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Backwater lengths in rivers

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The Author has arrived at an approximate formula to serve as a 'thumb rule' for the backwater length in rivers. While this is interesting, the reliability of such an approximate formula and the need for it, in this era of the digital computer, have to be questioned.

28. A more correct appreciation of how water backs up in a channel is possible if different numerical solutions of the gradually varied flow equation with different values for the friction coefficient and discharge are examined. As microcomputers are now available in almost every design office, any engineer should be able to accomplish this task with ease, using appropriate software.

29. The following computations were done by me, using the CHNLFLOW[15] software, with a view to effecting a comparison with the Author's approximate formula. I have computed the backwater lengths (as defined by the Author) given further down to an accuracy of a metre by numerical integration of the gradually varied flow equation, using Runge Kutta fourth-order integration[16] with Δx made equal to 12 m.

30. A channel corresponding to the first river in Table 2, with bed slope 0·00046, was assumed to be of trapezoidal section—bottom width 100 m and sides sloping 2 horizontal to 1 vertical. The backwater lengths in this channel computed for a number of combinations of discharge, Manning's n and $(y_n + \eta_0)$ are given below.

31. Each discharge was chosen such that, with the corresponding value of Manning's n, the normal depth evaluated to 4·5 m. The depth $(y_n + \eta_0)$ corresponds to each discharge with the same hydraulic structure at $x = x_0$.

$Q = 895{\cdot}847\ \mathrm{m^3/s}$ Manning's $n = 0{\cdot}03$ $(y_n + \eta_0) = 7{\cdot}2434$ m
Computed backwater length = 10052 m

$Q = 383{\cdot}9342\ \mathrm{m^3/s}$ Manning's $n = 0{\cdot}07$ $(y_n + \eta_0) = 6{\cdot}0595$ m
Computed backwater length = 8667 m

$Q = 268{\cdot}754\ \mathrm{m^3/s}$ Manning's $n = 0{\cdot}1$ $(y_n + \eta_0) = 5{\cdot}7294$ m
Computed backwater length = 8245 m

$Q = 179{\cdot}1693\ \mathrm{m^3/s}$ Manning's $n = 0{\cdot}15$ $(y_n + \eta_0) = 5{\cdot}4382$ m
Computed backwater length = 7868 m

$Q = 134{\cdot}377\ \mathrm{m^3/s}$ Manning's $n = 0{\cdot}2$ $(y_n + \eta_0) = 5{\cdot}2745$ m
Computed backwater length = 7654 m

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32. As a matter of interest, the results of three sets of computations performed similarly, using the Kutter and Ganguillette formula for Chezy C in the evaluation of the friction slope, are as follows.

$Q = 328{\cdot}029$ m^3/s Kutter's $n = 0{\cdot}1$ $(y_n + \eta_0) = 5{\cdot}9041$ m
Computed backwater length = 8136 m

$Q = 232{\cdot}9126$ m^3/s Kutter's $n = 0{\cdot}15$ $(y_n + \eta_0) = 5{\cdot}6175$ m
Computed backwater length = 7601 m

$Q = 181{\cdot}6482$ m^3/s Kutter's $n = 0{\cdot}2$ $(y_n + \eta_0) = 5{\cdot}4469$ m
Computed backwater length = 7278 m

33. It is apparent that backwater length (as defined by the Author), when calculated accurately for the channel chosen, varies considerably with the value of the friction coefficient, whatever formula is used in the evaluation of the friction slope. It has varied from 10052 m (corresponding to a Manning's n of 0·03) to 7654 m (corresponding to Manning's n of 0·2), and compares with the backwater length of 6900 m stated in Table 2 for the river Avon. Needless to say, the backwater length obtained by integration of the gradually varied flow equation will vary not only with the friction coefficient but also with the hydraulic parameters of the channel section and the bed slope.

34. These computations took me about 15 minutes, using an IBM PS/2 and the CHNLFLOW software. Given adequate data on channel sections, friction coefficients and bed slope, it is possible to obtain a value for the backwater length for any channel by accurate numerical integration of the gradually varied flow equation, in a few minutes.

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The sample calculations presented by *Dr Sivaloganathan* are mainly of academic interest and do not really address the principal point of the Paper. It was never intended that the estimate 0·7 D/s should give the backwater length to the nearest metre as implied by the discussion. The values in Table 2 are deliberately rounded to at most three significant figures to discourage any such spurious misinterpretation of the accuracy of the formula. In any case, the choice of the definition of the backwater length at the point at which the disturbance decays to 10% of the initial downstream value is somewhat arbitrary, but probably includes most cases of practical relevance.

36. The computations presented in the discussion do, however, have some value, in spite of using mostly significantly higher roughness values than are found in the majority of UK rivers. They demonstrate the assertion made in the Paper that the second-order term in the perturbation equation will increase the backwater length beyond 0·7 D/s for a M_1 profile. The smallest perturbation used in the discussion is about 17% of the bankfull or normal depth. It is gratifying that the estimate of 6·9 km is accurate to about 10% in this case, since the estimate is strictly valid for small perturbations only. Better estimates can obviously be made for the approximate lengths for M_1 and M_2 profiles by using representative mean values for depth and slope for the whole profile, if large variations in these values are likely to be of importance. For example, the use of the mean depth $\frac{1}{2}(4{\cdot}5 + 7{\cdot}24)m$ over the backwater length and the undisturbed values of slope would improve the estimate for the first example in the discussion to 8·9 km which

compares better with the computed value of 10 km. The Discussor attributes the variation in the computed backwater length to the variation in Manning's n. This is incorrect. The variation in the backwater length is due to the different tailwater depths in the sample calculations. The backwater length increases as the tailwater depth increases irrespective of the roughness value. The Discussor also states that the backwater length will depend on the channel slope and geometry. The Paper quantifies that link through the formulae in equations (19), (20) and (22).

37. One of the purposes of the Paper was, however, to provide some fundamental insight into factors that govern the behaviour of natural rivers and canals. Although computational models are invaluable for feasibility and detailed design studies in river engineering, the engineer may not have such a model available when needed, for example, in the field or during discussions when an opinion is needed. In any case, it is my opinion that an over-reliance on models is unwise if it obscures an understanding of the real life physics of the flow. A modeller divorced from field experience is prone to read undue significance into the 6th computed digit of stage or discharge, or to calibrate a model with unrealistic values of roughness. Not only do simple rules, such as that presented in the Paper, allow the main features of a problem to be assessed during preliminary discussion with a potential client, they also allow some checks to be made on the validity of data and computations.

References

15. CHNLFLOW—Software for open channel steady and unsteady flow and surge computations. Fluidmech Software Ltd. 1989.
16. KREYSZIG E. *Advanced engineering mathematics*. John Wiley, New York, London, 1988, 6th edn.