PRODUCTIVITY TOOLS IN DRAINAGE MODELING

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Introduction

There has long been a perception that many tasks undertaken as part of drainage studies, could be automated to a much greater degree than is currently the case. Particular aspects of drainage studies such as model construction, validation, time series and flood frequency analysis, criticality assessments and the design of remedial works could all benefit from enhancements to the available analytical software. While these tasks will always rely to some degree on the judgment of an experienced engineer, we believe that considerable scope exists for reducing the time spent by automating elements of the data processing through new modeling software.

This paper concerns a review of the current tools available to engineers undertaking such studies based on the authors' own experiences and attempts to provide some guidance on the needs for further development in particular areas. The paper is presented in 3 sections with the first section concerned with the potential for enhancement of the available software. This is followed by an assessment of the degree to which existing software meets the objectives and a final section pointing toward the need for further development.

(a) In an Ideal World....

In attempting to identify modeling processes, which would benefit from enhanced levels of automation, we have reviewed the major tasks and tried to identify aspects of the work that would be amenable to encoding. In general terms we found that the scope for productivity increases using newly developed modeling software tools tended to be linked to those tasks which would not normally require a judgment on the part of the engineer.

(i) Model Construction

We would argue that where a sewerage database exists for a particular catchment, model construction could be virtually completely automated and the engineer need only concern him/herself with its approximate size consistent with its intended use. Rule based systems governing the inclusion of particular asset and catchment details could be used to provide the appropriate degree of simplification. Many of these rules could derive directly from recommendations in the code of practice for sewer network modeling which could be easily encoded.

(ii) Model Validation

Validation of computer models is an area where a very high degree of engineering judgement is required. Although some guidance as to the goals to be attained in validating computer models is available through the code of practice, there is a virtually complete absence of guidance as to what actually constitutes an appropriately validated model for a particular purpose. Some R&D work was undertaken in the late 80's on developing a modelling 'Expert' system with the name of Serpes, this system could assist in undertaking a model verification. Although a prototype was developed, the project was not pursued to the development of a commercial product.

Because of these factors as well as possible doubts about the accuracy of the flow survey data in particular situations, it is difficult to compile definitive rules for validating hydraulic models. The process is not therefore readily amenable to encoding and the best that can be offered in these circumstances are tools to assist the engineer in decision making. Some suggestions include

- Sensitivity checks. Automated model file amendments and simulations to assess the sensitivity of model outputs to changes in various model parameters. This might for example include changes in surface flooding or CSO spill volume as a result of a globally applied change in impermeable area, pipe roughness etc. Such information might well provide valuable clues as to the source of a discrepancy detected at validation stage and point toward appropriate changes in the model.

- Greater emphasis on the use of recorded depth and velocity data. We believe that insufficient use is made of the data available from the flow survey. Examination of depth data immediately upstream of a CSO can reveal the point in an event where spill first occurs or point to the need to change an orifice coefficient etc.

(iii) Time Series and Return Period Analysis

This has long been an important factor in assessing the performance of a system but has perhaps become even more important in recent times. It has become increasingly common to run historical rainfall series, which often consist of selected events from several decades of data. Run times can extend to a number of days in the case of large models, with the time required to analyze the results being similarly onerous. As time series analysis usually only concerns CSO's, pumping stations, and storage tanks, it seems reasonable to assume that the models could be simplified to accurately represent the salient features of the drainage system. Such an approach is already incorporated into the SIMPOL model for UPM studies, but the loss of accuracy in terms of both the system hydraulics and hydrological inputs is judged by many to be unacceptable for the purposes of a drainage study. Instead we would propose to attempt a simplification which would incorporate all sewer ancillary structures, and the response characteristics of the catchment.

For the CSO/PS structures themselves we believe that it would be desirable to retain the calibrated asset data such as the full hydraulic model of CSO and Pumping Station structures and to run simulations using a time step which would allow for changes in incoming flows. The representation of the catchment response, we would suggest, could be undertaken by running a small number of simulations of rainfall events with duration's at least equal to the time of concentration of the point in the network where this simplification is required. When the characteristics of the catchment upstream of the point of interest have been established, it should be possible to construct a customized PR equation based on the existing catchment characteristics. From the authors' own experience, we believe that such an approach would enable the replacement of models comprising perhaps several hundred nodes/pipes with models comprising 10 or less pipes. The savings in terms of run-times, analysis etc. would be very considerable.

We also believe that return period analysis, highlighting the expected frequency of surcharging and flooding in a drainage system could be implemented relatively easily in the form of an additional modules to automatically undertake the necessary simulations and produce summary output files.

(iv) Design of Remedial Work for hydraulic problems

The design of remedial works for hydraulic problems identified as part of drainage study is often time consuming and repetitive. Solutions for some problems often only emerge from a trial and error type process with additional simulations undertaken to ensure that any measures proposed do not adversely impact on existing flooding service standards

- Elimination of surface flooding
- Reductions in the frequency of CSO spills
- Re-design of CSO chambers to meet current guidelines for storm separation

In our view the scope for enhancing existing software to include modules addressing these problems is considerable.

In the Real World....

(I) Model Construction

Data is still frequently supplied to the modelling office in paper format with sewer records being printed out from the corporate GIS system. Even when the data is passed over in a digital format, this is usually not compatible with any of the modelling packages and requires extensive manipulation to get the information into the model. The data, which was created primarily for another purpose i.e. sewer records, is often not sufficiently detailed enough for modelling with important hydraulic details missing, especially on ancillaries. Additional manhole surveys are frequently required to allow the model to be completed.

Given the quality of data mentioned above, the quickest way to build a model is still in a text editor using the now obsolete SSD format and then read the data into the simulation software to be automatically converted into the latest format.

As the quality of the data improves other alternatives are available which increase the productivity of the modeller.

STC25/FastSTC or SUS25 are a couple of examples of the programs that have been used to build models from sewer record databases, but as the records are constantly being migrated onto company GIS systems the issue of data compatibility is becoming more acute.

InfoWorks has provided a significant advancement in the area of model build with the provision of links to GIS data using MapInfo and various tools to aid construction of a model.

None of the programs listed above approach the ideal world that was discussed earlier but all of them can be seen as parental generations of 'Utopia'.

(ii) Model Validation

Having built the model, the verification process is almost identical to the process that was established 20 years ago. This is progressively working down the system by comparison between observed and predicted results, attempting to identify mismatches in the system performance and find an explanation for the differences.

Sensitivity analysis can be used to check locations for flow monitors and highlight 'insensitive' areas of the model that would not be susceptible to errors in the data. This allows the modeller to concentrate their efforts on the areas of the model that have most effect upon the results.

(iii) Time Series and Return Period Analysis

Assuming that you have successfully worked your way through the 'black art' of verification and now have before you a verified model, the next simple task is to find out why the system fails and what you need to do to 'fix it'.

As mentioned earlier running a time series through a moderately complex model can take a significant amount of time, this problem is multiplied during the design.

The majority of simulation software now produces a Return Period Analysis summary of design storms in the now well used X-X notation that was proposed by the SRM.

(iv) Design of Remedial Work for hydraulic problems

In the ideal world referred to above you would press a button and the software would quickly analyse the system using the desired design criteria and then tell you what changes are required to the system to meet the design brief.

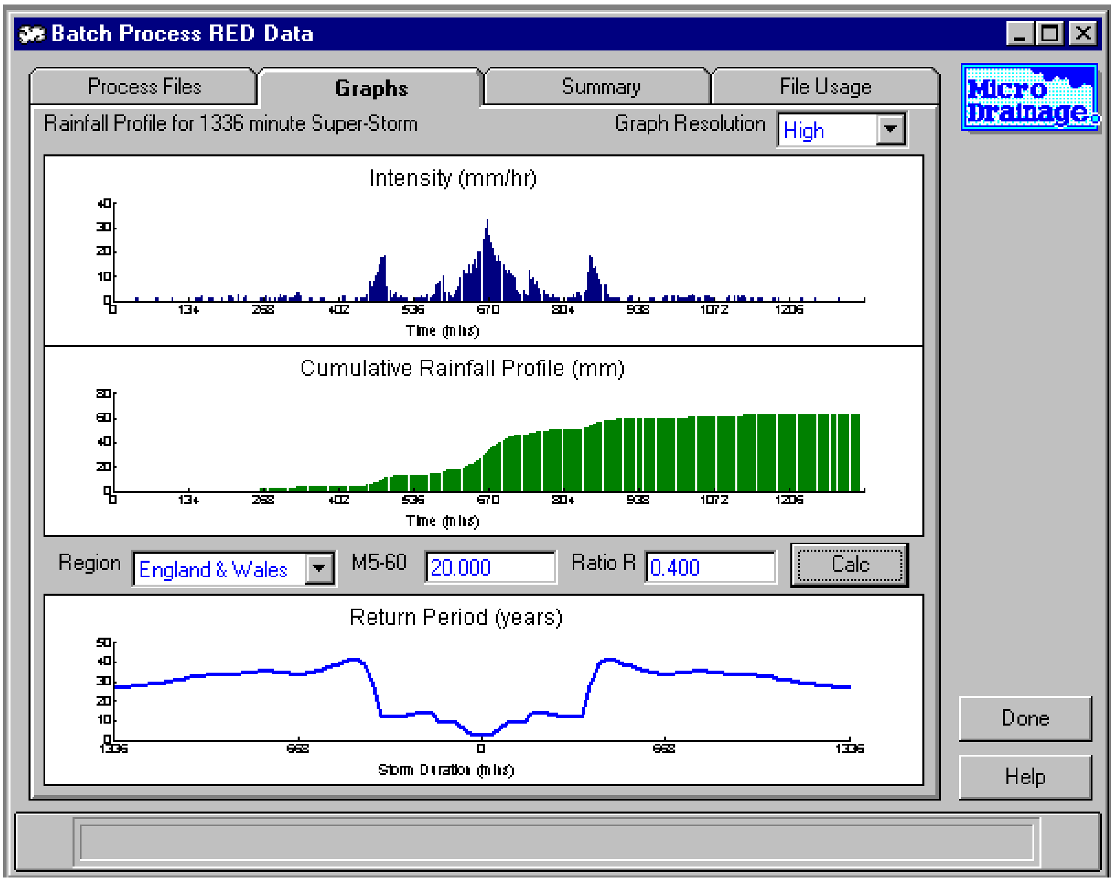
In the real world, the normal method is to make an 'educated guess' and test the system to see how close to the 'right' answer your guess was, having done this you revise your original guess and test the system again. Having made several guesses, you get out your deerstalker and set to achieving an understanding of how the system is responding to the changes you have made which should aid you in finding an 'optimum' solution to the system. To paraphrase Mr. Sherlock Holmes, "when you have eliminated all the possible options, then what you are left with, however unlikely, must be the solution".

The problem with this methodology is that sometimes "all the possible options" can be quite a lot. Analysing even a moderately small system using a comprehensive set of time series data can take the number of simulations into the hundreds, even into the thousands. This scale of data results brings with it the problem of data manipulation and trying to comprehend the picture created by hundreds of runs can be mind boggling. Add to this the 'human element' that has to juggle with all these numbers and the scope for errors is obvious.

If the descriptions above have totally depressed you then allow us to give you a glimpse of this future world. One recent development, which takes us one step nearer to the ideal world mentioned above, is WinDAP. This program has been developed by Microdrainage and provides assistance to the engineer during the design. The full scope of the software is too involved to adequately cover in this paper, but some of the elements are listed below.

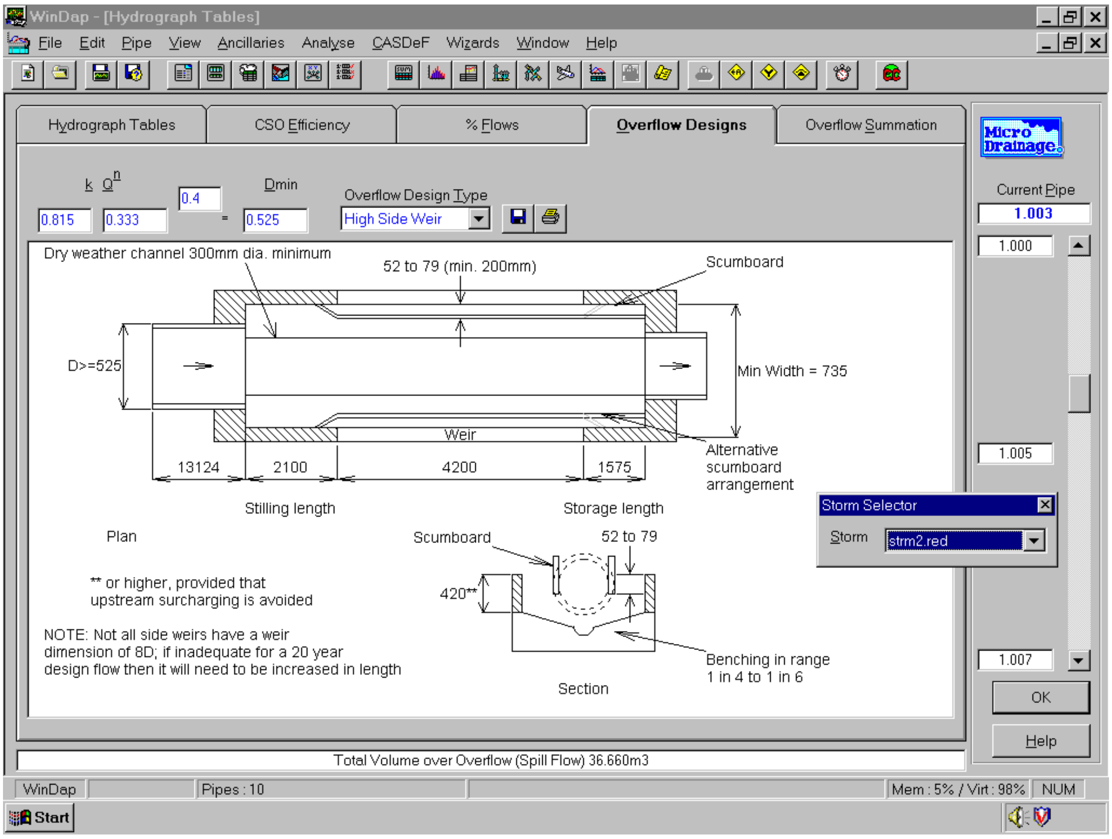
QuAM allows the modeller to import data in DSD or SSD format and checks the model for possible errors in the data input and will, in some cases automatically correct the errors.

Super Storm. This unit analyses a series of RED files, then takes the worst case Intensities and volumes for varying durations and builds a single storm, which contains the critical IDF data for all parts of the network. (Figure 1)



CASDeF The Computer Aided Simulation Design Framework allows a design target, such as no flooding and CSOs to be restricted to 3 spills per bathing season to be specified, the software then searches for a solution leaving the engineer free for other duties.

CSO design wizard. Having used CASDeF to find the solution to the problems, the wizard will use the results to dimension a CSO in accordance with Guide to the design of CSO structures FR0488 and the UKWIR guidelines. This meets the EA requirements of 80% of the volume spilled to pass a 6mm screen equivalent. (Figure 2)



These are not ‘black box’ modules, but assistants, which are a complex form of macros that allow the design specification to be altered by the engineer to meet the specific requirements of each project.

ENTEC ran tests of some of the new tools on a project that had been designed using conventional methods, the potential increase in productivity was very promising.

In Conclusion

Despite the good efforts of a number of organisations to address some of the problems discussed above, it is clear that they currently fall well short of what could be achieved. We believe that the solutions to some of the problems present significant commercial opportunities to the existing software suppliers and that solution’s will ultimately emerge from that quarter. We refer here particularly to sensitivity checks, model construction and specialised CAD software. A common data transfer format between corporate GIS systems, sewerage databases, and modeling software would be a considerable advance in pursuit of these goals.

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DISCUSSION

Question Richard Allitt Richard Allitt Associates

In the ideal world we would set out one type of model , whereas the cost of model production means say 3 types are required. Should we have a uniform model type across the catchment or can it vary.

Answer

Yes you need to vary the level of detail. If you are looking at interceptors you do not need housing estate pipes. You need a sophisticated software package to mix the levels of model together.