Benchmarking of 2D hydraulic modelling packages

Project Summary SC080035/R2

Environment Agency Report, SC080035/SR, "Desktop review of 2D hydraulic modelling packages", (© copyright: Environment Agency, 2009) discusses the theoretical background to 2D flood inundation modelling and makes recommendations for benchmark test cases to differentiate between 2D model types in terms of performance and predictive capability. The work reported here builds on this through further development of the benchmark test cases, the application of a range of software packages to these tests and comparative reporting of the outcome from the tests.

The objectives of this project are to provide:

1. Evidence to ensure that 2D hydraulic modelling packages used for flood risk management, by the Environment Agency and their consultants, are capable of adequately predicting the variables upon which flood risk management decisions are based.
2. A data set against which such packages can be evaluated by their developers in the future.

An open invitation to participate in the exercise was issued to all developers of 2D flood inundation software known to be applied in the UK. This resulted in a positive response from the suppliers of fourteen software packages. Of these ANUGA, FloodFlow, Infoworks 2D, ISIS2D, MIKE FLOOD, SOBEK, TUFLOW and TUFLOW FV solve the shallow water equations, alternatively some packages solve simplified equations. Packages in this category are:

1. JFLOW-GPU, and UIM which solve the 2D diffusion wave equation.
2. RFSM (Direct), employs a technique based on continuity and topographic connectivity.
3. Flood Risk Mapper, Flowroute and RFSM (Dynamic), use continuity to distribute flood volume between storage areas and then compute flow rates between these using Manning's equation or a weir flow equation.

It is important to note that the version of JFLOW used in the benchmarking exercise is JFLOW 7.1 GPU. This is a significantly different package from JFLOW 7.0 CPU currently used internally within the Environment Agency. Environment Agency users of JFLOW 7.0 CPU and JFLOW 7.1 CPU should not draw any conclusions on their fitness for purpose from the JFLOW 7.1 GPU simulations reported here.

Packages based on the shallow water equations are appropriate to support decision making across the full range of Environment Agency flood risk decision making. Exceptions to this apply where:

1. The area of application is large 1000 Km^2 or a probabilistic approach requiring multiple simulations is required. In such instances, the time taken to run simulations may be prohibitively long;
2. Where the detail of supercritical to subcritical flow transition is required, such as, in areas close to a dam or embankment breach. If this level of detail is required the numerical scheme used by the software has an influence on capturing the detail of the flow field. The results indicate that packages which employ a shock capturing numerical scheme (ANUGA, InfoWorks 2D, ISIS2D (TVD version), SOBEK and TUFLOW FV perform better in such circumstances.

Water levels predicted by packages based on simplified equations, Flowroute, JFLOW-GPU and UIM, predict water levels comparable to those predicted by shallow water equation packages. Where their performance is less comparable is in the prediction of velocities (with predictions often oscillating in rapidly varying flows), and in areas where momentum conservation is important, such as the prediction of water levels and velocities in the complex flow field close to a dam failure and where the spreading flood encounters an adverse slope on the floodplain. The comparisons of run-times indicate that there is no consistent saving in computational effort in applying simplified equation packages compared to shallow water equation packages for the tests reported here. However, this maybe a consequence of the scale of the tests used here which are over smaller domains than one would typically apply a simplified model to.

Where clear flow paths across the floodplain exist, RFSM (Direct) produces predictions of final inundation extent and depth that compare well with shallow water equation packages. For more complex topographies the comparisons diverge. This limits the application of RFSM to relatively large scale applications where dynamic effects are less significant in determining the direction of water movement. In all cases RFSM (Direct) requires significantly less computer effort than the other software packages.

The water level predictions made by Flood Risk Mapper and RFSM (Dynamic) show considerable variation with those from shallow water equation packages. Further work on these packages is necessary before they can be reliably applied to Environment Agency problems.

FloodFlow predictions deviated from the benchmark test specifications through the use of a depth varying value of hydraulic roughness. As a result the predictions are not directly comparable with those from the other packages and it was not possible to draw quantitative conclusions of its performance relative to the other packages.

The benchmark comparisons also highlighted a number of other issues of practical relevance to Environment Agency flood risk modelling.

Firstly, where 1D to 2D model linking is used to simulate river to floodplain flood volume exchange, the packages applied used different methods to simulate the hydraulic connectivity between the river and the floodplain. This resulted in significantly different predictions of the volume of water exchanged between the river and the floodplain. This has a knock on effect to the prediction of floodplain inundation and velocity. Predictions made using 1D river to 2D floodplain linking are therefore unlikely to be consistent between software packages. Further research is required to better understand the significance of this.

Secondly, significant differences (up to 100%) in velocity predictions were obtained for high resolution (2m grid) inundation modelling in urban areas. This suggests that a 2m grid is insufficiently fine to adequately resolve the underlying topography for this class of simulation and that, predictions of velocity will not be consistent between packages when applied to the same problem at grid resolutions greater than 2m.

Finally, when applied to the simulation of large scale valley inundation predictions from TUFLOW, ANUGA, and to a lesser extent MIKE FLOOD oscillate in some locations. This results in higher water level and velocity predictions than those obtained by the other shallow water equation packages. Using these predictions to create maps of maximum inundation and velocity could result in exaggerated inundation extent and velocity magnitudes.

For further information on accessing the benchmarking data and the results from the study please contact: fcerm.evidence@environment-agency.gov.uk.

The results and conclusions in this report are accurate at the time of publication, but they represent a ‘snap-shot’ in time. It is likely that development work will be undertaken on the software packages discussed in this report, and so in time it is possible that the results and conclusions may become less relevant to individual software packages. However, the conclusions which compare the generic use of models using the full equations and those using the simplified equations will probably be relevant over a longer time period.

This summary relates to information from Project [SC080035], reported in detail in the following output(s):-

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