2D OR NOT 2D? – AN AUSTRALIAN PERSPECTIVE

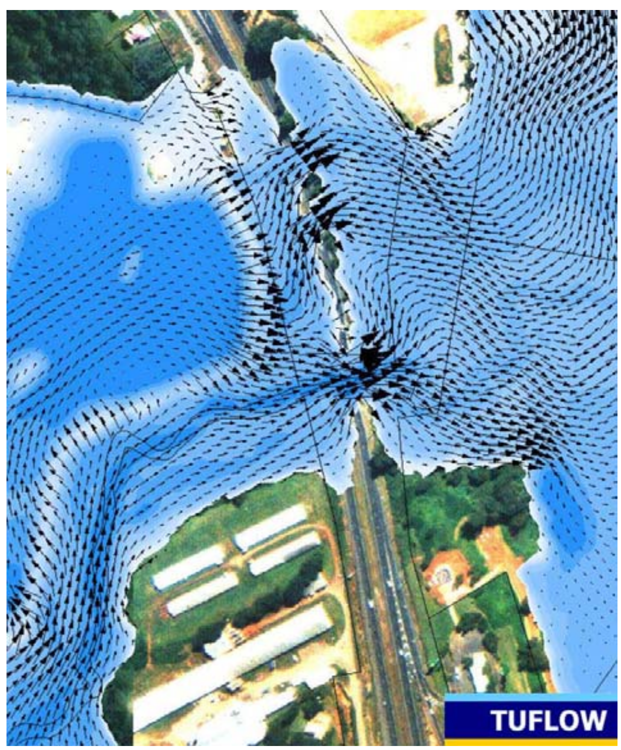
BILL SYME
WBM Pty Ltd

Key Words: 2D Flood Modelling, TUFLOW, ISIS

Abstract:
Australia, like elsewhere, suffers socially and economically from flooding, with an annual average direct damages bill in excess of $300million. Federal, state and local government policies and guidelines address this issue through a framework of objectives on how to assess, quantify and mitigate flood risks. Accurately predicting flood hazards to help identify the risks, within the array of uncertainties the practitioner deals with, is often a challenge.

2D and 2D/1D flood-modelling software has been researched, developed and embraced within Australia since the early 1990s, and is today, for many flood investigations, mandatory. Compared with 1D solutions, 2D or the combination of 1D and 2D, considerably improves the quality and accuracy in quantifying flood hazards. The primary benefits from 2D are: more accurate solution of the governing equations; two or three orders of magnitude higher resolution output; flowpaths do not have to be pre-defined; vastly more accurate mapping of flood inundation, flood levels and flood hazard; and importantly, the modelling is more easily understood and accepted by stakeholders. The primary disadvantage is the longer simulation times compared with 1D solutions. The pros and cons of 2D and 2D/1D flood modelling are discussed and illustrated through several examples.

INTRODUCTION
Managing the risk to property and people from flooding requires an understanding of the flood hazards, and how they spatially vary. Flood hazards are a function of flood depth, velocity, duration, warning time, ease of evacuation, etc. Quantifying hazards has traditionally been a difficult and subjective exercise, especially in urban areas and floodplains where the flow patterns are complex, and the limitations of 1D modelling add significant uncertainty to the process.



2D Flood Modelling in the late 1990s.

2D solutions can greatly reduce the uncertainties in predicting flood behaviour, and therefore in quantifying flood hazards. They are computationally intensive and data rich, producing on a fine resolution the variation in water level, depth, velocity and flood hazard.

As 2D solutions are not forced to follow pre-defined flowpaths, they are well suited to areas where the flows spread out and follow the lie of the land (eg. along streets and through properties). In these situations, 2D solutions have considerably less uncertainty than 1D solutions. They are, however, computationally much more intensive, and take significantly longer to process. They are also data intensive and require an accurate DEM.

Australian practitioners started applying 2D models to flood studies in the early 1990s. Their application today is now common with many flood studies specifying that a 2D approach be applied.

CASINO FLOOD STUDIES (1998-2001)

The township of Casino is located on the banks of the Richmond River, northern NSW. The local Council commissioned a Flood Study and Floodplain Risk Management Study in the late 1990s, that investigated a wide range of flood mitigation measures. Some of these measures were structural, which would affect the flood behaviour and potentially exacerbate the flood risks in some areas.

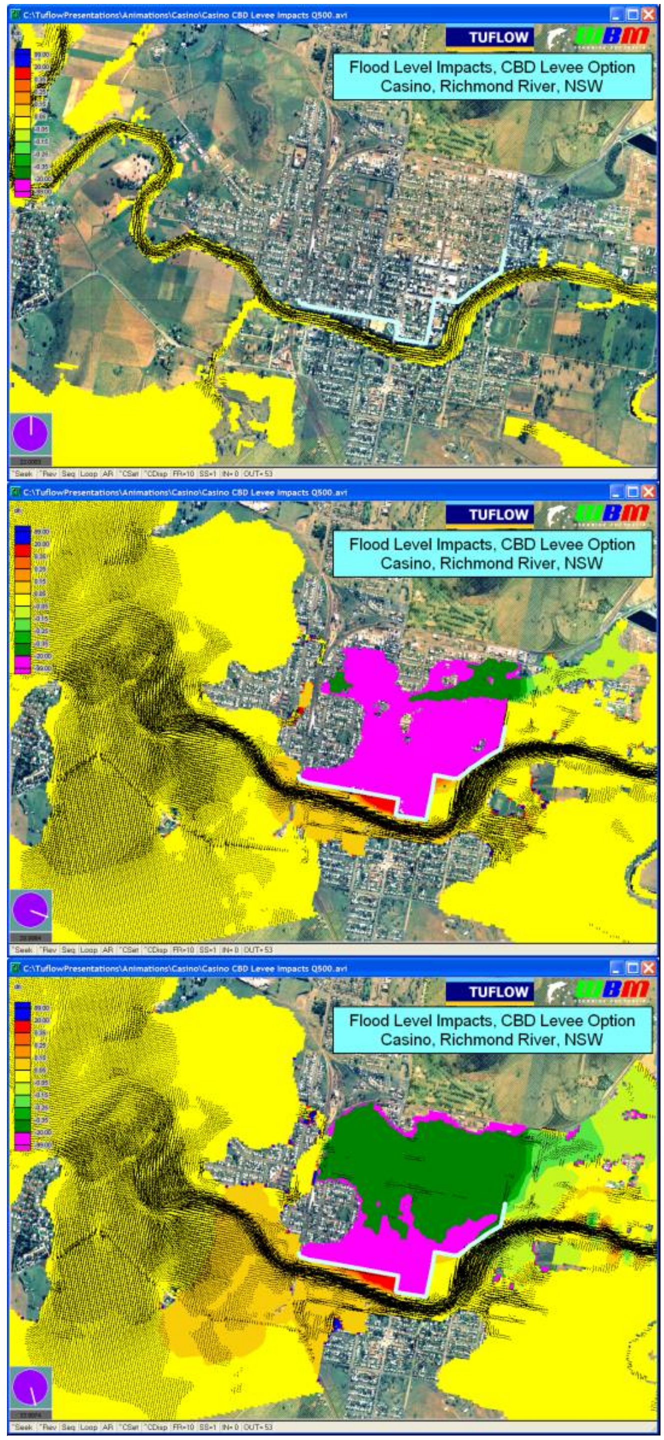
A 1D MIKE 11 model was developed and used for the Flood Study. The 1D representation, whilst networked to separate in-bank and out-of-bank flowpaths, was considered to over-simplify the complex hydrodynamic processes at the river bends and on the floodplains. Consequently, a TUFLOW 2D/1D model was constructed, calibrated and used to predict the change on flood behaviour of various mitigation measures.

The three video stills show the effect of one of the levees assessed. The yellow shade indicates less than 5cm change in flood level; orange to red shades indicate an increase in flood level; and green shades a decrease. The pink shade shows areas that were previously flooded, but would now be flood-free. The three stills are at the start, before the peak and near the peak of the flood.

There are significant benefits to the town as shown by the pink and green shades. There are also significant areas of adverse flood impacts to the south and west of the levee as indicated by the orange to red shades.

Conducting this assessment using a 2D approach provided considerable benefits to the study. The primary ones were:

- Significant improvement in the accuracy of the computer modelling.
- The ability to predict the spatial variation in flood impacts on a fine scale.
- Much improved understanding and more informed decision making by the steering committee.
- Immeasurable improvement in the community's appreciation and acceptance of computer modelling.



Computer video stills showing the effect on flood levels of a proposed levee using a 2D TUFLOW model.
The yellow areas indicate less than 5cm change in flood level; the orange/red shades an increase in flood level; and green shades a decrease. Pink areas were previously flooded, but are now flood-free if the levee is built.
The three stills are at the start, before the peak and at the peak of the flood.

2D RESOLUTION AND EMERGENCE OF 2D/1D MODELS

2D solutions offer orders of magnitude improvement in computational resolution compared with 1D schemes. However, the practitioner needs to be conscience of the limitations. These are primarily:

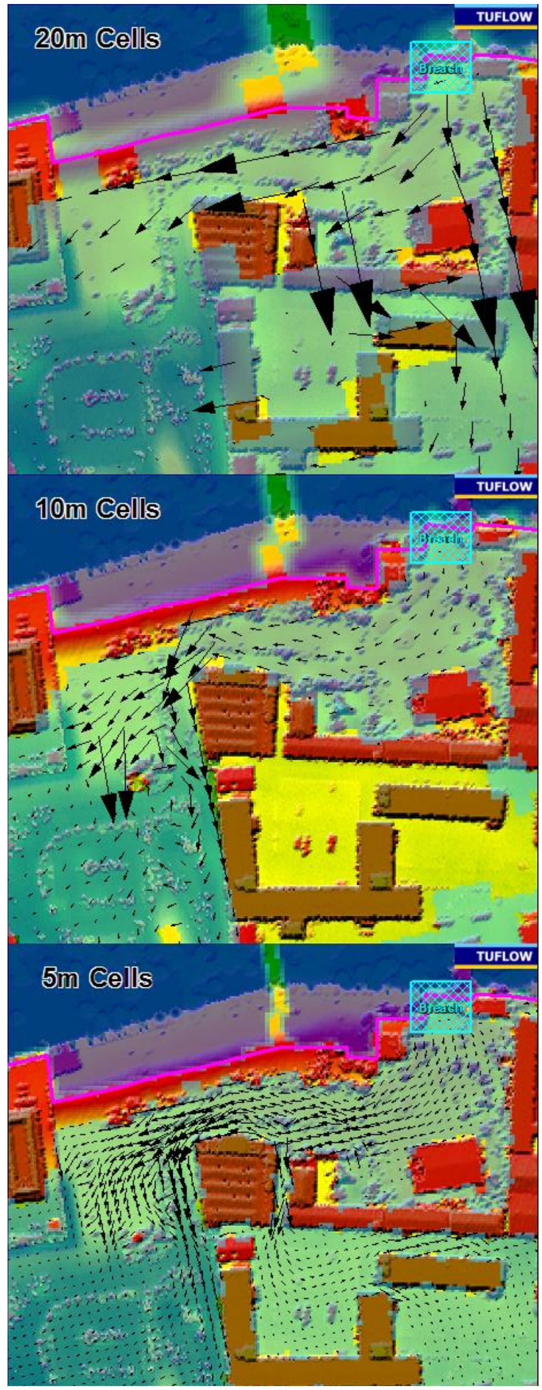
- Much longer simulation times.
- The 2D resolution must be sufficiently fine to represent the topography of the key flowpaths.

There often arises the need to balance long simulation times with the fineness of the 2D resolution. Variable mesh schemes (eg. finite element solutions) may offer an advantage in this regard by allowing varying element sizes, however, these schemes have found to be much more computationally slower than fixed cell size schemes (eg. finite difference solutions), and have considerable difficulty maintaining stability when modelling floods.

Whether the scheme uses a fixed or variable element size, the important issue is that the resolution is fine enough to adequately depict the topography of the key flowpaths. To illustrate the effect of cell size in an urban environment, the images show the flow patterns predicted from a breach in the flood defence walls near the Thames Barrier. The top image is for a 20m cell size, the middle 10m, and the bottom 5m.

Quite different flowpaths and inundation behaviour are predicted. The 20m resolution is too coarse to pick up the blockage effects of some of the buildings. The 10m resolution depicts the buildings much better, but fails to pick up some key flowpaths between the buildings. The 5m resolution, as would be expected, provides the best prediction. The disadvantage of the 5m resolution is that it will take approximately eight (8) times longer to compute than the 10m resolution and 64 times longer than the 20m. The factor of 8 arises from there being four times as many cells and the computational timestep usually needs to be halved.

This issue has lead to the emergence of 2D/1D models that offer the ability to merge 1D and 2D representations. A 1D solution can be used to represent narrow flowpaths such as rivers (in-bank), drains, hydraulic structures and underground pipes, thereby alleviating the need to use small 2D elements.



The above images show the different flow patterns arising from using three different 2D resolutions. In this instance, it is clearly beneficial to use a cell size of around 5m or smaller to reproduce the expected flowpaths.

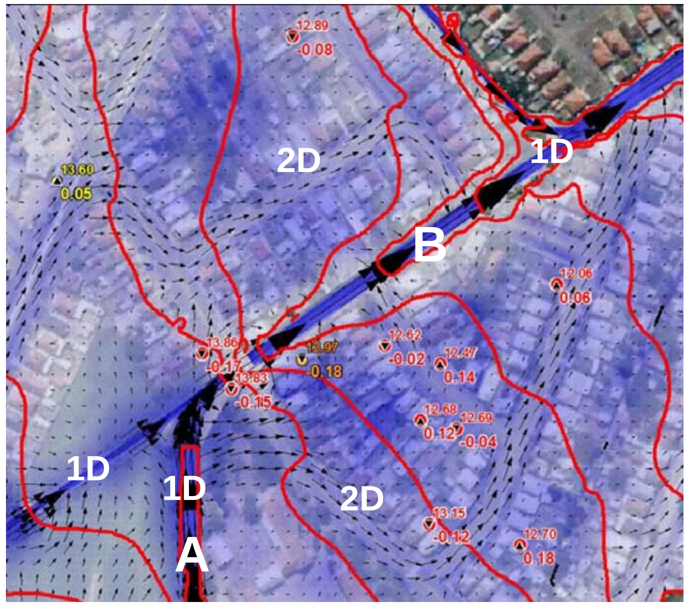
(The images are from the Thames Embayments Inundation Study being carried out by Halcrow and HR Wallingford for the UK Environment Agency.)

The TUFLOW software (www.tuflow.com), which was the product of R&D into dynamically linking 1D and 2D solutions in 1989/90, has led the way in this field. TUFLOW has also recently been merged with the ISIS software, offering the UK industry the opportunity to value add to existing ISIS models through the insertion of 2D domain(s) where the 1D solution is limited.

THROSBY CREEK FLOOD STUDY, NEWCASTLE, NSW, AUSTRALIA (2005-06)
A good example of 2D/1D model is that of Throsby Creek. The creek's catchment contains much of Newcastle's urban expansion since the mid 1900's. Creeks were realigned, covered and replaced by concrete channels and large box culverts. Rail, road and other embankments, and under designed structures, exacerbate the problem by diverting and blocking floodwaters (as was amply demonstrated during the 1988 and 1990 floods). Flood behaviour has changed dramatically, and made far more difficult to model than in the catchment's natural state.

The study area presents a range of modelling challenges including:

1. Several hundred box culverts.
2. Over a hundred bridges.
3. Underground pipe network.
4. Hundreds of open channels.
5. Complex overland flow.



The first four points above are best represented using 1D solutions, while the last one is suited to a 2D solution. A TUFLOW 2D/1D model was developed to represent this array of 1D and 2D flow patterns. The software's powerful 2D/1D linking options were critical to easily setting up the model, especially given the several thousand 1D elements linked into the surrounding 2D domain.

The image shows the flow patterns (velocity arrows), water level contours (red lines) and depths (blue shades) as predicted at the peak of the 1990 flood for a small section of the model. The recorded 1990 flood levels (smaller numbers) and the difference between the modelled and recorded level (larger numbers) are also shown.

Of note is the water levels, as shown by the red contours at 0.5m intervals, vary significantly across the flowpath. Where the water leaves the main channel (A), flood levels are higher in-bank than on the floodplain. Where the water returns to the channel (B), levels are substantially higher on the floodplain. The photo, taken just downstream of this area during the 1990 flood, shows overland flows (C) returning to the channel as the floodwaters recede (fortunately the model also shows this effect!). Accurately modelling this area in 1D would have been problematic and of poor accuracy, whereas the 2D/1D solution handles the problem well.

CONCLUSIONS
Extensive and wide-ranging application of 2D flood models in Australia over the last 15 years has greatly benefited the Australian industry and flood affected communities. With realisation of the benefits, 2D solutions are now common and often mandatory for the larger flood studies.

The powerful 2D/1D linking options of TUFLOW has led to the evolvement of complex 2D/1D models, offering the modeller the advantages of using both solutions in the one model. In the UK, the merging of the ISIS and TUFLOW software offers a great opportunity for the UK industry to embrace the benefits of 2D/1D models, and to build upon the substantial investment in 1D ISIS models to-date.

REFERENCES

Please refer to the publications available from http://www.tuflow.com/Downloads_Publications.htm.