MODELLING ANCILLARIES: ORIFICE COEFFICIENTS

David J Balmforth, MWH

1. INTRODUCTION

The ability to model ancillaries is an important feature of sewerage network models. To obtain accurate representation in the hydraulic model it is important that, appropriate values are used for the various parameters. This User Note gives guidance on the modelling of the outlet throttle at entry to the continuation pipe in the on-line and off-line tanks.

2. TYPES OF THROTTLE

There are four types of throttle in common use:-

(i) Throttle Pipe (Figure 1). This is described in Section 3
(ii) Orifice Plate (Figure 2). This is described in Section 4
(iii) Adjustable Penstock
(iv) Vortex Regulator (e.g. Hydro-Brake®). This is described in WaPUG User Note No 1.

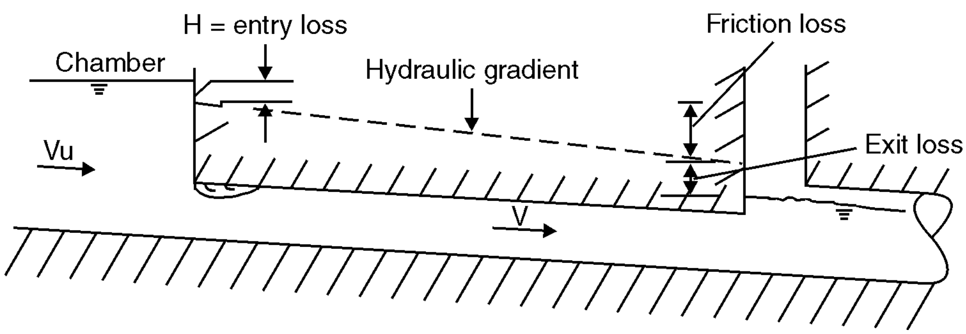

Figure 1 Longitudinal Section through Throttle Pipe

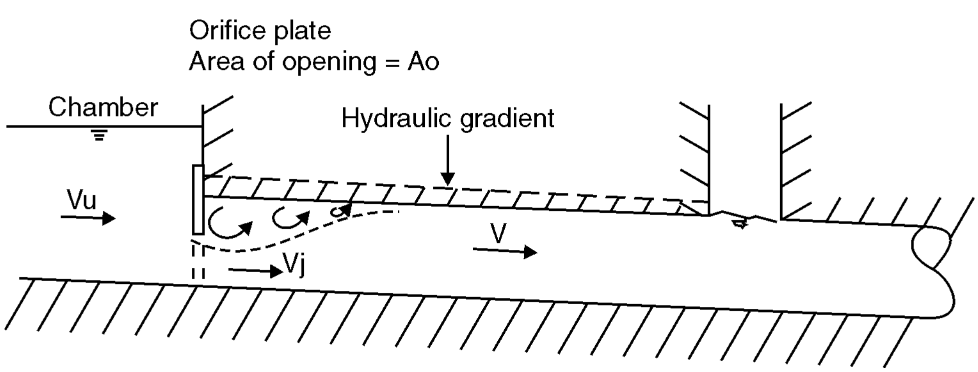

Figure 2 Longitudinal Section through Continuation Pipe with Orifice Plate Throttle

The adjustable penstock is effectively an orifice plate with a variable area of opening, and is modelled as an orifice. The same comments that apply to an orifice apply also to a penstock.

With older types of storm overflow structures, and with bifurcations, the continuation pipe may not have a specific throttle, the ongoing flow being limited solely by the capacity of the continuation sewer.

3. THROTTLE PIPES

3.1 General

Typically each pipe in the model is modelled separately by the program. At a particular discharge the program calculates friction losses from the Colebrook-White and Darcy equations (Ref 2) and entry and exit losses from K_1V^2 / 2g and K_2V^2 / 2g respectively (Figure 1). Standard values of K_1 and K_2 are typically built into the program but the user may be able to specify additional losses due to non-standard manholes.

3.2 Recent software

Recent software commonly includes a specific capability to model throttle pipes as a control link. In this case no special consideration is necessary.

3.3 Older software

Some older software (e.g. WASSP and WALLRUS), however, assumes that there is an orifice plate at the entry to the continuation pipe. The entry loss is not then calculated from K_1V^2 / 2g using standard (default) values, but by using an orifice discharge equation, as follows:

$$Q = C_0 A_0 (gH)^{0.5} \qquad (1)$$

where C_0 = orifice coefficient
A_0 = area of orifice opening (m^2)
H = head loss at entry to continuation pipe (m) (Figure 2)

Note that C_0 differs from the traditional coefficient of discharge C_d(C_0 – C_d $2^{0.5}$).

Rearranging equation (1) gives

$$H = \frac{Q^2}{gC_0^2A_0^2} \qquad (2)$$

The following points should be noted:-

(i) the programs assumed that the orifice is ‘drowned’ (Figure 2): a freely discharging orifice cannot be modelled;

(ii) if the continuation pipe does not have an orifice throttle at inlet (e.g. a throttle pipe) then the area and invert level of the orifice in the tank record should be left blank (default values taken from continuation pipe record).

(iii) for the conditions in (ii) above there is a fixed relationship between the orifice coefficient C_0 and the entry loss coefficient $K_1(C_0 = (2/K_1)^{0.5})$.

4. VALUES OF THE ORIFICE COEFFICIENT

The performance of an ancillary in the hydraulic model is extremely sensitive to the value of the coefficient for the orifice on the continuation pipe. In the absence of field data the engineer should carefully consider the path the flow takes in entering the continuation pipe. Generally, the more the flow is directed into the continuation pipe, and the less the contraction of the jet, the smaller will be the losses and the larger the value of C_0.

The value of the coefficient C_0 for, a drowned orifice may be obtained from the following equation,

$$C_0 = \frac{1.41}{1.70 - \left(A_0 / A\right)} \qquad (3)$$

where A_0 = area of orifice (m^2)
A = area of continuation pipe (m^2)

Equation (3) assumes that the continuation pipe runs full. Comparison of values given by equation (3) with measured values obtained from a limited number of laboratory tests (Ref 3) shows that equation (3) generally predicts values to within 15% of the measured values.

5. ALLOWANCE FOR VELOCITY OF APPROACH

In most practical cases the velocity in the chamber of the ancillary will be so small that the velocity head $V_u^2/2g$ will be negligible when compared with the depth of flow. When this is not so the value of C_0 should be increased to allow for the effects of the ‘velocity of approach’.

The value of C_0 may be increased using the multiplying factor F obtained from the equation

$$F = \frac{1}{1 - 0.5C_0^2 r^2}$$

where $r = A_0/A_u$

A_0 = area of orifice (m^2)

A_u = cross-sectional area of flow in chamber (m^2) for value of C_0 r not greater than 1.2.

6. STABILITY PROBLEMS

In recent software stability problems are not normally encountered.

When large values of C_0 (say greater than 2.5) are specified when using older software (e.g. with WASSP and WALLRUS), instabilities can occur in the computations. These are caused by small changes in water level (and therefore H) resulting in large changes in the continuation flow Q_0. Heavily overloaded systems, and systems which have two or more ancillaries in close proximity, are prone to this problem. It manifests itself in oscillating flows in flow hydrographs, excessively large flooded volumes and/or an imbalance of flow volumes. To overcome the problem the value of C_0 should be progressively reduced until the instability disappears. In general the subsequent error in C_0 will not have such a serious influence on the results as the instability.

7. REFERENCES

1. Anon, 'Design and Analysis of Urban Storm Drainage, The Wallingford Procedure', Volume 2, 'Program User's Guide', DoE, STC Report No 29, September 1981.

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3. Smith R K, 'The Design of Outlet Control Devices for Storm Water Overflows', Internal Report, Dept of Civil Engineering, Sheffield City Polytechnic, June 1979.

AMENDMENTS

Ver	Description	Date
1.	First Published	March 1986
2.	Revision	October 1996
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