# Peer Review of Bohle River Flood Study

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| Customer | Towsville City Council |
| Project | A10416 |
| Deliverable | 004 |
| Version | 00 |
| | 18 February 2022 |

# Document Control

## Document Identification

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|---|---|
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| Customer | Towsville City Council |
| Classification | BMT (OFFICIAL) |

| | |
|---|---|
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## Amendment Record

The Amendment Record below records the history and issue status of this document.

| Version | Version Date | Distribution | Record |
|---|---|---|---|
| 00 | 18 February 2022 | Townsville City Council | Draft Report |

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# 1 Introduction

## 1.1 Background

Townsville City Council (TCC) is currently updating flood modelling and mapping within the LGA as part of the Townsville Flood Modelling and Mapping Project (the Project). BMT has been engaged to provide expert peer review for the Project to support achieving sound and defendable outcomes for TCC by:

- Ensuring the study follows latest industry standard techniques and best-practice;
- Instilling confidence in the study products and outputs;
- Identifying potential missed opportunities which might be rectified within this study, or flagged for future works.

The modelling and mapping for the Townsville Flood Modelling and Mapping Project has been commissioned under five separate contracts with each contract pertaining to a hydrological catchment (or group of catchments). These five contracts are as follows:

- Bohle River catchment
- Black River, Althaus and Bluewater Creeks
- Ross River and Surrounds
- Alligator Creek and Whites Creek.
- Magnetic Island and Balgal Beach (five separate studies):
  - Balgal Beach
  - Arcadia
  - Horseshoe Bay
  - Nelly Bay
  - Picnic Bay.

This peer review report documents the review findings for the modelling contract undertaken for the **Bohle River** Catchment by Water Technology (WT) as part of the Bohle River Flood Study Update.

In May 2021 BMT were asked by TCC to provide comment on a finding from the WT draft report regarding the need for scaling of design rainfall data. BMT provided some brief feedback and suggested recommendations. The finalised WT flood study report makes reference to BMTs initial feedback and includes BMT’s commentary within Appendix F. Where applicable, further BMT commentary on this matter is provided within this review.

## 1.2 Supplied Data

BMT has relied on information from the following sources in the completion of this review:

- Bohle River Flood Study Update 2021, Final Report Volumes 1 and 2. Water Technology, 2021)
- Request for Quotation: Flood Model Updates for ARR 2016: Bohle River Flood Models, Phase 1 & 2 (TCC, March 2019)
- XP-RAFTS hydrologic model:
  - Model files and inputs
  - Supporting GIS files
- Hydraulic TUFLOW model:
  - Model input files
  - Raw peak output results grids
  - Processed results grids (processed for median temporal pattern and critical duration).

### 1.3 Peer Review Process

The peer review covers the following aspects:

- Technical review of the models for general configuration, parameters, calibration performance, model health etc;
- Assessment of conformance or otherwise to the Australian Rainfall and Runoff 2019 guideline (ARR2019);
- Assessment of the degree to which the deliverables provided to Council meet the stated aims in the respective project briefs and associated consultant proposals;
- Commentary on differences in flood levels from previous assessments (which were developed based on the Australian Rainfall and Runoff 1987 guideline (ARR1987) with hydraulic modelling undertaken using MIKE FLOOD software); and
- Commentary on the ability of the study outputs to be used for end purposes (i.e. application of the new flood models, flood maps and flood hazard maps for the planning, new development and rezoning purpose).

We have utilised a traffic light system to indicate how significant an issue might be. Each observation is allocated a colour (green, yellow or red) in accordance with Table 1 1. Where a potential issue has been identified, we have provided our recommendations on how to address or further investigate the issue.

At the end of each key review section, a summary table is provided of key review observations and recommendations along with an indication of the significance of the issue.

Table 1.1 Significance of Issue

| Category | Category Description |
|---|---|
| Green | Checks have showed either no issues or issues are of a minor or cosmetic nature that don't have any bearing on model results |
| Yellow | An issue which is unlikely to be significant but does warrant further checking or justification. |
| Red | Potentially significant issue which may have implications on model results and further investigation is required |

## 1.4 Limitations

In preparing this report, BMT has relied upon, and presumed accurate, information (or absence thereof) provided by Water Technology. Except as otherwise stated in this report, BMT has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete, then it is possible that our observations and conclusions as expressed in this report may change. It is assumed that the results provided by Water Technology correspond to the definitions in the control files provided for the model runs.

## 2 Modelling Overview

A single hydraulic model has been developed using TUFLOW HPC software for the Bohle River catchment. This model consolidates numerous separate hydraulic models previously developed for different parts of the catchment. The consolidated single model is the focus of this peer review.

Inflows to the hydraulic model are predominantly generated from a hydrologic XP-RAFTS model developed by WT for the flood study update, with allowances for additional inflows from the neighbouring Ross River catchment during large flood events.

It is understood that the original expectation was for use to be made of a hydrologic model previously developed/updated as a pilot study model under a separate commission[1]. Upon review, WT essentially found that this model was not fit for the intended purpose and redeveloped the hydrologic model. The original hydrologic model is outside the scope of this peer review, however the redeveloped model has been included in this review.

The hydraulic TUFLOW model utilises a 5m model grid and was calibrated to available data for the flood events which occurred in January/February 2019 and April 2014 flood. The model was then used to simulate design flood events with Annual Exceedance Probabilities (AEPs) ranging from 50% (most frequent) to 0.05% (rarest). The Probable Maximum Flood (PMF) has also been assessed.

The design event modelling uses the approach set out in the ARR2019 guideline (Ball et al, 2019).

The remainder of this report sets out the key findings from our peer review of the flood study covering both the technical setup and quality of the hydrologic and hydraulic models as well as the overall modelling approach.

The structure of the peer review generally follows the structure of the flood study under review. Model development and calibration is initially reviewed followed by design flood modelling (including use of ARR2019) techniques. Where applicable, review commentary is provided on the change in flood levels compared to previous assessments.

[1] Review of Hydrological Methods for the Townsville Region project Phase 3 – Catchment Simulations for Test Catchments (HARC, 2018)

# 3 Hydrologic Model Development and Calibration

## 3.1 Background

The hydrologic assessment has been informed by inputs from a series of investigations delivered under the 'Review of Hydrological Methods for Townsville Flood Modelling'. This includes:

- Rating curves and flood frequency analyses delivered under Phase 1 of the review (HARC, 2016)
- A hydrologic model of the Bohle catchment developed as a test model under Phase 3 of the review (itself consolidated from 13 pervious hydrologic models) (HARC, 2018).

WT identified a number of issues with the Bohle River catchment hydrologic model developed under Phase 3 of the 'Review of Hydrological Methods for Townsville Flood Modelling'. These issues were documented by WT as being the result of inconsistences between the original 13 component models which were not resolved in the compiled model. WT concluded that the hydrologic model could not be satisfactorily calibrated in its current form and have therefore substantially revised the hydrologic model.

WT has also revised rating curves developed under Phase 1 of the 'Review of Hydrological Methods for Townsville Flood Modelling' for four key gauges at:

- Bohle River at Mount Bohle (532053)
- Bohle River at Hervey Range Road (532043)
- Bohle River at Dalrymple Road (532089)
- Little Bohle River at Middle Bohle River Junction (532044).

It is outside the scope of the BMT review to consider the models or other outputs delivered through the 'Review of Hydrological Methods for Townsville Flood Modelling'. BMT cannot therefore provide further comment or verification of WTs findings on the model. BMT does acknowledge the effort WT has put into reviewing and updating the hydrologic model.  The updated WT model is the focus of the BMT review.

## 3.2 Hydrologic Model Review

### Model Development

The hydrologic model is developed in XP-RAFTS software. Separate models are provided for two calibration events and the design and PMF models. The design case model file is 'BOL_E_DES_10-1Losses_Design.xp'. The model uses the subcatchment delineations as applied in previous modelling (HARC, 2018). The updates by WT include ensuring consistent use of hydrologic routing (as opposed to simple lagging) and a consistent approach to modelling impervious areas utilising the XP-RAFTS split subcatchment approach.

BMT has undertaken basic checks on the applied model areas and slopes and no issues were identified. The hydrologic roughness coefficients are within the ranges presented by TCC in its Guidelines for Preparation of Flood Studies and Reports (TCC, 2020) and slopes are limited to 15% as per these guidelines. The single model applies a consistent approach to runoff and routing which will be of benefit to the study over previous use of multiple models.

## Model Calibration

The updated XP-RAFTS model has been calibrated to the historic flood events of January/February 2019 and April 2014.

The historic rainfall allocation to XP-RAFTS subcatchments is shown in the WT report (Figure 3-9 and Figure 3-10 for the 2014 and 2019 events respectively). A number of the gauges listed on Figure 3-9 and Figure 3-10 are not included in the tabulated list of available gauges (WT Table 3-3). For example, the following 2014 event gauges are listed on WT Figure 3-9 but not listed in WT Table 3-3:

- Deeragun
- Gleeson Mill
- Hervey Range Road
- Mt Margaret
- The Pinnacles
- Townsville Airport
- Vincent.

It is recommended WT Table 3-3 is updated to include all gauges shown in Figure 3-9 and Figure 3-10 of the WT report. It is also recommended that Figure 3-9 is made consistent with Figure 3-10 by showing the gauge locations.

Section 5.2 of the WT report is titled XP-RAFTS Calibration Results, however within this section all quoted model flows and flow comparisons are from the hydraulic TUFLOW model which is a bit confusing to the reader. BMT recognises that a joint calibration has been undertaken and that results from the hydraulic model are ultimately what should be compared against historic data. However, we recommend that hydraulic model results (including flows) are incorporated into the hydraulic model section of the report.

Section 5.2.2 quotes a difference in flows at Dalrymple Road of 4% but Table 5-2 says 7%.

Section 5.2.4 mentions that there is a difference of less than 10% between the TUFLOW flows and rated flows for the April 2014 and January 2019 events at the Dalrymple Road and Little Bohle gauges. However, in the case of the January 2019 event the difference at the Dalrymple Road Gauge was 31% according to WT Table 5-3.

Where the recorded (rated) discharge is not obviously in error but there are notable differences between recorded and modelled flows such as at Stony Creek and Saunders Creek in 2014 and Dalrymple Road in 2019, it would be worth describing the likely reasons for the discrepancy. For example, both the 2014 and 2019 recorded levels at Stony Creek Alert appear to have dubious spikes in data near the peak of the flood (Figure 5-5 and Figure 5-12 of WT report) and quoted peak levels (and flows) are based off these spikes in data and may explain in large part some of the differences from modelled data.

## 3.3 Summary of Hydrologic Model Observations and Recommendations

Table 3.1 Hydrologic Model Development and Calibration Summary

| ID | BMT Observation | BMT Recommendation |
|---|---|---|
| 3.1 | Inconsistency on documented rainfall gauges (Table 3-3 and Figures 3-9 and 3-10) | Check for consistency including formatting of the two figures |
| 3.2 | Section 5-2 on hydrologic model calibration reports on hydraulic model flows | Save discussion of hydraulic model results for section on hydraulic model calibration. |
| 3.3 | Inconsistency between report text and tables when describing calibration (S.5.2.2 and 5.2.4) | Check for consistency. |
| 3.4 | Report would benefit from further explanation of difference between modelled and rated flows eg. Dubious spikes in recorded data | Review text and update report |

# 4 Hydraulic Model Development and Calibration

## 4.1 Background

The hydraulic model is a new model developed using TUFLOW software, the results of which will replace seven separate MIKE-FLOOD models previously developed for different parts of the catchment. The TUFLOW model is predominantly 2D with nested 1D culvert elements. It uses TUFLOW HPC along with its Sub-Grid-Sampling (SGS) feature. The model was simulated using TUFLOW build 2020-10-AA-isp which was the latest version at the time of the assessment.

## 4.2 General Considerations

### Overview

The supplied model files consist of four TUFLOW control files (tcf) as follows:

- BOL_E_~s1~_~e1~_001.tcf
- BOL_E_~s1~_~e1~_~e2~_~e3~_001.tcf
- BOL_E_~s1~_~s2~_~e1~_~e2~_~e3~_001.tcf
- BOL_E_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_001.tcf.

These tcfs all utilise the same model input files and differences between them relate to the incorporation of different model scenarios and output locations for results files.

The model covers a significant catchment area at a relatively high resolution (5m).

### Naming Conventions

TCC has nominated a standardised hydraulic model naming convention to be used on models developed for the Project. The naming adopted by WT broadly meets the naming convention although does not conform exactly due to the ordering of components of the model name. In BMT’s opinion the adopted naming meets the intent of TCCs requirement for having standardised naming. The naming is clear, logical and allows TCC to easily identify it is a Bohle River model (or result file).

### General Setup

The model folder structure is set up in accordance with TCCs requirements and follows TUFLOW’s recommended folder structure approach. Default model settings are generally applied as recommended. Of note, a non-default set of viscosity coefficients has been applied by WT with a value of 0 representing the 3D coefficient ($C_{3D}$) and a value of 4 representing the 2D coefficient ($C_{2D}$). The default values are 7 and 0 for $C_{3D}$ and $C_{2D}$ respectively. Whilst the model has been calibrated, which is the ultimate proof of the model, the user should be aware that the viscosity coefficients selected may make the model more sensitive to changes in cell size than which would occur with use of default values. It is recommended that a statement is added to the report to explain the departure from default (recommended) values.

### Model Initialisation

When attempting to simulate the supplied model using the specified TUFLOW build (2020-10-AA) errors associated with 12 pit inlet levels being below the lowest channel/pipe resulted in the model failing to initialise. Of these errors, nine showed significant differences between the pit level and the lowest pipe level. Based on inspection of the affected locations it appears that a z shape file is significantly lowering ground levels to be below pipe invert levels.

For example, Pit IDs 'PIT_2858', 'PIT_3905', 'PIT_2854' and 'PIT_3906' are located in close proximity and all indicate that ground levels are in excess of 10m below the pit inverts. The ground elevations based on LiDAR are in general agreement with expected pipe inverts included in the model. The issue results from application of a z shape (2d_zsh_BOL_026_R.shp) which is causing a significant lowering of ground levels by 10m or more at the locations of these four pits. All of the nine instances of significant ground level lowerings are associated with this particular z shape file. When BMT tested the initialisation in a later build of the TUFLOW software (2020-10-AB), the issue with this particular z shape was no longer present thereby resolving 9 of the 12 error messages. The remaining 3 instances of the error ('PIT_286', 'PIT_3922' and 'PIT_1285') show very minor differences (in the order or millimetres) and are possibly to do with minor inconsistencies in the pipe inverts or topography.

It is not clear how WT simulated the supplied model in TUFLOW build 2020-10-AA without experiencing these issues. TUFLOW log files were not supplied to confirm matters. It is recommended that WT review the supplied model as other third party users of the model may experience similar issues.

## 4.3 Hydraulic Model Development

### Topography

The majority of base topography is formed from a 1m DEM generated from 2016 LiDAR survey. Supplementary topographic grids are then applied representing bathymetry and DEMs for development sites. The ordering of the layers applied in TUFLOW is appropriate.

Additional topographic modifications have been made where WT has noted the LiDAR insufficiently captures the bed of drainage channels as well as at a number of culvert inlets and outlets.

Breaklines representing road embankments and other linear raised features are not enforced in the model. Breakline enforcement is important when using TUFLOW's SGS feature when the topographic feature is narrow compared with the cell width. As the model cell size of 5m is relatively small, this is not likely to be a significant issue in the model.

### Materials

Based on a visual inspection of the land use delineation against available aerial imagery, the mapped land uses are generally appropriate and mapped to a reasonably high level of detail.

The Manning's n values are defined for seven land use types and adopted values fall within an acceptable range. A value of 0.075 for high density vegetation is within an accepted range but at the lower end of the range.

The model has been calibrated using these land uses and associated Manning's n values and a reasonable calibration has been achieved.

### Structures

Bridges have been modelled using TUFLOW's Method C approach and are defined using polygons. There is no documentation on how bridge form losses have been derived but the values fall within expected ranges. It is noted that the RFQ requests for head loss verification across structures and this has not been undertaken. However, the representation of the bridges in the model is appropriate and, given this is a catchment wide flood study, there would be minimal benefit in cross checking head loss at individual structures unless they were in a heavily urbanised area where head loss is important.

Site visits were conducted to many of the key structures by WT and have resulted in some important updates to how structures are represented in the model.

A significant number of culverts (395) and pipes (4171) are included in the model. A review has found that the representation of the culverts and pipes is generally appropriate notwithstanding the limitations of the input data relied upon. One example noted where the schematisation of the model could be improved is where culvert ID 'Culvert_321' discharges into Louisa Creek between the east bound and west bound lanes of the Bruce Highway (Figure 4.1). The cross drainage structure conveying flow from Louisa Creek under the Bruce Highway is modelled as a single set of culverts which passes under multiple solid embankments in the model DEM. Under this setup, Culvert_321 will discharge into the space between the highway and effectively become trapped. This may cause greater backup in the drainage channel conveyed by Culvert_321 than would otherwise occur. Overall this is likely to have minimal impact on peak flood levels in the main creeks but will prevent the model draining the catchment area of Culvert_321.

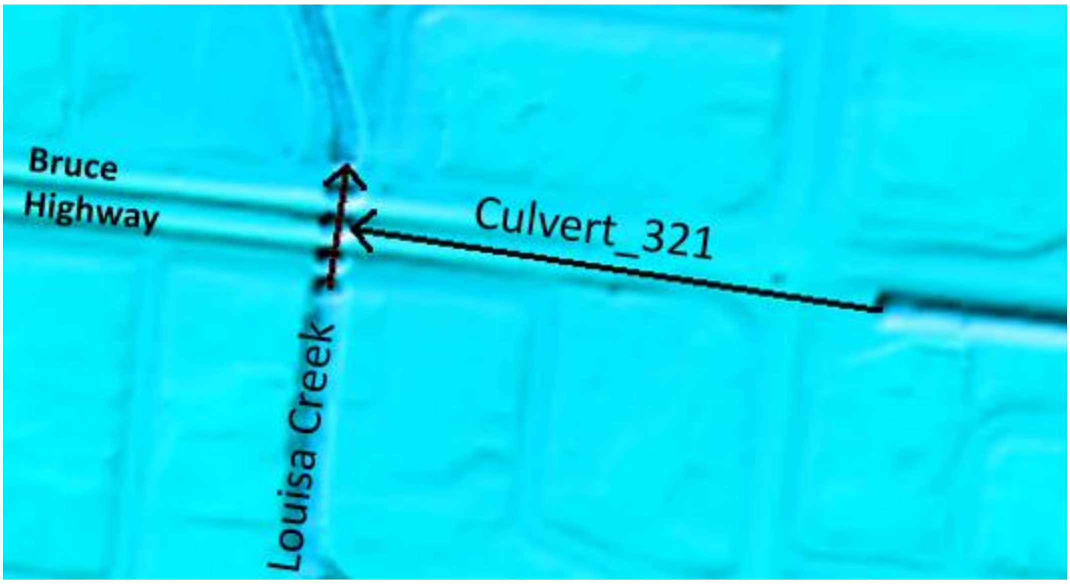



Figure 4.1 Culvert_321 discharging into Louisa Creek

## External Boundaries

The downstream boundary of the model is represented as a head versus time (HT) boundary. For design events this is a fixed tailwater level with levels as follows:

- Mean High Water Springs (MHWS): (1.254mAHD) for the 50%, 20% and 10% AEPs
- Highest Astronomical Tide (HAT): (2.254mAHD) for the 5%, 2%, 1%, 0.5%, 0.2% and 0.05% AEP events as well as the PMF event.

TCC guideline SC6.7.4 regarding the preparation of flood studies and reports for the Townsville City Plan requests that for coastal boundaries "*A fixed tailwater condition equal to the height of the Mean High Water Springs (MHWS) tide should be adopted*". WT has adopted a higher tailwater of the HAT for the 1% AEP event. This is therefore inconsistent with the guideline and neighbouring flood studies eg Ross River and Black River, reviewed by BMT. A further inconsistency is that the climate change simulations for the 2% and 1% AEP events apply sea level rise allowances onto a MHWS tailwater, not HAT. This is discussed further in Section 5.4 but means that a comparison of the 1% AEP with the 1% AEP climate change scenario is not showing the full impact of sea level rise.

An HQ boundary is represented along the catchment divide between the Ross and Bohle catchments. This allows Bohle catchment flow to exit the model into the Ross River catchment.

An inflow boundary (type QT) is included on the Ross River for events of the 0.5% AEP or rarer. An HT boundary is also included at the downstream end of the included reach of Ross River for the same events. It is assumed that this is to capture breakout flow which may enter the Bohle catchment from the Ross River catchment.

Inflows for the Ross River are included in the model files for the 0.5%, 0.2% and 0.05% AEPs as shown in Table 4.1 below. For comparison the peak dam outflows are provided from the finalised AECOM study of the Ross River (finalised after the WT study was completed).

Table 4.1 Ross River Inflows

| AEP (%) | Peak Inflow (m3/s) | Peak Dam Outflow (AECOM, 2021) |
|---|---|---|
| 0.5 | 933 | 1254 |
| 0.2 | 1674 | 1330 |
| 0.05 | 2010 | 1995 |

As the Ross River flow is applied as total flow within the Ross River channel as opposed to just the overspill, the model is reliant on its representation of the Ross River channel to generate the overspill. The land use delineation of the Ross River within the WT model is relatively coarse with the river and its immediate floodplain using a Manning's n value of 0.055. This may result in different breakout flow volumes to that which are modelled in the Ross River Flood Study (AECOM, 2021). It is recognised that such breakouts only occur for events at the more extreme end of those assessed and so is likely to be of minimal consequence to the outcomes of this study. A preferred approach would be to obtain the flow discharging into the Bohle catchment from the Ross River Flood Study and apply it as overtopping flows. However, this is also likely to be complicated due to differing critical durations in the respective studies.

In BMT's opinion, the approach taken for Ross River breakout flows is appropriate for a flood study, particularly given that design information from the neighbouring Ross River flood study was not finalised at the time of assessment. Overall it is recommended that the limitations of the approach are clearly stated in the report. Furthermore, any ongoing investigations that require more detailed information for extreme events should consider updating the model to reflect the modelled breakout flows from the Ross River Flood Study.

Inflows from the XP-RAFTS model are applied as source area inflows within TUFLOW. Checks by BMT have shown that all XP-RAFTS subcatchments are accounted for.

For a number of inflows across the urban areas, a proportion of that inflow is directed to modelled pits using the TUFLOW's 'SA to PITs' command. It is understood from WT that the proportions of flow directed to pits were determined by a ratio between the estimated pit capture area and the total area of the relating sub-catchment. The pit capture area was estimated to be a 50-meter radius buffered out from each pit across the entire model.

Overall the application of XP-RAFTS inflows to the TUFLOW model is considered satisfactory.

### Output Settings

Model output setting include a map cutoff depth of 0.01m and a Map Cutoff for SGS using the 10th percentile. TUFLOW will use the higher elevation i.e. 0.01m above the lowest SGS sampled elevation or the 10th percentile of the SGS elevations sampled within the cell. Based on an inspection of model outputs, these cut off depths appear appropriate.

### Model Calibration

Overall the calibration of the hydraulic model to the available 2014 and 2019 historic data shows a reasonable calibration has been achieved. The 2019 event in particular was a significant event with multiple flood peaks. The model results appear to replicate these recorded peaks and timings well providing confidence in the model. Furthermore, a community consultation feedback exercise was undertaken on preliminary 2019 calibration results and the model was updated resulting in improvements to the calibration outcomes. Our peer review makes the following observations.

A number of the recorded levels/flows quoted in the WT report are from gauges which are clearly in error due to gauge failure. As a general comment we recommend that data which is clearly erroneous is not included as values within tables and instead a comment is made that the gauge failed. This is to avoid these results being misunderstood and undermining perception of the calibration (eg WT Table 5-1 to Table 5-4).

WT's comparisons of peak flows present the differences as modelled minus recorded (Table 5-2 and Table 5-3) but comparisons of peak levels present differences as recorded minus modelled (Table 5-4 and Table 5-6). It is recommended that the peak level differences are also presented as modelled minus recorded. Likewise, for tables of debris marks (Table 5-5 and Table 5-7).

Table 5-6 states a modelled 2019 flood level at Dalrymple Road of 11.43mAHD which is 0.51m lower than the recorded value. Based on Figure 5-11, which shows the modelled level over time, the peak modelled level appears to match much more closely than stated in Table 5-6 with a peak modelled level around 12.0mAHD. It is recommended that the tabulated value is amended (if in error) to avoid undermining confidence in the calibration. Discrepancies in tabulated modelled values versus plotted values are also apparent at:

- Stony Creek (2019)
- Saunders Creek (2019) – difference between plotted and tabulated modelled peaks in excess of 0.5m.

It is recommended that all tabulated and plotted peak modelled values are reviewed and updated where appropriate.

## 4.4 Summary of Hydraulic Model Observations and Recommendations

Table 4.2 Hydraulic Model Development and Calibration Summary

| ID | BMT Observation | BMT Recommendation |
|---|---|---|
| 4.1 | Non default viscosity parameters have been selected with no explanation. This may impact on future use of the model. | Add statement to the report to explain the departure from default (recommended) values |
| 4.2 | Model provided to BMT did not initialise due to discrepancies between pipe inverts and ground levels resulting in initialisation errors | Review the supplied model as other third party users of the model may experience similar issues |

| ID | BMT Observation | BMT Recommendation |
|---|---|---|
| 4.3 | Minor issue in schematisation of culvert 'Culvert_321' discharging into Louisa Creek | Review schematisation and amend if located in an area of importance. |
| 4.4 | 1% AEP event uses a fixed tailwater corresponding to HAT which appears inconsistent with Townsville guideline and neighbouring catchment studies. | Review choice of downstream boundary. See also recommendation 5.8. |
| 4.5 | Applied flows on Ross River (events of 0.5% AEP or rarer) are different to those finalised for the Ross River Flood Study. | Update for consistency between studies. |
| 4.6 | The degree to which Ross River flows spill into the Bohle River catchment may differ between the Bohle and Ross River Flood Studies. | Include statement on limitations of approach. |
| 4.7 | When reporting on model calibration, a number of gauges have historic flows/levels quoted which are clearly in error (due to gauge failure) | Recommend that data which is clearly erroneous is not included as values within tables and instead a comment is made that the gauge failed |
| 4.8 | Issues of consistency when setting out differences between modelled and recorded flows/levels. Flows are modelled minus recorded whereas levels are recorded minus modelled. | Recommended that the peak level differences are also presented as modelled minus recorded |
| 4.9 | Inconsistencies between modelled flood levels on figures and in tables. | Review reported values and ensure consistency to avoid undermining confidence in calibration |

# 5 Determination of Design Floods

## 5.1 Overview

The approach to design flood estimation applied by WT uses approaches contained within the ARR2019 guideline. Two approaches to design flood estimation were undertaken as follows:

- Flood Frequency Analyses (FFA) at gauges identified as being suitable
- Design event simulation using the calibrated models.

The two largely independent techniques allow comparisons to be undertaken between the different methods of flood estimation as recommended by ARR2019.

WT has also provided commentary on the design Intensity Frequency Duration (IFD) rainfall data in the context of FFA and design flood modelling.

The remainder of Section 5 sets out BMT's review of the design flood estimation including the commentary on IFDs and the design event selection process for model simulations.

## 5.2 FFA

### FFA Locations

Two key gauges were identified by WT as being suitable for FFA:

- Bohle River at Mount Bohle (532053)
- Bohle River at Hervey Range Road (532043).

Following removal of potentially influential low flows (PILFs) the Mount Bohle and Hervey Range Road gauges have annual maxima series of 31 years and 17 years respectively. These are short record lengths relative to the design floods under consideration, but BMT is in agreement that undertaking the FFA is a worthwhile exercise as it provides an additional check on modelled peak flows.

### Rating Curves Used in FFA

WT has revised the rating curves for both the Mount Bohle and Hervey Range Road gauges and there are notable differences in the rating within the range of peak annual maxima flows, particularly for the Mt Bohle gauge. For example, a recorded gauge level of 8.0mAHD would equate to a peak flow of approximately 700$m^3$/s under the existing rating (HARC, 2016) and around 950$m^3$/s under the revised rating.

An observation made by BMT is that whilst WT have updated the rating curve for Mt Bohle based on the hydraulic model it is noted that the hydraulic model gives consistently lower results along this reach of river compared to recorded results for the January/February 2019 event. For example, at the closest debris mark location to the Mt Bohle gauge, the recorded water level was 8.53mAHD compared to the modelled peak level of 8.07mAHD (Figure 5-14 of WT report). This may imply the hydraulic roughness needs to be higher which in turn will increase the level on the rating curve for a given flow.

If available, it would be useful to include plots of any flow gaugings on Figure 6-1 and Figure 6-2 in the WT report as this would provide an indication of which rating curve better fits the gaugings for flows within the gauged range.

### FFA

The FFAs have been undertaken using FLIKE which follows best practice. FFAs are compared to the modelled TUFLOW peak flows[2] within the WT report. Table 5.1 below shows extracted peak flow estimates for the 1% AEP event.

Table 5.1 1% AEP FFA peak flow compared to TUFLOW Peak Flow[2]

| Gauge | FFA Peak Flow ($m^3/s$) | TUFLOW Peak Flow ($m^3/s$) | Difference (%) |
|---|---|---|---|
| Mount Bohle | 1930 | 1875 | -3% |
| Hervey Range Road | 1327 | 1668 | 26% |

It can be seen from Table 5.1 that the 1% AEP peak flows show good agreement at Mount Bohle. At Hervey Range Road the TUFLOW peak flow is notably higher. It is noted that the quoted TUFLOW peak flows include significant scaling of the design rainfall inputs (discussed in Section 5.3 of this review) in order to reconcile the results with the FFA estimates. It is also noted that the modelled design flows are based on a whole of catchment areal reduction factor (ARF) rather than an ARF to the gauge location which will understate flows. It is recommended that text is added to the WT report to make these assumptions clear.

Appendix H of the WT report is titled *Flood Frequency Curves with 1% AEP and 10% AEP design flood estimates*. Appendix H however is showing rating curves along with where the 1% AEP and 10% AEP design flood estimates sit in relation to the rating curves. It is recommended that the rating curve is replaced with the flood frequency curve based on FFA (AEP vs flow). As things stand, the statement in Section 7.12.1 that Appendix H includes a set of the FFAs at each gauge location should also be amended as the FFA results are not shown and a comparison of modelled flows against the FFA in these plots is not possible. Section 7.12.1 also refers to the hydrologic peak discharge summary but the 10% and 1% AEP peak flows referred to in Appendix H appear to be the hydraulically modelled flows.

### AEP of Historical Events

Within the FFA section of the report an analysis is included on the AEP of the 2019 event rainfall by comparing recorded rainfall to published IFD relationships. The results are presented in Figure 6-5 of the WT report. Commentary states that the magnitude of the rainfall depth was a 1 in 2000 AEP for durations greater than 24 hours. Based on the figure it appears that this is true for durations of 96 hours or greater but not for durations of 72 hours or less. It is likely that WT meant the 1 in 100 AEP rather than 1 in 2000 AEP in this statement. This should be checked and updated accordingly.

## 5.3 Comparison of Design IFDs with historical data

Section 7.5 within the WT report compares IFDs against historic 24 hour rainfall totals at 3 gauges located within the vicinity (but not within) the Bohle catchment. WT notes that historic 24 hour totals at two of the three gauges exceed the IFD 1% AEP, 24 hour duration depths. It is concluded that this "*may be suggestive that the BoM design IFDs may be an underestimate for the Bohle River catchment compared to historical rainfall*".

Sensitivity assessments have then been undertaken (Section 7.6) by applying a 1% AEP, 6 hour rainfall within the hydrologic model and varying the rainfall loss rates. The flows are then applied within the hydraulic model and the peak flows compared to the 1% AEP FFA estimates for the Mt Bohle and Hervey Range Road gauges (Table 7-2 of report). It is not explained why a 6 hour duration was

[2] These TUFLOW flows are based on factorised ARR2019 rainfall as discussed in Section 5.3.

selected for this purpose but it is assumed that this is the critical duration within XP-RAFTS for flows at the respective gauges.

The flow estimates derived by WT are reproduced in Table 5.2 below. An argument is presented WT that by setting the rainfall losses to zero and running the XP-RAFTS model, the peak flow only increased by 43m$^3$/s at Mount Bohle. The TUFLOW results of using zero rainfall losses are not presented but it is logically inferred by WT that they would not increase by a sufficient amount to match the FFA flow at Mt Bohle.

WT therefore conclude that it is likely the design IFDs are low and that factorisation of the IFDs is required. WT later detail that IFDs have been factored by 150%. WT applied the factored IFDs to the XP-RAFTS model resulting in higher modelled design flows, which were then subsequently input to the TUFLOW model. For the purpose of this review, modelled design flows resulting from the factored IFDs, are referred to as “factored flows”. The unfactored (original) IFDs and resulting flows are simply referred to as “unfactored IFDs” and “unfactored flows”.

Section 7.6 and Table 7-2 are confusing as the analysis appears to use the already factored IFDs and quotes the resulting factored flows in the analysis. For example, the final (factored) XP-RAFTS discharges, quoted later in the report within Table 7-6, match the values in Table 7-2. Table 7-2 cannot therefore be used to ascertain what the unfactored peak discharges are or how they compare to FFA. The unfactored flows are not supplied or reported on elsewhere so BMT cannot ascertain the magnitude of the peak flow differences which WT has used to justify factoring of IFDs. As such, this section is potentially misleading and BMT recommends that the unfactored modelled flows are quoted to better support WT’s arguments.

By way of comment on the factored flows replicated in Table 5.2 below, the factored flows from the TUFLOW model agree closely with the FFA at Mt Bohle (around 3% lower than FFA) and are significantly higher than the FFA estimate at Hervey Range Road (around 25% higher).

Table 5.2 Peak Flow Estimates for the 1% AEP

| Method | Discharge at Mt Bohle (m$^3$/s) | Discharge at Hervey Range Road (m$^3$/s) |
|---|---|---|
| XP-RAFTS (10mm IL, 1mm/hr CL) – Factored Flows | 2625 | 2181 |
| TUFLOW (10mm IL, 1mm/hr CL) - – Factored Flows | 1875 | 1668 |
| FFA | 1930 | 1327 |

In Section 7.7 WT state that a 150% increase to IFDs was applied based on a match between the TUFLOW 1% AEP flows and the FFA flows. In Section 7.8 WT provide additional discussion on the factoring. BMT provided preliminary review comments on the factoring of the IFDs by WT in May 2021 (Appendix F of WT report). These have been considered by WT with WT responses incorporated into Section 7.8.

BMT makes the following responses to the statements made in S7.8 by WT on the applied scaling:

***WT statement:*** *that the use of an FFA approach represents the most accurate estimation of design flood hydrology available by a considerable margin from other estimates.*

**BMT response:** This statement is only true if the FFA is supported by a reliable rating curve and suitable record length. WT describe in their report that there is considerable remaining uncertainty in the rating curves. Furthermore, a record length of around 30 years still requires considerable extrapolation to achieve a 1% AEP flow estimate. BMT fully agrees that the FFA should be undertaken, and it provides an alternative means of deriving peak flow estimates. However to fully rely on a 30 year record FFA with an uncertain rating curve to draw conclusions about scaling design IFDs across a whole catchment is in BMT's opinion not correct. Note that design IFDs are underpinned by rainfall frequency estimates using rain gauges with much longer datasets.

***WT statement:*** *that 'further to the FFA methodology adopted, the other alternative was to derive discharge estimates using the rainfall-runoff model based on ARR Datahub losses"*

**BMT response:** this statement is incorrect and is not aligned with ARR2019 recommendations. ARR recommends a hierarchal approach to rainfall losses with the Datahub losses generally considered as a last resort. Losses derived through a model calibration exercise should take precedence over data hub losses.

In BMT's opinion the need for scaling of the IFDs has not been sufficiently proven or justified by WT and, based on the reported data, it is BMTs view that the scaling is not defendable. The following points are made.

1. **With regard to the modelled peak flow estimates**:

    a. The original (unscaled IFD) differences in peak flow between modelled results and FFA are not reported so a sufficient reason for scaling is not demonstrated

    b. The flow comparison is based on the TUFLOW factored flows (vs FFA) corresponding to the critical temporal pattern and duration based on XP-RAFTS modelling. TUFLOW model results show the 9 hour duration to be critical in the hydraulic model for a 1% AEP compared to the 6 hour duration in the hydrology model. TUFLOW flows for a 9 hour duration would therefore expected to be higher than those quoted in Table 7-2. This will lead to an understatement of modelled flows.

    c. The ARF applied in the modelling is based on the entire Bohle catchment area. This will lead to an understatement of design areal rainfall (and therefore modelled flow) at the gauge locations. Based on a sensitivity analysis presented by WT in Section 7.14, it is likely that the rainfall runoff flows would increase by approximately 100m$^3$/s if using an ARF (and temporal rainfall pattern set) specific to the gauge locations.

2. **With regard to the FFA**:

    a. the WT revised rating curves which underpin the annual maximum flow estimates used in FFA give notably higher peak flow estimates at Mt Bohle compared to the previous rating curves (see Figure 3-13 in WT report). The revised rating curve is based on the calibrated hydraulic model and it is noted that the model gives notably lower levels when compared to recorded data along this length of river in the 2019 event. Given the criticality of this rating curve to WTs justification in factoring IFDs, more detailed reporting of the rating curve update should be provided including an assessment of its sensitivity to assumed hydraulic roughness values. Flow gaugings should also be presented if available.

    b. the FFA estimates are based on approximate 30 years of record so require considerable extrapolation to obtain 1% AEP flow estimates.

3. **With regards to the scaling applied and the outcomes:**

    a. A scaling factor of 150% has been applied to design rainfall (IFDs) across the entire catchment and for all AEPs. This is a significant increase[3].

    b. There will be higher confidence in design rainfall depths for more frequent events. Justification is not provided by WT for scaling of more frequent rainfall by 150% other than these events were not the primary focus of the study.

    c. WT allude to their experience of the 2016 IFD rainfalls being low in other catchments within Queensland. BMT has also noted similar issues but in BMT's experience these are related to localised orographic effects not being captured. BMT is not disputing that similar issues may be present in the Bohle catchment but our view is there is not sufficient evidence to apply a catchment wide scaling to IFDs.

    d. The resulting modelled TUFLOW discharge at the Hervey Range Road gauge is significantly in excess of the FFA estimate (around 25% higher). It is noted that the revised WT rating curve for this gauge remains similar to the previous rating curve for the range of historic flows used in the FFA.

    e. The resulting modelled TUFLOW discharge at the Mount Bohle gauge is similar to that of the FFA estimate (around 3% lower). The FFA estimate is highly dependent on which rating curve is used as discussed above.

In conclusion BMT does not agree with WT's justification of increasing the IFDs by 150%. We consider the outcomes to be overly conservative and not defendable.

## 5.4 Design Event Simulation

BMT has reviewed the approach taken by WT with design event modelling and, with the exception of the IFD scaling, agree that the adopted approach is in accordance with ARR2019. BMT offers the following additional comments:

- Spatially varying IFDs have been applied (6 regions using region centroids) which will allow the IFD rainfall gradient to be represented in the model.

- The WT approach adopts a primary focal point location approach for the selection of area specific ARR inputs such as the ARF and areal temporal pattern set. This is based on the full catchment area and so will understate rainfall and therefore flows in upper and middle parts of the catchment. BMT recognises it is impractical to introduce varying ARFs and temporal pattern sets and WT has demonstrated through sensitivity testing the implications of the adopted assumptions. BMT agrees with the adopted approach although we note that the implications of this should also be considered by WT in their decision to factor IFDs (see comments in Section 5.3).

- A downstream boundary (tailwater) condition of HAT (2.254mAHD) has been used for AEPs of 5% or rarer and MHWS (1.254mAHD) for more frequent events. Use of HAT for the 1% event is not consistent with neighbouring studies.

[3] For example, a 1% AEP 6h rainfall depth of approximately 260mm becomes 390mm which is in excess of a 1 in 1000 (0.1%) AEP rainfall

- An ensemble approach to design rainfall temporal patterns has been employed as recommended under ARR2019. Both the hydrologic and hydraulic models have been used to simulate ensembles with the hydraulic model ultimately used for event selection, which is a robust approach.

### Critical Duration / Event Selection

The WT report (Sections 7.3, 7.11 and 7.12) describes how the hydrologic model is used to determine the critical duration and temporal pattern. Results of the hydrologic critical duration are then presented. It is then stated that the critical durations will be assessed using the hydraulic model, effectively meaning that the results and discussion on the hydrologic assessment are superseded. To avoid confusion when reading the report it is recommended that it is stated early within the section on design flood modelling that the critical duration and patterns will be determined using the hydraulic model. The hydrologic assessment on critical durations may then sit better in an Appendix as it is effectively not used in the study.

WT describe how the hydraulic model was used to simulate ensembles for multiple duration and AEP combinations. A critical duration map is presented by WT in Figure 7.14 for the 1% AEP event. This approach of simulating all ensembles hydraulically is computationally intensive. However it results in a peak design flood elevation surface effectively based on a statistical analysis of results in keeping with the ARR2019 approach at every grid cell. A drawback of the approach is that a flood surface for any given AEP may be composed of results from many hydraulic model simulations and can impact the usability of the model from a practical point of view. For example, the 1% AEP Bohle flood surface is comprised of results from 55 hydraulic model simulations.

In conclusion BMT concurs that conducting the critical duration and event selection process in the hydraulic model is a superior and more robust approach than using the hydrologic model. However to improve future useability of the model it is recommended that the model is provided with some guidelines for its practical use, for example in flood impact assessments. The guidelines may be as simple as referring a third party user to mapped results identifying critical the critical pattern/duration.

### Sensitivity Analyses

Sensitivity assessment have been undertaken on climate change for both the 2% and 1% AEP in accordance with the study brief. Relative Concentration Pathway 8.5 (RCP 8.5) has been used for the assessment in accordance with the RFQ.

A sea level rise (SLR) allowance of 1.1m is used and the WT report mentions that this is in accordance with the Queensland Coastal Plan. BMT notes that the Queensland Coastal Plan (DERM, 2011) refers to a SLR allowance of 0.8m to the year 2100. A value of 1.1m is not referred to in the Queensland guidelines although BMT note that it is the upper limit of the ‘likely’ range based on the IPCC RCP 8.5. As neighbouring flood studies have adopted a SLR allowance of 0.8m it is recommended that use of 1.1m is reviewed and changed to 0.8m if warranted for consistency.

The 1% AEP adopts a tailwater of HAT (2.254mAHD). For climate change simulations a tailwater of MHWS+SLR is applied giving a peak tailwater elevation of 2.354mAHD. This is only 0.1m above the existing climate 1% AEP level. A comparison of the 1% AEP with and without climate change will therefore not show the full impact of future SLR. BMT recommends that SLR is applied to the same boundary conditions as adopted for the design events.

A blockage sensitivity on 1% AEP has been undertaken using a sub-set of temporal patterns and durations. A 25% blockage factor applied to all major culverts and bridges with the justification that this is reasonably conservative. BMT notes that the ARR2019 approach to blockage sensitivity is significantly more involved than the approach applied by WT. However for the purposes of a flood study sensitivity assessment, BMT concludes that the approach adopted by WT is pragmatic and sufficient for the intent of the assessment.

### Design Simulation Results

A comprehensive set of design results are included in a separate volume of the flood study report. Mapping includes flood extent, depth, velocity, classified hazard and floodplain classification (flood fringe, flood storage and flood way mapping) outputs. Given the significant number of maps within Volume 2, it is recommended that a table of contents is included to assist the reader locate specific maps.

The format of results labelling generally conforms to TCC's requested naming conventions.

## 5.5 Comparisons to Previous Assessments

Section 8 of the WT report presents a comprehensive comparison of peak flows and levels with previous flood studies. Typically the WT results are significantly higher than for previous studies.

With regard to the hydraulic model comparisons, WT states, in Section 8.5, that for the 1% AEP event, differences in peak flow of up to 8% are apparent. Based on the values reported in Table 8-3 of their report, a peak 1% AEP flow at Mount Bohle of 1875$m^3$/s compares to the 2014 flood study flow of 1555$m^3$/s, an approximate 20% difference. Likewise, the WT peak 1% AEP flow at the Hervey Range Road gauge of 1668$m^3$/s compares to a 2014 flood study flow of 1267$m^3$/s, a difference of over 30%. These differences are significantly greater than 8% reported in the text. It is recommended that the report text is updated accordingly.

The scaling of the IFDs by 150% will have significantly contributed to these differences in peak flows. As such it is difficult to draw any further conclusions regarding differences in peak flood flows between the prior and current studies.

With regard to differences in flood levels, the increased flows of the current study drive increased flood levels. Flood levels are also further increased in the 1% AEP event near the ocean due to the adoption of a downstream boundary set to HAT (prior studies used MHWS).

## 5.6 Summary of Design Flood Estimation Recommendations

### Table 5.3 Design Flood Estimation Summary

| ID | BMT Observation | BMT Recommendation |
|---|---|---|
| 5.1 | If available, include plots of the flow gaugings on Figure 6-1 and Figure 6-2 | Update plots with flow gaugings if available |
| 5.2 | Comparison between FFA and modelled flows does not make it clear that quoted modelled flows have already been reconciled with FFA by IFD scaling or that the applied ARF is for the whole of catchment and not to the gauge location. | Add footnote to Table 6-2 to 6-4 to clarify that TUFLOW peak flows include scaled IFDs. |
| 5.3 | Appendix H refers to flood frequency curves but does not show these. | Update Appendix to include flood frequency curves (AEP vs flow) or add as ne appendix |
| 5.4 | Section 7.12.1 refers to the hydrologic peak discharge summary when the 10% and 1% | Update Section 7.12.1 accordingly |

| ID | BMT Observation | BMT Recommendation |
|---|---|---|
| | AEP peak flows referred to in Appendix H appear to be the hydraulically modelled flows | |
| 5.5 | Inconsistencies noted between report text and associated figures when describing AEP of January 2019 event in Section 7.5 | Review wording around AEP of January 2019 event in Section 7.5 |
| 5.6 | Section 7.6 regarding sensitivity assessments on design flow comparisons to FFA is confusing as it quotes modelled flows which have already been subject to IFD adjustment. | Update section 7.6 to quote unfactored design flows to better support argument for scaling of flows. |
| 5.7 | BMT does not agree with the statement in Section 7.6 that factorisation of IFDs was required based on the arguments presented by WT. BMT also concludes that a global scaling of IFDs across all AEPs by 150% is not justified or defendable. | Remove scaling applied to IFDs or apply localised scaling with supported justification. |
| 5.8 | Use of a 1% AEP tailwater corresponding to HAT is not consistent with neighbouring flood studies which have applied MHWS | Check boundary and update if necessary |
| 5.9 | The report is a little confusing by presenting a critical event/duration analysis using the hydrology model and then superseding this with the hydraulic assessment. | Recommended that the report is updated to place hydrologic critical duration assessment in an Appendix or make clear that the analysis has been done using the hydraulic model and that the hydrologic analysis is shown for comparative purposes. |
| 5.10 | A large number of flood surfaces (55) comprise the 1% AEP event. To improve future useability of the model it is recommended that the model is provided with some guidelines for its practical use, for example in flood impact assessments. | Include guidelines on future use of the model which could simply be referring a third party user to mapped results identifying critical the critical pattern/duration. |
| 5.11 | A climate change SLR allowance of 1.1m has been used as opposed to 0.8m as specified in the Qld coastal plan. This value of 1.1m is inconsistent with neighbouring flood studies. | Review the use of 1.1m allowance for SLR and change to 0.8m if warranted. |
| 5.12 | The 1% AEP adopts a tailwater of HAT (2.254mAHD). For climate change a tailwater of MHWS+SLR is applied giving a total value of 2.354mAHD. This is only 0.1m above the baseline 1% AEP level and will therefore not highlight the impact of SLR. | Apply SLR to consistent boundaries as used in the design flood modelling for non climate change events. |
| 5.13 | To assist when locating relevant maps in Volume 2 it would be useful for each component volume to have an indexed map reference at the start. | Include indexed map reference at start of each mapping volume. |
| 5.14 | When comparing peak flows from the current study to previous studies, the text in Section 8.5 quotes a maximum difference of 8% whereas the tabulated values indicate | Review text in Section 8.5 for consistency with tabulated values. |

| ID | BMT Observation | BMT Recommendation |
|---|---|---|
| | differences of 20% and 30% for the Mt Bohle and Hervey Range Road gauges respectively. | |

# 6 General report comments/omissions

## 6.1 General Report Comments

Overall the WT flood study report is very comprehensive, contains a significant amount of technical information and represents a substantial quantity of modelling and assessment. In BMT's opinion the report would benefit from an executive summary to distil some of the key points from the assessment.

Comments are provided below on technical matters not covered elsewhere in this review:

- There is no documented approach on how the PMP/PMF has been derived. At a minimum the report should include the method used eg GTSMR, and key inputs.
- Section 10.1.3 is entitled Hydrologic Simulation and Scenarios but refers instead to hydraulic model simulations. This should be checked/clarified.
- Table 10-4 which quotes typical simulation times is useful for future users of the model. It would benefit from a footnote stating the GPU card used as simulation times can vary significantly on different cards.
- The first column in Table 10-4 quotes 540min as being the 6hr storm. This should be corrected to either 360min or 9h (whichever the simulation was for).

## 6.2 Report Omissions

The WT study is considered to meet the main requirements of the technical specifications of the RFQ, chiefly the development and calibration of hydrologic and hydraulic models and updated ARR2019 design flood modelling/mapping. BMT has listed below other specifications of the RFQ which are not presented by WT and has provided additional comment on these.

### Structure Head Loss Verification

The RFQ requests that head losses against cross drainage structures (which have a moderate to significant impact on flooding within the study area) will need to be verified with a HEC-RAS model. This has not been undertaken.

As stated in Section 4.3 of BMT's review, the representation of the bridges in the TUFLOW model is appropriate and, given this is a catchment wide flood study, it is BMT's opinion that there would be minimal benefit in cross checking head loss at individual structures unless there was significant head loss which could impact on urban areas.

### Flood Hazard Mapping

The RFQ requests that Flood Hazard Overlay GIS layers are prepared which are suitable for incorporation into the Townsville City Plan. Flood hazard categorisation used by the Townsville City Plan is set out in *SC6.7 Flood Hazard Planning Scheme Policy of the Townsville City Plan (2014)*. Under the plan, flood hazard from flood study output is classified as:

- High flood hazard (derived from 1% AEP);
- Medium flood hazard (derived from 1% AEP); and
- Low flood hazard (remaining area of PMF floodplain).

The high and medium flood hazard categories are based on velocity depth criteria as specified within SC6.7.

WT has provided an alternative 6 tier hazard classification based on the Australia Institute for Disaster Resilience (AIDR) classification. BMT acknowledges that the AIDR classification represents current best practice but that it differs from that currently used in the Townsville City Plan.

### Road Closure Points and Impacted Buildings

The RFQ requests that the technical report should include a flood assessment for different AEPs which include road closure points in major arterial roads. It also requests that the number of impacted buildings inundated by flooding based on existing flood level survey should be assessed. These items have not been undertaken.

### Joint Probability Zone

The original RFQ was issued with regard to the Upper and Middle Bohle catchment. The original RFQ therefore does not make mention of determining the joint probability zone with regard to riverine and oceanic flooding in accordance with ARR2019. BMT understands that the assessment was later expanded via a contract variation to also include the Lower Bohle. As such, it appears logical that the delineation of the joint probability zone should be included in the expanded study to be consistent with other TCC studies that have downstream ocean boundaries. It is not clear to BMT if this was required from WT by TCC under the contract variation.

### RPEQ Signoff

The RFQ requests that the flood modelling study is completed by a suitably qualified and experienced Registered Professional Engineer of Queensland (RPEQ). As such the report should include signoff demonstrating RPEQ oversight.

## 6.3 Summary of Hydraulic Model Recommendations

Table 6.1 General Report/Study Recommendations

| ID | BMT Observation | BMT Recommendation |
|---|---|---|
| 6.1 | The significant size of the report means it would benefit from an executive summary | Incorporate an executive summary |
| 6.2 | No documentation on the PMP/PMF derivation | Include PMP/PMF documentation in report |
| 6.3 | Section 10.1.3 is entitled Hydrologic Simulation and Scenarios but refers instead to hydraulic model simulations | Check/Clarify |
| 6.4 | Table 10-4 which quotes typical simulation times does not indicate what GPU was used. | Table would benefit from a footnote stating the GPU |
| 6.5 | Table 10-4 quotes 540min as being the 6hr storm | Amend |
| 6.6 | Classified Hazard output differs from that used in Townsville City Plan. | Update mapping if required |
| 6.7 | No analysis of road closures and inundated building counts | Undertake analysis if required |
| 6.8 | No delineation of joint probability zone | Undertake analysis if required |

| ID | BMT Observation | BMT Recommendation |
| --- | --- | --- |
| 6.9 | No RPEQ signoff included in report | Add RPEQ signoff |

# 7 Conclusions

This peer review report has documented the review findings for the modelling contract undertaken by Water Technology for the Bohle River Flood Study Update as part of Townsville City Council's Townsville Flood Modelling and Mapping Project.

Overall the study was found to generally follow best-practice modelling approaches and techniques and conform with approaches within ARR2019. The hydrologic and hydraulic models developed in the assessment represent significant improvements over previous models.

Observations and recommendations have been made by BMT on key aspects of the study. The most significant observations relate to some of the modelling assumptions and are summarised as follows:

- The design rainfall IFD data has been scaled across the catchment by 150%. In BMT's opinion, the justification for such scaling has not been provided and we do not consider such scaling to be defendable.
- When simulating sea level rise under future climate change scenarios for the 2% and 1% AEP events, WT has applied the sea level rise to a lower tailwater than that used in the 2% and 1% AEP existing climate simulations. This will not show the impacts of sea level rise when results are compared.

A further significant observation was that the supplied handover of the TUFLOW model would not initialise without additional modification from BMT. It therefore appears that the supplied model may not be consistent with the model that generated results presented in the flood study. Whilst the required modifications were minor, we have recommended that the supplied model is checked so that third party users do not experience similar difficulties when attempting to run the model.

Other observations were of a more minor nature with many relating to technical inconsistencies within the report.

In overall conclusion, TCC should be aware that use of the scaled IFDs will result in very conservative estimates of design floods for given AEPs.

# 8 References

AECOM (2021) Base-line Flooding Assessment – Ross River Flood Study – Volume 1 and 2. Prepared for Townsville City Council, October 2021

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

DERM (2011) Queensland Coastal Plan.

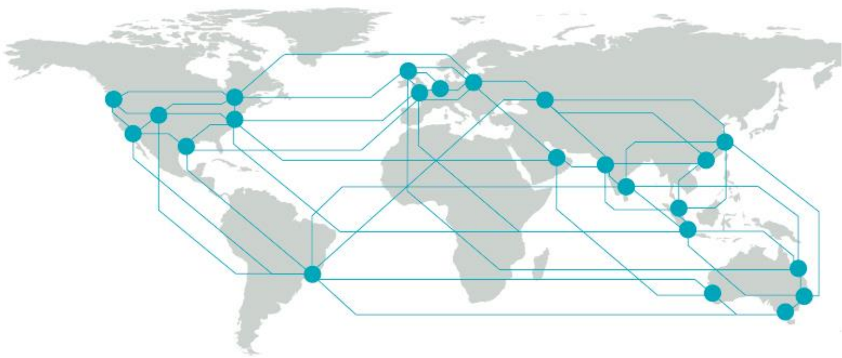
HARC (2016) Review of Hydrological Methods for the Townsville Region: Phase 1 – Background Data Review and Flood Frequency Assessment. Prepared for Townsville City Council, 2016.

HARC (2018) Review of Hydrological Methods for the Townsville Region: Phase 3 – Catchment Simulations for Test Catchments. Prepared for Townsville City Council, September 2019.

TCC (2019) Request for Quotation: Flood Model Updates for ARR 2016: Bohle River Flood Models, Phase 1 & 2, March 2019.

TCC (2020) SC6.7.4 Attachment 1 - Guidelines for Preparation of Flood Studies and Reports, Townsville City Plan Version 2020/03

Water Technology (2021) Bohle River Flood Study Update 2021 – Volume 1 and 2. Prepared for Townsville City Council, November 2021



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