UNIVERSITY OF RUHUNA

Faculty of Engineering

Mid-Semester 7 Examination in Engineering: June 2014

Module Number: CE7325 **Module Name: Environmental Engineering Design**

[Two Hours]

[Answer **all questions**, each question carries five marks]

Q1. Design a gravity-flow trunk sanitary sewer for the street given in Table Q1 (a) from the junction *J* to the junction *L* via the junction *K*. Major manholes are located at the junctions *J*, *K* and *L*. The design should include the design flow rates, pipe diameters, pipe slopes and the pipe invert elevations. Assume that the infiltration rate is negligible.Table Q1 (b) gives the design criteria. For the hydraulic design calculations, use the Manning equation [Figure Q1];$V = (1/n)R^{2/3}S^{1/2}$, where V = velocity (ms^{-1}); n = friction factor (0.013); R = hydraulic radius = cross-sectional area of flow (m^2)/wetted perimeter (m); S= slope of energy grade line (m/m).

Table Q1 (a): Street and sewer network information.

Line	From junction	To junction	Length of sewer (*m*)	Average residential flow (m^3/d)	Average commercial flow (m^3/d)	Average institutional flow (m^3/d)	Ground surface elevation (*m*)	
							At upper manhole	At lower manhole
1	J	K	500	6000	450	1400	22.0	21.0
2	K	L	500	2000	2000	500	21.0	20.0

Table Q1 (b): Design criteriaof the gravity-flow trunk sanitary sewer.

Description	Unit	Value
Peaking factors:	-	
Residential areas		2.5
Commercial areas		1.4
Institutions		3.5
The smallest pipe diameter permissible for this situation according to the local building code	*mm*	200
The minimum practical slope of a sewer for construction	*m/m*	0.00085
The allowable minimum velocity	*m/s*	0.75
The minimum depth of the cover over the top of the seweraccording to the local building code	*m*	2.0
The pipe wall thickness	*m*	0.05

[5.0 Marks]

Q2. a) Compare and contrast the similarities and differences between a conventional activated sludge process and an aerobic suspended growth flow-through aerated lagoon (without solids recycle).

[2.0 Marks]

b) Table Q2 gives the conditions and requirements for the design of a flow-through aerated lagoon (without recycle). Determine the surface area of the lagoon, effluent soluble 5-day biochemical oxygen demand (BOD_5) (*S*), effluent *TSS* (Total Suspended Solids) concentration and the oxygen requirement.

Table Q2:Design criteria of the aerated lagoon.

Description	Unit	Value
Wastewater flow(Q)	m^3/d	25 000
Influent SS (Suspended Solids) concentration; Influent SS are not biologically degradable	g/m^3	250
Influent soluble $BOD_5(S_0)$	g/m^3	200
Water temperature in the lagoon	^0C	30
Temperature coefficient(θ) at 20^0C	-	1.05
Conversion factor (x) for BOD_5 to BOD_L (Ultimate Biochemical Oxygen Demand)	-	0.60
Observed yield coefficient (Y_{obs})	-	0.35
VSS (Volatile Suspended Solids)/TSS ratio	-	0.80
First-order observed soluble BOD_5 removal –rate constant (k) at 20 ^0C	d^{-1}	2.6
Design solids retention time (SRT)	d	10
Depth of the lagoon	m	2.0

You may use the following equations:

$S/S_0 = 1/\{1 + k(V/Q)\}$; where V = volume of reactor;

$k_T = k_{20}\theta^{(T-20)}$; where T = temperature; k_T= 'k' at 'T' temperature;

$P_x = QY_{obs}(S_0 - S)$; where P_x = biological solids wasted per day ($kg\ VSS/d$);

Oxygen requirement $(kg\ of\ O_2/d) = \{Q(S_0 - S)/x\} - 1.42P_x$.

[3.0 Marks]

Q3. a) Discuss briefly the importance of having a secondary sedimentation basin following an aerated lagoon.

[1.0 Marks]

b) What is the composition of the organic content of the influent to a secondary sedimentation basin which follows an aerated lagoon?

[1.5Marks]

c) Table Q3 gives the conditions and requirements for the design of an earthen sedimentation basin which follows an aerated lagoon.Determine the total depth of the sedimentation basin excluding the free board. The accumulated sludge will be compacted to an average final value of 12 % of the initial solids volume. Assume that the maximum amount of volatile suspended solids (VSS) accumulated at the end of t^{th} year is given by the following equation:

$(VSS)_t$ = [0.7+0.4(t-1)] X mass of VSS added per year (kg/yr)

Table Q3: Design criteria of the earthen sedimentation basin.

Description	Unit	Value
Wastewater flow	m^3/d	22 000
Hydraulic detention time	d	3.0
Liquid level above the sludge layer at its maximum level of accumulation	m	1.6
Total suspended solids (TSS) concentration of the effluent from the aerated lagoon	g/m^3	400
TSS concentration of the effluent from the sedimentation basin	g/m^3	30
Volatile suspended solids (VSS) content of TSS discharged to the sedimentation basin	%	75
Period between two consecutive removals of sludge from the sedimentation basin	*years*	6
Relative density of the accumulated sludge	-	1.04

[2.5Marks]

Q4. A primary treated municipal wastewater is to be treated further using a staged *RBC* (Rotating Biological Contactors) system with a tapered feed flow for each stage. Table Q3 gives the design information. The soluble 5-day biochemical oxygen demand (BOD_5) in each stage (S_n) is given by the following equation:

$$S_n = \frac{-1+\sqrt{1+(4)(0.00974)(A_s/Q)S_{(n-1)}}}{(2)(0.00974)(A_s/Q)}$$; Where A_s=total disk surface area on stage '*n*'; *Q*=flow rate on stage '*n*'; the units for '*S*','A_s' and '*Q*' are g/m^3, m^2 and m^3/d, respectively.

Table Q4: Design criteria of the staged RBC system.

Description	Unit	Value
Flow rate (*Q*)	m^3/d	4000
Soluble BOD_5in the primary effluent	g/m^3	150
Target soluble BOD_5in the *RBC* effluent	g/m^3	10
No. of stages of the *RBC* system	-	3
Standard disk density	m^2/shaft	9300
Maximum organic loading (soluble BOD_5) on 1st stage for secondary treatment	$g/m^2.d$	14

a) Determine the number of *RBC* shafts for the stage 1.

[1.0Mark]

b) If the number of shafts of each subsequent stage decreases by one unit, draw a schematic flow diagram of the *RBC* system. The flow is perpendicular to the shaft.

[1.0Mark]

c) Is the target soluble BOD_5 in the RBC effluent achieved? Show calculations for the answer.

[2.0 Marks]

d) Calculate the overall organic (soluble BOD_5) and hydraulic loading rates of the *RBC* system.

[1.0 Mark]

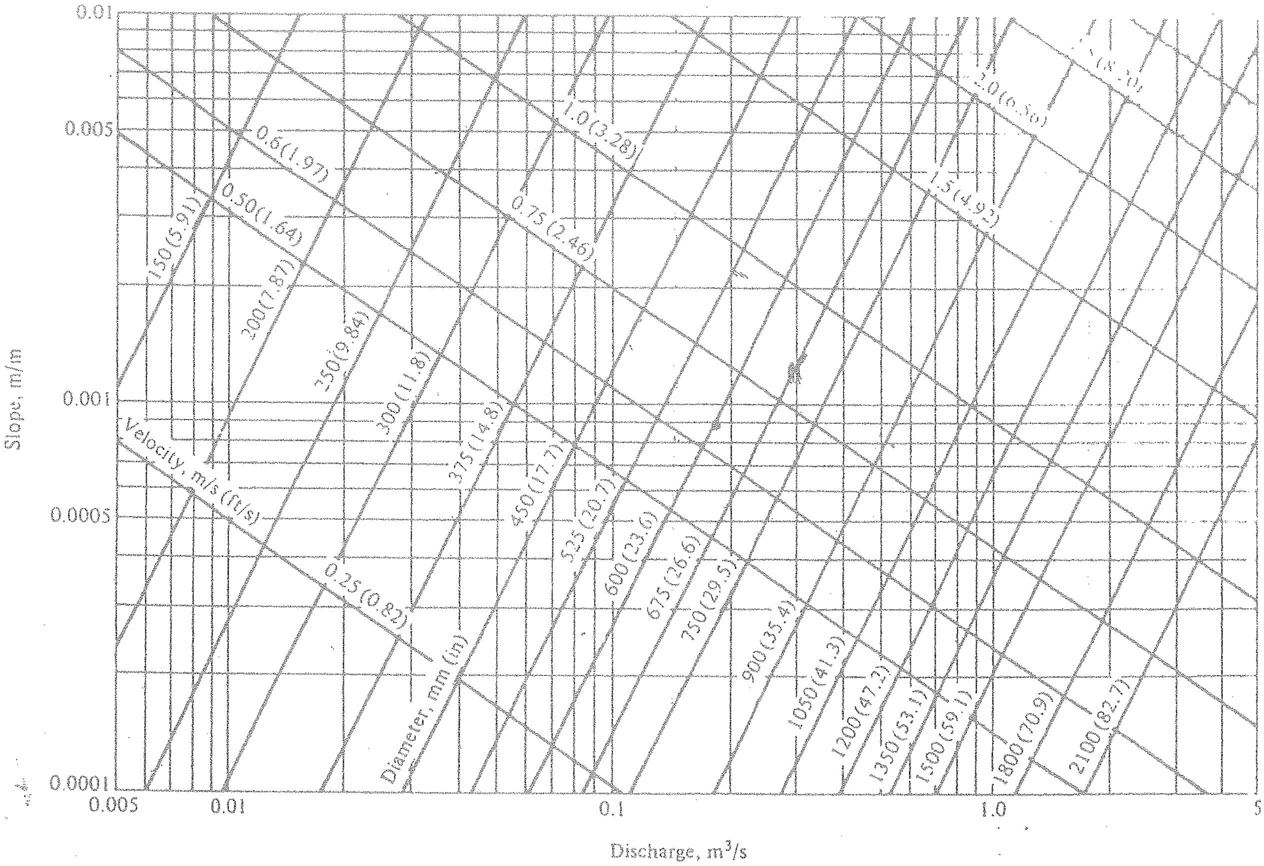

Figure Q1: Nomograph for solution of Manning's equation for n = 0.013