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SPIDA - Weaving its web

Dr. J.R. Wixcey and M. Lewy, Wallingford Software, Howbery Park, Wallingford, Oxfordshire, OX10 8BA.

Dr. G.D. Moys Integrated Hydro Systems, Bridge House, 12 Bolton Bridge Rd., Ilkley, W. Yorks, LS29 9AA.

INTRODUCTION

SPIDA, the new simulation model for the Wallingford Procedure was officially launched at Wallingford during March 1992. As described in a previous WaPUG Paper (Osborne, 1990) SPIDA extends the range of analysis of the Procedure by enabling reverse flows in free surface conditions to be simulated. This collaborative paper by staff from both Wallingford Software, who were involved in transforming a research tool into a robust engineering tool, and Integrated Hydro Systems, who have been involved in its use and testing on drainage studies, provides an update to this original paper.

DRAINAGE NETWORK MODEL

Within SPIDA a drainage network is defined in terms of two major components: links and nodes. A link may represent either a conduit, itself either a pipe or channel, or a control, such as a weir or a pump. A node may be an internal node, representing a junction between links at a point at which inflow may enter the system, or an outfall, at which flow leaves the system. Ancillary structures, such as combined sewer overflows or pumping stations, are built up from nodes and links representing individual components of the structure. This representation differs markedly from the approach used by WALLRUS-SIM for dendritic networks.

A full solution for the levels in the nodes and both the levels and discharges in the links must satisfy the St Venant equations in the conduits, external boundary conditions at inflows and outfalls, and control or junction continuity equations at internal boundaries.

External Boundary Conditions

Rainfall-runoff is represented by three submodels: initial losses, continuing losses and overland flow routing, as per other models in the Wallingford Procedure.

A daily dry weather flow may be defined as a constant or slowly varying base flow in the drainage network prior to a storm due to the infiltration of ground water or foul drainage. A separate inflow hydrograph may be specified at each node, defined in terms of population density, sub-catchment area or land use. Node inflow hydrographs may also be specified to represent inflows from other drainage systems or from industrial discharges.

The effect of tide or river levels on the drainage system may be modelled as individual level hydrographs at each outfall.

Nodes

In the definition of a node a ground level, referred to a common datum, is required in order to determine the occurrence of flooding. The storage volume available is defined by two different plan areas at respective levels, with the lower volume representing a tank or manhole chamber and the upper volume a manhole shaft extending to ground level. There is no storage at an outfall node.

An overloaded drainage system may be analysed by sealing the manhole to prevent flooding, or assuming flooded volume is permanently lost from the system by overland flow, or defining a relationship between flood area and flood depth. In the latter case, the flood volume at a particular flood depth is given by two conical volumes, with the cone area at ground level equal to the node plan area. No surface flood flow is modelled between nodes.

Links

The connectivity of a link is defined by the link label, which incorporates the node labels both upstream and downstream.

Conduit

In the definition of a conduit, the length must be specified together with invert levels, referred to a common datum, at each end. A variety of cross-sections may be used for both pipes and open channels, of either standard or user-defined shape. Two different values of hydraulic roughness may be assigned; one for the bottom third of the conduit and one for the remainder, which is in general smoother. A depth of sediment may be defined as a deposit on the invert, although erosion and deposition are not considered. At each end of a conduit a headloss condition accounts for energy lost through turbulence at a node or junction. An additional factor may be applied to represent extra headloss due to a bend or intermediate nodes not included within the model.

Control

A zero length is assumed for a control link. A variety of controls may be modelled, each of which have specific data requirements pertaining to the head-discharge relationship to be satisfied. No headloss condition is imposed at a control link.

Two categories of control link are used. In the first, primarily consisting of a circular orifice, compound weirs and orifices and rectangular penstock, the same flow characteristics are evident in both directions through the link.

The second category consists of a vortex, flap valve and pump control, in which flow characteristics differ with direction. Four types of pump can be represented by the model: fixed discharge pump, linear head-discharge pump, rotodynamic pump and archimedean screw pump.

NUMERICAL MODEL

Details of this are beyond the scope of this paper. Full details are provided in Wixcey et al. (1992).

MODEL APPLICATIONS

SPIDA has now been used successfully on a number of catchments. It forms part of the HYDRONAUT package which is being used extensively in Flanders, Belgium.

One of the major advantages of SPIDA is the versatility with which ancillaries of different types can be represented. There are many example applications where WALLRUS-SIM cannot explicitly represent ancillaries. For example, with respect to overflows WALLRUS does not allow a user-defined head-discharge curve to be explicitly defined for the overflow orifice or weir. This would be useful in the case of a syphon side weir. Another typical example is a pumping station in which individual pumps discharge to different locations. Finally, there is the perennial problem of reverse operation of overflows. In each case SPIDA can represent these features explicitly without recourse to major modelling simplifications. It should however be noted that SPIDA does not represent super-critical flow conditions. Hence, the modelling advice with regard to low side weirs is still generally applicable.

As part of IHS consultancy studies, hydraulic modelling of a small flat catchment in West Wales is being carried out using WALLRUS and SPIDA in conjunction. This catchment exhibits numerous features beyond the capabilities of WALLRUS. First, there are flat looped sections in the catchment experiencing frequent flooding. These could not be represented directly by WALLRUS-SIM. Secondly, the final pumping station in the catchment controlling behaviour of the lower parts of the catchment consists of a series of foul pumps diverting flows to the wastewater treatment works and storm pumps diverting excess flows to the river. This scenario could be modelled by WALLRUS-SIM if it were assumed that the overflow between the storm and foul wet wells acted as the dominant control. However, it is debateable if WALLRUS-SIM could produce stable results when free-surface backwater routing is used in the lower reaches of the catchment.

The final application described is the use of SPIDA in Paris. As part of a bid to the city council of Paris, IHS were requested to prove the use of the model by developing a catchment model of a 'small' section of the Paris central drainage network. The catchment modelled covered an area of approximately 16 km^2 with a principal sewerage network of 20 km. A SPIDA model of the catchment was built comprising 277 internal nodes, 25 outfall nodes, 255 conduits and 121 control links.

Particular features of this analysis were the unusual sewer shapes (86 different pipe shapes were identified!) and the large number of compound weirs and sediment basins within the catchment. The model was proven using observed data from a small storm. Results provided by SPIDA were generally very good.

As a further test of the model, a 'live test' was done over a two day period in the council offices. This was done to check the speed of operation and stability of the model under extreme conditions. After making modifications to the model (including the emplacement of a mobile weir to control outflow from the system), the model was operated for a dry weather flow period. This test was 'rigged' so that at the end of the simulation period extremely low flows were encountered in the drainage system. Unlike other models SPIDA continued through these periods of low flow and completed the simulation.

Then the model was operated with a ten year rainfall event. During this event SPIDA provided realistic predictions of flow behaviour. Also, the model successfully simulated the operation of the mobile weir predicting its opening in response to high downstream flows. We understand that other models could not predict reliably this behaviour.

Although, IHS were not successful in securing this study, SPIDA is now being used by consultants in Paris in the development of real time control systems for the city. In this work previous models of the catchments developed on a whole host of different models are being converted for use with SPIDA.

CONCLUSIONS

After a long period of development SPIDA has now been officially released by Wallingford Software. The latest versions of the model compared to earlier versions are extremely robust. A significant reason for this has been the large number of trials on real catchments of the software which have been conducted during the last year.

REFERENCES

Osborne M.P.(1990) SPIDA - Analysis of Looped Networks. WaPUG Autumn Meeting 1990.

Wixcey J.R., Lewy M and Price R.K. (1992) Computational Modelling of Highly Looped Networks of Storm Sewers. To be published in the proceedings of HYDROSOFT '92.

Moys G.D. (1992) Application of SPIDA to Paris. Paper presented at SPIDA launch, March 1992.

Wapug Spring Meeting 1992 - Discussion

Paper 1 : SPIDA - Weaving its Web (Gary Moys/John Wixey)

Neil Hardy, Severn Trent Water/Alan Woods Watson Hawksley : Could SPIDA be used to home in on the centre part of a WALLRUS model where there may be loops etc?

Answer: Yes, you can use WALLRUS for the dendritic parts to generate inputs to the SPIDA model. Care would be needed in determining where to break the model, ideally the break points of the WALLRUS model should have relatively free discharges ie not affected by downstream conditions.

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Richard Kellagher, Integrated Hydro Systems pointed out that SPIDA had the facility to convert existing WALLRUS SSD files.

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Nigel Simmonds, Consultant : Could SPIDA be used on separate foul/storm catchments where the foul and storm pipes ran in parallel along a road and the foul could overflow to the storm at common manholes along the length.?

Answer: Yes. Care might be needed with smaller, steeper pipes to ensure they did not require too many computational points. This can be avoided by restricting the length of modelled pipes.

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Dave Walters, M Barber & Co : Flow monitoring is only accurate to ±20%, and reverse flow cannot be measured, so is all this accuracy superfluous?

Answer : SPIDA can model situations that WALLRUS cannot. More accurate flow monitors will develop, and it is possible to measure reverse flows.

Neil Scarlett, IHS : Current doppler monitors can detect reverse flow but its measurement is not as accurate as forward flow.

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D Balmforth, Sheffield City Polytechnic : Will SPIDA be able to model a moving weir?

Answer : A Real Time Control facility is being developed including variable pumps, weirs, gates etc.

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