Technical Guideline

Hydrologic and Hydraulic Modelling

January 2024

Translating and interpreting assistance

The Queensland Government is committed to providing accessible services to Queenslanders from all cultural and linguistic backgrounds. If you have difficulty understanding this publication and need a translator, please call the Translating and Interpreting Service (TIS National) on 13 14 50 and ask them to telephone the Queensland Department of Transport and Main Roads on 13 74 68.

Feedback

Please send your feedback regarding this document to: tmr.techdocs@tmr.qld.gov.au

Contents

1 Introduction

This guideline defines the minimum requirements which must be met when undertaking hydrologic and hydraulic modelling and/or design work for the Department of Transport and Main Roads. This covers delivery of modelling work undertaken by either external Consultants or internal staff. This includes cross drainage and flooding assessments but does NOT cover road surface drainage / longitudinal drainage. This guideline is also intended to inform the Principal's Designer when developing a contract to engage HD2 / HD3 Consultants. All hydraulic design reports, including the models, result files and any mapping, must be submitted to the department's Representative in hard copy and electronic form.

2 Hydrologic and hydraulic modelling specifications for departmental projects

Hydrologic and hydraulic models must be developed to a high standard and be fit for the intended purpose. It is desirable to have high quality models already developed in the early project phases, however, at the latest, hydrologic and hydraulic models need to be suitable to be utilised during the Business Case and Detailed Design phases, with minimal change to the Base Case models.

- Hydraulic modelling and calculations must be undertaken to demonstrate that the general requirements, performance requirements, and drainage design requirements will be met.
- An appropriately qualified hydraulics Registered Professional Engineer of Queensland (RPEQ) must undertake appropriate flood modelling and certify the Hydrologic and Hydraulics Report of the project.

3 Minimum modelling requirements

3.1 Survey requirements

Survey is a critical component of any hydraulic model and may be collected specifically for a particular project. In general, up to date Airborne Laser Scanning (ALS) data of the floodplain and a detailed Ground and Feature Model (GFM) derived from ground survey in the vicinity of the area of interest are sufficient to undertake the hydraulic analysis. Mobile Laser Scanning (MLS) can also be used to enhance the road surface data in areas where no ground survey is available. In some cases, it may be necessary to obtain additional creek survey data, especially if there are areas that have not been picked up by the ALS data (below water terrain). In areas where no ALS data is available, ALS should be obtained, and only a preliminary hydraulic assessment in the early planning stages should be undertaken. All new survey data specifically collected for departmental projects shall be undertaken as prescribed in the current departmental *TMR Surveying Standards*, which provide instruction for the delivery of GFM information at bridge sites.

3.2 Hydrology

A hydrologic assessment is required to determine inflows and boundary conditions for the hydraulic model. The following guidelines must be followed when undertaking a hydrologic assessment for the department:

- Utilise the current versions of Australian Rainfall and Runoff (ARR), *Road Planning and Design Manual* (RPDM) – *Edition 2: Volume 3 – Supplement to Austroads Guide to Road Design Part 5: Drainage – General and Hydrology Considerations* and Austroads *Guide to Road Design – Part 5* in general, with some clarifications as below.
- As climate change has the potential to alter the prevalence and severity of rainfall extremes, storm surge and floods, it needs to be considered when designing roads and bridges for the department. For design rainfall events, the relevant increase in rainfall intensity and sea level rise must be determined in accordance with the department's Engineering Policy EP170 *Climate Change Risk Assessment Methodology*, the latest relevant State policies and/or the recommendations in ARR and be approved by the department prior to commencement of any project.
- At locations with a stream gauge in close upstream or downstream proximity, hydrologic and hydraulic models should be calibrated to recorded stream gauge data. Design discharges should be calibrated to a Flood Frequency Analysis (FFA) at the gauge location if sufficient recorded data exists. The stream gauge rating curve should be checked and improved if needed (for example, by using a hydraulic model) before undertaking the FFA. Any limitations with the rating curve should be clearly identified.
- Use runoff-routing modelling (URBS, RORB, WBNM and XP-RAFTS are all used by the department and are preferred) with model parameters determined either by calibration or regional parameters as per ARR for uncalibrated models. The Rational Method with ARR Intensity Frequency Duration (IFD) and/or other techniques, such as Quantile Regression Technique (QRT), should be used as a check on peak flows.
- The Rational Method as a primary flow estimation method is only supported for longitudinal design or for small rural catchments with corresponding times of concentration of less than 30 minutes.
- The use of ARR Regional Flood Frequency Estimation (RFFE) as a primary flow estimation method must be used with care and requires, as a minimum, an alternative check method to be validated against. It is preferred to use RFFE as a check method on peak flow for runoff-routing methods only.
- Losses obtained from the ARR Datahub cannot be relied on and must be reviewed and adjusted, if appropriate, based on either calibration or local knowledge.
- Initial and continuous loss rates must be applied to each catchment in accordance with ARR. It is acceptable to apply loss rates that have been derived from global pervious and impervious loss rates based on the fraction of imperviousness of each catchment.
- All temporal patterns need to be checked for "embedded bursts" in accordance with Chapter 5, Section 5.9.4 of *Book 2 – Rainfall Estimation* of ARR, and consideration be given to filtering out any embedded bursts.

- A range of design flood events up to the 1% Annual Exceedance Probability (AEP) needs to be assessed. This range should include the standard AEPs of 50, 20, 10, 5, 2, and 1% for most projects. In addition, the 0.05% AEP design flood is required to determine hydraulic impacts under an extreme event. The 0.05% AEP and the overtopping event are also required for the structural design of a bridge under Ultimate Limit State (ULS) conditions.

  For each location under consideration, a critical duration analysis must be undertaken for each AEP event in accordance with ARR. The full range of storm durations with associated temporal pattern ensembles must be assessed. Critical durations, critical flow rates and critical temporal pattern must be documented. The following definitions apply:

  - at any location under consideration the critical duration of each AEP design event is defined as the duration that results in the highest mean peak flow rate of the associated temporal pattern ensembles
  - the critical flow rate at the location under consideration is defined as the mean peak flow rate of the critical duration temporal pattern ensemble, and
  - the critical temporal pattern at each location under consideration is defined as the temporal pattern that results in a peak flow rate that is closest to the mean flow rate with a bias of 2 to those exceeding the mean.

- To reduce the amount of critical temporal patterns that need to be assessed in the hydraulic model, it is acceptable to consolidate critical temporal patterns if a suitable common temporal pattern can be determined. It needs to be demonstrated that the adoption of a suitable common temporal pattern has negligible impacts on the hydraulic results.

3.3 Hydraulics

The modelling process must be capable of accurately determining flows in the main channels and across the floodplain. In particular, the base case model must allow for the effects of addition / removal of bridges, culverts and other infrastructure within the floodplain so that their influence can be understood.

- Appropriate best-practice two-dimensional (2D) hydraulic modelling processes and methods are required in all but the simplest applications (preferably TUFLOW, but MIKEFLOOD, HEC-RAS 2D are also acceptable).
- While hydrologic runoff routing methods are the preferred method to derive flow hydrographs, Rain on Grid models can be appropriate for certain contexts, as long as results are validated as per Austroads *Guide to Road Design – Part 5* and ARR.
- The model must include sufficient detail (grid point spacing, structures, etc) to represent the features that are significant for the road corridor being modelled.
- If critical temporal patterns change between Base Case and Design Case, both cases need to be assessed with both critical temporal patterns.

- Hydraulic boundary conditions for the hydraulic model (inflows) for a specific design event must be based on a single, model-wide applied temporal pattern. To be clear, it is not acceptable to apply inflows at different model locations that have been derived from different temporal patterns. It may therefore be required to undertake multiple hydraulic model simulations for a specific critical duration at all locations under consideration if:
  - a suitable common temporal pattern cannot be determined, and
  - the critical temporal pattern changes between Base Case and Design Case.
- For each relevant AEP event, peak water levels of all critical durations (in either Base Case or Design Case) must be enveloped into a single composite peak water level (peak of peaks) for that specific AEP event. Afflux for each AEP event is determined by the difference in composite peak water levels between the Design Case and Base Case.
- Computational Fluid Dynamics (CFD) modelling must be considered for any complex bridge situations that cannot adequately be assessed by published existing bridge loss estimation methods. The need for CFD modelling shall be discussed with and agreed by the Director, Hydraulics and Flooding, Engineering and Technology, Transport and Main Roads email: TMRH&FProjects@tmr.qld.gov.au.
- Design blockage for new transverse drainage structures must be assessed using the approach detailed in ARR. Compliance of flood immunity must be demonstrated assuming design blockage at all new cross-drainage structures. Impact assessments (afflux) must be undertaken, assuming a no blockage scenario at all cross-drainage structures. Note: For new infrastructure in greenfield sites, it may be appropriate to also assess impacts under a blocked scenario.
- Any bridges that are relevant for the hydraulic assessment of the project works must be modelled in the hydraulic model as 2D structures if the bridge spans three or more grid cells and must have their head loss estimates validated using an alternative independent method (for example, CFD modelling, HEC-RAS, Austroads *Guide to Bridge Technology – Part 8: Hydraulic Design of Waterway Structures*).
- Safety barriers must be represented in the hydraulic model as 100% fully blocked for concrete barriers. Guardrail must include an appropriate blockage factor from pavement to the underside of the first cross-member, then 100% blocked above the underside of the cross member to the top of the barrier. However, all safety barriers that include motorcyclist injury countermeasures must be assumed as 100% blocked and modelled as a solid feature for the entire height of the barrier.
- Noise attenuation structures must be represented in the hydraulic model as 100% fully blocked.
- Rail ballast, including sleepers and rails, must be assumed to be impermeable and be included in the bathymetry of the model.

3.4 Bridge design considerations

Detailed hydraulic analysis needs to be undertaken to inform the structural bridge design. Flood and debris forces need to be considered in accordance with AS 5100.2 *Bridge design, Part 2: Design loads* and the department's *Design Criteria for Bridges and Other Structures*. Important bridge design inputs are peak water levels and peak velocities under Serviceability Limit State (SLS) and the Ultimate Limit State (ULS) conditions of the bridge design.

Hydraulic modelling to undertake a scour assessment at bridge piers and abutments needs to be conducted in accordance with the department's current *Bridge Scour Manual*.

3.4.1 Substructure losses

In case a bridge is modelled in TUFLOW as a BG Shape or a Layered Flow Constriction (LFC), the preferred method is to include the pier (L1) blockage ratio J (pBlockage), and to derive the pier (L1) FLC values from Figure 4.10 Austroads *Guide to Bridge Technology – Part 8: Hydraulic Design of Waterway Structures* modified by Equation 1 below to account for the increased velocities within the bridge section.

$$Pier\_FLC = \Delta K_P(1 - J)^2 \qquad (1)$$

These values are only to be applied if no calibration data is available and does not replace the requirement that all bridges must have their head loss estimates validated using an alternative independent method (see Section 3.3 above).

3.4.2 Superstructure losses

TUFLOW have introduced a new BG Shape input layer (2d_bg) to set up bridge structures that provide better options for representing surcharging, submergence, and upstream controlled pressure flow of bridge decks. Guidance on the default approach, and default values in applying BG shape layers, should be sought from the TUFLOW documentation. Recommended default values are only to be applied if no calibration data is available and does not replace the requirement that all bridges must have their head loss estimates validated using an alternative independent method (see Section 3.3 above).

3.4.3 Total bridge form loss

In case a bridge is modelled in TUFLOW as a BG Shape or a LFC, care needs to be taken when applying "region" or "wide / thick line" features which distribute form loss values to individual cell sides, especially if the bridge is not aligned with the grid orientation. The sum of individually applied form loss values at cell sides in flow direction must match the total estimated head loss over the entire bridge structure. The modeller must check that form loss is applied to the correct number of cell sides, thereby ensuring form loss values are not under or over estimated.

3.4.4 Guardrail losses

It is recommended to model guardrail in TUFLOW as a LFC. The form loss values detailed in Table 3.4.4 (based on limited CFD modelling) for standard departmental guardrail (w-beam, thrie beam, and box beam barriers) are recommended if no other calibration data is available. However, all safety barriers that include motorcyclist injury countermeasures must be assumed as 100% blocked and modelled as a solid feature for the entire height of the barrier, instead of using a LFC (for example, z-line instead of lfcsh).

Table 3.4.4 – Recommended LFC loss coefficients for standard departmental guardrail

LFC input variable	Standard departmental guardrail
Layer 1 obvert	Underside of the first cross-member
Layer 1 blocked ratio*	5.5%
Layer 1 form loss coefficient	0.05
Layer 2 depth	Depth of cross-member
Layer 2 blocked ratio*	100%
Layer 2 form loss coefficient	0.7

*Note: The applied blockage ratio only represents structure blockage and does not include an allowance for debris blockage. The blocked area ratio will need to be increased to allow for additional debris blockage.

4 Delivery specification

4.1 Reporting requirements

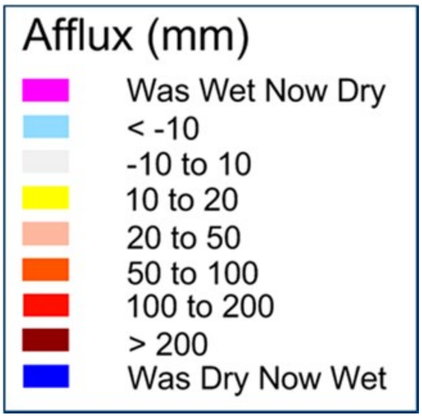
Any assumptions underlying a modelling parameter shall be clearly stated and explained, especially the assigned roughness coefficients and, if applicable, eddy viscosity.

Following acceptance of the draft document, the Consultant shall present a final report. Whilst the structure / format of the report is not rigid, the report shall incorporate the methodology and findings of the study in sufficient detail to support the validity of the conclusions. Therefore, the report must clearly state any assumptions, parameters used, their justification, and methods adopted in the hydraulic design. The report shall include the following as a minimum:

- Summarise previous work and outline relevant literature, such as the hydrologic investigation.
- Mapping (at an appropriate scale) of flood extents, levels, velocities, and flow distributions for all requested design events. This includes indicating, where relevant:
  - flow rates upstream and downstream of constrictions
  - maximum flood depth and afflux values at representative locations
  - flow velocity and depths at locations near to infrastructure
  - flood mapping scenario differences (levels, velocities), and
  - volume passing within drainage infrastructure.
- Flood peak duration (time of closure).
- If applicable, details of properties flooded over floor, floor level, change in flood depths, times of closure / submergence and calculation of Average Annual Time of Closure (AATC).
- If applicable, all raw flood damage data, including the location, floor level, size, age, and nature of all buildings likely to be affected by flooding.
- If applicable, all relevant design information (that is, design layouts or design strings) on flood maps.
- If applicable, identify property which may be inaccessible by conventional vehicles during flood events.

- Identify undersized road infrastructure crossing(s) or inlets which may constrict flows or are susceptible to blockage (that is, box or pipe culverts with respect to the 1% AEP flows).
- A model log which clearly indicates where model data has been changed for particular option scenarios including future development and major infrastructure scenarios.
- The following afflux legend (contour intervals and colours) is preferred by the department for all projects.

Figure 4.1 – Afflux legend



4.2 Supply of hydraulic model and result files

Hydraulic reports, including all relevant models and results, must be provided to the department. Sufficient data is to be provided to facilitate a peer review of the hydraulic modelling and the re-creation of model results. Electronic results of all design and scenario model runs are to be provided for interrogation as part of model documentation. A file fully defining and explaining the relevant files provided and their inter-relationship and purpose is also to be provided.

The spatial reference for the model is to be in the department's adopted datum and projection. The height datum is metres Australian Height Datum (AHD).

- Model data files and accompanying results and background are to be arranged in a file structure, and shall be clear and logical, for example:

  (Project > Model / Background > Design / Calibration > Runs).

- Log data of model runs, that is, the input files used to make up each model run, to enable re-creation of results in future.

4.3 Model GIS data

The results of the modelling shall be mapped. The data shall be a contiguous digital data set and arranged within a workspace, i.e. not as separate files for each individual map sheet. The files should include flood attributes such as depth, level and velocity. All modelled design and calibration events shall be included in the dataset.

4.4 Modelling log and naming conventions to be used on departmental projects

A modelling log must be provided. The log may be in Excel, Word or another suitable format. An experienced modeller should be able to understand the modelling log during a review. It should contain sufficient information to record model versions during development and calibration, file naming conventions and observations from simulations. Model file naming conventions and locations are important in ensuring that simulations can be undertaken efficiently, with high traceability, and that old simulations can be reproduced as required. They also assist the Quality Assurance (QA) process. Successful model file naming conventions have the following characteristics:

- files are named using a logical and appropriate system that allows easy interpretation of file purpose and content – refer below
- a model version naming and numbering system (designed prior to modelling) should be included in input data file names
- a logical and appropriate system of folders is used that manages the files, and
- documentation of the above in, for example, the study's Quality Control Document and/or Modelling Log.

4.5 Completion and handover of a departmental modelling project

At the completion of the project, the modeller is required to compile all data files and document details of the hardware and software used and the runtime of the models. The final models to be handed over to the department must include all adopted design features and be consistent with the final set of design drawings (for example, As Constructed or Issue for Construction (IFC) drawings).

The hydrologic and hydraulic software packages are not required in the hand-over. However, any software developed (including source) or acquired by the Consultant to interface or transfer data between the hydrologic model to the hydraulic model, or to pre-process data into a format required for input to these models, or post-process data to a required output format, is to be supplied (along with any licences) to the department as part of the study.

As a minimum, the department needs to be confident that all results presented in the final Hydrologic and Hydraulics Report can be re-created.

The Consultant is to also include the following with documentation at handover:

- Underlying survey data, including any GFM, cross-sectional data points or digital elevation model (DEM). Any new survey data specifically collected for departmental projects shall be delivered as prescribed in the current departmental *TMR Surveying Standards* which provide instructions for the expected delivery of survey data to the department. Unless otherwise specifically instructed, all survey data shall be submitted to:
  - Director (Geospatial Technologies), Engineering & Technology Branch, Transport and Main Roads email: TMR_Spatial_Enquiry@tmr.qld.gov.au
- All raw flood damage data, including the site visit photography, location, floor level, size, age and nature of all buildings likely to be affected by flooding.
- Copies of any aerial photographs and satellite images (hard copy and/or electronic) that may have been acquired during the course of the study.

The Consultant should provide as many of the items requested on electronic medium. The electronic medium is to include a fully detailed 'Read Me' file to explain the content and purpose of all files contained within.