



# Lesson 3

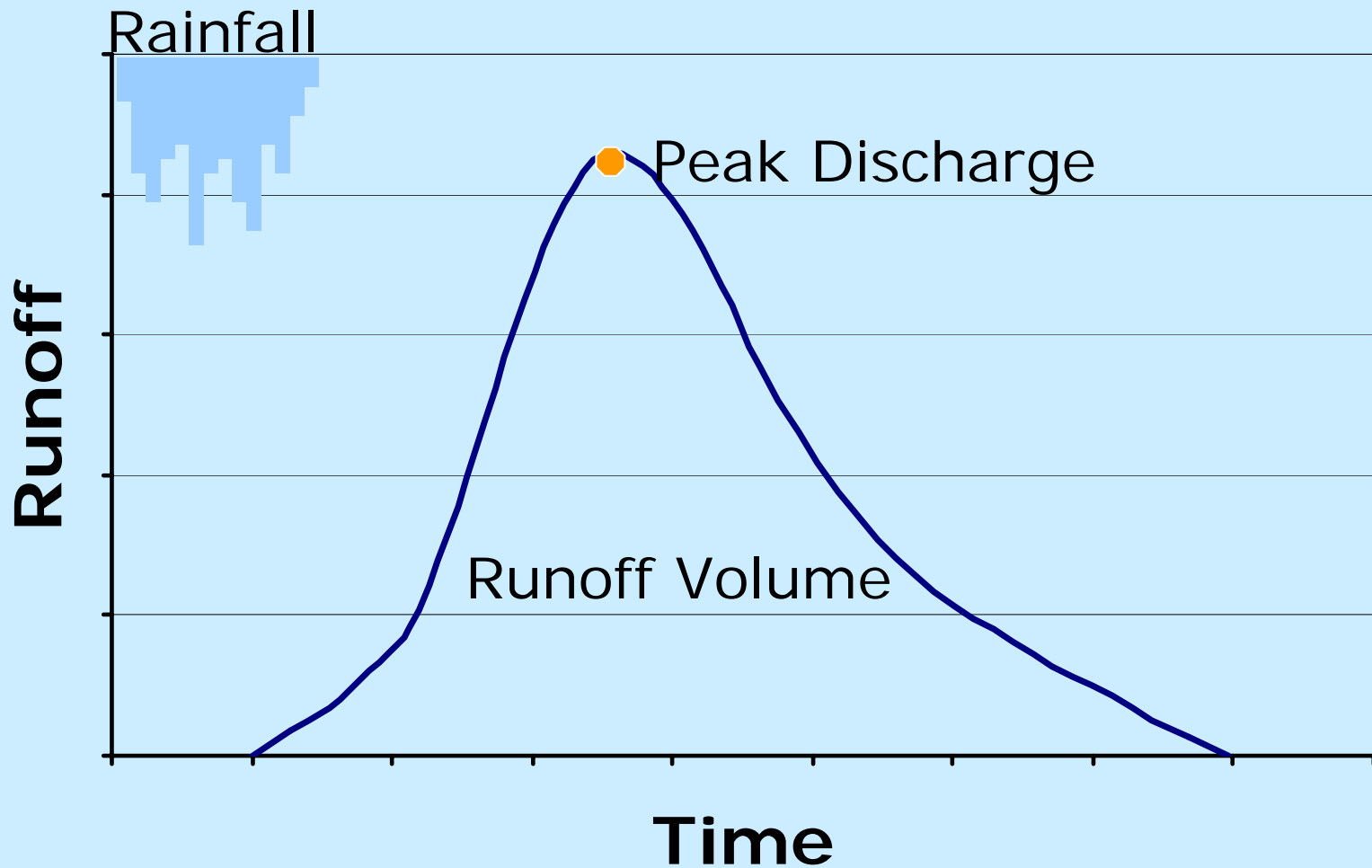
## Runoff Hydrology

## Overview

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- Hydrographs
- On-Site Factors
- Off-Site Factors
- Detention & Retention
- Infiltration
- Tools

# Runoff Hydrograph



# Site Factors Affecting Runoff

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***What characteristics of a site affect runoff from that site?***

***List as many as you can. Use the Rational Formula for finding peak runoff flow as a guide.***

$$Q = CiA$$

# Rational Formula

$$Q = CiA$$

$Q$  = Discharge ( $\text{ft}^3/\text{s}$ )

$C$  = Runoff coefficient

$i$  = Rainfall intensity ( $\text{in}/\text{hr}$ )

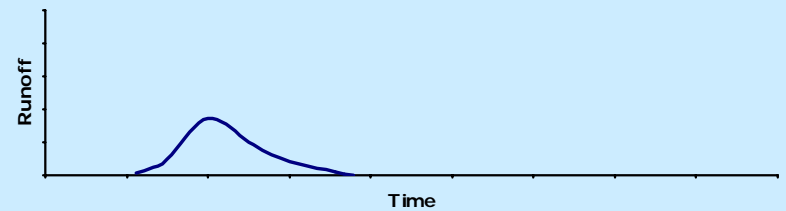
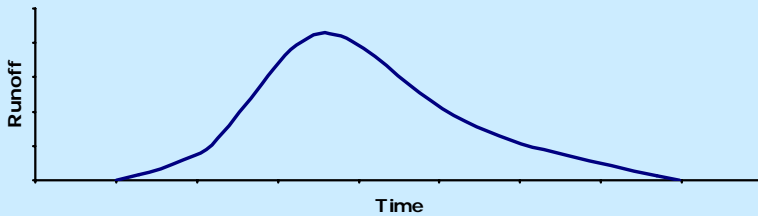
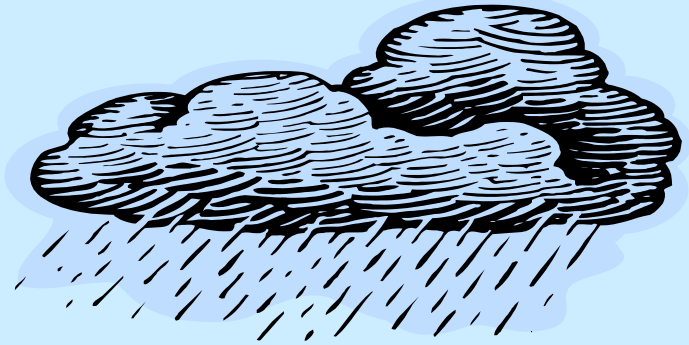
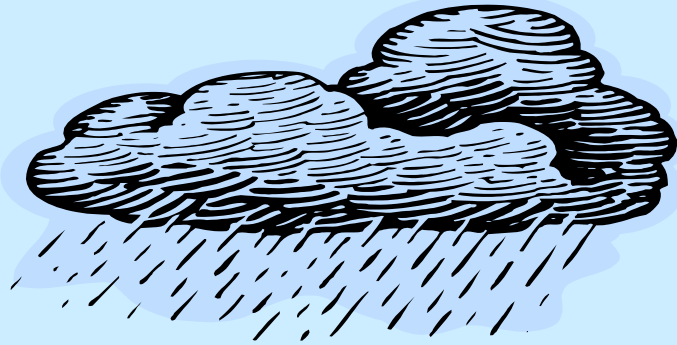
$A$  = Drainage Area (acres)

# Site Factors Affecting Runoff

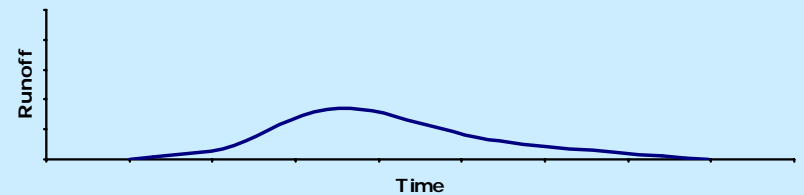
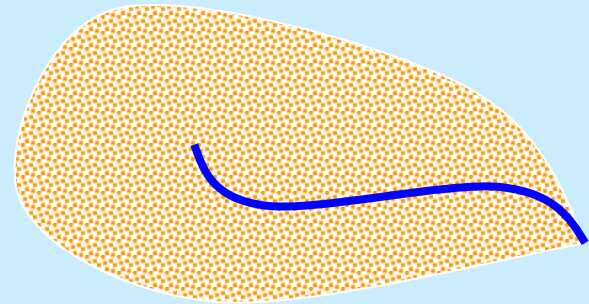
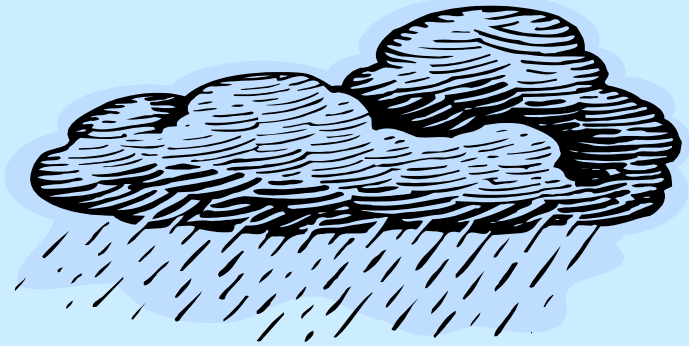
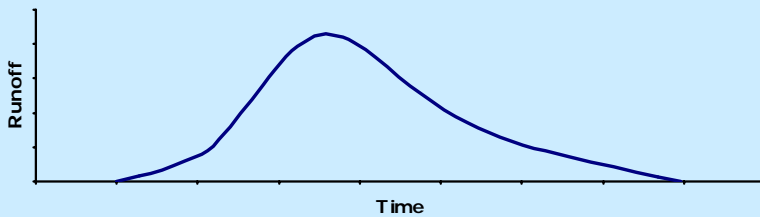
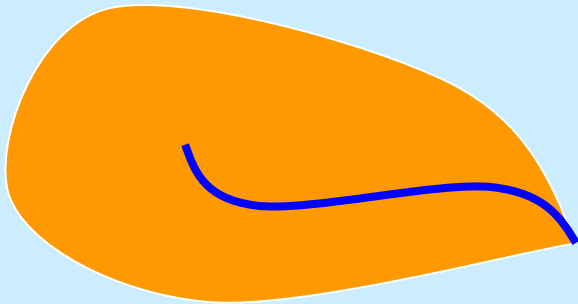
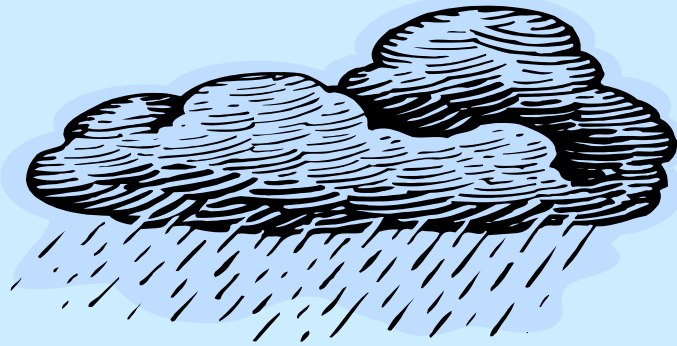
- Drainage area
- Roughness
- Imperviousness
- Vegetation
- Drainage density
- Slope
- Storage
- Flow path length

***How do each of these affect runoff?***

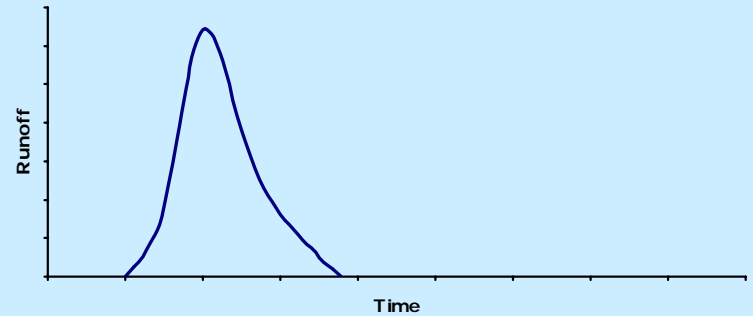
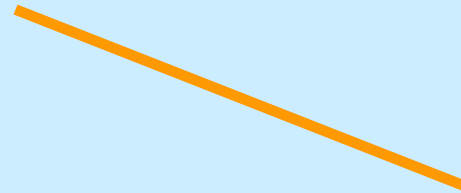
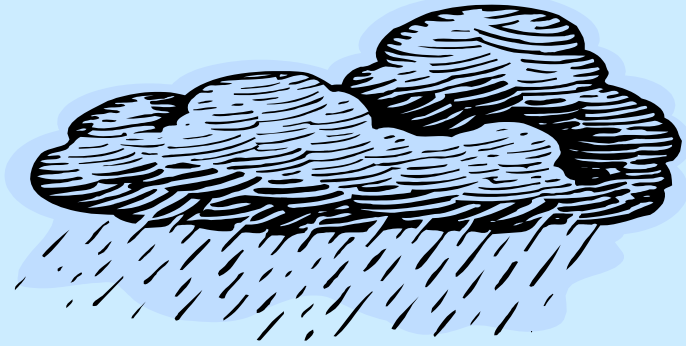
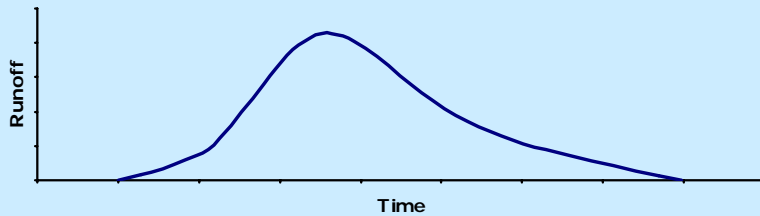
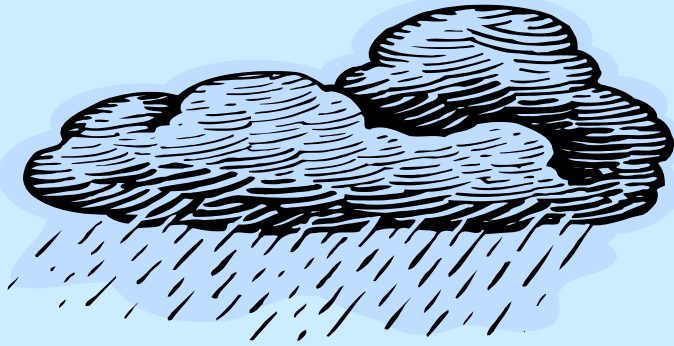
# Drainage Area



# Roughness



# Slope



## Off-site Impacts of Increased Runoff

- Higher Peak Flows
  - Flooding
  - Erosion
  - Disruption of habitat
  - Increased pollution
- Higher Volumes
  - Erosion
  - Higher downstream peak flows
  - Increased pollution

# 3 Methods of Analysis

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- Single rainfall event
- “Average Annual Storage”
- Continuous

# 3 Methods of Analysis

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- Single event analysis
  - Initial conditions assumed
  - No between-storm conditions modeled
  - Uses factors that reflect ability of landscape to absorb water
    - Initially (hydrologic abstractions)
    - During storm (infiltration)

# Single Event: Unit Hydrograph

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- Unit Hydrograph Methods
  - Input
    - Rainfall pattern
    - Abstraction and infiltration pattern
    - Runoff pattern
  - Calculation method: Convolution
    - Subdivide rainfall pattern
    - Add hydrographs generated by each increment of rainfall.

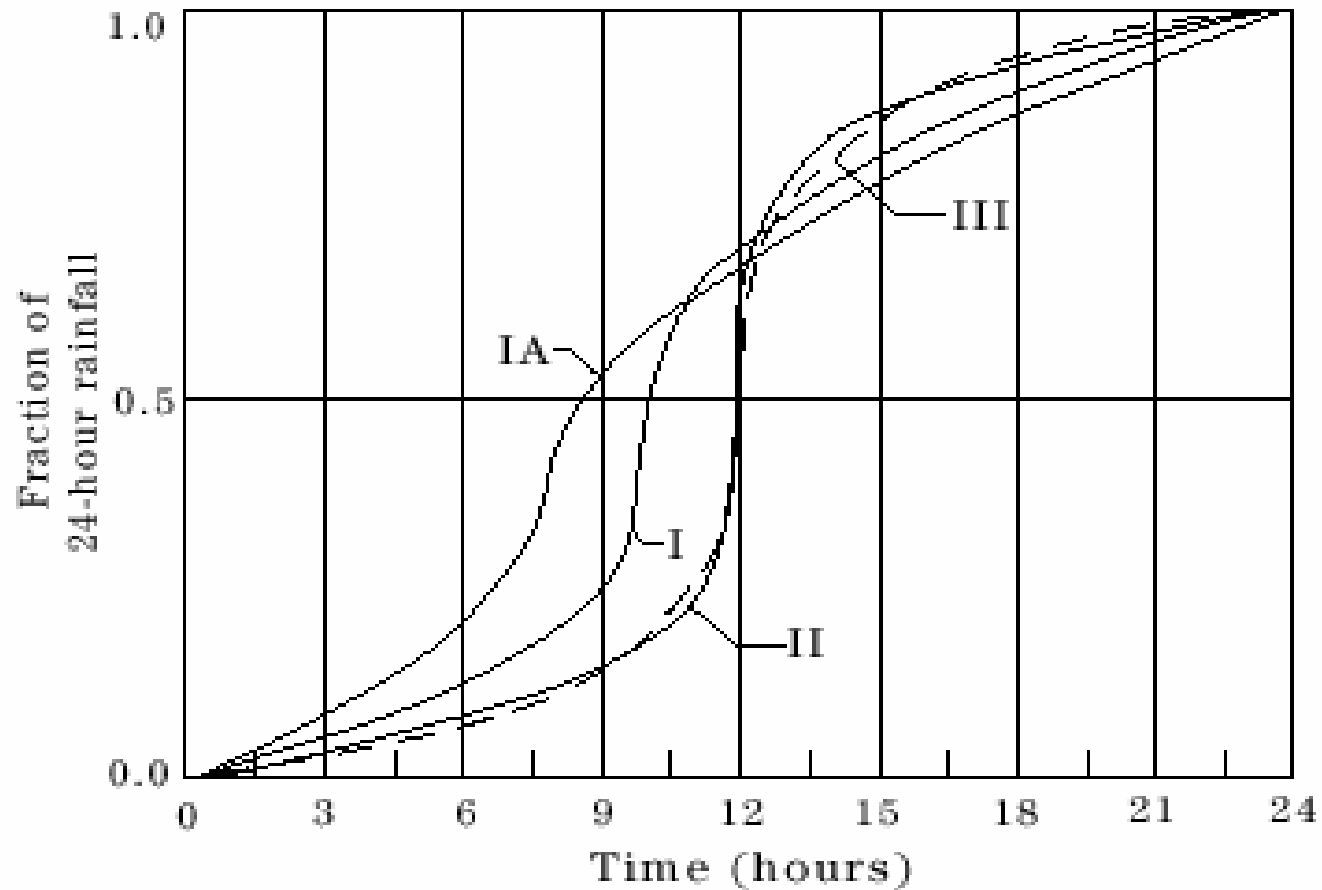
# Single Event Unit Hydrograph (cont'd)

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- Rainfall Pattern
  - Recorded storm of your choosing
  - “Design storm” developed by agency, multiplied by rainfall depth
  - Example: SCS Type II Distribution

# Rainfall Patterns

SCS 24-hour rainfall distributions



# Initial Abstraction Defined

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- The amount of precipitation that will be absorbed by the landscape before any runoff is generated.
- Quantity depends on
  - Vegetation density (affects interception)
  - Antecedent moisture conditions
  - Soil type
  - Roughness (small depression storage)

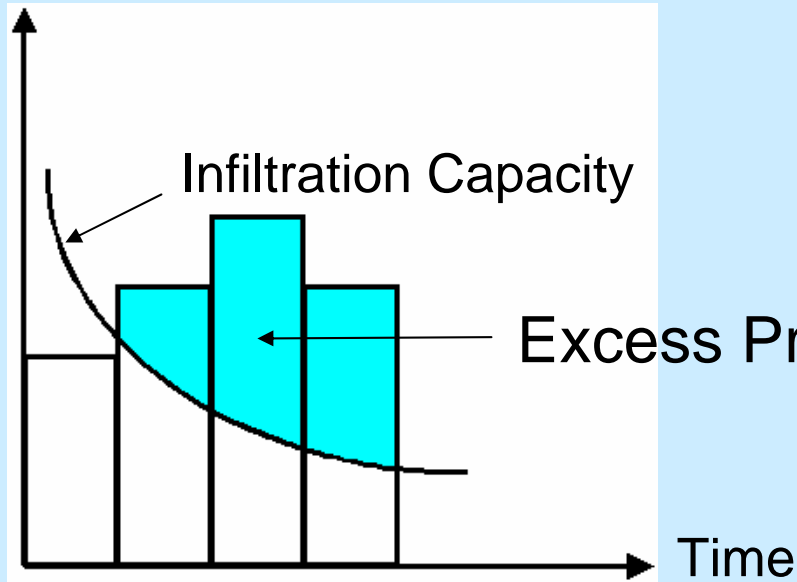
# Analyzing Runoff (UH cont'd)

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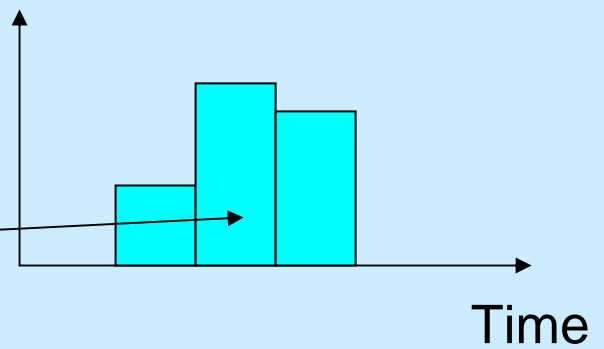
- Abstraction and Infiltration Pattern
  - Initial abstraction is a storage volume
  - Infiltration is rate that typically declines with time
- Excess rainfall: Pattern that remains after initial abstraction and infiltration is removed

# Excess Precipitation

Precipitation

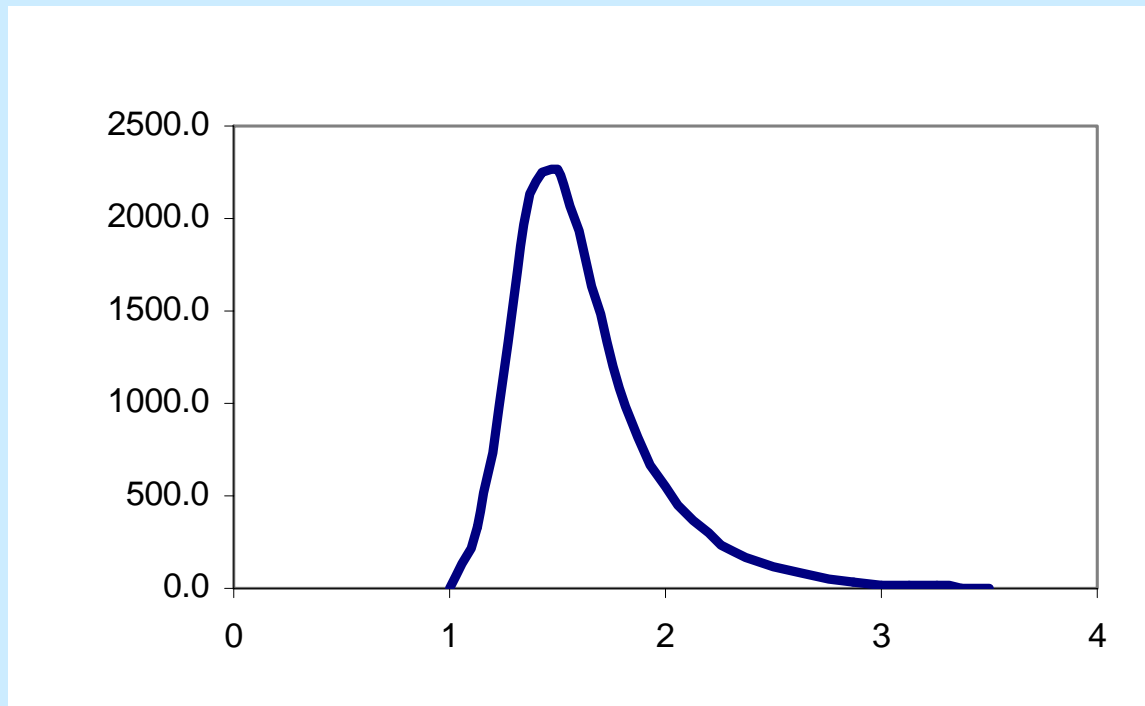


Precipitation



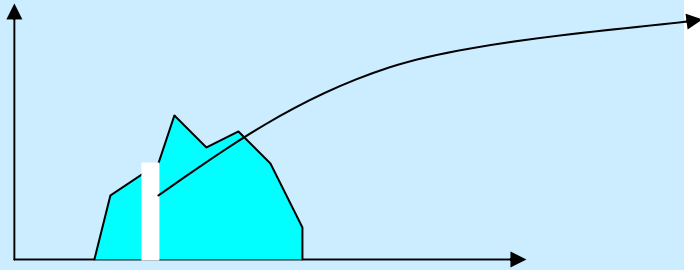
# Runoff Pattern

- Unit Hydrograph shows response of drainage area to 1 unit of excess rainfall

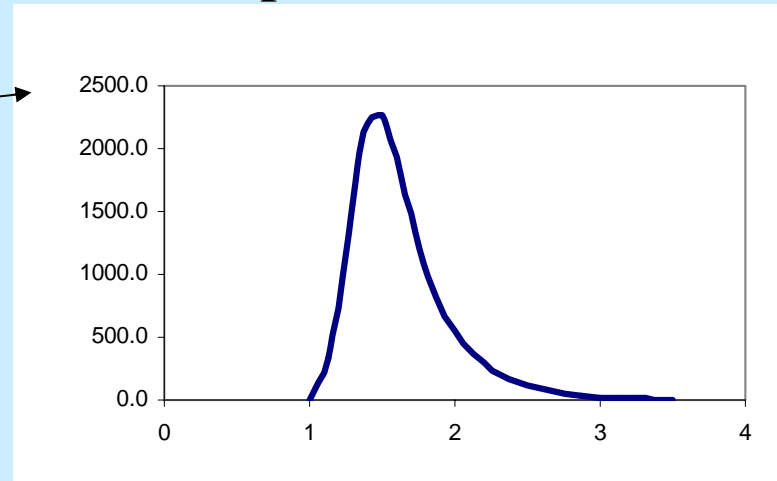


# Unit Hydrograph Method

Excess Precipitation  $P(t)$

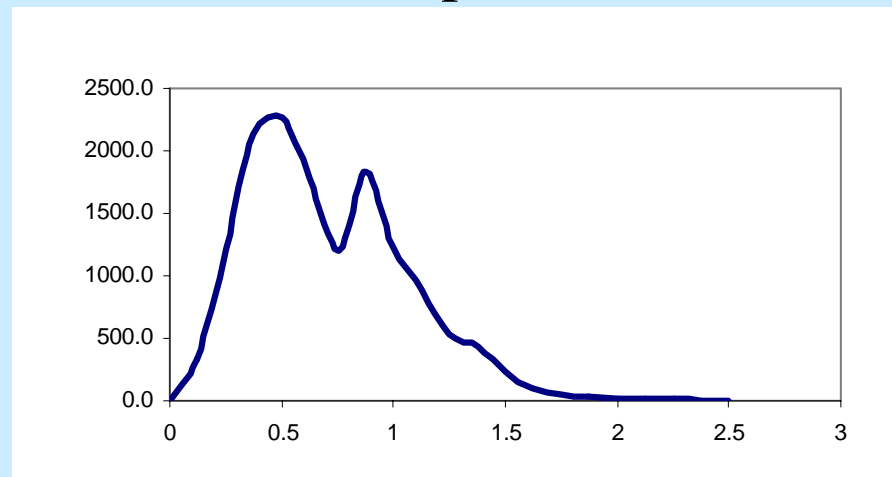


Unit Response Function  $U(t)$



Runoff pattern from each increment of excess rainfall is calculated, then summed

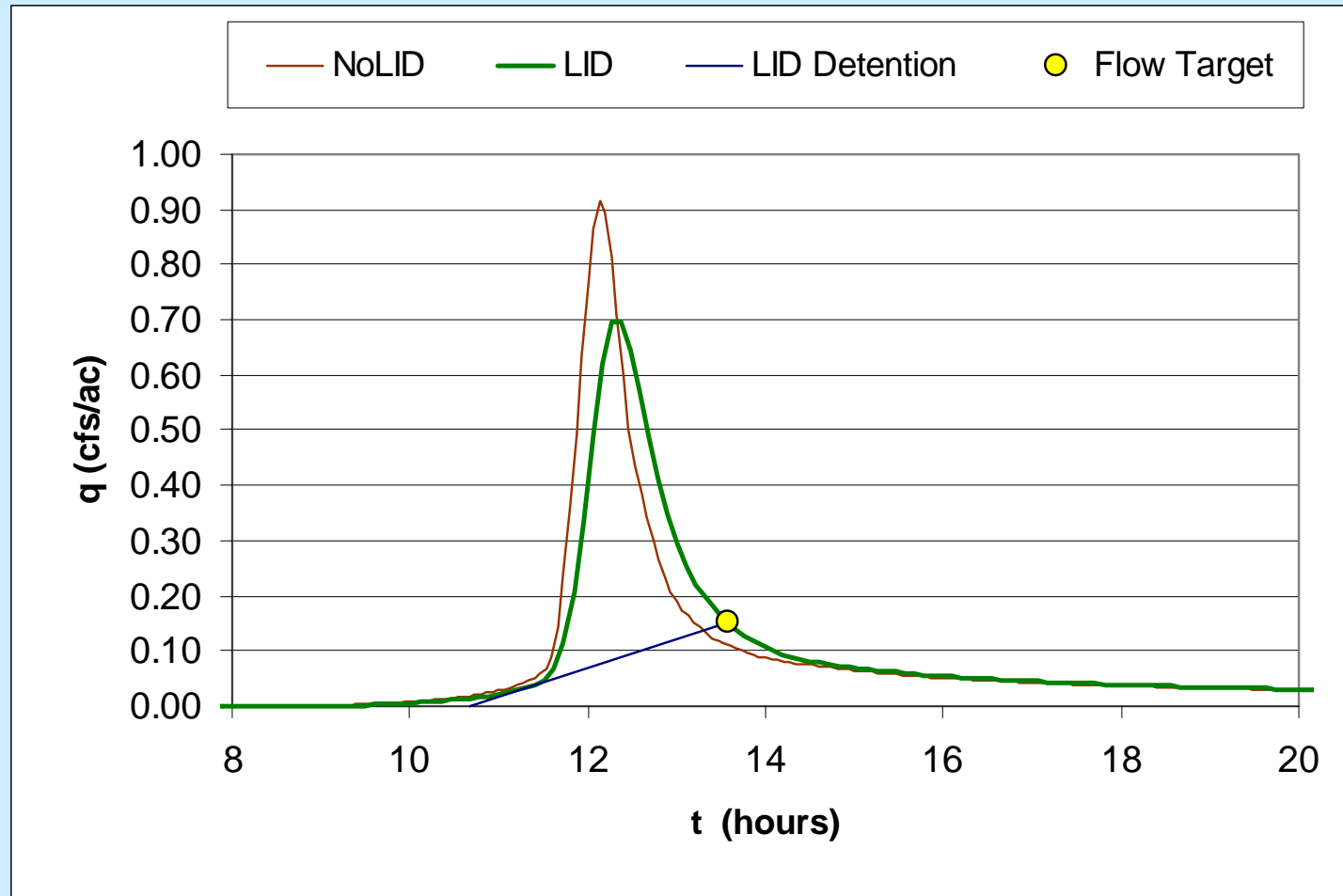
Event Response  $Q(t)$



# NRCS Terminology

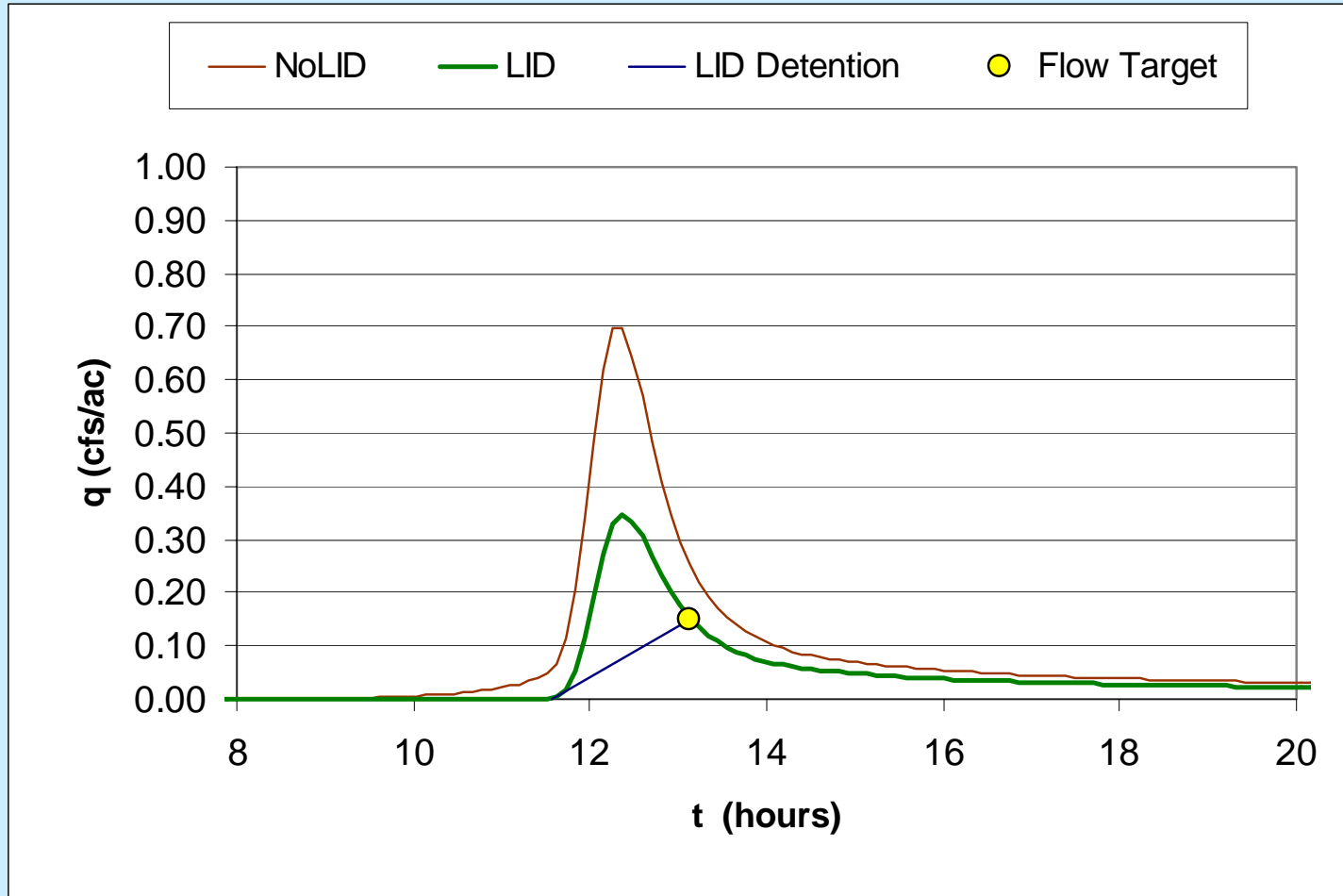
- **Tc: “Time of Concentration”**  
Longest time that drop of rainfall will take to get to outlet.
- **CN: “Curve Number”**  
Reflects tendency of drainage area to shed water.  
E.g. CN = 46 for wooded, sandy area  
CN = 99 for pavement

# Increasing Tc



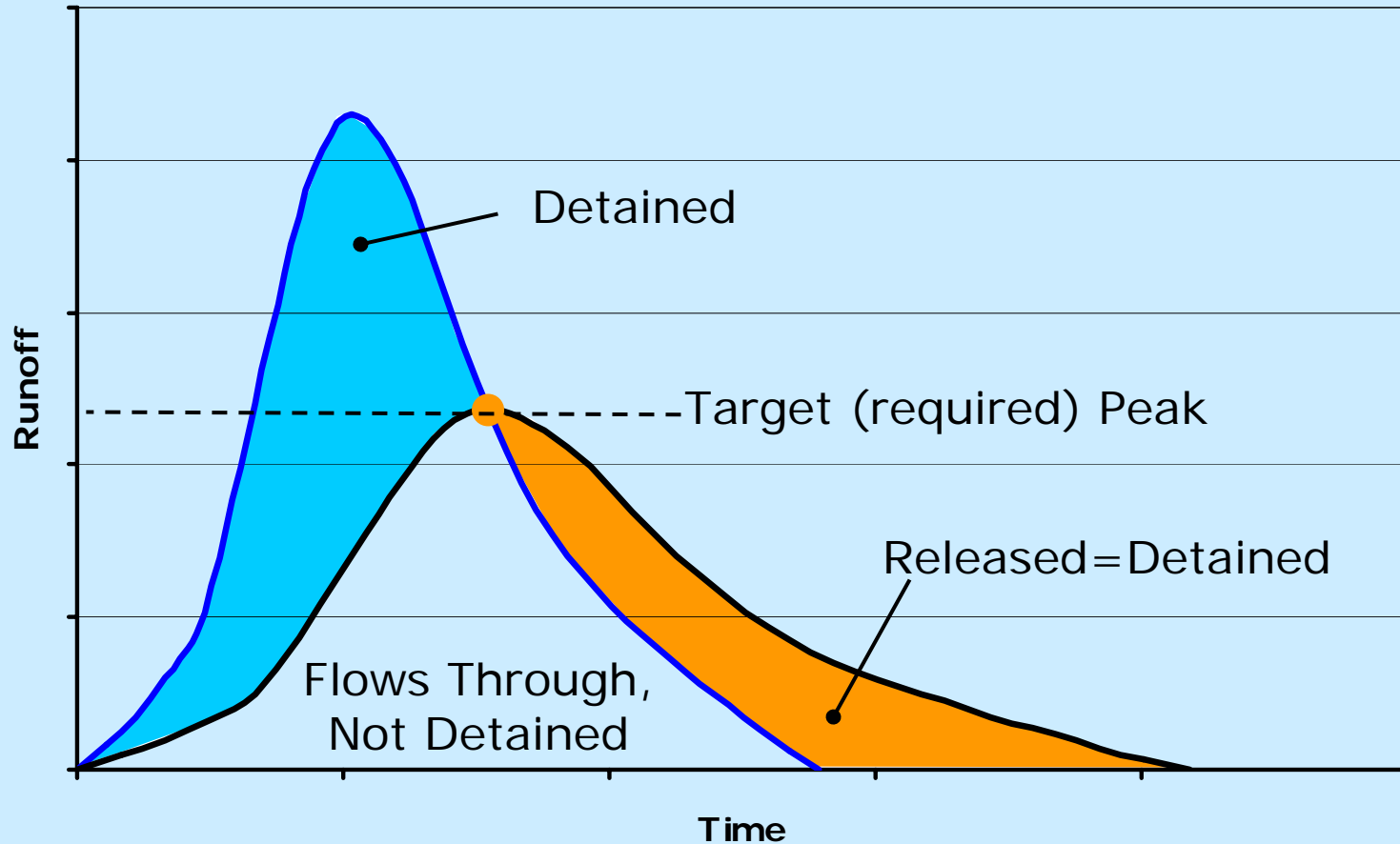
Precip = 2.57 inches, CN = 85,  
Tc increased from 0.5 to 0.8 hr

# Decreasing CN



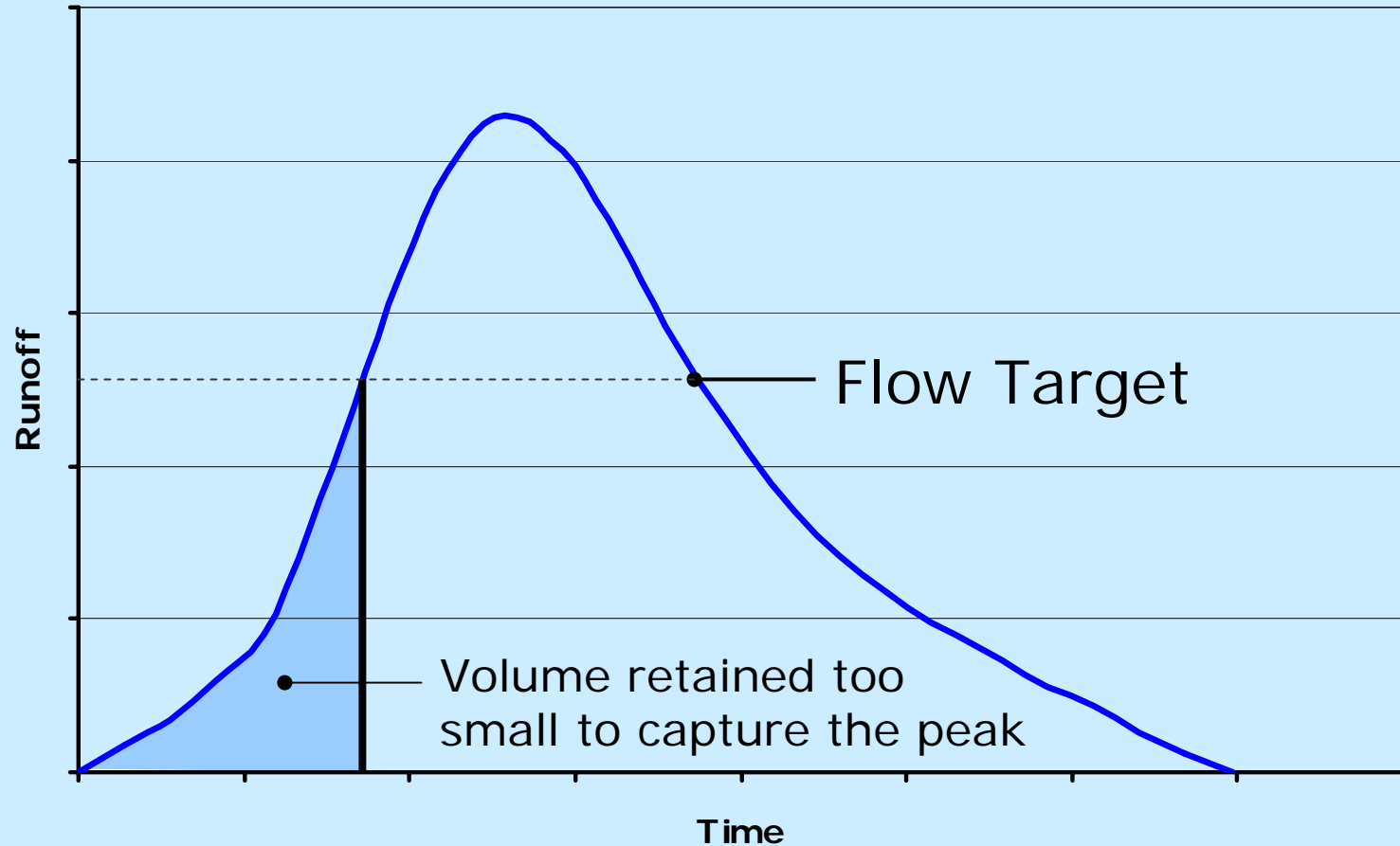
Precip=2.57 inches, TC = 0.8 hr,  
CN decreased from 85 to 75

# Detention Design



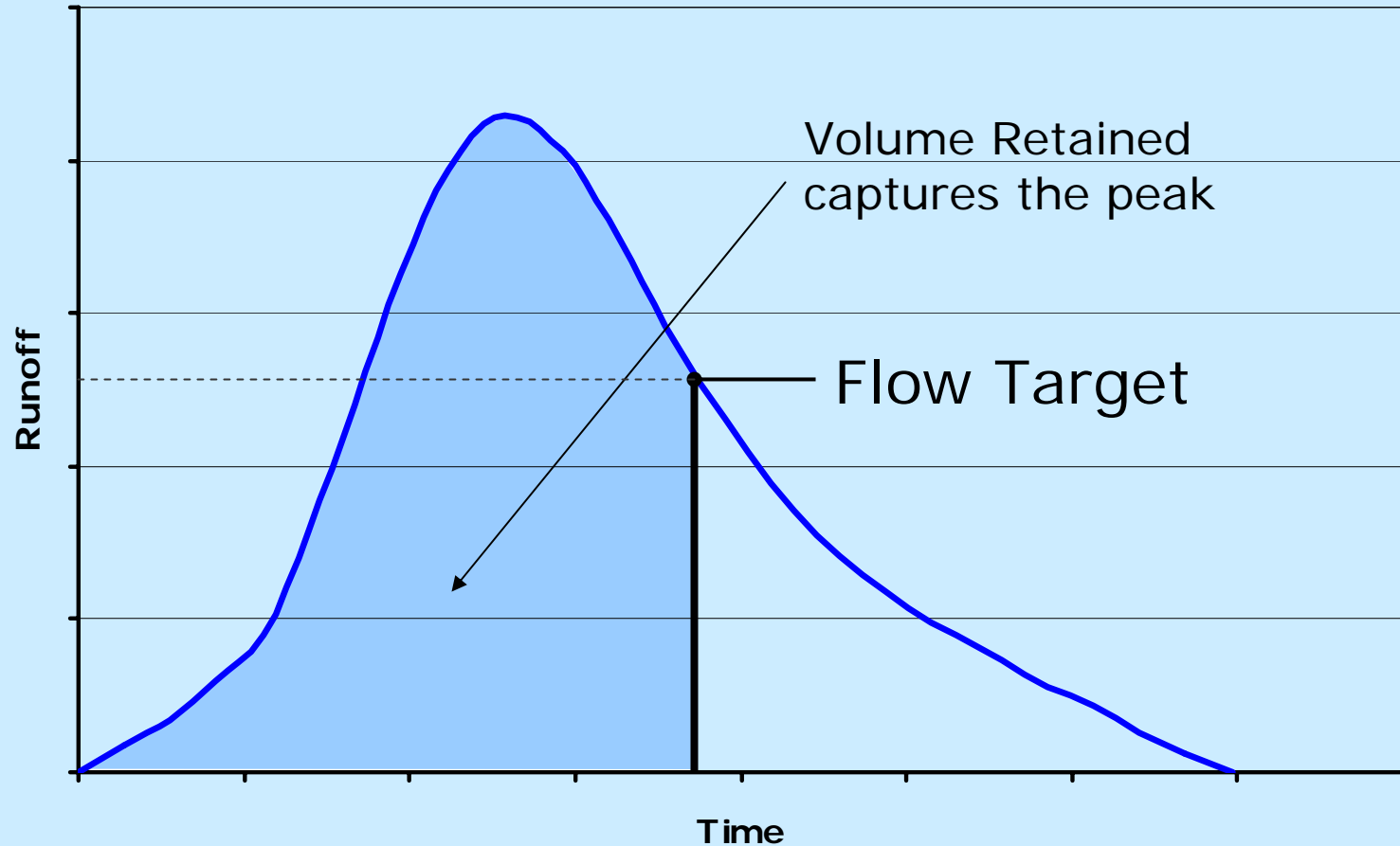
# Retention Design

## In-Line Option 1



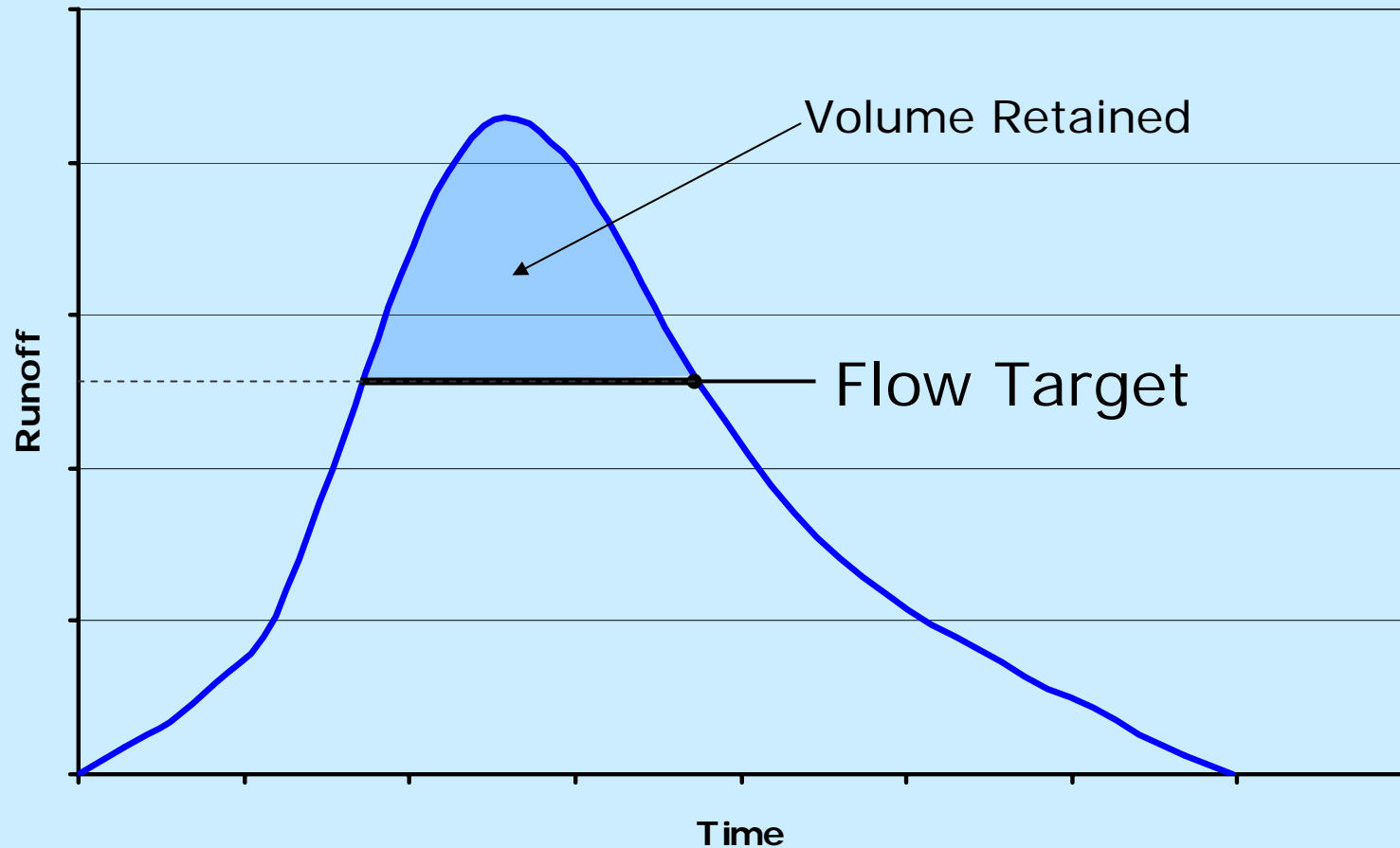
# Retention Design

## In-Line Option 2

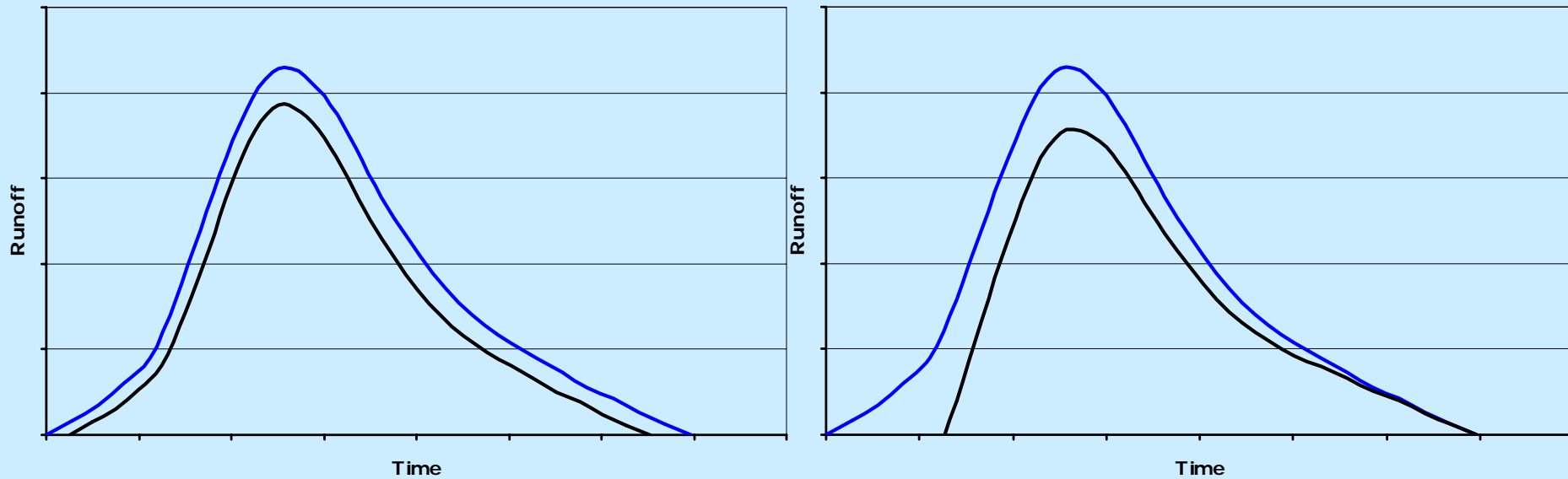


# Retention Design

Off-Line (Split Flow) Option

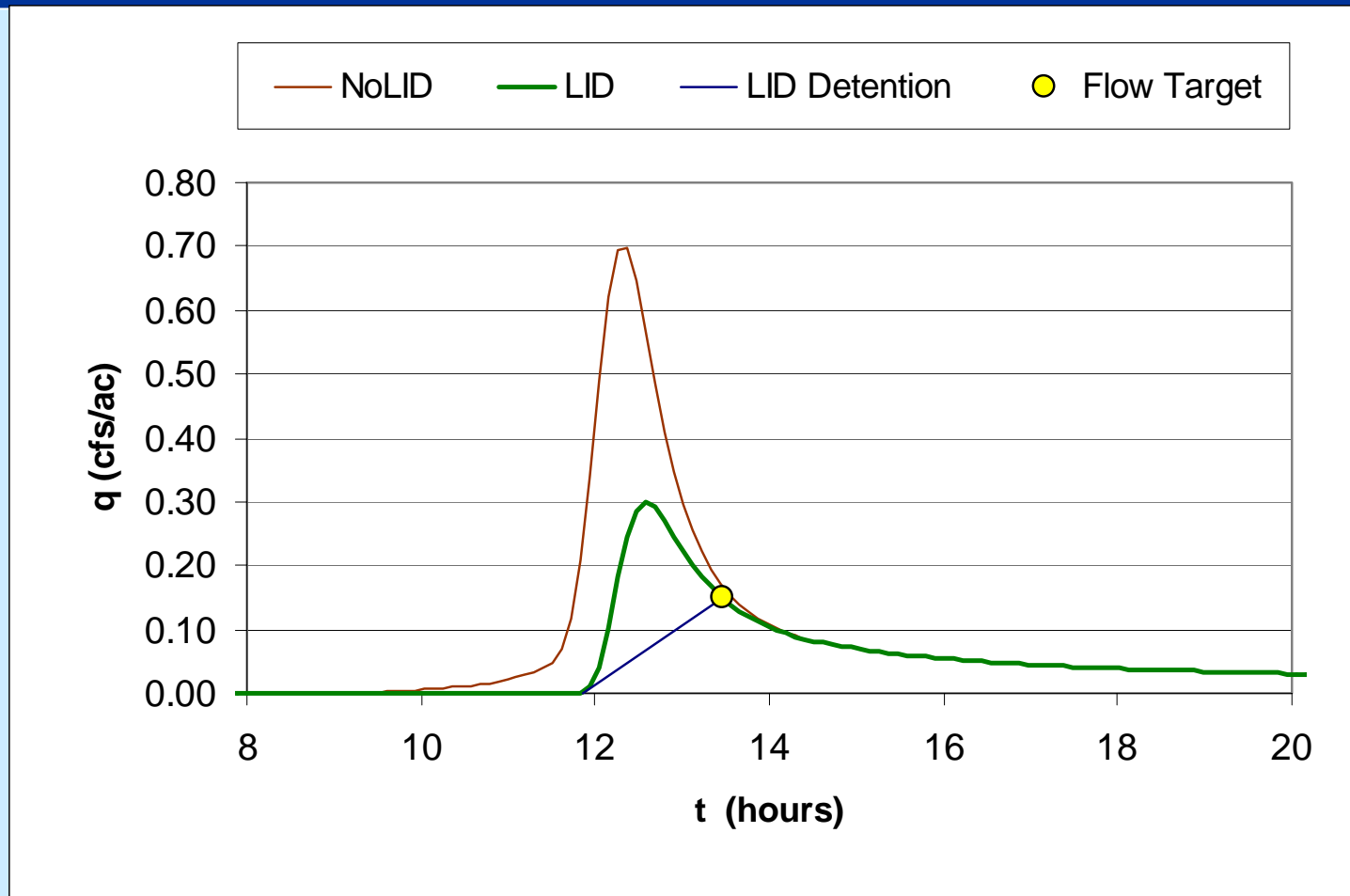


# Which Infiltration Pattern?



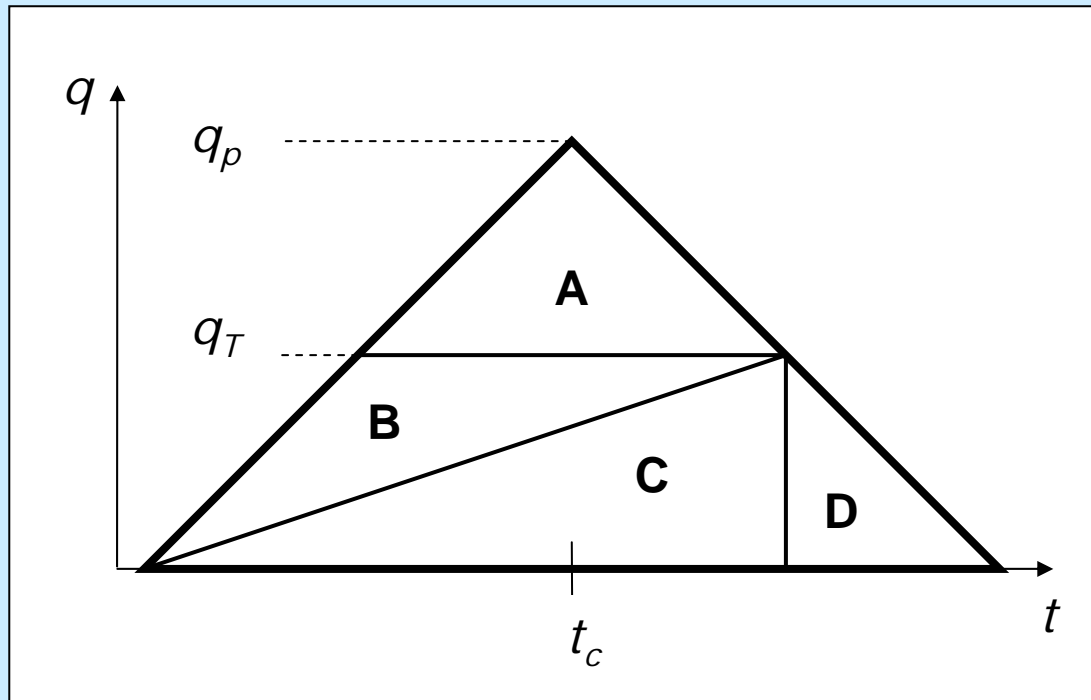
*They can't be both correct!*

# Distributed On-Site Retention



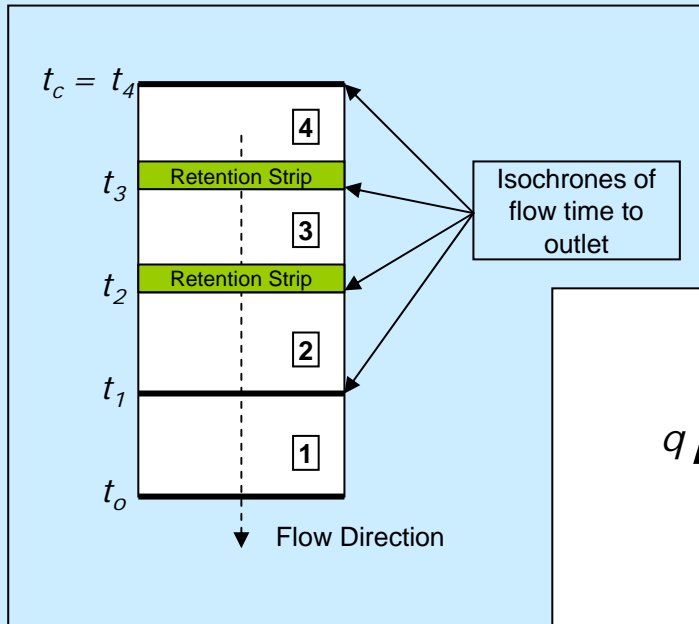
Precip = 2.57 in.,  $T_c = 0.8$  hr, CN=85,  
Retention 9 inches across 4% of 100-acre D.A.

# Storage Options Compared

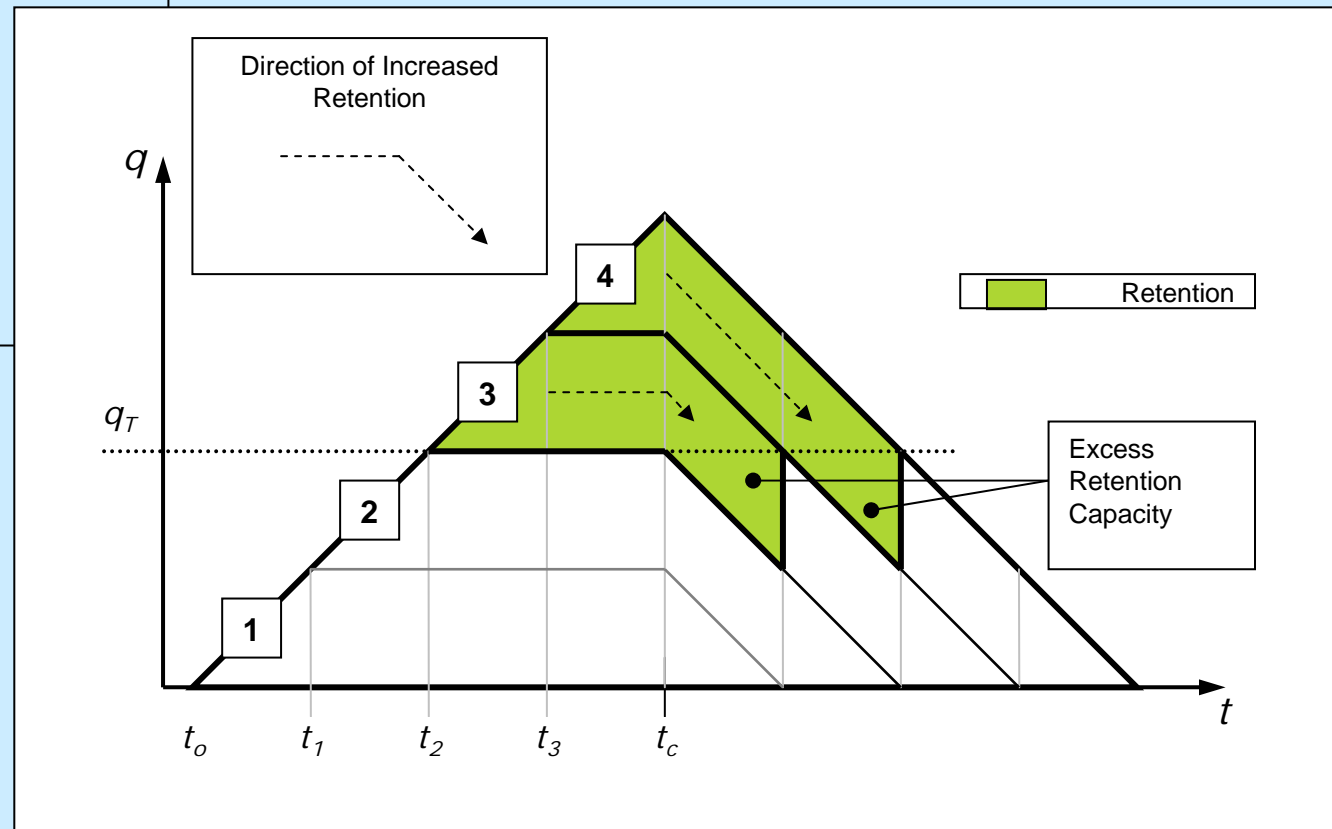
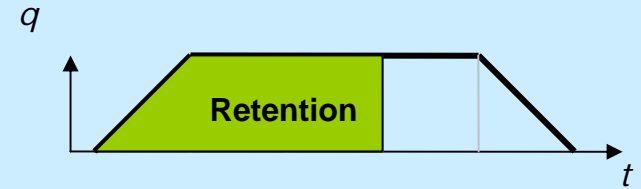


Total runoff	$A + B + C + D$
Retention if sized at outlet	$A + B + C$
Capacity of detention	$A + B$
Minimum retention needed	$A$

# Tiered Retention Concept for Peak Flow Control



Truncated hydrograph for subarea

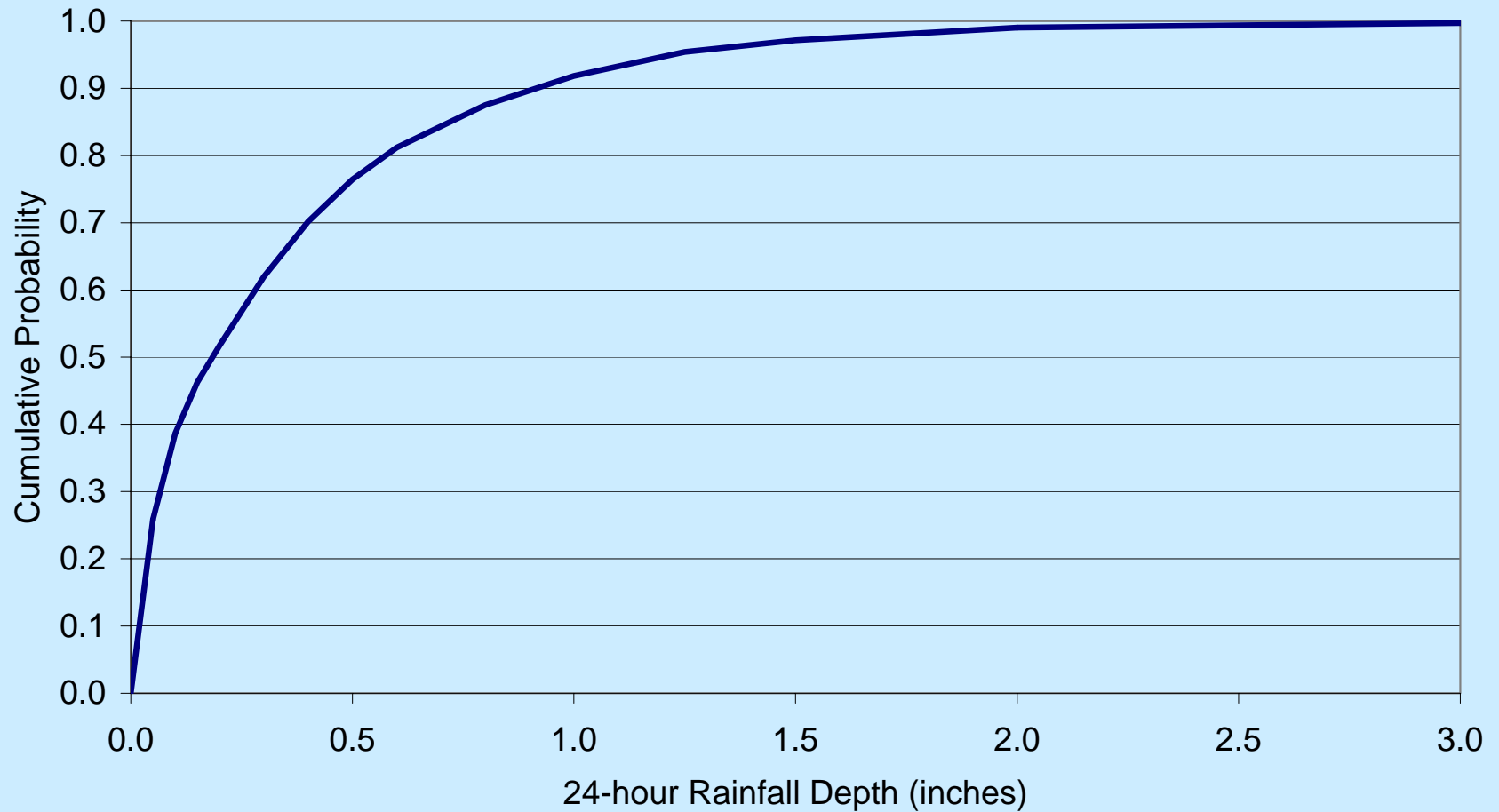


# Analysis Method #2: Average Annual Storage

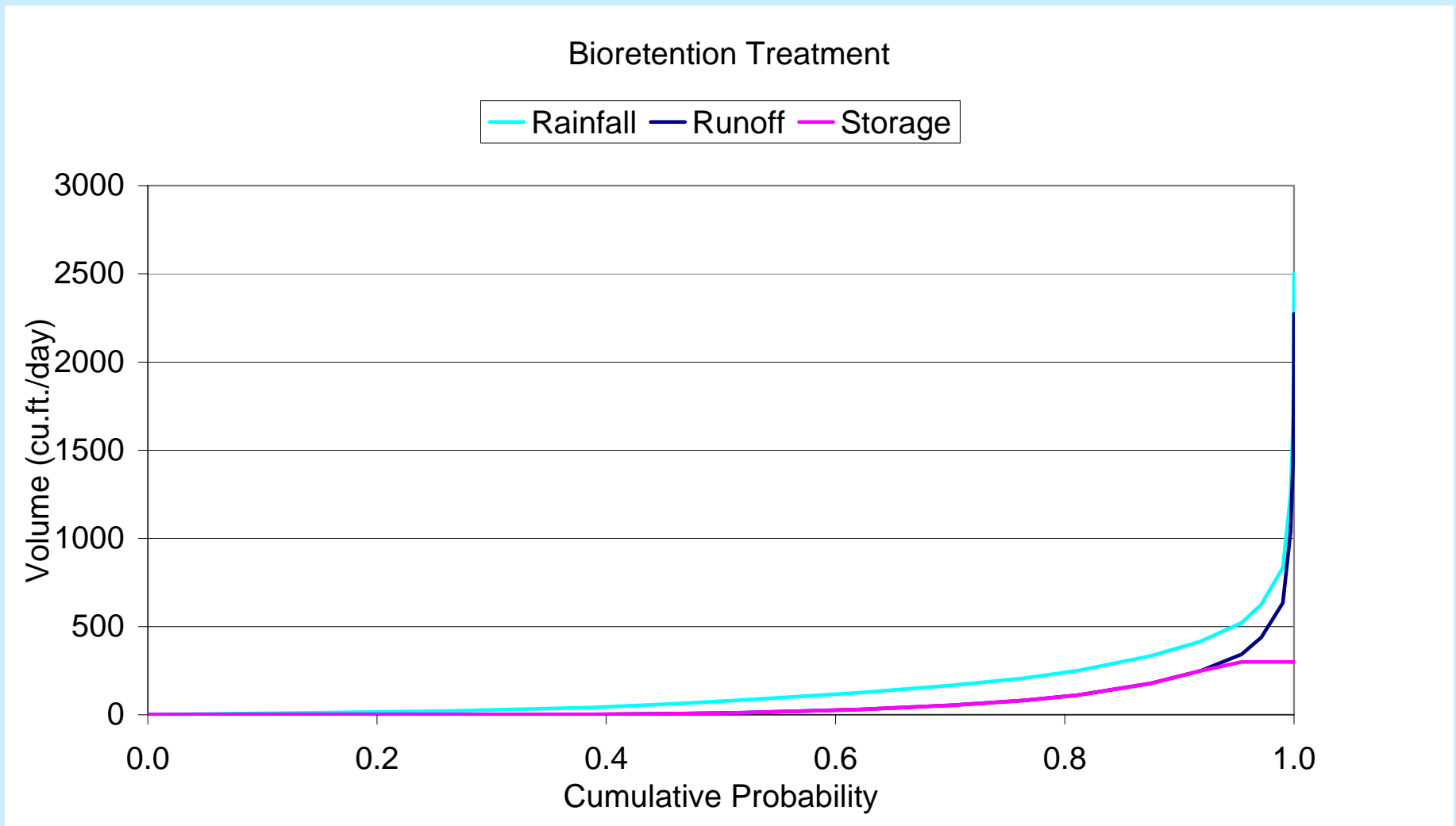
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- Retention capacity based on ponding volume and subsurface void space in soil or filter media
- Use cumulative probability distribution of depth for all storm events of given duration
- Assume retention volume will drain before next storm event

# Rainfall Distribution Curve



# Runoff Distribution Curve

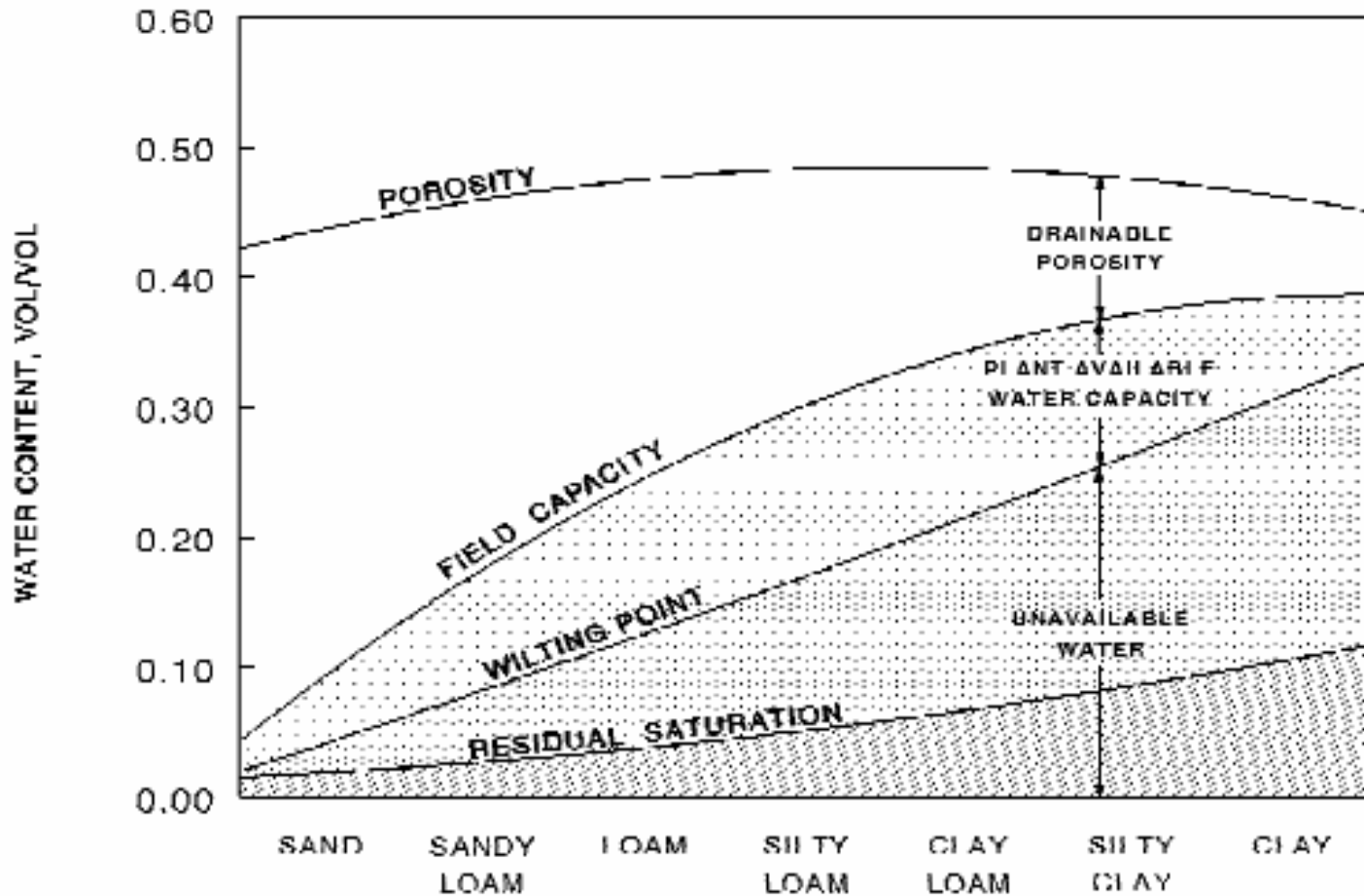


# Continuous Simulation

- Much more detailed
- Requires rainfall records
- ET rates between storms
  - Observed averages, or
  - Calculated from weather conditions
- Soil drainage rates between storms
- Linkages between LID features, e.g. permeable pavement, swales, bioretention



# Soil Moisture Capacity



# Modeling Tools

- Single-event
  - TR-20, TR-55
  - HEC-1, HEC-HMS
- Continuous, detailed flow paths
  - SWMM (EPA)
  - InfoWorks (UK)
  - MUSIC (Australia)

*Discussion: What tools do you use?*

# Questions? Answers!

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**Q & A**