CIVL3140 Introduction to Open Channel Hydraulics - TUTORIAL 3

1. Uniform equilibrium flows

1.1 A concrete trapezoidal channel (1V:3V sideslopes, 1.2 m bottom width) is designed to carry 52 m^3/s. Calculate the uniform equilibrium depth for a bed slope of 0.0012. Is the invert slope a *mild* or *steep* slope ?

Numerical solution: d_o = 2.25 m (k_s = 1 mm), Mild slope (but almost critical slope (Fr_o = 0.84))

1.2 An open channel must be lined with riprap to satisfy environmental regulations. The channel has a trapezoidal cross-section with an invert slope of 0.0009. The bottom width is 3-m and the side slopes are 1V:2H. Assuming a Gauckler-Manning coefficient of 0.03, calculate the normal depth for Q = 28 m^3/s.

Numerical solution: d_o = 2.63 m

1.3 Considering a rectangular channel (B = 12 m), the uniform equilibrium depth is 1.1 m and the bed slope is 0.02. The channel is rough concrete (k_s = 5 mm). Calculate the flow rate.

Numerical solution: Q = 110 m^3/s, f = 0.021, Fr = 2.5, τ_o = 182 Pa

1.4 A storm waterway channel consists of a 1.5 m deep concrete lined rectangular channel (B = 2.3 m) surrounded by two grass-lined flood plains (B = 25 m each, k_s = 100 mm). The beds of the flood plain are at the same elevation : i.e., 1.5 m above the deep channel invert. The bed slope is 0.001 (S_o = 0.1%).
During a flood event, the observed water depth in the deep channel is 2.1 m. Assuming uniform equilibiurm flow conditions, calculate the total flow rate conveyed by the storm waterway. Estimate the discharges in the concrete-lined and in each flood plain.

Numerical solution: Q = 35.6 m^3/s (10.6 m^3/s in the deep channel and 12.5 m^3/s in each flood plain)

2. Gradually-varied flows

2.1 A concrete-lined rectangular channel (B = 21 m) supplies a discharge of 33 m^3/s to a hydropower plant. The longitudinal bed slope is 5 m per km. At a gauging station, the measured flow depth is 1.85 m.
(a) Predict the type of free-surface profile (as per textbook pages 104-105, or Henderson pages 107-111).
(b) Will the downstream flow depth be larger or smaller than at the gauging station ?
(c) From where is the flow (at the gauging station) best controlled ?.

Numerical solution:
(a) d_o = 0.483 m & d_c = 0.63 m $\Rightarrow d_o < d_c < d$
This is a steep slope with a S1 free-surface profile :e.g., a subcritical flow downstream of a hydraulic jump on a steep slope.
(b) The flow depth will increase with incresasing downstream distance (Profile S1).
(c) The flow is subcritical and it is best controlled from downstream as for any Profile S1.

2.2 An artificial canal carries a discharge of 20 m^3/s. The channel cross-section is trapezoidal and symmetrical, with a 1.1-m bottom width and 1V:1.5H sidewall slopes. The longitudinal bed slope is 12.5 m per km. The channel bottom and sidewalls consist of a mixture of fine sands (d_{50} = 0.8 mm). At a bridge, crossing the waterway, the observed flow depth, at the gauging station, is 2.1 m.
(a) Predict the type of free-surface profile (as per textbook pages 104-105, or Henderson pages 107-111).

Assume that the equivalent roughness height equals the median sediment size. See discussions in textbook pages 84 & 234-235.
(b) Using the software HydroChan, compute the water depth 80 m upstream of the bridge.
Assume a Keulegan coefficient $k = d_{50}$. See discussion in textbook p. 78.
(c) Assuming that the observed water depth at the bridge is 3.2 m, use the software HydroChan to compute the water depth 80 m upstream of the bridge.

Numerical solution:
(a) $d_o < d_c < d \Rightarrow$ profile S1
This situation corresponds to a steep slope ($d_o < d_c$)
(b) The problem cannot be solved because the observed flow depth is smaller than the subcritical conjugate depth and greater than the supercritical conjugate depth.
Physically, this flow situation may occur downstream of a break in slope, or downstream of a control structure, but it cannot take place in a long prismatic channel.
(c) The problem has a solution because the observed flow depth is greater than the subcritical conjugate flow depth : d = 1.15 m at x = -80 m. Note the presence of a hydraulic jump at x ~ -62 m

2.3 A 25-m wide rectangular spillway is designed to carry 1000 m^3/s. The spillway system comprises a broad-crest followed by the spillway chute built on the downstream slope of the embankment dam. The chute invert slope is 25º. (The channel is made of rough concrete (k_s = 10 mm).)
Calculate the water depth and flow velocity at an elevation 10-m below the crest elevation (i.e. $z_o = z_{crest} - 10$ m).
Design your own spreadsheet calculations using a standard step method (distance calculated from depth). (See textbook pages 106-108 & 275-288.)

Numerical solution: d = 2.335 m, V = 17.13 m/s

Revision problems

Each and every student is strongly encouraged to work on the Revision exercises and Problems in the textbook, pages 111-118 & 533-572. The latter pages include also some hydrology questions.

Textbook

More exercises in textbook pp. 87-93, 108-110, 111-118, 288-289, 533-572.
"The Hydraulics of Open Channel Flow: An Introduction", *Butterworth-Heinemann Publ.*, Oxford, UK, 2004.

More Exercises at : {http://www.bh.com/companions/0340740671/}
Go to Exercises, Part 1 : {http://www.bh.com/companions/0340740671/exercises/exercisesP1.htm}