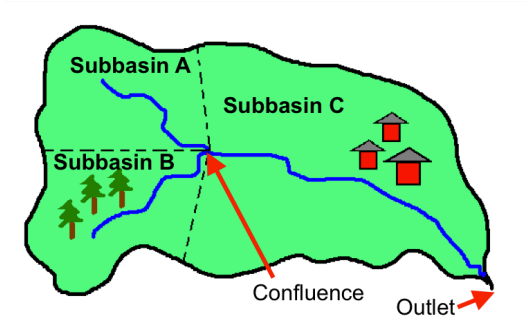
Jones Creek Case Study

Introduction

In this case study we will examine the fictitious watershed of Jones Creek. This watershed has one confluence and can therefore be divided into three subbasins. The problems in this study relate to basic rainfall and runoff calculations which can be done either in excel or by hand.



Problem 1

Calculate the volume of direct runoff of subbasin A and plot the net rainfall on the resulting hydrograph.

Given Information

Outlet Flow

Q(cfs)	Time(hr)
0	0
1	150
2	300
3	450
4	600
5	525
6	450
7	375
8	300
9	225
10	150
11	75
12	0

Rainfall

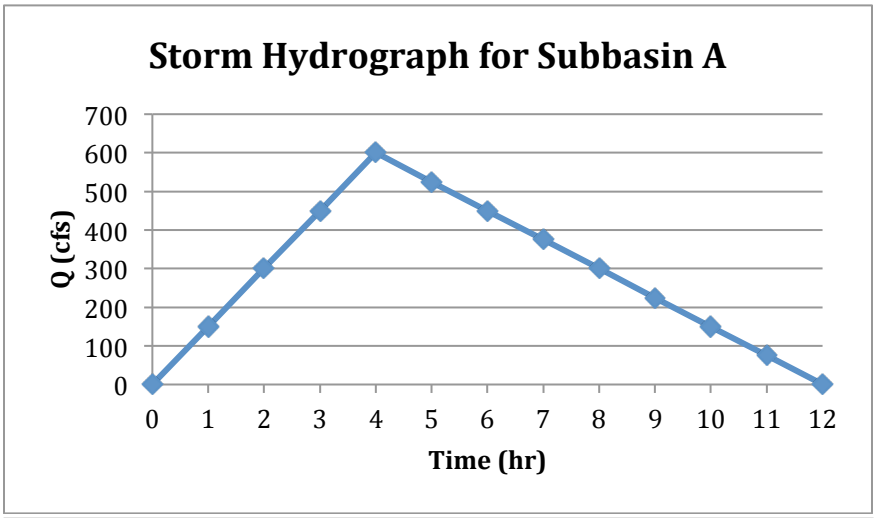
Time(hr)	Intensity(in/hr)
1	3
2	1.5
3	1

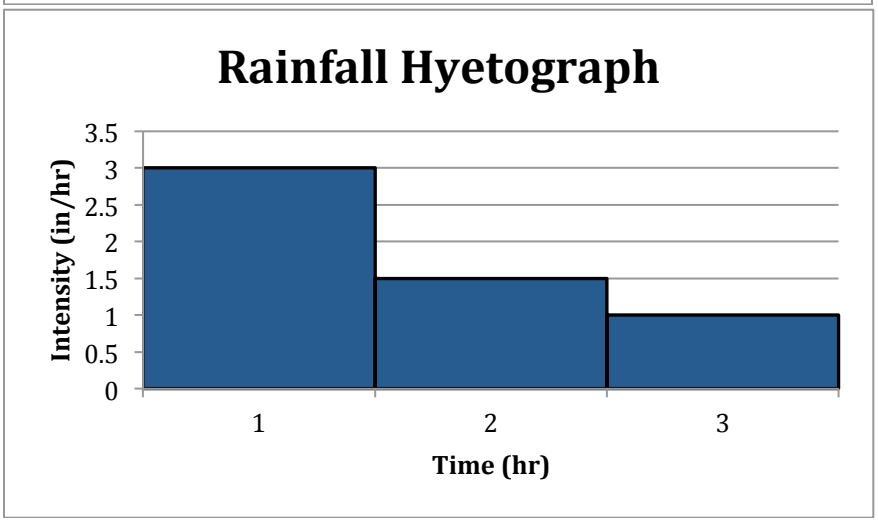
Given Values

Baseflow for Subbasin A	100 cfs
Initial Infiltration for 0≤t≤1	0.5 in
Constant infiltration	025 in

Solution Method

1. Create the storm hydrograph and rainfall hyetograph by putting the values into excel and graphing.





2. Calculate the area under the hydrograph to get the total volume of all runoff:

$$\frac{12hr \bullet 600cfs \bullet 3{,}600\ {}^{s}/_{hr}}{2} \bullet \frac{1ac-ft}{43{,}560\,ft^3} = 297.5ac-ft$$

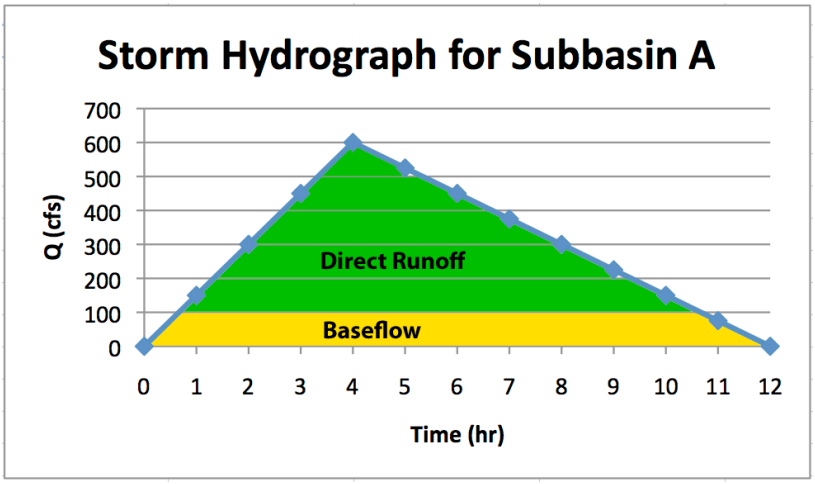
An acre-foot is a volume with an acre footprint filled 1 ft deep with water.

3. Calculate the total volume of baseflow:

Keep in mind: area of trapezoid = $\boxed{\frac{(b_1+b_2)\bullet h}{2}}$

$$\frac{(12hr+10hr)\bullet\left(100cfs \bullet 3{,}600\ {}^{s}/_{hr}\right)}{2} \bullet \frac{1ac-ft}{43{,}560\,ft^3} = 90.9ac-ft$$

4. Calculate Direct Runoff:

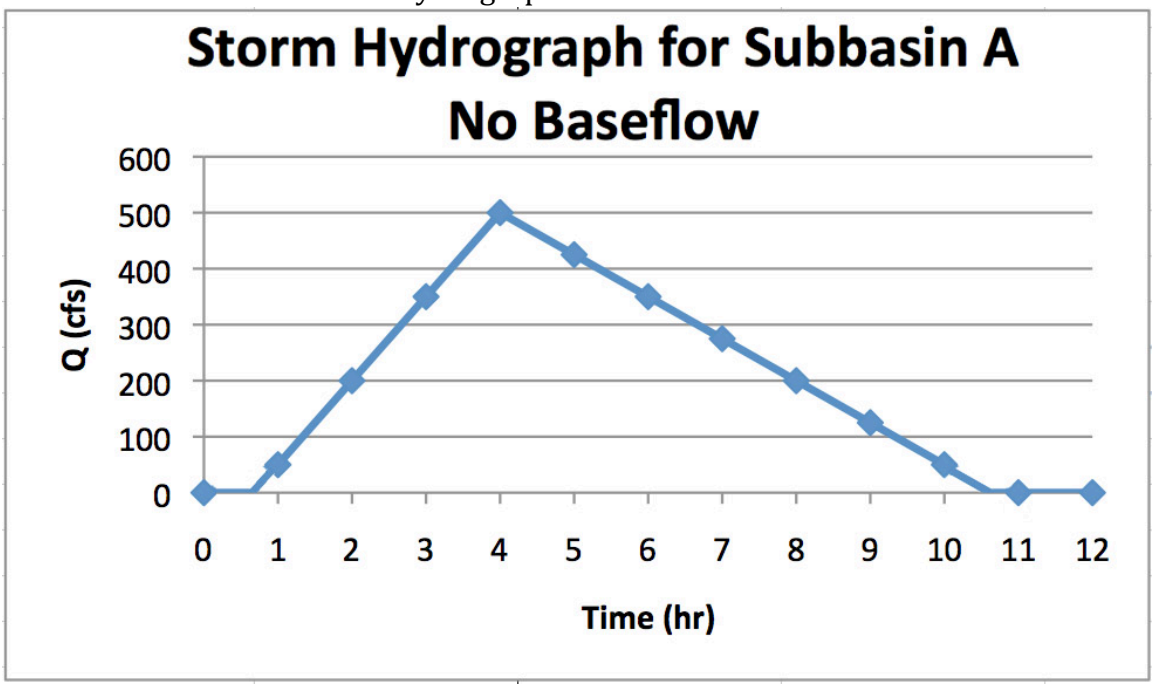


You do not need to generate this. It is just for explanation and clarity.

DRO = Total Runoff – Base Flow

DRO = 297.5ac-ft – 90.9ac-ft = 206.6ac-ft ✓

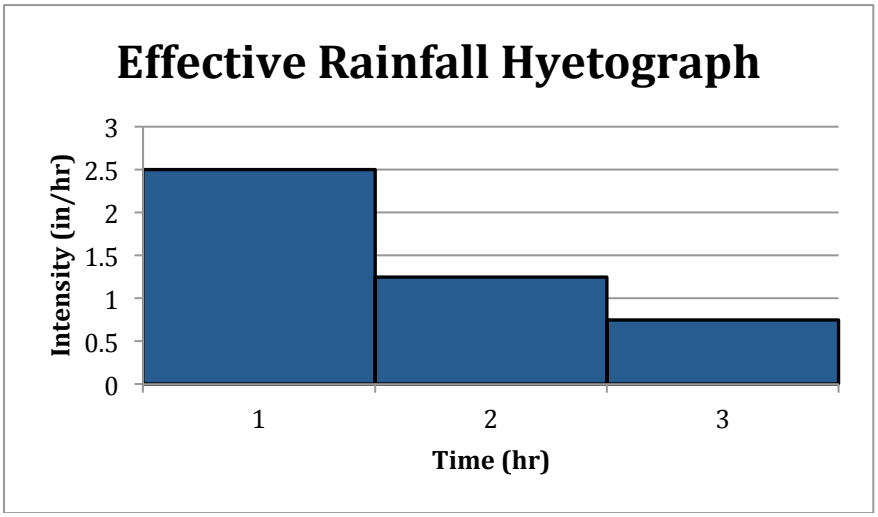
5. Create the new storm Hydrograph without baseflow.



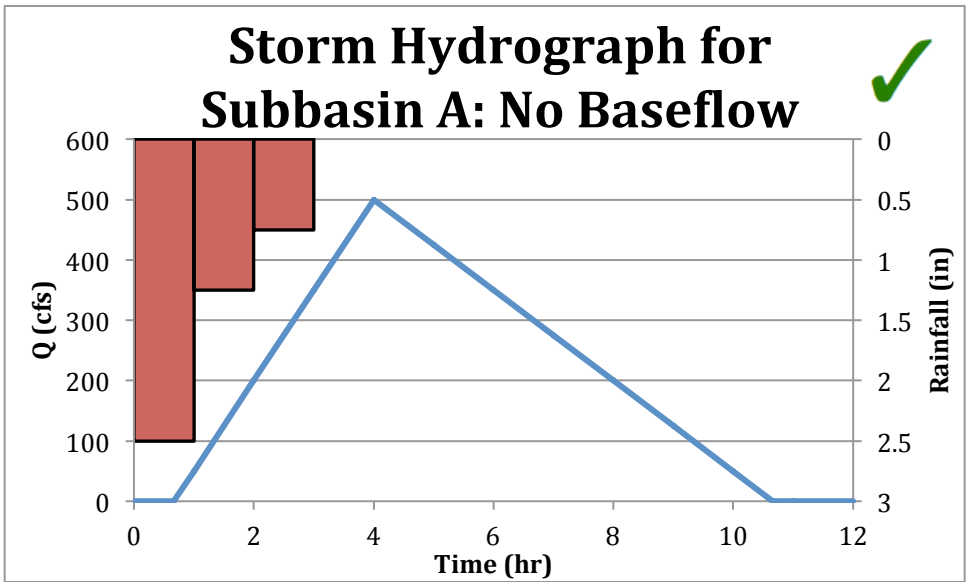
If you just generate this as a line chart then hours 0 and 1 as well as 10 and 11 will directly connect. This flares out the bottom of the triangle and is not accurate. The way to get around this is to create two extra points (.66 hr, 0 cfs) and (10.66 hr, 0 cfs) and then graph the whole thing as a scatter plot.

6. Subtract out the infiltration to get the effective rainfall and generate new bar chart.

Time(hr)	Intensity(in/hr)	Infiltration(in/hr)	Effective Rainfall
1	3	0.5	*2.5*
2	1.5	0.25	*1.25*
3	1	0.25	*0.75*



7. Place the effective rainfall hyetograph in the upper left hand corner of the resulting hydrograph.



This chart is difficult to generate in excel and is easier to do by hand. However, if you want to generate it in excel the steps are listed on the next page.

Creating a Hydrograph with Rainfall

- You will need a tables that looks something like this:

Time(hr)	Q - BF
0	0
0.66	0
1	50
2	200
3	350
4	500
5	425
6	350
7	275
8	200
9	125
10	50
10.66	0
11	0
12	0

Time(hr)	Intensity(in/hr)
1	2.5
2	1.25
3	0.75

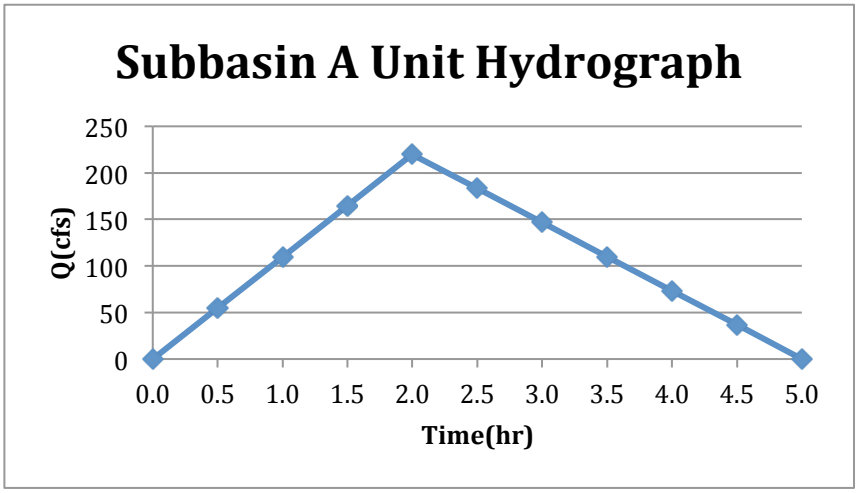
- Create the hydrograph just like you did in step 5 by using a connected scatter plot.
- Right click on the graph and go to the "Select Data" menu and add a second series with the data from the intensity table above.
- The data will show up almost flat to the x-axis. Right click on the graph and select the "format data series menu." Select the "axis" tab and click "secondary axis"
- The data should show up as a connected scatter plot with the values correctly corresponding to the new axis on the right.
- Left click on any point in the rainfall data plot to select that series. Right click and select "Change Series Chart Type." Change the series to a column chart (older versions of excel call it a bar chart.)
- Double click on the new axis on the right and under the "scale" tab click "values in reverse order."
- Your graph should now look like the one above (after you add in labels).

Example 2
Part A

Prove that the unit hydrograph given is in fact a unit hydrograph.

Given Information

Time(hr)	Q(cfs)
0.0	0
0.5	55
1.0	110
1.5	165
2.0	220
2.5	183.333
3.0	146.667
3.5	110
4.0	73.333
4.5	36.667
5.0	0



Area of Subbasin A	550 ac
Baseflow	0 cfs
Infiltration	0 in/hr

Solution Method

1. First you will need to remember two facts:
   - A unit hydrograph is defined the direct runoff response for 1 inch of rain for 1 hour over the whole watershed.
   - 1 cfs-hr corresponds to 1 ac-in.

2. Calculate the area under the given hydrograph.
   $220cfs \bullet 5hr \bullet \frac{1}{2} = 550ac - in$

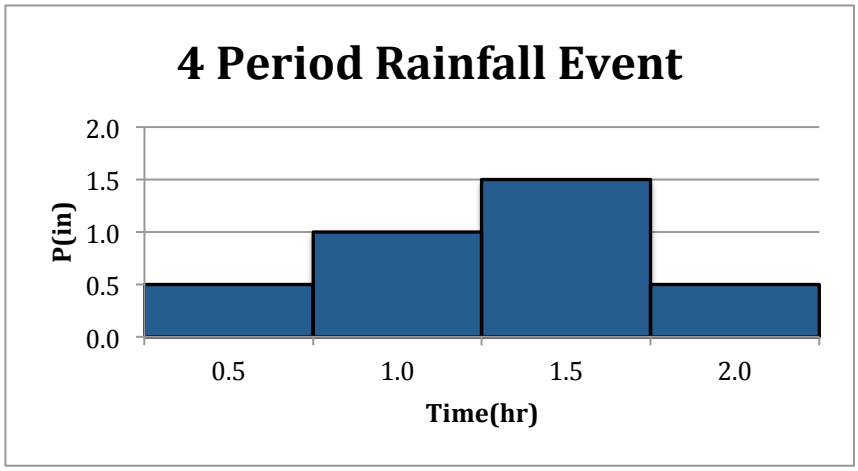
3. Divide area under hydrograph by subbasin area to check if it is a unit hydrograph.
   $\frac{550ac - in}{550ac} = 1in$ ✓
   This is a unit hydrograph because the amount of direct runoff corresponds to 1in of rain over the whole watershed for 1hr.

Part B

Create the storm hydrograph for the given rainfall event using the "add and lag" method.

Given Information

Time(hr)	Q(cfs)
0.0	0
0.5	55
1.0	110
1.5	165
2.0	220
2.5	183.333
3.0	146.667
3.5	110
4.0	73.333
4.5	36.667
5.0	0



Area of Subbasin A	550 ac
Baseflow	0 cfs
Infiltration	0 in/hr

Solution Method

1. Create a spreadsheet with a header row like the one below.

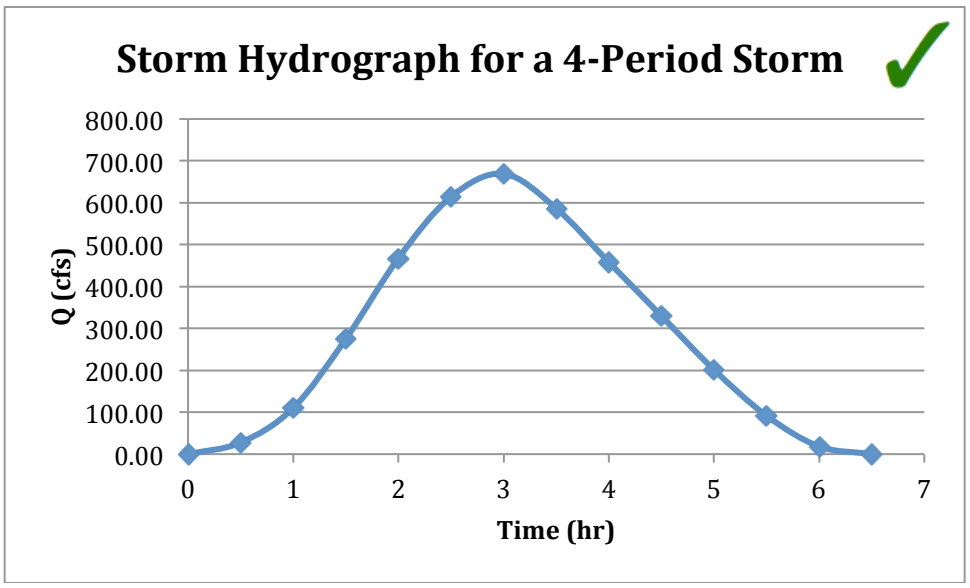
2. For precipitation period 1 (P1) start at t = 0 and multiply the total P1 rainfall by the value in the unit hydrograph table.

3. For every subsequent period do the same procedure as before but lag the start time by 1 period.

4. Add up the cfs for every time period into a cumulative flow volume Q.

5. Graph those Q values to come up with the storm hydrograph.

Time(hr)	P1*UH (cfs)	P2*UH (cfs)	P3*UH (cfs)	P4*UH (cfs)	Q (cfs)
0	0.00				**0.00**
0.5	27.50	0.00			**27.50**
1	55.00	55.00	0.00		**110.00**
1.5	82.50	110.00	82.50	0.00	**275.00**
2	110.00	165.00	165.00	27.50	**467.50**
2.5	91.67	220.00	247.50	55.00	**614.17**
3	73.33	183.33	330.00	82.50	**669.17**
3.5	55.00	146.67	275.00	110.00	**586.67**
4	36.67	110.00	220.00	91.67	**458.33**
4.5	18.33	73.33	165.00	73.33	**330.00**
5	0.00	36.67	110.00	55.00	**201.67**
5.5		0.00	55.00	36.67	**91.67**
6			0.00	18.33	**18.33**
6.5				0.00	**0.00**



Example 3

Find the time to peak (t_p), time to rise (T_R), and the maximum flow (Q_p) by the SCS triangular unit hydrograph method for subbasin B. Use that information to generate the unit hydrograph (with rainfall) for subbasin B.

Given Information

Area Subbasin A	550 ac
Length to divide	1 mi
Average Slope	25 ft/mi
Rainfall Durration	0.5 hr
Curve number	71

Solution Method

1. Find these four equations in the text book (pg 95-96).

$$t_p = \frac{L^{0.8}(S+1)^{0.7}}{1900 \bullet y^{0.5}}$$

(2-18)

L = Length to divide (ft)
y = Average watershed slope (%)
S = (1000/CN) – 10in
CN = Curve number for the various soil/land use
t_p = Time to peak

$$T_R = \frac{D}{2} + t_p$$

(2-17)

D = Rainfall duration
T_R = Rise time of hydrograph

$$Q_p = \frac{484 \bullet A}{T_R}$$

(2-16)

A = Area (mi^2)
Q_p = Peak flow

$$V = \frac{Q_p \bullet T_R}{2} + \frac{Q_p \bullet B}{2}$$

(2-12)

V = Volume of direct runoff
B = Time base

2. Compute t_p using 2-18.

$$t_p = \frac{(1 \bullet 5280)^{0.8} \bullet (4.085+1)^{0.7}}{1900 \bullet 0.474^{0.5}} = 2.27hr$$ ✓

3. Use your computed t_p to find the T_R using 2-17.

$$T_R = \frac{0.5}{2} + 2.27 = 2.52hr$$ ✓

4. To find Q_p first convert the watershed area to mi^2. Then compute peak flow using 2-16.

$$550ac \bullet \frac{43{,}560\,ft^2}{ac} \bullet \frac{1mi}{5280\,ft} = 0.859mi^2$$

$$Q_p = \frac{484 \bullet 0.859}{2.52} = 165.0cfs$$ ✓

5. Now that you have Q_p and T_R all you need is base time in order to generate the Hydrograph. This is easily computed by rearranging 2-12.

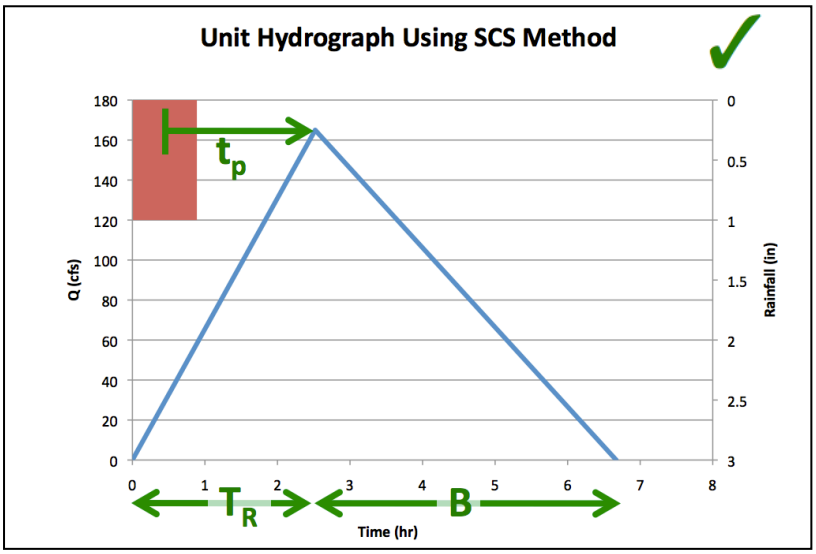
$$\frac{2 \bullet V}{Q_p} - T_R = B$$

$$\frac{2 \bullet 550}{165} - 2.52 = 4.15hr$$

(If you double check the equation above with dimensional analysis you must remember that 1ac-in is equivalent to 1cfs-hr.)

6. You now have all of the information you need to generate the unit hydrograph with rainfall.

T_R	2.52 hr
B	4.15 hr
Q_p	165 cfs



When you generate this you do not need to add the arrows and labels.

This hydrograph can be generated by creating a scatter plot of this table:

Time (hr)	**Q (cfs)**
0	0
2.52	165
6.67	0

The rainfall bar can be added using the method described earlier.