WaPUG Autumn Meeting 2004
The FastNett Project

Steve Hogg and Matt Elphick, Ewan Group plc

Summary

FastNett is a software tool that comprises a rapid sewer simulator and an optimising system designed to find the most cost-effective solutions to sewer flooding. The simulator interfaces with InfoWorks CS. FastNett has been produced by Ewan Group plc (EGP) under a collaborative development project for Dwr Cymru Welsh Water, Severn Trent Water, Thames Water, United Utilities and Yorkshire Water. Exeter University are consultants to the project, providing technical advice and support.

Introduction

Having recognised that sewer flooding represents one of the worst service failures faced by customers, Ofwat's draft determination announced recently, reduces projected spend dramatically in this critical area creating a dilemma for the water companies.

According to the National Flood Forum, last year alone there were more than 7,000 reported cases of internal sewer flooding causing great distress and misery to the occupants of those households. Add to that, insurance damages of between £15,000 and £30,000 in a typical sewerage flooding case according to the Association of British Insurers (ABI). The same organisation suggested in a paper earlier this year that annual damages from this specific cause could rise from £270 million to between £2 billion - £15 billion unless swift action is taken. However for now, having had their requested £1.1 billion spend to tackle the most pressing sewer flooding projects over the next five years pegged back by the regulator to £710 million, the pressure is on water companies to respond and meet the demands placed upon them. The FastNett project is aimed at helping to achieving this objective.

Background

FastNett has its basis in a research project carried out at Exeter University during 2002-2004. In a PhD project supported and partly funded by EGP, a rapid sewer simulator and optimising tool based on HydroWorks network data was developed.

The Exeter model for simplified sewer flows was based on the principle of continuity of volume, storage at discrete locations and constant time of flow between nodes. The original idea came from a simplified sewer flow model developed at the University of Liverpool (Thomas: 1998,1999,2000) for use with a simple interceptor sewer system to facilitate real time control of pollution levels caused by storm overflows. The model network was a non-branched series of sewers, with nodes equally spaced along its length. A time step for the problem was chosen such that it was equal to the time of flow between each interceptor point, the time of flow being treated as a constant for a sewer of known diameter, roughness and gradient. The model can be described in terms of a chain of discrete packets of water flowing down the interceptor system. Each 'packet' of water is treated as being separate in time and space from any other. This allows a set of water chains for all time steps to be developed without any interference.

Having developed the general methodology, Thomas (2000) expanded the basic approach to allow varying of the distances between interceptor points. This was achieved by ensuring that each distance was an integer multiple of the time step, thereby allowing a slightly more realistic network to be established. The resulting methodology allows time-varying storm inputs to be propagated through the simple model system very rapidly. Results of a comparison with standard analysis techniques showed that there was also reasonable accuracy for this simple system (Thomas, 2000).

It was clear that the above approach provided a very rapid method of analysis, fast enough for on-line optimisation of decisions for the simple interceptor system that was modelled in the study. However, it was not clear whether this simplified methodology could be usefully applied to the more complex issue of sewer system design.

To be a useful tool for rapid analysis and design of real networks, an expanded model needs to be able to handle a range of features. These include branching networks (with converging and diverging flows), storage within and external to the network, and simple controls such as orifices. Flooding that occurs in the system must also be handled in a logical fashion, and will generally be considered as occurring at any manhole, with water stored above ground level until it can return to the sewer at a later stage in the storm event. The software needs to remain computationally quick, robust and of reasonable accuracy. The prime consideration was computational speed, so that it would work well with an optimisation technique such as Genetic Algorithms, which requires very large numbers of simulations of proposed network modifications.

The velocity of flow, and hence the time taken for a packet of water to travel between manholes, was based on uniform steady full-flow conditions. Conventional theory (e.g. Chadwick and Morfett, 1998) shows that the velocity derived in this way is within 15% of the theoretical velocity for any uniform non-surcharged flow greater than 25% of the pipe-full capacity. Times of flow were rounded up so that each water packet takes a specific integer number of time steps to travel from one manhole to another. This was necessary to allow the inputs to be easily added to each other, initially using a spreadsheet application, thus allowing the total flow to be calculated simply and rapidly at each position at each time step.

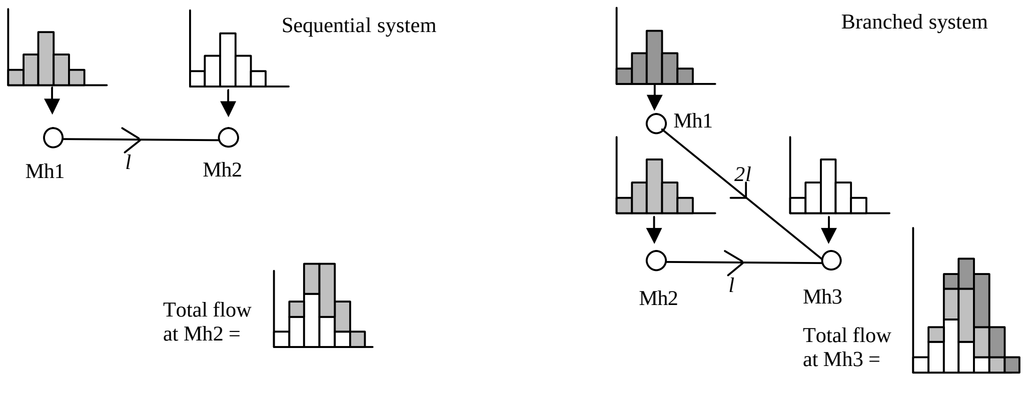


Figure 1: The ‘packet approach’ concept.

The Collaborative Development Project

During 2003 EGP discussed the FastNett concept with a number of interested water companies. A staged approach was proposed to develop the software, with the first stage being the delivery of a software tool to be used to achieve capital cost savings in flood reduction.

At this stage it was decided that the new software should interface with InfoWorks, which had by that time become the industry software of choice. It was also agreed that a closer correlation with the output of the detailed modelling software in heavily overloaded flood conditions than so far achieved was required. This was because in real-life application the tool would be set to resolve flooding only in selected areas of a catchment, so that flooding might remain elsewhere. The overloading that would thus remain represents complex hydraulic problems requiring more accurate simulation. EGP therefore decided to prepare new code to implement this alternative approach, and this forms the basis of the current software. The software reads in InfoWorks network data (i.e. the physical description of the network). This ensures that the physical network will exactly match the InfoWorks model. The software then takes the inflow data comprising all storm flows, foul and trade inputs from an InfoWorks results file. This means that loadings will be exactly the same as the InfoWorks model.

The EGP software uses a modified diffusion wave routing method developed specifically for this project. The routing method accounts for kinematic forces but not inertial forces. Although more complex than the basic packet approach method, it is still a conceptually simple and computationally fast method. In the implementation developed by EGP the routing method accounts for flow in part-full pipes and the simplification relating pipe lengths to computation time-steps is no longer needed. Routing methods of this type are not naturally suited to modelling reverse flows in conduits, but EGP have developed a novel solution to this problem that has been shown to work adequately in most conditions. The software development specification set a notional target for accuracy based on comparison with InfoWorks results from the same simulation, as follows.

- overall volume balance within 1%
- flooding locations identical
- flood volumes within 10%
- conduit peak flow and volume within 10% and shape similar
- node peak depth within 0.1m and shape similar

These targets are met in most conditions. During operation of the software, the user selects simulation parameters to achieve an acceptable balance between speed and accuracy. Experience has shown that an acceptable degree of accuracy can be obtained with simulation speeds approximately twenty times that of InfoWorks.

The fast simulation engine forms one key part of the FastNett software. The other key part is the goal-seeking, or optimising module. This module allows the user to specify targets, options and costs.

Targets are those nodes where flooding is to be eliminated up to a specified return period. All other nodes are monitored to ensure that flooding is not made worse, within a tolerance set by the user.

Options are specified by the user based on an engineering assessment of what it is possible to build in different parts of the catchment. For example,

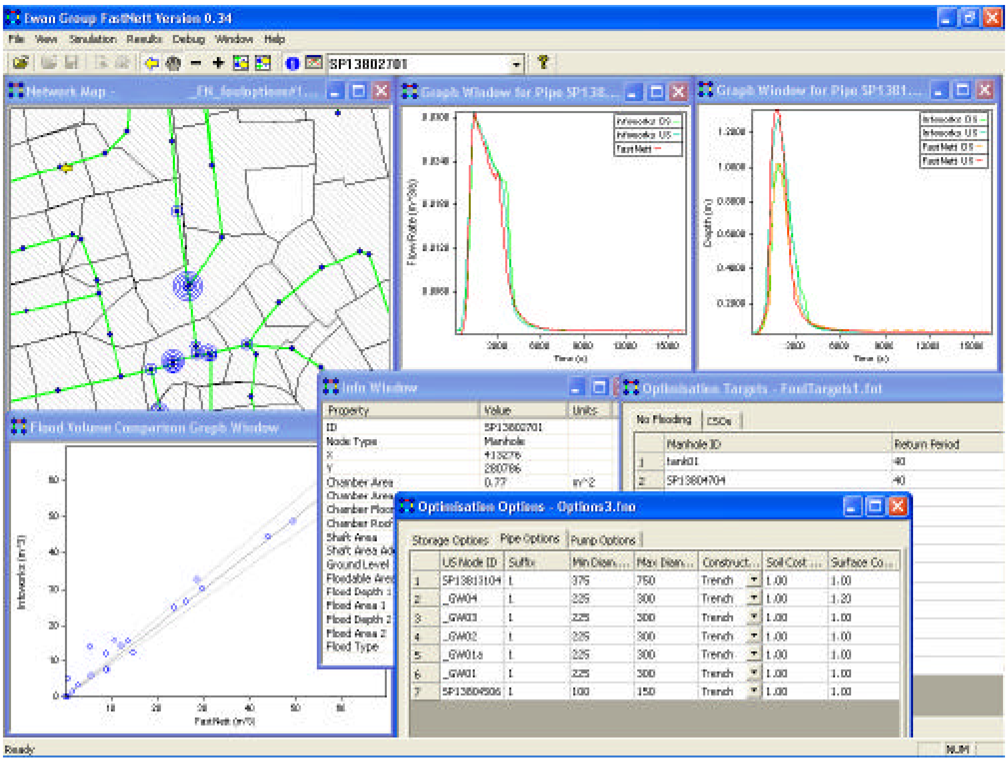
- storage can be made an option at certain sites, with maximum limits on the volume that can be built at each site individually specified.
- sewer runs can be identified as capable of being upsized, again within user-specified limits, while elsewhere new sewer runs can be specified.

In all cases the optimising module can choose from the range of options available in each location, or can keep the existing system.

Costs are specified by the user in a simple yet flexible matrix structure. All-in costs per metre of sewer are entered, as are the costs of a range of storage volumes. At each location the user can apply adjustment multipliers to account for specific surface and soil conditions.

In addition to checking that flooding is not made worse at non-target nodes, the software also tracks CSO spill to ensure that options do not make CSO performance worse than the current performance. A future version of the software will permit the user to specify CSO performance targets in terms of frequency and/or volume and this will help users to seek integrated flooding and pollution management solutions.

In optimisation mode FastNett is designed to run a matrix of events covering the target return periods and sufficient variation of durations to span the critical durations for the various options in all parts of the network. For example a typical optimisation run may involve using summer and winter storms of 20 years and 40 years return period and durations of 30, 60, 120, 240, 360 and 480 minutes to cover options involving both storage and resewerage.



FastNett uses genetic algorithm techniques to find the optimal solution to the targets set. A large population of unique networks are generated by the software, each being formed by selecting from the 'menu' of option types and sizes available. These are each run through the simulation engine for each of the matrix of storms, and the fitness of each member of the population is determined by combining a measure of its effectiveness in meeting the targets and its cost. 'Fit' options are allowed to exchange 'genes' (elements of the network) and mutate, while 'unfit' options are discarded. This process is acknowledged as an effective way of finding the optimum combination of a large number of variables and targets. In operation it has been shown that a near-optimum solution can be found after a relatively small number of iterations, compared to the many millions of possible combinations that are available. The software performs checks that prevent unsound engineering practices such as pipe sizes decreasing in the downstream direction being selected.

The project is currently at pilot stage, in which each collaborating company has provided data for a catchment that has flooding problems. The software is being used to develop optimal solutions to these problems and these will be compared to those obtained by conventional optioneering techniques.

Future Development

Stage one of the project is scheduled for completion during December 2004. Subsequent stages of the project are in planning. These will add functionality and extend the use of the software into continuous simulation of long rainfall series, water-quality based solutions, flood risk management and asset management planning.

References

Fullerton J. (2004) PhD Research Project, Exeter University.

Chadwick, A. and Morfett, J., (1998). Hydraulics in Civil and Environmental Engineering, Third Edition, E & FN Spon, London, pp. 112.

Fullerton,J.N., G.A.Walters and D.A.Savic, (2002), “Simplified Modelling of Storm Water Flows for Optimisation”, in Hydraulic Information Management, Brebbia, C.A. and W.R.Blain (eds), WIT press, Southampton, pp.133-142.

Morley,M.S., R.M. Atkinson, D.A. Savic and G.A. Walters, (2001), “GAnet: Genetic Algorithm platform for pipe network optimisation”, Advances in Engineering Software, Vol. 32. No. 6, pp. 467-475.

Thomas, N.S., Templeman, A.B. and Burrows, R., (1998). Optimal Control Models for Interceptor Sewer Systems, Proceedings of the 4th International Conference on Developments in Urban Storm Drainage Modelling (UDM'98), 2, pp. 691-698.

Thomas, N.S., Templeman, A.B. and Burrows, R., (1999). Optimal Pollution Control of Large Interceptor Sewer Systems, Proceedings of the 8th International Conference on Urban Storm Drainage, 3, pp. 1098-1106.

Thomas, N.S., (2000) Optimal Pollution Control Models for Interceptor Sewer Systems, PhD thesis, Department of Civil Engineering, University of Liverpool.

Acknowledgement

HydroWorks and *InfoWorks* are registered trademarks of Wallingford Software.

Disclaimer

The views expressed in this paper are those of the authors and do not necessarily represent the views of Ewan Group plc, Exeter University or the collaborating water companies.