NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF CIVIL AND WATER ENGINEERING

IRRIGATION SYSTEMS DESIGN
TCW 3204

Main Examination Paper
May 2015

This examination paper consists of 4 pages

Time Allowed: **3 hours**

Total Marks: 100

Special Requirements: NONE

Examiner's Name: MR T. THEBE

INSTRUCTIONS

1. Answer ALL questions
2. Each question carries 25 marks

MARK ALLOCATION

QUESTION	MARKS
1.	25
2.	25
3.	25
4.	25
5.	25
TOTAL	100

QUESTION 1

1. You are given the following details for the designing of a suitable semi-portable/semi-permanent sprinkler irrigation system in a low rainfall area with a reliable groundwater supply:

The area targeted for irrigation is 25 ha. The soils are dark clay loams with a maximum infiltration rate of 10 mm/hr. The soil available water is 150 mm/m. Maize with a maximum crop height of 2 m, rooting zone depth of 0.7 m, peak water requirement of 6.1 mm/day, and allowable soil moisture depletion of 55% is to be grown during the dry season when there is no effective rainfall. The maximum wind speed is 11 km/hr. A borehole with a maximum safe yield of 100 m^3/hr supplies water to a 250 m^3 plastered brick reservoir that is located at the top edge of the field (15m from the beginning of the field). Field slope is 1% from the location of the reservoir to the bottom edge of the field. Electricity supply is available at the reservoir. Adequate semi-skilled and unskilled labour is available for system operation.

Design a semi-portable/semi-permanent sprinkler irrigation system for the 25ha rectangular field with your chosen field dimensions, complete with a bill of quantities and clearly stated assumptions. You can make use of Table 1 below for sprinkler selection. **[25 marks]**

Table 1: Sprinkler characteristics under different layouts.

Nozzle diameter size	**Sprinkler operating pressure (kPa)**	**Sprinkler discharge (m^3/hr)**	**Sprinkler wetted diameter (m)**	**Sprinkler precipitation rate (mm/hr) at 12 x 12m layout**	**Sprinkler precipitation rate (mm/hr) at 12 x 18m layout**	**Sprinkler precipitation rate (mm/hr) at 18 x 18m layout**
3	350	0.68	26.2	4.72	-	-
3.5	350	0.89	28.35	6.18	-	-
4	350	1.16	30.50	8.06	5.37	-
4.5	350	1.42	32.0	9.86	6.57	-
4.5	400	1.52	33.05	10.56	7.04	5.25
5	350	1.84	34.3	-	8.52	5.68
5	400	1.96	35.6	-	9.07	6.05

QUESTION 2

2a). Propose an alternative drip irrigation system for the irrigation of the same field given in question 1. Assume a maize spacing of 0.9 m between rows, and 0.3 m within rows. State any other assumptions that you make. **[15 marks]**

2b). Compare the two systems and state the system that would be more preferable to the client (farmer) focusing on water resources, pumping cost, capital cost, prospective yields. **[10 marks]**

QUESTION 3

3ai). Design a concrete-lined irrigation main canal to carry 300 m^3/hr from a take-off point that is at an elevation of 97 m above a reference datum to a point that is the canal field turnout at an elevation of 96 m above a reference datum at a distance of 1 km away from the take-off point. Assume that the canal follows a straight line and that the ground slope is uniform along the full length of the canal. Assume a roughness co-efficient, *n*, of 0.016. Ignore the take-off and turn-out structural details. **[13 marks]**

3aii). State the material and equipment requirements for the construction of your given design with given assumptions about each material type, presenting a bill of quantities. **[5 marks]**

3b). Is it possible to replace the concrete-lined main canal stated above with a PVC pipe main line of an acceptable and available size. Justify your answer based on calculations. **[7 marks]**

QUESTION 4

4a). Explain the role of night storage reservoirs in irrigation schemes that make use of the surface irrigation method in group-managed schemes compared to individually-managed irrigation schemes. **[5 marks]**

4b). Detail the method that is internationally accepted for the estimation of reference crop evaporation-transpiration and how it is used to determine crop water requirements for the purposes of designing irrigation systems. **[8 marks]**

4c). Discuss the major management variables considered in the design and operation of irrigation systems and the key hydraulic evaluations undertaken to assess irrigation system performance. **[12 marks]**

QUESTION 5

5a). A 1 m contracted rectangular weir is constructed to measure flow in a lined secondary canal where water is being diverted from the main canal to irrigate a block of fields that measure 50 ha. These fields are irrigated using surface irrigation methods over a 6 day cycle during day-time hours not exceeding 12 hours. The soil available water is 150 mm/m. Wheat with a maximum crop height of 0.85 m, rooting zone depth of 0.9 m, peak water requirement of 5.9 mm/day, and allowable soil moisture depletion of 50% is to be grown during the dry season when there is no effective rainfall. Assuming a 50% overall system efficiency from the take-off point to on-field use, calculate the amount of water diverted and the design water depth measured at the weir. **[15 marks]**

5b). Explain the importance of land leveling in the design of surface irrigation systems and the key factors for consideration in land leveling operations. **[10 marks]**

END OF QUESTION PAPER

ANNEX A – USEFUL FORMULAE FOR PRESSURIZED IRRIGATION SYSTEM DESIGN

Christiansen's**:** *m* co-efficient = 1.852 for Hazen-Williams equation

$$F = \frac{1}{m+1} + \frac{1}{2N} + \frac{\sqrt{m-1}}{6N^2}$$

$$F' = \frac{2N}{2N-1}\left(\frac{1}{m+1} + \frac{\sqrt{m-1}}{6N^2}\right)$$

Number of sprinklers, N	**F**	**F'**
2	0.64	0.52
3	0.53	0.44
4	0.49	0.41
5	0.46	0.40
6	0.44	0.39
7	0.43	0.38
8	0.42	0.38
9	0.41	0.37
10	0.40	0.37
12	0.39	0.37
14	0.39	0.36
16	0.38	0.36
18	0.38	0.36
20	0.38	0.36
25	0.37	0.36
30	0.37	0.36
35	0.37	0.36
40	0.36	0.36
50	0.36	0.35

Hazen-Williams:

$$h_f = K\frac{LQ^{d_1}}{D^{d_2}}$$

where:

L = the length of pipe, m;
Q = the flow in L/s;
D = the inside diameter of the pipe, mm;
K = $1.21 \times 10^{10}\,C^{-1.852}$ *where C is the pipe roughness coefficient* (assume 140 for PVC and 120 for aluminium)*;*
$d_1 = 1.852$ *and* $d_2 = 4.87$

For travelling rain guns:

$$d_{gross} = q_s / (vW_T)$$

where W_T is the width of the travel lane (i.e. the distance between travel lanes) and *v* is the linear velocity of the sprinkler cart.

$$h_l = kV^2 / 2g$$

where h_l = *the loss, k = the loss coefficient,* $V^2/2g$ *= the velocity head.*
The loss coefficients in the sprinkler cart and hose-reel cart were found to be 1.76 and 3.91, respectively.