Large scale ecohydraulic modelling on the Goulburn River

Lachlan Inglis[1] and Ben Tate[2]

1. Water Technology, 15 Business Park Drive, Notting Hill, 3168, lachlan.inglis@watertech.com.au

2. Water Technology, 15 Business Park Drive, Notting Hill, 3168

Key Points

- Hydraulic modelling has advanced allowing larger areas at higher resolution to be modelled
- Graphics processing units are now being used to increased simulation run times
- The Goulburn River from Lake Eildon to the River Murray has been modelled using GPU
- Faster run times allow for more scenarios to be modelled and a better understanding of watering options

Abstract

Hydraulic modelling applications and techniques have progressed a long way in the last decade, from basic 1D modelling of channel and river reaches to 2D floodplain applications and more recently 3D contaminant transport modelling. Advancements in floodplain hydraulic modelling have enabled advancements in the management of environmental watering management. The broad application of 2D modelling was made possible with the rapid development of computing hardware more than a decade ago. In recent years hydraulic modelling software providers have begun making use of the computer's graphics card (GPU) for processing simulations. Using the graphics card has led to 100-fold speed increases in 2D hydraulic modelling allowing entire river systems and wetlands to be modelled at high resolution providing detailed information on flood extents, connectivity and a range of flow regimes.

This paper details the investigation undertaken into the flood modelling using GPU as part of the Goulburn River Constraints project undertaken by the Goulburn Broken Catchment Management Authority in conjunction with the Murray Darling Basin Authority. Environmental flow releases on the Goulburn River system have a number of implications for stakeholders in the area. Previous flood modelling techniques were limited by the available technology and required a number of assumptions. The use of GPU software tic infirm validity of these assumptions, and improve model run times has allowed the constraints and opportunities of environmental flows on the river system to be realised.

For ecohydraulics and stream management, we can take environmental flow studies beyond looking at individual sites of importance and consider an entire river reach and the connectivity between river, floodplain and wetlands to provide a better understanding of how to achieve desired watering outcomes.

Keywords

Ecohydraulics, 2D Hydraulic Modelling, GPU, Goulburn River, TUFLOW

Introduction

The Murray Darling Basin Authority Plan outlined the need for a business cases to assess the feasibility of easing constraints on the Goulburn River in relation to environmental flow releases. This in turn would realise a number of benefits to improve floodplain watering on the Goulburn River system. As a result of the requirement for releasing environmental flows and the knowledge of a number of constraints to flow releases, an increased understanding of the hydraulics of the Goulburn River was required to improve decision making regarding future environmental flow releases. The aim of increasing knowledge was to identify the extent of areas impacted by a range of flow releases including out of bank flows. Existing eco-hydraulic modelling of the Goulburn River, though industry best practice at the time of development, was limited by the available technology which required 8 separate models across the system with some model run times stretching out to more than a week. The model results also lacked sufficient resolution to accurately depict wetland connectivity across the floodplain.

In 2015, the Goulburn Broken Catchment Management Authority commissioned a project to develop a detailed hydraulic model of the Goulburn River from Lake Eildon to the Murray River to evaluate the constraints and benefits of environmental flow releases along the river. The modelling technique adopted for the constraints project allowed for much higher resolution results to observe wetland connectivity as well as provide more detail surrounding the implications and constraints associated with out of bank environmental flows. The modelling techniques used and results are covered in the following pages.

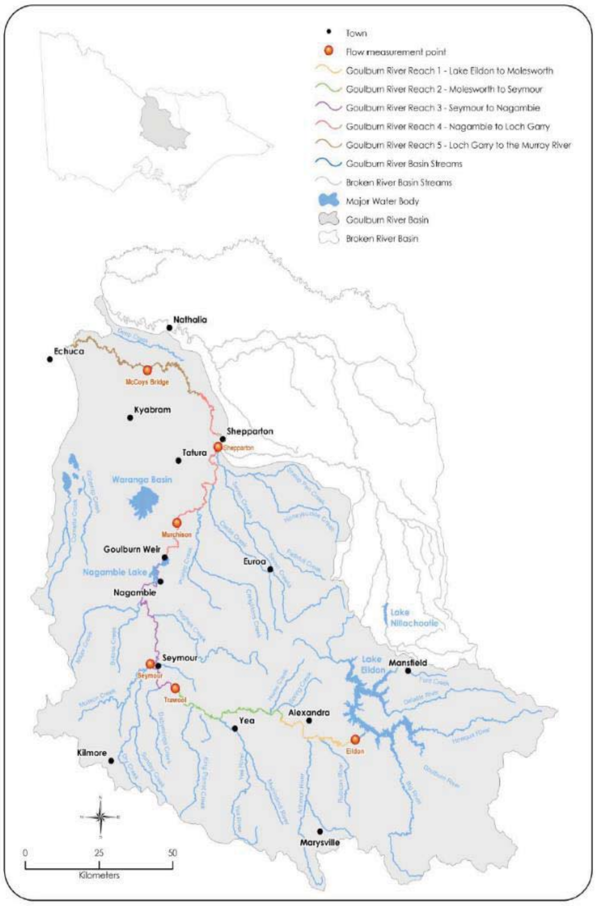

Figure 1. Goulburn River Catchment (GBCMA)

The Goulburn River begins its journey near Woods Point on the slopes of the Victorian Alps, then meanders north and flows into Lake Eildon at Jamieson. Lake Eildon is a major storage which services a highly productive agricultural region in Victoria. The Goulburn River downstream of Lake Eildon is thus highly regulated with irrigation releases from August through to May each year. The river continues its journey from Lake Eildon heading west to Seymour, before turning north and flowing through to Nagambie, where again it is impounded by the Goulburn Weir. The weir feeds three major offtakes, the East Goulburn Main Channel which provides water to the Shepparton Irrigation district through to Katamatite, the Stuart Murray Canal and Cattanach channels divert water to Waranga Basin which in turn provides irrigation water to areas almost 200 km west through 62,600 ha known as the Goulburn Irrigation district. The river continues north to Shepparton and then heads north-west through the Lower Goulburn floodplain where it reaches the Murray River just upstream of Echuca. In total the Goulburn River measures approximately 570 km in length, with a catchment area of approximately 1.6 million hectares (GBCMA, 2013).

The Goulburn River's mean annual flow is approximately 3,040 GL. Lake Eildon has a capacity of 3,334 GL. Close to 90% of the water released from Lake Eildon is used for irrigation purposes, leaving little for the environment. The river and its floodplain and wetlands support highly significant populations of threatened species, river red gum forest and also hold high cultural value for the traditional aboriginal owners of the land. Due to these environmental and cultural values the Goulburn River occasionally receives environmental flow releases from Lake Eildon. There are a number of constraints to the maximum flow that can be released down the Goulburn River due to flooding of public and private assets.

Hydraulic Modelling Method

Earlier hydraulic models of this reach were developed by Water Technology (2010) prior to the current advancement of GPU hydraulic model software. These previous models used the classic MIKE FLOOD software (MIKE by DHI 2014). Due to the limitations at the time of computing hardware and model software, the reach from Eildon to the Murray River was split into 9 separate models. The models from Lake Eildon to downstream of Shepparton were developed using a 25x25 m model grid resolution. The final model from downstream of Shepparton to the Murray River, where the lower Goulburn River floodplain spreads out broadly over an expansive area used a 60x60 m model grid resolution. A number of issues were encountered using these earlier models. The model grid resolution was not fine enough to represent many of the anabranches and complex flow paths of the Goulburn River wetland system. This required the representation of the model channel in a 1D MIKE11 branch laterally linked to the 2D MIKE21 grid (MIKE by DHI 2014). However not all anabranches could be represented in 1D due to constraints in time and budget. As a result, the connectivity of many wetlands and anabranches was not preserved in the model. This discontinuity between the main channel and wetlands is a major drawback in providing decision makers with accurate information about the benefits gained from watering scenarios. Another major issue was the discontinuity between each of the model areas, often resulting in significant differences in water levels from one model to the next due to model boundary assumptions. Beyond the quality issues mentioned above, a major issue for previous projects using these models was the model run time. To run each model for a nominal 10 day hydrograph at a flow rate with only minor out of bank flooding the models would take a combined run time of 16 days.

As a result of issues in the earlier studies and the significant advancement in model software and hardware, it was decided that the Goulburn River would be remodeled using GPU software to speed up run times and allow a reduced model grid size. At the time of the study Water Technology was using both MIKE Flexible Mesh GPU and TUFLOW GPU. There are a number of key difference between the two modelling software packages, these were described and benchmarked at the Victorian Flood Forum in 2014 (Connell et al, 2014). TUFLOW GPU was chosen as the modelling software package as it allowed for fast manipulation of the model bathymetry compared to MIKE Flexible Mesh Modelling which requires significant time to adjust large areas of model bathymetry. A pilot study was completed which produced flood extents for estimated design floods including the 1% AEP flow between Lake Eildon and Murchison. Results of this pilot study generally matched the estimated 1% AEP flood contours contained in the Victorian Flood Database.

The model developed for the Goulburn Constraints project was required to investigate the flood extents at bankfull and slightly overbank flows, which required significant modification to provide an accurate representation of channel conveyance, for which LiDAR datasets do not provide due to their inability to sample below water. The model topography was constructed using a number of available LiDAR datasets with vertical accuracy of ±0.2 m. Bathymetry survey was available for a large section of the downstream reach from Lake Nagambie to the Murray River. LiDAR products do not provide survey of the stream bed as they do not penetrate the water surface. TUFLOW bathymetry editing functionality used to enforce the bathymetry on to the LiDAR with the modeller buffering out the bathymetry (often just a centerline) to best approximate the actual bed shape. In the upstream section where bathymetry survey was not available the stream bed profile was estimated using a limited number of cross-sections. The stream bed profile was later edited through the calibration phase of the project to ensure that an accurate representation of channel capacity was developed for in bank, bankfull and overbank flows. Standard Manning's 'n' roughness values were used and were again revised through calibration.

Given that the Goulburn Weir forms a major hydraulic control in the modelling reach, two models were developed, the first from Lake Eildon to the Goulburn Weir, and the second from Goulburn Weir to the Murray River, including a large reach of the Murray River from Lower Moira to Echuca. Due to the limitations of the TUFLOW GPU not being able to model hydraulic control structures this also suited splitting the model at this location.

Upon review of the Goulburn River geometry it was decided that a grid cell size of 10 m would sufficiently resolve the channel capacity without the need for any 1D elements. At this grid resolution we would still maintain relatively fast model run times.

Hydraulic Modelling Results

Model Calibration

The GPU modelling results were calibrated using a number of permanent streamflow gauges located along the river system. These gauges have established rating curves. Given the number of ungauged tributary inflows to the Goulburn River traditional model calibration using a historic event was difficult. Instead a series of steady state flows were modelled throughout the system and modelled water levels were compared to gauge rating curve water levels. In addition to the rating curve calibration the model was also tested against a series of temporary gauges in the mid Goulburn area below Lake Eildon that were in place during two different minor environmental flow releases. Through calibration a number of modifications were made, mainly in relation to the assumptions regarding the estimated bathymetry of the river. These modifications ensured that the flow rates at in bank and bankfull flows were accurately represented in the model. The calibration was closely reviewed by the Goulburn Broken CMA and was found to be acceptable with water levels generally within 200 mm of the observed levels.

In addition to the calibration to gauge data and the Goulburn Broken CMA undertook community consultation to get feedback on the model results. Overwhelming the response was that the modelling was accurate at the flow rates modelled and only minor changes were required to better represent the commencement of flow of some smaller anabranches and into the floodplain. The effort that Goulburn Broken CMA went to in ensuring that local knowledge was incorporated into the project helped make the modelling as good as it could be.

Model Design Flows

A series of flows were modelled covering the range of likely environmental flow releases from Lake Eildon in the upper reaches and the target design flows in the lower reaches with the addition of tributary inflows. A comparison of the model results using the 10 m GPU model and the 60 m CPU models is provided in Figure 2 for the same flow rate. This clearly shows the vastly improved connectivity of the anabranches and wetlands using the smaller grid size. The fact that the GPU software allowed the models to cover the entire reach with the only discontinuity at the Goulburn Weir, where a major structure is located, vastly streamlined the modelling process and eliminated discontinuities. Modelling and mapping of the system was continuous without the need for numerous boundaries, where water levels would be forced by the modeller. This led to an improved result again. The GPU software also greatly improved model run time, despite the finer resolution. The two models now ran similar hydrographs to those mentioned earlier in under 2 days, only 11% of the original total run times.

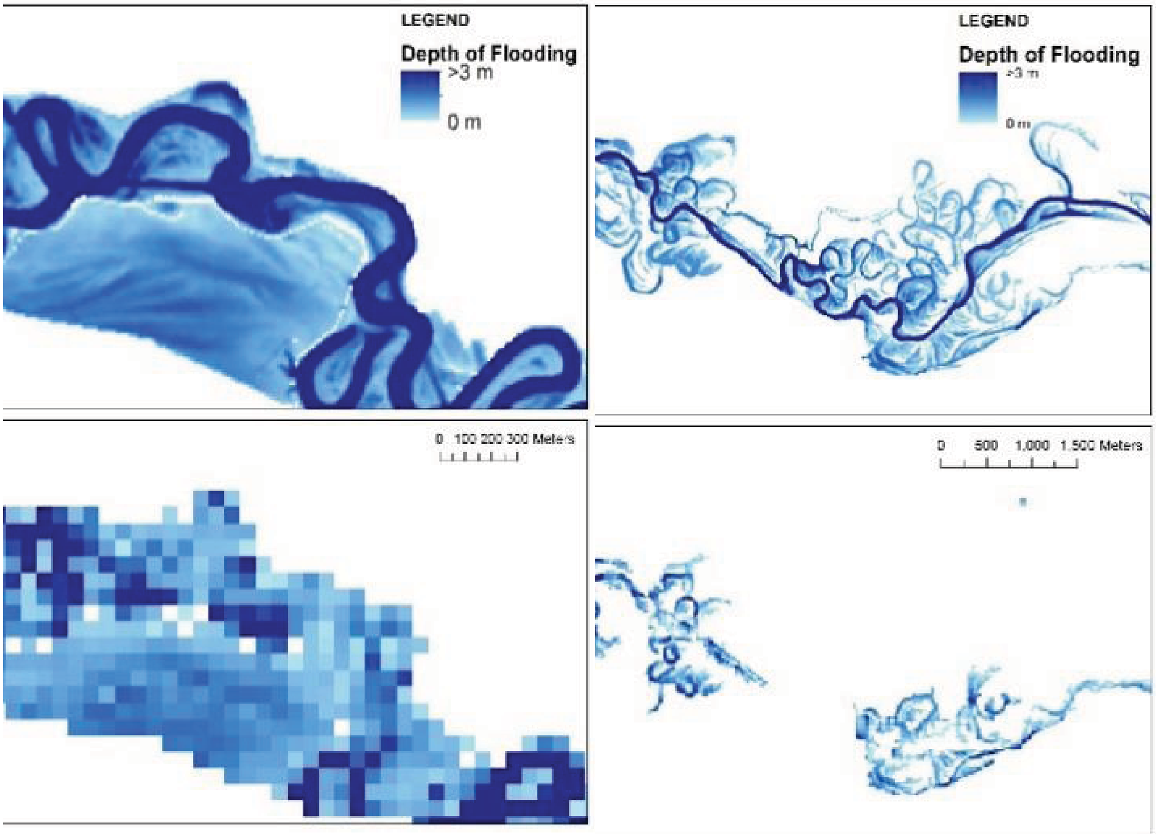

Figure 2. Examples of GPU 10 m grid model results (top) and CPU 25 m (bottom right) 60 m grid model results (bottom left). Top and bottom examples are direct comparisons of the same geographical extent.

Conclusions

The results presented above clearly show a significant increase in the quality of the model results through the use of GPU enabled modelling software. The level of connectivity between river, anabranch and wetland is significantly enhanced using the finer resolution GPU modelling. This has led to vastly improved outcomes for understanding the impact of flooding in both its environmental benefit and its potential impacts on public and private land and infrastructure. The higher resolution results allow more accurate cost and risk estimates of economic factors associated with different flow rates. In turn the results also allow for more informed decisions to be made regarding the volumes of water released, ensuring the desired flow outcomes are undertaken in the most efficient manner. These improved results have greatly reduced the uncertainties surrounding decision making regarding the Goulburn Constraints project. As well as the improvement in quality of modelling results, the GPU modelling software has also enabled the model scenarios to be completed much faster and more efficiently compared to previous 2D hydraulic modelling software. This has enabled more scenarios to be modelled and time/cost savings for undertaking the work.

This case study provides one example of how far hydraulic modelling software has progressed in the last 5 years, and what is achievable using today's technology. The adoption of GPU hydraulic modelling software enables another leap forward in the modelling of riverine and catchment systems as a whole. These further improvements in modelling software and computing power are likely to lead to advances in providing highly detailed hydraulic models providing natural resource managers with accurate information to make informed decisions.

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