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Hydrolink

FLOOD MODELLING – WHAT NEXT?

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Computational flood modelling has been in use for some fifty years to inform decision making in flood management. Over this time there have been significant improvements in the modelling systems as they evolved from standalone simulation codes representing specific rivers, into generic modelling systems combining model building, simulation management and results presentation within a GIS-like framework.

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The marketing material associated with the current commercially-available flood modelling systems paints the picture of comprehensive, integrated, fast and easy-to-use systems that fully meet user needs. However, user experience suggests that this is not the case and further development, underpinned by academic research, is needed as the needs of users continue to evolve.

So, what more do we need from our flood modelling systems? We need them to be faster for building models and faster and more robust for running models. The systems need extended functionality to generate the outputs that the decision makers need now and in the future. The results need to be more accurate, more detailed and easier to use. The modelling process needs to be more efficient and the modelling systems more intelligent so that only 'fit for purpose' results are generated. The whole life cost needs to be controlled and the software must run well on standard IT hardware and use available input data.

These issues are discussed in more detail below from the perspective of a practitioner delivering flood modelling projects. Possible research opportunities to help address these issues are suggested. It is hoped that this article is a useful contribution to the ongoing challenge of aligning IAHR activities with industry needs.

Faster to build and run

The standard flood modelling process includes the following main steps:

(1) Select the optimum modelling approach given the specific project objectives, data availability and time/modeller resources
(2) Build the initial model (collecting new data where required and feasible)
(3) Test, calibrate and validate the model
(4) Undertake production runs and provide quality-controlled processed results

Each of these main steps could be made more efficient and some examples are provided below.

An 'expert system' could be provided to guide modellers through the modelling approach selection process (step 1) – this would require research on which modelling approaches are appropriate for each type of study given the availability of data and other project constraints. Benchmarking studies, such as [1], can provide some of the evidence.

Step (2), the model build process, could be improved through standardisation of data formats. Working with software developers, survey organisations and modellers, the Environment Agency (EA) has recognised this and has developed a 'universal transfer format' (called EACSD) to improve the efficiency of data transfer from surveyors into flood modelling packages. There is the opportunity to develop automated model building modules based on this new format.

Step (3), testing, calibration and validation, could be speeded up through the development of tools that identify common issues and help resolve them, and through automated calibration/validation processes. The danger here is that model parameters are automatically adjusted beyond physically realistic limits in order to produce a good fit to calibration data. In many instances a better solution may have been to change the modelling approach, model schematisation or question the accuracy of the calibration data. Research is needed on combining automated calibration with strategies for identifying deficiencies in the modelling approach, schematisation or calibration data.

Faster run times, step (4), can be achieved through a range of measures. Many of the established modelling systems use numerical solvers that were designed many years ago when computer memory restrictions were a key constraint – RAM is now plentiful and different solvers are likely to be more appropriate. Similarly, the ready availability of parallel processing hardware is a recent change and the traditional solvers may need replacing to make use of parallelisation on either the GPU or CPU. Commercial modelling system developers are already making good progress in this area, but other approaches exist for improving run times; it would be useful if all approaches were assessed systematically and independently to identify which approaches are most likely to make the largest positive impact on run times.

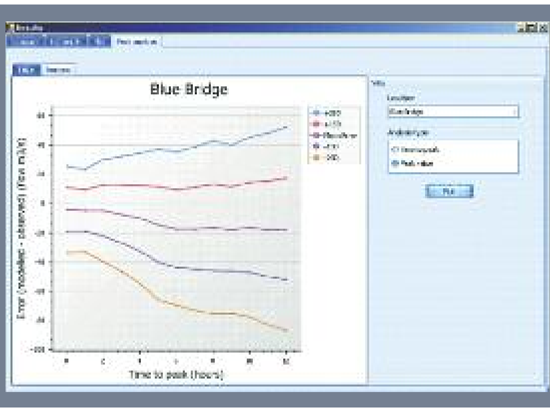

Figure 1.
FORPAST- a Halcrow tool to calculate and communicate how forecast model accuracy varies with lead time

Figure 2. 3D visualisation of flooding (ISIS 2D)

Extended functionality

Flood modelling is used to inform a large range of types of flood management decisions, including issue of flood warnings, setting design levels for new flood embankments, and understanding how plausible ranges in future climates will impact on flood risk. Each of the types of flood decisions may require different functionality in the flood modelling systems. The most common requirements of maximum water levels and flood inundation extent for single events are well catered for by the established modelling systems. However, user needs are evolving and may require new functionality informed by research activities. Examples are provided below.

Traditionally, flood mapping shows single sources of flooding (e.g. fluvial flooding, coastal flooding or surface water flooding). However, there is a growing understanding that 'all sources' mapping is required that enables stakeholders to understand the likelihood of flooding (from any one or multiple sources). There is thus the growing need for practical modelling approaches to generate this 'single value' of flood risk at a point. Interactions between different sources need to be included as does joint probabilities. A step towards an 'all sources' method was made by the Environment Agency [2] and the method (called MAST) is now implemented in the ISIS modelling system. However, further research is required, for example, to improve the method used for accounting for dependencies.
Flood depth and inundation extent will remain core outputs from flood modelling, however other outputs are required in order to better understand and manage the impacts of flooding on people, property, infrastructure and the environment. Risk to life is a key factor and while some modelling systems already generate a 'hazard rating', there is much more that should be done to improve the predictions of flood risk to life – particularly as in some countries flood-related deaths tend to be related to car travel. The debris carried by flood water is a key hazard in itself and also affects the flow paths (for example bridge openings blocked by trees or cars). Pollutant transport and morphological change during flood events are further potentially important factors which are usually ignored in flood modelling. While some methods already exist to enable simulation of these processes, standard practical approaches do not exist and therefore these are likely to be useful areas for research.

There is a growing need to better understand and communicate uncertainty in modelling outputs - improved methods are required to understand how the uncertainties in input data and modelling processes affect the outputs. This is an active research area (e.g. [3]) but no practical approaches have yet become standard in flood modelling practice. Methods to communicate uncertainty information targeted at different types of users are also required.

More accurate

The most important requirement is that the modelling results are of sufficient accuracy to support robust decision making. For some uses, relatively low accuracy is sufficient (e.g. broad scale analysis of future climates to help understand the potential magnitude of future flood risk). Whereas for other uses much higher accuracy is required (e.g. setting of crest levels for new structures designed to control flood flows). The challenge is to identify the situations (physical processes and flood management decisions) where the current flood modelling methods are not sufficiently accurate and then develop methods that provide the required accuracy. Figure 1 shows an example of how to communicate the variation in forecasting model accuracy with lead time.

In many cases it may not be appropriate to improve the representation within the base flood modelling system and a better approach would be to link through to different solvers. The OpenMI (www.openmi.org) standard has been developed to facilitate the simulation of interacting processes through enabling different models to exchange data as they run. OpenMI provides opportunities for researchers to dynamically link their research codes through to commercial modelling systems.

Easier to use and more intelligent systems

Commercial flood modelling systems are capable of producing vast amounts of different types of outputs. For end users, it can be challenging to extract from this mass of data the key information that is required to inform the decision. Another challenge can be to present the information in a way that is easy for the decision maker to understand (where the understanding needs to also cover the confidence they should have in the information). Visualisations using 3D photorealistic animations can be a very accessible way to present flood simulation data to non-modellers (e.g. Figure 2). A research area which would require collaboration between different academic departments would be to develop such 3D visualisation methods that also enable the uncertainty information to be communicated to stakeholders. A more general need is the development of guidance on how best to present flood modelling outputs for specific flood management decisions. An example of a product specifically developed for one use (real time flood incident decision making by non-modellers, thus focusing on ease of use and resilience) is FloodViewer (Figure 3).
The concept of an expert system to help decide on the overall modelling approach was introduced earlier. This could be extended to support the full modelling process and could cover aspects such as: suitable grid sizes and time steps, advice on suitable parameter selection including roughness (e.g. www.river-conveyance.net), and advice on how to decide if the outputs are sufficiently accurate for the intended use. Some of these aspects would require further research and development.

Best use of available IT technology and data

Making best use of modern IT and data acquisition technologies are two key ways to improve the flood modelling process and manage whole life costs. New IT technologies, such as cloud computing, GPUs, mobile devices and touch screen devices, provide opportunities for step changes in flood modelling. Perhaps even more significant change will be provided through new data acquisition technologies. The ready availability of terrain data from LIDAR has already transformed flood modelling in the UK where 2D modelling of floodplains is now the norm. Data from satellites and from widespread terrestrial sensors may have the same transformational impact in the future (perhaps a Google 'River View' for all water courses and including elevation data). While some of these new data sources will be high cost, others may be free to use (such as Google Earth, Google Street View and OpenStreetMap).

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IAHR role

Further advancements in flood modelling systems are inevitable. The commercial software developers will be leading many of the advancements but there are clear roles for other members of the IAHR community to ensure developments are aligned with user needs and are scientifically robust. Some end users are seeking to drive the underlying research through publication of research strategies (e.g. [4]). Other developments will be on the back of external catalysts (such as satellite data or IT industry breakthroughs). Modellers themselves are also introducing innovation as they use available systems and data to meet the needs of their internal or external clients. Academics are looking for both challenge-led and discovery-led research opportunities in flood modelling.

IAHR has an important role in disseminating research outputs and, perhaps more importantly, encouraging collaboration between the various stakeholders to ensure advances in flood modelling meet the evolving needs of decision makers. IAHR can help develop ideas and new ways of thinking while ensuring that the hydraulic fundamentals are not forgotten. We live in a connected world which is becoming even more connected - IAHR has the opportunity to play a pivotal role in steering further advances in flood modelling which can lead to benefits for communities at risk of flooding throughout the world.

References

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Figure 3. FloodViewer – making flood mapping data easier to use in emergency situations (www.halcrow.com/floodviewer)