TOWARDS A CATCHMENT BASED MODEL AFTER TWO DECADES OF MODELLING IN THE RICHMOND

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Abstract

The past and present approach to flood risk management in NSW has been to develop Flood Risk Management Plans (FRMPs) for targeted urban villages and towns located on floodplains. FRMPs are usually funded jointly through Local and State Government programs and are often based on individual council's need and available budget at the time.

For some smaller catchments this approach meets its purpose. However, for most larger catchments a range of issues are evident, including:

- inadequate coverage of rural areas;
- poor synchronisation of FRMPs;
- discrepancies at model interfaces;
- inconsistent modelling and mapping approaches; and
- inadequate use of flood information for flood response.

This disjointed approach has its limitations from a flood risk management perspective; not only is it narrowly focused but also costly to State and Local Government.

The Richmond River catchment in northern NSW offers a prime example of the limitations with the conventional flood risk management process. The majority of the catchment covers five local government areas. Over the past two decades, separate flood studies and FRMPs have been prepared for Kyogle, Lismore, Casino, Ballina, and some of the rural villages between. A combination of modelling methods have been applied using three hydrologic programs, five hydraulic programs, totalling 15 separate flood models.

The benefits of a catchment based approach to flood risk management are clear, and the Richmond River County Council and the Office of Environment and Heritage are making progress towards consolidating floodplain management in the Richmond. Individual flood models are being coupled together into a modular 'mega-model' based on catchment, rather than local government boundaries.

The catchment based model provides a platform for multiple uses. Locally it has been used in a post-doctoral study for modelling sea level rise and the associated impacts on coastal wetlands and water quality, developing a retreat strategy for asset management, and improving flood risk management across rural areas where population growth is a major consideration.

In a local government managers context the model also provides an information resource to review flood mitigation assets if they are redundant in the current world requirements. Given that some assets are over 50 years old, and given changes in land use and community expectations, some assets could be rationalised or removed. This could reduce costs and in some cases restore natural drainage paths on the floodplain and lead to environmental repair.

Introduction

The floodplain management process followed in NSW is defined in the NSW Floodplain Development Manual. Following formation of a Floodplain Management Committee, the process involves five sequential stages:

1. Data Collection
2. Flood Study (FS)
3. Flood Risk Management Study (FRMS)
4. Flood Risk Management Plan (FRMP)
5. Plan Implementation

Data collection is an ongoing process, although hydrographic and topographic data are usually collated and documented as part of the Flood Study stage. Following completion of the Flood Study, the Flood Risk Management Study and Plans are prepared, generally commissioned as one combined project. The past and present approach in NSW has been to develop FRMPs for targeted urban villages and towns located on floodplains. FRMPs are usually funded jointly through Local and State Government programs and are often based on individual council's need and available budget at the time.

In large catchments where there are multiple villages, towns and administrative regions, the floodplain management process is often disjointed in space, time and technical approach.

This paper uses the Richmond River as an example of where a catchment based approach to floodplain management can offer a more consistent and efficient approach.

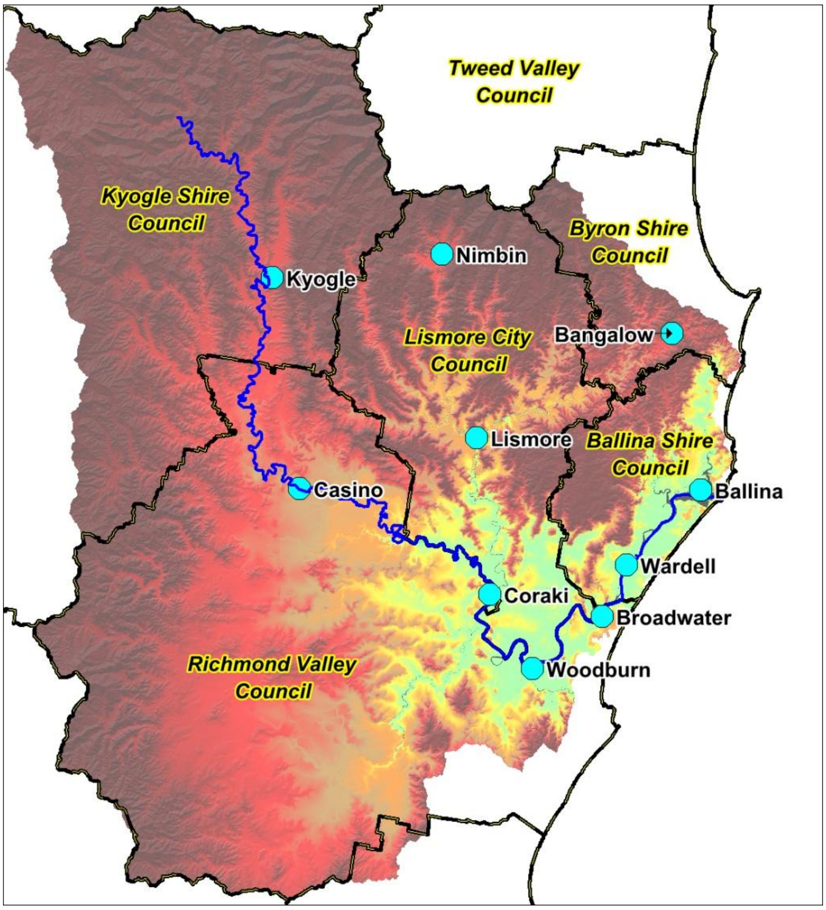

Figure 1: Richmond River Topography and Local Government Areas (green indicates lower elevation)

History of Flood Modelling in the Richmond

Up until the 1990's, flood modelling in the Richmond, like in most other Australian catchments, revolved around one-dimensional (1D) representation of the rivers, associated floodplains and the estuary. Refer to Figure 2. The functionality of some software enabled complex flood behaviour to be represented reasonably well. Typical inputs into the 1D models were cross section survey of the rivers and floodplains, together with survey of hydraulic controls such as weirs and levees. Topographic maps were used to define the storage within the floodplains. The accuracy of these models, as with most models, was essentially proportionate to the accuracy of the input data.

Figure 2: One-dimensional Flood Mapping from 1997 Ballina Flood Study (water levels at nodes; discharge along channels)

As access to faster computers and aerial survey improved in the 1990's, the opportunity arose to assess flood behaviour using a two-dimensional (2D) approach. Today, most flood studies in Australia are based on a combination of 1D and 2D modelling methods. The ability for most commercially available software to dynamically link 1D and 2D domains offers substantial flexibility to the user. The 1D/2D models offer greater accuracy, functionality and flexibility associated with flood mapping and mitigation assessment. Refer to a Figure 3 which shows 1D/2D flood mapping from part of the same area shown in Figure 2.

Since 2000, the original 1D models of the Richmond have been progressively upgraded, making use of high resolution aerial survey. As model upgrades have been associated with FRMPs or flood impact assessments of infrastructure, the focus of each flood model has been on a specific part of the catchment. Over the past two decades, separate flood studies and FRMPs have been prepared for Kyogle, Lismore, Casino, Ballina, and some of the rural villages between. A combination of modelling methods have been applied using three hydrologic programs, five hydrodynamic programs, totalling 15 separate flood models. Refer to Table 1 for list of studies, date of completion, software used and modelling technique.

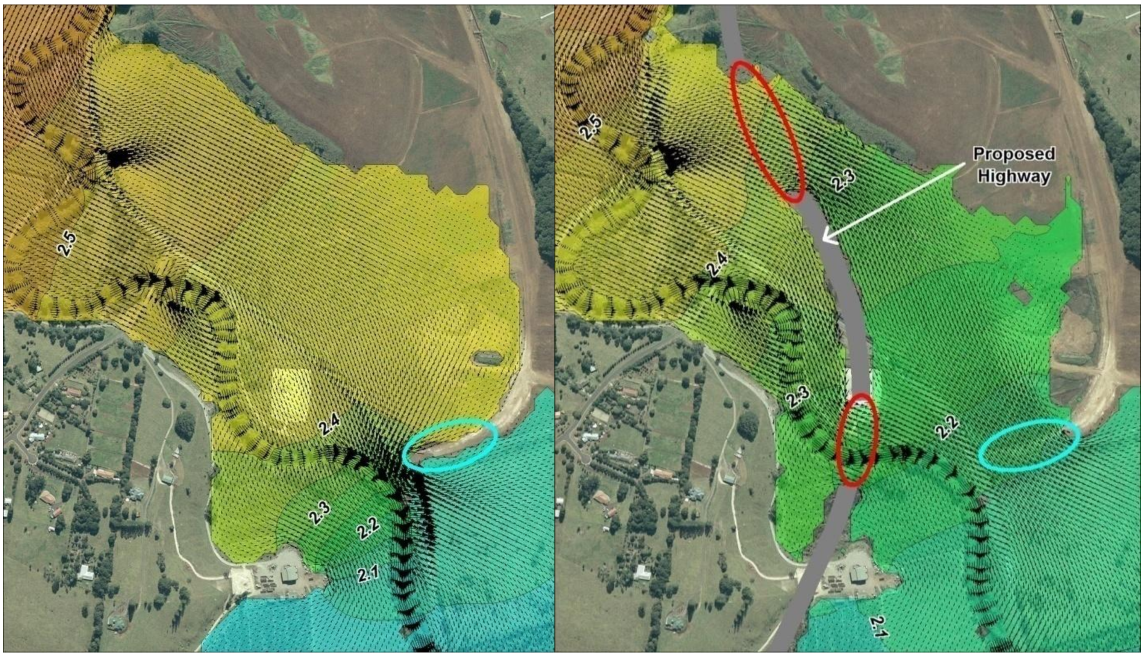

Figure 3: Two-dimensional Flood Mapping from 2009 Ballina Bypass FIA (water level contours and velocity vectors)

Table 1: Flood Modelling History of the Richmond River Catchment

Year Completed	Location	Purpose	Software	Modelling Method
1993	Lismore	FS	Mike 11	1D
1997	Ballina	FS	Estry	1D
1998	Casino	FS	Mike 11	1D
1999	Mid-Richmond	FS	Mike 11	1D
2000	Deep Creek	FIA (Summerland Way)	Tuflow	1D/2D
2002	Casino	FRMS	Tuflow	1D/2D
2002	Lismore	FRMS	RMA2	2D
2003	Mid-Richmond	FRMS	Estry	1D
2004	Kyogle	FS	Tuflow	1D/2D
2004	Tuckombil Canal	FS	Tuflow	1D/2D
2006	Woodburn	FIA (Pacific Hwy)	Sobek	1D/2D
2006	Newrybar Swamp	FIA (Pacific Hwy)	Tuflow	1D/2D
2008	Ballina	FS Upgrade	Tuflow	1D/2D
2009	Kyogle	FRMS	Tuflow	1D/2D
2009	Wardell and Cabbage Tree Island	FRMS	RMA2	2D
2009	Ballina	FIA (Ballina Bypass)	Tuflow	1D/2D
2010	Mid-Richmond	FMS	Tuflow	1D/2D
2011	Ballina	FRMS	Tuflow	1D/2D
2012	Newrybar Swamp	FRMS	Tuflow	1D/2D

Note:
FS – Flood Study
FMS – Flood Mapping Study
FRMS – Flood Risk Management Study
FIA – Flood Impact Assessment

Issues

From a modelling perspective, five local government areas using various different modelling methods and software is highly undesirable. For some smaller catchments this approach meets its purpose. However, for larger catchments a range of issues are evident, including:

- inadequate coverage of rural areas;
- poor synchronisation of FRMPs;
- discrepancies at model interfaces;
- inconsistent modelling and mapping approaches; and
- inadequate use of flood information for flood response.

Each of these issues are discussed in the following sections.

Coverage of Rural Areas

The towns of the Richmond River catchment are spread out across the catchment with up to 25km of agricultural land between. In the past, the focus of FRMPs has primarily been on the urban areas, hence, there have been substantial gaps in the flood mapping coverage.

In the Richmond, individual Councils (with the assistance of Richmond River County Council and the NSW Office of Environment and Heritage) have been expanding the flood mapping coverage to fill the gaps between previous studies and develop catchment wide flood mapping, covering both rural and urban areas.

Synchronisation of FRMPs

The preparation of Flood Studies and subsequent Flood Risk Management Plans have been undertaken at different times for different areas in the Richmond. For most flood modification works proposed, this has not been a major issue, as the impacts (positive and negative) have generally been confined to the extent of the study.

Figure 4: Lismore Levee during the May 2009 Flood Event - A Potential Levee Breach has been assessed using the Modular 'Mega-model'

In cases where floodplain management measures overlap between study areas, there is the potential for recommendations to vary from one study area to another. An example could be proposed planning measures incorporated in the relevant Council's Development Control Plan. In some cases planning measures have varied from one area to another within the same local government area (LGA), each recommended from separate studies according to the needs of the particular study area.

Model Interfaces

Another key issue from a technical perspective are discrepancies between flood behaviour and associated peak flood levels where models overlap. This issue is primarily related to the application of model boundary conditions.

During each individual study, boundary conditions were selected, applied and tested, to ensure the choice of boundary condition would not affect modelled flood behaviour at the particular area of interest, i.e. downstream of a hydraulic control such as a narrowing of the floodplain. In two locations in the Richmond, overlaying the results from two separate models (different data, software and/or consultants) has highlighted the need to exercise caution when using flood mapping close to the upstream and downstream extents of models.

Modelling and Mapping Approaches

The approach used for modelling varies between the separate models, often due to data availability and software used. However, a step to resolving this issue is the recent upgrade of all models to include 2D representation of the floodplain. In most cases, rivers and creeks are still represented in 1D.

Whilst a consistent modelling approach is feasible, the mapping of flood risk precincts is complicated to standardise. Each Council has a specific formulation for flood hazard depending on local factors. Richmond Valley Council have developed an interactive website for flood mapping across their LGA. The flood mapping was prepared during the 2010 Richmond River Flood Mapping Study, which covers a substantial area of the Lismore City LGA. With both Councils having different flood hazard definitions, there is a discontinuity along LGA boundaries.

Flood Response

A common issue to most parts of Australia is the inadequate use of flood mapping in an operational context. During flood emergencies, response agencies often default to local knowledge of past flood behaviour, rather than make use of the information available from Flood Studies and Flood Risk Management Studies. A factor which could contribute to this issue is the numerous, and sometimes conflicting, studies available for a single catchment.

Further, a collection of localised flood models has limited use for flood warning purposes. Response agencies require an overview of the complete hydrologic system, rather than having to waste time making interpretations between separate sources of information.

Towards a Catchment Based Model

The benefits of a catchment based approach to flood risk management are clear, and the Richmond River County Council and the Office of Environment and Heritage are making progress towards consolidating floodplain management in the Richmond. Individual flood models are being coupled together into a modular ‘mega-model’ based on catchment, rather than local government boundaries.

Technical Aspects to Modelling

A constraint in the past to the development of such a large model has been computer processing time. With recent additions to the TUFLOW hydrodynamic software, the model has been designed in a database format. All GIS modelling layers and files are stored in a modelling database, with a master model run file. The Richmond River floodplain is divided into seven sub-models which can be run in isolation, or in combination with other neighbouring sub-models. Refer to Figure 5 for sub-model areas. At run-time, options are passed to the software indicating what type of simulation is required:

- Catchment geometry
  - Historical for calibration simulations
  - Existing case for impact assessment benchmarking
  - Future case for impact assessments or planning purposes
- Flood event
  - Historical events (seven calibration events are currently incorporated representing significant floods across different parts of the catchment)
  - Design events
    - various return periods
    - various event durations
    - joint probability event combinations
    - tidal conditions
    - climate change allowances
- Location
  - One or more of seven different sub-models

The TUFLOW model automatically selects the boundary conditions to be applied to each model simulation depending on which, if any, of the neighbouring sub-models are also being simulated. For example, a simulation of the Mid Richmond sub-model in isolation would have pre-defined flow versus time boundaries applied to the upstream ends and a pre-defined rating curve used for the downstream boundary. If the Ballina sub-model was also included in the run, the downstream boundary of the Mid Richmond sub-model would convert to a dynamic 2D boundary to apply flows directly to the Ballina sub-model. The automatic naming of model output files allows the modeller to clearly identify the conditions used for the simulation, thus, assisting traceability.

Improved Flood Response

In Australia, the Bureau of Meteorology (BOM) provides forecasted peak water levels and timings at critical gauge locations along major watercourses. Some local Councils, such as the Richmond Valley Council, are developing systems to translate the predicted flood height into more meaningful information for the community, such as the SES Flood Intelligence Cards applicable to each river gauge. Due to the sparse coverage of river gauges in many catchments, there are substantial gaps in the information that is available to communities with respect to potential flooding at their properties. The complete flood mapping coverage provided by the catchment based model is a move towards providing meaningful information to the whole community.

Neighbouring Councils have expressed a requirement for improved flood warning and consistent flood response measures to be applied across each LGA. In a step towards this Lismore City Council recently changed its flood warning stations to be relative to the Australian height datum, whereas the rest of the Richmond Valley still uses the Richmond Valley datum. A concerted effort from all Councils in the area and other Government agencies would be required to bring about a single datum for the Richmond Valley to improve flood warning and flood response. This is one example of many broader issues to be addressed with respect to flood response.

The catchment based model could ultimately form the basis for an advanced flood warning system for the valley to complement the BOM's existing flood warning activities within the upper catchment.

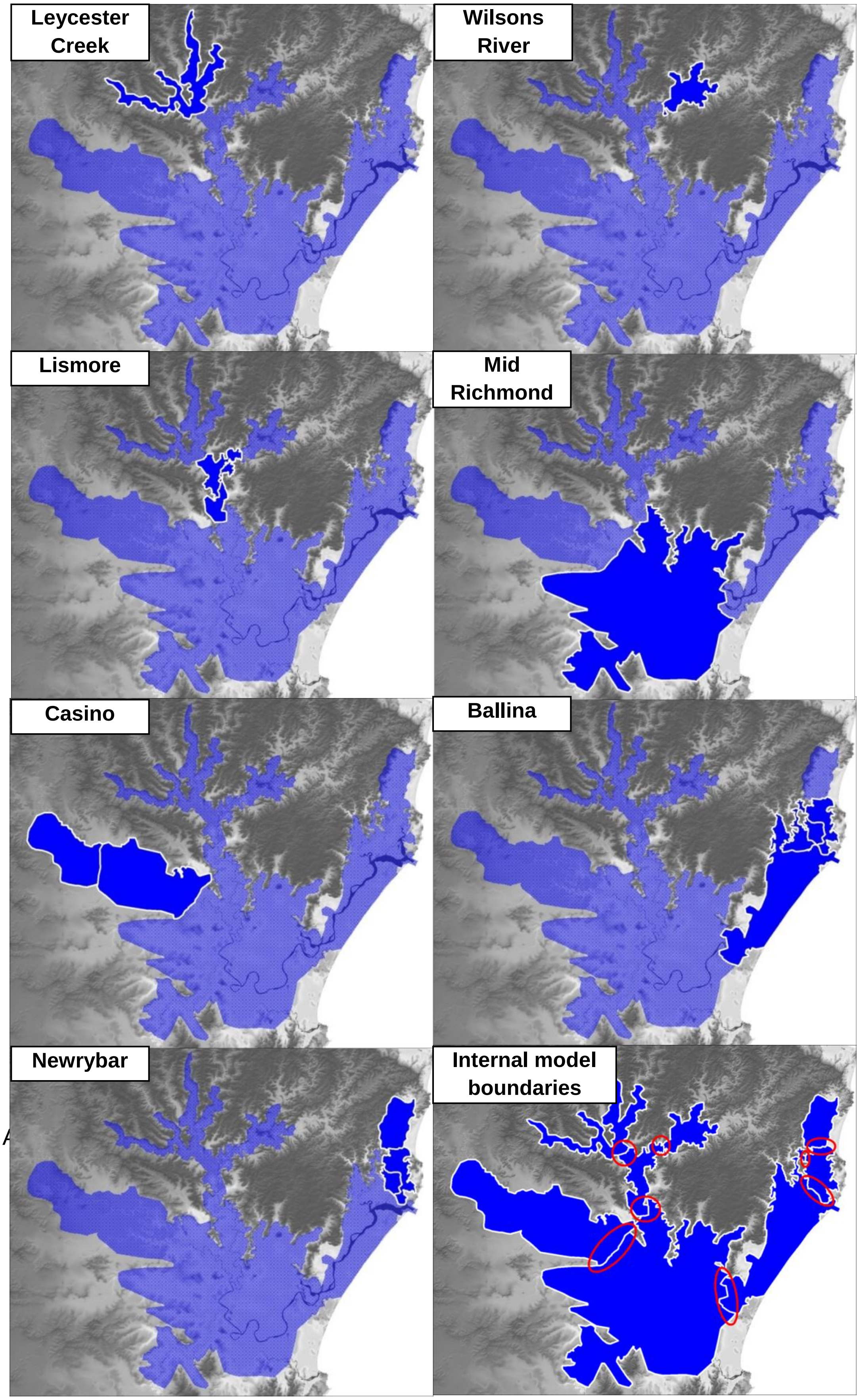

Figure 5: Seven Modelling Areas Comprising the Modular 'Mega-Model' and Internal Model Boundaries

Additional Uses

The catchment based model provides a platform for multiple uses. In a local government managers context the model also provides an information resource to review flood mitigation assets and development of retreat strategies for asset management. Of current interest is the assessment of whether mitigation measures have become redundant in the current world requirements. Given that some assets are over 50 years old, and given changes in land use and community expectations, some assets could be rationalised or removed. This could reduce costs and in some cases restore natural drainage paths on the floodplain and lead to environmental repair.

Concluding Comments

The conventional approach to floodplain management is to assess flood behaviour and prepare Flood Risk Management Plans for targeted areas. The spatial extent of many such studies is limited by administrative, rather than watershed boundaries. A range of issues associated with this approach have been discussed in this paper.

The Richmond River County Council and the NSW Office of Environment and Heritage are making progress towards consolidating flood modelling in the Richmond Valley with the ultimate goal of a catchment wide approach to floodplain management. The various separate flood models produced in the Richmond Valley have been consolidated into a modular ‘mega-model’ to overcome many of the apparent issues. The way the modular flood model is able to address the five key issues discussed in the paper include:

- Improved coverage of rural areas – the numerous flood models of urban areas have been linked, providing complete coverage of the rural areas between. For modelling efficiency, the model is modular in form, allowing sections to be activated or deactivated depending on the area of interest for the particular modelling and mapping task.

- Basis to improve synchronisation of FRMPs – improvements to the synchronisation of FRMPs is limited by the need and available budget of the individual Councils within the catchment. However, with a single flood model, a collaborative approach to floodplain management between neighbouring Councils is more feasible.

- Consistent flood mapping at model interfaces – discrepancies between flood mapping at interfaces between separate flood models are removed, thus providing more consistent and reliable flood mapping.

- Consistent modelling and mapping approaches – all areas of the floodplain are modelled in a consistent manner, using one software and one style of mapping. However, there remain discrepancies between flood hazard definition between neighbouring Councils, which can only be resolved through a collaborative approach to floodplain management.

- Opportunities for improved use of flood information for flood response – the catchment model enables flood information to be provided to the community in areas not covered by river gauges. Further, there are opportunities for using the model to enhance flood warning capabilities.

A catchment based approach to flood modelling, mapping and floodplain management should be considered by all Councils where a river system is shared by more than one local government. Together with the benefits presented here, the collaborative approach will ultimately result in significant cost savings to State and Local Government.

References

- BMT WBM (2010) *Richmond River Flood Mapping Study*
- BMT WBM (2009) *Pacific Highway Upgrade Ballina Bypass Flood Impact Assessment*
- BMT WBM (2008) *Ballina Flood Study Update*
- NSW Government, Australia (2005) *NSW Floodplain Development Manual*
- WBM Oceanics Australia (1997) *Ballina Flood Study*
- WBM Oceanics Australia (1998) *Mid Richmond Flood Study*