Wallingford Procedure Users Group

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Free-surface Reverse Flows

A Case Study

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At the WaPUG Spring Meetings of 1990, the author co-presented a case study of the failure of Wallrus to simulate free surface reverse flows in a large diameter trunk sewer (the Chellaston Trunk Foul Sewer (CTFS)) laid to very slack gradients and with downstream real-time control. The mechanisms governing the performance of the system were deduced from an analysis of the flow survey results but Wallrus was unable to reproduce the behaviour.

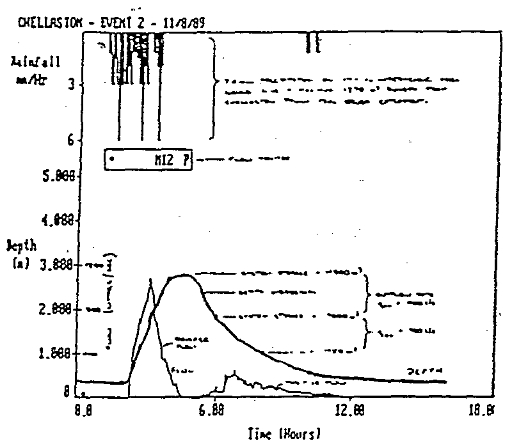
The City of Derby and several outlying villages are served by a number of trunk and interceptor sewers which collect flow from a total population of about 250,000. The sewage treatment works is situated on the east bank of the River Derwent, but 75% of the City lies on the opposite west bank. The main sewers serving this larger area (of which the CTFS is one) join together before crossing the river and entering the works. Automatic penstocks at the confluence regulate the amount of flow entering the works to prevent flooding of the inlet pumping station. The CSOs protecting the works are situated some distance upstream of the penstocks.

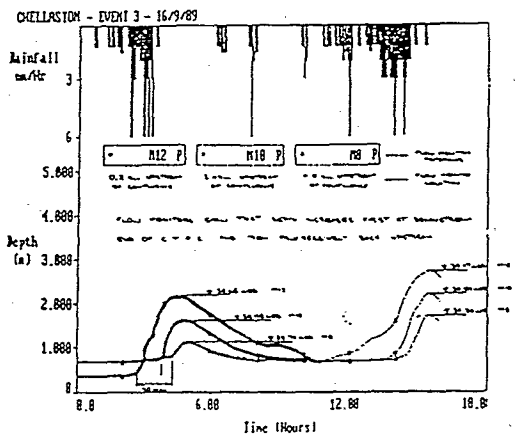
The CTFS comprises 5.5km of 1650mm and 1800mm diameter sewer laid to a gradient of about 1:4000.It serves a comparatively small and remote catchment and is the lowest of the sewers joining at the works. Consequently in storm conditions as flows increase in the other main sewers and the automatic penstocks are lowered to protect the works the excess flows from the other main sewers enter the downstream end of the CTFS and fill it by reverse flow. This process continues until the CTFS is full and the other sewers become backed up to the CSO weir level. As the storm flows subside the works penstocks are gradually raised and the flows stored in the CTFS enter the works to be pumped into the treatment stream. The rate of emptying is much less than the rate of filling, velocities are very low and the solids carried into the CTFS by the reverse flow become stranded in its upstream reaches.

Because the CTFS is large and flat, almost all of this reverse flow behaviour takes place in free-surface conditions. It is this aspect that Wallrus was unable to handle. The volume of storage provided by the CTFS is about 12400m^3, which clearly will have a very significant effect on the performance of the system and the inability to model this has been a constant frustration until the advent of SPIDA. In 1992 Severn Trent Water commissioned Acer to carry out a Drainage Area Study of the area adjacent to the works including a SPIDA simulation of the main sewers converging on the works inlet. A detailed Wallrus model of the area was built first and was used as the basis of the SPIDA model. A great deal of simplification was needed to keep within the limits of SPIDA400, but this was carried out on the minor branch sewers, allowing a more accurate representation of the main, large diameter flat trunk sewers to be made.

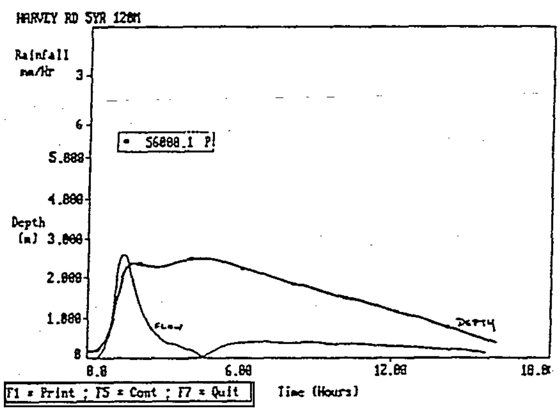
The SPIDA model has yet to be fully verified, but initial results using design events are very encouraging. The real-time control has so far been modelled simply as a small diameter pipe at the works inlet. In due course the real-time control simulation capability of SPIDA will be used to enhance the verification. The results already compare well with the flow survey records taken during the Chellaston study. The initial rapid filling by reverse flow from the downstream end is predicted, with depth increasing later in the event in the upstream reaches of the CTFS. SPIDA also predicts the flow reversal and slow emptying of the CTFS after the storm has subsided.

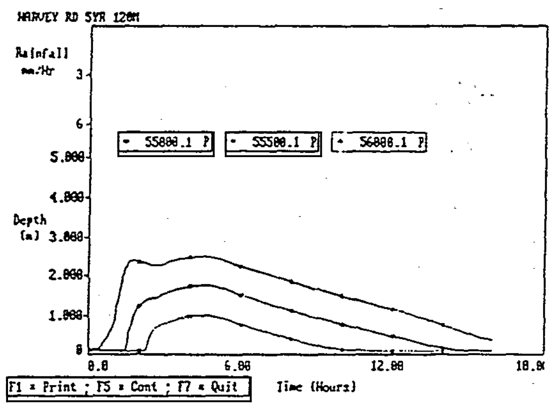
<u>Flow Gauging (observed event)</u>





<u>SPIDA simulation (Design event)</u>





SPIDA has also proved to be particularly useful in the simulation of the performance of a number of low-side-weir CSOs on large diameter sewers, where spill commences before pipe-full conditions are reached and where the downstream surcharge is having a significant effect on the onset of spill.

Although the Study has yet to be completed, there is no doubt that SPIDA is well able to simulate the complex free-surface flow regime in the sewer system. SPIDA has proved to be flexible during the model construction stage and stable in use. It is a welcome addition to the resources available to the sewerage engineer.

The permission of Severn Trent Water to publish this paper is gratefully acknowledged.

Reference: Chellaston DAS Case Study, RJ Long and CJB Ramler, Scott Wilson Kirkpatrick & Partners, WaPUG Spring 1990, Glasgow and Hertsmere.

FREE SURFACE REVERSE FLOWS, R.J. LONG, ACER ENGINEERING LTD

Question

David Beale, DHV Burrow Crocker Consulting

Would SPIDA handle Real Time Control in the inlet works or did it have to changed manually?

Answer

It had to be done manually with someone stopping the model run and changing things.

Question

Dave Walters, MW Barber Group

Were the depth hydrographs not controlled by available ground levels rather than the discharge conditions?

The depth hydrographs at the penstocks were 2 - 3 metres high, was this because the roof of the chamber or the local ground level was around this height, making the depth hydrograph almost independent of storm input?

Answer

The flow regime was such that the flows backed up the system from the bottom end with flow against the pipe gradient. The pipes were full but did not flood. It would have been nice to show this using the Visualiser replay facility but this is not possible in the Hall.

SPIDA handled the transition from surcharge to free surface very smoothly.

Question

John Farrer, MW Barber Group

How was flow measurement in 2 directions assessed when standard flow measurement equipment can only measure in 1?

Answer

*The assessment referred to was of the **flow survey** results, which indicated peak depth at zero flow, together with a volume of discharge for greater than could have been generated by the relatively small directly connected catchment. Reverse flow was the only explanation for these effects.*

Written Question

DR Haddon, Acer Consultants Ltd

Question

In cases where significant reverse flow is known or expected, is it possible to install flow monitors in pairs so that velocity can be measured in both directions?

Answer

Installing flow monitors in pairs (presumably one looking up stream and one downstream) would not aid interpretation of the data. A single "velocity" sensor reads flow going in either direction, but yields only the speed of the flow and does not record which direction the flow is going in.