TOTAL 118 PTS

+1 Student Name: SOLUTION SPRING 2016

CE 3354 Engineering Hydrology
Exam 1, Spring 2016

Students should write their name on all sheets of paper. Students are may use printed notes and book excerpts to help answer questions. Students **ARE** permitted to use calculators. Students are **NOT** permitted to use laptops, tablets, phones to access the internet or communicate during the exam.

1. Hydrology is

   a) A study of the processes of evaporation, infiltration, and storage

   b) The study of the relationship between rainfall and runoff

   +1 c) Study of the atmosphere, ocean, and surface waters

   +2 d) The study of the occurrence, distribution, and movement of water above, on, and below the surface of the earth

2. The fundamental analytical unit of hydrology is?

   +2 a) The watershed

   b) The main channel slope

   c) The rainfall depth

   d) The main channel length

3. What is the relationship between the Annual Exceedance Probability (AEP) and the Annual Recurrence Interval (ARI)?

   a) The ARI is a plot of probability and magnitude

   b) The AEP is a plot of probability and magnitude

   c) The ARI is the average number of years between years containing one or more events exceeding a prescribed magnitude

   +2 d) The AEP and ARI are the multiplicative inverse of one another

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4. How can one calculate the Annual Exceedance Probability (AEP) from the Annual Return Interval (ARI)?

+2 a) $AEP = \frac{1\ yr}{ARI}$

b) $ARI = \frac{1\ yr}{AEP}$

c) $ARI = \frac{Rank_i}{N+1}$

d) Cannot

5. An annual recurrence interval of 100-years is equivalent to an AEP of what percent?

a) 100-percent.

b) 50-percent.

c) 10-percent.

+2 d) 1-percent.

$$AEP = \frac{1yr}{100yr} = 0.01 = 1\%$$

6. What is a flood frequency curve?

a) A plot of discharge and time

+2 b) A plot of estimated exceedance probability and discharge

+1 c) A plot of the frequency and discharge

+1 d) A plot of the discharge magnitude and the Weibull plotting position

7. What is a plotting position?

a) The multiplicative inverse of relative frequency

b) An estimate of probability associated with an observation based on its magnitude relative to the arithmetic mean

+2 c) An estimate of probability associated with an observation based on its position within a ranked sample set

d) Location in a chart of a data pair

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8. To what type of data series would we apply the Bulletin 17B procedure ?
   a) Instantaneous discharge
   b) Hourly rainfall
   c) Annual maximum rainfall
   +2 d) Annual maximum discharge
9. Rainfall behavior is expressed as a combination of
   +2 a) depth or intensity, duration, and probability or frequency
   b) intensity and probability or frequency
   c) duration and probability or frequency
   +1 d) depth and duration
10. Rainfall intensity is
   +1 a) instantaneous rainfall rate
   b) slope of the depth duration curve at a duration of one hour
   +2 c) the ratio of accumulated depth to duration
   d) integral of the depth duration curve from 0 to 24 hours
11. In the rational equation, $Q = CIA$,
   a) the intensity, I, is the ratio of depth to watershed impervious cover
   b) the intensity, I, is the ratio of depth to watershed discharge
   +2 c) the intensity, I, is the ratio of depth to the time of concentration
   d) the intensity, I, is the ratio of depth to watershed area
12. Regional analysis is used to
   a) establish a typical functional drainage area
   b) delineate watersheds
   c) relate discharge to drainage area
   +2 d) construct regression equations from historical data on many streams within a region

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+1

13. Figure 1 is a depth-duration-frequency plot for precipitation.

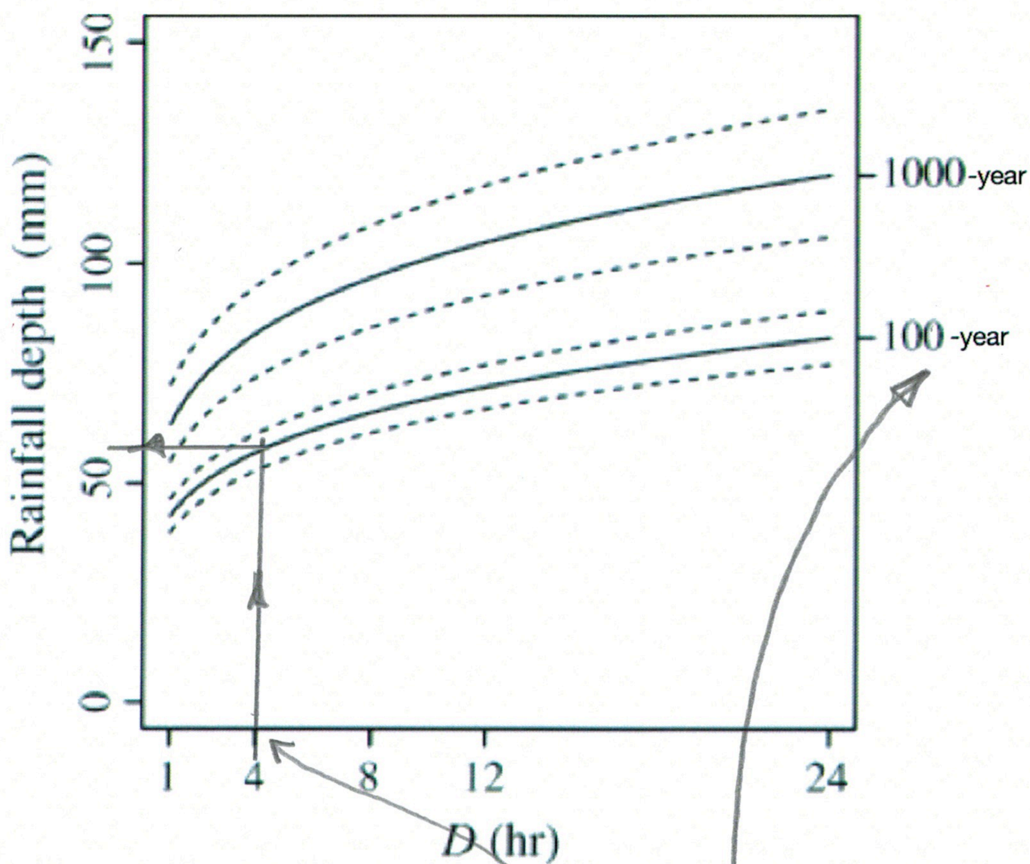

Figure 1: Depth-duration-frequency curve

The approximate depth, in millimeters, for a 4 hour, 100-yr (1% chance) storm is

a) 45 millimeters

+2 b) 55 millimeters

c) 75 millimeters

d) 125 millimeters

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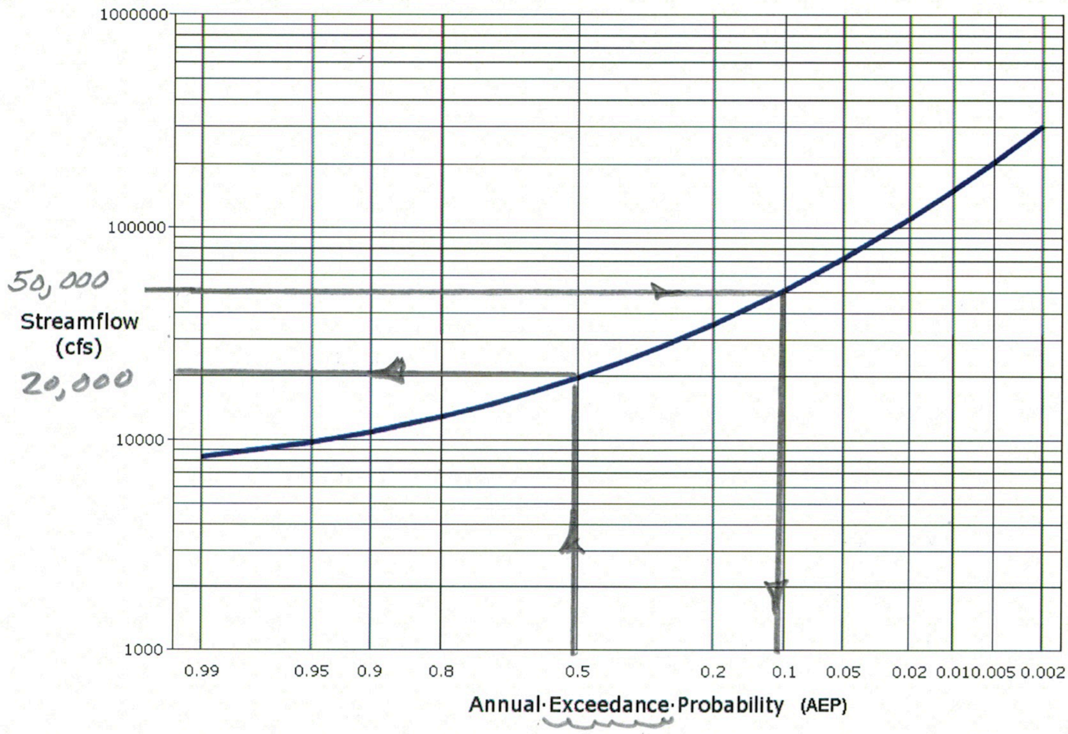

Figure 2: Flood frequency curve for a gaging station

14. Figure 2 is a flood frequency curve. The probability of observing a discharge of magnitude of 50,000 CFS or more is

    (a) 0.50

    +2 (b) 0.10

    (c) 0.05

    (d) 0.01

15. The median discharge from Figure 2 is

    Median = 0.5 (50th %)

    (a) 90,000 CFS

    (b) 50,000 CFS

    +2 (c) 20,000 CFS

    (d) 10,000 CFS

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16. Figure 3 is a topographic map of a small drainage basin. The drawn contour interval is 20 feet. Many of the contours are labeled. A culvert structure is located on the Eastern portion of the basin, near the outlet shown on Figure 3. The red line is a highway alignment, beneath which the culvert structure is placed. Figure 4 is a photograph of the culvert system that is comprised of 4-parallel , 4-foot diameter, 100-foot long culverts. The lowest portion of the road near the culverts is at elevation 595 feet. The culverts are laid on a dimensionless slope of 0.02.

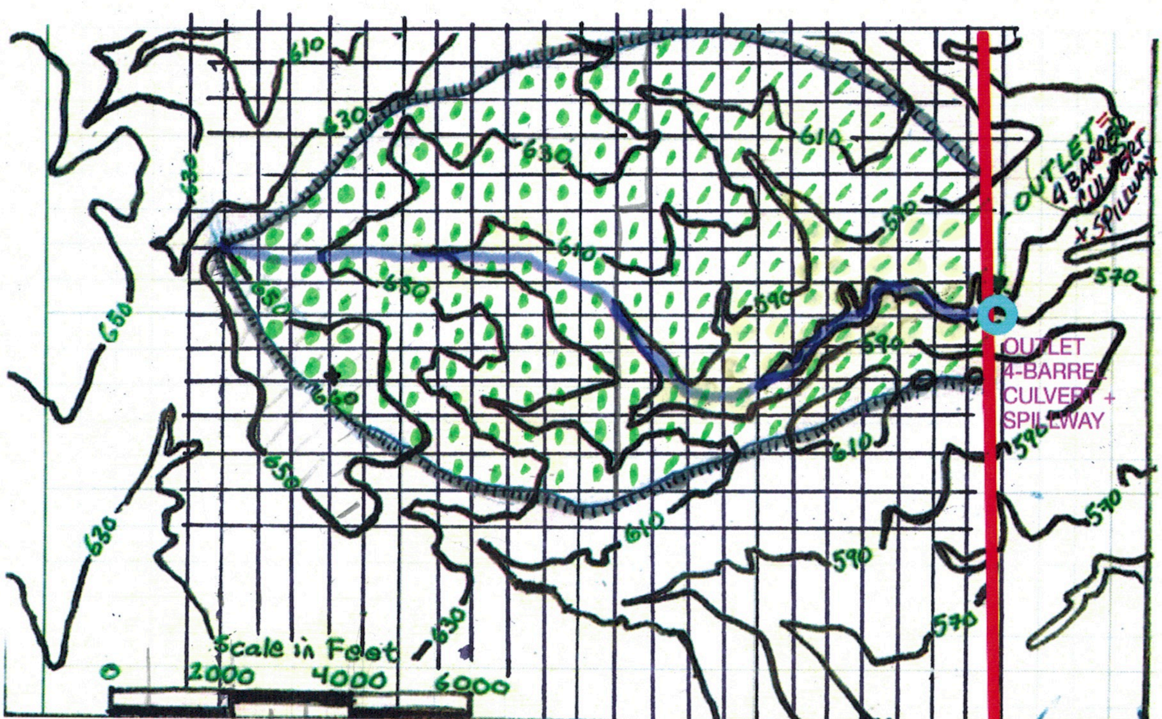

Figure 3: Topographic Map of a portion of the Earth. Elevations and linear distances are in *feet*. North (by convention) is up. The light line splitting the watershed is a main channel. The shaded and hatched line is the watershed boundary.

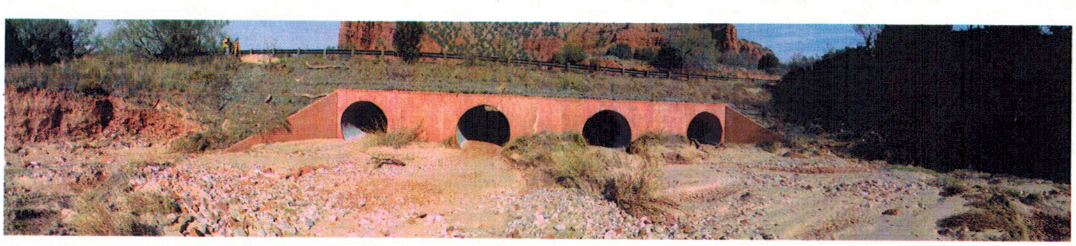

Figure 4: Multiple-barrel outlet structure

+4 "COUNT SQUARES" EVIDENCE

+1 "MEASURE MCL" EVIDENCE

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a) Estimate the drainage area in square feet of the drainage basin. The boundary is already drawn on the map.

AREA 1 SQUARE = 443,556 ft²

200 SQUARES * 443,556 ft² = 88,711,200 ft² (+1) (+1)

~ 666 ft EACH SIDE (+1)

[−10% 79,000,000 ft² ; +10% 98,000,000 ft²]

b) Convert the drainage area from square feet into acres. (+1)

$88,711,200\ ft^2 \cdot \frac{1\ acre}{43,560\ ft^2} = 2036.5\ acres$ (+1)

[−10% 1832 acres ; +10% 2240 acres]

c) Convert the drainage area from acres into square miles.

$2036.5\ acres \cdot \frac{1\ mi^2}{640\ acres} = 3.18\ mi^2$ (+1) (+1)

[−10% 2.8 acres ; +10% 3.5 acres]

ASIDE

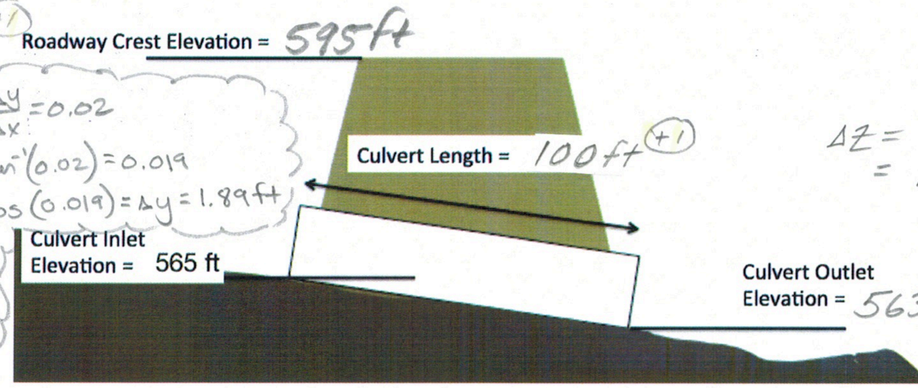
$\frac{\Delta y}{\Delta x} = 0.02$

$\tan^{-1}(0.02) = 0.019$

$100\cos(0.019) = \Delta y = 1.89\ ft$

∴ CULVERT OUTLET 563.1 ft

— THE APPROX. IS PRETTY GOOD!



$\Delta Z = 0.02(100\ ft) = 2\ ft$

Figure 5: Culvert system elevation view sketch

d) The water surface area when the culvert system (like a dam, with 4 holes in the wall) impounds water to a water surface elevation of 565 *feet* is zero. Complete the elevation (side) view sketch of the road embankment and culvert system in Figure 5 by indicating the elevations on the sketch of the roadway crest in feet, the culvert outlet elevation in feet, and the culvert barrel length in feet.

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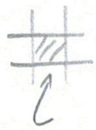
e) Estimate the water surface area (area of the pool on the upstream side of the road embankment) when the embankment impounds water to a water surface elevation of 590 *feet*. Describe how you made the estimate.



Area 1 sq. = 443,556 ft^2

29 squares * 443,556 ft^2 = 12,863,124 ft^2 (+1) (+1)

$12,863,124 \text{ ft}^2 \cdot \frac{1 \text{ acre}}{43560 \text{ ft}^2} = 295.2$ acres (+1) (+1)

[−10% 265 acres
+10% 325 acres]

f) Estimate the main channel length in feet.

MAIN CHANNEL CUTS THRU
~ 24 SQUARES * 666 ft = 15,984 ft (+1) (+1)

[−10% 14,385 ft
+10% 17,582 ft]

(OR CAN MEASURE USING TURNING POINT TECHNIQUE)

g) What is the elevation at the most upstream of the main channel (where the main channel would intersect the watershed boundary), in feet?

z = 650 ft (+2)

h) What is the elevation of the outlet point of the watershed (the culvert invert elevations)?

z = 565 ft (+2)

i) Using these values, estimate the average watershed slope along the main channel. Express the result in dimensionless slope and percent slope.

$$\text{SLOPE} = \frac{650 \text{ ft} - 565 \text{ ft}}{15,984 \text{ ft}} = 0.0053$$ (+2)

~ 0.5%

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17. Figure 6 is a chart for applying the NRCS-Overland method.

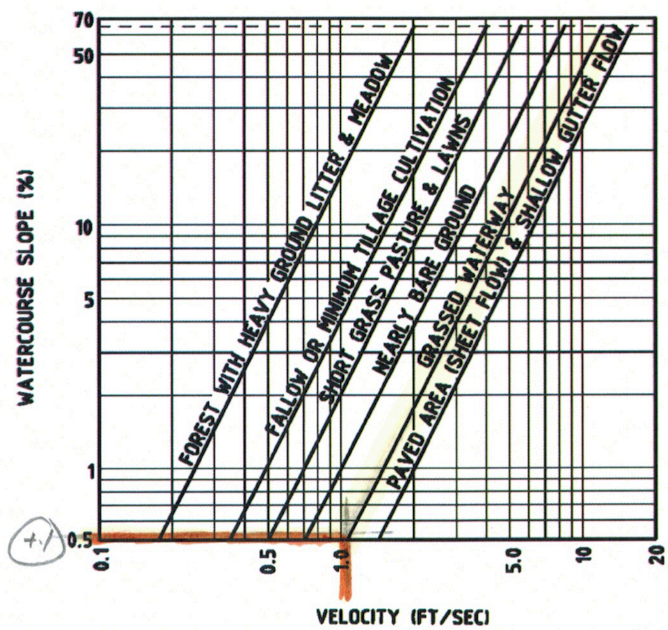

Figure 5-4. Velocities for Upland Method of Estimating Time of Concentration--English (Adapted from the National Engineering Handbook Volume 4)

Figure 6: NRCS Upland Method Chart for Estimating Time of Concentration

a) What is the watercourse slope in percent for the watershed in Figure 3? (Draw a horizontal line on the NRCS chart above for the watercourse slope).

0.5% (FROM 16i) +1 ✓

b) What is the estimated travel velocity from the chart in feet/second? (Draw a vertical line where the horizontal slope line intersects the GRASSED WATERWAY line)

~ 0.9 ft/sec +2 (units)

c) What is the main channel length in feet for the watershed in Figure 3?

15,984 ft +2 (units)

d) What is the travel time for water traveling from the most remote point on the main channel to the outlet in hours?

+2 +1 +2

$$t_{sec} = \frac{15{,}984\,ft}{0.9\,ft/sec} = 17{,}760\,sec \cdot \frac{1\,hr}{3600\,sec} = 4.93\,hrs$$

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18. Figure 7 is a tabulation of an observed storm and runoff for the drainage area depicted by the map in Figure 3. The runoff was measured at the location indicated by the blue circle on the map.

MULTIPLY NON-ZEROS BY 3600 TO GET FT^3

TIME-HOURS	ACC-RAIN-INCHES	OBSERVED-FLOW-(CFS)	INCREMENTAL-FLOW-(CUBIC FEET)	CUMULATIVE-FLOW-(CUBIC FEET)
0	0.000	0.00	0	0
1	0.000	0.00	0	0
2	0.000	0.00	0	0
3	0.000	0.00	0	0
4	0.000	0.00	0	0
5	0.000	0.00	0	0
6	0.000	0.00	0	0
7	0.000	0.00	0	0
8	0.101	1.40	5040	0
9	0.106	0.31	1116	5040
10	0.111	0.31	1116	6156
11	0.115	0.31	1116	7272
12	0.120	0.31	1116	8388
13	0.120	0.40	1440	9504
14	0.150	0.40	1440	10944
15	0.750	24.66	88776	12384
16	2.750	588.23	2116800	101,160
17	2.940	808.70	2911320	2,217,960
18	3.030	154.28	555408	5,126,760
19	3.030	94.68	340848	5,682,168
20	3.030	27.56	99216	6,023,016
21	3.090	36.13	130068	6,122,232
22	3.210	19.65	70740	6,252,300
23	3.300	7.00	25200	6,323,040
24	3.300	0.00	0	6,348,240

+2

TOTAL PRECIPITATION	3.3	INCHES +1
TOTAL RUNOFF	6,348,240 ft^3 +1	CUBIC FEET
WATERSHED AREA	88,711,200 ft^2 +1	SQUARE FEET
TOTAL RUNOFF (FT^3)/WATERSHED AREA (FT^2)	0.07	(WATERSHED) FEET +1
TOTAL RUNOFF (WATERSHED FEET*12) =	0.85	(WATERSHED) INCHES +1

Figure 7: Cumulative rainfall for a 24-hour period on watershed determined for Figure 3

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a) How many seconds in one hour? 3600 sec/hr (+1)

b) If water flows past an observation location at 1.0 cubic feet per second, for one hour, what volume in cubic feet have passed the observation location?

$\frac{1 ft^3}{sec} \cdot \frac{3600 sec}{hr} \cdot 1 hr = 3600 ft^3$ (+2)

c) Use the results above to complete the column labeled INCREMENTAL-FLOW(CUBIC FEET) in Figure 7. Provide a sample calculation below where you show how you determined the incremental volume for HOUR 17.

(+2)

$808.7 \frac{ft^3}{sec} \cdot \frac{3600 sec}{1 hr} \cdot 1 hr = 2{,}911{,}320 ft^3$

d) Use the results above to complete the column labeled CUMULATIVE-FLOW(CUBIC FEET) in Figure 7. Provide a sample calculation below where you show how you determined the value accumulated at the end of HOUR 8 (beginning of HOUR 9).

HOUR 8 CUM = 0.0 (+2)

HOUR 8 INC. = $5040 ft^3$

HOUR 9 CUM = $0.0 + 5040 ft^3 = 5040 ft^3$

e) What is the total **volume** of runoff in cubic feet from the storm? Enter the result in the box labeled TOTAL RUNOFF in Figure 7.

ABOUT $6.4 \cdot 10^6 ft^3$ (+1)

f) Enter the watershed area in square feet in the box labeled WATERSHED AREA in Figure 7. (+1)

ABOUT $88.7 \cdot 10^6 ft^2$

g) Convert the runoff volume from cubic feet into watershed feet, then watershed feet into watershed inches. Enter the appropriate values in the boxes labeled TOTAL RUNOFF (FT^ 3)/WATERSHED AREA (FT^ 2) and TOTAL RUNOFF (WATERSHED FEET*12) in Figure 7.

WATERSHED FT = $\frac{6.4 \cdot 10^6 ft^3}{88.7 \cdot 10^6 ft^2} = 0.07 ft * \frac{12 in}{ft} = 0.85$ inches

(+2)

h) What is the fraction of rainfall that becomes runoff?

$\frac{RUNOFF}{RAIN} = \frac{0.85 in}{3.3 in} = 0.25 \times 100 = 25.7\%$

(+2)

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19. The watershed in Figure 3 is located in Briscoe County, Texas. Figure 8 is a map of counties in Texas. Figures 9 and 10 are excerpts from the Texas DDF Atlas.

a) Circle Briscoe county on Figure 8. +1

b) Circle Briscoe county on Figure 9. +1

c) Circle Briscoe county on Figure 10. +1

d) Write the formula that converts the Annual Exceedence Probability (AEP) into an Annual Recurrence Interval (ARI).

$$ARI = \frac{1yr}{AEP}$$ +1

e) Estimate the precipitation **depth** in Briscoe county for a 3 hour storm with an Annual Exceedence Probability (AEP) of 0.2 (20 %).

+2 $ARI = \frac{1yr}{0.2} = 5yr$ 5yr, 3hr, Fig 9 ~ 2.3 inches

f) Estimate the average rainfall **intensity** in Briscoe county for a 3 hour storm with an Annual Exceedence Probability (AEP) of 0.1 (10 %).

$ARI = \frac{1yr}{0.1} = 10yr$ 10yr, 3hr, Fig 10 ~ $\frac{2.8 \text{ inches}}{3 \text{ hrs}}$

+3 = 0.93 in/hr

g) Using the results from the prior problem, estimate the runoff volume in watershed inches for a 3-hour, 10-year storm.

3hr, 10yr depth = 2.8 inches

+4 RUNOFF = (0.257)*(RAINFALL) = (0.257)(2.8 inches)

= 0.72 inches

h) Is a 3-hour storm a good duration based on the time-of-travel for water along the main channel?

+1 A bit short; travel time is nearly 5 hrs.

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HERE IT IS!
+1

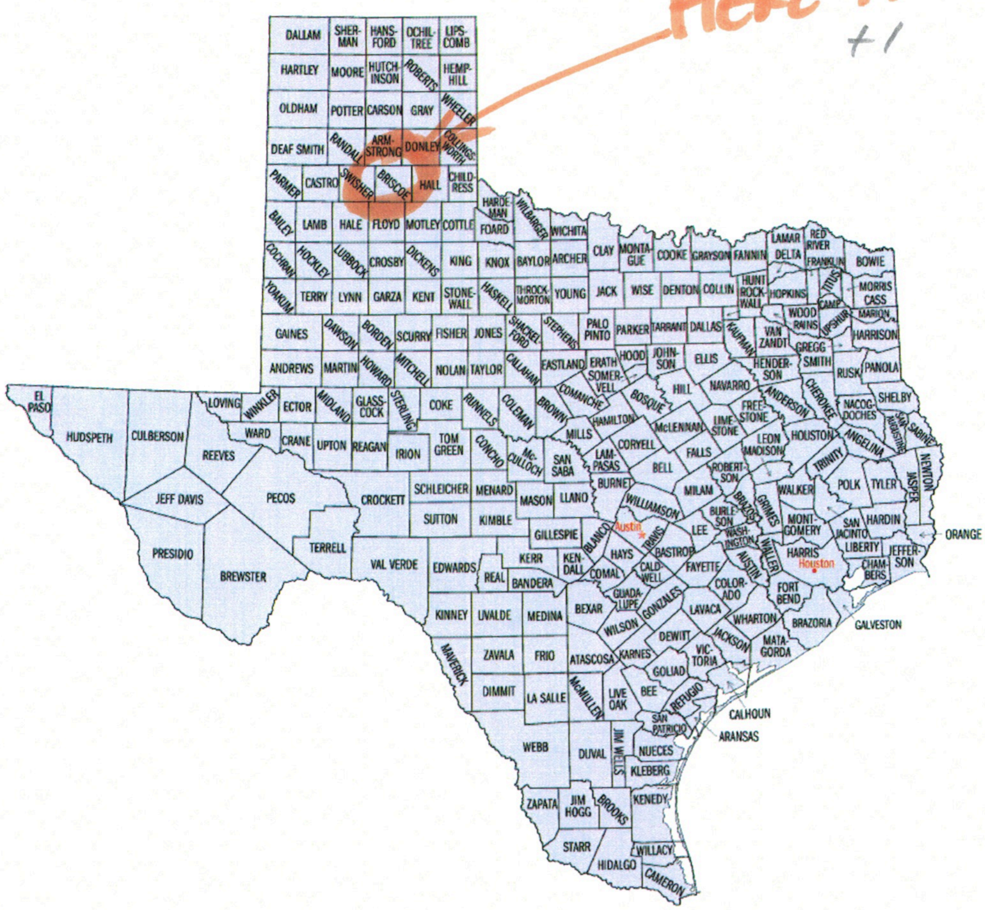

Figure 8: Map of Texas Counties

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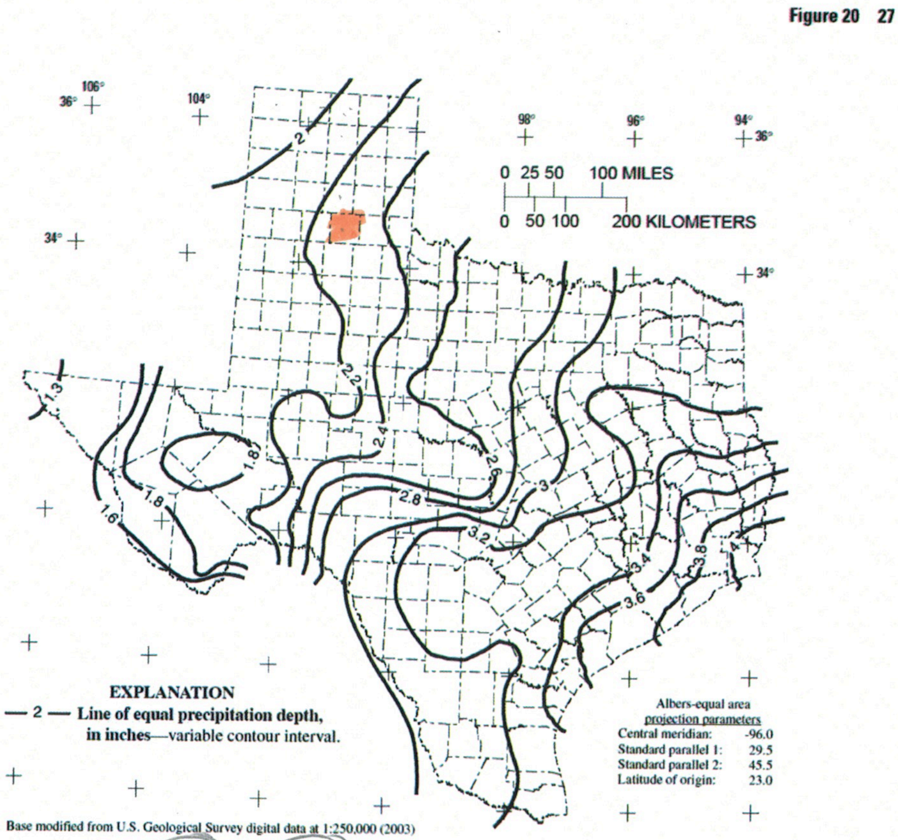

Figure 20. Depth of precipitation for 5-year storm for 3-hour duration in Texas.

Figure 9: Cumulative rainfall for a 3-hour period on watershed determined for Figure 3

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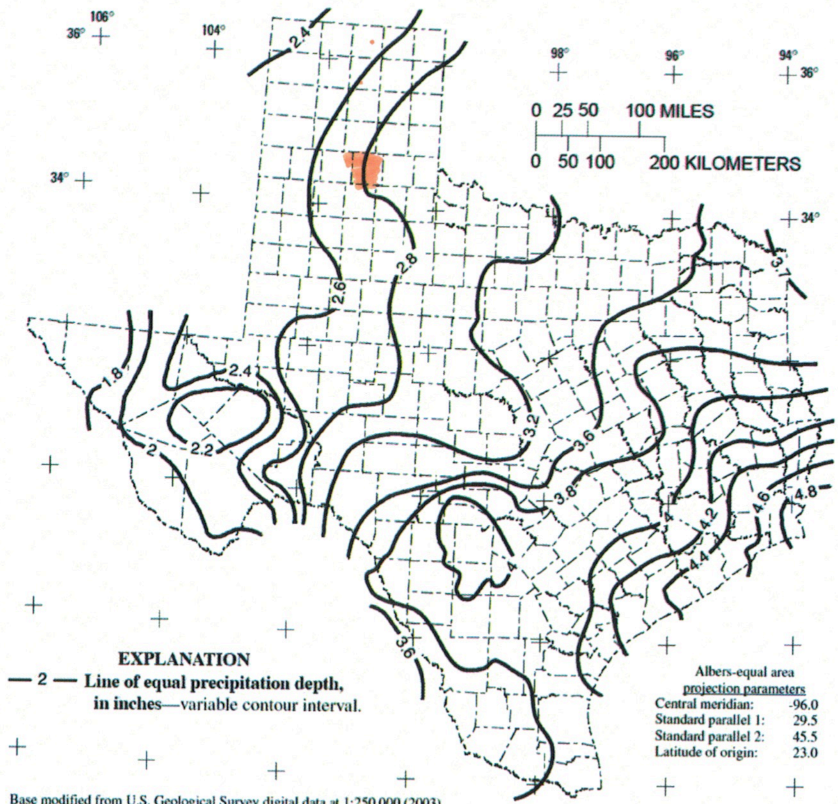

Figure 32. Depth of precipitation for 10-year storm for 3-hour duration in Texas.

Figure 10: Cumulative rainfall for a 3-hour period on watershed determined for Figure 3