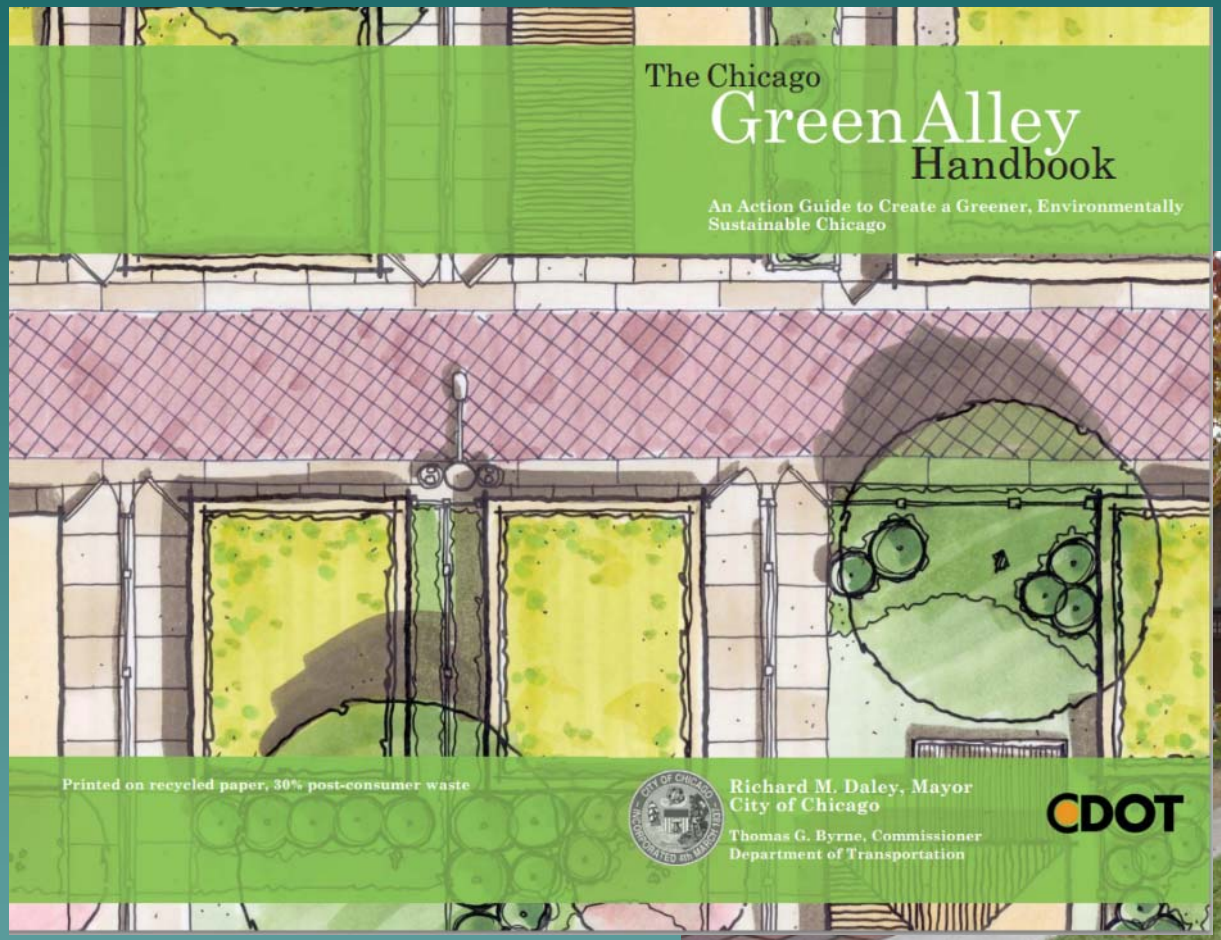
Grasspave/Gravelpave ™



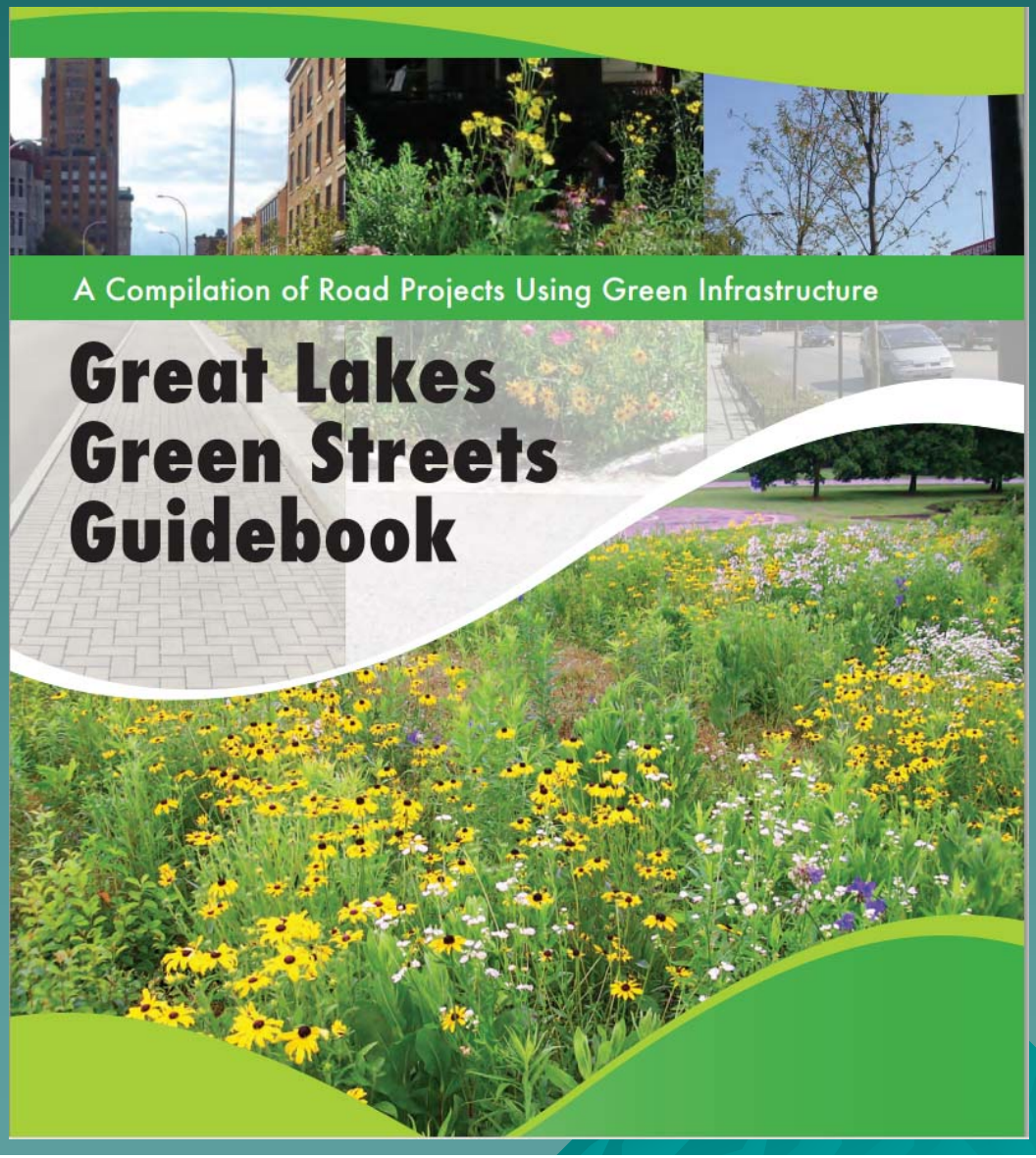
Green Alleys



City of Chicago - Green Alleys



SEMCOG Green Streets

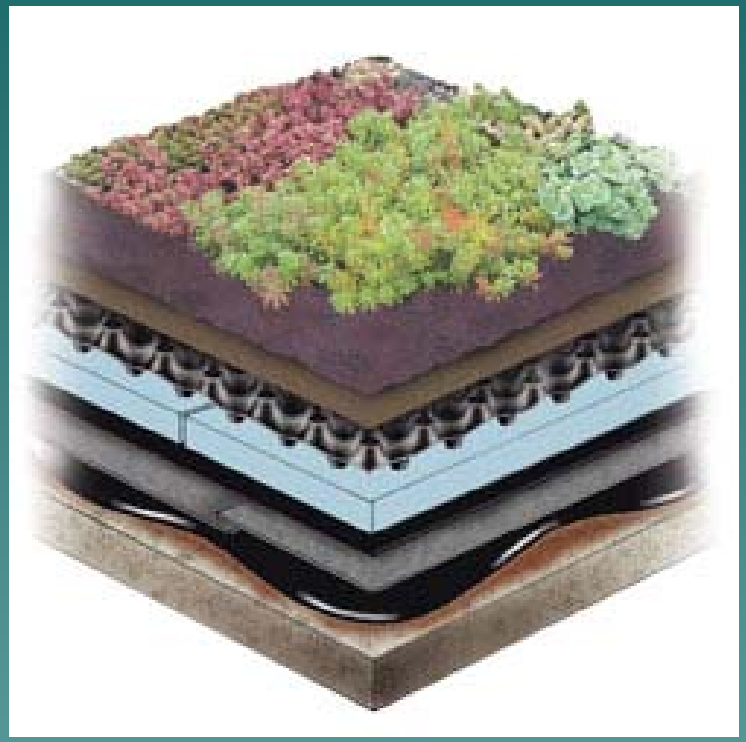


Porous Pavement Design Parameters

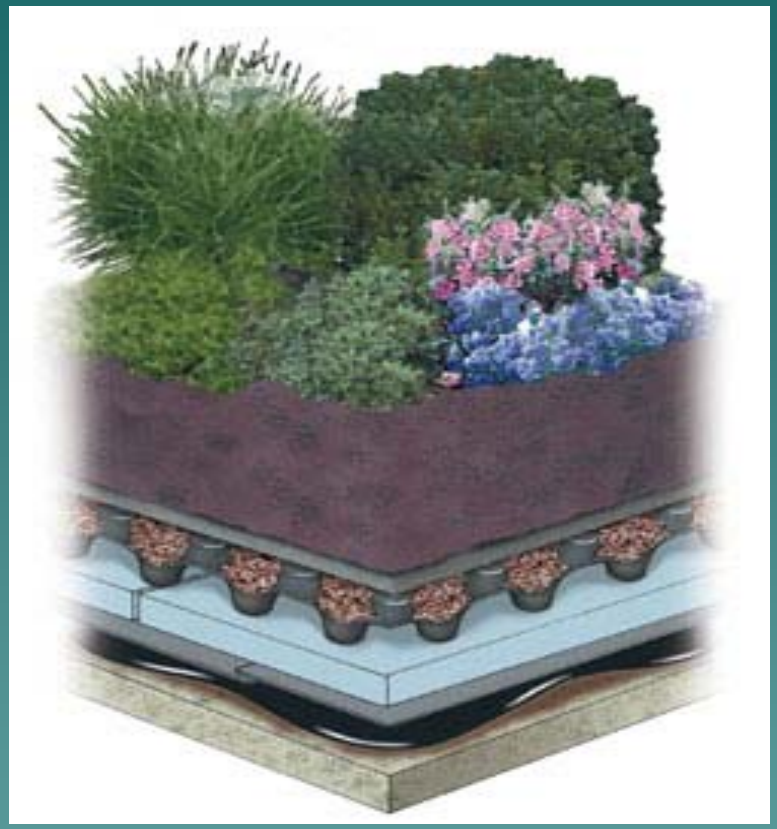
- CN can vary from 45 to 80 for design storms
  - Improved from 98 (impervious)
- T_c from impervious sheet flow to flow through porous media or rough surface if overland flow
- Infiltration can effect GW recharge and WQ volume
- Storage volume in pores reduces hydrograph volume

Vegetated Roofs

Types of Vegetated Roofs



Extensive



Intensive

Vegetated Roofs

Comparison

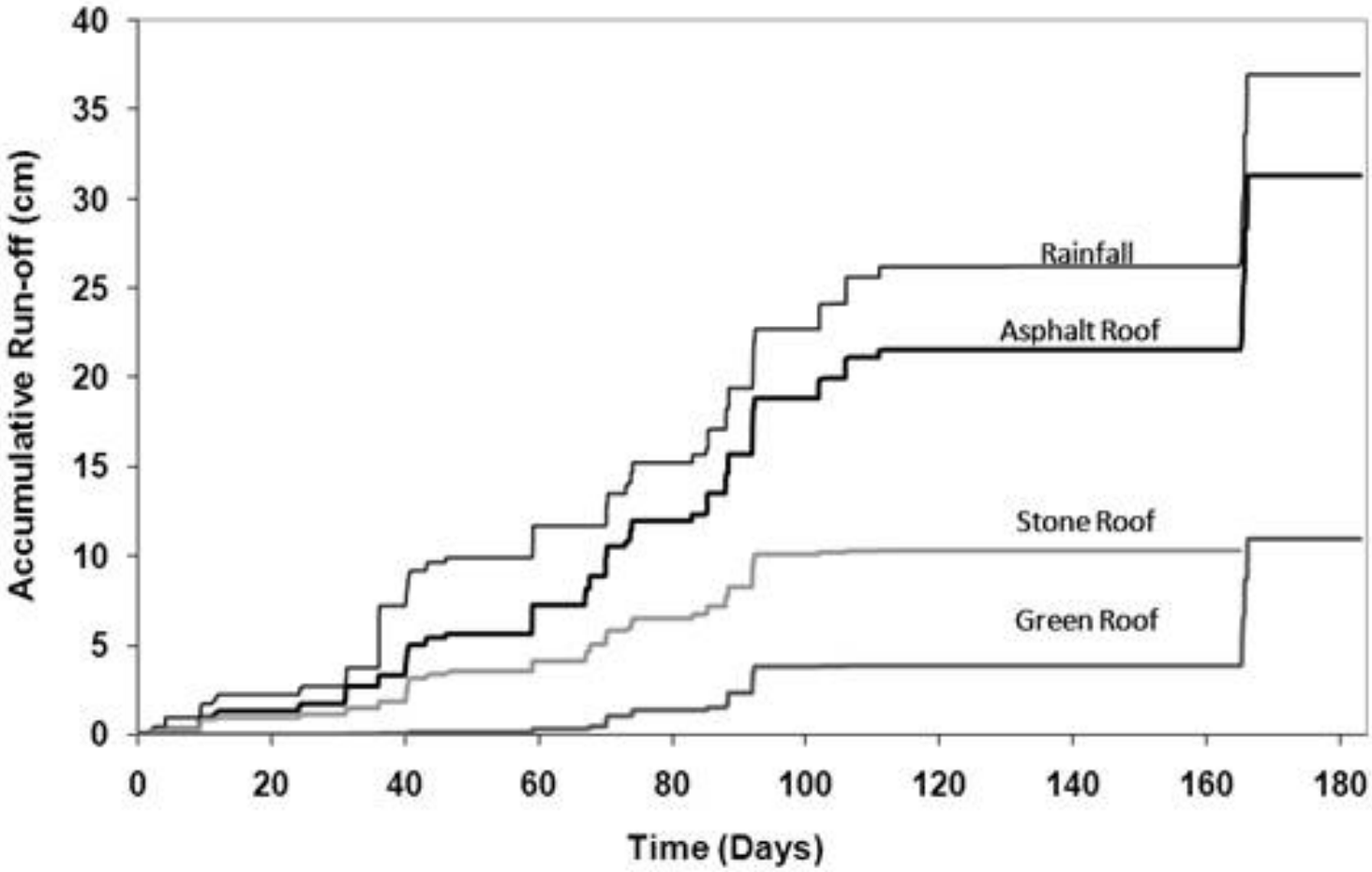
Characteristics	Intensive Vegetated Roof	Extensive Vegetated Roof
Soil	Requires minimum of one foot of soil depth	Requires only 1 to 5 inches of soil depth
Vegetation	Accommodates large trees, shrubs, and well-maintained gardens	Capable of including many kinds of vegetative ground cover and grasses
Load	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	Includes complex drainage systems	Simple drainage system

Michigan Extensive Roofs

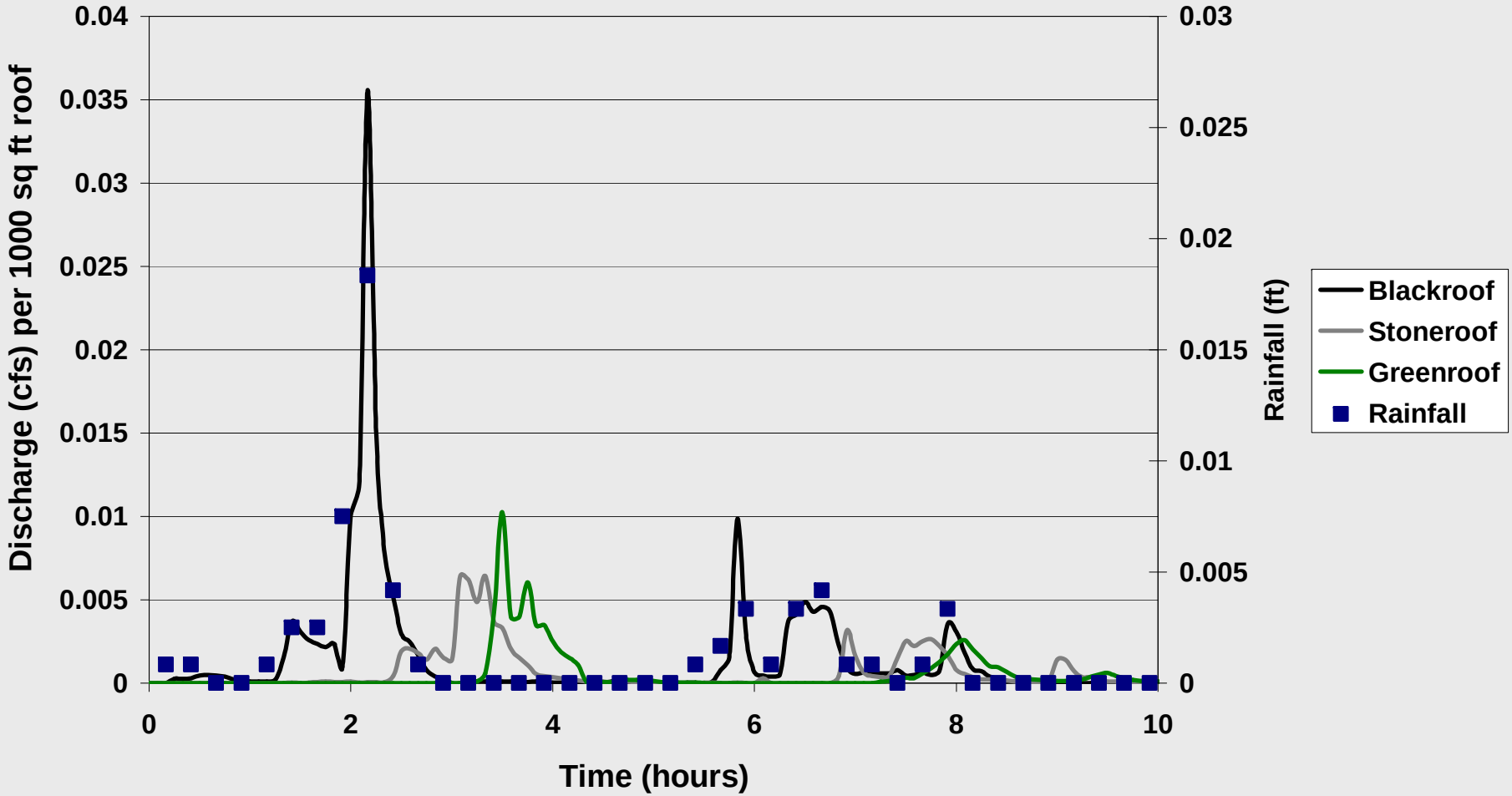
Vegetated Roof Design

- Hydrologic response is dependent on roof type and rainfall characteristics
- Most roof companies report annual retention values – not helpful for storm design
- CN and C will vary for each storm – need site specific information or modeling

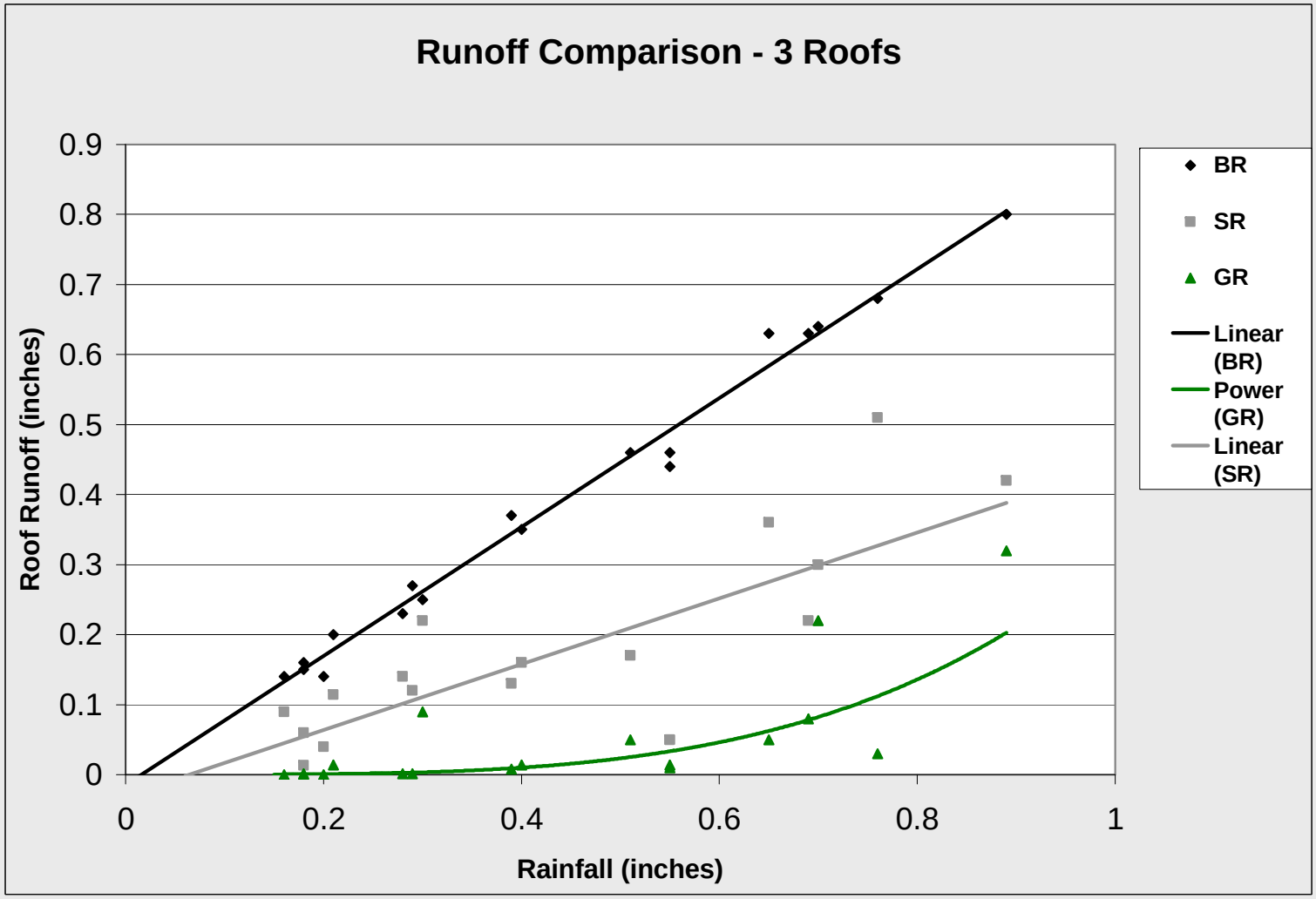
Cumulative Runoff Depth (ft)



Runoff Hydrographs



Runoff Volume Coefficient



Extensive Vegetated Roofs Design Parameters

- Recommend Hydrologic Modeling for Performance BUT…
- Curve Numbers
  - CN = 65 for rain events 3 x's depth of media (MI LID Manual)
  - CN = 84 for events greater than moisture holding capacity (ASCE Green Roof TC)
- Runoff Volume Coefficient
  - $0 < Cv < 0.8$ in Midwest (exponential relationship)
- Time to Peak (T_c)
  - At least one hour

Bioretention Cells and Rain Gardens

Bioretention Cells or Rain Gardens?

Rain Gardens

Ann Arbor, MI

Bioretention Cells

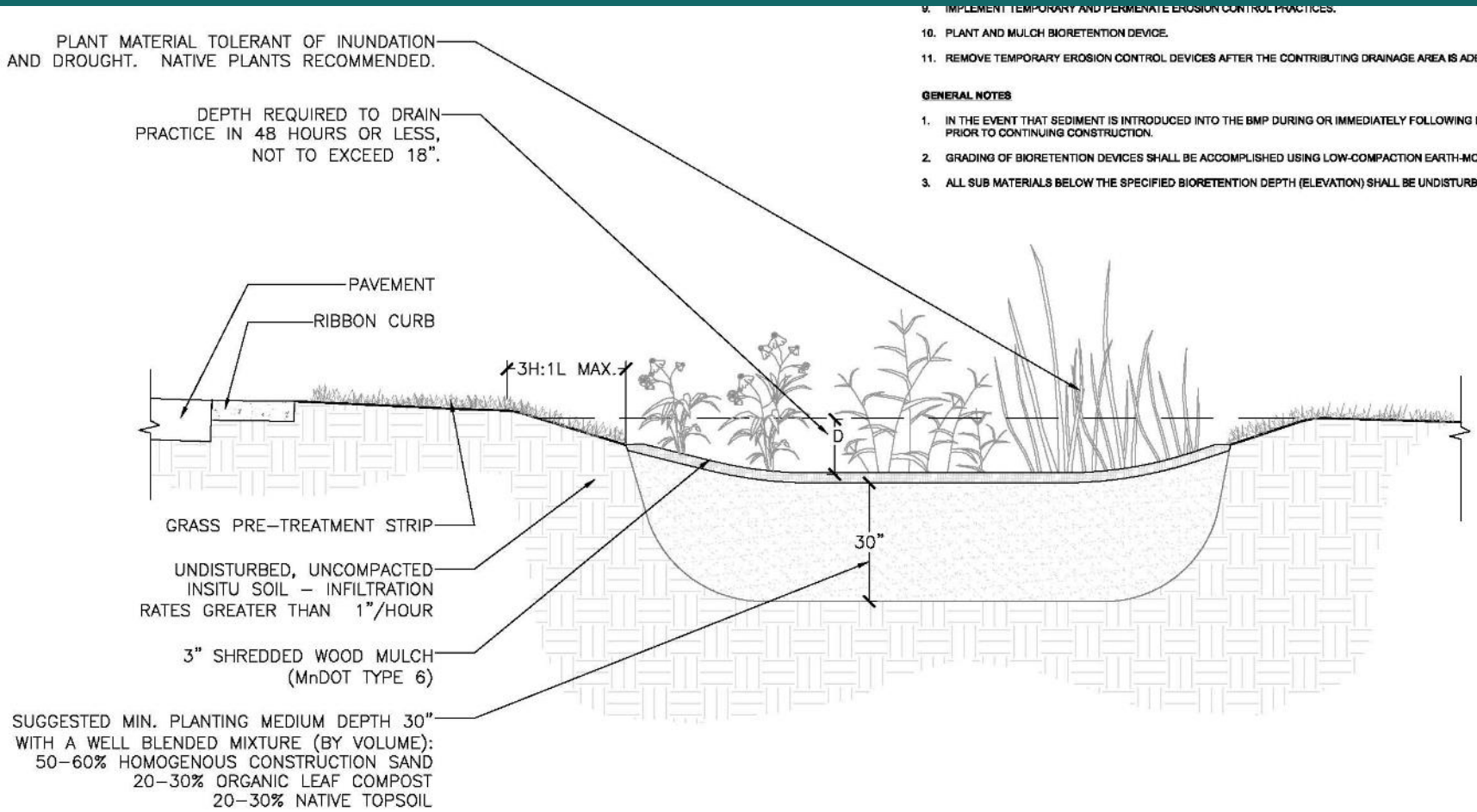
Macomb Co. Municipal Bldg
Mount Clemens, MI

ROW Bioretention

9. IMPLEMENT TEMPORARY AND PERMENATE EROSION CONTROL PRACTICES.
10. PLANT AND MULCH BIORETENTION DEVICE.
11. REMOVE TEMPORARY EROSION CONTROL DEVICES AFTER THE CONTRIBUTING DRAINAGE AREA IS ADEQUATEL

GENERAL NOTES

1. IN THE EVENT THAT SEDIMENT IS INTRODUCED INTO THE BMP DURING OR IMMEDIATELY FOLLOWING EXCAVAT PRIOR TO CONTINUING CONSTRUCTION.
2. GRADING OF BIORETENTION DEVICES SHALL BE ACCOMPLISHED USING LOW-COMPACTION EARTH-MOVING EC
3. ALL SUB MATERIALS BELOW THE SPECIFIED BIORETENTION DEPTH (ELEVATION) SHALL BE UNDISTURBED, UNLI



INFILTRATION/ RECHARGE FACILITY CROSS–SECTION

NOT TO SCALE

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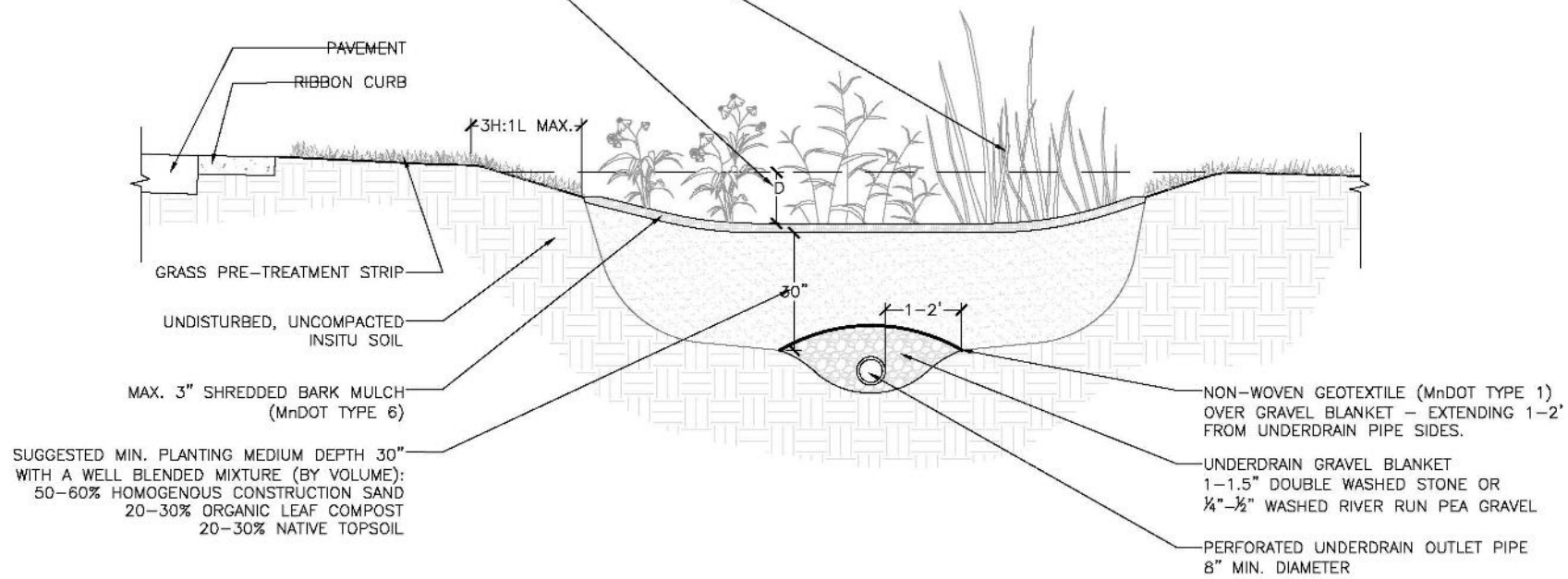
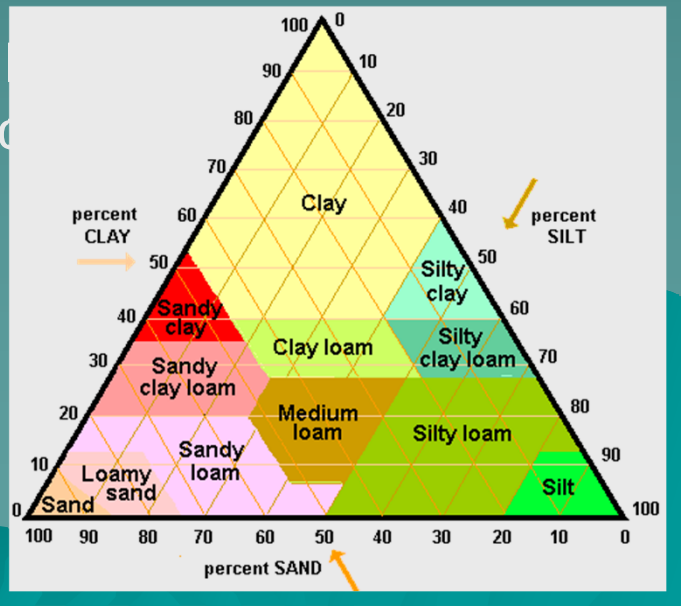


FILTRATION/ PARTIAL RECHARGE FACILITY
CROSS-SECTION

NOT TO SCALE

Rain Garden Mix Designs

- Numerous recommended mix designs have been published
- For new community developments mix designs might be specified by municipality
- Example Mix Designs:
  - 50% sand, 30% topsoil, 20% com
  - 20 – 40% sand & 60 – 80% compo
  - NRCS Soil Triangle (Loamy Sand to Sandy Loam)



Rain Garden Sizing Techniques

- Homeowner How-to Manuals available from U of Wisc. Ext., VA Dept of Forestry, & SOCWA
- Numerical Design Techniques
  - Run-off Method
  - Darcy's Law

Run-off Method

- Developed in the Mid-Atlantic
- Assumptions
  - 1” of rainfall will be capture
  - 2.5 ft and 4ft of planting depth with 50/30/20 mix
  - 6” ponding with 48 hour drainage time
  - Doesn’t consider native soils

$$SA = 0.07 * \left(C_{imp} * DA_{imp} + C_{green}\, DA_{green}\right)$$

$$SA = surface\ area\ of\ \ filter\ bed\ (rain\ garden)\ (ft^2)$$

$$C_{imp} = runoff\ \ coefficient\ of\ impervious\ surfaces = 0.9$$

$$C_{green} = runoff\ \ coefficient\ of\ \ green\ areas = 0.25$$

$$DA = drainage\ area\ (ft^2)$$

Simplified Darcy's Law

- Simplified by Dr. Carpenter
- Assumptions
  - 1" of rainfall will be capture (90% of all rain events)
  - Excess rainfall should be bypassed
  - Well maintained rain garden with mix of compost/sand
  - 48 hour drainage time
  - Includes infiltration rate of native soils

Simplified Darcy's Law

$$SA = \frac{0.04 \times c \times DA \times depth}{(i) \times (depth + ponding)}$$

$$SA = surface\ area\ of\ rain\ garden\ (ft^2)$$

$$DA = drainage\ area\ (ft)$$

$$depth = planting\ bed\ depth\ (ft)$$

$$i = infiltration\ rate\ (ft/day)$$

$$c = runoff\ coefficient\ (between\ 0.1\ and\ 0.9)$$

$$ponding = average\ ponding\ depth\ (ft)$$

Rain Garden Sizing Comparison

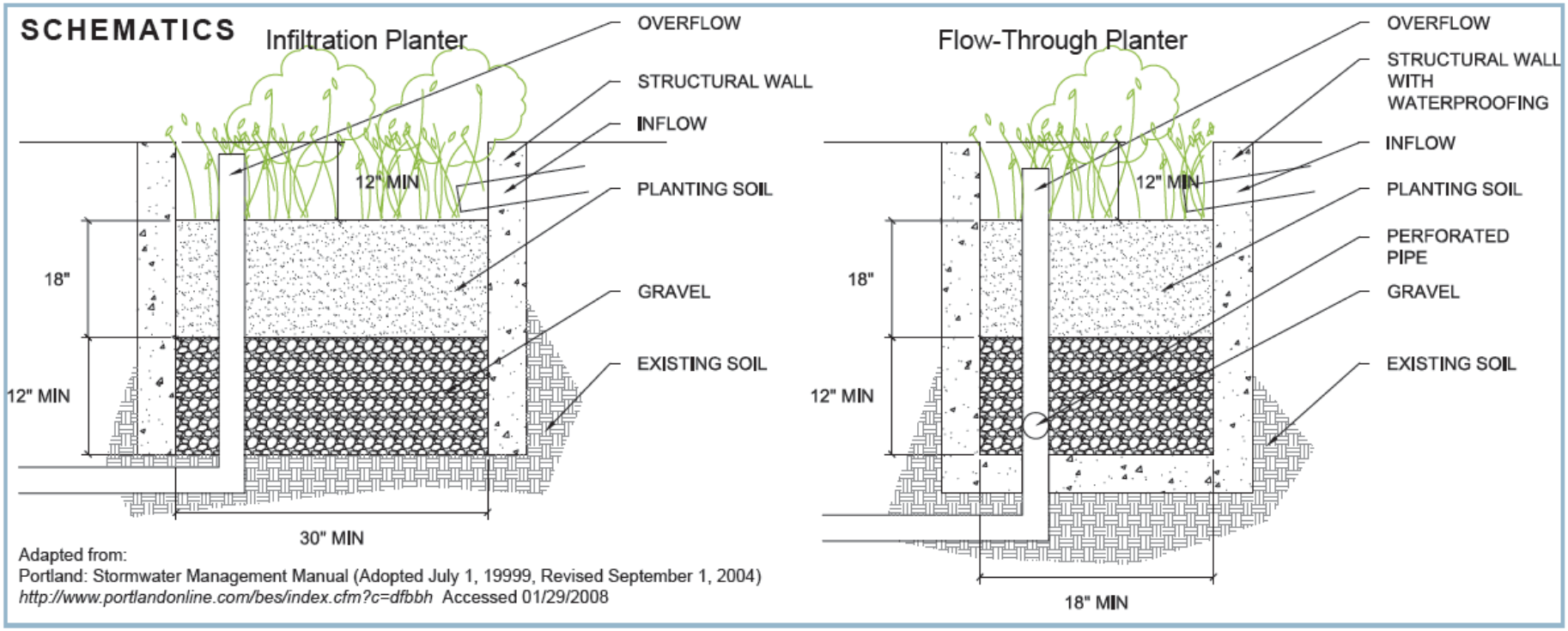
- 1000 sq ft of roof (all impervious)
- 2.5 ft of planting depth & 0.5 ft ponding
- Sand (1.0 ft/day) & Clay (0.2 ft/day)

	Darcy's Law	Run-off
Sand	30 sq ft	63 sq ft
Clay	150 sq ft	63 sq ft

Planter Boxes

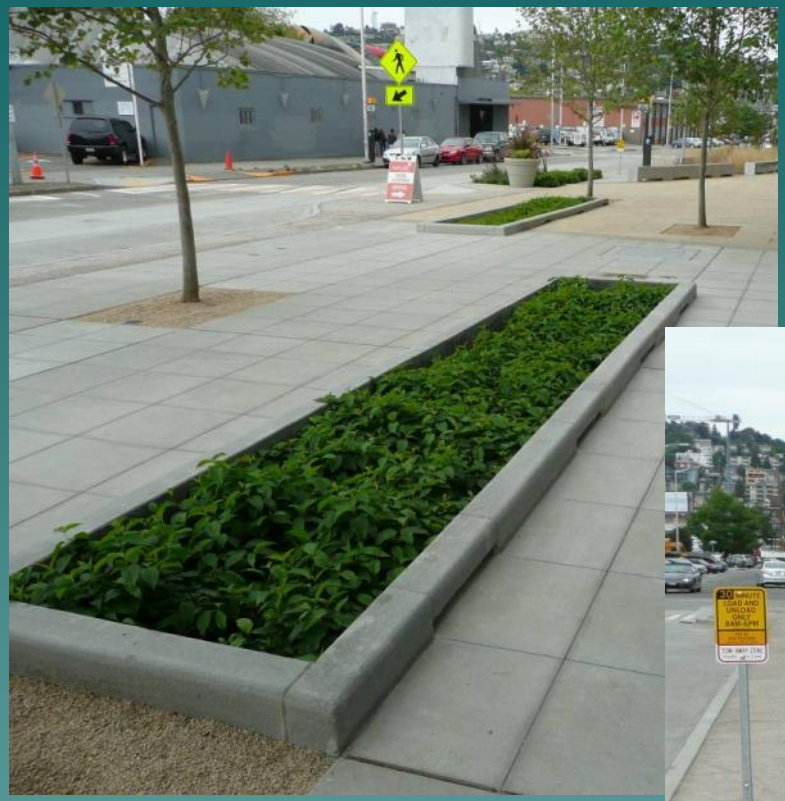
Planter Boxes

Stormwater Planter



Adapted from:
Portland: Stormwater Management Manual (Adopted July 1, 19999, Revised September 1, 2004)
http://www.portlandonline.com/bes/index.cfm?c=dfbbh Accessed 01/29/2008

Planter Boxes

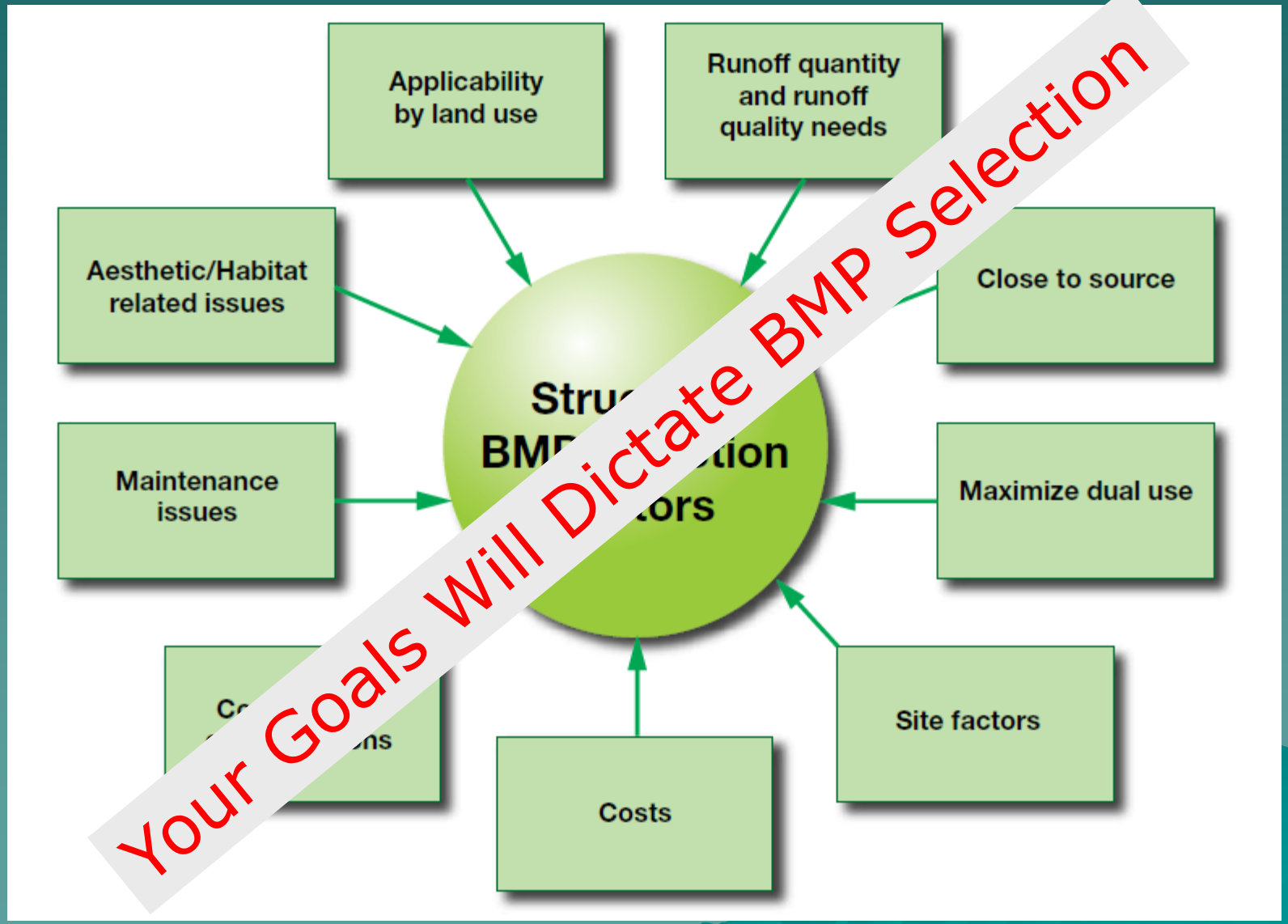


Planter Boxes

Rain Garden Design Parameters

- CN classification of meadows on good soil
- T_c from overland sheet flow to flow through porous media if underdrain
- Infiltration can effect GW recharge and WQ volume
- Storage volume in pores reduces hydrograph volume

Structural BMP Selection Factors



Your Goals Will Dictate BMP Selection

Questions?