GOING FROM FLOOD STUDIES TO HIGHWAY DESIGN – CHALLENGES FACED AND LESSONS LEARNT

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Abstract

The emergence of advanced 1D/2D flood modelling tools in the last decade has seen the widespread adoption of these tools in floodplain modelling, as part of a catchment-wide flood study, as well as in detailed design of major infrastructure projects. These two uses have very different objectives. Flood studies are conducted to understand flood behaviour and manage flood risks, be it for a large rural catchment or a highly developed urban area or even for individual developments. Most of these studies are now facilitated by the use of 1D/2D flood modelling tools such as TUFLOW. Increasingly, with the ease of use of such tools and the complex nature of flood behaviour on the floodplains, these floodplain management tools are subsequently adopted for use in the design of bridge structures or cross drainage culverts in major infrastructure projects in lieu of the more traditional approaches, such as estimating flows using the rational method and 1D hydraulic models. However, the flood modelling requirements in detailed design projects are often more rigorous from those of the standard catchment flood studies. The initial models developed for the flood studies may have to undergo substantial revision in order to allow for the reliable and optimal design of structures such as embankments, bridges and culverts as well as to address the stringent afflux requirements associated with the approvals of major infrastructure projects.

This paper reports on the typical challenges faced when adopting hydraulic models initially developed for a catchment-wide flood study, for use in the detailed design of an infrastructure project. The observations made herein are based on experiences in conducting flood modelling for various infrastructure projects within Australia.

Introduction

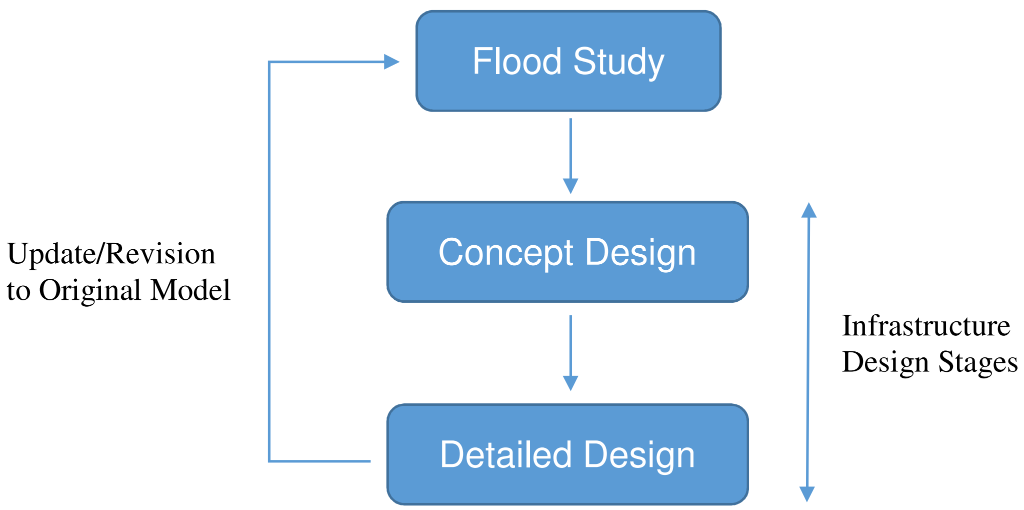
Recent advancement in computing technology and the reduced cost in spatial data acquisition have seen the rise in the use of complex 1D/2D (one-dimensional/two-dimensional) flood modelling software in the industry (Babister & Barton, 2012). These modelling packages have traditionally been used in conducting catchment-wide flood studies, developing measures to alleviate flood risks and informing development controls within a floodplain. The development of these tools has matured to a point whereby practitioners are now adopting these complex hydrodynamic models in a wide and increasing variety of engineering projects for predicting design flood behaviour in lieu of the traditional 1D hydraulic models such as HEC-RAS and DRAINS.

In NSW, it has become standard practice for local councils to require consultants to use 1D/2D flood modelling software like TUFLOW to conduct flood studies as part of the NSW Floodplain Risk Management Programme (DIPNR, 2005). The primary objective of these studies is mainly to establish existing flood behaviours and identify flood prone areas. This information is then used to develop appropriate flood mitigation measures as well as establishing development controls and planning evacuation routes. The models that are developed for councils are generally for planning purposes and built from data covering a wide area such as LiDAR and assets information that may be outdated.

When an infrastructure project is proposed and the project site falls within a certain catchment, the pre-existing flood model (or models) is usually obtained and utilised for the concept design and subsequent detailed design of the drainage infrastructure. The project may be the construction of a new highway, railway, bridge or major land development. The focus of the flood modelling exercise is then on ensuring flood immunity is attained for the infrastructure assets and on minimising the potential development impacts on the existing flood behaviour. Generally, the flood afflux resulting from the development must meet the requirements or conditions set by the regulatory bodies, or else flood mitigation measures must be proposed to alleviate the worsened flood conditions caused by the development. Therefore, the flood modelling is subject to much intense scrutiny compared to that of the original flood study.

Chart 1 shows the typical flow of the usage of flood models from a catchment-wide flood study to their application in the various design stages of an infrastructure project. The original models developed for the initial flood study may have to undergo substantial refinements at the infrastructure design stages to allow for the reliable and optimal design of drainage structures as well as to address the stringent requirements associated with infrastructure projects.

Chart 1: Various Stages of Flood Model Usage



Refinement to Flood Modelling

During the design stages of an infrastructure project, new and more detailed data including detailed ground survey and CCTV survey of the existing pits and pipes network is usually available. With this information, the flood models can be further refined (often incorporating elements previously omitted from the initial flood study) to provide simulation results that more accurately replicate the existing flood behaviour. Inevitably, this leads to review of the original model assumptions and revision to the flood modelling results. For instance, updated ground survey data may reveal an alternate overland flow path or previously assumed culvert inverts may change significantly with the availability of new survey data leading to changes to the culvert peak flows. These changes may be problematic for modellers wanting to refine a hydraulic model to carry out the flood assessment during the design stages of an infrastructure project but may be hindered from doing so with the restrictions placed by the original owners of the model. In addition, this presents a dilemma for councils who have approved planning and drafted documents based on the previous flood results.

Table 1 outlines the distinct aspects of the flood modelling process of typical flood studies carried out for a local council compared against that for a drainage design assessment conducted for an infrastructure project. The contrast highlights the difficulty in applying the same flood model to the two different assessments with disparate objectives and outcomes.

Table 1: Comparison of the Flood Modelling Process of Typical Flood Studies against That of Drainage Design for Infrastructure Projects

	Typical Flood Study	Infrastructure Drainage Design
Objectives/Outcomes	• Establish flood planning levels (FPLs) • Flood risk management • Evacuation route planning • Prepare flood certificates • Land use planning • Assess flood liability and damages for property	• Drainage design of pipes, culverts and bridges • Establish embankment/fill level for flood immunity • Assess development impact and changes to flood behaviour • Scour protection design
Clients	• Local councils • State authorities, i.e. Sydney Water etc.	• Public or private, including road authority, state authorities, water regulatory bodies, developers and contractors

	Typical Flood Study	Infrastructure Drainage Design
Process	• Floodplain risk management programme • Asset management driven	• Environmental impact assessment • Concept design • Detailed design
Model source	• From scratch, prior models often non existent	• Often from existing flood studies, modification sometimes not allowed, model can be outdated by the commencement of project
Digital terrain model (DTM)	• LiDAR • Topographic contour survey data	• Ground survey data in addition to LiDAR and topographic data • Inclusion of more details of topographic features picked up by ground survey
Source of pits/pipes network information	• From council or local authority, usually outdated and inaccurate	• CCTV survey conducted as part of project in addition to information from council • Inclusion of smaller size pipes omitted in flood studies
Adopted model parameter assumptions	• May be more conservative than industry standard	• Industry standard, based on AR&R where applicable
Grid size	• Tend to be coarser as focus is on the whole catchment	• Tend to be more refined for project corridor/area with the use of a 'nested' model. Sometimes may require additional models for the local catchments
Sub-catchments delineation	• Based on DTM and pits/pipes network	• Revision of existing catchments required to match post-development scenario
Model review	• Usually only the internal QA of the consultants	• More rigorous peer review process by one or more consultants

	Typical Flood Study	Infrastructure Drainage Design
Project duration and run times	• Usually lengthier time line for completion	• Time constraints require shorter model run times
Modelled design flood events	• 1, 2, 5, 10, 20, 50, 100, 200, 500 year ARI events and PMF	• Varies depending on design requirements and approvals, but typically 10, 50, 100 and 2000 year ARI events
Critical Duration	• Critical duration based on the event duration resulting in peak flood levels for majority of the catchment • May be in the order of hours or days especially for catchment influenced by mainstream/riverine flooding	• Critical duration for the design of drainage infrastructure tend to be dominated by the local catchment event characterised by shorter duration flood

The Predicament

Local authorities (like councils) generally use information from the flood models to manage flood risks within their local government area with the use of planning controls and physical measures that modify flood behaviour. As such, the parameter values adopted for the flood modelling tend to incorporate a certain level of conservatism resulting in a worst-case flood scenario. In the detailed design of a major infrastructure, the design may be driven by the need to develop cost efficient solutions that the client can afford to construct. In which case this level of conservatism becomes a hurdle. Often, the local authorities who own the baseline flood model have reservations in permitting modifications to the original model assumptions that could lead to substantial changes to the original modelled flood information that may have been disseminated to the public. Therefore, the competing demands of the different purposes of the flood model usage may dictate the underlying assumptions made in defining the model parameters, in order to ensure that the final product (model) is fit for purpose.

Design consultants are then faced with the dilemma of having to refine the model to provide an optimised design of drainage systems to meet budget cost whilst at the same time having to adhere to the constraints imposed by the owners of the original models who are reluctant to allow any changes be made specifically on the model parameter assumptions of the flood models, with the exception of the incorporation of the new survey data and surveyed pits and pipes data. This inevitably result in an extended negotiation process between the contractors and the owners of the models to establish a middle ground, often to the expense of the project design costs. The situation becomes more critical if the model is found to contain deficiencies during the design stages of the infrastructure project, which then is not “up-to-the-task” in providing a reliable and accurate flood assessment of the project.

Lessons Learnt

Without recognising this potential conflict that may rise during the project, consultants and contractors entering into the bidding process for the infrastructure project may under allocate resources to the flood modelling aspect, resulting in the underestimation of time required to complete the flood modelling as well as underestimation of the costs involved.

Further, the responsibility of managing deficiencies in the original flood model is passed on to the subsequent consultants in the drainage design stages. Often the consultants in the latter stages bear the risks of resolving any flood model defects and this may not be easily resolved, particularly if it requires a major revamp to a model that council has adopted.

This presents significant risks for the latter party considering the tight budget and time constraints for project delivery and the contingency allocated for the project may or may not cover these unforeseen issues.

Moving Forward

Possible solution to manage the conflicting demands of the intended purpose of the flood model can be in the form of communication of non-negotiables in terms of the underlying model assumptions that the receiving consultants have to adhere to. With the communication of expectations at the early stage of the project, this will save much angst and allow time to prepare contingency plans. For the consultants, accounting for the uncertainty present in the flood models within the budget will help manage risks associated with the need to fix or refine the model. Previous consultants who worked on the original flood study should document clearly each assumption for future users of the models. It should be the foremost priority to form an agreement from the various parties including the owners of the model and the consultants/contractors utilizing the model on the model assumptions at the beginning of the project.

Issues concerning the deficiencies of the original flood model or competing demands on the models which necessitate major revamp of the model should be communicated to the relevant stakeholders such as the owners of the model (councils) and contractors at the earliest opportunity to allow for time for the resolution of the issues without significantly affecting project delivery. It must be recognised that no flood model is perfect and the rigorous review that the flood modelling has to undergo during the design stages of the infrastructure project will more than likely lead to the discovery of model issues that previously have gone unnoticed during the initial flood study.

The owners of the original flood model such as councils or state authorities, may also consider allowing the consultants/contractors utilising the models to adopt different model parameter values if it can be demonstrated that the modelled flood results are not altered significantly and recalibration/validation of the model with historical events show similar results or perhaps even improvement from the original flood study.

To conclude, this paper serves to raise awareness on the potential issues that may arise when adopting hydraulic models developed for a catchment-wide flood study for use in the detailed design of infrastructure projects. The increasing use of these 1D/2D flood models in a wider range of projects have seen consultants and contractors caught off guard with the presumption that the flood models can be readily applied without a thorough review of the underlying assumptions made in developing the models. The recommendations offered herein are by no means exhaustive and communication between the different parties involved in the flooding modelling exercise remains top priority in attempting to resolve the issues.

References

Babister, M. and Barton, C. (2012). *Project 15: Two Dimensional Modelling in Urban and Rural Floodplains*, AR&R Report Number P15/S1/009.

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