Getting More From DAP Models

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Abstract

Water Companies have invested significant amounts of money in DAP models over recent years. Such models tend to be used for a variety of purposes subsequently and may require further investment in extension, modification or adaptation. This paper explores how better value can be obtained from DAP models in a variety of areas without the need for substantial additional work.

Keywords

Model performance, Extreme Events, Water Quality, Continuous Simulation, Ancillary Structures.

Introduction

It is becoming increasingly common that we are now re visiting drainage areas for which models have already been constructed. The purpose of the current programme of work often differs from that for which the model was originally constructed and verified. Clearly the user does not want the cost of building a new model when an existing one is available. The purpose of this paper is to identify how an existing DAP model can be improved and adapted for use in a wider range of applications from that for which was originally intended.

The paper discusses improving DAP models in the following areas: -

- Performance of structures during large events
- Extreme events and flood risk
- Water quality modelling
- Storage solutions where significant run-off derives from permeable areas.

As computers increase in speed and memory size, the ability of models to simulate ever more complex issues and investigate detailed problems also increases. Models no longer have any real technical constraints with regard to their size and detail. However modelling cost plays an important part in the extent of modelling appropriate to a particular project. Subsequently a model developed for one purpose may be used for another. In these circumstances further investment in modelling may be justified. The additional extent of further modelling must however balance the benefit in making the model fit for its new purpose.

Performance of Ancillary Structures

Earlier versions of modelling software such as WALLRUS or WASSP may have required complex ancillary structures to be simplified due to the limitations of the software at the time. Models built in later versions of the software may also have structures represented in a simplified form either because there was insufficient data available at the time the model was built, or because of constraints on time and cost.

Many ancillary structures, for example combined sewer overflows (CSOs), can have an important effect on system performance. Models with a simplified method of representing ancillaries may represent prototype performance reasonably well for the lesser rainfall events used for verification, but evidence has showed that at times such simplified models do not perform well in the more extreme events used for design. This is particularly true when verification has involved a degree of calibration of the ancillary structure.

Typical examples of problems with ancillary structure modelling include

- Failure to account for a change in hydraulic performance at higher flow
- Failure to identify that an outlet pipe may discharge as a “short pipe” (orifice control)
- Incorrect combination of different hydraulic controls, such as screens and weirs
- Missing outfall pipe or outfall water level control

For example, a low side weir may be represented by weir link with a discharge coefficient that allows for the varying head along the weir (figure 1). This will be satisfactory unless in more extreme events the hydraulics of the system changes (figure 2). A failure to fully understand and account for the hydraulic performance of the structure can result in the model failing to properly simulate prototype performance.

Figure 1. Side Weir CSO Under Test at Low Flow showing Rising Water Surface Profile (*courtesy United Utilities)*

Figure 2. Side Weir CSO Under Test at High Flow showing the Formation of a Hydraulic Jump in the Weir (*courtesy United Utilities)*

The latest software has the capacity to model in much greater detail and contains more complex algorithms designed to better replicate how a number of the ancillary structures within a network operate.

When modelling any sewerage structure, there are three important steps:

- Understanding the hydraulic performance of the structure
- Understanding how the algorithms within the software work
- Matching the two together to produce a model that replicates the performance of the prototype structure across the full range of flows.

To illustrate this principle, consider a CSO structure fitted with a weir and screen. Perhaps the simplest approach would be to model the weir as a conventional weir link but to modify the weir coefficient to account for the additional head loss generated by the screen. An alternative approach might be to represent the weir and screen characteristics by a head discharge relationship, based, say, on the manufacturer's data for screen performance. Both these methods have two distinct drawbacks however. Firstly they do not represent the true inter-relationship between weir and screen, which will be different depending on where the screen is located (wet side, dry side or on the weir), nor will they allow for any backing-up that may occur due to restricted flow in the spill pipe or high receiving water levels. These effects may not be apparent with the smaller rainfall events used for verification.

Prototype testing of screens has shown that their hydraulic characteristics can be represented by the orifice formula with a discharge coefficient of 0.6 and an area of opening equal to the combined opening of the screen mesh projected at 90° to the flow. The area of opening should allow for the blinding of the screen mesh, which can be expected to be between 25 and 50% during normal operation (depending on screen type). Thus a CSO chamber with a wet side screen (e.g. Longwood Stormguard) may best be represented by an orifice link followed by a weir link, whereas a dry sided

screen (such as the Rotamat ROK1) can be modelled with the reverse arrangement. Weir mounted screens (e.g. Rotamat ROK2 and Hydro Heliscreen) are best modelled with the weir link but reducing the effective weir length to allow for the proportion of screen opening to total screen area.
Using the full capabilities of the software in this way ensures that the correct hydraulic performance will be replicated across the full range of flows, and that the subsequent effect of new structures on the level of service of the sewerage system can be properly represented.

Adaptation of the model to account for the issues raised above is normally straightforward and requires little modelling investment once the base data has been assembled.

Extreme Events and Flood Risk

Climate change is forecast to result in a significant rise in the frequency of extreme events in the future. Recent studies suggest short duration rainstorms could increase in intensity by up to 40% (UKWIR 2004), and this will clearly impact upon the performance of sewer systems (Digman & Shaffer 2004).

The current reporting system for flooding is imperfect. Storms that occur at night and cause localised surface flooding may go unnoticed and unreported. Flooding may go unreported due to confusion over whom to report the problem to or for fear of higher insurance premiums and re sale problems (UKWIR 2004).

On occasion extreme events will inevitably be too large for the existing drainage system. In these cases a substantial volume of flood flow may be conveyed on the surface. This can transfer large volumes of floodwater from one part of the drainage area to another. Models that do not allow for this factor are likely to wrongly identify the location and extent of flooding, and this can lead to wasted investment in infrastructure improvement.

In the past, identification of surface flood pathways has not been common because of the high cost of obtaining surface topographical data at the required accuracy. However, using modern LIDAR data now allows such pathways to be readily and economically identified. These pathways can often be confirmed from flood reporting records and by interviewing those affected by flooding.

Modern simulation engines now allow the explicit modelling of surface channels and have been shown to considerably enhance the performance of models when replicating extreme events (figures 3 and 4)

Figure 3. Flood Locations from Conventional Sewer Network Model.
In this case the location of flooding was found to be significantly different from that reported at the time of the event

Figure 4. Improved Representation of Flood Location by Explicit Modelling of Above Ground Flood Pathways
With the surface flood channels modelled the location and mechanism of flooding is correctly identified.

Further enhancement is possible by linking flooding to individual properties for the assessment of flood risk. Figure 5 shows the use of LIDAR data to assign each property a ground level. Each property is linked to the nearest node in the model. If the model does not contain sufficient detail, the model may require a small amount of updating in the areas of the study, with further survey as necessary. Results can be colour coded to distinguish properties with different level of flood risk (figure 6).

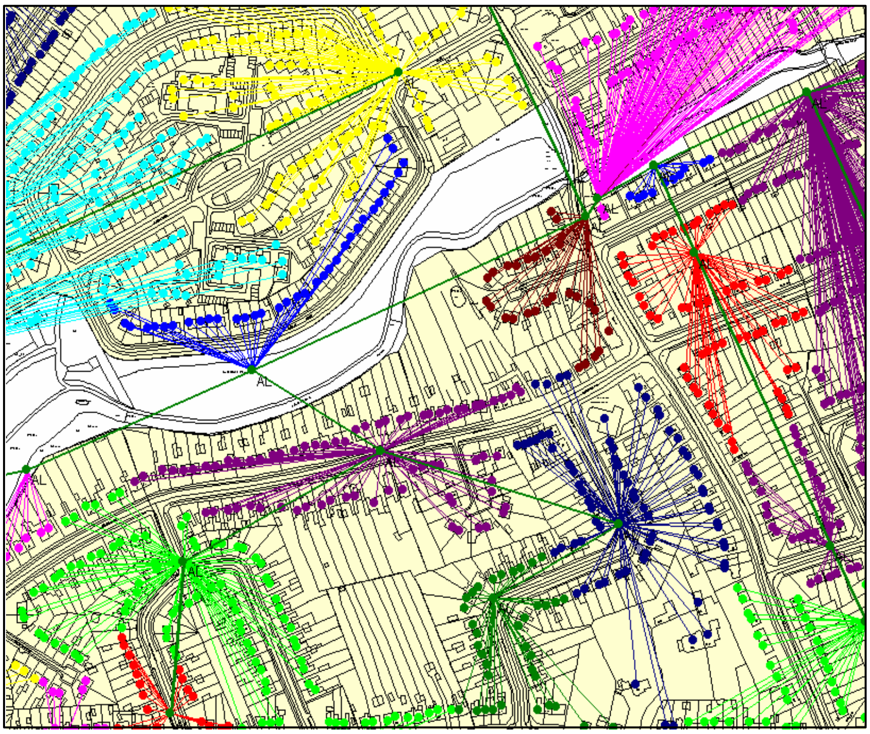

Figure 5. Use of Lidar Data to assign Property Levels and Link Address Points to Nodes in the Sewer Network Model.

An allowance for properties with basements can be included. Flooding from high surcharge levels as well as surface flooding can be accounted for.

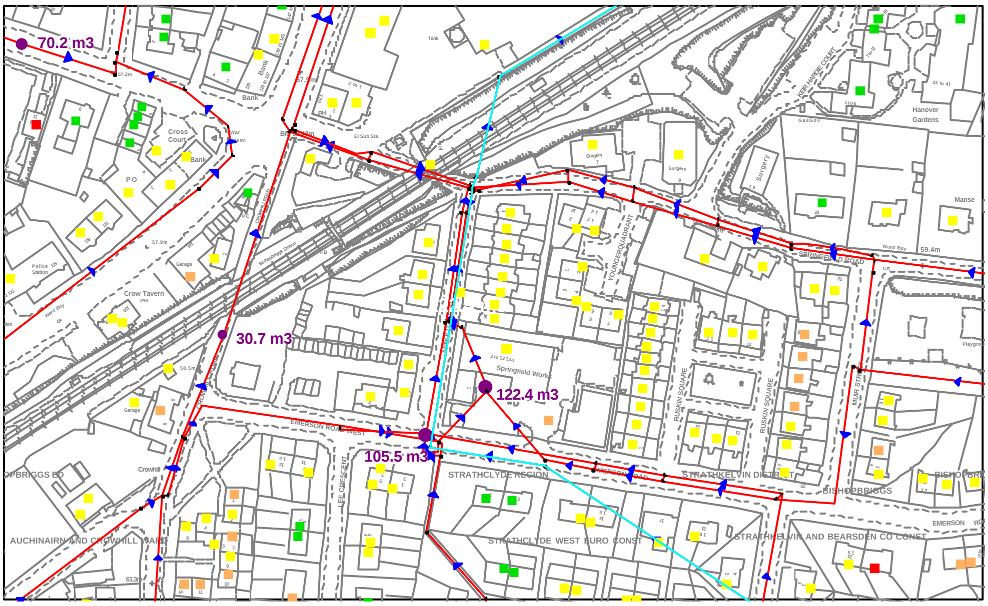

Figure 6. Assessment of Flood Risk at the Level of the Individual Property (*from MWH's Flood Risk Tool)*

The properties are distinguished on the basis of a flood risk score that can account for both the probability and the consequence of flooding (e.g. flood damage costs)

Extending Models for Water Quality

The experience gained from the UPM program during AMP3 has shown that DAP models can, in many cases, be used for water quality assessment without the need for substantial enhancement and verification from water quality sampling. CIRIA dry weather flow profiles (CIRIA Dry Weather Flows in Sewers, Ainger, Armstrong & Butler 1998) and standard default water quality values can be used with confidence if the catchment is essentially domestic and therefore devoid of significant industrial input.

Figure 7 compares the modelled dry weather flow using a CIRIA DWF profile and default water quality parameters (Table 1). There is good agreement between both flow and pollutant levels and this is typical of such results for principally domestic drainage areas.

In areas where significant industrial input is located the results (figure 8) demonstrate how the CIRIA profiles default parameters fail to allow for the specific nature of the industrial effluent and the shift working of the industrial processes.

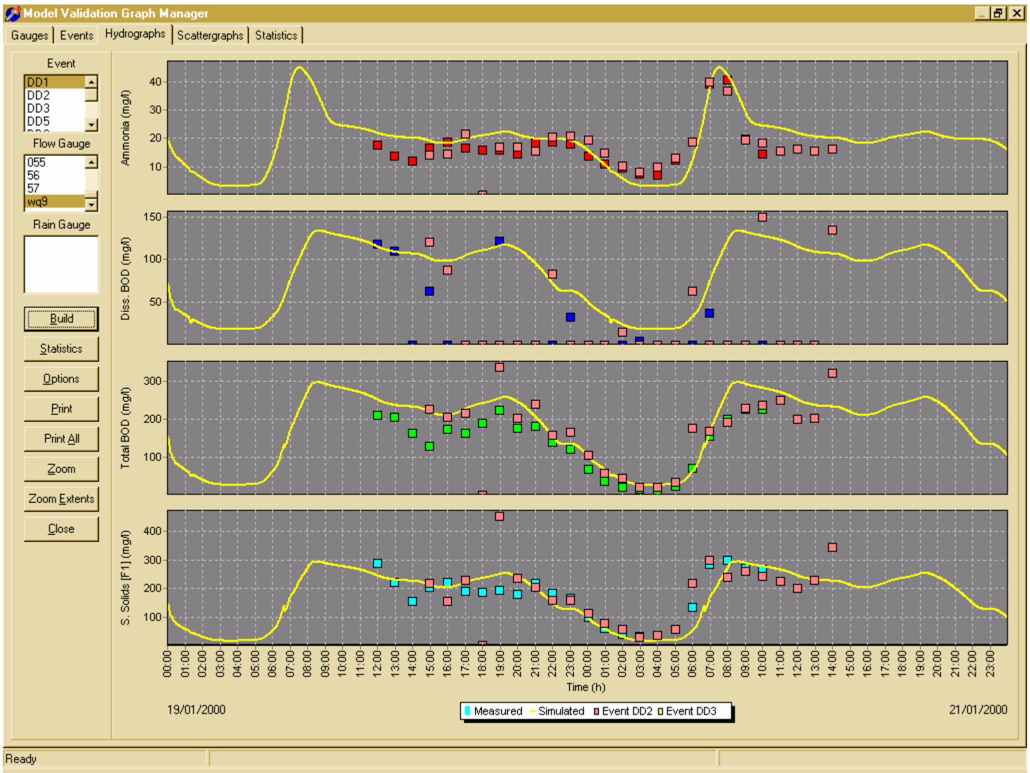

Figure 7. Comparison of Measured DWF Water Quality Parameters with Sewer Network Model using CIRIA DWF Profiles and Default Water Quality Parameters

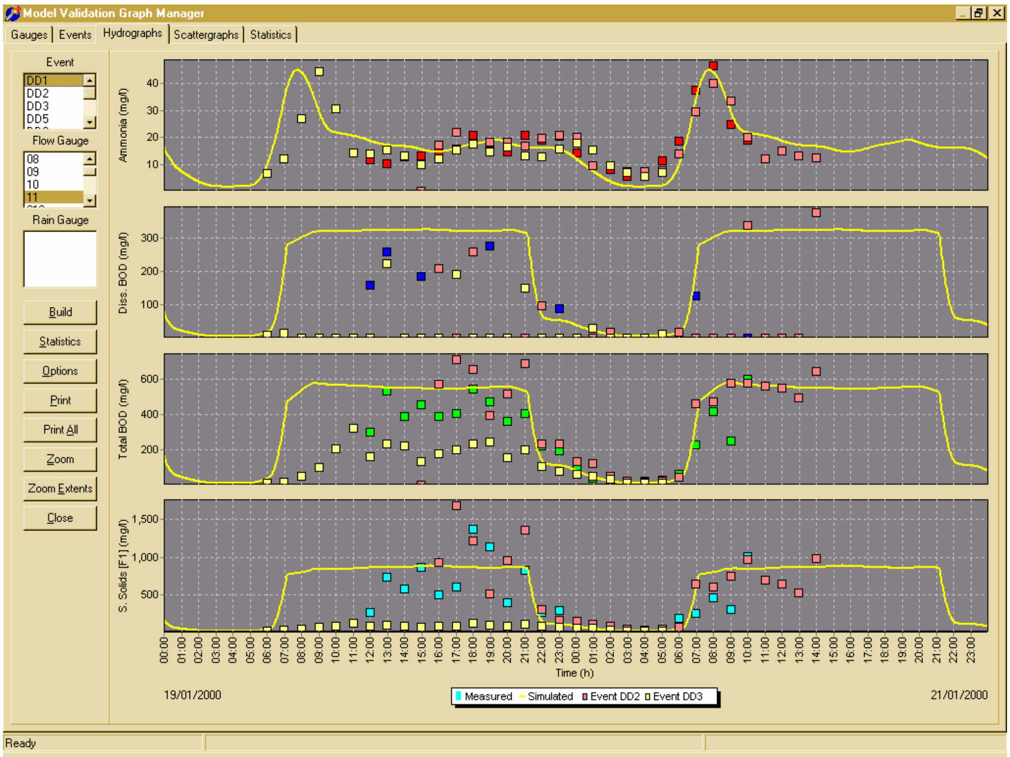

Figure 8. Comparison of Measured DWF Water Quality Parameters with Sewer Network Model showing the Effects of Industrial Inputs and Shift Working.

Table 1. Default Parameters used in Water Quality Modelling of Domestic Areas.

Pollutant Figures	
Usage (l/p/d)	140
Dissolved NH4 (mg/l)	47
Dissolved BOD5 (mg/l)	172
Ave Conc SF1 (mg/l)	390
BOD5 Factor att to SF1	0.56

Average Profile Factor	
Ave Flow	1
Ave NH4	0.94
Ave SS/BOD	0.9

Per Capita Loadings			
	Calculated	Required	Recommended
NH4 (g/p/d)	6.6	6.6	7-6
BOD5 (g/p/d)	55.2	55.2	55-60
SS (g/p/d)	55.2	55.2	55-60

Expenditure on data collection should be carefully managed. To achieve the best results for water quality projects, data collection in the receiving waters could be more valuable to the project. Being conservative in the model by using defaults and focussing on understanding the interaction between the sewerage system and the receiving watercourse can prove more cost effective. The use of WwTW inlet flows can also be used as a lower cost alternative.

Contributing Permeable Areas and Wet Weather Infiltration

Models built with earlier version of simulation software may not benefit from the features of later versions. This is particularly true where run-off is affected by flow from permeable areas and by varying levels of infiltration. In earlier models the traditional Wallingford PR equation may have been used. This relies on actual SMD values for filling the soil store. This system is less flexible then the New UK as the API30 calculates the permeable water store frequently and not just using start conditions.

Run-off from permeable areas may be recognised by a "long tail" on the measured flow hydrograph. Correct replication of the "long tail" is important when upgrading solutions. The traditional answer is to apply New UK runoff to the model, which replicates the time lags and attenuation of permeable surface run-off.

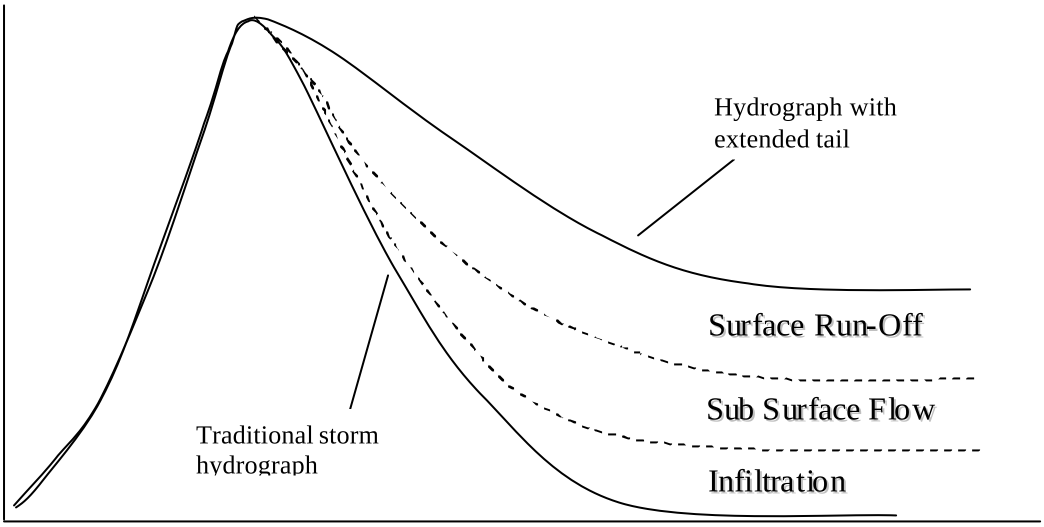

Figure 9. Storm Hydrograph and Factors Causing 'Long Tails'

The longer tails of storms can generally be attributed to three types of flow, as indicated in the graph (figure 9).

- Groundwater Infiltration – Caused by rainfall percolating deep into the ground and causing sufficient rise in groundwater level to cause ground water infiltration.

- Sub Surface flow – Represents the movement of water below the ground but above the groundwater level.

- Surface Run off – Caused when the permeable area is saturated or the rate of rainfall is sufficiently intense that water will run off the surface before percolation can occur.

Representation of these effects can be achieved using the New UK run-off model together with the infiltration module. “InfoWorks models rainfall-induced infiltration and groundwater infiltration using equations based upon the double reservoir model” (InfoWorks Manual 2005).

The infiltration module does not affect the model during the dry periods, but during a storm event acts to replicate the rise in ground water and the reduction in permeable area storage. Verification indicates that the groundwater module tends to over predict flows during the summer months, where soil moisture deficits tend to be larger. Conversely the winter months where permeable areas could be full the addition of the ground infiltration module often produces more representative results. To aid this assessment the use of SCADA data or the installation of systems such as “Hawk Eye” could prove a low cost addition to assessment of seasonal variation.

Great care is needed in adapting existing DAP models to use the New UK Run-off model. Seasonal variations should always be accounted for, when reviewing verification information, Where the 10m rule has been applied then it may be necessary to redefine the contributing areas in the model. The temptation to calibrate the model by adding ad-hoc permeable areas should be resisted since this can lead to an over-representation of run-off during larger storm events, and lead to the over design of upgrading solutions. Nevertheless, the additional run-off generated from permeable surfaces will almost always lead to a greater requirement for sewer upgrading investment. For this example, for a small drainage area of 12 hectares, to provide 20 year protection based upon 2011 uplift values, the New UK rainfall requires 68% more storage volume in a storage tank solution designed to give a 20 year level of protection against flooding.

Conclusions

The paper describes a number of methods in which deficiencies in existing DAP models can be resolved without the need to re-build or completely re-verify them. These are by no means exhaustive, but illustrate that considerable additional benefits can be realised with minimal additional investment in model enhancement and/or field measurement. The paper demonstrates how the modeller can make informed decisions as to the most cost-effective approach to developing models for use beyond their original intended purpose.

Modelling software has advanced greatly in the last 10 years and better algorithms are now incorporated. A sound understanding of the background hydraulics and how this is replicated in the model algorithms is important in getting the most out of an updated model. Additional data collection may be necessary in order to ensure the best results are obtained.

Climate change research has demonstrated that the frequency and intensity of storms are expected to increase in future years (UK WIR 2004). Adapting an existing DAP model to incorporate flood pathways provides the user with a better understanding of above ground flooding issues and hence the most cost effective solution.

The use of defaults for water quality modelling using a verified model in domestic areas leads to cost savings for the client and when used appropriately is not to the detriment of the analysis. This can provide considerable additional benefit without significant additional modelling or survey costs.

Contributing permeable areas can significantly increase required storage volume in flooding solutions, and hence increase cost. Correctly assessing the contributing permeable area and using appropriate run-off models can lead to more cost-effective storage solutions Understanding when to apply the right rainfall parameters is critical, however, and a move to assessing storage solutions using long term time series rainfall may provide more robust solutions in the future.

It is important to note that before any upgrade is made to have access to a good audit trail to gain confidence in the model and carry out a through review of the model and supporting information is critical before progressing.

Upgrading existing models is not a panacea for developing upgrading solutions. In some cases the model may be so far from what is needed that it will prove more cost effective to build a new model from scratch. In such circumstances it may still be possible to re-use old survey data in model build and verification however.

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