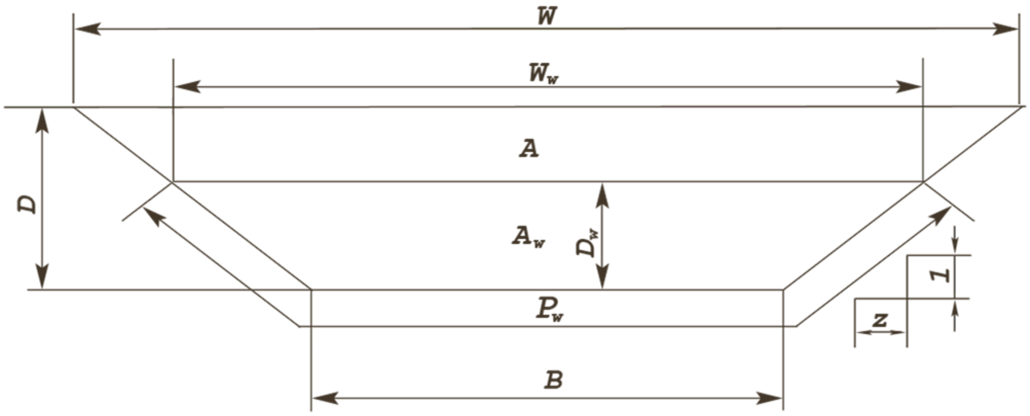
THE ENVIRO ENGINEER
SCIENCE, ENGINEERING & TECHNOLOGY
CALCULATION SHEET

Hyraulic computations to determine the mean channel flow velocity and maximum flow capacity in a trapezoidal channel of known size, calculated using the Manning's equations as follows. (input values shown in blue boxes):



Input values (from a site visit and topographical survey):

Top width of channel: $W := 3.0\ m$ Depth of the channel: $D := 0.96\ m$

Bed of the channel : $B := 0.60\ m$ Length of drainage channel : $L_{ditch} := 54.17\ m$

Metric constant : $\mu := 1$ Vertical drop along channel length : $V_{ditch} := 2.0\ m$

Manning's Coefficient: $n := 0.0345\ s\ m^{-\left(\frac{1}{3}\right)}$

Hyperlink to Manning's n Values Reference tables (Chow 1959)

Hyperlink to Manning's n Values Reference tables (Chow 1959)not available from SMath Cloud

"Natural stream of clean straight, full stage with stones and weeds"

For a specified rainfall event annual exceedance probability of 0.5% AEP Peak flow runoff rate for this AEP is: $Q_1 := 5.75\ m^3\ s^{-1}$

Angle of side slope of channel in radians: $\theta := -\operatorname{atan}\left(\frac{2 \cdot D}{B - W}\right) = 0.6747\ rad$

Horizontal slope: $z := \frac{1}{\tan(\theta)} = 1.25$

Total cross sectional area of channel: $A := B \cdot D + z \cdot D^2 = 1.728\ m^2$

Total wetted perimeter of channel: $P_w := B + 2 \cdot D \cdot \sqrt{1 + z^2} = 3.6735\ m$

Hydraulic Radius: $R_H := \frac{A}{P_w} = 0.4704\ m$

Longitudinal slope of channel bed : $S_0 := \frac{V_{ditch}}{L_{ditch}} = 0.0369$

Mean velocity along channel at full capacity : $V := \frac{\mu}{n} \cdot R_H^{\frac{2}{3}} \cdot S_0^{\frac{1}{2}} = 3.3687\ m\ s^{-1}$

Maximum flow along channel : $Q := \frac{\mu}{n} \cdot A \cdot R_H^{\frac{2}{3}} \cdot S_0^{\frac{1}{2}} = 5.8211\ m^3\ s^{-1}$

Maximum water depth and velocity at specified flow rate

If the peak flow rate generated during a rainfall event with a specified annual probability is known the maximum depth of water in the channel during the event can be estimated as follows:

Peak flow runoff rate specified above: $Q_1 = 5.75\ m^3\ s^{-1}$

Calcultes the roots of the polynominal equation with respect to D

$$D_w := \text{solve}\left(Q_1 - \left(\frac{1}{n}\cdot\left(B\cdot D + z\cdot D^2\right)\cdot\left(\frac{B\cdot D + z\cdot D^2}{B + 2\cdot D\cdot\sqrt{z^2+1}}\right)^{\frac{2}{3}}\cdot\sqrt{S_0}\right), D\right) = \begin{bmatrix}-1.4597\\ 0.9547\end{bmatrix} m$$

See notes below

The solve function is included in the SMath Plugin "Special Functions" by Andrey Ivashov reference 1.12.7030.1435. This function needs to be installed on SMath Studio and this calculation sheet downloaded to get the solve function to work.

Temporary input for Dw to allow sheet to work: $D_w := 0.9547\ m$

This input field for SMath Cloud only.In SMath Studio remove this input field.

Estimated depth of water in channel for peak flow of Q1: $D_w = 0.9547\ m$

Cross sectional area of channel at depth Dw : $A_w := B\cdot D_w + z\cdot D_w^2 = 1.7121\ m^2$

Wetted perimeter at depth Dw : $P_w := B + 2\cdot D_w\cdot\sqrt{1+z^2} = 3.6565\ m$

Hydraulic radius at specified flow Q1 : $R_H := \frac{A_w}{P_w} = 0.4682\ m$

Width of channel a depth Dw : $W_w := B + 2\cdot D_w\cdot z = 2.9867\ m$

Hydraulic mean depth in channel : $D_m := \frac{A_w}{W_w} = 0.5732\ m$

Mean velocity of water at Q.1 : $V_1 := \frac{Q_1}{A_w} = 3.3584\ m\ s^{-1}$

Flow inertia to gravity or Froude number : $F := \frac{V_1}{\sqrt{g_e\cdot D_m}} = 1.4164$

if F>1 supercritical flow

Result: "The results show that the channel has supercritical flow and may not flood"

Water depth and velocity if supercritcal flow

If the type of flow is transitional from subcritical to supercritical then the depth increases until a hydraulic jump occurs and the flow switches to the upper, subcritical part of the depth-specific energy curve.

Depth of water if supercritical flow:

$$D_{sup} := \text{if } F < 1 \quad D_w \quad \text{else} \quad \left(\frac{D_w}{2} \cdot \left(\sqrt{1 + 8 \cdot F^2} - 1\right)\right) = 1.4937 \text{ m}$$

Supercritical flow cross sectional area:

$$A_{sup} := B \cdot D_{sup} + z \cdot D_{sup}^2 = 3.6853 \text{ m}^2$$

Wetted perimeter at supercritical flow:

$$P_{wsup} := B + 2 \cdot D_{sup} \cdot \sqrt{1 + z^2} = 5.3823 \text{ m}$$

Hydraulic radius at supercritical flow:

$$R_{Hsup} := \frac{A_{sup}}{P_{wsup}} = 0.6847 \text{ m}$$

Width of channel at supercritical flow:

$$W_{sup} := B + 2 \cdot D_{sup} \cdot z = 4.3343 \text{ m}$$

Hydraulic mean depth at supercritical flow:

$$D_{Msup} := \frac{A_{sup}}{W_{sup}} = 0.8503 \text{ m}$$

The mean velocity during supercritical flow:

$$V_{sup} := \frac{Q_1}{A_{sup}} = 1.5602 \text{ m s}^{-1}$$

As the depth of water changes the cross sectional area of the flow will increase and the Froude number will change:

Revised flow inertia to gravity or Froude number:

$$F := \frac{V_{sup}}{\sqrt{g_e \cdot D_{Msup}}} = 0.54033$$

Result: "The results show that the channel has subcritical flow and flooding may occur"

Notes:

A Matrix of the more common Manning's Coefficients has been included in the hidden area at the top of the document. If the coefficient is not included, the "n" value can still be typed into the input field, or the matrix can be changed or new values added.

If the depth of water Dw calculated using the roots of the polynominal has two values, the highest value will normally be selected.

Warning:

These equations are provided as an example of Manning's equations used to estimate flow rates for open channels. This model should only be used commercially by a professional who has a knowledge of hydrology. No liability will be accepted for errors in the equations or improper use of the calculation sheet.

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