City of Wichita

Urban Hydrology Approach Changes

December 7th, 2010

Topics

- Quick Hydrology Overview
- Chapter 4 Overview
- "Might Be" New Stuff:
  - Downstream Assessment
  - WQ Volume and Peak Flow
  - Channel Protection Volume Estimates

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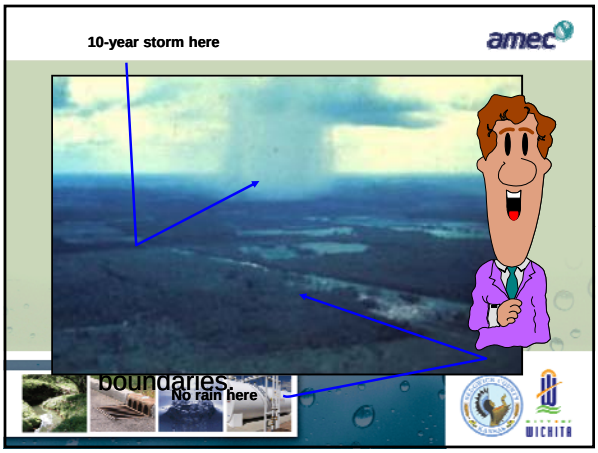
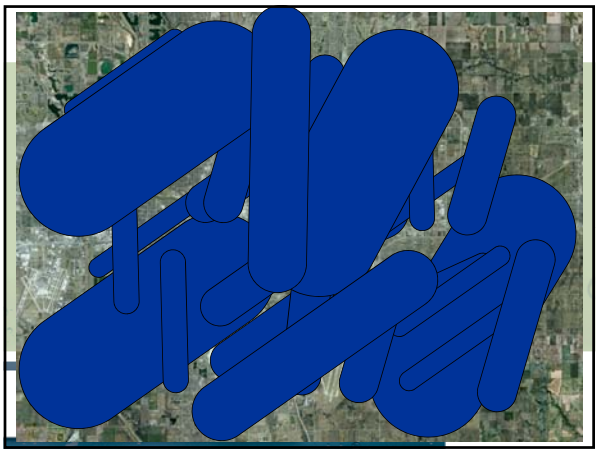
There are a only a few things you do in hydrologic design

- Calculate volumes
  - WQ_v, Cp_v
  - Sediment chamber
  - Gravel filled basin
- Calculate flow rates
  - Water quality, RO peak
- Do layouts and elevation figuring
- Design WQ_v diversion structures
- Figure filtration or infiltration rates
  - Darcy's law
- Find orifice and weir sizes
  - Drawdown
  - Overflow
- Downstream analysis

Hydrology: How Much How Often

- "What is the 10-year storm?"
- "What is the runoff hydrograph post development?"
- "What is the peak flow allowable from this detention pond?"
- "What is the water quality volume and flow rate?"





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Chapter 4 covers:

- **Rainfall**
- Losses**: SCS Method**
- Timing Calcs.
- Regression Equations
- Rational Method
- Hydrograph Methods
- Routing
- **D.S. Hydrology**
- **WQ Hydrology**
- **Channel Protection Volume**
- **Backwater**
- **Water Balance**

Chapter 4 - What's New: Misc. ?

1. Curve Numbers

- Mandated CN values
  - 4.3.3
- Separate pervious and impervious analysis
  - 4.3.4
  - DCIA meant here

Table 4-2 Pre- and Post-Development Curve Numbers

Land Use	Hydrologic Soil Group			
	A	B	C	D
Pre-Developed or Undisturbed Pervious	55	71	80	84
Developed or Disturbed Pervious	71	80	84	88
Impervious	98	98	98	98

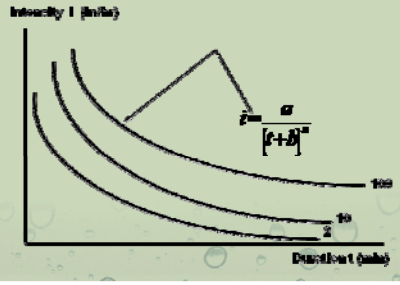
Chapter 4 - What's New: Misc. ?

1. Curve Numbers
2. IDF Curves

- Table given in Appendix B up to 120 minutes
  - That can be slow so…

–Merry Christmas!

IDF CURVE DEFINITION



Good up to 60 minutes

Return Period	a	b	n	R^2
1	17.58419	6	0.596	0.998
2	36.87744	8	0.7243	0.999
5	51.73839	11	0.7459	1.000
10	54.54903	11	0.7201	1.000
25	60.35839	11	0.7058	1.000
50	64.99433	11	0.6938	1.000
100	67.66033	11	0.6802	1.000

- You never again have to read rainfall off of a chart or graph

Sec 4.16 Water Balance

$$\Delta V = P + Ro + Bf - I - E - Et - Of$$

- **P** = precipitation * pond surface area
- **R_o** = runoff based on watershed efficiency
- **B_f** = baseflow, normally zero
- **I** = infiltration, either measured or estimated
- **E** = evaporation based on free surface map derived for Georgia
- **E_t** = evapotranspiration, use free surface unless lots of emergent vegetation
- **O_f** = pond overflow when ever pond exceeds capacity

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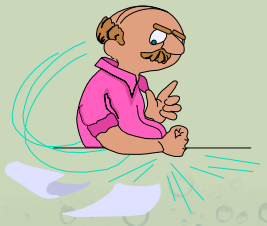
Why is there flooding downstream?

I have a detention pond!!



Reason 1 - Timing

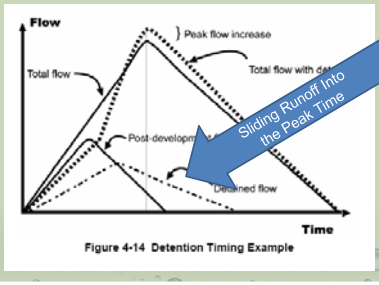
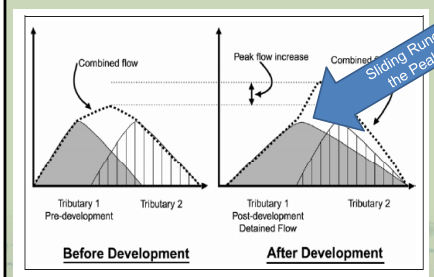


Figure 4-14 Detention Timing Example

- Detention could be waived in this case

Reason 2 - Volume



- Detention could be upsized in this case

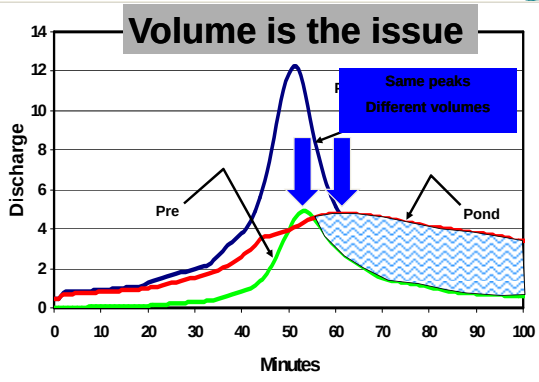
Downstream Assessment

- The "poor man's master plan".
- Look downstream until the flow is small compared to the total flow
- Based on modeling numerous locations

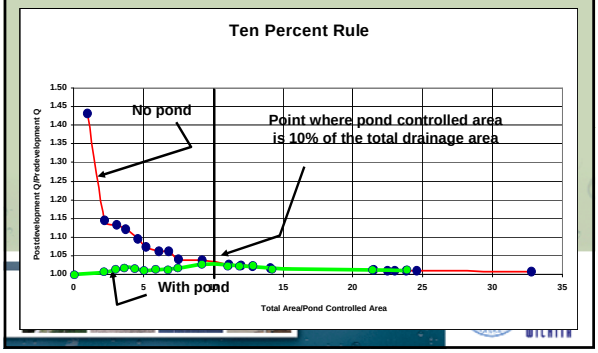
You are trying to answer these questions:

- How do I know I am not increasing flooding downstream?
- Is there a way I can get detention waived if I don't need it?
- Is there a way I can do something that protects downstream flow elevation increases without detention?

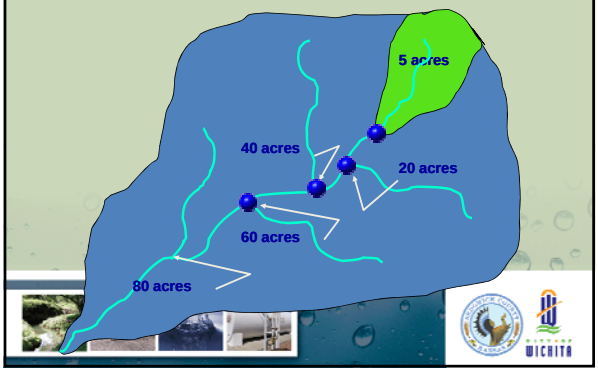
Volume is the issue



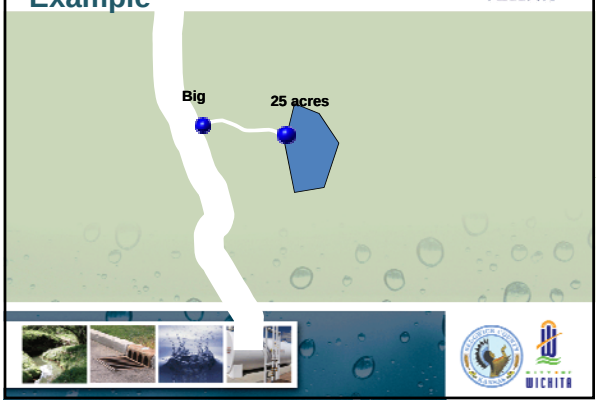
Ten Percent Rule
Example



Example 1



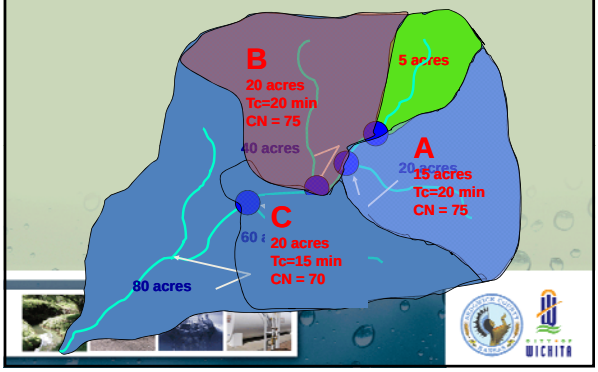
Example

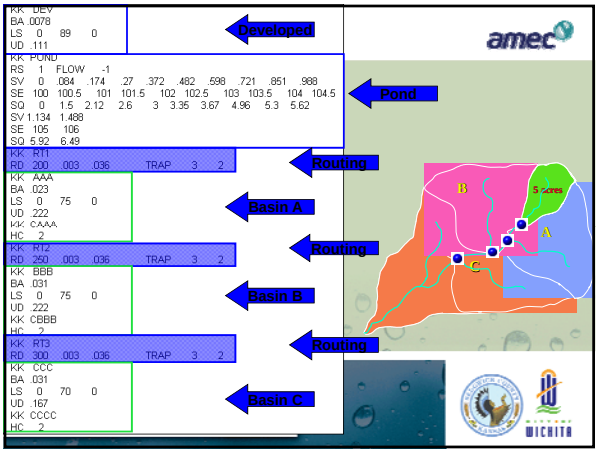


10% Rule Steps

- Determine the 10% point
- Determine pre-development flows to 10% point
- Determine post-development flows to 10% point
- Note any increases
- Design detention for no increase or negotiate another solution
  - Flow easement
  - Downstream improvements
  - Regional solution
  - ???

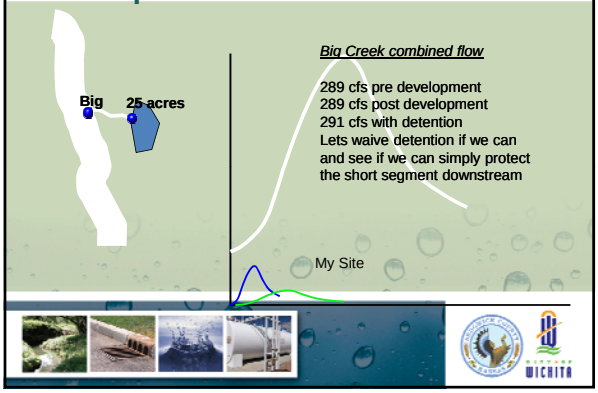
Example 1





SITE	PRE	POST	TRIAL POND 1	FINAL POND 2
	(cfs)			
PRE	6	-	-	-
DEV	-	23	23	23
POND	-	-	6	4
RT1	6	22	6	4
A	37	37	37	37
COMB A	42	56	46	41
RT2	42	55	45	41
B	50	50	50	50
COMB B	91	105	93	89
RT3	90	101	92	89
C	47	47	47	47
COMB C	132	148	133	131

Example 2



Advantages

- Fairly easy to accomplish
- Protects from the liability of downstream impacts
- Allows for potential waiver of detention
- Stops unnecessary or harmful detention
- Allows for “horse trading”
- Cheaper than master planning
- Do not use with extended detention design

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Water Quality Volume Calculation - 85% Rule

WQ_v = (1.2 in) (Rv) (A)/12 (ac ft)
= (Rv)(A)/10

where: WQ_v = water quality volume
Rv from table
A = site area

Equation 4-24 $R_V = R_{VU}U + R_{VD}D + R_{VI}I$

Table 4-13 Volumetric Runoff Coefficients by Land Use and Hydrologic Soil Group

Land Use	Hydrologic Soil Group A	B	C	D
Undisturbed Woods, Meadow or Ag. Land (R_{VU})	0.02	0.03	0.04	0.05
Turf or Disturbed Soils (R_{VD})	0.15	0.20	0.22	0.25
Impervious Cover (R_{VI})	0.95	0.95	0.95	0.95

Water Quality Volume Calculation

- Impervious cover can be taken directly off plans or estimated using TR-55 land use factors
- WQ_v should be calculated and addressed separately for each drainage area on a development site
- Off-site drainage areas should be routed around WQ structures or must be designed for

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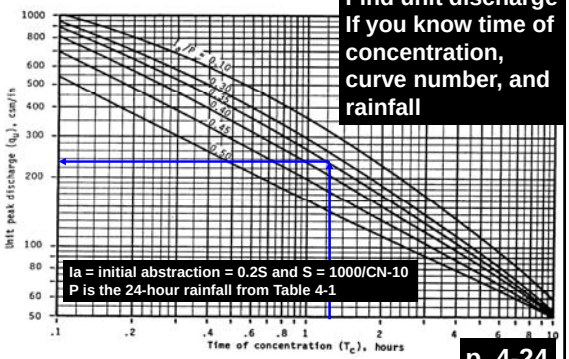
The Three Amigos

- Graphical method
- Based on extended detention – 24-hours
- Approximate but proven accurate
- Avoids iterative approaches

Detention: The Three Amigos

- A QUICK GRAPHICAL approach to estimating storage volumes
- 3 Charts for extended detention
- ONLY the last chart for normal detention
- Quicker than any known model !!

Find unit discharge If you know time of concentration, curve number, and rainfall



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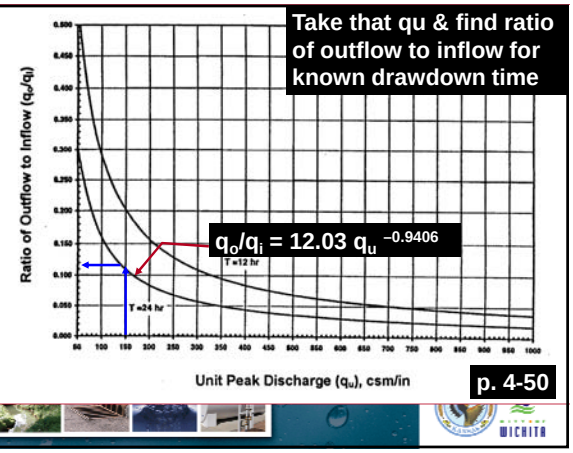
Take that qu & find ratio of outflow to inflow for known drawdown time



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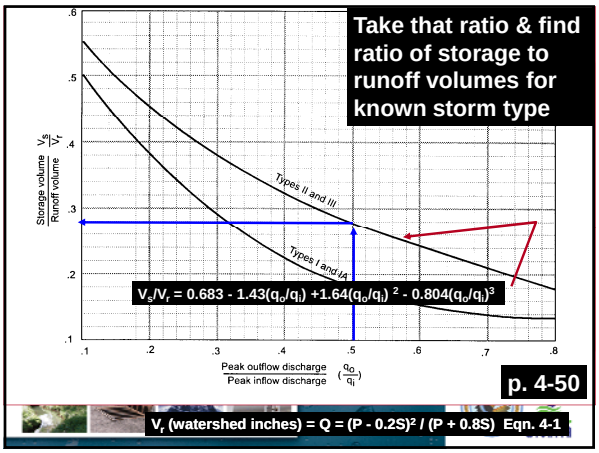
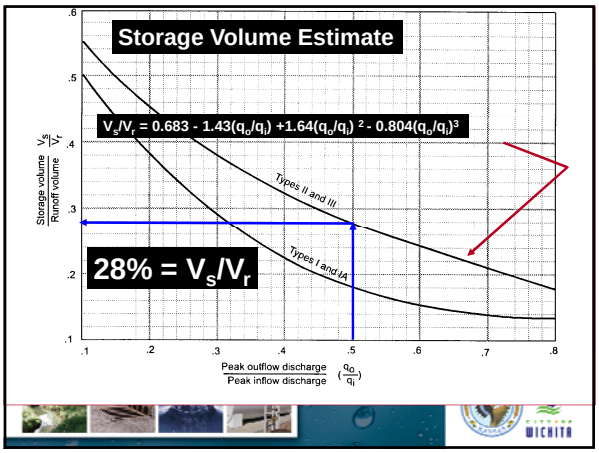


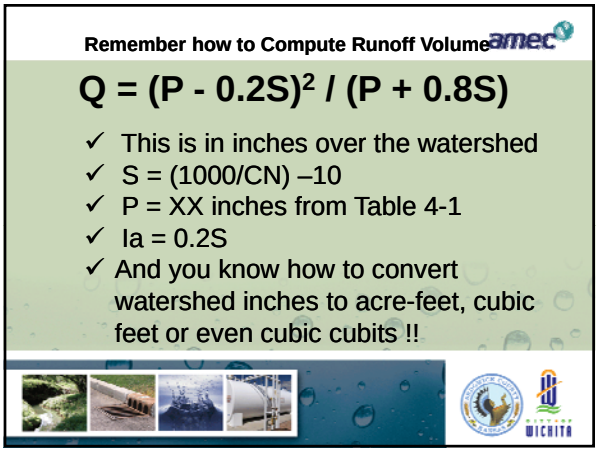
Normal Detention ONLY The Last Amigo

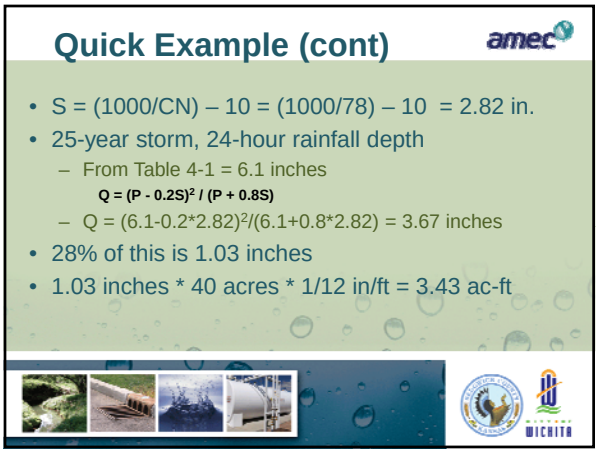
- You know the ratio of inflow to outflow peaks from your site calculations (i.e. pre- and post-development)
- From that read the ratio of storage volume to runoff volume
- Multiply by the known runoff volume

Quick Example: Detention

- 40 acres residential – want 25-year detention storage
- Site runoff calculations give predevelopment flow of 101 cfs and post development flow of 202 cfs
- Curve number is 78


Storage Volume Estimate
$V_s/V_r = 0.683 - 1.43(q_o/q_i) + 1.64(q_o/q_i)^2 - 0.804(q_o/q_i)^3$
Storage volume / Runoff volume $\frac{V_s}{V_r}$
Types II and III
Types I and IA
28% = V_s/V_r
Peak outflow discharge / Peak inflow discharge $(\frac{q_o}{q_i})$
.1
.2
.3
.4
.5
.6
.7
.8


Remember how to Compute Runoff Volume
amec
$Q = (P - 0.2S)^2 / (P + 0.8S)$
✓ This is in inches over the watershed
✓ S = (1000/CN) –10
✓ P = XX inches from Table 4-1
✓ Ia = 0.2S
✓ And you know how to convert watershed inches to acre-feet, cubic feet or even cubic cubits !!


Quick Example (cont)
amec
• S = (1000/CN) – 10 = (1000/78) – 10 = 2.82 in.
• 25-year storm, 24-hour rainfall depth
– From Table 4-1 = 6.1 inches
$Q = (P - 0.2S)^2 / (P + 0.8S)$
– Q = $(6.1-0.2*2.82)^2/(6.1+0.8*2.82)$ = 3.67 inches
• 28% of this is 1.03 inches
• 1.03 inches * 40 acres * 1/12 in/ft = 3.43 ac-ft

Extended Detention ALL Three Amigos

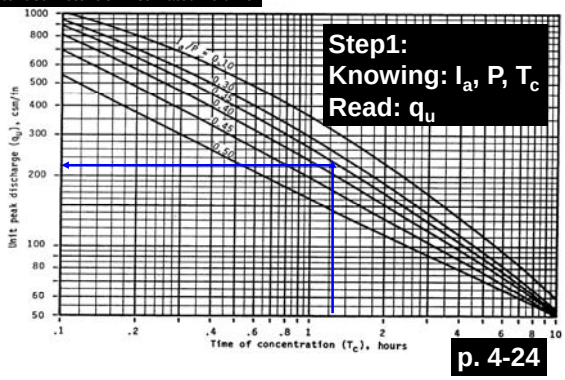
- Get a unit discharge of cfs per square mile per inch of runoff
- From that read the ratio of inflow to outflow for 24-hour drawdown
- From that read the ratio of storage volume to runoff volume

Extended 1-yr Detention

Step 1- Compute Unit Peak Discharge

- Ia = 0.2S and S = (1000/CN) –10
- P = 2.8 inches (1-year storm) from Table 4-1
  Ia/P = 0.2S/P
- T_c = developed conditions time-of- concentration
- q_u = from Figure 4-6
  cubic feet per square mile per inch (csm/in)

Extended Detention Estimated Volume



Step1:
Knowing: I_a, P, T_c
Read: q_u

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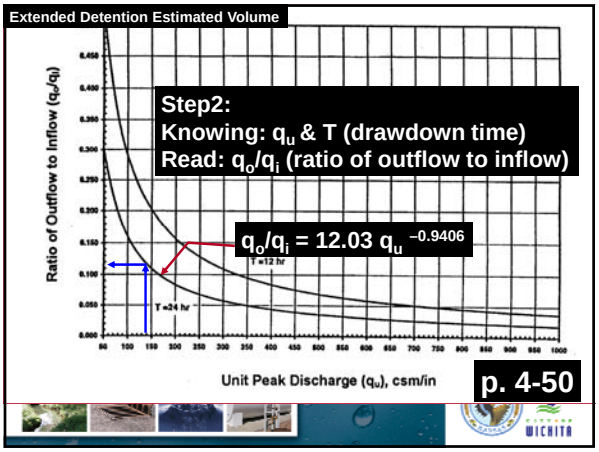
Extended Detention Estimated Volume



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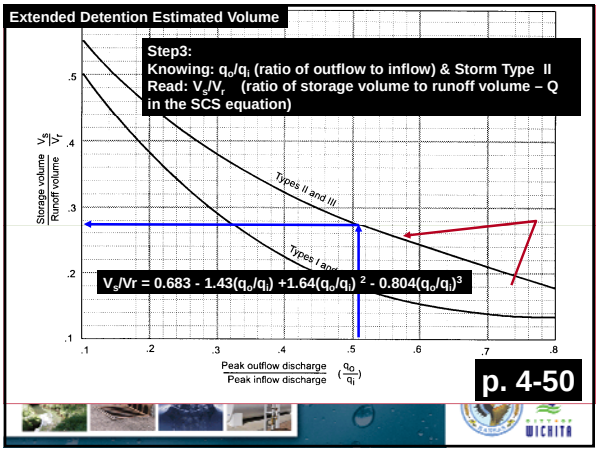
Extended Detention Estimated Volume



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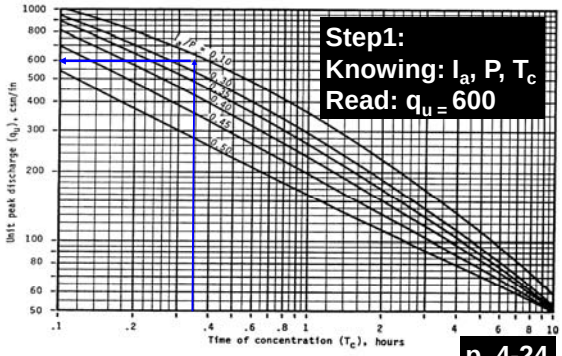
Quick Example: Extended Detention 1-yr storm

- S = (1000/CN) – 10 = (1000/CN) – 10 = 2.82 in.
  - Ia = 0.2S = 0.2 * 2.82 = 0.56 in.
- Tc = 21 minutes = 0.35 hours
- 1-year storm, 24-hour rainfall depth
  - From Table 4-1 = 2.8 inches
  - Ia/P = 0.20

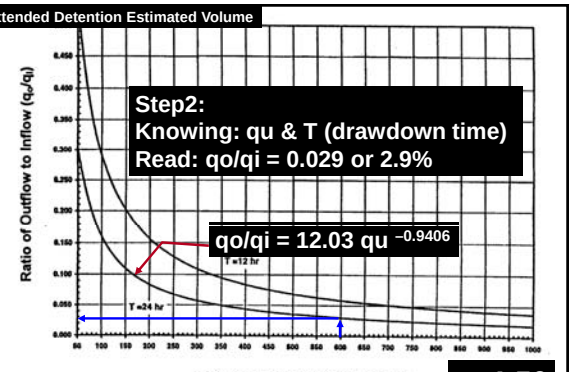
Peachtree City Extended Detention Volume



Step1:
Knowing: I_a, P, T_c
Read: q_u = 600

p. 4-24

Extended Detention Estimated Volume



Step2:
Knowing: qu & T (drawdown time)
Read: qo/qi = 0.029 or 2.9%

$qo/qi = 12.03\ qu^{-0.9406}$

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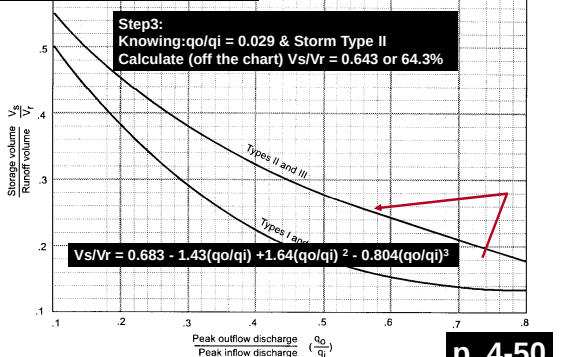
Extended Detention Estimated Volume



Step3:
Knowing:qo/qi = 0.029 & Storm Type II
Calculate (off the chart) Vs/Vr = 0.643 or 64.3%

$Vs/Vr = 0.683 - 1.43(qo/qi) + 1.64(qo/qi)^2 - 0.804(qo/qi)^3$

p. 4-50

Quick Example: Extended Detention 1-yr storm (cont.)

$$Q = (P - 0.2S)^2 / (P + 0.8S)$$

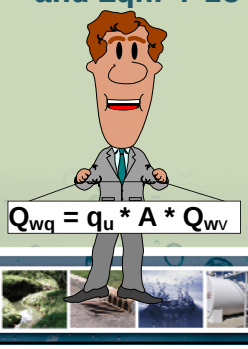
- $Q = (2.8-0.2*2.82)^2/(2.8+0.8*2.82)$
  $= 0.99$ inches
- 64.3% of that is 0.636 inches
- Over 40 acres
  - 0.636 * 40 * 1/12 = 2.12 ac-ft storage required

Then for 2-, 5-, 10-, 25-, 100-year, etc. storm volume:

For:
Know Q_{in} and $Q_{out} = q_o/q_i$ p. 4-50
Read V_s/V_r
V_r= runoff volume
Then V_s= storage volume (af)

But experience shows at least 15% low when extended detention is in the bottom– so arbitrary increase for multi outlets

Water Quality Peak Flow Only the first Amigo and Eqn. 4-18



$Q_{wq} = q_u * A * Q_{wv}$

- Get a unit discharge of cfs per square mile per inch of runoff from the first Amigo
- Using the SCS Simplified Peak Flow equation multiply the unit discharge
  - By Area
  - By WQ runoff volume in inches

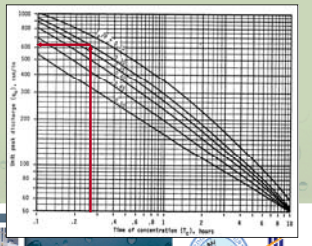
WQ Peak Flow

1. Due to SCS "problems" we first need to back out curve number

$$CN = 1000/[10 + 5P + 10Q_{wv} - 10(Q_{wv}^2 + 1.25\ Q_{wv}P)^{½}]$$

2. Calculate unit peak discharge using the first Amigo and Ia, P and Tc
3. Calculate peak discharge as:

$$Q_{wq} = q_u * A * Q_{wv}$$



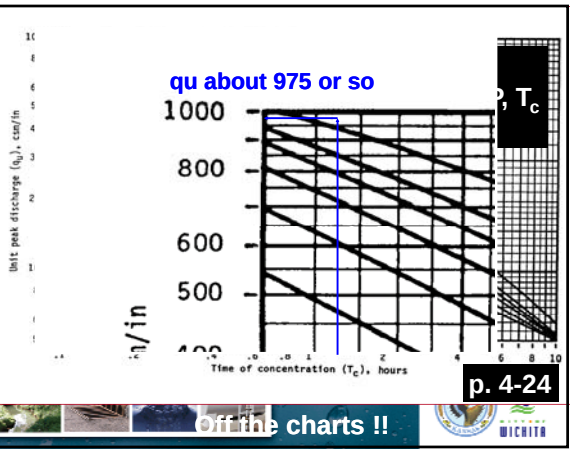
Ia=0.2S=1000/CN-10

Quick Example

- 2 acres @ 85% impervious B soil
- Rv = 0.85*0.95 + 0.15*0.20 = 0.838
- Q_{wv} (inches) = 1.2 * Rv = 1.01 inches

$$CN = 1000/[10 + 5P + 10Q_{wv} - 10(Q_{wv}^2 + 1.25\ Q_{wv}P)^{½}]$$

- $CN = 1000/[10+5*1.2+10*1.01-10(1.01^2+1.25*1.01*1.2)^{1/2}]$
  $= 98.25 = 98$
- S = (1000/CN) – 10 = 1000/98 – 10 = 0.204"
- Ia = 0.2S = 0.041"
- Ia/P = 0.041/1.2 = 0.034 Tc = 8 min = 0.13 hrs



Quick Example

- For qu = 975 we calculate the peak runoff for water quality volume design for flow through devices

$$Q_{wq} = q_u * A * Q_{wv}$$

- Area is in square miles (kind of strange huh?)
- Q_{wq} = 975 * 2/640 * 1.01 = 3.08 cfs

For small highly impervious sites lets make it simple

- Use q_u = 1000, A in acres, 1.2*Rv for P and 0.95 for Rv
- Q_{wq} = 1000 * A/640 * 1.2* 0.95

  $Q_{wq} \approx 1.78$ A

For our example:

Q_{wq} = 1.78 * 2 = 3.56 cfs