# Stormwater BMPs: Design and Review/Approval Challenges

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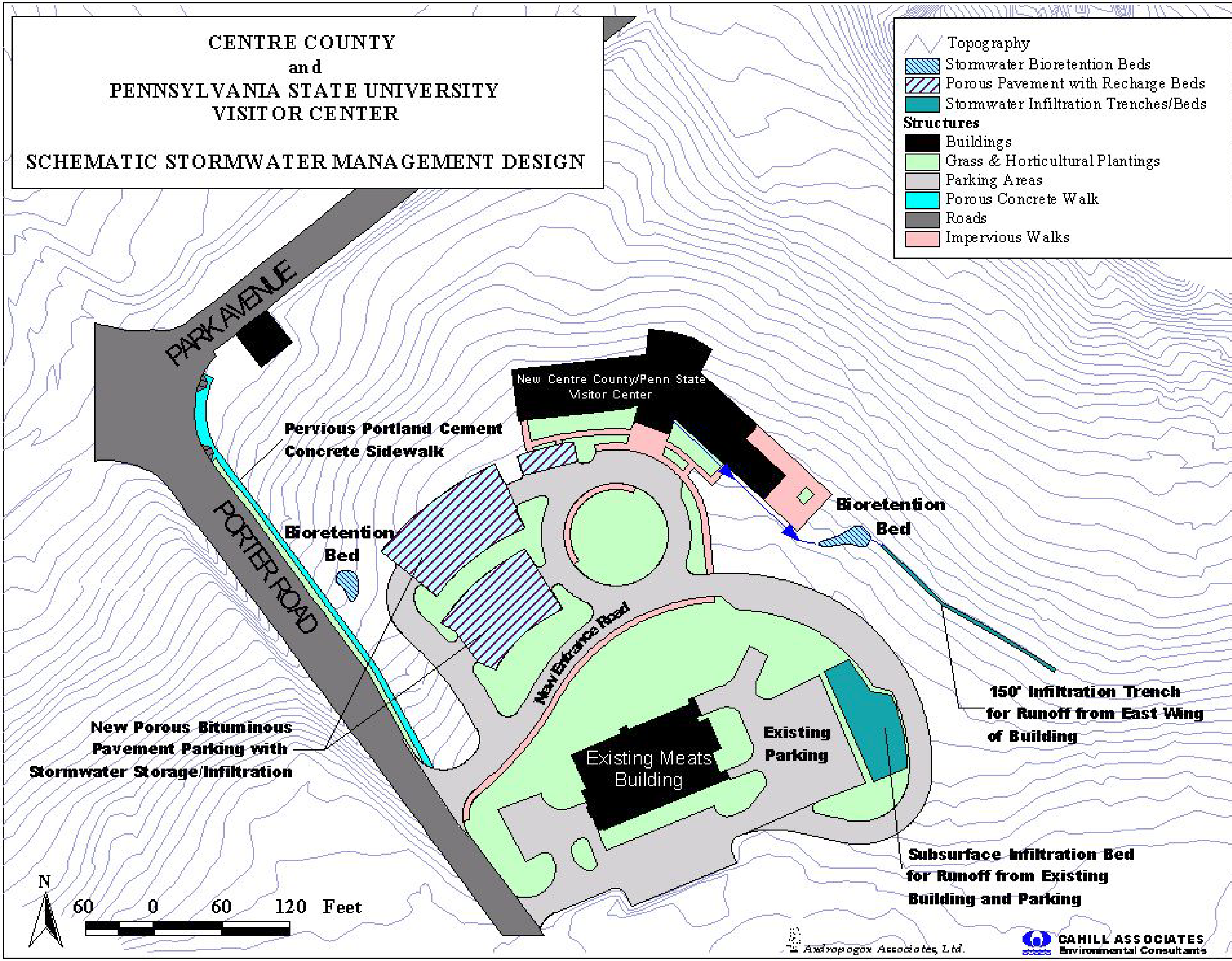
# Goals and Challenges

- More Widespread Use of BMPs
- Address All Elements of Stormwater:
  - Peak Rate (Municipal Ordinance)
  - Quality
  - Volume and Streambank Protection
  - Infiltration


CENTRE COUNTY
and
PENNSYLVANIA STATE UNIVERSITY
VISITOR CENTER
SCHEMATIC STORMWATER MANAGEMENT DESIGN
Topography
Stormwater Bioretention Beds
Porous Pavement with Recharge Beds
Stormwater Infiltration Trenches/Beds
Structures
Buildings
Grass & Horticultural Plantings
Parking Areas
Porous Concrete Walk
Roads
Impervious Walks
PARK AVENUE
PORTER ROAD
New Centre County/Penn State Visitor Center
Pervious Portland Cement Concrete Sidewalk
Bioretention Bed
Bioretention Bed
New Entrance Road
150' Infiltration Trench for Runoff from East Wing of Building
New Porous Bituminous Pavement Parking with Stormwater Storage/Infiltration
Existing Meats Building
Existing Parking
Subsurface Infiltration Bed for Runoff from Existing Building and Parking
N
60 0 60 120 Feet
Andropogon Associates, Ltd.
CAHILL ASSOCIATES
Environmental Consultants

# Challenge

- How to Show Compliance?
- Municipal Review and Approval
  - Peak Rate Attenuation
- NPDES – Volume

*Most Design Engineers and Most Municipal Review Engineers are not Hydrologists - Must Wear Many Hats.*

# What Have Other States/Cities Done?

- $WQ_v$ Water Quality Volume
- $Re_v$ Recharge Volume
- $Cp_v$ Channel Protection
- $Q_p$ Peak Control (2-year, 10-year)
- $Q_f$ Flood Safe Passage (100 year)

*Maryland, Georgia,*

# What's Happened?

- BMPs for Quality/Recharge added
- Still designing Large Detention Facilities for Peak
- Extended Detention – Channel Protection

# Design Goals for Calculations

1. Mitigate Peak Rates 2-Year to 100-Year
2. No Volume Increase for 2-Year Event
3. Maintain Groundwater Infiltration

*Provide Calculations for Municipal Approval*

*Dry Channels…*

*Eroded Streambanks…*

# Bankfull Flow Forms and Maintains Channel

- Recurrence Interval 1.5 Years
- Higher Flows Exceed Channel Capacity
- More Frequent Bankfull more important than large floods in shaping channel.

*The Channel is shaped by the Bankfull Flow*

# Three (Real Life) Case Studies

1. Institutional LID – Penn State Visitor Center
2. Commercial – Small Retail Shopping Center
3. Residential – High Density Townhouse, Quad, and Singles

# Design "Rules of Thumb"

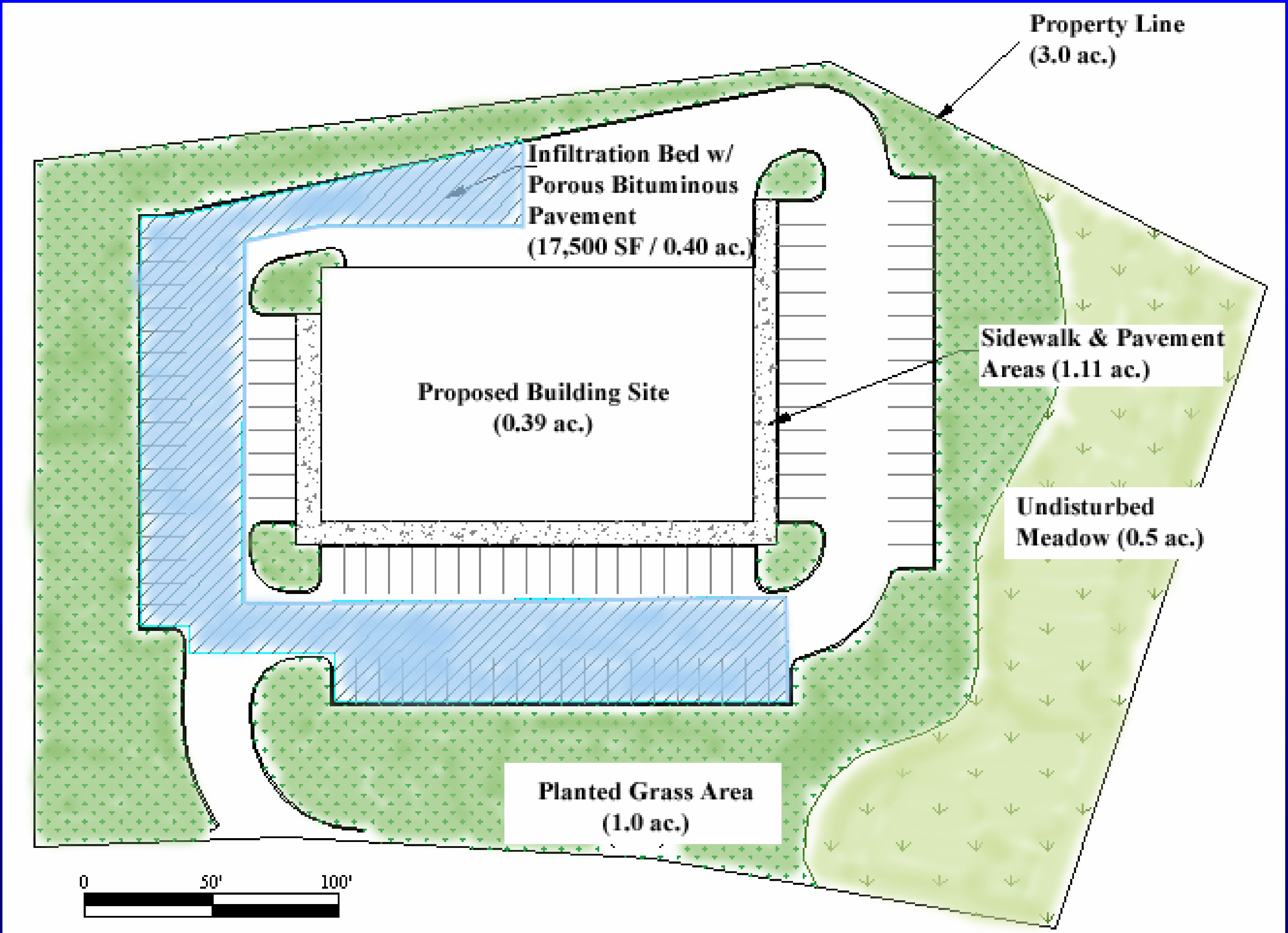
- Retain 2-Year Net Increase in Volume
  - Net Increase: 5,765 CF
  - Available Storage before Overflow: 6,532 CF
- Infiltrate at a Maximum 5:1 Ratio Impervious:Infiltration Area
  - Impervious Area: 61,000 SF
  - Infiltration Area: 12, 425 SF

Ratio 5:1

# Proposed Development 2: Commercial Shopping Center

- 3.0 Acre Site
- 1.5 acres Impervious (50%)
  - 17,000 Square Foot Building
  - 48,340 Square Feet Parking, Roads

*26% for People, 74% for Cars!*


Property Line
(3.0 ac.)
Infiltration Bed w/
Porous Bituminous
Pavement
(17,500 SF / 0.40 ac.)
Proposed Building Site
(0.39 ac.)
Sidewalk & Pavement
Areas (1.11 ac.)
Undisturbed
Meadow (0.5 ac.)
Planted Grass Area
(1.0 ac.)
0
50'
100'

# Case Study

- Existing (CN = 58):
  - – 3.0-acre meadow on HSG “B” soils
  - – SCS Lag Time of 12 minutes
- Proposed (CN = 79):
  - – Commercial Site
    - 1.5-acres pavement & building
    - 1-acre lawn
    - 0.5-acre undisturbed meadow
  - – SCS Lag Time of 6 minutes

# Design/Calculation Approach

- Size Infiltration System for Net increase in Volume for 2-year storm
- Mitigate Peak Rate for larger storms
- Compare to Typical Detention Basin Paradigm

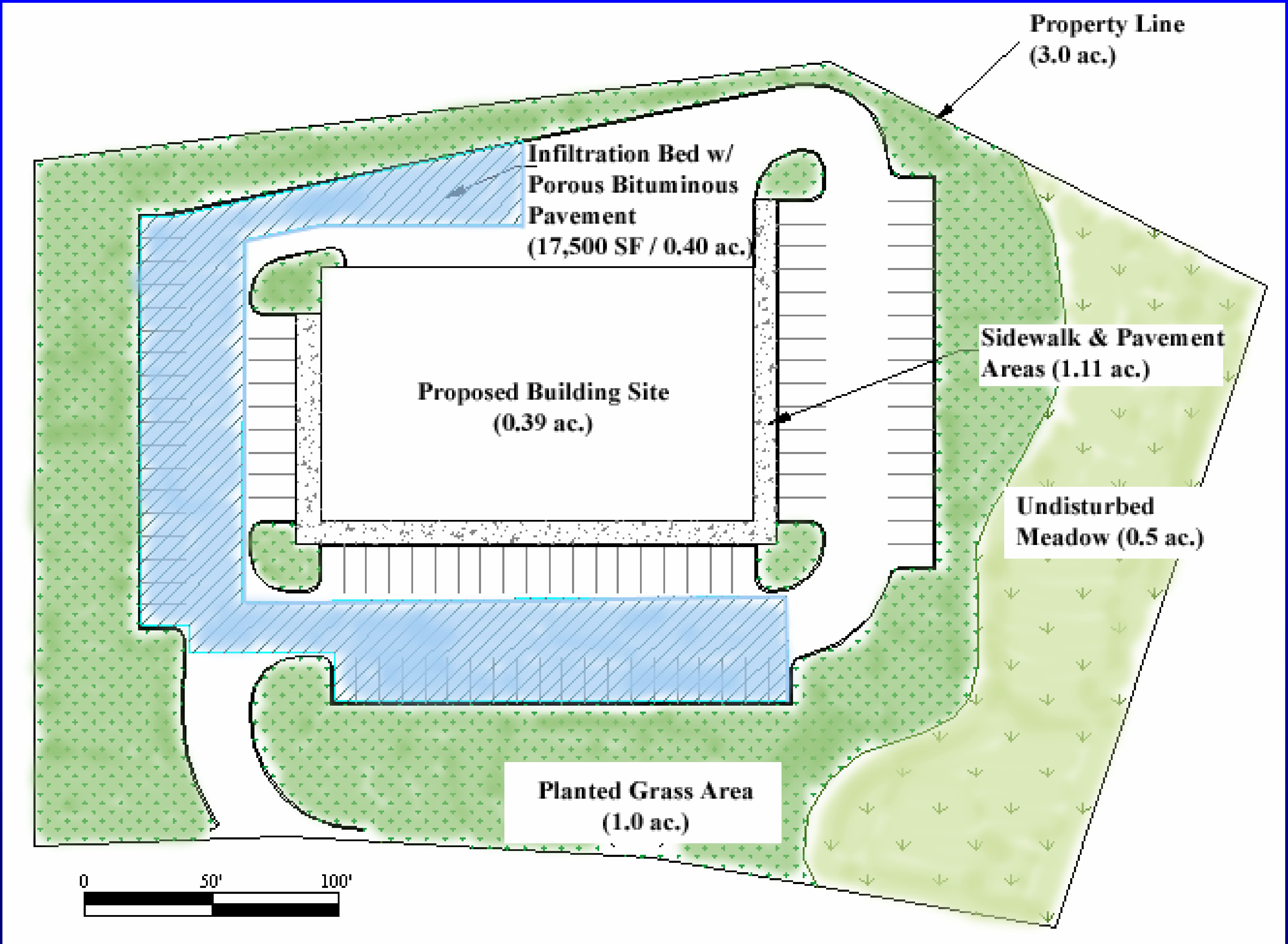
# Net increase in Volume for 2-year storm

| Condition | Area (ac) | Weighted CN | S (in) | $I_a$ (in) | Runoff Q (in) | Runoff Volume (cf) |
|---|---|---|---|---|---|---|
| EXISTING | 3.00 | 58.0 | 7.24 | 1.45 | 0.31 | 3,341 |
| Post-Development | | | | | | |
| Pervious | 1.50 | 60.0 | 6.67 | 1.33 | 0.37 | 2,015 |
| Impervious | 1.50 | 98 | 0.20 | 0.04 | 2.87 | 15,616 |
| TOTAL POST-DEV | 3.00 | 79.0 | 2.66 | --- | 1.62 | 17,631 |

**NET CHANGE IN RUNOFF VOLUME (CF): 14,290**

# Stormwater Management Techniques

- Innovative Design
  - 0.4 ac (17,500 SF) Porous Asphalt w/ Infiltration Beds (2 foot storage depth)
  - Storage Volume = 14,000 CF (0.32 ac-ft)
  - Steady-state Infiltration Rate = 2 inches/hour
    - Modeled in HEC-HMS as a Diversion
    - Infiltration Rate included in Stage-Storage-Discharge Table
- Conventional Design
  - Detention Basin instead of undisturbed meadow (2 foot storage depth)
  - Storage Volume = 20,000 CF (0.46 ac-ft)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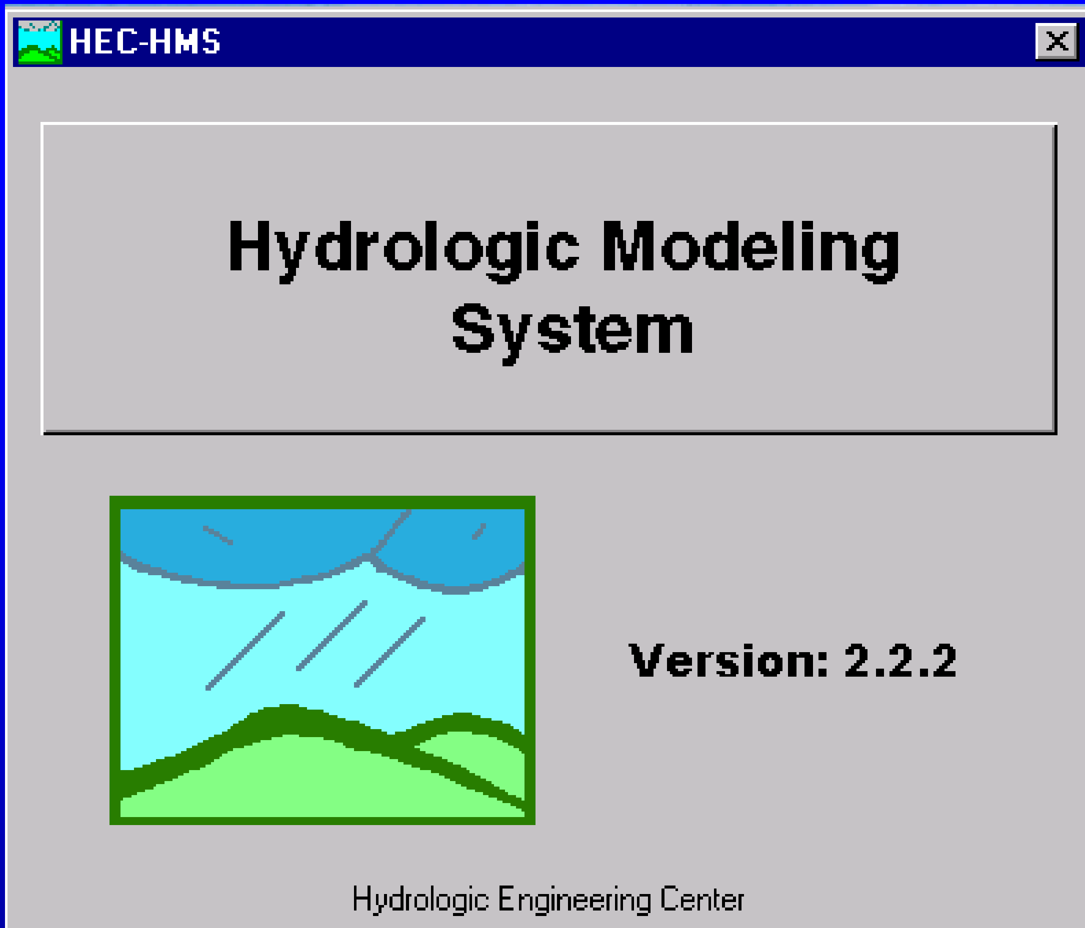
Areas (1.11 ac.)
Undisturbed
Meadow (0.5 ac.)
Planted Grass Area
(1.0 ac.)
0
50'
100'

# Hydrologic Calculations

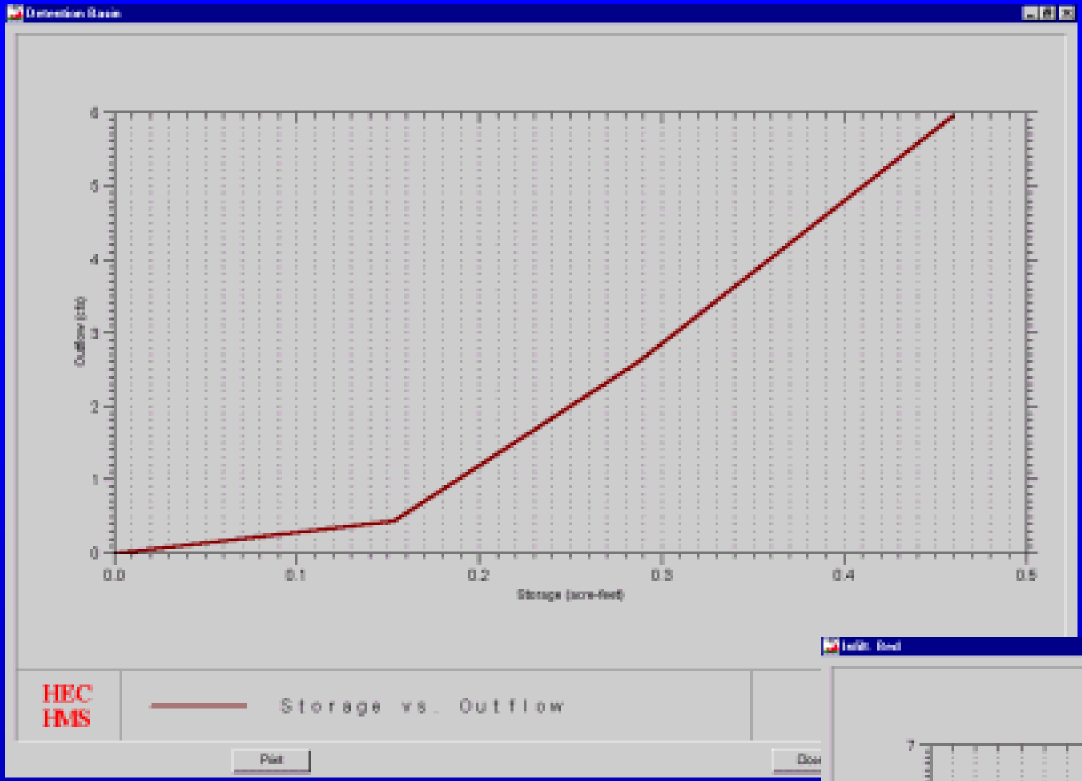
- USDA-NRCS Cover-Complex Method (TR-55)
- US Army Corp of Engineers' *Hydrologic Engineering Center – Hydrologic Modeling System* (HEC-HMS), Version 2.2.2 (28 May 2003)

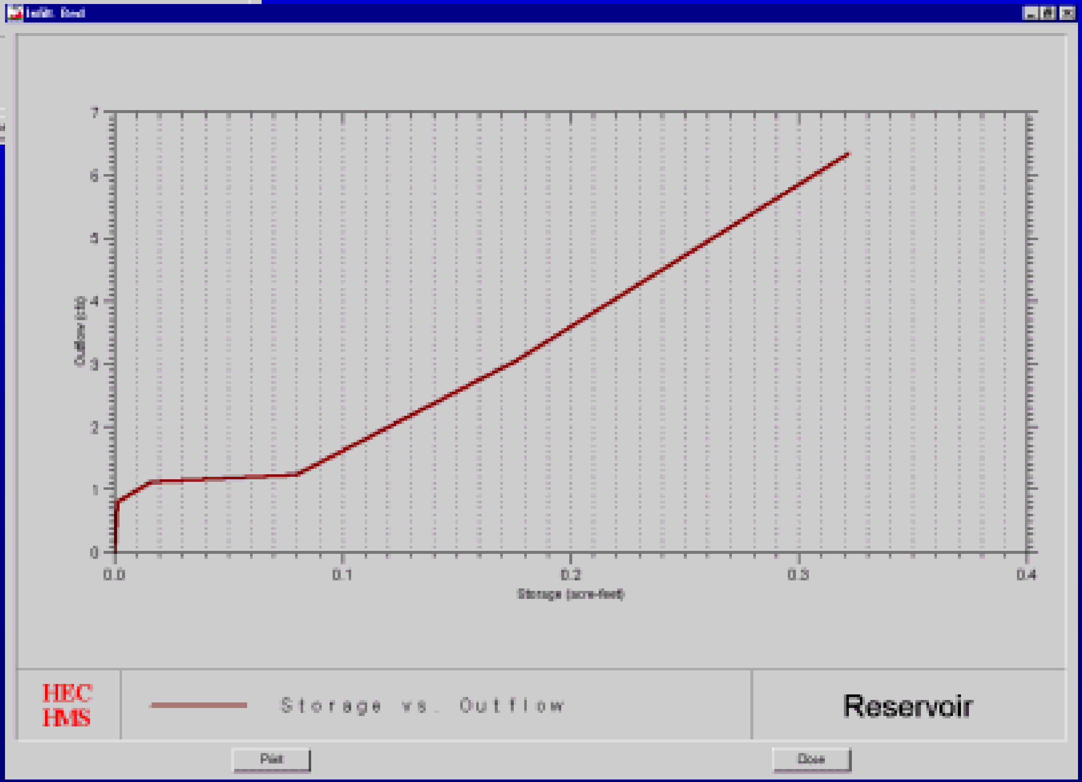
http://www.hec.usace.army.mil/software/hec-hms/hechms-download.html

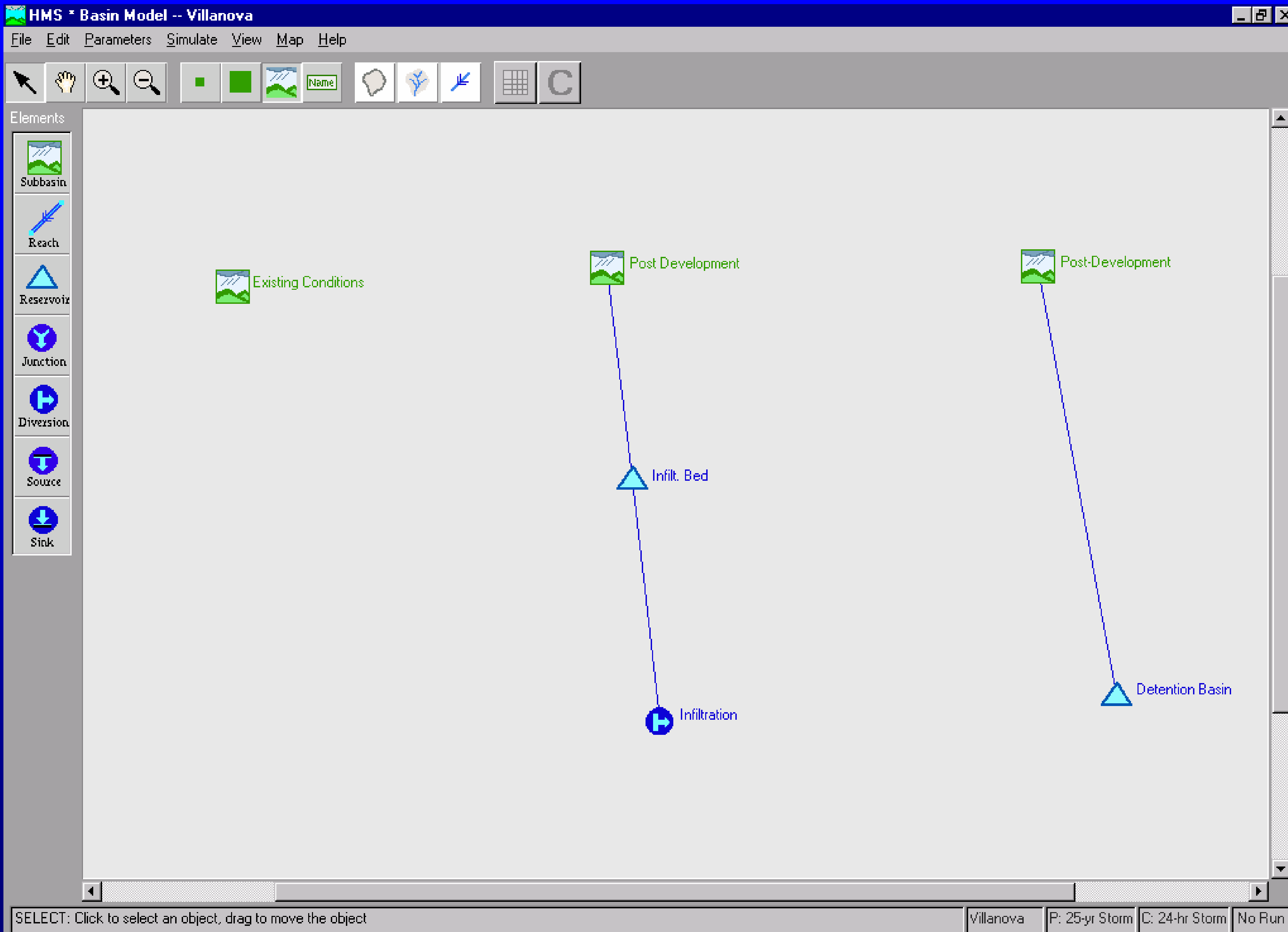

HEC-HMS
Hydrologic Modeling System
Version: 2.2.2
Hydrologic Engineering Center


HEC-HMS
HEC Hydrologic Modeling System
Version: 2.2.2 (28 May 2003) Build 1091
For more information contact:
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616
(530) 756-1104
Copyright 1995 Visix Software Inc., All Rights Reserved
(Galaxy Run Time Components Only)
OK
View License Agreement

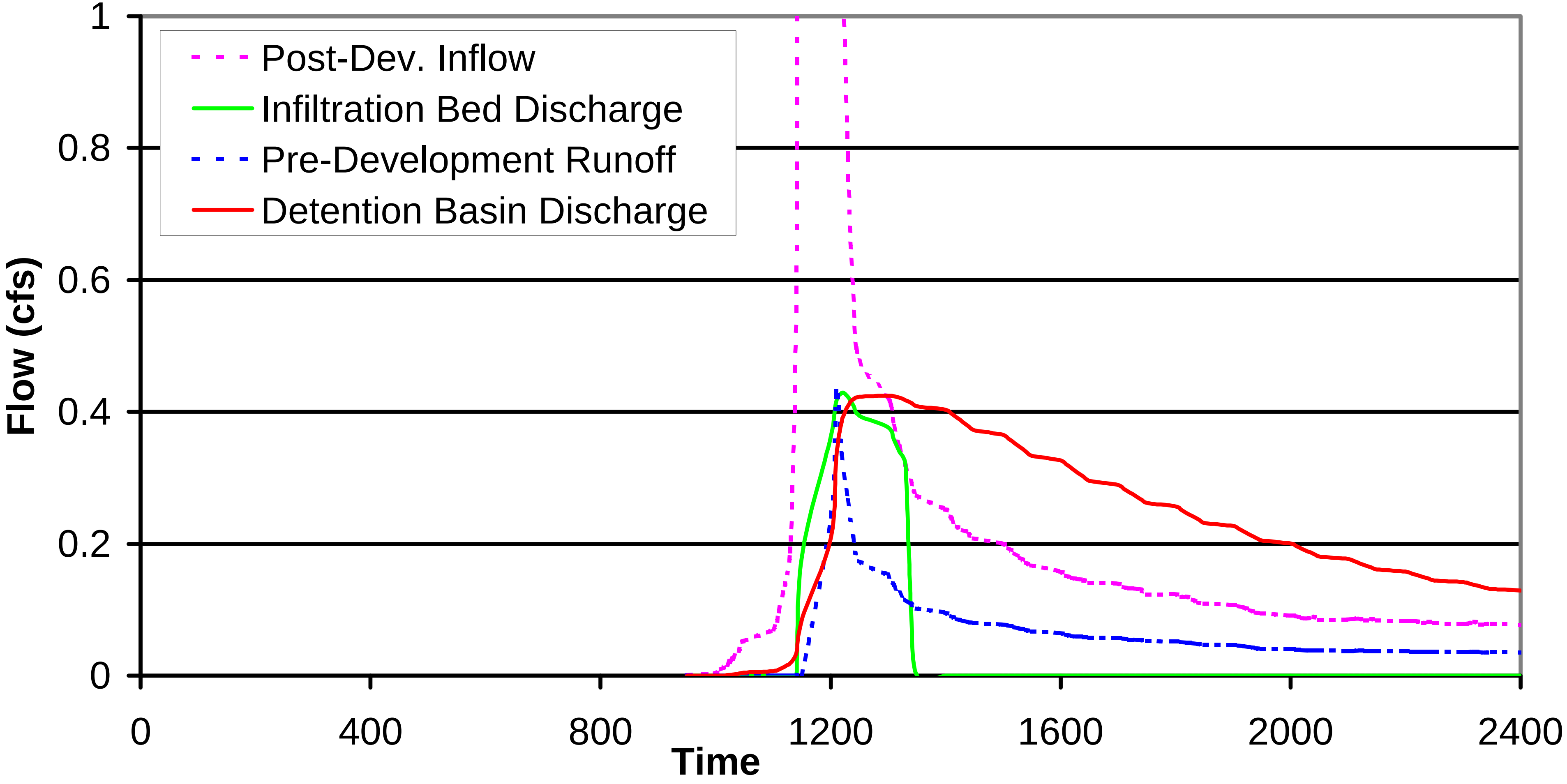
# Stage-Storage-Discharge Curves



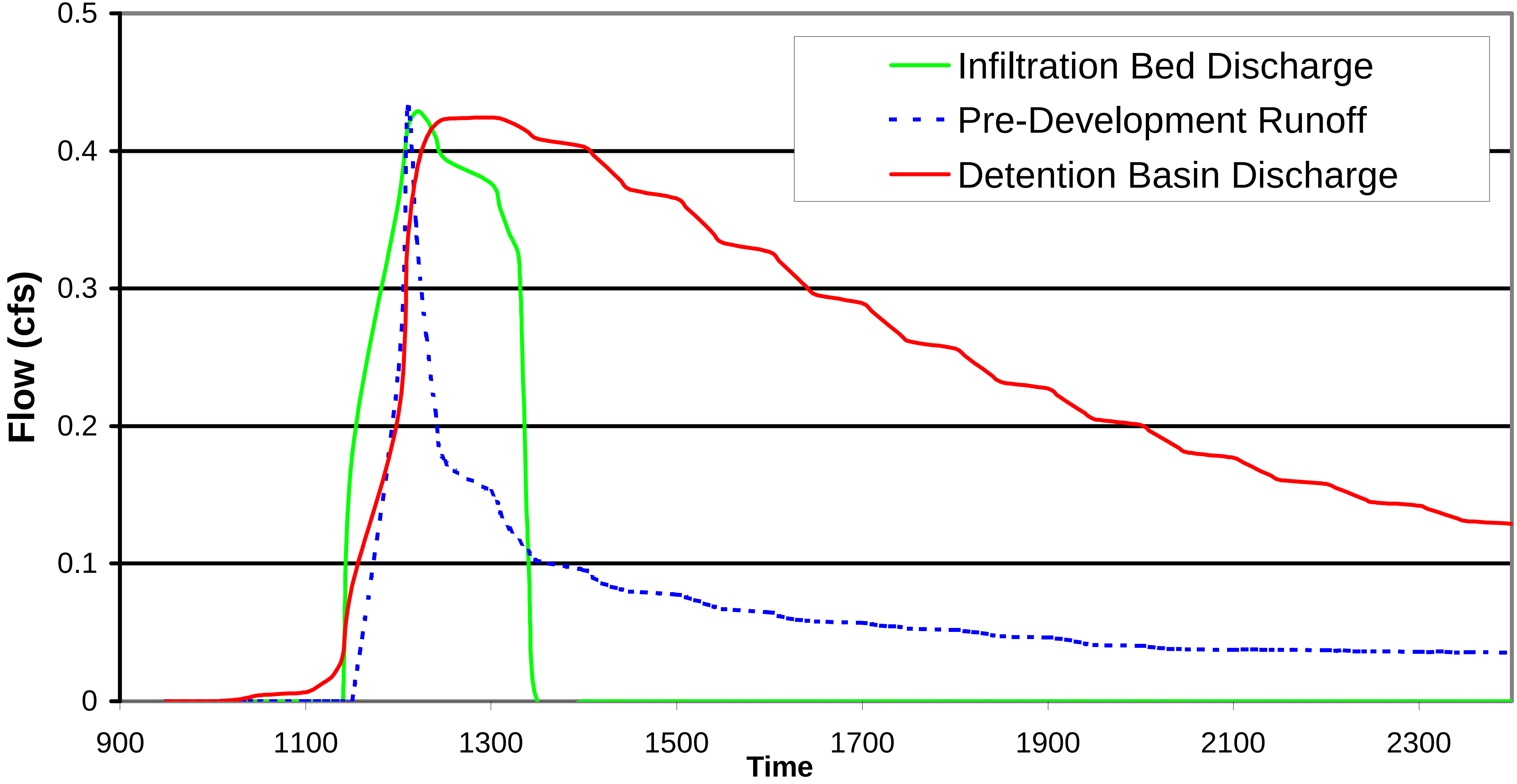




HMS * Basin Model -- Villanova
File
Edit
Parameters
Simulate
View
Map
Help
Name
Elements
Subbasin
Reach
Reservoir
Junction
Diversion
Source
Sink
Existing Conditions
Post Development
Post-Development
Infilt. Bed
Infiltration
Detention Basin
SELECT: Click to select an object, drag to move the object
Villanova
P: 25-yr Storm
C: 24-hr Storm
No Run

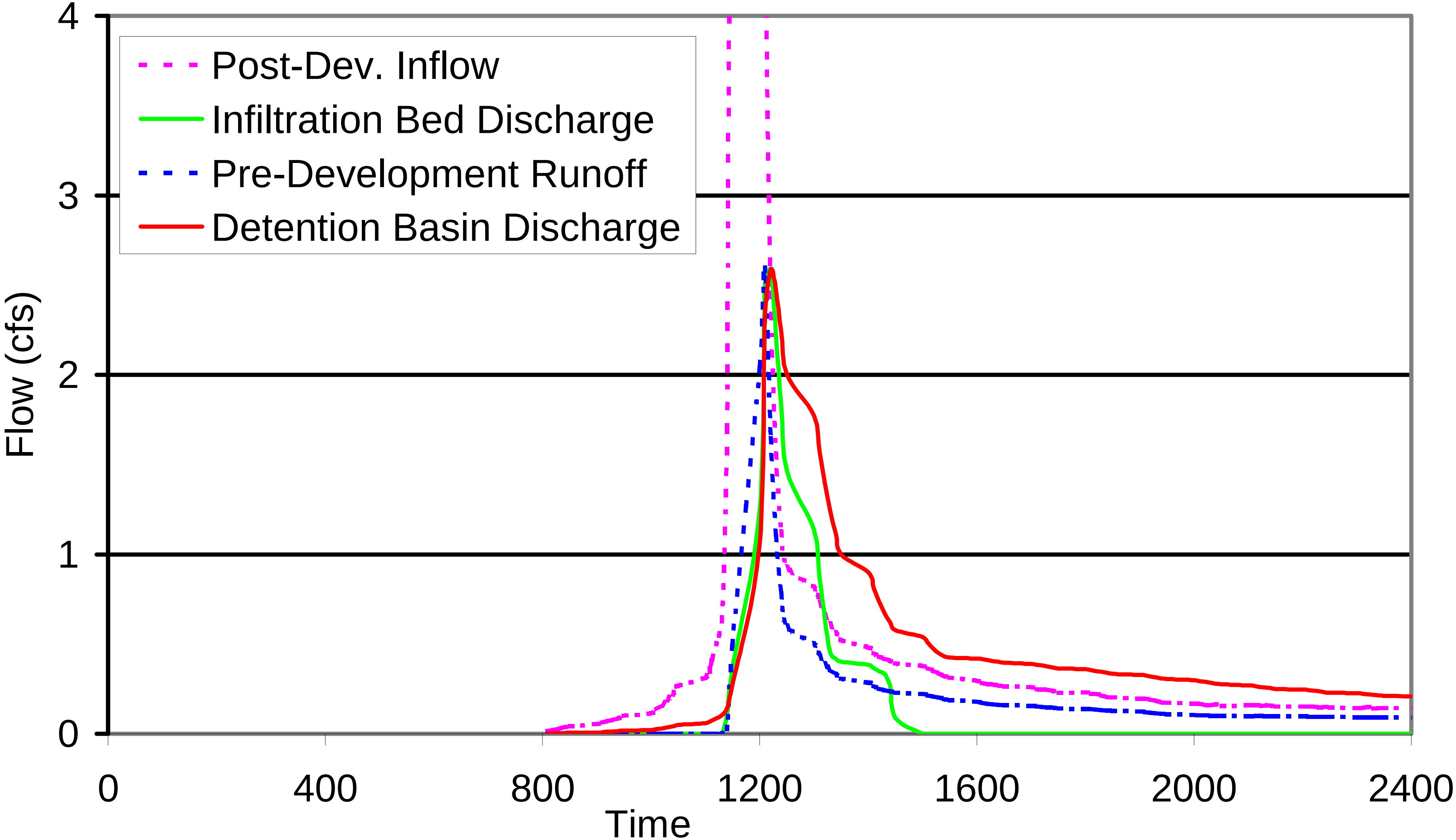
# 2-yr Storm Hydrographs (3.1”/24 hr)



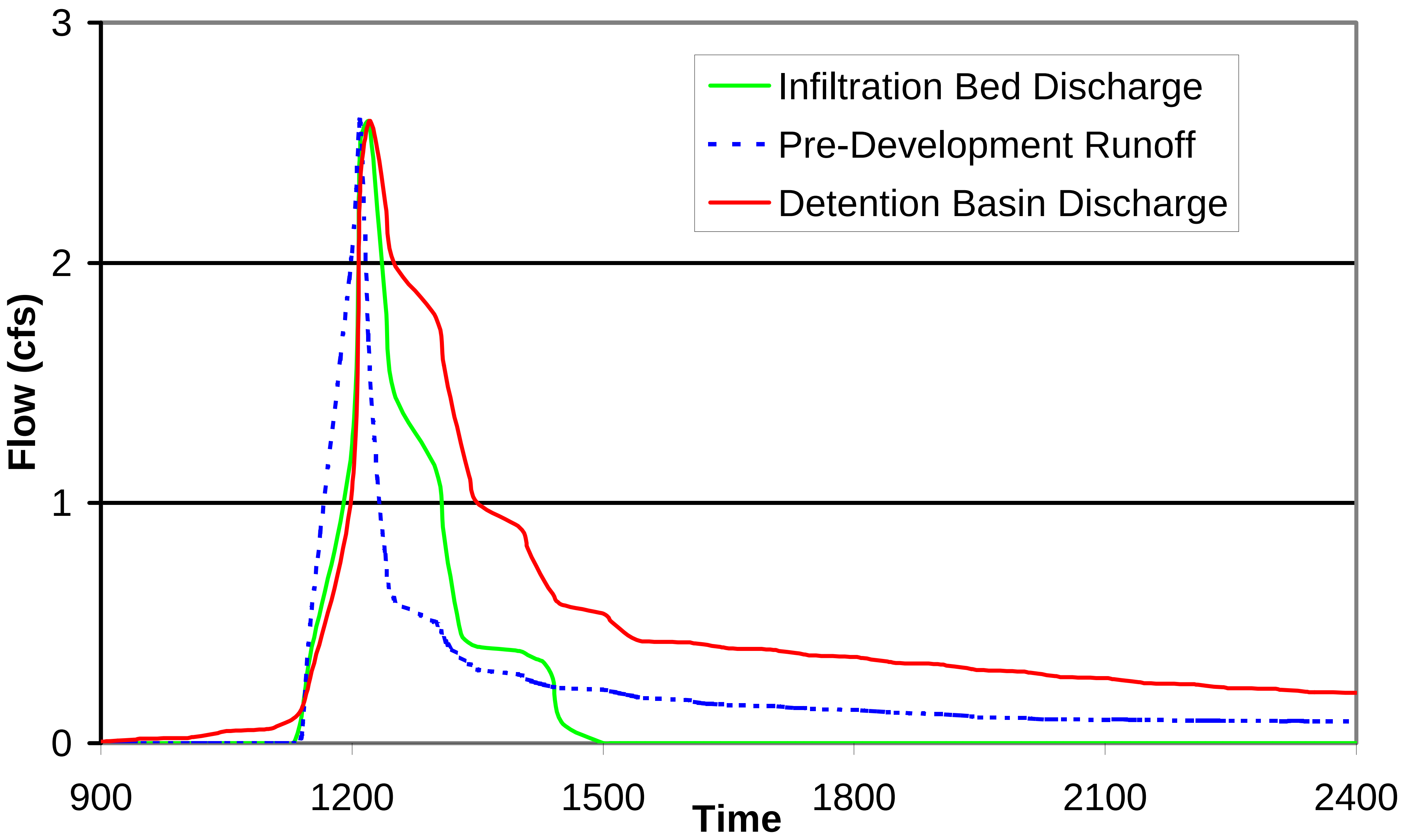
# 2-yr Storm Peak Rates



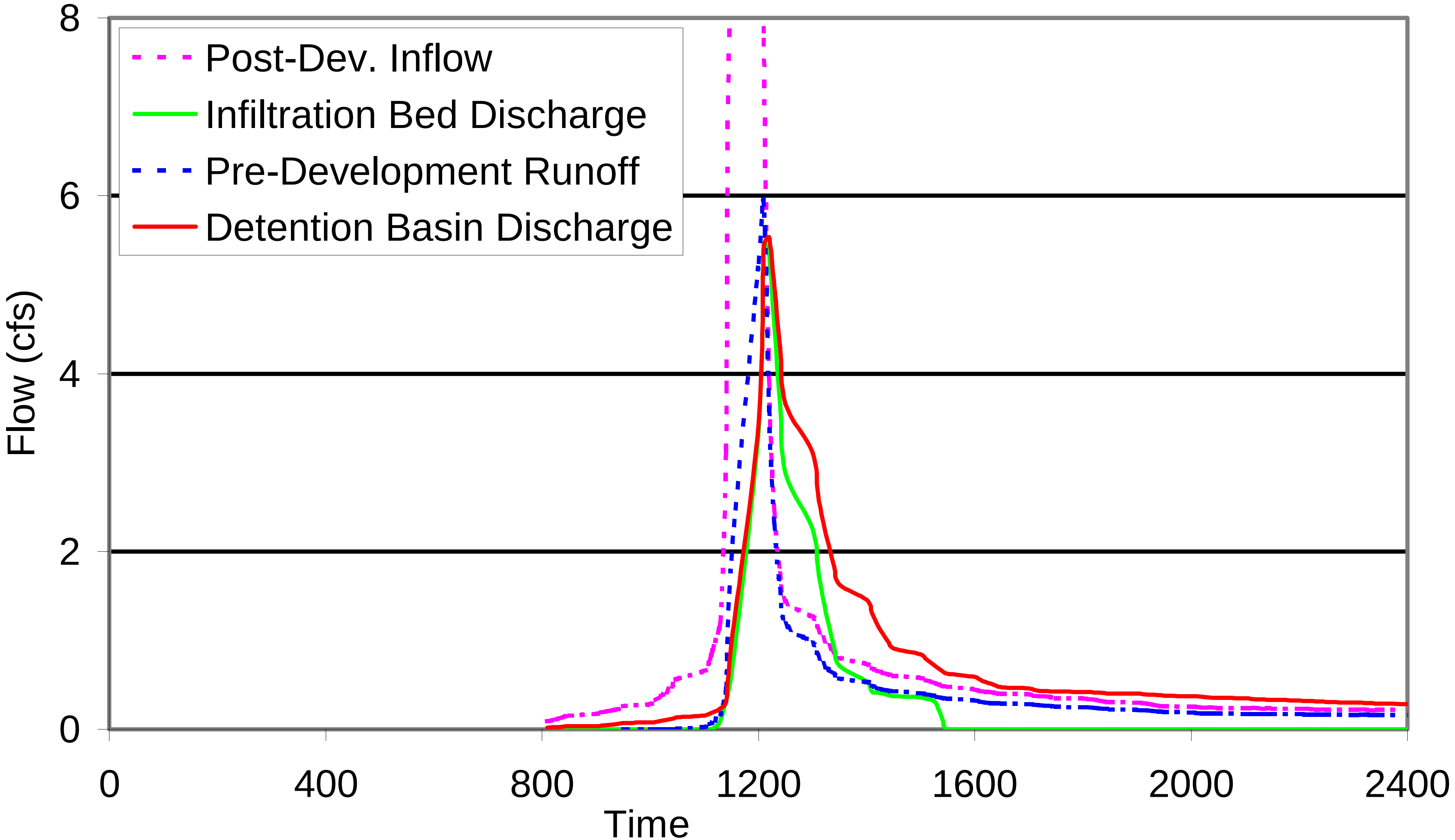
# 10-yr Storm Hydrographs (4.9”/24 hr)



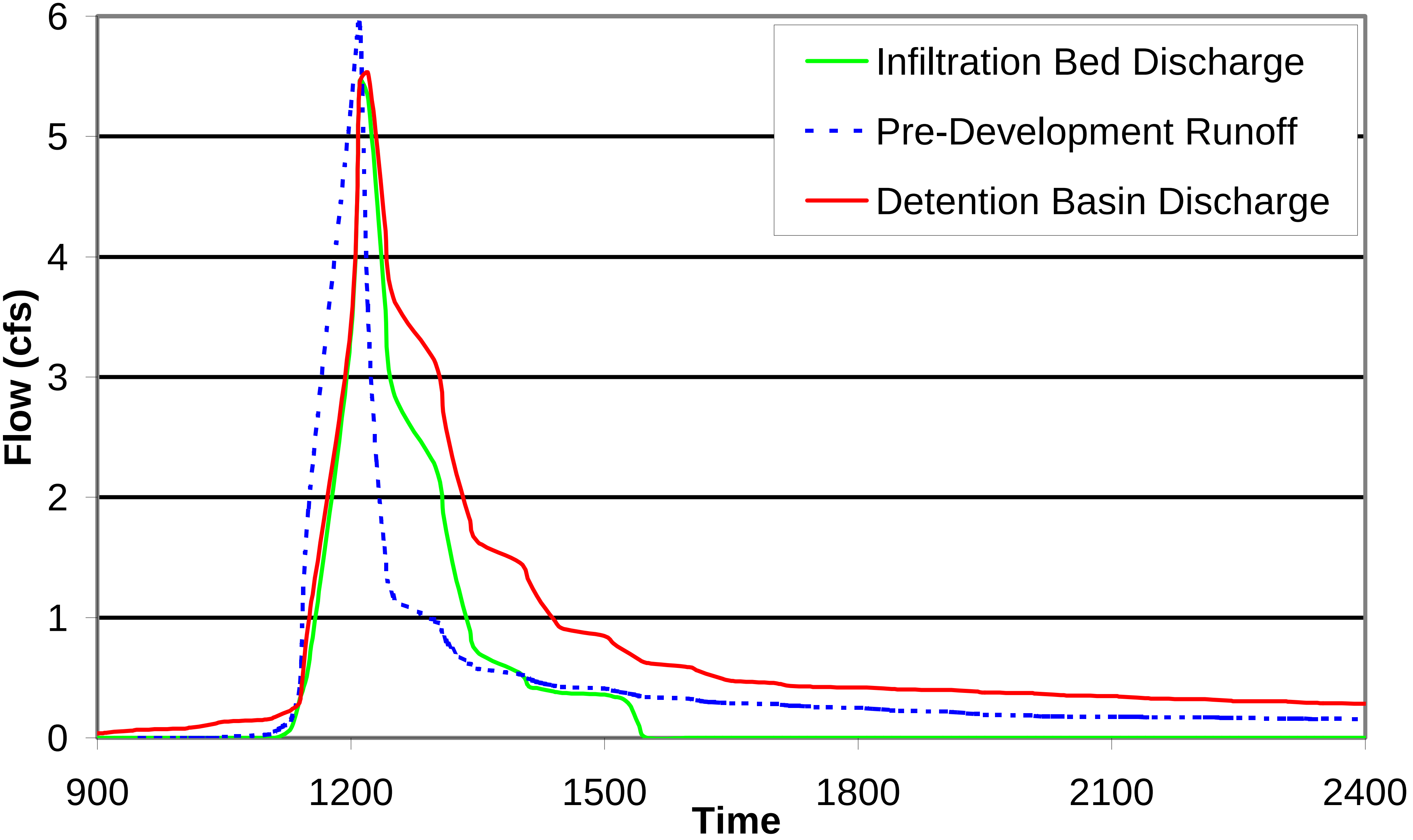
# 10-yr Storm Peak Rates



# 100-yr Storm Hydrographs (6.9”/24 hr)



# 100-yr Storm Peak Rates



# Summary Results – Peak Rates

| Storm Frequency (year) | Existing Runoff Rate (cfs) | Unmitigated Post-Dev. Runoff Rate (cfs) | Infiltration Bed Discharge (cfs) | Detention Basin Discharge (cfs) |
|---|---|---|---|---|
| 2 | 0.43 | 4.58 | **0.43** | **0.42** |
| 10 | 2.59 | 9.89 | **2.59** | **2.59** |
| 25 | 3.52 | 11.75 | **3.40** | **3.48** |
| 100 | 5.93 | 16.14 | **5.45** | **5.53** |

# Summary Results – Infiltration

| Storm Frequency (year) | Existing Runoff Depth (in) | Unmitigated Post-Dev. Runoff Depth (in) | Total Infiltration (in) | Infiltration Bed Discharge (in) | Percentage of Existing Volume |
|---|---|---|---|---|---|
| 2 | 0.30 | 1.26 | 1.01 | **0.25** | **83%** |
| 10 | 1.11 | 2.71 | 1.68 | **1.03** | **93%** |
| 25 | 1.44 | 3.23 | 1.87 | **1.36** | **94%** |
| 100 | 2.33 | 4.48 | 2.30 | **2.18** | **94%** |

# Detention

| Storm Frequency (year) | Existing Runoff Depth (in) | Post-Dev. Runoff Depth (in) | Percentage of Existing Volume |
|---|---|---|---|
| 2 | 0.30 | 1.26 | **420%** |
| 10 | 1.11 | 2.71 | **244%** |
| 25 | 1.44 | 3.23 | **224%** |
| 100 | 2.33 | 4.48 | **192%** |

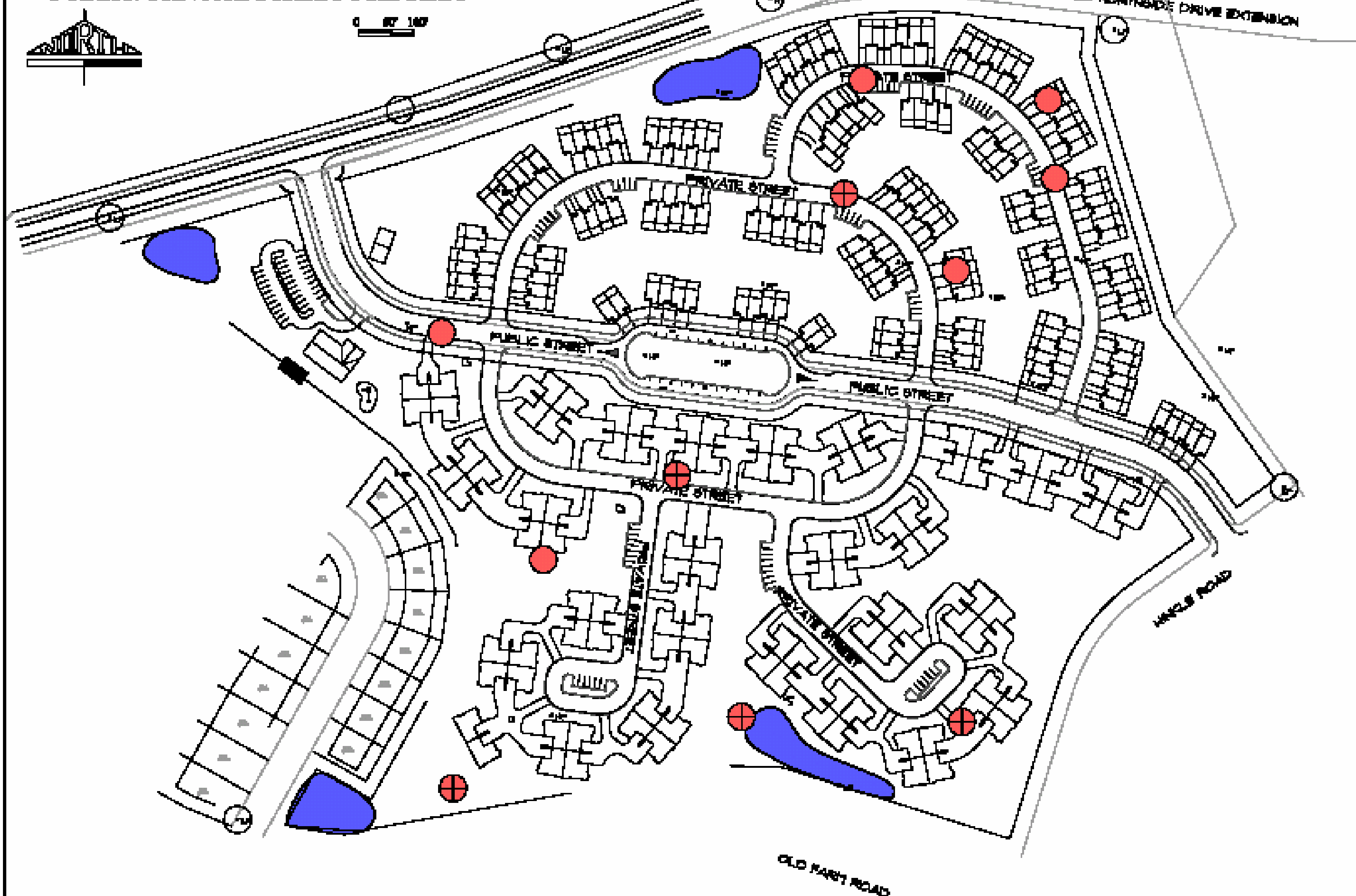
# Stormwater Management for The Village at Springbrook Farms

- Site marked by closed depressions and some sinkholes
- Proposed plan consists of:
  - Revised layout with setbacks from depressions and sinkholes
  - Distributed infiltration system, heavily vegetated

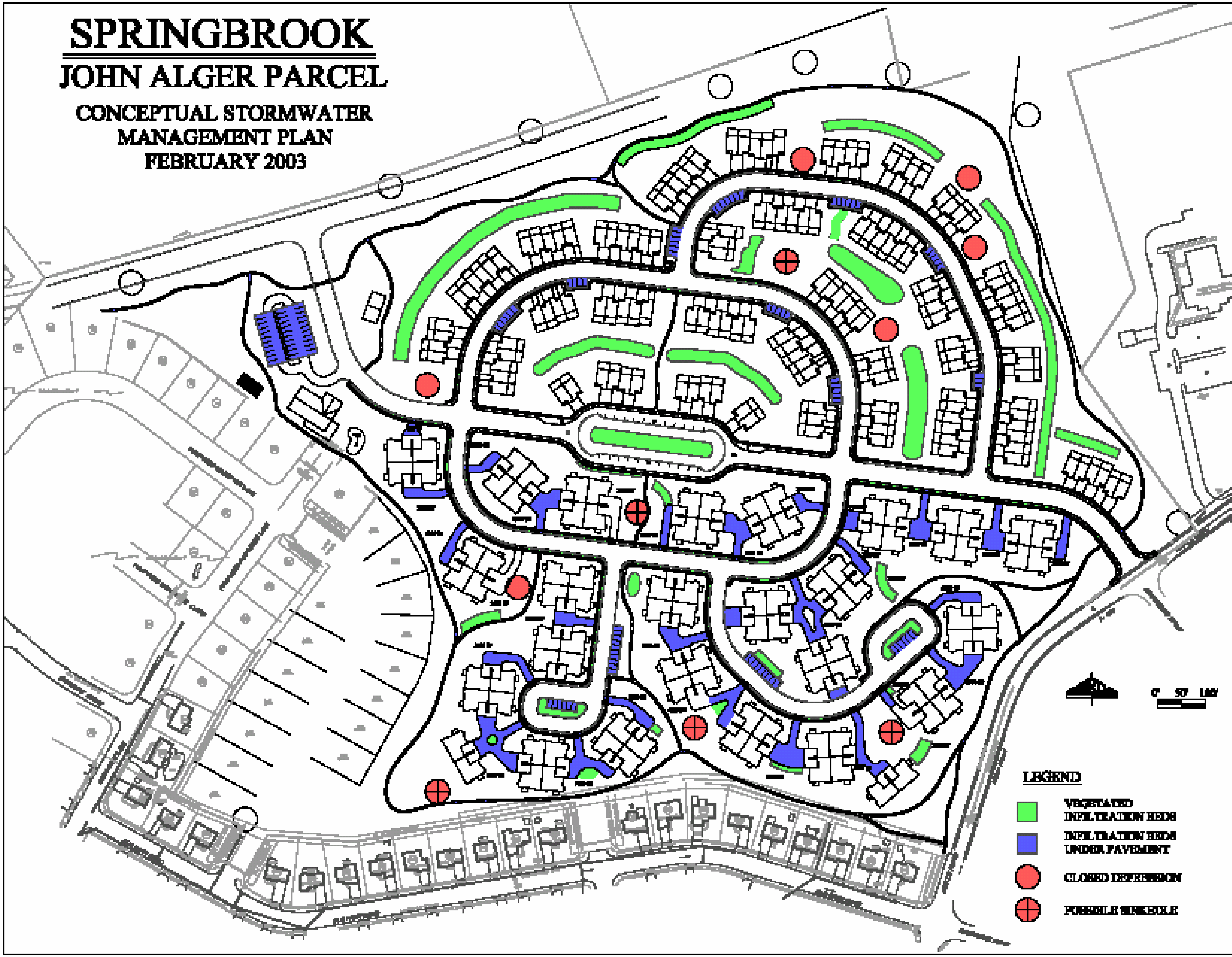
# SPRINGBROOK

## JOHN ALGER PARCEL

### PUBLIC/ PRIVATE STREET SCENARIO



# SPRINGBROOK
## JOHN ALGER PARCEL
### CONCEPTUAL STORMWATER MANAGEMENT PLAN
FEBRUARY 2003



# Example Drainage Area

- Existing (CN = 70.6):
  - 24 acres of Row Crops
  - **Because of Closed Depressions, only 7.5 acres discharge offsite!!!**
- Proposed (CN = 81.3):
  - 24 acres of townhouse development
  - To avoid collecting stormwater in existing Closed Depressions, **all 24 acres discharge offsite!!!**

# Summary Results – Infiltration

| Storm Frequency (year) | Existing Runoff Depth (in) | Unmitigated Post-Dev. Runoff Depth (in) | Total Infiltration (in) | Infiltration Bed Discharge (in) | Percentage of Existing Volume |
|---|---|---|---|---|---|
| 2 | 0.24 | 1.33 | 1.27 | **0.06** | **27%** |
| 10 | 0.62 | 2.84 | 1.78 | **1.06** | **170%** |
| 25 | 0.74 | 3.28 | 1.91 | **1.37** | **185%** |
| 100 | 1.10 | 4.56 | 1.97 | **2.59** | **236%** |

# Detention

| Storm Frequency (year) | Existing Runoff Depth (in) | Post-Dev. Runoff Depth (in) | Percentage of Existing Volume |
|---|---|---|---|
| 2 | 0.24 | 1.33 | **561%** |
| 10 | 0.62 | 2.84 | **458%** |
| 25 | 0.74 | 3.28 | **443%** |
| 100 | 1.10 | 4.56 | **415%** |

# TR-55 To Estimate Peak Rate Reduction Based on Storage Volume

D:\PROGRA~1\TR-55\TR55.EXE

TR-55
URBAN HYDROLOGY FOR SMALL WATERSHEDS
Version 2.00

1 = HELP TO SELECT METHOD

2 = RUNOFF CURVE NUMBER COMPUTATION

3 = TIME OF CONCENTRATION AND TRAVEL TIME

4 = GRAPHICAL PEAK DISCHARGE METHOD

5 = TABULAR HYDROGRAPH METHOD

6 = STORAGE VOLUME FOR DETENTION BASINS

SELECTION = 1

Press 1-6 or ↑↓ to Select, then press ←┘Enter

NUM

F1Help F2Print F3Load F4Save F5DOS F6Zero

# TR-55 To Estimate Peak Rate Reduction Based on Storage Volume

D:\PROGRA~1\TR-55\TR55.EXE

TR-55 STORAGE VOLUME FOR DETENTION BASINS Version 2.00

Depending on what information is provided, either the required detention basin storage or peak outflow is estimated. Basin storage volume is determined from peak inflow rate, volume of storm runoff and desired outflow rate. Peak outflow rate is determined from peak inflow rate, volume of storm runoff and basin storage.

The method applies where :

Shortcut flood routing is based on average storage and routing effects.

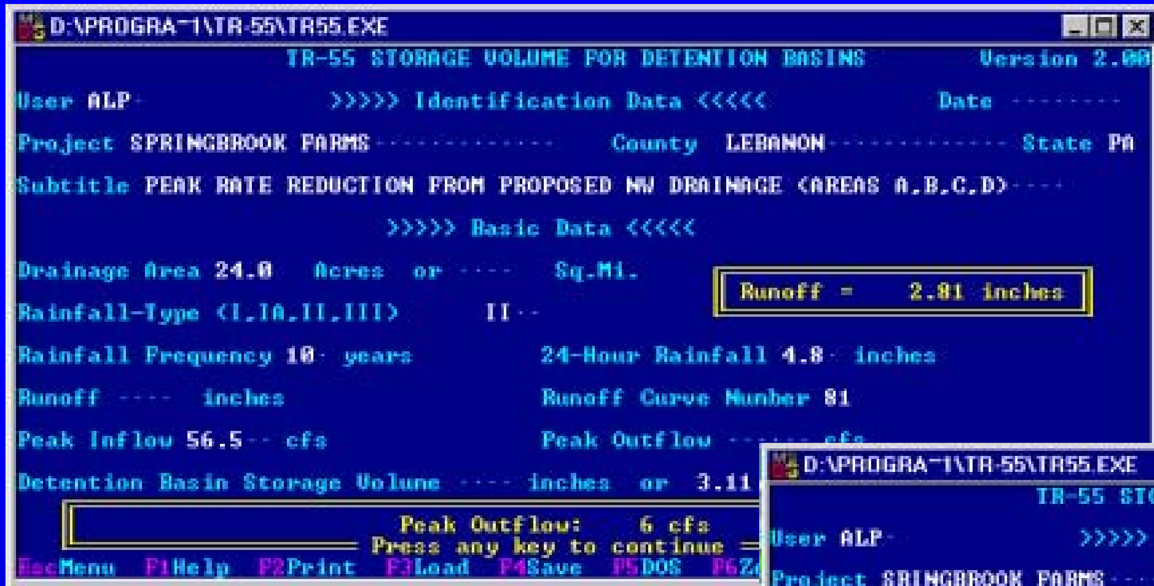
The ratio of qo/qi does not approach unity.

Errors in basin storage volume of up to 25 percent are acceptable.

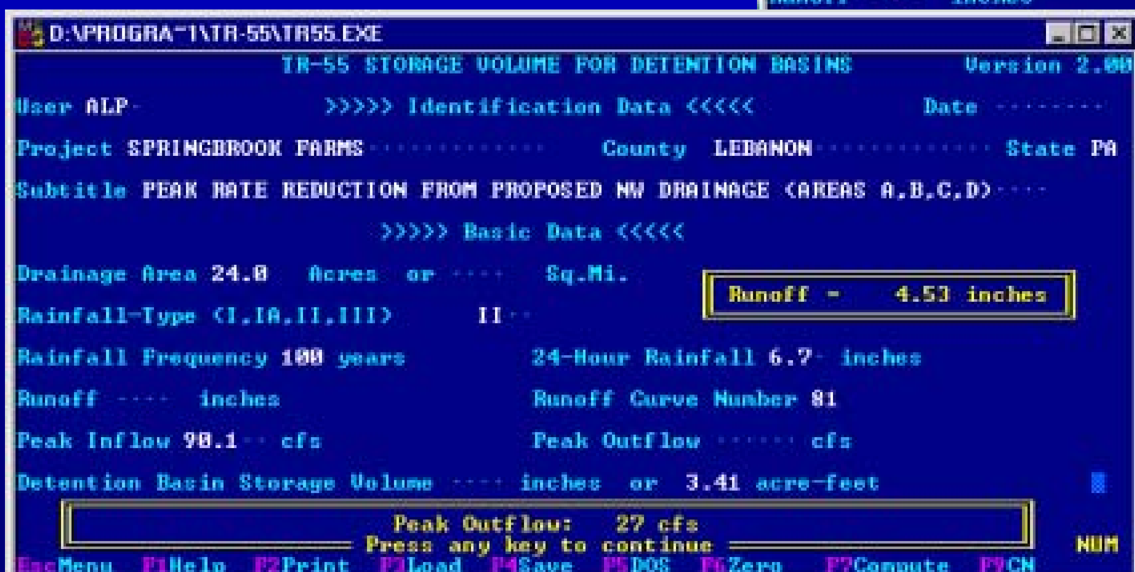
PRESS F1 FOR HELP, PgDn FOR NEXT PAGE, Esc TO RETURN TO Menu

NUM

# TR-55 Results







# Summary Results – Peak Rates

| Storm Frequency (year) | Existing Runoff Rate (cfs) | Unmitigated Post-Dev. Runoff Rate (cfs) | Estimated Infiltration Bed Discharge (cfs) | Typical Detention Basin Discharge (cfs) |
|---|---|---|---|---|
| 2 | 10 | 42.7 | **1** | **10** |
| 10 | 14 | 56.5 | **6** | **14** |
| 25 | 17 | 65.2 | **8** | **17** |
| 100 | 27 | 90.1 | **27** | **27** |


How we Manage Stormwater on
a Site-by-Site Basis affects the
entire Watershed

# Designing Infiltration Systems

# Site Criteria

- Soil Permeability greater than 0.25 in./hr
- Minimum Bedrock Separation of 2 feet
- Infiltration device at least 3 feet above seasonally high water table

# Design Criteria

- Spread It Out!
- 5:1 Impervious to Recharge Area
- Minimize excavation / maximize soil buffer
- Pre-treatment for “hot-spots”
- Construction oversight!!
- Level Bed Bottoms
- Keep it Clean – E&S Control

# Construction Criteria

- Protect infiltration BMPs from sediment until drainage area is completely stabilized
- Do not compact soil under infiltration areas
- Protect infiltration BMPs from sediment
- Do not compact soil