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MODELLING LOW SIDE WEIRS

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INTRODUCTION

When simulating the performance of existing sewerage systems it is most important to ensure that ancillary structures are modelled correctly. This is particularly true with storm sewage overflow structures which can have a major impact on system performance. Low side weirs are one of the more common types of overflow on existing systems and can cause significant problems in modelling.

There are two stages in the successful modelling of an ancillary structure in WASSP-SIM.

(i) The engineer must firstly understand the hydraulic performance of the ancillary.

(ii) The data must then be chosen to reflect the actual performance of the prototype in the computer model.

HYDRAULIC PERFORMANCE OF SIDE WEIRS

Frazer[1] identified five possible flow types of side weir flow, as illustrated in figure 1.

Type I Flow: Occurs with low side weirs in mild sloping sewers. A mild sloping sewer is defined as a sewer where uniform flow is subcritical. Low side weirs normally have a crest below the centreline level of the upstream sewer, and this flow type occurs when the energy at inlet exceeds twice the weir height,

i.e. $$d_1 + \frac{V_1^2}{2g} \geq 2C_1 \qquad (1)$$

where d_1 = depth at the upstream end of the weir
V_1 = velocity at the upstream end of the weir
C_1 = height of weir crest at the upstream end of the weir

The head over the weir decreases along the length of the chamber and water levels (and hence weir discharge) are governed by conditions at inlet to the chamber, where the depth will be between 0.85 and 0.90 of the critical depth. When this flow type occurs, conditions in the downstream sewer have no influence on the weir discharge nor on the level of the hydraulic gradient in the upstream sewer. Flow in the chamber is supercritical.

Type II Flow: Occurs with high side weirs, which usually have their crest above the centreline level of the upstream sewer. Water levels in the chamber, and the weir discharge, are determined by the throttle at entry to the downstream sewer, and the discharge and level of the hydraulic gradient in that sewer. In this case the head on the weir increases along the length of the chamber. Flow in the chamber is subcritical.

Type III Flow: Occurs in mild sloping sewers with low side weirs fitted with a throttle at the downstream end of the chamber, or with low side weirs where the downstream sewer is surcharged. Conditions in the downstream sewer influence the weir discharge but do not determine the level of the hydraulic gradient in the upstream sewer. Flow in the chamber is a combination of Type I and II with a hydraulic jump forming.

Type IV Flow: Occurs with low side weirs in steep sewers. It is similar to type I flow but the approaching flow is uniform and d_1 approximates to the depth of uniform flow in the upstream sewer.

Type V Flow: Occurs with low side weirs in steep sewers where the chamber has a throttle at outlet, or where the downstream sewer is surcharged. It is a combination of Types IV and II and is similar in character to Type III.

A number of alternative methods exist for analysing side weir flow and calculating weir discharges. Balmforth and Sarginson(2) have reviewed the various methods and explain how the discharge capacity of side weirs can be calculated. An estimate of weir discharge should be made using one of these methods.

MODELLING REQUIREMENTS

In WASSP-SIM storm overflow structures are modelled using the on-line tank records. It is assumed that the flow in the chamber is governed by the continuation throttle and conditions in the downstream sewer. However, with low side weirs water levels and weir discharges are governed by conditions in the upstream sewer at entry to the chamber.

If the actual chamber dimensions and weir coefficients are used directly in the WASSP model then the model will overpredict the weir discharge and the water levels in the upstream sewer, as figure 2 demonstrates. For a particular inflow, the correct weir discharge can be simulated simply by reducing the weir coefficient to give the desired result. However, the level of the hydraulic gradient in the upstream sewer will be overpredicted and this can affect the discharge capability of the upstream system and flooding may be predicted where it does not occur in practice.

Overprediction of upstream water levels can be avoided by artificially oversizing the first sewer length immediately downstream of the chamber, and if necessary reducing its gradient to maintain the correct first spill value. For type I and IV flows the procedure is best summarised as follows:

(i) Using proportional depth-discharge calculations for the upstream and downstream sewers determine the setting of the overflow.

(ii) Upsize the downstream sewer. An increase to twice the actual diameter is normally sufficient, though both higher and lower multiples have proved necessary at times.

(iii) Adjust the gradient of oversize pipe to give the correct overflow setting by raising the downstream invert level (the ground level at this point may also have to be raised).

(iv) For the upstream sewer running approximately three-quarters full, calculate the weir discharge and continuation discharge using an established method of calculating side weir flow (2). The weir coefficient used in these calculations should be reduced by 10 to 20% to allow for the affects of any scumboards or screens where fitted.

(v) Using proportional depth discharge calculations determine the depth of flow in the oversize downstream sewer at the calculated continuation discharge. Calculate the drop in the level of the hydraulic gradient at the throttle using the WASSP-SIM throttle equation. Add this drop to the depth in the oversize sewer to give the depth at the downstream end of the chamber.

(vi) WASSP assumes a horizontal water level and weir crest in the chamber, so that the downstream depth may now be used to determine the head on the weir and the water level in the upstream sewer. Use the former, together with the actual weir length and the calculated weir discharge, in the WASSP-SIM weir equation to obtain an equivalent weir coefficient for use in the model. This may be much smaller than traditional values.

(vii) Review the calculated water level in the upstream sewer and if it is significantly higher or lower than that which actually occurs, alter the diameter of the oversize downstream sewer and adjust the other parameters accordingly.

When test running the model particular attention should be paid to the conditions adjacent to the low side weir overflow. In particular, if the sewer immediately downstream of the oversize pipe surcharges to any extent then type III or IV flow conditions will probably occur in practice. In this case the downstream sewer should not be oversized.

For Type III and V flow the following procedure should be adopted:

(i) Model the downstream sewer as built.

(ii) Assume the hydraulic jump forms half way along the weir, that the head along the downstream half of the weir is constant, and that the discharge over the upstream half of the weir is negligible.

(iii) Use the actual weir length but halve the weir coefficient.

With smaller side weir chambers in particular it is possible that the whole chamber becomes drowned so that the weir has little effect, and the weir discharge and continuation flow are determined by the size of their respective outlets. In this case it is better to model the chamber as a "hole-in-manhole" overflow, but with the invert of the overflow orifice set level with the crest of the actual weir.

CONCLUSIONS

Adoption of the above procedures will greatly improve the simulation of sewer systems containing a number of low side weir overflows, as figures 3 and 4 show. During verification it is permissible to make minor changes to the ancillary data provided they can be justified in the way the ancillary has been modelled, and not purely as a means of force fitting the data. Care should be taken to identify possible type III and V flow conditions. This is particularly true when running a verified model with design storms where greater surcharging may cause the flow case to change from I to III or IV to V in practice. It may be necessary therefore to amend ancillary data between verification and running with design storms. Time-series rainfall should be run with the verification data however.

Often the data used to model low side weirs appears strange, bearing little resemblance to actual values. This is because the on-line tank model in WASSP-SIM behaves differently to the physical performance of low side weirs, and this has to be compensated for when specifying the ancillary data.

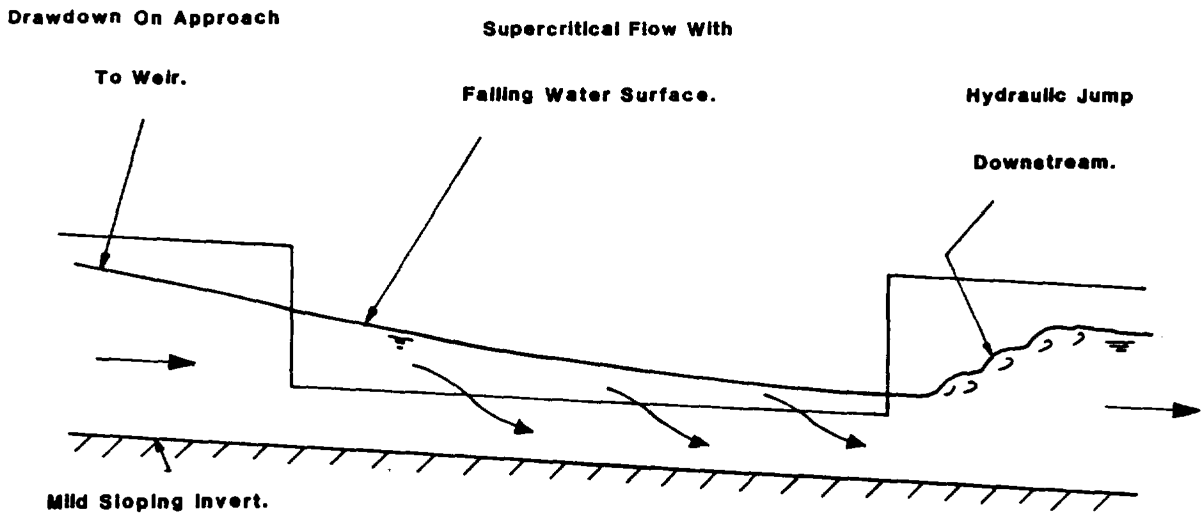
REFERENCES

1 Frazer W, "The Behaviour of Side Weirs in Prismatic Rectangular Channels", Proceedings of the Institution of Civil Engineers, Vol 6, February 1957.

2 Balmforth D J and Sarginson E J, "A Companion of Methods of Analysis of Side Weir Flow", Chartered Municipal Engineer, Vol 105, No 10, October 1978.

ACKNOWLEDGEMENTS

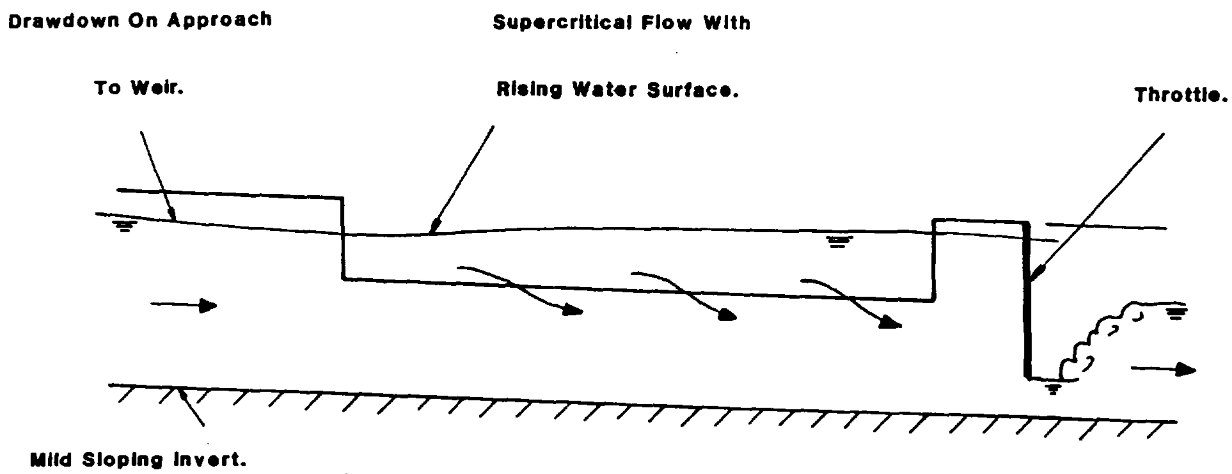
The author is grateful to Husband & Co, Consulting Engineers, Sheffield, for their permission to use the information contained in figures 3 and 4.



TYPE I FLOW.

Low Side Weir.

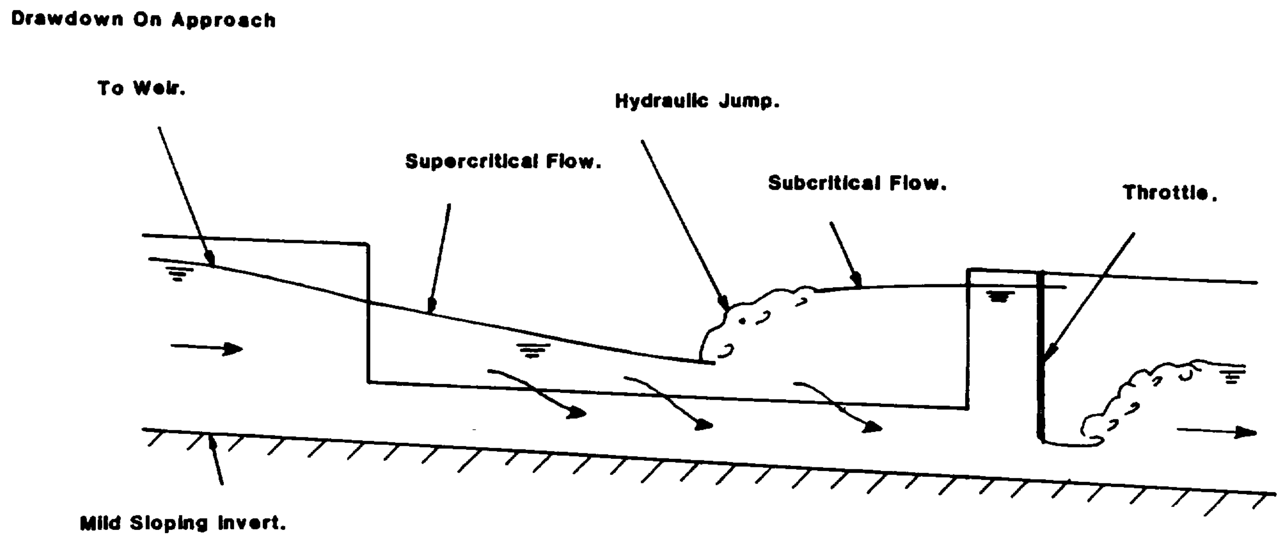
Figure 1a



TYPE II FLOW.

High Side Weir With Throttle.

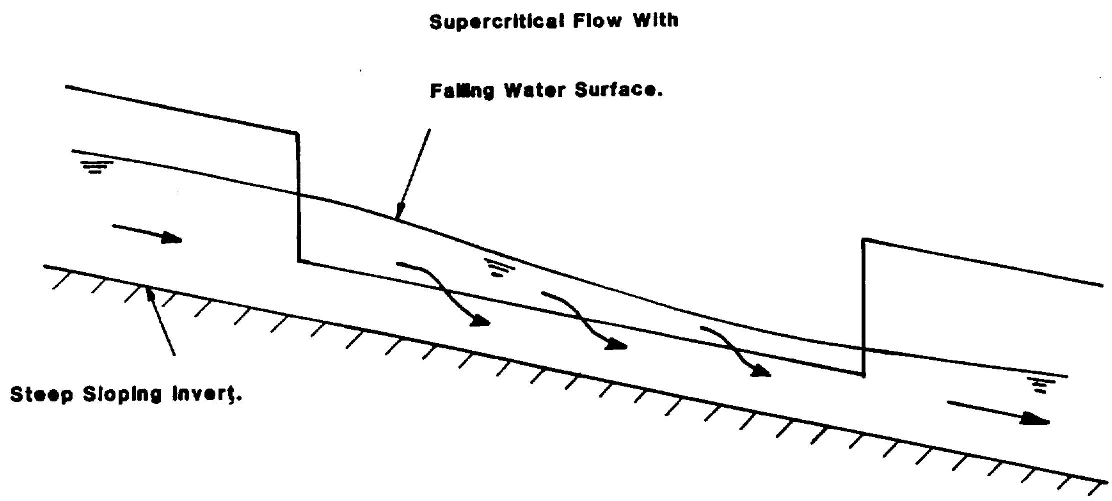
Figure 1b



TYPE III FLOW.

Low Side Weir With Throttle.

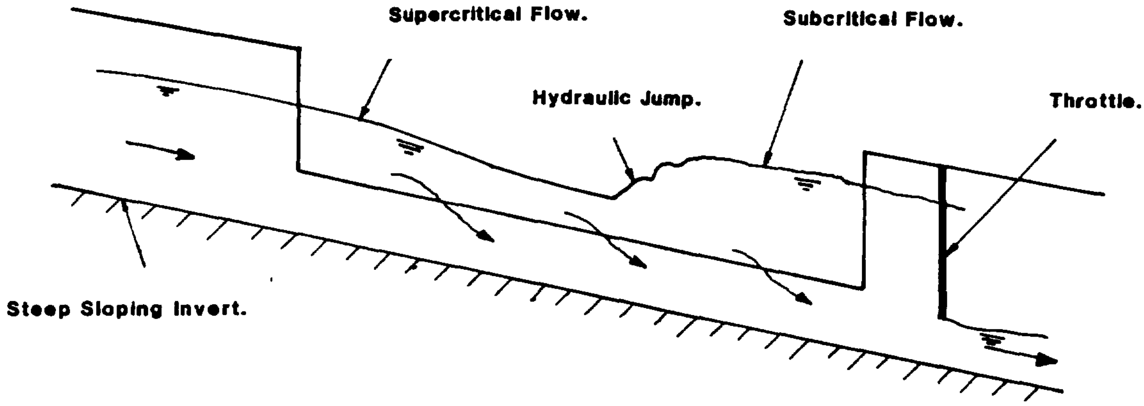
Figure 1c



TYPE IV FLOW.

Low Side Weir.

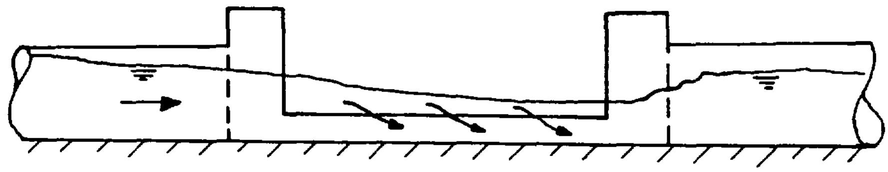
Figure 1d



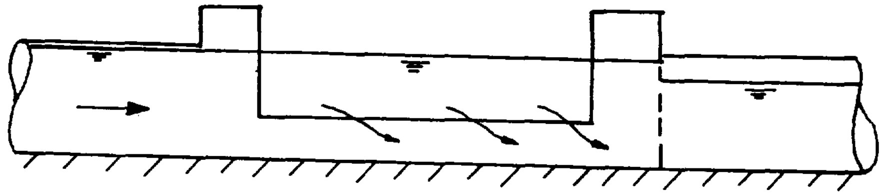
TYPE V FLOW.

Low Side Weir With Throttle.

Figure 1e



ACTUAL FLOW CONDITIONS.



WASSP MODEL.

Figure 2

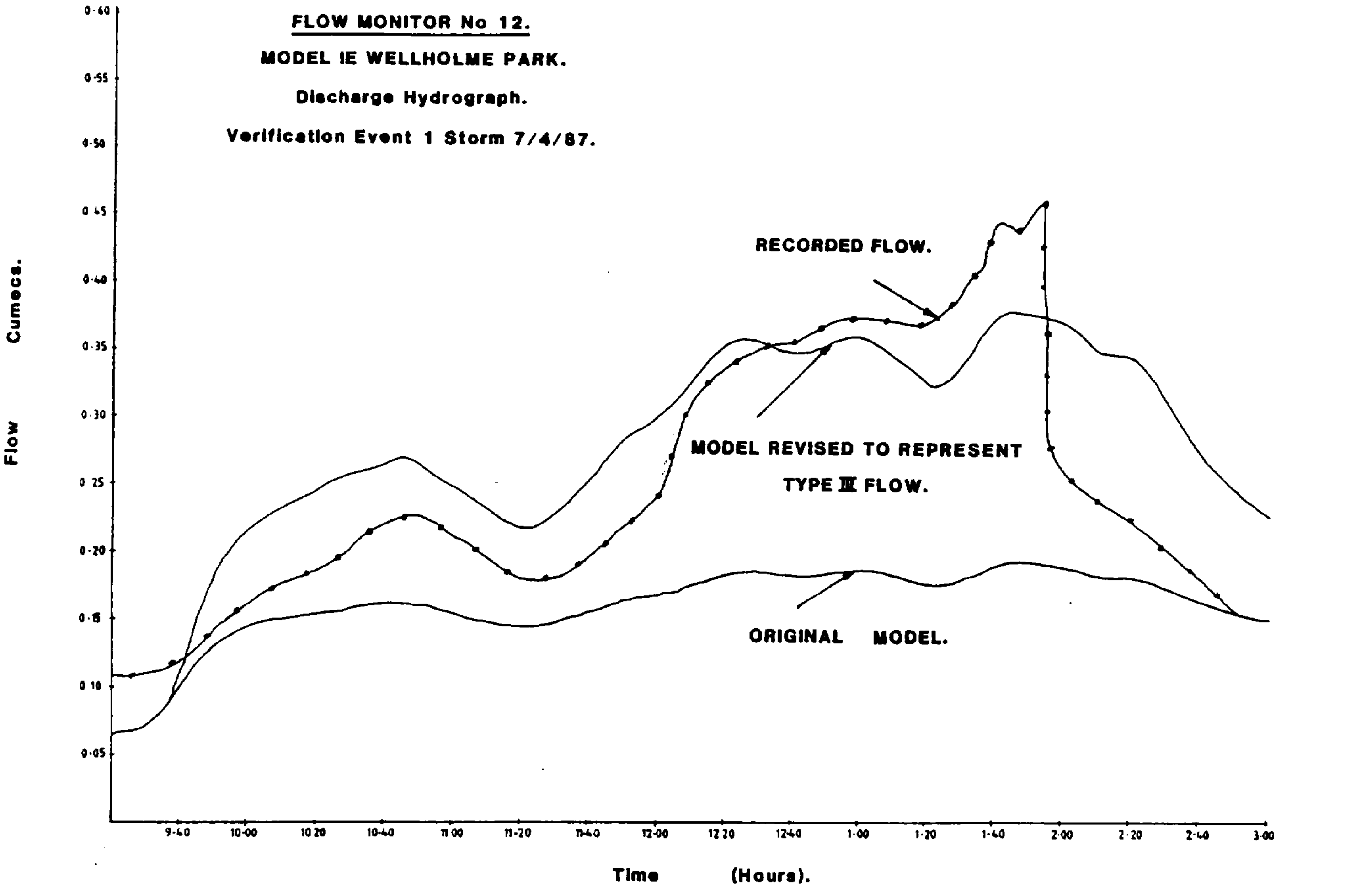


Figure 3

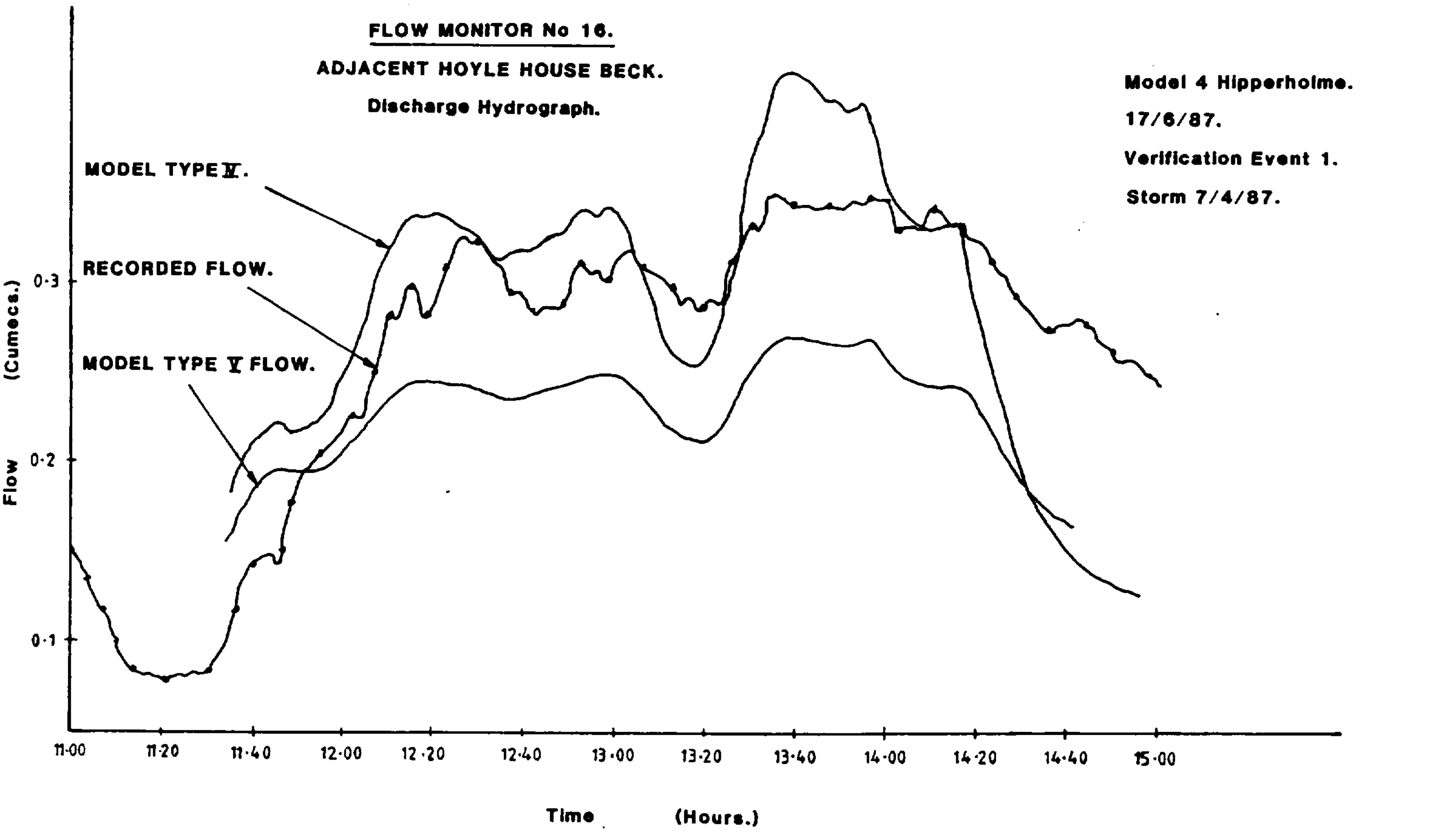


Figure 4

Discussion on D Balmforth's Paper

1 Ricardo Torres Ruiz (Paraguay)

Q An oversized carry-on flow pipe is recommended for some conditions. Is this an artificial pipe?

A Yes, this pipe is only included in the model - there is no practical significance.

2 D Williams (WRc)

Q Some successful verification exercises for side weirs have been carried out where the type of flow has not been considered. It is possible for conditions to change over the operational range - what is generally recommended and which situation should be used for design?

A High flow conditions should be modelled and appropriate changes should be made regardless of whether or not verification of low flow conditions was achieved.

3 R Chaplin (York City Council)

Q How long should the control pipe be and should its apparent storage capacity be compensated for?

A The recommended length is between 20 and 50 metres. The addition storage is not considered to cause significant errors.