

Student Name: SOLUTION

FALL 2024

NAME: 12

MULT GUESSES 12

13: 18

14: 39

15: 16

JUST TRYING

: 3

100

CE 3354 Engineering Hydrology
Exam 1, Fall 2024

Students should write their name on all sheets of paper.

Students are permitted to use the internet to help answer questions.

Students are permitted to use their own notes and the textbook.

Students are **forbidden** to **communicate with other people** during the examination.

1. Hydrology is

- VERBATIM FROM NOTES!** →
- a) Study of the atmosphere, ocean, and surface waters
 - b) The study of the occurrence, distribution, and movement of water above, on, and below the surface of the earth
 - c) A study of the processes of evaporation, infiltration, and storage
 - d) The study of the relationship between rainfall and runoff

2. The fundamental unit of hydrology is ?

- a) The rainfall depth
- b) The main channel length
- c) The main channel slope
- d) The watershed

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

- a) The ARI is the average number of years between years containing one or more events exceeding a prescribed magnitude
- b) The AEP and ARI are the multiplicative inverse of one another
- c) The AEP is a plot of probability and magnitude
- d) The ARI is a plot of probability and magnitude

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

- a) 1-percent.
- b) 10-percent.
- c) 50-percent.
- d) 100-percent.

$$\frac{1}{100} = 0.01 \times 100 = 1\%$$

5. What is a flood frequency curve?
- a) A plot of the discharge magnitude and the Weibull plotting position
 - b) A plot of the frequency and discharge
 - c) A plot of estimated exceedance probability and discharge
 - d) A plot of discharge and time
6. What is a plotting position?
- a) Location in a chart of a data pair
 - b) The multiplicative inverse of relative frequency
 - c) An estimate of probability associated with an observation based on its position within a ranked sample set
 - d) An estimate of probability associated with an observation based on its magnitude relative to the arithmetic mean
7. To what type of data series would we apply the Bulletin 17C procedure ?
- a) Annual maximum rainfall
 - b) Hourly rainfall
 - c) Annual maximum discharge
 - d) Instantaneous discharge
8. Rainfall behavior is expressed as a combination of
- a) depth and duration
 - b) intensity and probability or frequency
 - c) duration and probability or frequency
 - d) depth or intensity, duration, and probability or frequency
9. Rainfall intensity is
- a) the ratio of accumulated depth to duration
 - b) instantaneous rainfall rate
 - c) slope of the depth duration curve at a duration of one hour
 - d) integral of the depth duration curve from 0 to 24 hours



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

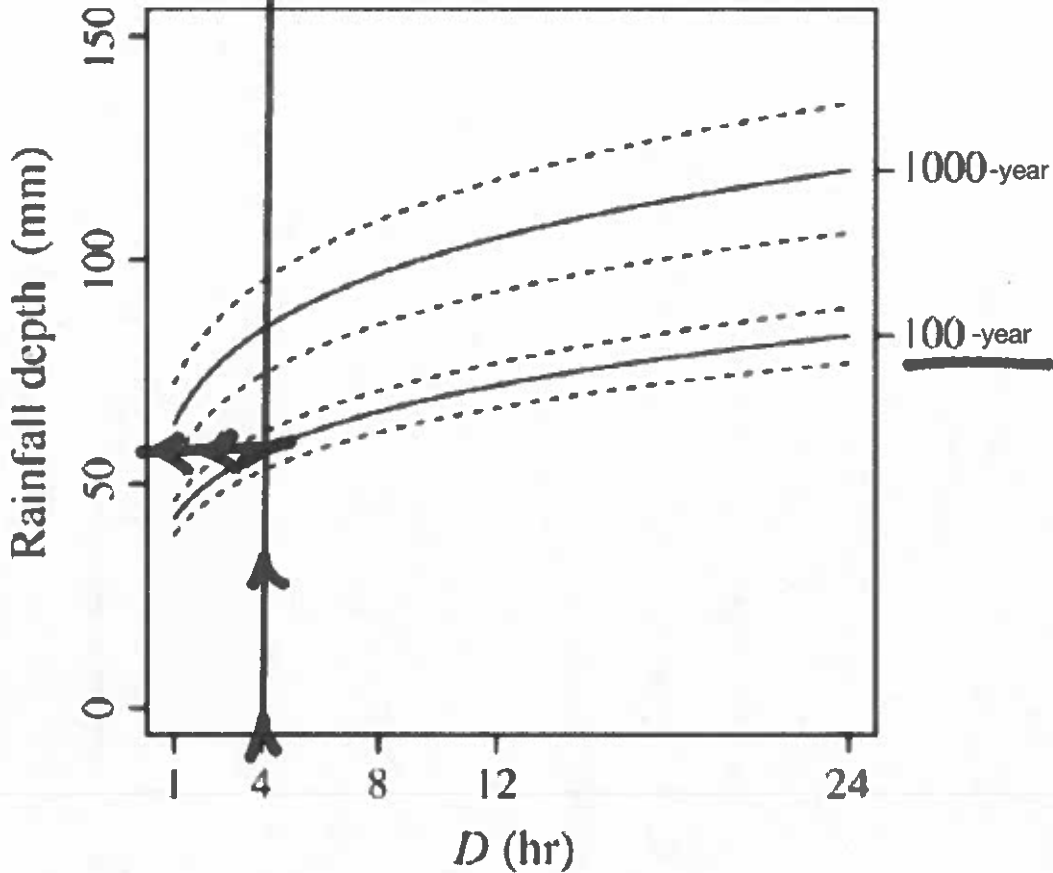


Figure 1: Depth-duration-frequency curve

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

- a) 125 millimeters
- b) 75 millimeters
- c) 55 millimeters
- d) 45 millimeters

**(BIGGER THAN 50;
SMALLER THAN 75
SO MUST BE 55)**

①

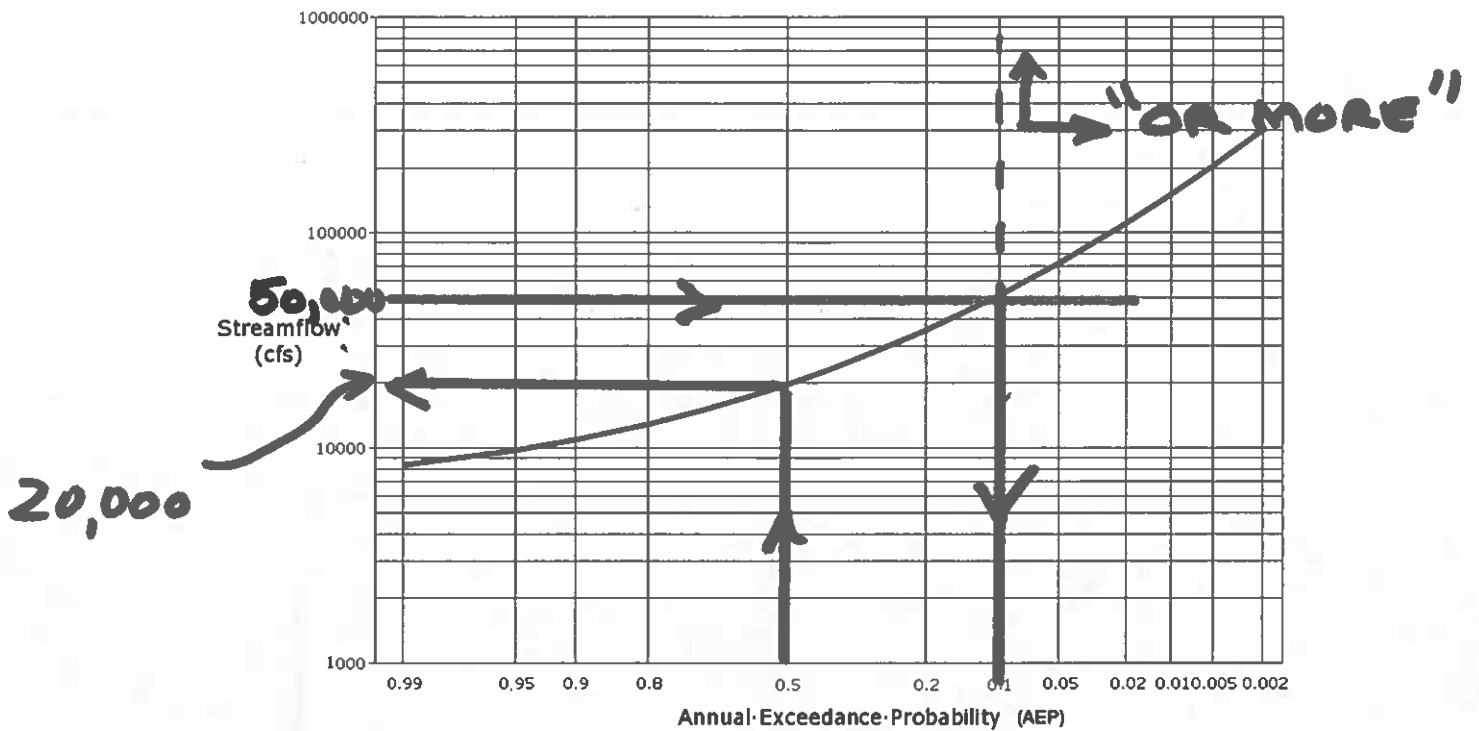


Figure 2: Flood frequency curve for a gaging station

11. Figure 2 is a flood frequency curve. The probability of observing a discharge of magnitude of 50,000 CFS or more is
 - (a) 0.01
 - (b) 0.05
 - (c) 0.10
 - (d) 0.50

12. The median discharge from Figure 2 is
 - (a) 10,000 CFS
 - (b) 20,000 CFS
 - (c) 50,000 CFS
 - (d) 90,000 CFS

MEDIAN MEANS
AEP = 0.5

(2)

13. The equation $k \frac{dQ}{dt} + Q(t) = I(t)$ is used to describe the response of streamflow to a constant rate of precipitation applied indefinitely on some watershed. Suppose that $Q(t) = 0$ for $t = 0$, the watershed characteristic time constant is $k = 2 \text{ hrs}$, and $I(t) = 2$ for $t = [0, 12) \text{ hrs}$ and then $I(t) = 0$ for $t = [12, 24) \text{ hrs}$.

Determine:

- (a) The necessary equation(s) to predict the response $Q(t)$ over the 24-hour period.
- (b) Plot the values of $Q(t)$ over the 24-hour period (i.e. complete Figure 3 below, showing the discharge $Q(t)$).

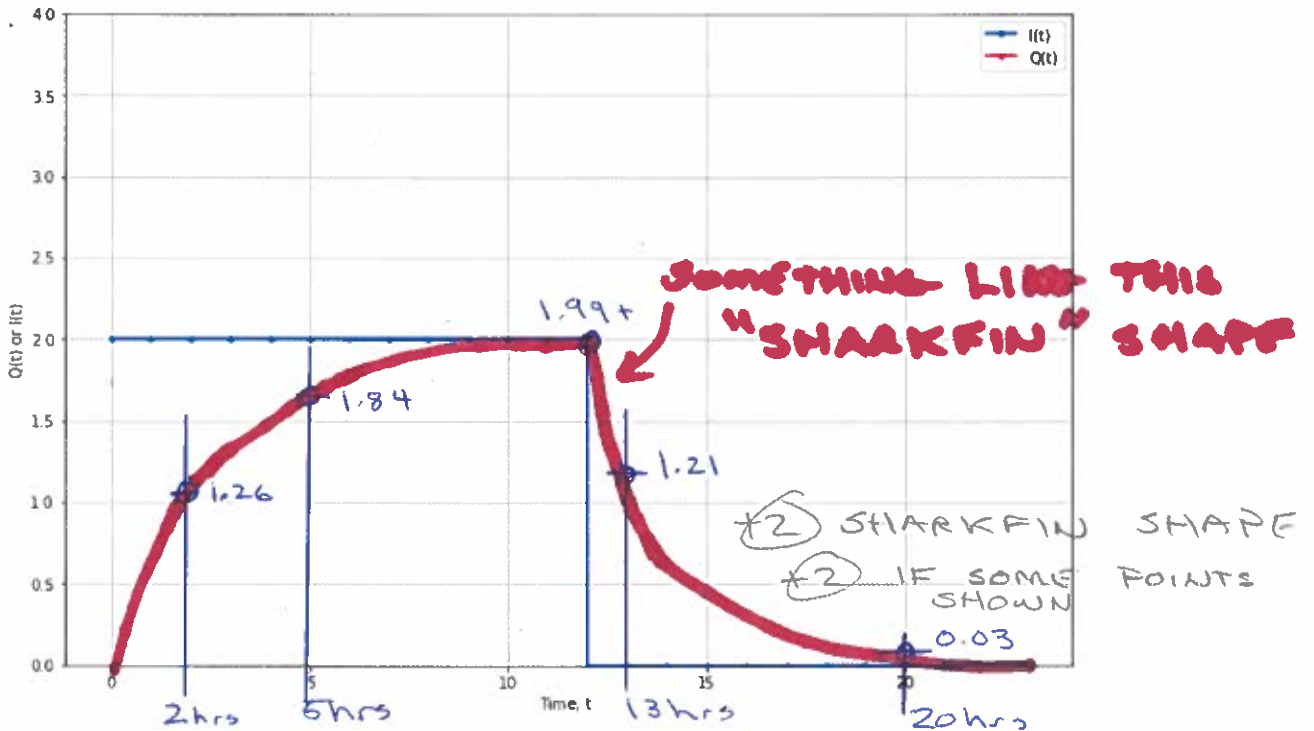


Figure 3: Plot of Runoff for Watershed described by $k \frac{dQ}{dt} + Q(t) = I(t)$, where $I(t)$ is as shown (in blue)

Show your work below (and on next page) (6) (FORMULAS & TIME SHIFTS) $k=2$
 For $t < 0$; $Q(t) = 0$
 $0 \leq t \leq \tau = 12$; $Q(t) = 2[1 - e^{-\frac{1}{k}t}]$
 $\tau \leq t < +\infty$; $Q(t) = 2[1 - e^{-\frac{1}{k}t}] - 2[1 - e^{-\frac{1}{k}(t-\tau)}]$

10

USING SOLUTION ES-7

Continued

$$R \frac{dQ}{dt} = I - Q$$

$$\frac{R dQ}{I - Q} = dt$$

$$\frac{dQ}{I - Q} = \frac{1}{R} dt$$

Also
OFT
I=1

let
 $u = I - Q; du = -dQ$

$$\frac{-(-dQ)}{1 - Q} = -\frac{du}{u} = \frac{1}{R} dt$$

$$\int -\frac{du}{u} = \int \frac{1}{R} dt$$

$$\ln|u| = -\frac{1}{R} t + C$$

Evaluate C at $t=0$

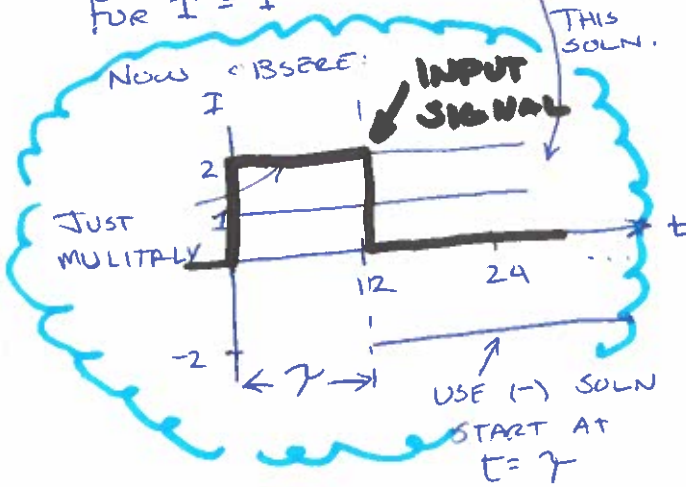
$$\ln|u| = -\frac{1}{R} t$$

$$u = e^{-\frac{1}{R} t}$$

$$1 - Q = e^{-\frac{1}{R} t}$$

$$Q = 1 - e^{-\frac{1}{R} t}$$

For $I = 1$



Now THE "MATH"

For

$$0 \leq t \leq \tau$$

$$Q(t) = 2 \left[1 - e^{-\frac{1}{R} t} \right]$$

For

$$\tau \leq t < +\infty$$

$$Q(t) = 2 \left[1 - e^{-\frac{1}{R} t} \right] - 2 \left[1 - e^{-\frac{1}{R} (t - \tau)} \right]$$

For

$$t < 0$$

$$Q(t) = 0$$

IN THIS CASE

$$\tau = 12 \text{ hrs (given)}$$

$$R = 2 \text{ hrs (given)}$$

$$I = 2 \text{ (Implied; given)}$$

⑧ ANALYSIS (EST OK) THEN ADDITIONS & TIME SHIFTS

① START AT POUR POINT

② MARK HIGH SPOTS SEVERAL DIRECTIONS FROM POUR POINT

Student Name: FROM POUR POINT

FALL 2024

③ DRAW DRAINAGE PATHS USING TOPOGRAPHY

14. Figure 4 is a topographic map of a small drainage basin. The contours show elevation in meters. Draw the boundary of the basin. A culvert structure is located on the Eastern portion of the basin, near the outlet shown on Figure 4. The red line is a proposed impoundment alignment, beneath which the culvert structure is placed.

④ DRAW BOUNDARY - JOIN HIGH POINTS

⑤ COUNT SQUARES TO FIND AREA

BNDRY
METHOD
DRAINS
LINE
SQUARES
TOTAL



400

WEST BNDRY
NOT OBVIOUS

COUNTS

100
20
25
34
10
100
100
100
71

560

Figure 4: Topographic Map of a portion of the Earth. Elevations are in meters. Each square is 150 meters on a side. North (by convention) is up.

Figure 5 is a photograph of a representative culvert system comprised of 4-parallel, 4-foot diameter, 100-foot long culverts. The lowest portion of the proposed impoundment structure directly above the culverts is at elevation 810 meters. The culverts are to be laid on a dimensionless slope of 0.02.

SOLUTION

1600

5



Figure 5: Multiple-barrel outlet structure

a) Delineate the drainage area to the culverts using the 810 meter elevation as the pour point elevation (located at the blue marker in the drawing).

b) Determine the area of each small square.

PG 7 ✓

③ $A_i = (150\text{m})(150\text{m}) = 22,500\text{m}^2$

c) Estimate the drainage area in square meters of the drainage basin.

③ $DA = (560\text{ squares}) \left(\frac{22,500\text{m}^2}{\text{sq.}} \right) = 12,600,000\text{m}^2$
 $12.6 \cdot 10^6\text{m}^2$

d) Convert the drainage area from square meters into acres.

③ $12.6 \cdot 10^6\text{m}^2 \left(\frac{3.28\text{ft}}{1\text{m}} \right)^2 \left(\frac{1\text{acre}}{43560\text{ft}^2} \right) = 3,111.94\text{ac}$

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

③ $3,111.94\text{ac} \left(\frac{1\text{mi}^2}{640\text{ac}} \right) = 4.86\text{mi}^2$

- ARITHMETIC ①
- ANSWER ①
- UNITS ①

f) 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 760 meters is essentially zero. Complete the elevation (side) view sketch of the embankment and culvert system in Figure 6 by indicating the elevations on the sketch of the roadway crest, the culvert inlet elevation (also the upstream base of the embankment), and culvert outlet elevation.

OUTLET ELEV.

760 \triangle 0.02 (30.48)

(2) ARITHMETIC + RESULT



760 - 0.6096

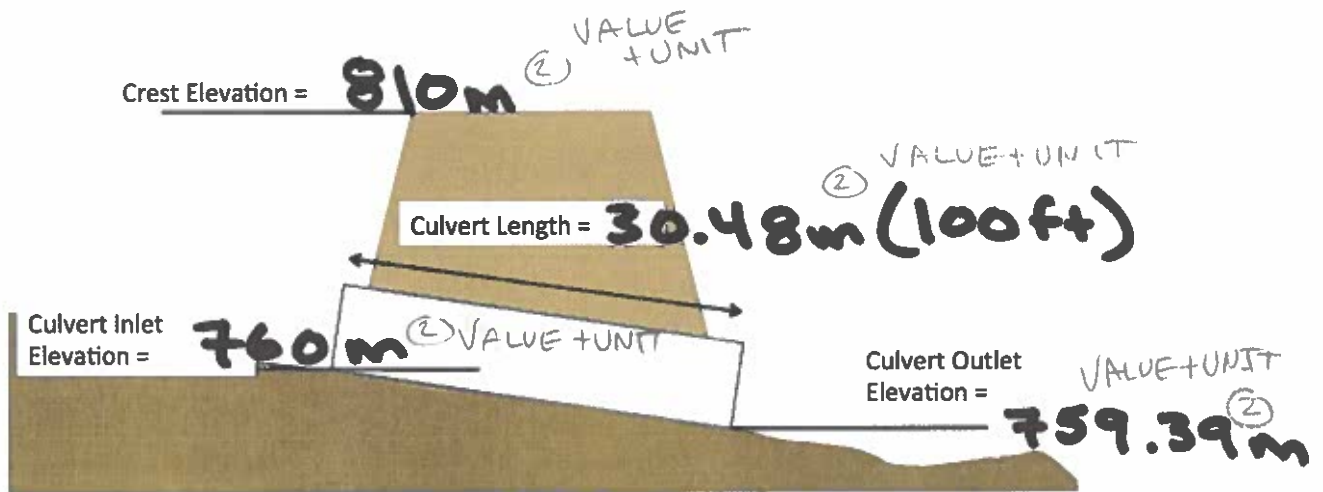


Figure 6: Culvert system elevation view sketch

10

g) Estimate the water surface area (area of the pool on the upstream side of the embankment) when the embankment impounds water to a water surface elevation of 780 meters. Describe how you made the estimate.

FIND 780 CONTOUR (1) METHOD

COUNT SQUARES ~ 49 (1) RESULT

$$\frac{(49)(22,500)(3.28)(3.28)}{43560} = 272.3 \text{ ac.}$$

(2)
VALUE + UNIT

h) Estimate the water surface area when the embankment impounds water to a water surface elevation of 790 meters. Describe how you made the estimate.

FIND 790 CONTOUR (1)
COUNT SQUARES ~ 60 (1)

$$\frac{(60)(22,500)(3.28)(3.28)}{43560} = 333.42 \text{ ac.}$$

(2)

i) Estimate the water surface area when the embankment impounds water to a water surface elevation of 810 meters. Describe how you made the estimate.

FIND 810 CONTOUR (1)
COUNT SQUARES ~ 92 (1)

$$\frac{(92)(22,500)(3.28)(3.28)}{43560} = 511.25 \text{ ac.}$$

(2)

14. Figure 4 is a topographic map of a small drainage basin. The contours show elevation in meters. The contours are labeled every 10 meters. A culvert structure is located on the Eastern portion of the basin, near the outlet shown on Figure 4. The red line is a proposed impoundment structure. The culvert structure is placed **REPRODUCED FOR CLARITY**

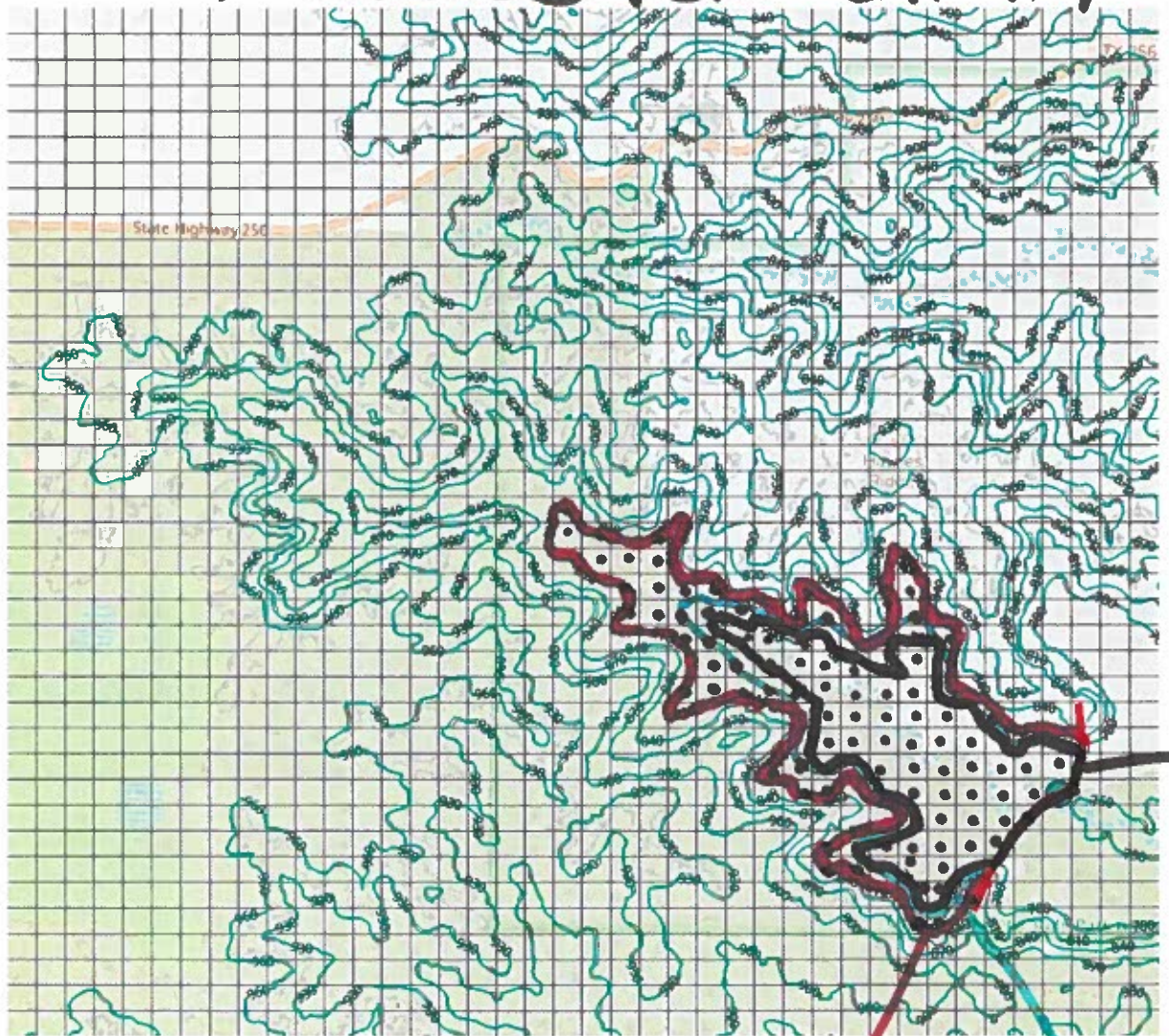


Figure 4: Topographic Map of a portion of the Earth. Elevations are in meters. Each square is 150 meters on a side. North (by convention) is up.

Figure 5 is a photograph of a representative culvert system comprised of 4-parallel, 4-foot diameter, 100-foot long culverts. The lowest portion of the proposed impoundment structure directly above the culverts is at elevation 810 meters. The culverts are to be laid on a dimensionless slope of 0.02.

15. Figure 7 is a tabulation of an observed storm and runoff for the drainage area depicted by the map in Figure 4. The runoff was measured before the installation of the roadway, at the location indicated by the blue circle on the map.

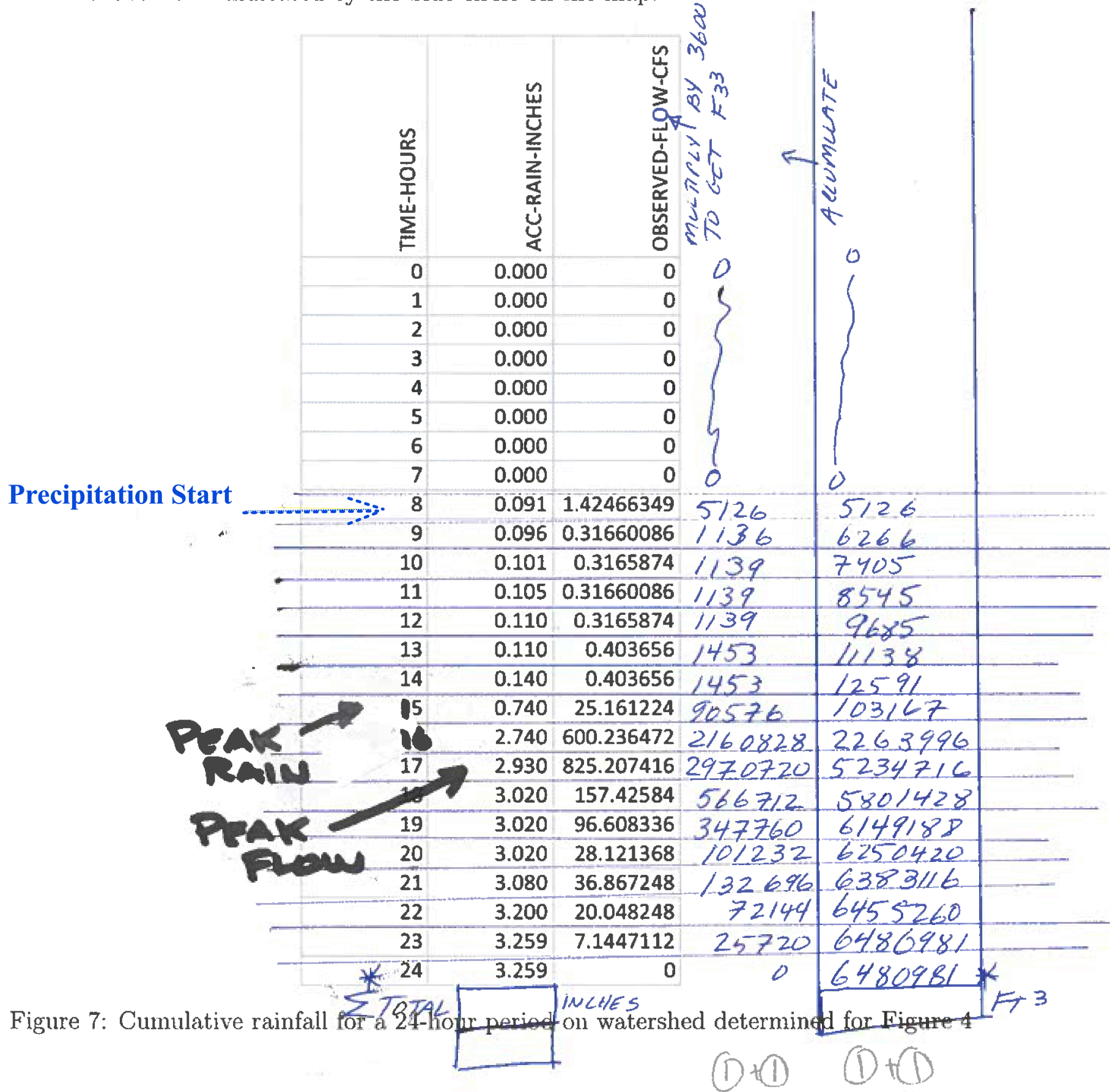


Figure 7: Cumulative rainfall for a 24-hour period on watershed determined for Figure 4

a) Estimate the total volume of runoff in cubic feet from the storm. Describe how you made your estimate.

ACCUMULATE OBS FLOW PER EACH HOUR (COLUMN 3 & 4) Pg 11

6,480,981 ft³ (ASSUMING ARITHMETIC OK) ^② VALUE + UNIT + EXPLAIN

b) Convert the estimate of runoff volume from cubic feet into watershed inches.

$WS\ IN. = \frac{TOTAL\ VOLUME}{WS\ AREA}$

$\frac{6,480,981\ ft^3}{3,111.94\ (43560\ ft^2)} = 0.0478\ ft \times 12 = 0.574\ in$ ^④ VALUE + UNIT + EXPLAIN + EQ.

c) How long (in hours) from the beginning of rainfall until the peak discharge occurs?

PEAK RAIN: HR 15 → 16

Rain Start Hr 8

PEAK FLOW HR 16 → 17

Time to peak = 17 - 8 = 9 hrs

^② LOGIC + VALUE

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

TOTAL RAIN: 3.259 in

TOTAL RUNOFF: 0.574 in

FRACTION $\frac{0.574\ in}{3.259\ in} = 0.176$ ^② VALUE + LOGIC

~ 17.6% OF RAIN BECOMES RUNOFF