Solution Homework 3

Hydraulic Engineering Design

Spring 2014

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1. Consider the storm drain inlet at the corner of Dean Keaton St and San Jacinto Blvd. How large is this? Assuming the same drainage area you worked with in Problem 1 of Homework 2, determine the design discharge and the top width of the spread of the water across the street at this location. The best estimate that I can make of the elevations on the road from the airborne LIDAR data at this location is 533.6 ft above datum at the curb and 534.5 ft above datum at the center of the road off the median strip, which is 45 ft from the curb. Will the spread of the water across the road satisfy the City of Austin’s Design Criteria in a 2 year storm? In a 25 year storm? What proportion of the flow bypasses the inlet during these events?

$$Inlet Length= 11.9 ft$$

Estimating the slope from the center of the road to the gutter:

$$Sx= \frac{(534.5-533.6)}{45}=\frac{0.9}{45}=0.02 \frac{ft}{ft}$$

From previous homework, we know that the slope along the gutter is:

$$So= \frac{14.57}{343}=0.0424 \frac{ft}{ft}$$

Estimating the design discharge capacity and top width spread

The time of concentration is 5 minutes as estimated in Homework 2. Intensities from table 2-4 and C from table 2-1 of the Drainage Criteria Manual of the City of Austin:

$$Q\_{2 year}=C i A=\left(0.73\right)\left(5.76\right)\left(0.292\right)=1.2614 acre\frac{in}{hra}=1.274 cfs$$

$$Q\_{25 year}= C i A=\left(0.86\right)\left(10.1\right)\left(0.292\right)=2.6058 acre\frac{in}{hra}=2.632 cfs$$

From the Gutter Flow formula

$$Q=\frac{C\_{f}}{n}S\_{x}^{\frac{5}{3}} T ^{\frac{8}{3}}S\_{0}^{\frac{1}{2}}$$

Where

Q = flow in gutter (cfs)

Cf = coefficient (0.56 for US units, 0.376 for SI units)

So = longitudinal slope

T = spread (ft)

Sx = transverse slope

$$T\_{2 year}=\left(Q\frac{n}{C\_{f}S\_{x}^{\frac{5}{3}}S\_{0}^{0.5}}\right)^{\frac{3}{8}}=\left(1.274 \frac{0.016}{0.56\left(0.02\right)^{\frac{5}{3}}\left(0.042\right)^{0.5}}\right)^{\frac{3}{8}}=6.03 ft$$

$$T\_{25 year}=\left(Q\frac{n}{C\_{f}S\_{x}^{\frac{5}{3}}S\_{0}^{0.5}}\right)^{\frac{3}{8}}=\left(2.632\frac{0.016}{0.56\left(0.02\right)^{\frac{5}{3}}\left(0.042\right)^{0.5}}\right)^{\frac{3}{8}}=7.917 ft$$

According to Table 3-1 of the Drainage Criteria Manual of the City of Austin the minimum clear width of roadway design when gutter is flowing full is 12 ft in each direction. The distance of the center of the road and the inlet is 45 ft, so $T\leq 33$. In both cases this criteria is satisfied.

From the required length formula:

$$L\_{T}=C\_{f}Q^{0.42}S\_{0}^{0.3}\left(\frac{1}{nS\_{x}}\right)^{0.6}$$

Where

LT = required length to intercept all flow (ft)

Q = flow in gutter (cfs)

Cf = coefficient (0.60 for US units, 0.817 for SI units)

So = longitudinal slope

Sx = transverse slope

$$L\_{T2year}=C\_{f}Q^{0.42}S\_{0}^{0.3}\left(\frac{1}{nS\_{x}}\right)^{0.6}=\left(0.60\right)\left(1.274\right)^{0.42}\left(0.042\right)^{0.3}\left(\frac{1}{\left(0.016\right)\left(0.02\right)}\right)^{0.6}=32.08 ft$$

$$L\_{T25year}=C\_{f}Q^{0.42}S\_{0}^{0.3}\left(\frac{1}{nS\_{x}}\right)^{0.6}=\left(0.60\right)\left(2.64\right)^{0.42}\left(0.042\right)^{0.3}\left(\frac{1}{\left(0.016\right)\left(0.02\right)}\right)^{0.6}=43.951 ft$$

 Calculating proportion of the flow bypasses the inlet

 The proportion of flow captured:

$$E\_{2year}= 1-\left(1-\frac{L}{L\_{T}}\right)^{1.8}=1-\left(1-\frac{11.9}{32.08}\right)^{1.8}=0.566$$

$$E\_{25year}= 1-\left(1-\frac{L}{L\_{T}}\right)^{1.8}=1-\left(1-\frac{11.9}{43.951}\right)^{1.8}=0.434$$

 Therefore, the proportion of flow bypasses the inlet

 $Flow bypasses\_{2 year}=100-100\left(E\_{2year}\right)= 43.41\%$

$$Flow bypasses\_{25 year}=100-100\left(E\_{25year}\right)= 56.64\%$$

1. Continue this study of the storm drainage on Dean Keaton upstream to the drainage divide near the Student Services Building (Figure 1(b)). How many storm inlets are there? How large are they? What is the distance between them? Will this portion of Dean Keaton St satisfy the City of Austin’s Drainage Criteria for spread of water on the street considering a 2 year storm? A 25 year storm? What proportion of the street flow bypasses the inlets during these events? If you conclude that the street drainage capacity is not adequate, what could you do to alter it? A web map is presented at http://bit.ly/1jhywhz and more information on the corresponding elevations is shown on the next page.

6 inlets in the area

Figure 1 shows the data obtained from the cross sections and ArcGIS online map

San Jacinto

1

2

3

4

54

6

7

8

b

a

c

d

Z = 590. 8

Z = 562

Z = 546.9

Z = 533.9

Z = 534.05

Z = 547.45

Z = 561.8

Z = 592.4

Z = 592.4

Z = 562.7

Z = 547.8

Z = 534.6

A1

A2

A3

80 ft

70.2 ft

63.5

65.1

342 ft

307.4 ft

 ft

550 ft

 ft

574.5 ft

 ft

307.8 ft

 ft

332.2 ft

 ft

$$A\_{1}=362,020.06 ft = 0.8269 Acres$$

$$A\_{2}=20,944.28 ft=0.4808 Acres$$

$$A\_{3}=25,563.62 ft=0.5869 Acres$$

Estimating the Slopes:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Relation | Profile | Lengthft | SlopeSx | SlopeSo |
| 1&a | cross section | 32.55 | 0.052 | - |
| a&2 | cross section | 32.55 | 0.003 | - |
| 3&b | cross section | 31.75 | 0.022 | - |
| b&4 | cross section | 31.75 | 0.028 | - |
| 5&c | cross section | 35.1 | 0.026 | - |
| c&6 | cross section | 35.1 | 0.010 | - |
| 7&d | cross section | 40 | 0.018 | - |
| d&8 | cross section | 40 | 0.014 | - |
| 1&3 | longitudinal | 550 | - | 0.052 |
| 3&5 | longitudinal | 307.4 | - | 0.049 |
| 5&7 | longitudinal | 342 | - | 0.038 |
| 2&4 | longitudinal | 574.5 | - | 0.053 |
| 4&6 | longitudinal | 307.8 | - | 0.047 |
| 6&8 | longitudinal | 352.2 | - | 0.038 |

Estimating the Time of Concentration for each inlet catchment (double click to enter to excel sheet):



Estimating the Discharge at each inlet (double click to enter to excel sheet)



Estimating the top width spread (double click to enter to excel sheet)



According to Table 3-1 of the Drainage Criteria Manual of the City of Austin the minimum clear width of roadway design when gutter is flowing full is 12 ft in each direction. The excel below shows the estimation of the requirement needed for



As we can see, in all cases the specification is satisfied ($T\_{2year}<Requirement City of Austin; and T\_{2year}<Requirement City of Austin$).

The graphs below show a better visualization of the spread along Dean Keaton.

Estimating required length, inlet efficiencies and the proportion of flow bypasses the inlets (double click to enter to excel sheet)



As shown in the table above, the flow bypasses by almost 52% on one side of the Dean Keaton (inlets 3, 5 and 7) for a 2 year event, and 66% for a 25 year event. On the other hand, flow bypasses by 60 % the other side of Dean Keaton (inlets 4, 6 and 8) for a 2 year event, and 71% for a 25 year event. The *T* required by the City of Austin is much higher than the designed, but the proportion of flow that bypasses is relevant. A way of reducing the percentage of flow bypassing the inlets is by implementing infiltration trench as the ones in the redevelopment area of Mueller Airport. It will be interesting to do the same exercise with a 100 and 500 year storm event to see how the system behaves in more extreme conditions.