Appendix I. Technical Memo – Entrance Geomorphic Modelling

JACOBS

Technical Note

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Subject	**Geomorphic Entrance Modelling**
Project Name	Lower Macleay Flood Study
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1. Introduction

1.1 Project background

Kempsey Shire Council (KSC) has engaged Jacobs to undertake a flood study of the Lower Macleay catchment, downstream of Kempsey.

Jacobs has prepared a Model Development and Calibration Report for the flood study, which identified that flood conditions on the Lower Macleay floodplain are sensitive to the configuration of the entrance of the Lower Macleay River and a scoured river entrance configuration needed to be incorporated in the flood model to simulate flood conditions during past flood events with sufficient accuracy.

A recommendation following the Model Development and Calibration Report was to further examine the likely scour behavior of the river entrance during severe catchment flood events to assist with establishing what entrance geometries should be adopted in the modelling of design flood events

KSC requested Jacobs to undertake a study to address the recommendations with respect to entrance scouring during flood events, and to provide advice how likely effects of dune overtopping are to be included in the flood study.

The memo summarises the findings of these investigations.

1.2 Scope

The task components of the scope included:

- Establishment of a hydrodynamic morphological Delft3D model of the entrance of the Lower Macleay River;
- Assessment of the change in flow-area for a range of design flood event scenarios;
- Qualitative assessment of on the potential for dune breakout during extreme flood scenarios and;
- Qualitative assessment of the entrance dynamics of the Killick and Korogoro creek entrances during extreme flood scenarios.

2. Geomorphic entrance model

2.1 Introduction

A geomorphic model of the Lower Macleay River entrance was developed using Delft3D to investigate the behavior of the river entrance during severe flood events.

2.2 Delft3D model

2.2.1 Model description

Delft3D is a suite of programs suitable for investigating hydrodynamics, sediment transport, morphology and water quality for fluvial, estuarine and coastal environments. The hydrodynamics package of Delft3D, FLOW, calculates non-steady flow and transport phenomena resulting from tidal and metrological forcing on a curvilinear, boundary fitted grid. The MOR module is capable of simulating sediment transport (suspended & bed load) and morphological changes for cohesive or non-cohesive sediment fractions.

2.2.2 Mesh and bathymetry

The Delft3D model developed for the morphological modelling performs computations on a curvilinear grid with a variable resolution, allowing a high resolution to be applied in the areas of interest, whilst at the same time limiting the total number of model elements. The smallest grid cell lengths were around 10m and ranged in size up to about 300m near the offshore boundary of the model.

The model domain covers the 4.5km most downstream section of the Lower Macleay river. The model does not include any tributaries or floodplain areas of the river.

The adopted model bathymetry was based on the NSW OEH Multi-beam bathymetry of the Lower Macleay River estuary, combined with C-MAP electronic navigation chart data.

The model extent and mesh of the adopted Delft3D model is shown in Figure 1, and the initial (pre-flood) model bathymetry in Figure 2.

Figure 1 Delft3D model extents and adopted mesh

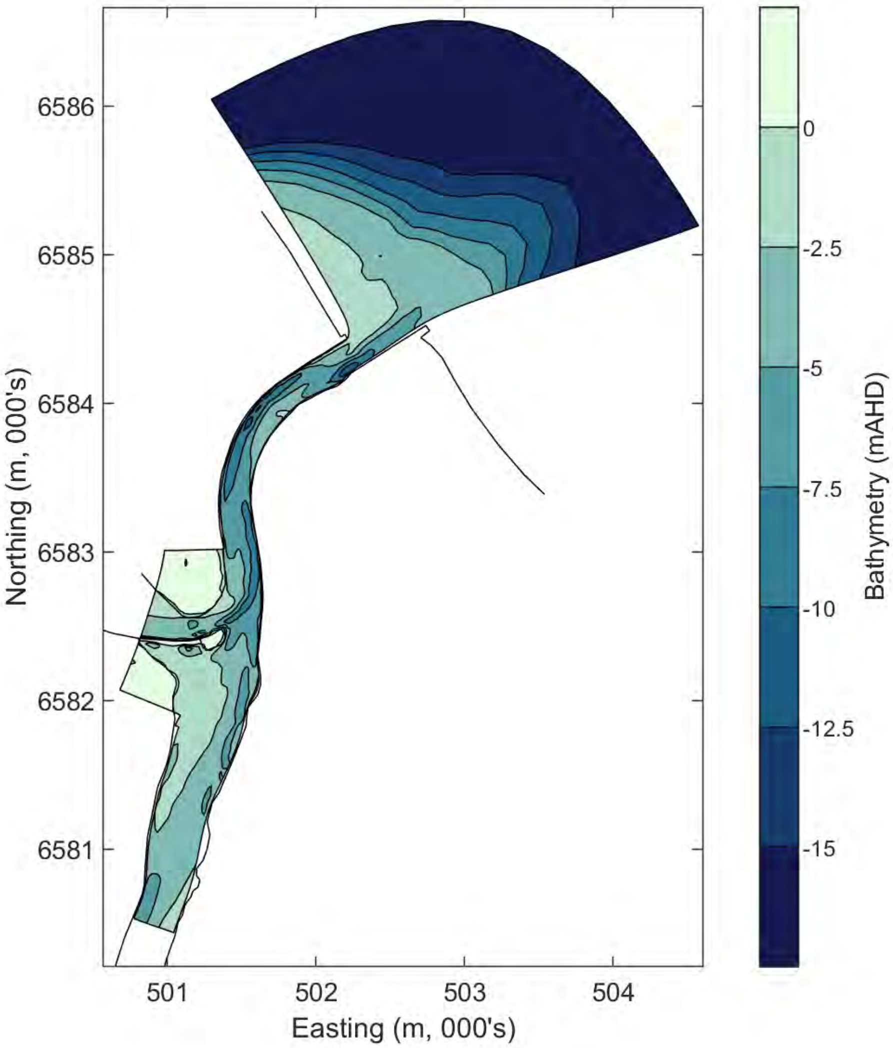

Figure 2 Initial Delft3D model bathymetry (mAHD)

2.2.3 Boundary conditions

The Delft3D model was forced using an inflow boundary on the upstream end and a water level boundary on the downstream (i.e. Ocean) boundary. The upstream discharge boundary condition was based on results from the TUFLOW flood model for the associated flood event. Discharge was extracted from the TUFLOW model across a transect just upstream of Macleay Arm (Refer to Figure 3). Other arms further downstream from the boundary transect were not included in the model because the TUFLOW results indicated that roughly the same discharge occurs near the river entrance as what occurs at the selected boundary transect.

Figure 3 Discharge extraction line from the TUFLOW flood model

At the ocean boundary, a time-varying water-level was applied based on either measured water-levels at Port Macquarie for 2001 calibration flood event, or a 20 or 100 year ARI design storm tide event for the 100-year or 500-year / PMF flood event respectively, as recommended by OEH flood modelling guidelines and adopted in the TUFLOW flood model (further details will be provided in the Draft Flood Study Report, currently being prepared by Jacobs).

2.2.4 Sediment transport parameters

Sediment sampling results taken between South-West Rocks and the river entrance indicate that the bed sediments are mostly made up of ‘Fine – Medium’ sub-rounded quartz grains with no silt or clay content (Webb McKeown & Associates, 2009). The river-bed sediment characteristics adopted in the modelled have hence been based on a fine to medium sized sand, with a median grain size of 0.2mm.

The sediment transport formulation by Engelund-Hansen (1967) was utilised in this study to simulate the flood flow-induced sediment transport in the study area. The Engelund-Hansen (1967) formulation has been commonly used for riverine and estuary studies in the past (Deltares, 2014).

2.3 Model scenarios

The 2001 flood event and three key design flood events were simulated in the Delft3D model, namely:

- The 1 in 100 year ARI design flood event
- The 1in 500 year ARI design flood event

- The probable maximum flood event

The inflow boundary conditions for the three design flood events are presented in Figure 4.

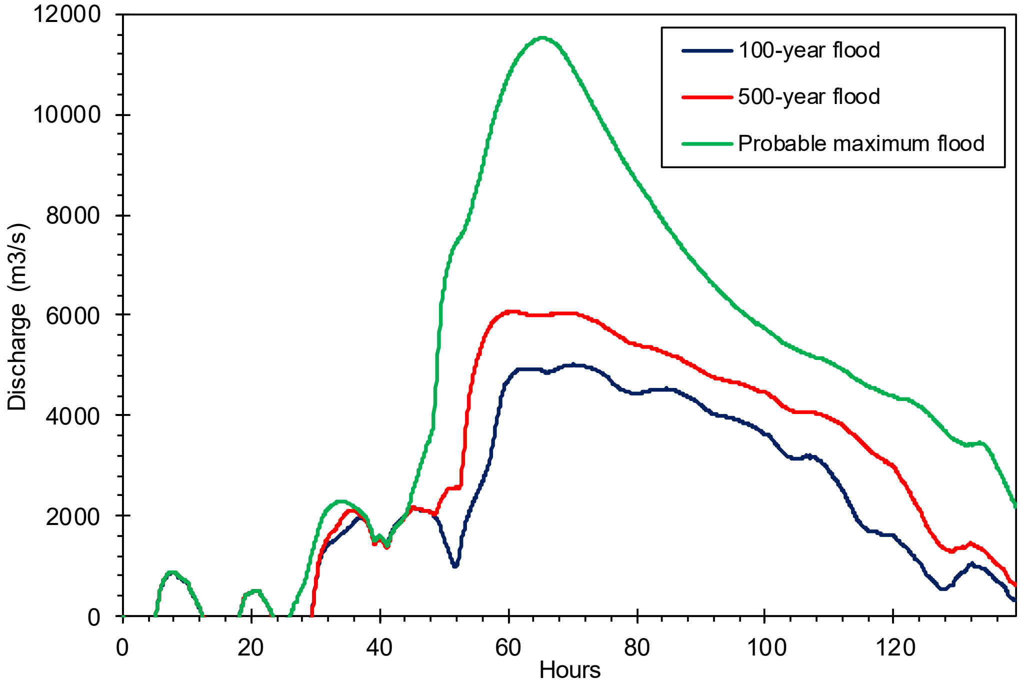

Figure 4 Upstream model boundary flood hydrographs

2.4 Model results

Bed levels at key stages of the model simulation were analysed to provide an understanding of the likely bed level changes in the river entrance during significant flood event. Figure 5 presents the bed level at the start and end of the simulation of the 500-year design flood event and Figure 6 the total modelled bed level change during this event.

The model results indicate that:

- Substantial changes in the bed levels are predicted to occur in the main channel downstream of Maclean Arm, with significant erosion predicted in the inner bend near western arm of Spencers Creek and accretion near the eastern arm.
- The entrance bar is predicted to experience erosion;
- Significant volumes of bed material are predicted to be transported from the main channel into the coastal zone; where it is likely to deposit in deeper water offshore of the existing entrance bar.
- With increasing flood severity, the change in modelled bed levels become larger.

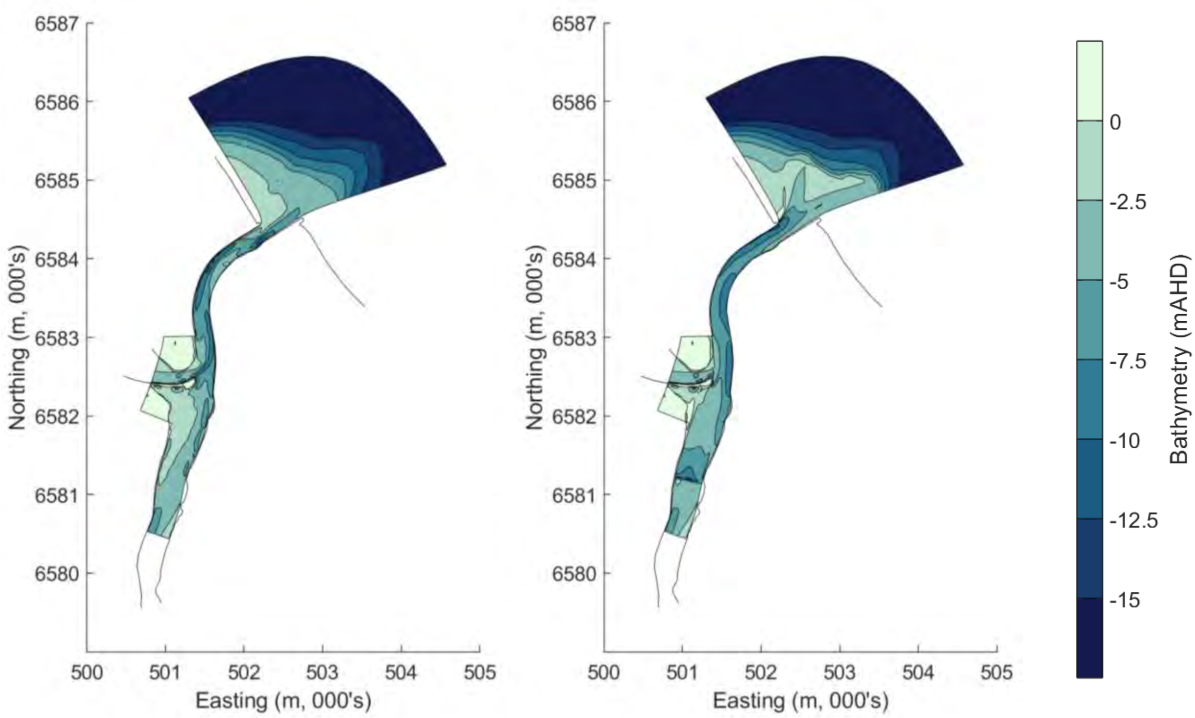

Figure 5 Bed-level at the start and end of the 100-year design flood event

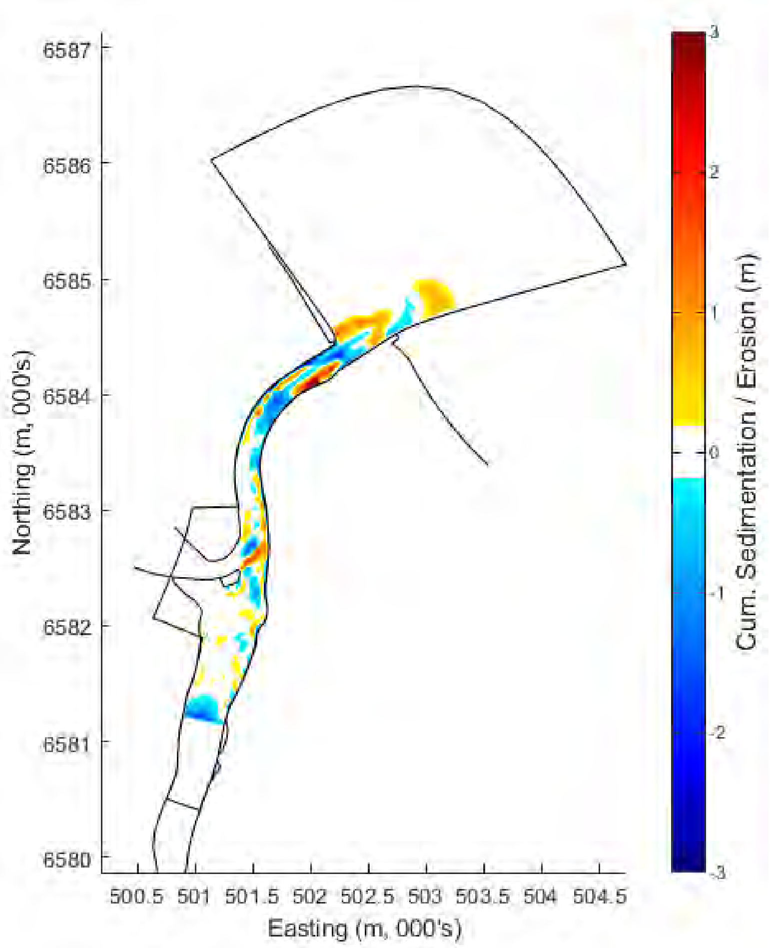

Figure 6 Cumulative erosion and sedimentation just prior to the peak of the flood

The Delft3D model results were processed to calculate the flow-area during the simulation at a key cross-section along the river that aligns with a location where a 'scoured condition' was assumed in the TUFLOW flood model (Refer to Figure 7).

Figure 8 to Figure 11 compare the modelled flow-area of the Delft3D model at key stages of the flood event against the flow-area adopted in the TUFLOW model for the 2001 calibration event and 100-year and 500-year ARI and PMF events, respectively.

The figures show that in general, scouring of the riverbed begins once the river discharge exceeds about 1,500 m^3/s, and continues up until the peak of the flood has passed or not long after.

Figure 8 demonstrates that the flow area predicted by the Delft3D model at the peak of the flood event is very close to the flow area adopted in the TUFLOW flood model, estimated during the model calibration process. Figure 8 also shows that the Delft3D model predicts that the river cross section will experience accretion after the peak of the flood event has passed

For the design flood events, the Delft3D model predicts the flow area during the peak of the flood to be larger than the flow area adopted in the TUFLOW model, particularly for the 500-year ARI and PMF design flood events.

There will always be a degree of uncertainty with geomorphic modelling due to many reasons, such as unknown bed sediment composition (and hence erosion rate) below the known sandy surface layer as well as the possibility of bed-rock patches. This means that uncertainty in the model results increases with flood severity (i.e. for very extreme events such as the 500-year and PMF events, the model predictions may be less reliable).

Figure 7 Cross-section location for flow-area comparison between Delft3D and TUFLOW models

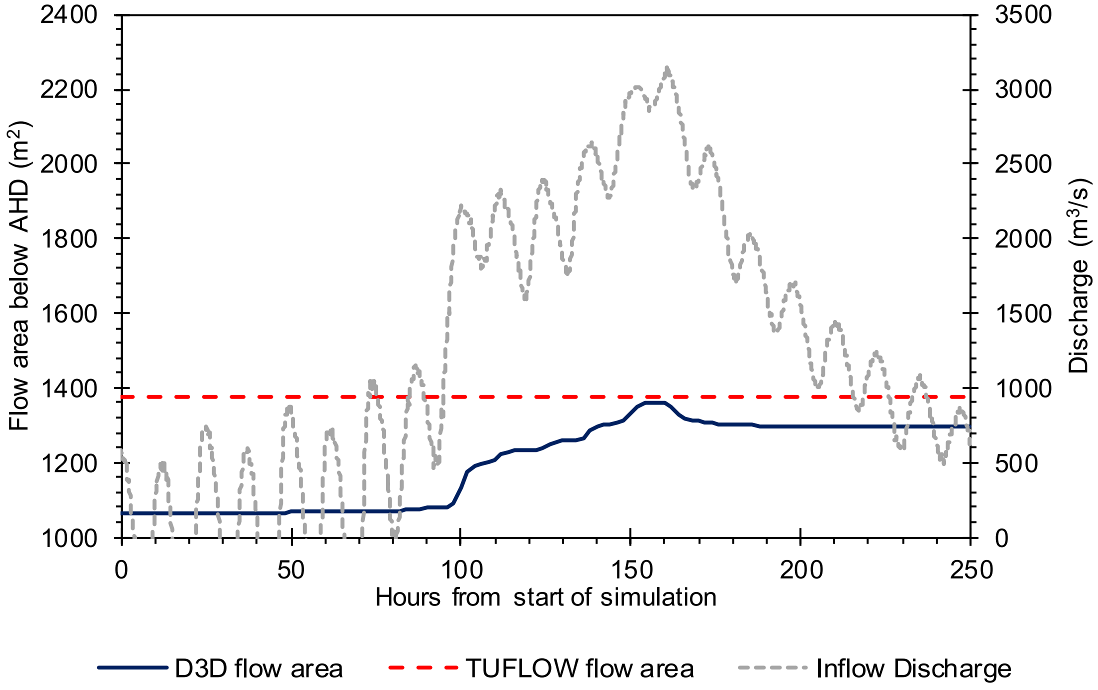

Figure 8 Modelled change in cross-sectional area during the 2001 flood event

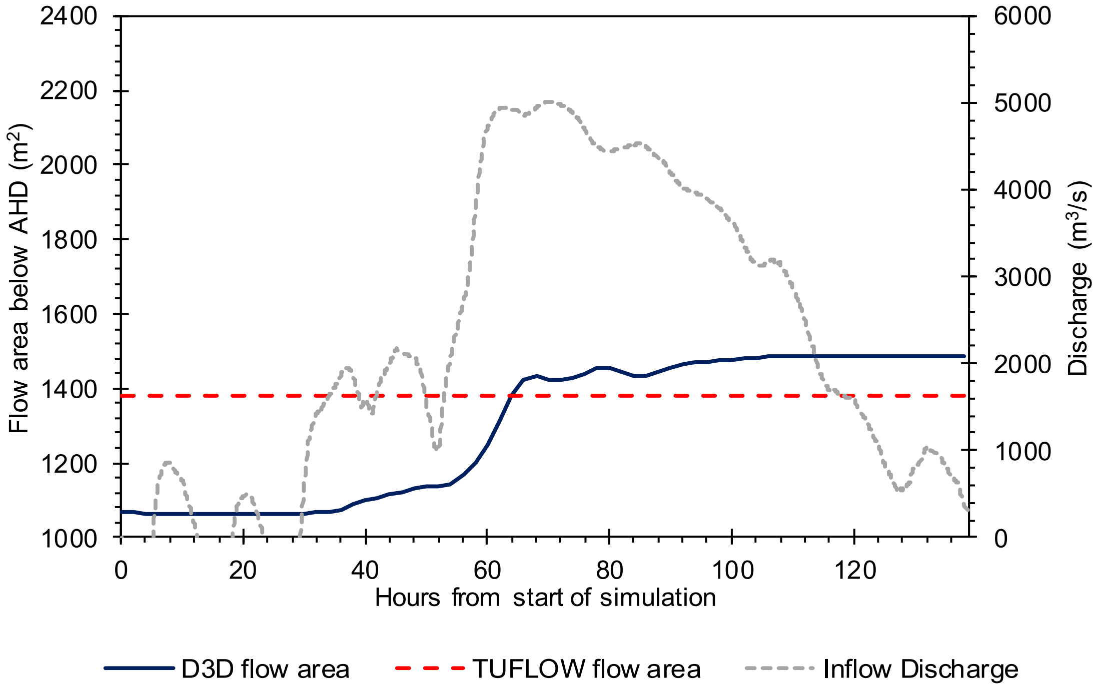

Figure 9 Modelled change in cross-sectional area during the 100-year design flood event

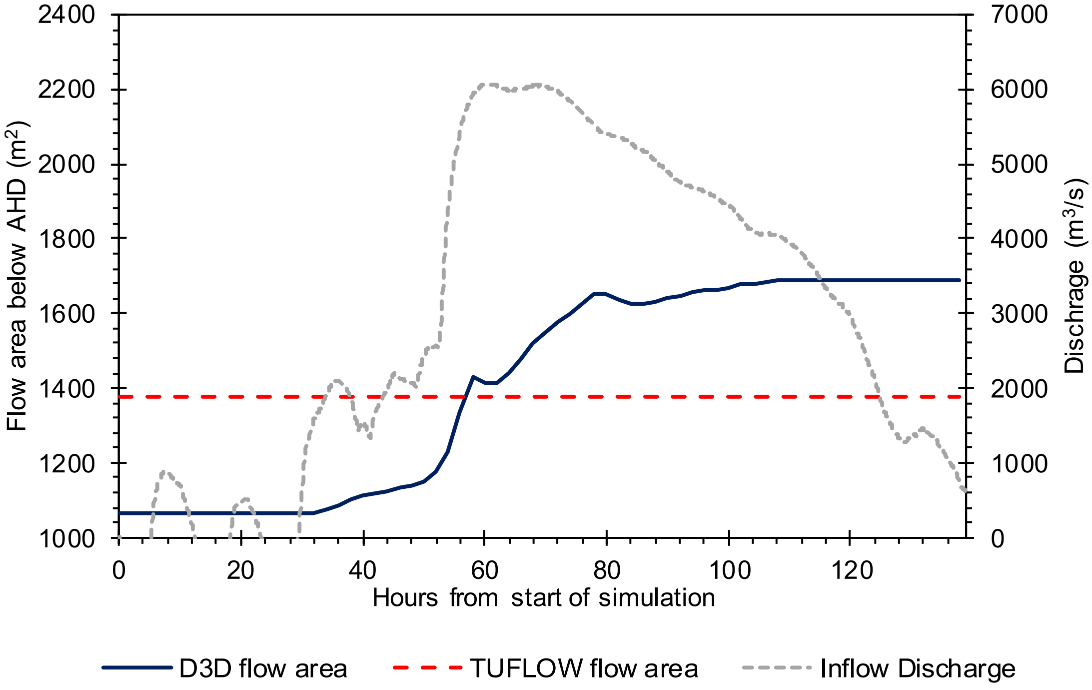

Figure 10 Modelled change in cross-sectional area during the 500-year design flood event

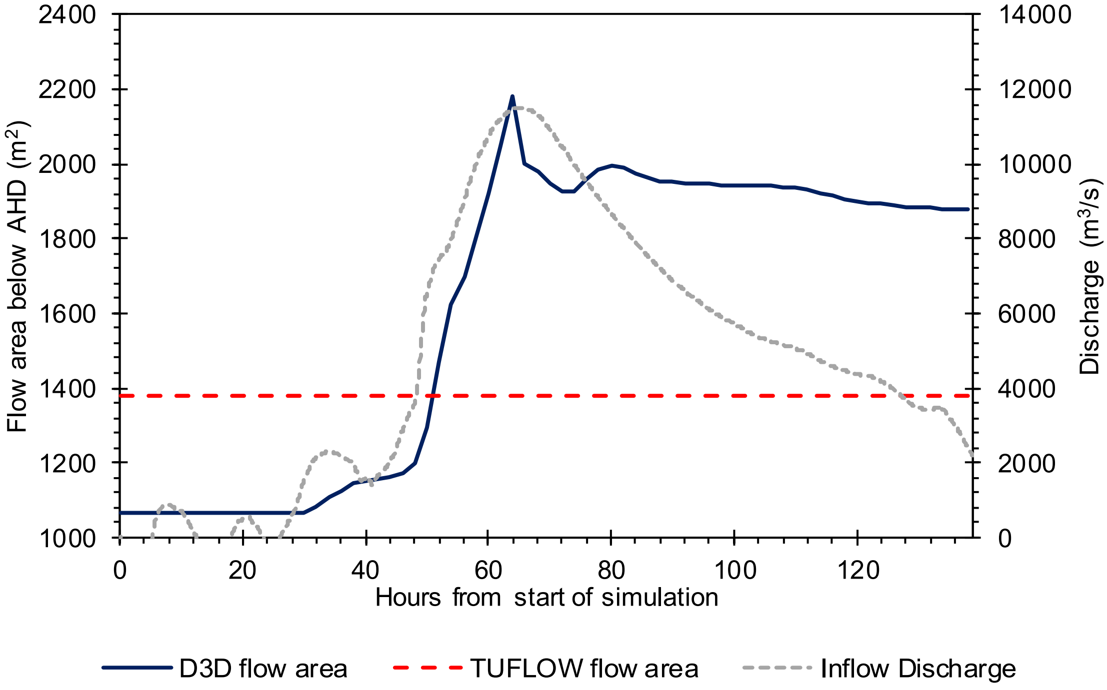

Figure 11 Modelled change in cross-sectional area during the Probable Maximum Flood event

3. Dune Breakout

A qualitative assessment of the potential for dune breakout during extreme flood events has been undertaken to inform how overtopping of the dunes is most appropriately represented in the flood modelling of the Probably Maximum Flood event for the Lower Macleay Flood Study.

Prior to construction of the Lower Macleay River training walls in 1895, the entrance location migrated between the south and north ends of Stuarts Point Beach, from South West Rocks to Grassy Head (with Back Creek connected to the Macleay system). Large flood events would have caused the river to breakout at locations which occasionally led to new outflow locations of the river. For example, in 1893 when the river broke through the dunes at its present location. Prior to the 1983 flood the main river outflow location was located near Grassy Head, approximately 9km to the north of the present outflow location. During calmer weather, the entrance would migrate slowly north under the influence of typically south-easterly waves and northerly directed longshore transport.

Due to this dynamic history, the coastal barrier that separates the lower Macleay floodplain from the ocean to the north of the present entrance location is relatively undeveloped. In a number of locations, the dune system is only approximately 20m wide. Crest levels of 4.5 to 5m AHD are not uncommon along this section of the coast, with a short section of dunes just to the north of the current entrance with a crest level as low as 3.3 to 4m AHD.As such, during very severe flood events flood water may spill over the coastal barrier. Where overtopping of the dunes occurs, this could result in the development of breakouts, similar to those experienced before training of the entrance. However, the occurrence is uncertain, and the location and nature of such potential dune breakouts is difficult to predict. As the intention of the Probable Maximum Flood (PMF) event is to estimate the largest conceivable flood conditions, it appears to be appropriate to assume that no breakouts will occur in the flood modelling of the PMF.

4. Scouring of Minor Creeks

A qualitative assessment of entrance dynamics of Killick and Korogoro creek during extreme flood events was undertaken to inform the Lower Macleay Flood Study.

Killick Creek and Korogoro Creek are small estuaries located directly adjacent to the townships of Crescent Head and Hat Head respectively. The estuaries are both permanently open to the ocean, however, Killick Creek has undergone several modifications in the late 1950s to remain open, whereas Korogoro Creek remains untrained.

Under typical wave-dominated coastal processes, marine sediments are transported towards shore, forming a sometimes-significant shoal over the estuary entrances. Historically, the shoals have been noted to erode during significant rainfall events, indicating that the catchment can generate flows strong enough to cause erosion of the entrance.

TUFLOW results for the 100-year flood event show that flows at Killick and Korogoro Creeks were generally between 2–3m/s for a considerable amount of time (1-2 days), hence it is likely that significant scouring will occur in these estuaries during severe Macleay River catchment flood events. However, the maximum depth of erosion could be controlled by bed rock across the entrance.

Figure 13 and Figure 12 show Coastal Quaternary Geology Maps focused on Killick and Korogoro Creek respectively (Hashimoto & Troedson, 2008). The maps show that both the river entrances are located directly adjacent to prominent headlands. These headlands are large rock features that quite likely extend to beyond the current river entrance locations, as suggested on the coastal erosion and recession hazard maps of the Kempsey Coastal Processes and Hazard Definition Study (BMT WBM, 2013).

Figure 14 and Figure 15 show creek bathymetry near the entrances relative to AHD, based on single-beam soundings provided by NSW OEH. These plots show that bed levels within the creeks around the headlands show elevations of less than -1mAHD, suggesting that the bedrock lies below this elevation. However, bathymetric data of the reef surrounding the headland of Killick Creek (i.e. immediately north-east of the entrance) indicate a rock-platform slightly higher, between -0.5m to -1mAHD.

Based on this, it appears reasonable to assume that bedrock is present between -0.5m to -1mAHD at Killick Creek and around -1mAHD at Korogoro Creek, and that it is possible that the creek entrances could erode down to these levels.

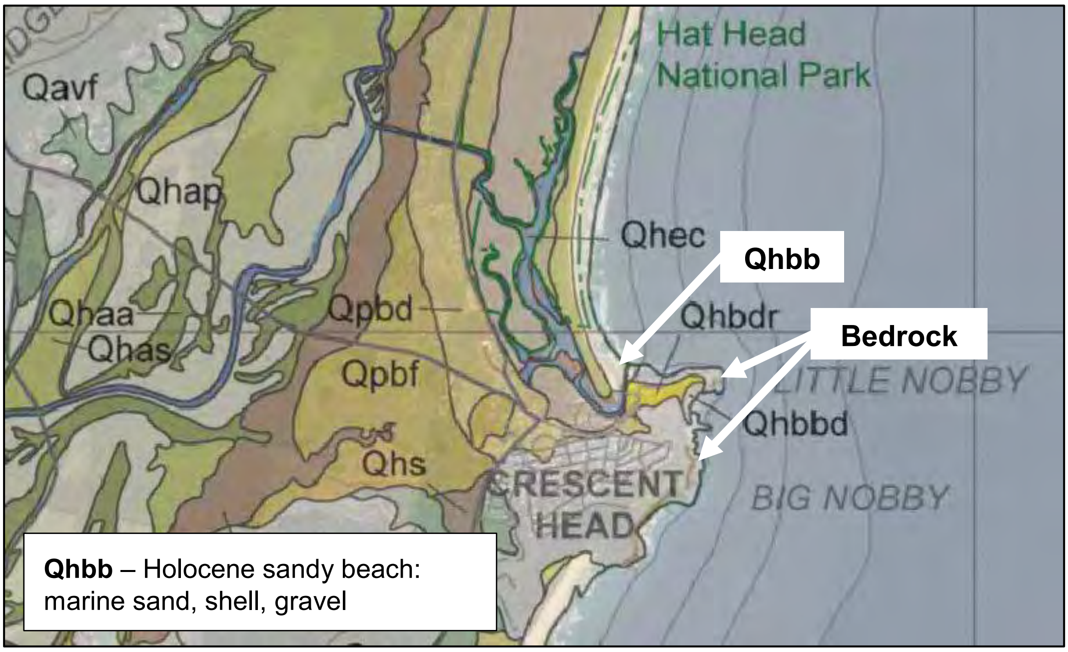

Figure 12 Kempsey Coastal Quaternary Geology Map at Killick Creek (Hashimoto & Troedson, 2008)

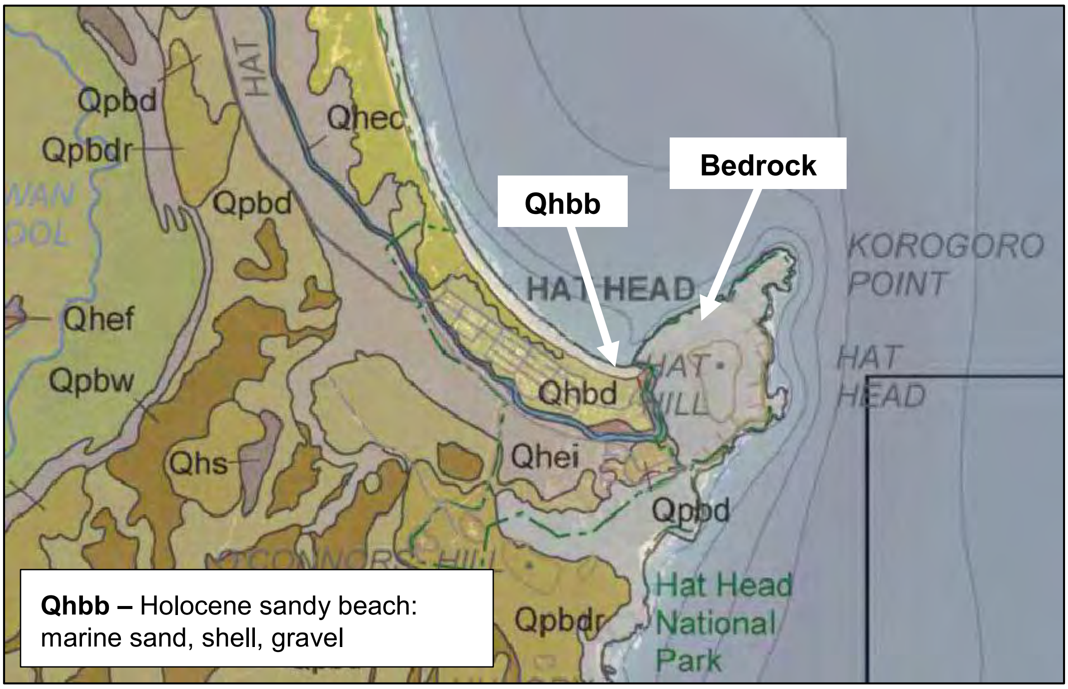

Figure 13 Kempsey Coastal Quaternary Geology Map at Korogoro Creek (Hashimoto & Troedson, 2008)

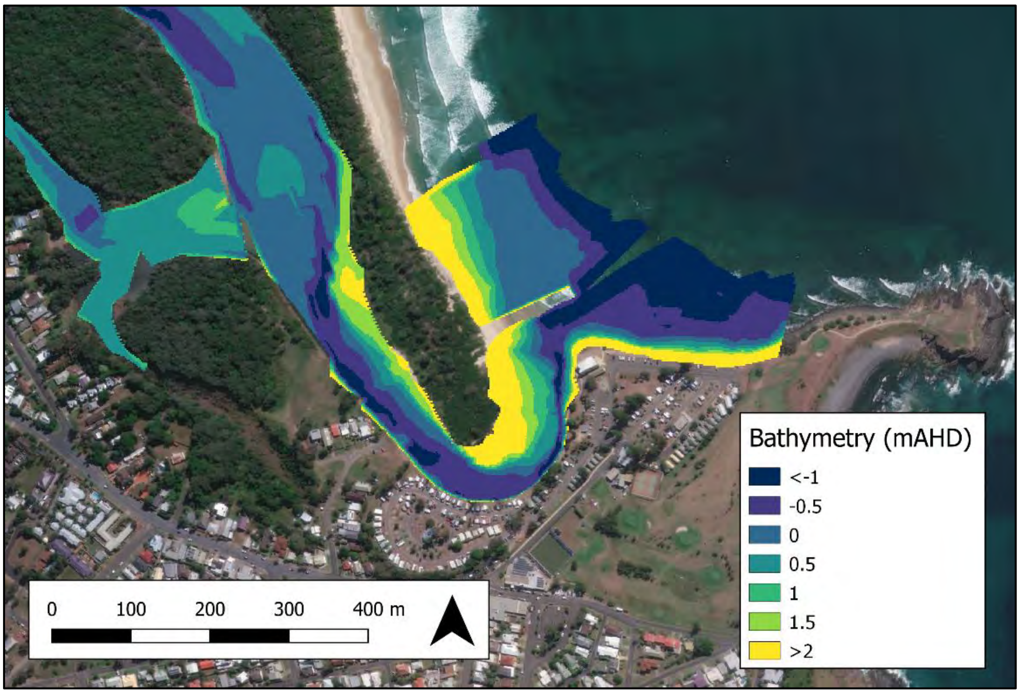

Figure 14 Bathymetry along Killick Creek (mAHD) (Source: NSW OEH)

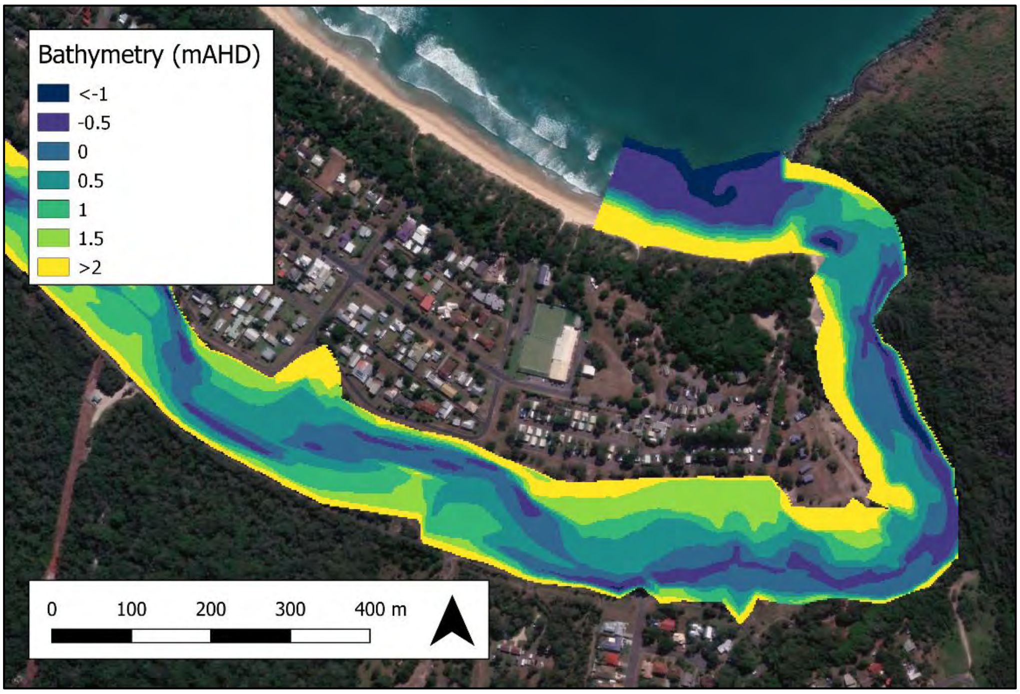

Figure 15 Bathymetry along Korogoro Creek (mAHD) (Source: NSW OEH)

5. Recommendations

Based on the modelling undertaken in conjunction with the desktop analyses, the following recommendations are made with respect to the flood study:

- For the calibration event and 100-year ARI design flood event, the geomorphic modelling predicts a similar entrance geometry as the adopted entrance geometry in the TUFLOW flood model. Although peak discharge rates are greater in the 100-year ARI event compared to the calibration event, the duration of flood flow is shorter, hence a similar entrance geometry. However, for more severe events (i.e. 500-year and Probable Maximum Flood (PMF) design flood events), the geomorphic modelling undertaken suggests that bed levels are likely to erode beyond what has previously been adopted in the flood model. Further lowering of the general channel could be considered, with the figures presented in Section 2.4 providing an indication of the modelled flow area for each of the design events.
- While a dune breakout could be experienced during a very severe flood event, it is not recommended to consider dune breakout in the PMF event because the intention of modelling this event is to provide an estimate of the maximum conceivable flood conditions.
- Available data indicates that bed-rock could be present at Killick Creek at elevations around -0.5mAHD to -1mAHD, and approximately -1mAHD at Korogoro Creek. As this may control the maximum erosion depth of the entrance, it is recommended that no entrance geometry below this level is used.

6. References

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