Peer review of Horseshoe Bay Flood Study

Customer	Townsville City Council
Project	A10416
Deliverable	007
Version	00
	3 May 2022

Document Control

Document Identification

Title	Peer review of Horseshoe Bay Flood Study
Project No	A10416
Deliverable No	007
Version No	00
Version Date	3 May 2022
Customer	Townsville City Council
Classification	BMT (OFFICIAL)

Author	Barry Rodgers, Richard Sharpe
Reviewed By	Cathie Barton
Project Manager	Barry Rodgers

Amendment Record

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

Version	Version Date	Distribution	Record
00	03 May 2022	Townsville City Council	Draft Report

This report is prepared by BMT Commercial Australia Pty Ltd (“BMT”) for the use by BMT’s client (the “Client”). No third party may rely on the contents of this report. To the extent lawfully permitted by law all liability whatsoever of any third party for any loss or damage howsoever arising from reliance on the contents of this report is excluded.
Where this report has been prepared on the basis of the information supplied by the Client or its employees, consultants, agents and/or advisers to BMT Commercial Australia Pty Ltd (“BMT”) for that purpose and BMT has not sought to verify the completeness or accuracy of such information. Accordingly, BMT does not accept any liability for any loss, damage, claim or other demand howsoever arising in contract, tort or otherwise, whether directly or indirectly for the completeness or accuracy of such information nor any liability in connection with the implementation of any advice or proposals contained in this report insofar as they are based upon, or are derived from such information. BMT does not give any warranty or guarantee in respect of this report in so far as any advice or proposals contains, or is derived from, or otherwise relies upon, such information nor does it accept any liability whatsoever for the implementation of any advice recommendations or proposals which are not carried out under its control or in a manner which is consistent with its advice.

Contents

Tables

Figures

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 **Horseshoe Bay Flood Study** prepared by AECOM under the Magnetic Island and Balgal Beach contract.

1.2 Supplied Data

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

- Horseshoe Bay Flood Study Base-line Flooding Assessment Volumes 1 and 2, Revision A dated 8 October 2021 (AECOM, 2021)
- Request for Quotation: Townsville Recalibrated Flood Modelling and Mapping – Magnetic Island & Balgal Beach (TCC, undated)

- Townsville Recalibrated Flood Modelling and Mapping Naming Convention Report (TCC, March 2020)
- Hydrologic Models:
  - HorseshoeBay_Design_NewLosses.xp
  - HorseshoeBay_Design_PMF.xp
  - Supporting GIS datasets
- Hydraulic Models:
  - HB-~s1~-~s2~-~e1~-~s3~~e2~.tcf

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; 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 issue 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 AECOM. 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 AECOM correspond to the definitions in the control files provided for the model runs.

2 Modelling Overview

The Horseshoe Bay Flood Study uses a hydrologic XP-RAFTS model to convert rainfall to runoff. Runoff hydrographs are then extracted from the XP-RAFTS model and applied as inflows to a TUFLOW HPC hydraulic model. The TUFLOW HPC model also includes catchment area which is modelled with direct rainfall input. The direct rainfall is applied in combination with the XP-RAFTS derived inflows.

The TUFLOW model uses a 5m model grid and has been used to simulate design flood events with AEPs ranging from 50% (most frequent) to 0.05% (rarest). The Probable Maximum Flood (PMF) has also been assessed along with climate change scenarios for the 2% and 1% AEP events. The design hydrology is based on the Australian Rainfall and Runoff 2019 guideline (ARR2019) (Ball et al, 2019).

Model calibration was not undertaken as there are no water level gauges within the catchment. A verification of design flows has been performed against the Rational Method. A verification exercise has been performed on the hydraulic model by comparing modelled flood extents for the events of January/February 2019 and January 2020 against anecdotal data.

The hydrologic model was developed under a separate contract to that which is subject to this peer review. As such the majority of this review is focussed on the hydraulic modelling with commentary on the hydrologic modelling limited to the overall suitability and defensibility of its implementation in the hydraulic model.

The remainder of this report sets out the key findings from our peer review.

3 Hydrologic Assessment

3.1 Background

As described in Section 2, the hydrologic modelling was undertaken using XP-RAFTS software. The XP-RAFTS model was developed as part of a *Review of Hydrological Methods for the Townsville Region, Phase 4* (AECOM, 2019) which is a separate contract to that which is the subject of this peer review. The Phase 4 study refers to XP-RAFTS model as being originally developed for the Horseshoe Bay Flood Study. Further minor updates were made to the XP-RAFTS model as part of the current study which were focussed on integrating the model with the TUFLOW hydraulic model.

A review of the development of the XP-RAFTS model is beyond the scope of this peer review. The peer review of the hydrologic modelling is limited to its overall suitability and defensibility of its implementation. The hydrologic review covers following aspects:

- High level checks on the appropriateness of the hydrologic modelling for the purposes of the flood study.
- Consistency checks that the hydrographs output from XP-RAFTS are applied at appropriate locations in the TUFLOW model and that all runoff is accounted for in the TUFLOW model.
- The application/implementation of ARR2019 methodology in deriving appropriate design hydrology.

3.2 Hydrologic Review

General Comments

A check on the total modelled catchment area agreed with the catchment area delineated in GIS (12.1km^2). Overall, the catchment areas are appropriate.

The AECOM report (Table 4) notes the routing approach as being channel lagging but channel routing has been applied in the model. The report should be updated to reflect this.

High level checks indicate that overall the XP-RAFTS model appears well composed and no significant issues have been identified by BMT.

Model Calibration/Verification

The hydrologic model was simulated for the historic events which occurred in January/February 2019 and January 2020. There are no stream gauges within the catchment and so the calibration has been assessed based on applying the hydrologic model derived flows within the hydraulic model and comparing results (peak flood levels and extents) to available anecdotal data. This is reviewed under Section 4.3.

As a comparison of modelled hydrologic flows against recorded (rated) flows could not be undertaken, AECOM has performed a verification of the hydrologic design flows against the Probabilistic Rational Method.

Use of the Probabilistic Rational Method was common under the ARR1987 guideline but current practice set out within ARR2019 no longer favours its use except at a localised lot scale[1]. This is primarily to do with the lack of scientific evidence underpinning for its runoff coefficient. It is noted however that the Queensland Urban Drainage Manual (QUDM) (IPWEAQ, 2017) still supports its use for urban catchments of less than 500 hectares or rural catchments of less than 25km^2 or as a checking tool for numerical models developed for small ungauged catchments.

BMT recognises that there is very limited historic data to calibrate/verify the model and therefore we consider that the use of the Rational Method as a tool to check for potential gross errors is acceptable.

AECOM has verified the hydrologic design event peak flows against the Rational Method at three nominated locations within the catchment. Generally, the peak flow estimates compare reasonably well with no highlighted gross errors.

Overall, BMT is satisfied, given the limited data, that suitable verification has been performed.

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	The report (Table 4) notes the routing approach as being channel lagging, but channel routing has been applied in the model.	Update report to reflect applied approach

[1] ARR2019 advises that the Rational Method should only be applied within a catchment where more detailed analysis of rainfall runoff observations have defined its parameters (runoff coefficient and time of concentration).

4 Hydraulic Model Development and Calibration

4.1 Background

The hydraulic model is a new model developed using TUFLOW software. 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

The supplied model files include a single TUFLOW control file (tcf) as follows:

HB-~s1~-~s2~-~e1~-~s3~~e2~.tcf

TUFLOW's events and scenarios feature has been used allowing the same tcf to be used to simulate different design events, calibration events and sensitivity tests.

Naming Conventions

TCC has nominated a standardised hydraulic model naming convention to be used on models developed for the Project. The naming adopted by AECOM broadly meets the naming convention although does not conform exactly. For example, the AEP identified is larger than the requested 3 characters. A model run identifier is also not included which is important for ongoing model quality control practices.

Whilst not strictly in accordance with the requested naming conventions, in BMT's opinion the adopted naming remains clear, logical and allows TCC to easily identify it as a Horseshoe Bay model (or result file). It is however recommended that a run ID is incorporated into the model name.

General Setup

The model folder structure is set up in accordance with TCC's requirements and follows TUFLOW's recommended folder structure approach. Default model settings are generally applied as recommended. In test simulations, BMT was able to initialise and run the design case model with the supplied model files.

The extent of the model is appropriate to cover the main urban area of Horseshoe Bay. However, given the relatively small size of the model and the very quick simulation times, it would have been possible to include all upstream sub-catchments as local inflows into TUFLOW to limit the use of total inflows and limitations of hydrologic routing or lagging.

4.3 Hydraulic Model Development and Calibration

Topography

The base topography is based on a 1m DEM of 2019 LiDAR data, defined in the model using a 5m grid. Modifications are made in the form of breaklines to improve representation of the base topography around structures and to reinforce road crest elevations and key levees.

Two additional DEMs are read into the model:

- SURVEY 0000 DTM_20200610.dem

- SURVEY 0000 DTM COMBINED.dem

Of these DEMs, only the combined DEM is applied in the model as the other DEM appears to have non-MGA zone 55 coordinates and is not being applied within the model domain. It is recommended that the coordinate system of the grid 'SURVEY 0000 DTM_20200610.dem' is reviewed in case it is a key part of the topography currently missing from the model.

One of the road centrelines extends across much of the lagoon and there does not appear to be a road crossing there. However, as elevations are sampled from the LiDAR, the applied elevation is essentially the same as the LiDAR, which has been used to represent the lagoon.

Materials

Based on a visual inspection of the land use delineation against available aerial imagery, the mapped land uses are generally appropriate. The land use layers are used to set the rainfall losses for the parts of the model to which direct rainfall is applied. This is discussed further below (section on external boundaries). Some specific points are noted below:

- The dominant land use allocated in the model is rural residential (ID 401). Upon inspection a significant proportion of the land marked as rural residential appears to be undeveloped forest. Given the Manning's n of 0.08 for rural residential is similar to that allocated to bushland (0.07) it is not considered necessary to update the model.

- Material ID 110 represents mown grass but it has been allocated rainfall losses based on an impermeable land use type. The modelled area covered by land use 110 represents only around 4% of the model domain so amendment to losses is not expected to be significant.

Structures

The model includes one bridge modelled using TUFLOWs layered flow constriction feature. The bridge appears to be a small pedestrian bridge over Saltwater Creek. The report does not say how the bridge form (energy) losses have been derived but the values appear to be within typical expected ranges.

AECOM report that there are a number of small private bridges which have not been included in the model for various stated reasons, principally lack of survey data. BMT agrees with AECOMs rationale for not including them and agrees with the recommendations stated by AECOM to capture more survey detail if a more detailed model representation of such areas is required.

There are 15 culverts included in the model. No issues were identified with these culverts.

The model includes 5 weir structures represented in 2D using a z-shapes placed along a drainage channel. The z shapes are polygons but are narrower than the cells they are intended to modify. As a result some of the weirs show no or minimal modification to the cell elevations. It is recommended that these are changed to thin z lines with 'ridge' specified to force the cell sizes to be modified to the required elevations. As a consequence of the current set up, these weirs may not be represented as intended.

TUFLOW can automatically create manholes at pipe junctions for energy loss calculations. AECOM has disabled this function and has digitised manhole locations. The default Engelund loss approach has been applied to these digitised manholes. The digitised manhole locations appear appropriate against the limited number of pipes included in the model.

Head loss verification has been undertaken on two modelled structures; culverts under Horseshoe Bay Road and the pedestrian bridge over Saltwater Creek. The verification has been undertaken for the 1%

and 10% AEPs using HY-8 and HEC-RAS. In all cases, the head losses are similar in TUFLOW and the alternative methods.

External Boundaries

The model downstream boundary is configured as a water level vs time (type HT) boundary snapped to the active code boundary.

Hydrologic model results are applied to the TUFLOW domain as 6 QT boundaries and 44 source area (type SA) boundaries. The QT boundaries represent total catchment flows whereas the SA boundaries represent local subarea runoff. This schematisation is typically the recommended approach.

The boundaries were checked and the application of total and local flows appears as intended.

Direct rainfall is applied across the majority of the TUFLOW domain. Checks show that no local hydrologic inflow are applied within the area of direct rainfall and so there is no double accounting of flow.

Output Settings

A 'Map Cutoff Depth' of 0.1m has been applied within TUFLOW. The 'Map Cutoff SGS' approach is also set to 'Exact' which in effect is also a cut off depth as the elevation sampled exactly at each cell centre is used as the elevation below which the cells are shown as dry. Depth in the cell is measured from the cell minimum elevation as sampled by SGS. Therefore, whilst every cell receiving direct rainfall is wet, if the depth in the cell remains below the elevation sampled at the cell centre, the cell is mapped as being dry. The higher of these two cutoff depths is applied within the model.

The maximum velocity cutoff depth is set to zero (default value in TUFLOW is 0.1). This will track the maximum velocity irrespective of the depth of water and can potentially result in mapping showing high velocities for shallow depths. Overall this is considered a conservative approach but users should be aware that this setting is applied.

It is noted that TCC has requested that map outputs are post processed to exclude depths below 0.1m except where velocities exceed 0.8m/s. AECOM has not applied the additional velocity consideration for results filtering and state their rationale in Section 4.1. From a hydraulic output perspective, BMT is satisfied that suitable cut off criteria have been applied.

Model Calibration

The hydraulic model was verified to two historic events which occurred in January/February 2019 and January 2020. As discussed in Section 2, there were no stream gauges to assist with model calibration. The approach taken was therefore to simulate recorded rainfall and compare hydraulic model output against anecdotal data.

The report provides a summary of comparisons of modelled results with anecdotal data including commentary on a selection of photos showing the aftermath of the 2020 event. In BMT's opinion the reporting demonstrates that effort has been put into verifying the model and that the verification is satisfactory, notwithstanding the limited amount of data which could be used in the assessment.

4.4 Summary of Hydraulic Model Observations and Recommendations

Table 4.1 Hydraulic Model Development and Calibration Summary

ID	BMT Observation	BMT Recommendation
4.1	Naming conventions are not in strict accordance with requested naming convention by TCC	For consideration by TCC. In BMT's opinion the adopted naming remains clear, logical and allows TCC to easily identify it is a Horseshoe Bay model. We do recommend that a run ID is incorporated into the model name.
4.2	The small size and of the model and the fast simulation times meant that it would have been feasible to include all upstream subareas as local TUFLOW inflows.	Observation only
4.3	A DEM read into the model 'SURVEY 0000 DTM_20200610.dem' does not appear to be in the correct coordinate system and does not form part of the modelled topography.	Review in case this is a key part of the model.
4.4	One of the road centrelines extends across much of the lagoon and there does not appear to be a road crossing there.	Observation only. As 'road' elevation is sampled from LiDAR this will simply apply the elevation of the lagoon to this length of road.
4.5	Rural residential land use appears to cover significant areas of undeveloped forest	Manning's n values allocated to bushland and rural residential are similar so amending would have minimal effect on results.
4.6	Land use material ID 110 is set as an impermeable land use type for the application of rainfall losses when it appears to be permeable.	Review the classification of material ID 110 as an 'impermeable' land use type.
4.7	Five weirs represented using z-shape files appear to not fully apply the intended weir crest.	Review schematisation and its potential to impact on results. Suggest applying these as polylines rather than polygons.
4.8	Results filtering is not strictly in adherence with TCC requested filtering criteria as it omits the velocity component.	Cutoff depth applied appears reasonable but TCC to review against requirements.

5 Determination of Design Floods

5.1 Overview

The approach to design flood estimation applied by AECOM uses approaches contained within the ARR2019 guideline. As no stream gauges exist within the catchment the approach relies upon design event simulation using the hydrologic and hydraulic models developed in the assessment.

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

5.2 Design Event Simulation

Design Parameters

A single IFD location appears to have been used to generate the direct rainfall. The IFD data has been correctly documented and applied.

The PMP rainfall depth within XP-RAFTS is 540mm. In the direct rainfall component of TUFLOW it is 513mm. When querying the applied temporal patterns against that recommended under the GSDM method, it appears that the pattern applied in TUFLOW is missing an interval of the temporal pattern and causing the mismatch.

The report states that an areal reduction factor (ARF) has been applied based on the 'East Coast North' region. BMT notes that an ARF of 1.0 has been applied in the modelling essentially meaning that no areal reduction in rainfall has been applied. It is likely that the ARF of 1.0 has resulted due to the 'East Coast North' region not extending across Magnetic Island. As such no ARF parameters are available for catchments on Magnetic Island. If an ARF was to be applied BMT recommends that the 'East Coast North' parameters are manually entered. However, an ARF of 1.0 is a conservative approach and in BMTs opinion is suitable for the assessment. An ARF of 1.0 is also consistent with what has been applied in the direct rainfall.

An ensemble approach to temporal patterns has been applied as set out in ARR2019. Point temporal patterns have been applied as the catchment area is less than $75km^2$.

With regards to rainfall losses the approach taken follows that given in ARR2019 whereby an initial storm loss is converted to an initial burst loss by accounting for pre-burst rainfall. For permeable areas an initial storm loss of 66mm is reported for both hydrology and hydraulic (direct rainfall) components of the modelling. The continuing loss is reported as being 2.5mm/h (1.0mm/h for the 0.05% AEP event) for permeable areas. These loss values differ from that specified in the ARR2019 datahub which lists a storm initial loss of 72mm and a continuing loss of 4mm/h. BMT notes that the adopted values better approximate the continuing loss values determined through model verification and agrees with their use. It is noted that within Table 11 of the AECOM report, the permeable continuing loss is stated as being 2.0mm/h. Based on what is applied within the model and reported on earlier, this should be 2.5mm/h.

The downstream boundary is specified as a constant level set at MHWS (1.1mAHD) for all design events. Use of MHWS is in accordance with the TCC Guideline.

Critical Duration / Event Selection

An ensemble approach to modelling rainfall temporal patterns has been applied in the design flood modelling. This is in accordance with ARR2019. The ensemble approach relies upon a representative average ensemble member being selected for a given AEP/Duration. This representative ensemble member may vary across the catchment being modelling and so its selection can be based on assumptions and judgement. BMT has reviewed the event selection process undertaken by AECOM and makes the following comments/observations.

- Identification of the critical durations and temporal patterns has been undertaken using the hydraulic model. This has involved running full ensembles (10 events) for each duration/AEP combination and analysing the flood levels in every grid cell. It results in a significant number of simulations but is feasible due to the rapid simulation times of the model (typically less than 5 minutes).

- The process 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. For a given AEP, this process first identifies the median flood level for each duration in every grid cell and then generates a flood surface based on the maximum of the median flood levels. 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. Given the rapid simulation times, running many hydraulic simulations is unlikely to be an issue. However this can cause complications when using the model for impact assessments. It is recommended that TCC/AECOM provide supplementary guidance on how to select appropriate events for flood impact assessments to avoid a variety of approaches being applied by third parties.

- The report does not state, but it is assumed that, the process for deriving other gridded flood surfaces (velocity, hazard etc) is the same as that used for peak level (a max of the median approach). For a given location and for a given AEP, it is possible that different model simulations have generated the peak flood level and the peak of another output variable eg velocity. This can cause complications when using the model outputs for purposes beyond the flood study. It is recommended that the supplementary guidance referred to in the above point also includes selection of events for outputs other than peak level

Sensitivity Analyses

Climate Change

A sensitivity assessment has been undertaken on climate change for both the 2% and 1% AEP in accordance with the RFQ. Relative Concentration Pathway 8.5 (RCP 8.5) has been used for the assessment which is also in accordance with the RFQ. Rainfall intensity has been increased by 15.4% and an allowance of 0.8m has been made for sea level rise (SLR).

The mapped results are in agreement with expectations and BMT has identified no issues.

Joint Probability Zone

AECOM has undertaken a pre-screening analysis in accordance with Book 6, Chapter 5 of ARR2019 for the consideration of riverine and oceanic flooding. This has been done for the 1% AEP and the 1% AEP with climate change.

Changes to rainfall and tidal boundary parameters (as per reporting) for the joint probability assessment scenarios were confirmed to be implemented correctly in modelling files, via alternative boundary conditions databases and TUFLOW logic. It is noted from the results that the defined storm tide level in the Townsville City Plan is greater than the fully dependent flood surfaces within the defined JPZ.

Therefore existing planning provisions effectively already account for any uncertainty in choice of downstream boundary condition. BMT therefore agrees with AECOMs statement that a full design variable method is not warranted for Horseshoe Bay. Overall, the approach is consistent with ARR2019.

Structure Blockage

A blockage assessment has been undertaken which is in accordance with ARR2019. This assessment has been undertaken on the Saltwater Creek pedestrian bridge and modelled culverts and pipes. Blockage factors of 10% for the bridge and 60% for the culverts have been applied in the 1% AEP event. A further assessment on the 50% AEP event applied a 40% blockage to the culverts.

BMT notes that in ARR2019 the 'design blockage' is the blockage condition that is most likely to occur for a given storm and that an 'all clear' (no blockage) scenario should be the sensitivity test. In the AECOM study, the sensitivity test is the one with the design blockage and the 'all clear' case has been adopted when producing the final flood surfaces. However, we understand the blockage scenario was specified as a sensitivity assessment in the RFQ.

In BMT's opinion, the blockage assessment has been undertaken in accordance with TCC's requested approach and blockage values are reasonable for the purposes of the sensitivity assessment. When using the results of the study to inform planning levels, the results of the blockage sensitivity test should be reviewed. Any areas where water levels are particularly sensitive to structure blockage should consider the water level under the blockage scenario for planning purposes.

Design Simulation Results

A comprehensive set of design results are included in a separate volume of the flood study report. Mapping includes flood level, depth, velocity, classified hazard (AIDR, 2017), and classified hazard in accordance with the TCC flood hazard overlay.

The labelling of the digital results generally conforms to TCC's requested naming conventions but is subject to the same comments as described in Section 4.2 on model naming conventions.

The results have also been analysed to provide information as follows:

- Counts of buildings within each AEP
- Water depth of main roads at selected crossings
- Commentary on what AEP inundates community buildings and infrastructure

5.3 Comparisons to Previous Assessments

A flood study was previously completed for Horseshoe Bay by TCC in 2011. BMT understands that output from that study was used to inform the flood mapping in the current Townsville City Plan. BMT also understands that flood study results from the updated AECOM study will be used to update the flood mapping in the planning scheme. TCC has asked BMT to provide comment on any changes in flood levels between the AECOM updated study and the 2011 flood study.

Section 4.4 of the AECOM report provides a mapped comparison (change in peak water levels) between the respective flood study results. AECOM notes that, at a broad scale, the new model results are generally 20mm to 350mm lower in the upper catchments and there is an 110mm increase in the Horseshoe Bay Lagoon (for the 1% AEP). Significant local increases of up to 1m were noted at the mouths of Endeavour Creek and Saltwater Creek and this was attributed to sedimentation at the river mouths.

Overall BMT agree with AECOMs reasoning for the change in peak flood levels and we provide the following additional comments.

It would be expected that flood levels are different due to the following principal factors:

- A revised hydrologic approach (ARR2019 vs ARR1987)
- Updated model topography (more recent LiDAR of higher spatial resolution)
- Advancements in hydraulic modelling (finer grid resolution and improved solution schemes).

The principal changes implemented through use of ARR2019 are updated design rainfall depths and a revised approach to temporal storm patterns whereby an ensemble of ten patterns is now modelled and a representative average pattern/s selected.

With regards to design rainfall, the design rainfall depths applied in the updated study are typically lower than those derived from the ARR1987 IFDs used in the 2011 study. For example, in a 1.5 hour storm, which is noted by AECOM as being critical at the mouth of Beeran Creek, the current 1% AEP rainfall depth is 140mm compared to the previous depth of 150mm. Likewise a 1% AEP 1 hour rainfall depth is 113mm compared to a previous depth of 128mm.

With regards to temporal patterns, the previous ARR1987 approach was to use a single storm temporal pattern referred to as an AVM (Average Variability Method). The intention of both the ensemble and the AVM approaches is to preserve probability neutrality i.e. so that a 1% AEP rainfall approximates a 1% AEP resultant flood. However, the AVM approach has limitations in that it does not account for how different temporal patterns can interact with catchments to produce a range of peak flows and hydrographs. ARR2019 better accounts for this by modelling an ensemble of varying temporal patterns. In BMT's experience, use of the ensemble approach typically results in lower peak flood estimates although it is recognised that this may not always be the case and that it can be difficult to isolate the effects of the temporal pattern approach without specific sensitivity testing.

The date of the LiDAR capture used in the 2011 study is 2009. The LiDAR used in the updated AECOM modelling was captured in 2019. The 10 year difference in capture date will include differences in landforms as a result of development as well as natural catchment changes due to erosion and sedimentation processes (which may also be exacerbated by development). BMT has undertaken an independent comparison of the 2019 and 2009 LiDAR datasets and makes the following observations:

- As a general observation the 2019 LiDAR shows lower elevations across the modelled area.
- In the lagoon, the 2019 LiDAR is around 0.3m lower which likely reflects a change in water surface elevation between the two capture dates.
- The morphological condition of the estuary of Endeavour Creek is notably different between the 2019 and 2009 LiDAR datasets as shown in Figure 5.1 below. In 2019, the LiDAR shows an outlet through the dunes to the ocean, albeit highly constricted, whereas in 2009 there is a continuous sand bar across the entrance to the estuary. The LiDAR levels within the waterbody of the estuary are typically 0.1m to 0.3m higher in the 2019 LiDAR. This will likely reflect the water level at the time of capture. The increase in peak flood level in the Endeavour Creek estuary appears to be similar to the magnitude of the increase in LiDAR elevation.

In conclusion, based on a high level comparison it appears that the slight reduction in peak flood levels through the majority of urban areas outside of the influence of the tide are attributed to lower design rainfalls and the use of the ARR2019 ensemble approach to storm temporal patterns. The more notable differences (typically increases) in peak level within the lower parts of the catchment are attributed to the changes in estuary morphology and water level captured within the respective LiDAR datasets. This is despite the 2011 study using a higher tailwater (MHWS is stated as being 1.17mAHD in the 2011 study compared to 1.1m used in the AECOM study). Localised changes in peak flood levels may have also resulted from catchment development or drainage modifications.

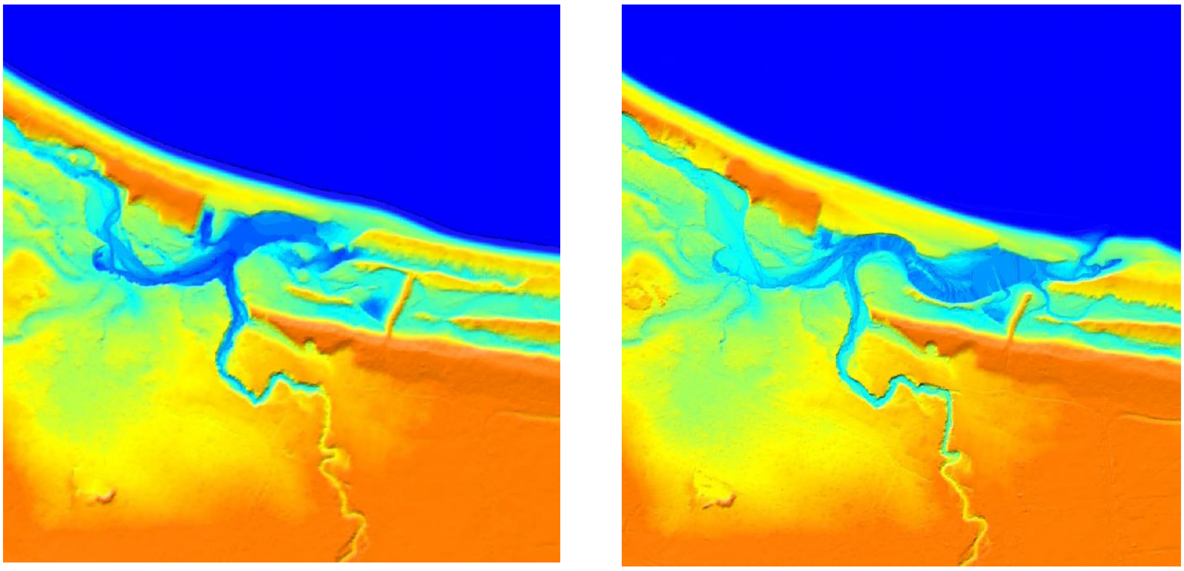


Figure 5.1 Topographic Changes at the Mouth of Endeavour Creek (left 2009 LiDAR, right, 2019 LiDAR)

5.4 Summary of Design Flood Estimation Recommendations

Table 5.1 Design Flood Estimation Summary

ID	BMT Observation	BMT Recommendation
5.1	There is a mismatch in PMP rainfall depths between what is applied in XP-RAFTS and in TUFLOW (through direct rainfall)	Whilst the difference is not significant, it should be made consistent for completeness.
5.2	An ARF of 1 (no reduction) is applied. The report states ARFs from the East Coast North region are applied but this is not the case.	Update report to state an ARF of 1.0 is applied.
5.3	Table 11 of the AECOM report states the pervious design continuing loss as being 2.0mm/h. Based on what is applied within the model and reported on earlier, this should be 2.5mm/h.	Update Table 11 in report
5.4	The approach to simulate all ensembles and durations to generate a flood surface of a given AEP can complicate approaches taken for flood impact assessments.	TCC/AECOM provide supplementary guidance on how to select appropriate events for impact assessments, including selection of events for outputs other than peak level.

6 Other Considerations

6.1 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.

6.2 Other Considerations Summary

Table 6.1 Summary of Other Considerations

ID	BMT Observation	BMT Recommendation
6.1	No RPEQ signoff included in report	Add RPEQ signoff

7 Conclusions

This peer review report has documented the review findings for the Horseshoe Bay Flood Study undertaken by AECOM 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.

Observations and recommendations have been made by BMT on key aspects of the study with a summary of these tabulated in each section of this report. No significant issues were identified by BMT. A number of more minor issues were noted, the majority of which relate to requests for clarifications within the report.

8 References

AECOM (2019) Review of Hydrological Methods for the Townsville Region: Phase 4 – AR&R 2019 Hydrologic Model Updates. Prepared for Townsville City Council, September 2019

AECOM (2021) Base-line Flooding Assessment – Horseshoe Bay Flood Study – Volume 1 and Volume 2 – Report (Revision A). Prepared for Townsville City Council, October 2021.

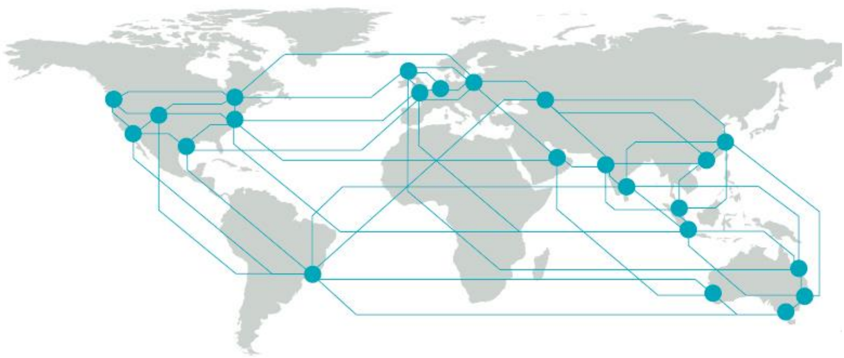
AIDR (2017) Managing the Floodplain: A Guide To Best Practice in Flood Risk Management in Australia, Handbook 7, third edition. Australian Institute of Disaster Resilience.

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.

IPWEAQ (2017). Queensland Urban Drainage Manual (QUDM), 4th Edition prepared by Institute of Public Works Engineering Australasia, Queensland Division, 2016.

TCC (undated) Request for Quotation: Townsville Recalibrated Flood Modelling and Mapping – Magnetic Island & Balgal Beach, RFQ002345.

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



BMT is a leading design, engineering, science and management consultancy with a reputation for engineering excellence. We are driven by a belief that things can always be better, safer, faster and more efficient. BMT is an independent organisation held in trust for its employees.

Level 5
348 Edward Street
Brisbane
QLD 4000
Australia
+61 7 3831 6744

Registered in Australia
Registered no. 010 830 421
Registered office
Level 5, 348 Edward Street,
Brisbane QLD 4000 Australia

For your local BMT office visit www.bmt.org

Contact us

enquiries@bmtglobal.com

www.bmt.org

Follow us

www.bmt.org/linkedin

www.bmt.org/youtube

www.bmt.org/twitter

www.bmt.org/facebook