Peer Review of Nelly Bay Flood Study

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Amendment Record

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

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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 **Nelly 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:

- Nelly 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:
  - NellyBay_Jan2019.xp
  - NellyBay_Design.xp
  - Supporting GIS datasets
- Hydraulic Models:
  - TUFLOW model NB-~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 Nelly 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).

Hydrologic 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, 2020) 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 Nelly Bay Flood Study and that only minor updates were made to this model for the Phase 4 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

Two separate models are supplied within the design folder as follows:

- NellyBay_Design.xp
- NellyBay_Jan2019.xp

BMT notes that both models have different subarea delineations. Based on the XP-RAFTS outflow files being read into the TUFLOW model, it appears as though the NellyBay_Jan2019.xp model is used. This corresponds to the supplied GIS subareas but is different to that shown in Figure 2 of the report and does not correspond to the subareas listed in Appendix A.

Some further inconsistencies were noted with regards to the subarea delineations. For example, it appears as though the NellyBay_Jan2019.xp model has subdivided subarea labelled NB-2.03 in Figure 2 into two areas termed NB-2.03A and NB-2.03B. The original NB-2.03 has an area of 42.4ha (obtained from Appendix A by summing the split subareas). When the areas of the revised subareas are queried, NB-2.03A has an area of 19.73ha and NB-2.03B has an area of 42.4ha. Therefore, the combined area of NB-2.03A and NB-2.03B is approximately 62.1ha compared to 42.4ha in the original NB-2.03. This additional area associated with NB-2.03B appears to be an error and will generate additional runoff. As the TUFLOW model replaces subarea NB-2.03B with direct rainfall, then this overstatement of catchment area will not follow through to the flood study outcomes. Caution should be applied if using the XP-RAFTS model to derive flows independently from the TUFLOW model.

A check on total modelled area in the XP-RAFTS model shows an area of 803.3ha has been modelled which compares to 790.0ha from a GIS query of the subareas. Overall therefore the cumulative differences in area appear minor. It is recommended that the report is updated to refer to the latest model when showing the subarea breakup (Figure 2) and details (Appendix A).

Inconsistencies were also noted with the approach to modelling impervious areas. Generally the use of the split subarea approach has been employed which separates out the pervious and impervious areas. This is recommended practice. For subareas such as NB-3.05, which is within the main urban area, no area is allocated to the second subarea with impervious area lumped into the overall catchment. As urban areas are within the zone to which direct rainfall is applied in place of XP-RAFTS generated flows, this will not affect the study outcomes.

A check of the vectored slope in the main town (flat areas) has found that the slopes are generally reasonable. The slopes in the mountainous areas have been limited to 15% as per Townsville Guideline.

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 recorded levels and extents. 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. For the majority of AEPs, the modelled XP-RAFTS flows are higher than the flows generated by the Rational Method but not excessively so.

The reported XP-RAFTS flows in Table 2.4 of the AECOM report match those provided in Table 14.5 of the Phase 4 study. However, the Rational Method verification flows differ between the two reports. A supporting spreadsheet containing the Rational Method checks also provides the same Rational Method flows as detailed in the Phase 4 study. Therefore, it is not clear how the Rational Method verification flows reported in Table 2.4 of the Nelly Bay Flood Study have been derived.

BMT has subsequently undertaken our own Rational Method for catchment locations NB-10.00 and NB-5.00 using both Bransby-William's and the stream velocity method (with 0.9m/s) and results are similar to the AECOM reported flows for the Phase 4 study.

[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).

BMT notes that additional methods of verification such as the Regional Flood Frequency Estimate (RFFE) and checks on consistency of flow between the hydrologic and hydraulic models could have also been undertaken but may not have added much additional insight into the flow estimates.

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 hydrologic model used to derive inputs to the TUFLOW model appears to have a different subarea delineation to that in shown in Figure 2 of the report and does not correspond to the subareas listed in Appendix A.	Check for consistency and update report.
3.2	The subarea areas of NB-2.03A and NB-2.03B appear incorrect.	Observation only as this is effectively replaced by TUFLOW direct rainfall.
3.3	Inconsistencies in the approach to modelling impermeable area within different subareas.	Observation only as this is effectively replaced by TUFLOW direct rainfall.
3.4	The Rational Method verification flows differ between the AECOM report (Table 2.4) and the supplied supporting data (spreadsheet).	Review flows and update report or supplied data as required.

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:

NB-~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 is a Nelly 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 a test simulation, 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 Nelly 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.

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 elevations and drainage lines.

An issue was noted with the topography associated with Gustav Street footbridge whereby the structure invert is set to an elevation of 9999m effectively blocking the channel in the 2D domain. This is discussed further under structures.

No other issues were identified with the topography.

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 sufficient level of detail for the purposes of the assessment.

One of the land use layers (Land_use_roughness.shp) appears to be included in the model by error as it covers the Ross River catchment. Whilst it does not affect the model results, it is recommended this layer is removed from the model to avoid confusion from end users.

Whilst the majority of the applied Manning's n roughness values are appropriate, tidal waterways have a Manning's n of 0.06 which is very high. Forested areas have been allocated values of either 0.07 or 0.08 which is considered low. Roads have also been modelled with a Manning's n of 0.011 which is outside of the range typically applied.

Buildings in the direct rainfall area use a depth varying roughness for sheet flow and concentrated flow. This is appropriate.

The materials layers are used to set the rainfall losses for the parts of the model to which direct rainfall is applied. This is discussed further in section on External Boundaries.

The high Manning's n values in tidal waterways will introduce a degree of conservativeness in the lower reaches in the form of higher flood levels but the lower values for forest and road may not. BMT recommends that further justification is provided for using these values.

Structures

Two bridges have been represented in the model using TUFLOWs layered flow constriction feature. It is noted that the AECOM report states no bridges were included in the model. This statement should be updated in the report.

Only one bridge is located on the main waterway (a footbridge over Gustav Creek adjacent to Sooning Street). An issue was identified with the representation of this bridge whereby the bridge invert level (creek bed) is set to an elevation of 9,999m. It is assumed that a value of 99,999 was supposed to be specified in order that the base topography is used. As it stands, the invert elevation of 9,999mAHD blocks any flow through the layered flow constriction. Sooning Street Road bridge is represented as a 1D nested culvert which passes under both the road and footbridge. Therefore, flow can still pass through the footbridge via the culvert. If the capacity of the culvert is exceeded, the current representation of these structures can lead to greater back up of water behind the structures than would otherwise occur. The effect of this issue appears limited due to the eastern bridge approach being at a lower elevation than the bridge (AECOM bridge deck approximately 4.1mAHD and eastern bridge approach around 3.6mAHD). Therefore, bypassing of the bridge on its eastern side would occur before overtopping commences. Prevention of the bridge overtopping may still have an effect on events larger than the 1% AEP and so the footbridge should be amended in the model.

A bridge connecting the island to part of the marina containing a boat ramp is not included in the model. This bridge provides passage for tidal flows into the marina. Given that only static water levels are applied in the model then this omission is not expected to have any bearing on the modelled flood levels.

Other structures are modelled as 1D culvert elements. In total 37 structures are modelled in this way. The set-up of these structures is generally appropriate.

A number of pits and pipes are included in the model. 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. Whilst a significant number of manholes are specified by AECOM, the disabling of the automatic creation of manholes means that some pipe junctions will not include these energy losses. Overall this will have minimal bearing on the outcomes of the assessment. It is assumed that IDs, dimension data and spatial locations of pit elements has been correctly assigned to TUFLOW as per the supplied network data. A review of the base dataset is outside of BMTs scope.

Head loss verification has been undertaken on the Gustav Creek crossing at Sooning Street for the 1% and 10% AEPs using HY-8. The head losses are comparable between the two modelling approaches.

External Boundaries

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

The external inflow boundaries are configured as a combination of type QT, type SA and direct rainfall boundaries. The QT boundaries are not snapped to the active code boundary (noting this is not a significant issue but does allow backflow). Some inflows are also not positioned near the subareas they represent (examples include NB-10.01 and NB-13.00) however the effect of this is not likely to be significant.

Three SA inflows are split, each into two SA polygons sharing the same ID (NB-7.04, NB-8.01 and NB-8.02). The boundary condition database scales these three inflows using a factor of 0.5. It is assumed that the intention is to distribute each inflow across the two SA polygons sharing the same ID, 50% going to each polygon. TUFLOW does not treat the boundary in this way. SA polygons sharing a common ID are treated as a single multi part polygon. The inflow is then distributed to the lowest or wet cells across the multipart polygon. Under the current set up, only 50% of the subarea runoff from each of the three inflows is being applied to the hydraulic model. This will lead to an understatement of flow in the model. Note that QT type inflows specified in a 2d_bc layer can be split in the intended way.

The local inflow applied from subarea NB-10.02 is applied twice in the model through two QT inflow boundaries. The inflow is not scaled (reduced) in the boundary condition database and so is effectively applies double the subarea flow to the TUFLOW model.

Direct rainfall is applied across the majority of the hydraulic model domain. Hydrologic model inputs are not applied within the area represented by direct rainfall and the direct rainfall extent generally matches the subarea boundaries in which it replaces. The direct rainfall losses (initial and continuing) are applied through the tmf file. Losses for impermeable land use types are specified within the tmf and do not vary with event. Losses for permeable land uses are allocated to a variable which is specified within a separate TUFLOW read file (trd) and varies with event AEP and duration.

When checking the applied losses for land use categories it was noted that land use ID 110 corresponds to ‘mowed grass’ but has been allocated impermeable initial rainfall losses that do not vary by event. Land use ID 110 represents a significant area of the model domain (17%) so adoption of impermeable type rainfall losses may overstate rainfall.

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 3.2, there were no stream gauges to assist with model calibration. The approach taken was therefore to simulate recorded rainfall (based on the Nelly Bay pluviograph) for the two events and compare hydraulic model output against anecdotal data.

The reporting on comparison of modelled results with anecdotal data is very limited. For example the report states that '*QFES data indicated 12 properties across the Nelly Bay catchment as having moderate damage during the 2019 event and these areas of impact were reflected in the modelling results*'. The model results are presented as a map showing the modelled flood extent and depth but the 12 property locations are not shown. BMT recommends that these locations are included on mapping to verify the statement made in the report.

Overall BMT recognises that model calibration is very limited due to availability of data. BMT is satisfied that AECOM has attempted to verify the model to a satisfactory, albeit limited, standard using available data.

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 Nelly 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	One of the land use layers (Land_use_roughness.shp) appears to be included in the model by error as it covers the Ross River catchment.	Remove layer from model to avoid confusion
4.4	Tidal waterways have a Manning's n of 0.06 which is very high. The Manning's n of 0.011 for roads is very low	BMT recommends that further justification is provided for using these values.

ID	BMT Observation	BMT Recommendation
4.5	Two bridges are included in the model but reporting states no bridges were modelled.	Update report to reflect modelling
4.6	The footbridge over Gustav Creek (Sooning Street) incorrectly has an invert set at 9999mAHD. This prevents any flow through the 2D structure.	Whilst the effect of this is tempered by the road culvert extending through the footbridge and the lower embankment to the east, the bridge representation should be fixed as it can affect floods in excess of the 1% AEP.
4.7	Three SA inflow boundaries only apply 50% of the intended flow	Sa IDs should be allocated unique IDs and then referenced to the bc_dbase
4.8	Local inflow NB-10.02 is applied twice, doubling the subarea runoff into the TUFLOW model	Remove second inflow or scale each inflow by 50%
4.9	Minor issues with boundaries were noted such as QT boundaries not snapping to model code and the positioning of some boundaries away from the subareas they represent.	Recommend that these are tidied up but unlikely to reflect outcomes of assessment.
4.10	Land use ID 110 corresponds to 'mowed grass' but has been allocated impermeable initial rainfall losses.	Given the relatively large proportion of land covered by this land use, we recommend it is allocated a permeable rainfall loss or otherwise explained.
4.11	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.
4.12	Verification of 2019 event refers to 12 inundated properties which are reflected in the modelling. These properties are not shown on mapping	Include 12 properties on Figure 10 of AECOM report

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. Checks by BMT on the 1% AEP event show that the IFD depths are consist between the hydrologic and hydraulic models and those reported in Table 7 of the AECOM report.

Two inconsistencies were noted with the application of the PMP rainfall. Both the 90 minute and 180 minute PMP storms appear to have been used in the final results. BMT has noted the following issues:

- A minor issue with the 90 minute rainfall total in XP-RAFTS (550mm) not matching that in the TUFLOW model (522.5mm). It appears as though an interval from the GSDM temporal pattern is missing in the TULFOW file.
- The 180 minute rainfall in XP-RAFTS commences approximately 45 minutes into the model simulation due to a number of zeros at the start of the storm. In TUFLOW the rainfall commences at the start of the simulation. A significant proportion of the TUFLOW modelled rainfall will have already fallen by the time the XP-RAFTS rainfall starts. These two rainfall components should match.

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 70mm 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.

This reported initial loss value (70mm) differs from that used in the XP-RAFTS model (66mm). The applied loss values also differ from those specified in the ARR2019 datahub which lists a storm initial loss of 72mm and a continuing loss of 4mm/h. It is noted that the model has been verified with the losses used and that as the losses are lower than the datahub losses they will be more conservative.

The pre burst depths and burst losses are shown in Table 5.1. It can be seen that pre burst depths are significant for the 90, 120 and 180 minute durations meaning that the resulting initial burst loss (given by ‘initial storm loss’ minus ‘pre burst depth’) is low for these durations.

The change in continuing loss from the ARR datahub value of 4mm/h to an adopted value of 2.5mm/h is more significant. AECOM notes that the adopted value is more conservative and is based on the verification of the hydrologic model to the rational method and experience of modelling for the Townsville region. BMT notes that the verification was very limited but accepts that the adopted value is more conservative.

Table 5.1 1% AEP Pre Burst Depths

Duration (min)	Pre Burst Depth (mm)	Resulting Initial Burst Loss (mm)*
20	14	56
25	14	56
30	14	56
45	14	56
60	14	56
90	47.9	22.1
120	70.2	0
180	85.5**	0

***Based on an Initial storm loss of 70mm**

****This is greater than the storm initial loss of 72mm so the resulting burst initial loss is 0mm.**

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 Nelly 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 modelled culverts and pipes with the critical blockage mechanism determined as being from sediment blockage rather than floating debris. The assessment is undertaken for both the 50% and the 1% AEP events.

The report notes that a blockage of 15% was derived. Based on the supplied model files a blockage of 60% has been applied for the 1% AEP and a blockage of 40% for the 50% AEP. The higher modelled blockages will provide a more precautionary assessment of blockage.

BMT also notes that whilst non-floating debris (sediment) was determined as being critical, Figure 20 in the AECOM report clearly shows floating debris causing significant blockage at Sooning Street in the 2020 event.

The two bridges within the model do not form part of the structure blockage assessment. It is recommended that these are also included in the sensitivity assessment. As these structures are relatively minor this is not considered to be a significant omission.

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.

With the exception of the observations stated above, 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 Summary of Design Flood Estimation Recommendations

Table 5.2 Design Flood Estimation Summary

ID	BMT Observation	BMT Recommendation
5.1	The hydrologic model applies a PMP depth (90 minute duration) of 550mm whereas the direct rainfall applies a PMP depth of 522.5mm	These should be made consistent
5.2	The PMP temporal pattern used for the 180 minute duration differs between the XP-RAFTS and TUFLOW models with the XP-RAFTS rainfall commencing around 45 minutes later than in TUFLOW.	These should be made consistent
5.3	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.
5.4	Minor discrepancies noted between reported and modelled initial loss (storm) values.	Review for consistency

ID	BMT Observation	BMT Recommendation
5.5	Blockage sensitivity factors differ between report (15%) and modelled (40% and 60%).	Clarify in report what blockage factor has been applied.
5.6	The two modelled bridges are not included in the blockage sensitivity assessment.	It is recommended that the two modelled bridges are included in the blockage sensitivity.
5.7	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 Nelly 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. Issues of potential significance were noted as follows:

- The model representation of the footbridge over Gustav Creek is incorrect and prevents this bridge from being overtopped. Flow can bypass the bridge on the eastern side, but this may affect large events (rarer than the 1% AEP).

- The schematisation of inflows in the hydraulic model applies half of the intended flow at three boundaries and double the intended flow at one boundary.

Remaining identified issues were of a more minor nature, 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 – Nelly Bay Flood Study – Volume 1 and Volume 2 – Report (Revision A). Prepared for Townsville City Council, October 2021.

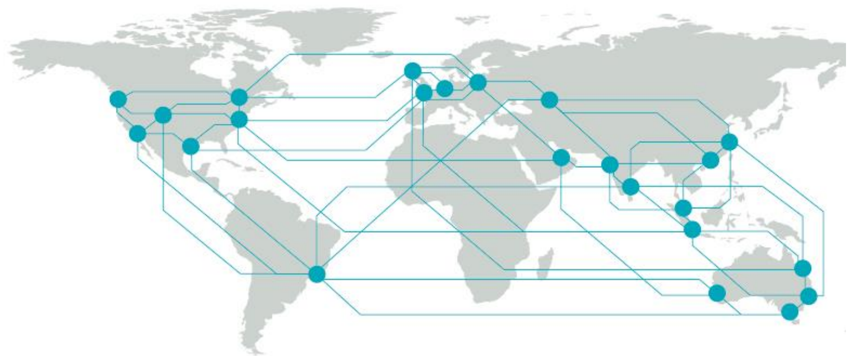
AIDR (2017) Managing the Floodplain: A Guide To Best Practice in Flood Risk Management in Australia, Handbook 7, third edition. Australian Institute of Disaster Resilience.

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



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