Name: Maidment

CE 365K Hydraulic Engineering Design **First Exam** **Spring 2015**

There are five questions on this exam. Please do all five questions.

1. Hydraulic Design

(a) Name and give a brief description of the six steps in the HydroDesign process.

(i) Representation – describe the study area

(ii) Process – how does it operate

(6) (iii) Evaluation – is it working well?

(iv) Change – how might it be altered?

(v) Impact – what differences would result?

(vi) Decision – how should the study area be changed?

(b) Hydraulic engineering for stormwater management has evolved through the years. Name and briefly describe four goals of this kind hydraulic engineering design over this period.

(i) Stormwater runoff disposal – get the water off the site as quickly as possible

(8) (ii) Stormwater detention – slow down the stormwater so that the peak flow after development is not more than before

(iii) Water Quality Control – retain and filter water on site

(iv) Low Impact Development – Dispersed, onsite infiltration and retention schemes

(c) Hydraulic design for water quality enhancement can employ a number of different "Best Management Practices" for design. Name and briefly describe three of these "BMP's".

(i) Porous pavement – absorbs and filters water on streets & parking lots

(6) (ii) Grassy swales – filters pollutants as water flows through

(iii) Sand filters – direct filtration beds of sand with underdrains to pipe away filtration

2. Design Context

(a) Hydraulic design always occurs in a particular context or site location. Geographic information systems are used to describe this context. Define the term Geographic Information System.

(4) GIS – a system designed to capture, store, analyze, manage and present all kinds of geographic data

(b) GIS uses thematic data layers to describe a region. These are usually vector or raster data. Give three examples of GIS data layers, and specify for each one whether it is vector, raster or another data type:

(3)

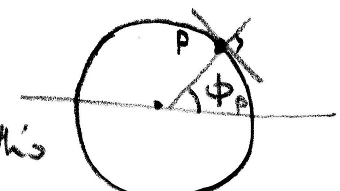
(i) Stream map – Vector lines

(ii) Digital Orthophoto – Raster cells

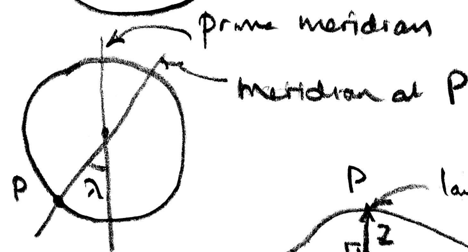
(iii) Digital Elevation Model – Raster cells

(c) When I am driving in my car, there is a display that shows my Latitude, Longitude and Elevation. Define each of these terms, using a diagram to illustrate your definition.

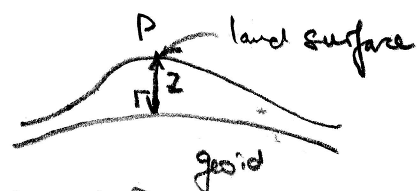
(i) Latitude ϕ_p – angle made at
(3) equitorial plane of a normal line to the tangent plane on earth's surface at P



(ii) Longitude
λ_p = angle between a cutting
(3) plane through the prime meridian and a cutting plane thru meridian at P



(iii) Elevation
Distance vertically above the geoid – a
(3) surface of constant gravitational potential (geodetic datum)

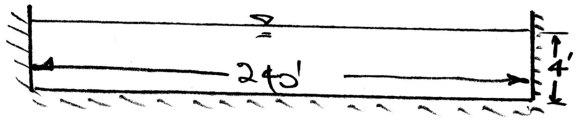


(d) During a severe storm, the stormwater collection system is designed to permit traffic flow without excessive street flooding. Briefly describe how this is accomplished.

(4) Create stormwater inlets and a subsurface piping system that drains water off streets and conveys it to streams.

3. Flow in an Open Channel

(a) A creek is approximated as a rectangular channel that is 240 ft wide with a roughness coefficient of 0.035, longitudinal slope of 0.01. If the creek is flowing at a normal depth of four feet, determine the corresponding discharge (cfs)



$$Q = \frac{1.49}{n} R^{2/3} S_o^{1/2} A$$

(8)

$$A = 240 \times 4 = 960 \text{ ft}^2$$

$$P = 240 + 2 \times 4 = 248 \text{ ft}^2$$

$$R = A/P = 960/248 = 3.87 \text{ ft}$$

$$Q = \frac{1.49}{0.035} \cdot (3.87)^{2/3} \times (0.01)^{1/2} \times 960$$

$$Q = 10{,}075 \text{ cfs}$$

(b) Determine the corresponding velocity (ft/sec), velocity head (ft), specific energy (ft), and Froude number. Is the flow supercritical or subcritical?

(8)

$$V = Q/A = 10075/960 = 10.5 \text{ ft/sec}$$

$$V^2/2g = 10.5^2/2 \times 32.2 = 1.71 \text{ ft}$$

$$E = y + \frac{V^2}{2g} = 4 + 1.71 = 5.71 \text{ ft}$$

$$F_R = \frac{V}{\sqrt{gy}} = \frac{10.5}{\sqrt{32.2 \times 4}} = 0.923$$

This is subcritical flow

(c) For a discharge of 10,000 cfs, determine the critical depth (ft) in this channel.

(4)

$$y_c = \sqrt[3]{\frac{q_c^2}{g}}$$

$$q_c = \frac{Q}{B} = \frac{10{,}000}{240} = 41.67 \text{ ft}^2/\text{sec}$$

$$y_c = \sqrt[3]{\frac{41.67^2}{32.2}}$$

$$= 3.78 \text{ ft}$$

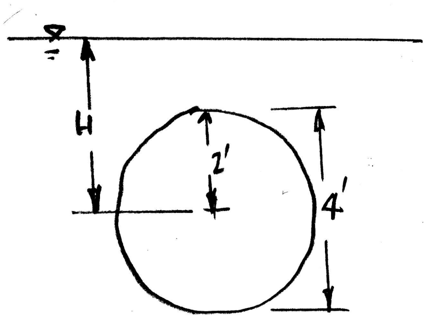
4. Flow through Culverts

(a) Suppose that a 4 ft diameter circular culvert pipe is flowing under inlet control where its inflow can be approximated as an orifice with a coefficient of 0.6. If the discharge through the pipe is 150 cfs, determine the height of the upstream water surface above the top of the pipe (ft).

$$Q = C_d A \sqrt{2gH}$$

$$A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \times 4^2 = 4\pi$$

$$= 12.57 \text{ ft}^2$$



$$\frac{Q}{C_d A} = \sqrt{2gH}$$

(10)

$$\therefore 2gH = \left(\frac{Q}{C_d A}\right)^2$$

$$H = \frac{1}{2g}\left(\frac{Q}{C_d A}\right)^2$$

$$= \frac{1}{2 \times 32.2}\left(\frac{150}{0.6 \times 12.57}\right)^2$$

$$= \frac{1}{64.4} \times 19.89^2$$

$$H = 6.14 \text{ ft}$$

This is 4.14 ft above top of pipe

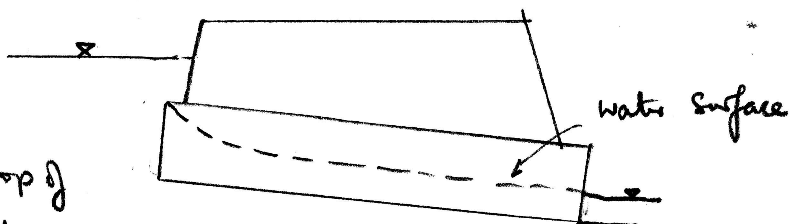
(b) The discharge through a culvert can be determined by inlet or outlet control. Using a diagram in each case, describe the type of culvert and flow conditions when you would expect:

Inlet Control

(5)

Short pipe

Tail water below top of pipe at outlet

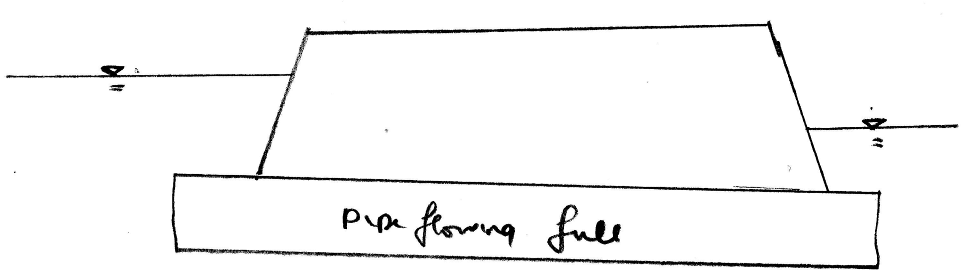


Outlet Control

(5)

Longer pipe

Tail water above top of pipe at outlet



5. Rational Method

(a) Write the equation for computing flows using the rational method and define its terms.

$Q = CiA$

(4)

Q = peak discharge (cfs)

C = runoff coefficient (0–1)

i = rainfall intensity (in/hr)

A = drainage area (acres)

(b) State five assumptions used in applying the rational method for determining design flows

(i) Storm duration is equal to the time of concentration

(ii) Constant rainfall intensity for this duration

(3)

(iii) Return period for Q is same as for i (50 yr storm produces a 50 yr flood)

(iv) Rainfall is uniform over the drainage area

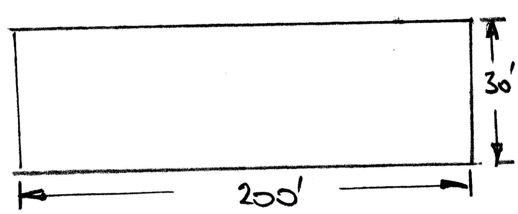
(v) Maximum discharge happens when the entire drainage area contributes to flow at outlet.

(c) A section of an asphalt street in Austin flowing to a stormwater inlet is 200 ft long and 30 ft wide from the crown of the road to the gutter. Determine the design discharge (cfs) from the street for a 10 year storm. Assume the time of concentration is 5 mins. A table of runoff coefficients and rainfall intensities is attached. 1 acre = 43,560 ft^2.

$A = 200 \times 30 = 6000 \text{ ft}^2$

$= 6000/43560$ acres

$= 0.1377$ acres



(8)

$t_c = 5\text{min}$, $T = 10\text{yrs} \Rightarrow i = 8.57''/\text{hr}$

asphalt street, $T = 10\text{yrs} \Rightarrow C = 0.81$

$\therefore Q = CiA$

$= 0.81 \times 8.57 \times 0.1377$

$Q = 0.96$ cfs

TABLE 2-1
RATIONAL METHOD RUNOFF COEFFICIENTS FOR COMPOSITE ANALYSIS
Runoff Coefficient (C)

Character of Surface	Return Period 2 Years	5 Years	10 Years	25 Years	50 Years	100 Years	500 Years
DEVELOPED							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass Areas (Lawns, Parks, etc.)							
Poor Condition*							
Flat, 0-2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2-7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair Condition**							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good Condition***							
Flat, 0-2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2-7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
UNDEVELOPED							
Cultivated							
Flat, 0-2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2-7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0-2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2-7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Table 2-4. Intensity-Duration-Frequency Table for Austin and Travis County
Intensity of Precipitation (inches per hour)

Recurrence Interval (year)	5 min*	15 min	30 min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	5.76	3.92	2.64	1.72	1.08	0.773	0.445	0.255	0.143
5	7.39	5.04	3.42	2.28	1.45	1.04	0.593	0.339	0.208
10	8.57	5.88	3.96	2.68	1.71	1.24	0.702	0.401	0.254
25	10.1	7.04	4.72	3.28	2.10	1.52	0.857	0.492	0.318
50	11.2	8.04	5.36	3.79	2.44	1.76	0.990	0.572	0.370
100	12.5	9.16	6.08	4.37	2.83	2.04	1.14	0.663	0.424
250	14.5	10.9	7.14	5.26	3.43	2.46	1.37	0.806	0.501
500	15.9	12.4	8.04	6.06	3.97	2.84	1.58	0.934	0.564