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ADVENTURE BAY FLOOD STUDY

Inundation Risk Modelling and Mapping

17 February 2020

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Document information

Document title	Adventure Bay Flood Study
	Inundation Risk Modelling and Mapping
Client organisation	Kingborough council
Client contact	Alan H Walker
ConsultDM number	ENTURA-12E116
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Project number	E307686 - P515370

Revision history

Revision 1.2

Revision description			
Prepared by	Aleksandar Jokanovic/Colin Terry	Final	11/02/2020
Reviewed by	Colin Terry		
Approved by	David Fuller		
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Distributed to	Alan H Walker (name)	Kingborough council (organisation)	(date)

Executive summary

Entura was engaged by Kingborough Council to conduct a flood risk assessment of Captain Cook Creek at Adventure Bay for a range of land and sea-based storms. The assessment incorporated climate change scenarios for years 2050 and 2100, with the current catchment and infrastructure level of development.

The study involved hydrological and hydraulic flood modelling, and inundation extent and hazard mapping. The modelling was based on the latest Australian Rainfall and Runoff (ARR) guidelines (Ball, et al., 2019).

An integrated hydrological and hydraulic 1D/2D XPSWMM (version 2019.1) software package was used for modelling. The software allows hydrological and hydraulic calculations to be conducted within the same model.

Hydrological modelling of the Captain Cook Creek catchment was performed by splitting catchment into several smaller sub-catchments and using Laurenson Runoff Routing procedure. Thehydrological model was used to select one design temporal pattern for 2D model inflows in order to reduce modelling time. The hydraulic modelling had a 2D domain covering part of Adventure Bay, the Adventure Bay township, and further upstream to cover most of the Environmental Living Planning Zone. The shape of the ground in the 2D domain was defined using a combination of LIDAR and bathymetric survey of the lower reaches of Captain Cook Creek.

A sensitivity analysis was conducted in order to better understand the impact of the sandbar on flood levels around the creek lagoon. The sandbar raised upstream flood levels 0.1 – 0.15 m when there was 1 m AHD tailwater during 1% AEP river storm.

Flood extents maps and flood hazard maps are provided in Appendix E. The recommended scenario to be adopted for the 1% AEP flood extent is 1% AEP river flood with 2100 rainfall combined with the 3 m tailwater.

This study did not investigate mitigation of the existing flood extents, other than to note the sensitivity of the flood levels on sandbar during the current climate highest astronomical tide scenario. Community engagement will be a key component of moving forward with solutions to risk the flood risk.

The results of the flood study show there are existing properties and houses within the 1% AEP flood extent. The critical storm which causes the highest inundation will last in the order of 9 hours (from the river flooding component) to 48 hours (from the sea storm component). Further modelling work as part of flood evacuation planning is recommended to refine the inundation duration.

It is recommended that Council adopt the 1% AEP flood extent mapping with 0.3 m freeboard for use in their planning processes, engage with the community with these results and consider the benefit of extending the use of the flood model that has been developed for this project for mitigation and emergency planning studies.

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1. Introduction

Entura was engaged by Kingborough Council to conduct a flood risk assessment of Captain Cook Creek at Adventure Bay.

The project aims to better understand and demonstrate flood risks posed to the Adventure Bay population and produced mapping to demonstrate flood extents in 2020, 2050 and 2100 incorporating the climate change impacts.

Captain Cook Creek starts below Mount Midway on Bruny Island at an elevation of 437 m AHD and flows into Adventure Bay, which is adjacent to the Tasman Sea. The creek is 8.3 km long and its catchment area covers approximately 20 km2. Captain Cook Creek catchment is presented in Figure 1.1.

Entura's assessment included:

- Information and data review from sources available or relevant to Adventure Bay Flood Study.
- Field survey of Captain Cook Creek bathymetry from coast to caravan park.
- Development of flood modelling and mapping methodology by considering approaches undertaken by Kingborough Council for Kingston Beach and Snug Flood Studies.
- Development and running of relevant hydrological and hydraulic models.
- Preparation of flood extent and hazard maps for 1% annual exceedance probability (AEP) event.

Entura issued project notes on 21 May 2019 which described document review and project methodology. The proposed methodology was discussed and accepted by Council represented by Alan Walker during the meeting on 22 May 2019.

This report is based on the projects notes and documents the major findings of the study.

The project was conducted without site inspections, except for a field survey.

Figure 1.1: Captain Cook Creek location on Bruny Island

2. Data review

2.1 Reports

The following reports have been received from Kingborough Council and reviewed for their applicability for the study:

1. Adventure Bay - Local Area Report for Communities and Coastal Hazards project (AECOM, 2016)
2. A first pass coastal hazard assessment for Kingborough Local Government Area, Tasmania (Sharples & Donaldson, 2014)
3. Groundwater Monitoring, Adventure Bay, Bruny Island. Kingborough (Cromer, 2015)
4. Kingston Beach Flood Study (Kingborough Council, 2016)
5. Snug Flood Study (early draft) (Kingborough Council, 2019)
6. Adventure Bay Dynamic Tailwater Levels (UNSW Water Research Laboratory, 2017)
7. Captain Cook Bridge Replacement Design Drawings (SKM, 2000)

Kingston Beach Flood study (Kingborough Council, 2016) and Snug Flood Study (Kingborough Council, 2019) served to develop a methodology and parameters for Captain Cook Creek flood study. Snug Flood Study report did not have the hydraulic and hydrological chapters at the time of writing. Kingston Beach Flood Study was complete and used as the primary guide for this study.

The Adventure Bay Dynamic Tailwater Levels Report (UNSW Water Research Laboratory, 2017) used for tailwater levels.

Captain Cook Bridge Design Drawings (SKM, 2000) were used to understand the bridge structure, with a field survey used for elevations used in the model.

Although AECOM (2014) and Sharples & Donaldson (2014) raised concerned about the coastal hazards including erosion, sea-level rise and coastal inundation, the coastal geometry was considered to be static in the study. Further, Entura assessed the removal of the Captain Cook Creek sandbar from the beach as part of a sensitivity analysis.

Sea level rise was covered in the UNSW Water Research Laboratory (2017) report and Kingston Beach Flood Study (Kingborough Council, 2016). These two documents were key inputs to establishing the sea level boundary condition scenarios for this project.

Cromer (2015) report monitored the groundwater at the coast and which is not significant for a riverine flood study compared to other factors, such as sea and tide levels, and this report wasn’t directlyed used.

2.2 Topographic data

The following Digital Elevation Models (DEM) are available for the study:

- The Department of Premier and Cabinet (DPAC) based on the LiDAR dataset collected in 2014.
- Mineral Resources Tasmania (MRT), which is formed from the combination of DPAC and Forestry Tasmania LiDAR datasets.

DPAC LIDAR dataset covers several Tasmanian coastal towns not included in the previous Climate Futures or Geoscience Australia LiDAR projects.

The Forestry Tasmania LiDAR dataset was collected between 2010 and 2015 over several areas within Tasmania and covers approximately 26,500 square kilometres of land over the state. Forestry Tasmania LIDAR is unavailable.

DEM assessment indicated that DPAC DEM is of better quality as MRT DEM has “noise” due to the fact it was combined datasets from two flights. However, DPAC has a higher ground level in the creek channel which may be due to different water level at the time of the survey.

Consequently, Entura agreed with the Council to:

1. Use DPAC DEM where available. DPAC DEM coverage is shown in Appendix A.
2. Use MRT DEM in the remaining areas (ie. upstream of the DPAC coverage).
3. Conduct a bathymetric survey of the Cook Creek channel over approximately 1.4 km length from the estuary. This bathymetric survey was combined with the DPAC DEM.
4. Sandbar from the beach was not removed, but a sensitivity analysis was conducted to assess sandbar being washed away.
5. Use SeaMap Tasmania Bathymetric Data for ocean bathymetry.

2.3 Bathymetric survey

Entura conducted a bathymetric survey of Captain Cook Creek in June 2019. The survey covered 1.4 km of the creek channel from the creek mouth. Survey outputs were incorporated into the DEM.

2.4 Streamflow gauges

Streamflow gauges were not available.

2.5 Land use data

Aerial photos were used as a guide for land use. Land use is required as an input to both hydraulic and hydrological model. The current level of development was assumed in the models. Under the current planning zones, the land use with the greatest potential for changing the runoff characteristics of the catchment is from forestry activities.

3. Model development

3.1 Approach

Modelling methodology was developed using Entura's standard modelling procedures and Kingston Beach Flood Study (Kingborough Council, 2016).

An integrated hydrological and hydraulic 1D/2D XPSWMM (version 2019.1) software package was used for modelling. The software allows hydrological and hydraulic modelling to be conducted within the same model.

3.2 Model extents and layout

The extent of the hydraulic model is shown in the flood maps in Appendix E. Two-dimensional (2D) hydraulic model domain covers the nearshore coastal area, township and extends further upstream to cover most of the Environmental Living Planning Zone. This ensured the model results cover nearly all areas that can potentially be developed with the current planning scheme.

The hydrological model covered the entire catchment area. The total catchment area was delineated into 20 sub-catchments[1], as shown in Appendix B.

3.3 Hydrological model

3.3.1 Hydrologic model set-up

The hydrological model was developed using the latest Australian Rainfall and Runoff (ARR) (Ball, et al., 2019) recommendations and new design rainfall intensity-frequency-duration (IFD) estimates (BOM, 2016) and temporal patterns (ARR, 2019a).

This approach is different to the Kingston Beach Flood Study which used the 1987 ARR method. The 2016 ARR (Ball, et al., 2019) approach requires ten (10) times more model runs for each modelled scenarios, as it uses 10 temporal patterns for each rainfall duration, whereas, the 1987 ARR method used one temporal pattern for each duration.

Therefore, in order to reduce the number of model runs, Entura adopted the following methodology:

- Develop a hydrological model using 1D hydraulic links between sub-catchment nodes.
- Each hydraulic link is a cross-section at node location. Essentially, one cross-section is a representative cross-section between two nodes. Link length and slope were automatically

[1] Initial catchment delineation included two (2) small sub-catchments that drain into the bay north of Captain Cooks Creek. Hence, total number of delineated catchments was twenty two (22), of which twenty (20) belong to Captain Cooks Creek which were modelled in the 2D floodplain model.

calculated from the map and cross-section invert levels. Manning's coefficient (n) between 0.05 and 0.06 was used for the creeks.

- Captain Cook Creek lagoon storage was modelled as two links with wide cross-sections. Cross-section and link length contained sufficient storage volume and therefore, storage node was not used to represent the storage volume curve.
- Ten (10) temporal patterns were run for twelve (12) durations in the hydrological model for 1% AEP: 1 h, 1.5 h, 2 h, 3 h, 4.5 h, 6 h, 9 h, 12 h, 18 h, 24 h, 30 h and 36 h.
- The model was set-up and run for current climate (2020), 2050 and 2100 future climate scenarios. Rainfall depths were increased by 10% and 30% for 2050 and 2100 climate, respectively, in consistent with (Kingborough Council, 2016).
- The hydrological model results were used to select the critical rainfall duration and one (1) temporal pattern, as discussed in Section 4.

Single rainfall depth was assumed across the entire catchment with an appropriate aerial reduction factor supplied by ARR Data Hub (ARR, 2019). ARR (Ball, et al., 2019) recommends to adopt a uniform spatial pattern for catchments smaller than 20 km^2. However, the catchment area for this project (20 km^2) and at any event the gridded spatial data from BOM only contains just over one grid cell limiting the ability to calculate a spatial pattern accurately.

3.3.2 Catchment delineation and parameters

Captain Cook Creek was delineated into twenty (20) sub-catchments[2] based on LIDAR generated contours and preliminary rain-on-grid model developed in HEC-RAS.

An assessment of catchment imperviousness concluded that less than 0.1% of the catchment area was impervious and therefore catchment was assumed 100% pervious in the model.

Manning's n in the hydrological model was adopted as 0.03 for every sub-catchment which represents a mixture of forested hillsides and rough creek. It should be noted Manning's n in the hydrological model represents storage delay time coefficient modifier and is not the same as hydraulic roughness. Default value was used as the model was not calibrated.

Geometric sub-catchment data, such as area, slope and the longest flow path length, were extracted from the DEM.

3.3.3 Rainfall losses

There are no local stream gauges to calibrate to, so generic values are used that are releavent for this area. An initial loss of 28 mm and continuing loss of 3.2 mm/h were adopted, as recommended by ARR data hub (ARR, 2019a).

[2] Initial catchment delineation included two (2) small sub-catchments that drain into the bay north of Captain Cooks Creek catchment. Hence, total number of delineated catchments was twenty two (22), of which twenty (20) belong to Captain Cooks Creek which were modelled in the 2D floodplain model.

3.3.4 Runoff routing procedure

Laurenson Runoff Routing procedure, also known as the RAFTS model was applied in the XPSWMM hydrological model. RAFTS model was used in the Kingston Beach Flood Study (Kingborough Council, 2016). The inputs for this routing procedure included catchment area, imperviousness, catchment slope and catchment roughness.

3.3.5 Peak flow estimation

A typical flood frequency analysis was not conducted to estimate the peak flows in the Captain Cook Creek catchment as there was no observed data.

The peak flow was estimated using ARR regional flood frequency estimation model (ARR, 2019b) as presented in Table 3.1 below. Peak flow estimates were used to validate outputs from the hydrological model.

Table 3.1: Peak flow estimatation using regional flood frequency estimation model (ARR, 2019b)

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	12.4	5.83	27.0
20	21.8	10.1	47.4
10	29.7	11.8	73.5
5	38.6	12.8	111
2	52.3	13.8	182
1	64.3	14.4	257

3.4 2D hydraulic floodplain model

3.4.1 DEM and computational grid

A 4 m gridwas used for the 2D model domain using the DEM as described in Section 0. This grid size was chosen for the purpose of maximising the accuracy of the model, while respecting the resolution of the input data, model size and computation time. The width of the creek channel was between 10 m and 40 m in the area of interest. Therefore, 3–10 cells were used to cover channel width which was appropriate for the expected lower velocities.

3.4.2 Hydraulic structures

Captain Cook Creek Bridge was modelled as a 1D bridge structure and was linked to the 2D domain using SX links (ie. sourced from an external model). The the bridge data was obtained from the design drawings (SKM, 2000) and the bathymetric survey (Section 2.3).

There is an allowance for wave run up in the 2 m AHD and 3 m AHD scenarios. Wave run-up is dynamic, oscillating with short wave period, but for this modelling the tailwater to the model is held constant. For the purposes of flood risk up within Captain Cook Creek, the oscillations from wind waves are expected to moderate as the wave energy enters Captain Cook Creek. While relationships for wave run-up on a beach exist, the complex interaction between the wave and Captain Cook Creek has not been analysed in this study. Instead, a judgment has been made to adopt a constant tailwater level.

The 1 m AHD scenario represents the highest astronomical tide in the current climate plus wave set up from a wind storm that has the probability of 1 exceedance per year (EY)[3] and no allowance for wave run-up. That is 0.8 m AHD tide plus 0.2 m wave setup = 1 m AHD.

The 2 m AHD scenario represents a range of events. Either small storms and a 2050 sea level rise (0.3 m), or major storms and current climate.

The 3 m AHD scenario represents a 1% AEP sea storm (1.44 m AHD), wave setup from a 1% AEP wind storm (0.48 m) and an allowance for wave run up if this was represented by a constant water level (0.08 m), and 1 m sea level rise. That is 1.44 m AHD + 0.48 m + 0.08 m + 1 m = 3 m AHD.

As a comparison to the 2100 1% AEP sea storm, the 2100 5% AEP sea storm (Table 3.4) is 0.16 m lower. That is the impacts of sea level rise and normal tide variation make up a much larger proportion of tailwater level than the storm rarity (for rarer events).

It should be noted that there could be variation around the statistical description of the tailwater, and there was no assessments conducted forrare events such as tsunamis. Also, the timing of sea level rise due to climate change is uncertain and the values used are based on the best available science. There are a range of political and social factors that will alter the timing of sea level rise that are outside the scope of this study. The estimates for sea level rise by the International Panel for Climate Change and local translations of this data should be monitored as they are updated. If this boundary condition significantly changes, model and maps should be updated to reflect the changes.

Table 3.3: Recommended tide levels

Scenario	Level	Rationale
Low	1 m AHD	1 EY (ie. 63% AEP) for current climate
Medium	2 m AHD	5% AEP for 2050 climate
High	3 m AHD	1% AEP for 2100 climate

Levels are Peak Nearshore Water Levels from the Adventure Bay Dynamic Tailwater Levels Report (UNSW Water Research Laboratory, 2017) plus an allowance for the effect of sea wave run-up.

[3] 1 EY corresponds to 63% AEP according to the new ARR (Ball, et al., 2019) probability terminology. ARR advises the events that are more frequent than those with a 50% AEP to be expressed as X Exceedances per Year (EY).

Table 3.4: Adventure Bay sea levels (UNSW Water Research Laboratory, 2017)

Year	ARI	Sea Level Rise (m)	Tide at Peak (m AHD)	Anomaly at Peak (m)	Local Wind Setup at Peak (m)	Wave Setup at Peak (m) (Shoreline)	Peak Nearshore Water Level (m AHD)
Present Day	1	0	0.53	0.44	0	0.21	1.18
	10		0.53	0.68	0	0.36	1.57
	20		0.53	0.75	0	0.48	1.76
	50		0.53	0.84	0	0.46	1.83
	100		0.53	0.91	0	0.48	1.92
2050	1	0.3	0.53	0.44	0	0.21	1.48
	10		0.53	0.68	0	0.36	1.87
	20		0.43	0.75	0	0.48	1.96
	50		0.53	0.84	0	0.46	2.13
	100		0.53	0.91	0	0.48	2.22
2100	1	1	0.53	0.44	0	0.21	2.18
	10		0.53	0.68	0	0.36	2.57
	20		0.53	0.75	0	0.48	2.76
	50		0.53	0.84	0	0.46	2.83
	100		0.53	0.91	0	0.48	2.92

3.4.6 Other parameters

Other critical parameters for the XPSWMM model are provided below:

- Calculation time-step: 1 second
- Flooding and drying depth: 0.002
- Eddy viscosity: Smagorinsky formula with default coefficients.

3.5 Model calibration

No flood calibration data was available, so the hydraulic model was not calibrated. The accuracy of the flood inundation mapping was therefore reliant on the accuracy of the topographical information and drawings provided.

4. Design storm modelling

4.1 Hydrological model

A hydrological model with simple hydraulic links, as described in Section 3.3, was used to select the design temporal patterns for 2D model inflows. The hydrological model was run with three (3) downstream model boundaries defined in Table 3.3.

4.1.1 Critical storm duration

Critical rainfall durations and temporal patterns were observed from the results at two key locations: at the main creek inflow to the 2D model and at the lagoon. The average maximum flow for twelve (12) durations at the main creek inflow is presented in Appendix C1 and the average maximum flows and levels at the lagoon for twelve (12) durations and three (3) tide levels are presented in Appendix C2.

For the main creek inflow to the 2D domain, 6 h duration produced the highest average maximum discharge of 45 m^3/s for the current climate and was designated as the critical river duration. For the lagoon, 18 h rainfall duration produced the highest depths and was selected as the critical lagoon duration.

Maximum average water levels in the lagoon are 1.8 m AHD, 2.2 m AHD and 3.1 m AHD for tide levels of 1 m AHD, 2 m AHD and 3 m AHD respectively. These maximum average levels correspond to a range of flows between 71 m^3/s in and 79 m^3/s in the lagoon, depending on the tide level. This flow rate is 10% higher than the estimated peak flow using Regional Flood Frequency Estimation Model (ARR, 2019b). This difference is an acceptable range considering uncertainties within hydrological models, and validates the hydrological model.

4.1.2 Design temporal pattern selection for 2D model

Detailed result interrogation showed that temporal pattern number 9 for 18 hours duration produces levels and flows marginally higher than the maximum average levels and flows in the lagoon for 18 hours duration. The same pattern produces 46 m^3/s flow at the main Captain Cook Creek inflow to the 2D domain, which was close to the aforementioned 45 m^3/s for critical river duration.

Consequently, pattern number 9 for 18 h rainfall duration was selected to be run in the 2D hydraulic model as it is a good representative of average maximum flows for study area.

4.1.3 Preliminary conclusions

Hydrological model results indicated that the water levels in the lagoon were significantly influenced by tide, especially for higher tide levels. At 2 m AHD elevation, lagoon floodplain covers an area of approximately 50 ha, which can retain a significant volume of water. For example, for 2 m tide level, 1% AEP is expected to increase levels by 0.25 m in the lagoon.

4.2 2D floodplain model runs

Entura ran the following nine (9) scenarios in the 2D floodplain model:

1. 2020 1% AEP river flood + 1 m AHD tailwater level
2. 2020 1% AEP river flood + 2 m AHD tailwater level
3. 2020 1% AEP river flood + 3 m AHD tailwater level
4. 2050 climate (1% AEP + 10% Rainfall increase) river flood + 1 m AHD tailwater level
5. 2050 climate (1% AEP + 10% Rainfall increase) river flood + 2 m AHD tailwater level
6. 2050 climate (1% AEP + 10% Rainfall increase) river flood + 3 m AHD tailwater level
7. 2100 climate (1% AEP + 30% Rainfall Increase) river flood + 1 m AHD tailwater level
8. 2100 climate (1% AEP + 30% Rainfall Increase) river flood + 2 m AHD tailwater level
9. 2100 climate (1% AEP + 30% Rainfall Increase) river flood + 3 m AHD tailwater level

The purpose of these model runs was to assess and delineate tailwater and riverine influences on flooding. Rainfall depth increases for climate change scenarios were adopted from Kingston Beach Flood Study (Kingborough Council, 2016) and agreed with Council representative.

Table 4.1 below presents the model results as water levels at three locations for the above scenarios. Selected reporting locations are downstream of the bridge, upstream of the bridge and at the lagoon, as shown in Figure 4.1.

Figure 4.1: Water surface levels reporting points

Table 4.1 Water surface levels for 9 scenarios at 3 locations

		Water surface (m AHD)		
Tide (m AHD)	Climate (year)	Downstream of the bridge	Upstream of the bridge	Lagoon
1m	2020	2.1	2.3	2.5
1m	2050	2.3	2.4	2.6
1m	2100	2.4	2.6	2.7
2m	2020	2.3	2.5	2.6
2m	2050	2.3	2.5	2.6
2m	2100	2.4	2.6	2.8
3m	2020	3.0	3.1	3.1
3m	2050	3.1	3.1	3.1
3m	2100	3.1	3.1	3.2

There is approximately 0.8 m difference in flood depth upstream of the bridge for most extreme scenarios (Scenarios 1 and 9).

The results also show that flood levels in the lagoon and around the bridge are sensitive to riverine flooding for tide levels between 1 m AHD and 2 m AHD. For the tide level of 3 m AHD, the water levels in the lagoon raised only up to 0.1 m due to riverine flooding.

A joint probability assessment was required when the flood levels upstream of the bridge were sensitive to combining both extreme river flooding and sea storm tailwaters. However in this case the impact of the narrow Captain Cook Creek and detention effect of the lagoon, have provided enough hydraulic disconnection that simplified the assessment.

4.3 Sensitivity analysis to sandbar removal

A sensitivity analysis was conducted in order to better understand the impact of the sandbar on flood levels around the creek lagoon. The currently surveyed sandbar has a minimum ground level of approximately 1.1 m AHD. The analysis was carried out by removing the sandbar for three tide level scenarios and 1% AEP 2100 storm event. The results showed that the sandbar raised flood levels upstream of the bridge by 0.1–0.15 m when there was 1 m AHD sea during a 1% AEP river storm or 0.05-0.1 m when there was 2 m AHD sea level. For 3 m AHD sea level, removal of sandbar reduces flood levels by 0.01 m, which was less than the modelling accuracy.

Based on the analysis of the results and terrain, the sandbar was expected to meaningfully influence water levels downstream of the bridge for tailwater levels up to 1.6 m AHD. This was clear from water surface longitudinal profiles described in the following section. Water levels can be increased by 0.3 m downstream of the bridge for tide levels below 1.6 m AHD due to presence of sandbar.

Typically the sensivity of model output to roughness and grid size are tested for flood models, more often with faster flowing water and conveyance resistricted models. In this case the grid size used is resonabley fine and the critical flooding areas are controlled by the tailwater level (rather than conveyance in a river), so other checks are not required. Tailwater level is a key model scenario input.

4.4 Longitudinal profile

A water level longitudinal profiles for nine (9) scenarios described in Section 4.2 are shown in Appendix D. The profile was developed for 1.8 km from the sea outlet to upstream of the outlet. Tailwater levels end influencing water levels at 1.8 km upstream of the sea outlet.

The profiles showed that the riverine flood and sandbar had an insignificant impact on the water levels in the lagoon for extreme tide levels of 3 m AHD.

4.5 Flooding mechanism

Narrow Captain Cook Creek channel outlet restricts the flow just upstream of the beach. This restriction is encircled in red in Figure 4.2. The result of these restrictions is that the water levels upstream of the bridge are not directly controlled by the tailwater level.

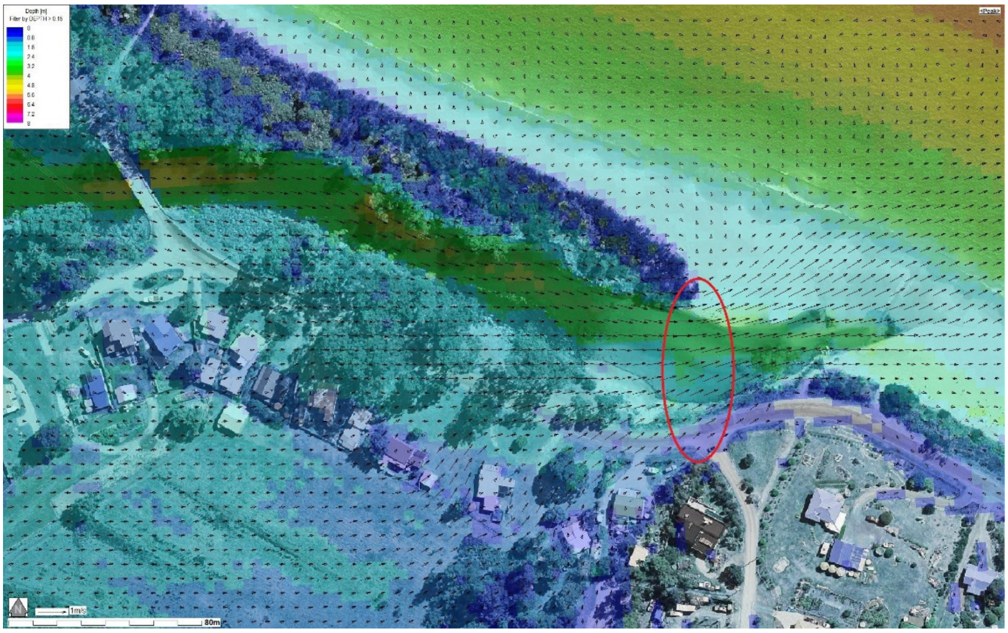

Figure 4.2: Captain Cook Creek channel outlet narrow section

The shape of the land just upstream of the bridge show a creek and flat overbank flood plain. There are several properties and buildings in the flood plain which are expected to be inundated during major storms (Figure 4.3).

There were no scenarios modelled with major changes to the opening up of the connection between Captain Cook Creek and Adventure Bay, or erosion of the land between Adventure Bay and Captain Cook Creek at the lagoon.

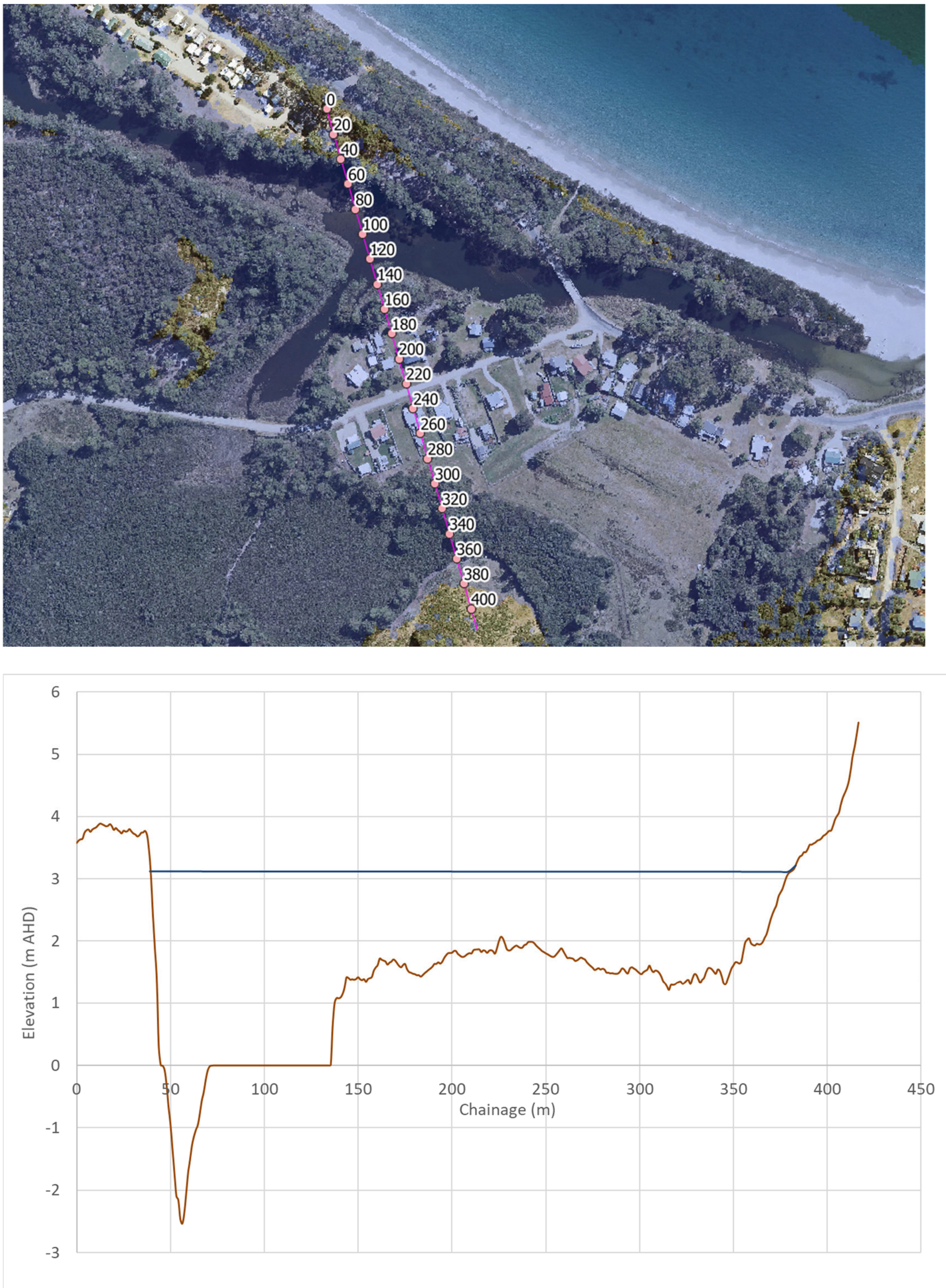

Figure 4.3: Typical flood plain cross-section upstream of the bridge (3 m sea, 2100 1% AEP river flood)

4.6 Rarity of the flood extent mapping

The recommended 1% AEP scenario was used for the flood extent has 1% AEP river flooding and a 3 m AHD tailwater. The 3 m tailwater scenario represented a 1% AEP sea storm anomaly at its high tide, the 1 m sea level rise expected by 2100, wave set up from a 1% AEP wind wave, and an allowance of wave run-up.

Amonth the different components of the scenario, the 3 m AHD tailwater has the most impact on existing houses. The sea storm and wind were considered dependant on each other (UNSW Water Research Laboratory, 2017).

Adopted combination of various land, sea and wind events may look as if the scenario is rarer than 1% AEP. However, for this particular situation, where tide level has dominant influence and with the current level of analysis, a 1% AEP can be considered the rarity of the recommended scenario. The expected raise in water levels in the lagoon is 0.1 m due to riverine flooding.

As a comparison the Kingston Beach flood study (Kingborough Council, 2016) used scenarios with a 1% AEP riverine flood with a 5% AEP sea storm, and another scenario with 5% AEP riverine flood with a 1% AEP sea storm. For Captain Cooks Creek, if the 2100 1% AEP sea storm tide boundary (3 m AHD) was reduced to a 2100 5% AEP sea storm (a reduction of 0.16 m at the sea boundary), the expected impacts[4] with an approximation (using linear proportions) are a 64 mm reduction in levels within the lagoon. This small amount is within the modelling and DEM accuracy. That is, adopting a 1% AEP sea storm combined with a 1% AEP riverine flood for Adventure Bay is slightly more conservative than using 1% AEP sea storm combined with a 5% AEP riverine flood, but this difference is within the accuracy of the modelling would not make any material impact on the flood maps.

It is noted that while the 1% AEP storm scenario was adopted for calculationg the flood extents in the maps, there are rarer events which may cause a greater flood extent, including rainfall up to the probable maximum precipitation, rarer sea storms and higher levels of sea-level rise.

4.7 Scenarios

Flood extents, flood depth and flood hazard maps for the recommended scenario are provided in Appendix E. These cover a range of tailwater and climate combinations.

The criteria for hazard mapping is based on the latest Australian Rainfall and Runoff (Ball, et al., 2019) hazard curves shown in Figure 4.4.

[4] calculated as a linear proportion (0.16 m out of the 1 m difference between 3 m tide and 2 m tide) of the resultant difference between the lagoon levels from the 3 and 2 m tides (3.2 m minus 2.8 m from Table 4.1) = 0.16 m x 0.4 m = 64 mm

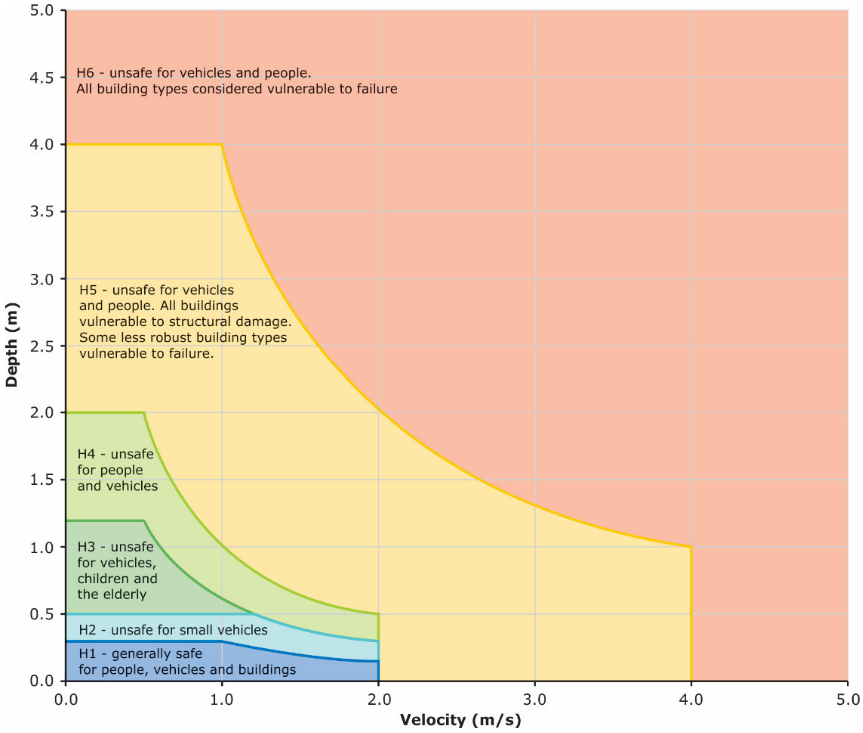

Figure 4.4: Flood hazard curves (Smith, et al., 2014)

4.8 Limitations

It should be noted that the flood inundation maps cannot show inundation patterns of actual historic floods. Actual inundation patterns vary from one flood to another due to blockage of structures, changes in floodplain topography, the state of vegetation cover and other factors.

The flood extents shown on the maps are not the boundary between flood-prone and flood-free land. Larger floods could inundate areas outside the limits shown. The inundation patterns relate to a prediction of land affected, for the specific level of risk, and not necessarily to the buildings located on that land.

The work has been undertaken using current best practice and it is acknowledged that there are uncertainties associated with the digital terrain and flood models which can affect the estimation of the floods. Variations in the flood information can be expected by the incorporation of additional and accuratedata, developments in the flood modelling approches, land development and/or changes in catchment conditions.

The modelling assumes no erosion or deposition of eroded material within Captain Cook Creek or within the floodplain.

The hydraulic modelling includes the impact of wind-wave run-up of tailwater. There are phenomena not included in the flood model which can increase the flood levels and therefore, should be accounted by a freeboard of 0.3 m in the designs. These phenomena include local hydraulic disturbances such as standing waves, waves in the lagoon, bow waves from vehicles and boats driving through floodwaters, debris floating or blocking the flow.

5. Conclusions

Entura has undertaken an investigation into flooding from Captain Cook Creek in Adventure Bay township on Bruny Island. The objectives of the study were to:

- Review existing information, including reports and topographic data
- Conduct a bathymetric survey along Creek estuary (ie. lagoon).
- Develop coupled hydrologic and hydraulic XPSWMM® model for the study area
- Determine the flood levels and the extent of flooding within the catchment in its current state of development for 1% AEP with an overview of the potential impact of climate change.
- Prepare flood extents and hazard maps for selected scenarios (a combination of 1% AEP riverine flood event and tide level)

Floodplain modelling showed:

1. Tailwater/sea level has a stronger influence on floodwater levels for the properties impacted than riverine flows.
2. Impacts of tailwater changes on water levels in the lagoon in major storms are reduced by the narrow entry to Captain Cook Creek (eg. 1 m difference in tide level can correspond to less than 0.5 m water level difference in water level in the lagoon during storm events).
3. The impact of the sandbar is not significant in major storms with tide levels above 1.6 m AHD.
4. The flood plains near Captain Cook Creek are impacted by major storms, and once the water rises above the creek banks there are several properties impacted.
5. There is little difference in the horizontal extent of flooding for 1, 2 and 3 m AHD tailwater scenarios, and there is some impact on flood depth between these scenarios to few properties near the confluence of Captain Cook Creek and the beach.

The recommended scenario for use as the designated flood zone and levels are the results from the 3 m AHD tailwater with the 1% AEP riverine flooding for year 2100 (Appendix E). This scenario included high tide, 1 m sea level rise, 1% AEP sea storm anomaly, 1% AEP storm wind-wave set up, minimal local wave run-up, and 30% increase in rainfall from climate change impacting on river flooding. A freeboard of 0.3 m was added to the flood levels in the maps for setting floor levels.

1% AEP event at the 2100 has an insignificant impact on the water levels in the lagoon by riverine flooding. For such extreme tide levels, tide had major influence on flood extents in the lagoon and lower reaches of the creek (ie. the area of interest).

6. Recommendations

It is recommended that Council

- Adopt the 1% AEP flood extent map for 2100 with 0.3 m freeboard for the use of future planning and development of the township.
- Engage with the community about the results of this study.
- With the community undertake mitigation studies to reduce the risk and undertake emergency planning for any risual risk, noting river based storms have a critical duration of around 9 hours and sea storms have 48 hour duration. This work should consider the impacts of coastal erosion and sea level rise.
- Undertake flood studies on the other creeks around Adventure Bay: unnamed creek at the northern end of Adventure Bay, Blighs Creek and Dorloff Creek. Combining these in an overall flood map and planning approach.

7. References

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Appendices

A. Digital elevation model (DEM)

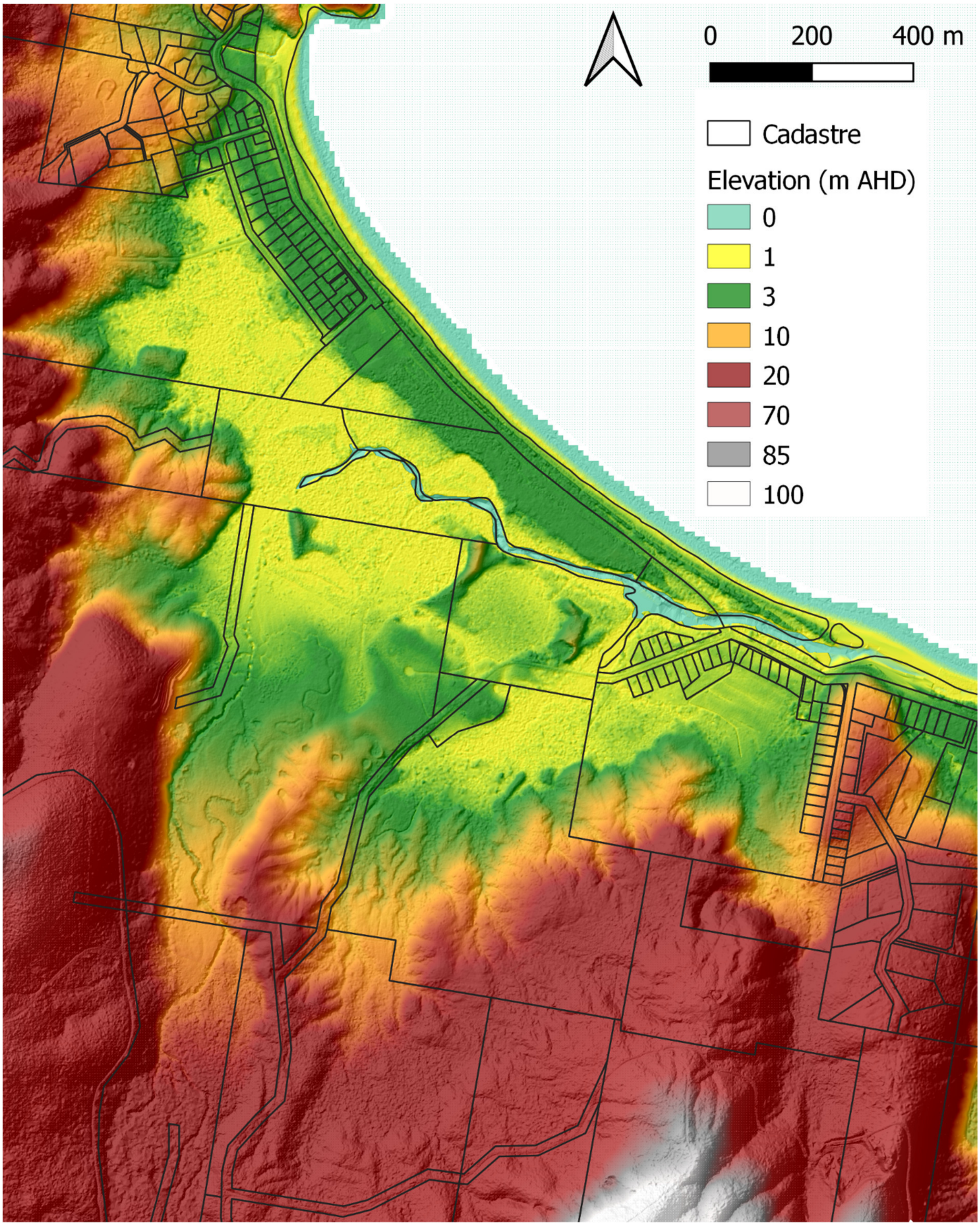
B. Hydrological model sub-catchments

C. Hydrological model results

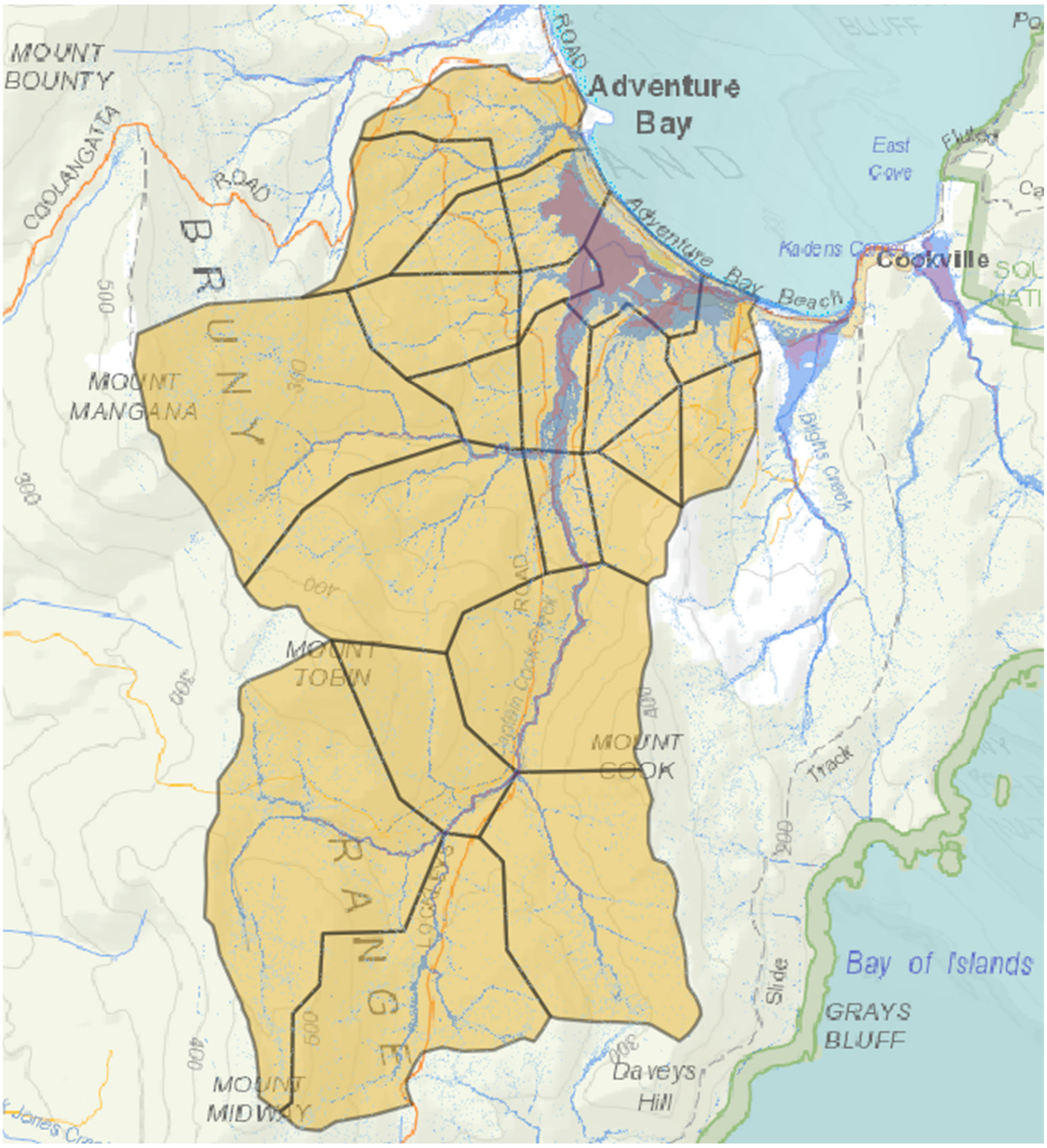
D. Water surface levels longitudinal profiles

E. Flood maps

A Digital elevation model (DEM)



B Hydrological model sub-catchments



C Hydrological model results

C.1 Maximum average flows at the main creek inflow to the 2D model

Note: Row highlighted in yellow is the critical duration.

	Average of Maximum flows (m3/s)		
Duration (h)	*Current (2020) climate*	*2050 climate*	*2100 Climate*
1	*0*	*1*	*13*
1.5	*5*	*12*	*30*
2	*15*	*23*	*42*
3	*31*	*39*	*54*
4.5	*41*	*51*	*70*
6	*45*	*52*	*66*
9	*44*	*51*	*65*
12	*39*	*44*	*54*
18	*44*	*50*	*61*
24	*32*	*37*	*47*
30	*32*	*37*	*46*
36	*28*	*32*	*40*

C.2 Maximum average levels and flows in the lagoon (upstream of the Captain Cook Bridge)

Note: Row highlighted in yellow is the critical duration.

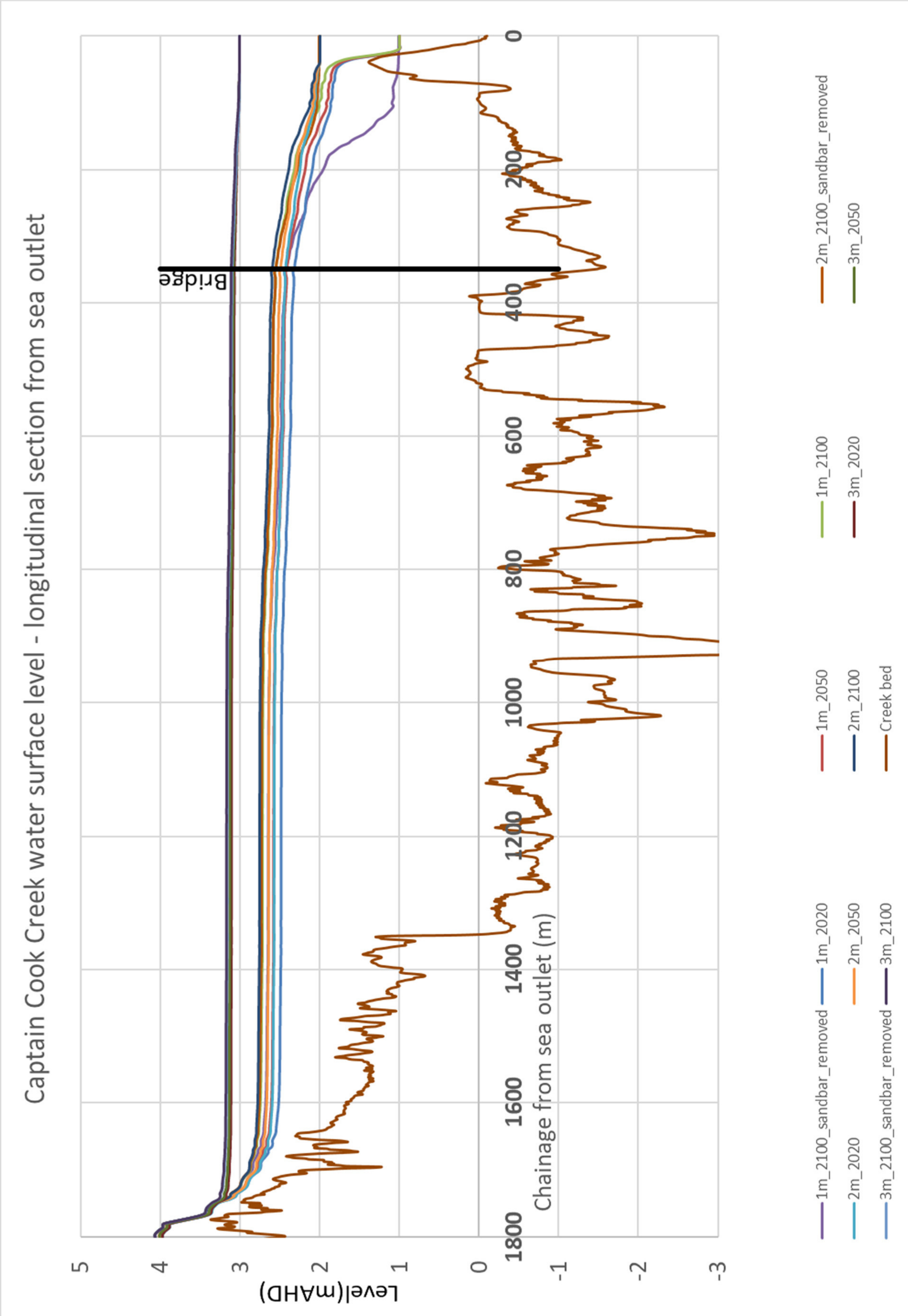
		Average of maximum levels (mAHD)			***Average of maximum flow (m^3/s)***		
Tidel level	*Rainfall duration (h)*	*Current (2020) climate*	*2050 climate*	*2100 Climate*	*Current (2020) climate*	*2050 climate*	*2100 Climate*
Tide 1m	*1*	*1.00*	*1.03*	*1.36*	*0*	*1*	*13*
Tide 1m	*1.5*	*1.21*	*1.35*	*1.56*	*5*	*13*	*35*
Tide 1m	*2*	*1.39*	*1.51*	*1.70*	*15*	*27*	*54*
Tide 1m	*3*	*1.62*	*1.71*	*1.84*	*40*	*52*	*77*
Tide 1m	*4.5*	*1.74*	*1.81*	*1.93*	*57*	*71*	*100*
Tide 1m	*6*	*1.81*	*1.86*	*1.96*	*67*	*78*	*100*
Tide 1m	*9*	*1.81*	*1.87*	*1.99*	*67*	*78*	*101*
Tide 1m	*12*	*1.80*	*1.84*	*1.95*	*62*	*71*	*89*
Tide 1m	**18**	**1.84**	**1.89**	**1.99**	**71**	**80**	**99**
Tide 1m	*24*	*1.76*	*1.81*	*1.89*	*54*	*62*	*78*
Tide 1m	*30*	*1.77*	*1.82*	*1.92*	*55*	*63*	*79*
Tide 1m	*36*	*1.73*	*1.78*	*1.87*	*49*	*56*	*69*
Tide 2m	*1*	*2.00*	*2.00*	*2.06*	*0*	*3*	*-7*
Tide 2m	*1.5*	*2.04*	*2.03*	*2.11*	*-9*	*22*	*18*
Tide 2m	*2*	*2.05*	*2.08*	*2.17*	*20*	*22*	*49*
Tide 2m	*3*	*2.12*	*2.17*	*2.25*	*49*	*61*	*84*
Tide 2m	*4.5*	*2.18*	*2.23*	*2.32*	*64*	*62*	*105*
Tide 2m	*6*	*2.21*	*2.24*	*2.32*	*57*	*81*	*102*
Tide 2m	*9*	*2.21*	*2.26*	*2.34*	*55*	*62*	*103*
Tide 2m	*12*	*2.19*	*2.23*	*2.30*	*63*	*58*	*72*
Tide 2m	**18**	**2.23**	**2.26**	**2.33**	**73**	**68**	**87**
Tide 2m	*24*	*2.16*	*2.19*	*2.26*	*55*	*62*	*64*
Tide 2m	*30*	*2.17*	*2.21*	*2.28*	*57*	*64*	*67*
Tide 2m	*36*	*2.15*	*2.18*	*2.24*	*50*	*57*	*71*
Tide 3m	*1*	*3.00*	*3.00*	*3.01*	*0*	*-2*	*29*
Tide 3m	*1.5*	*3.01*	*3.01*	*3.03*	*1*	*28*	*58*
Tide 3m	*2*	*3.01*	*3.02*	*3.04*	*30*	*46*	*76*
Tide 3m	*3*	*3.03*	*3.04*	*3.07*	*58*	*71*	*96*
Tide 3m	*4.5*	*3.04*	*3.06*	*3.10*	*76*	*92*	*122*
Tide 3m	*6*	*3.05*	*3.07*	*3.10*	*80*	*92*	*114*
Tide 3m	*9*	*3.05*	*3.06*	*3.09*	*78*	*90*	*113*
Tide 3m	*12*	*3.04*	*3.05*	*3.07*	*70*	*79*	*97*
Tide 3m	**18**	**3.06**	**3.07**	**3.10**	**79**	**89**	**108**
Tide 3m	*24*	*3.03*	*3.04*	*3.06*	*58*	*67*	*85*
Tide 3m	*30*	*3.03*	*3.04*	*3.06*	*59*	*67*	*83*
Tide 3m	*36*	*3.02*	*3.03*	*3.04*	*52*	*59*	*73*

D Water surface levels longitudinal profiles

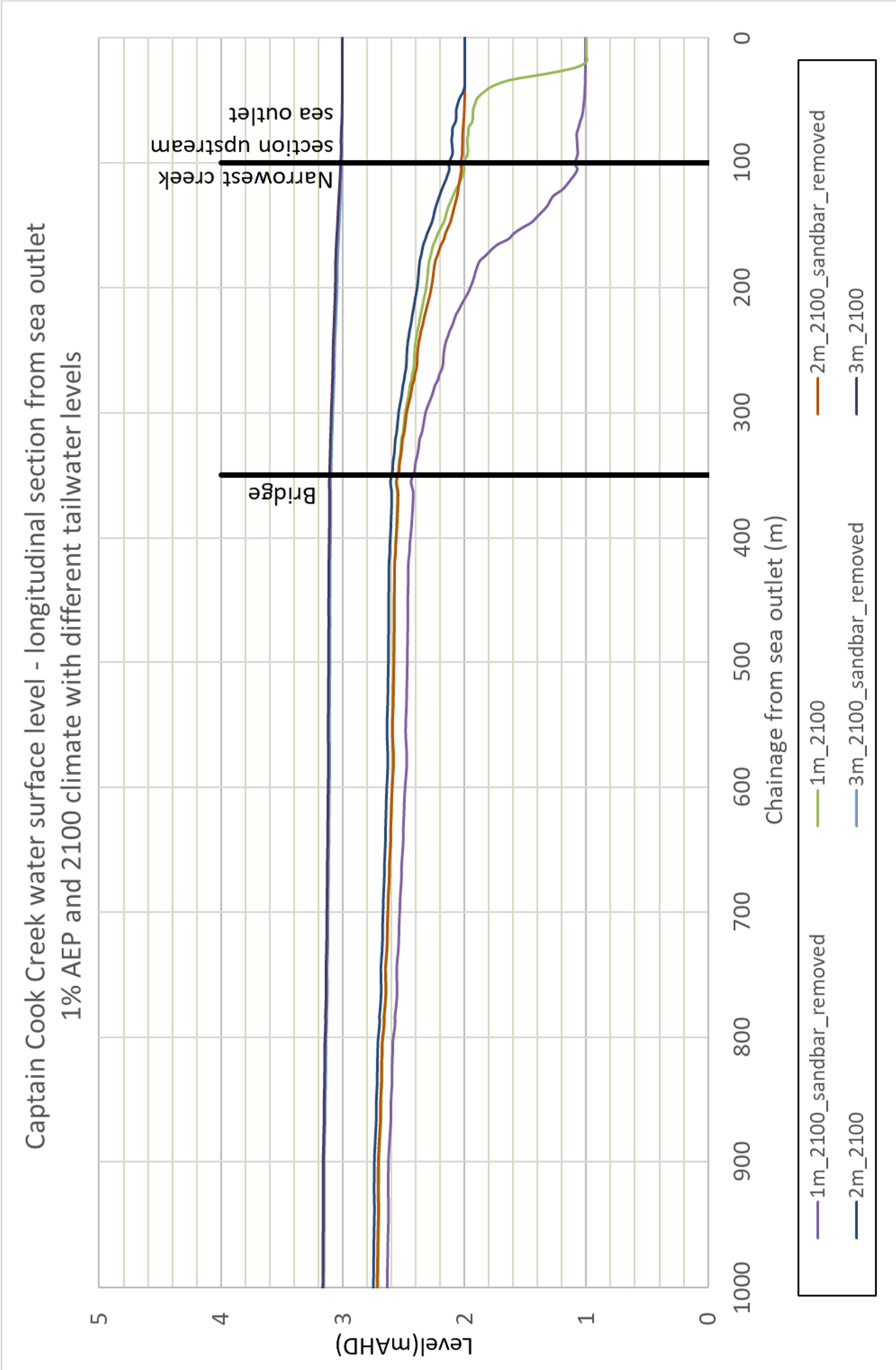
D.1 Plan view with chainages

See over for longitundinal sections.

D.2 Longitudinal profile with 12 analysed scenarios



D.3 Profile for 1% AEP and 2100 climate scenarios (including sandbar removals)



E Flood maps

Figure 1. Flood extents

- 2020 1% AEP with 1 m AHD tailwater
- 2100 1% AEP with 1 m AHD tailwater
- 2100 1% AEP with 2 m AHD tailwater
- 2100 1% AEP with 3 m AHD tailwater

Figure 2. Flood depth for 2020 1% AEP with 1 m AHD tailwater

Figure 3. Flood level for 2020 1% AEP with 1 m AHD tailwater

Figure 4. Flood hazard for 2020 1% AEP with 1 m AHD tailwater

Figure 5. Flood depth for 2050 1% AEP with 2 m AHD tailwater

Figure 6. Flood level for 2050 1% AEP with 2 m AHD tailwater

Figure 7. Flood hazard for 2050 1% AEP with 2 m AHD tailwater

Figure 8. Flood depth for 2100 1% AEP with 3 m AHD tailwater

Figure 9. Flood level for 2100 1% AEP with 3 m AHD tailwater

Figure 10. Flood hazard for 2100 1% AEP with 3 m AHD tailwater

Note

1. Maps have been filtered for clarity as the direct rainfall used as part of the hydrology produces a small amount of water depth everywhere. The filtering method includes
   (a) Clipping extents so there is a minimum of 0.15 m water depth, minimum depth times velocity of 0.2 m^2/s and a minimum contiguous ponded area of 10,000 m^2.
   (b) Buffering out the clipped area by 5 m to account for the reduction in extent from 0.15 m minimum depth clipping, and removal of internal holes where there are islands of higher ground within the flood extent.
2. Model results are sensitive to the climate, land and infrastructure geometry and land-use. Should there be changes to the assumptions used for this report then the flood extents may change, and maps may need to be updated.
3. Results are shown for a particular rarity flood event (1% AEP) and there are rarer events that will have a greater flood extent. Being outside the 1% AEP flood extent line does not mean this area is safe from any flooding.
4. A freeboard of 0.3 m should be added to flood levels to set floor levels, which accounts for phenomena not accounted for in the hydraulic model. In some flatter areas, this could extend the flood extents.

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Title

Figure 1.
Captain Cook Creek Flood Extents

Flood Extent

- 2020 1% AEP with 1 m tailwater
- 2100 1% AEP with 1 m tailwater
- 2100 1% AEP with 2 m tailwater
- 2100 1% AEP with 3 m tailwater
- Property boundary

Data Acknowledgement

Notes

To be read in conjunction with the Captain Cook Creek Flood Study - Inundation Risk Modelling and Mapping report.

Peak flood conditions have been derived by calculating the envelope of maximum values across a range of storm durations, with subsequent filtering by applying the following criteria:
- Minimum flood depth
- Minimum flood hazard
- Minimum ponded area

0 100 200 300 400 metres

Coordinate System: GDA 1994 MGA Zone 55
Scale 1:10,000 A3 paper size

Locality

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Title

Figure 2.
Captain Cook Creek Flood depth for 2020 1% AEP with 1 m tailwater

Flood Depth (m)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- >2
- Property boundary
- Flood extent for 2100 1% AEP with 3 m tailwater

Data Acknowledgement

Base data is from TheLIST © State of Tasmania

Notes

To be read in conjunction with the Captain Cook Creek Flood Study - Inundation Risk Modelling and Mapping report.

Peak flood conditions have been derived by calculating the envelope of maximum values across a range of storm durations, with subsequent filtering by applying the following criteria:
- Minimum flood depth
- Minimum flood hazard
- Minimum ponded area

0 100 200 300 400 metres

Coordinate System: GDA 1994 MGA Zone 55
Scale 1:10,000 A3 paper size

Locality

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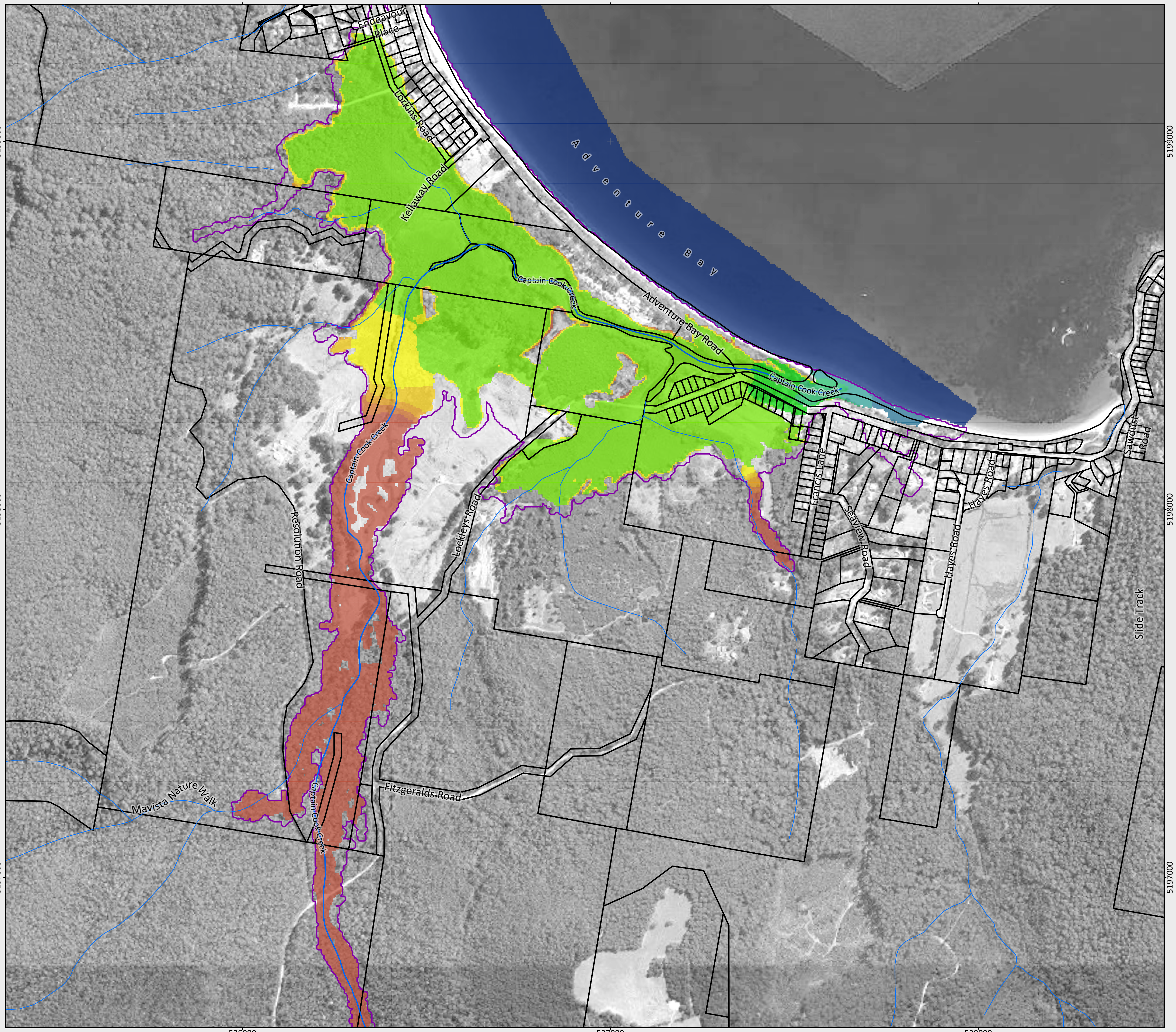

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Figure 3.
Captain Cook Creek Flood level for 2020 1% AEP with 1 m tailwater

Flood Level (m AHD)

- ≤ 1.25
- 1.25 - 1.50
- 1.50 - 1.75
- 1.75 - 2.00
- 2.00 - 2.25
- 2.25 - 2.50
- 2.50 - 2.75
- 2.75 - 3.00
- 3.00 - 3.25
- 3.25 - 3.50
- > 3.50

- Watercourse
- Property boundary
- Flood extent for 2100 1% AEP with 3 m tailwater

Data Acknowledgement

Base data is from TheLIST © State of Tasmania

Notes

To be read in conjunction with the Captain Cook Creek Flood Study - Inundation Risk Modelling and Mapping report.

Peak flood conditions have been derived by calculating the envelope of maximum values across a range of storm durations, with subsequent filtering by applying the following criteria:
- Minimum flood depth
- Minimum flood hazard
- Minimum ponded area

0 100 200 300 400 metres

Coordinate System: GDA 1994 MGA Zone 55
Scale 1:10,000 A3 paper size

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Figure 4.
Captain Cook Creek Flood hazard for 2020 1% AEP with 1 m tailwater

Flood Hazard Categories

- **H1** Generally safe for people, vehicles and buildings.
- **H2** Unsafe for small vehicles.
- **H3** Unsafe for vehicles, children and the elderly.
- **H4** Unsafe for vehicles and people.
- **H5** Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
- **H6** Unsafe for vehicles and people. All building types considered vulnerable to failure.

Property boundary

Flood extent for 2100 1% AEP with 3 m tailwater

Data Acknowledgement

Base data is from TheLIST © State of Tasmania

Notes

To be read in conjunction with the Captain Cook Creek Flood Study - Inundation Risk Modelling and Mapping report.

Peak flood conditions have been derived by calculating the envelope of maximum values across a range of storm durations, with subsequent filtering by applying the following criteria:
- Minimum flood depth
- Minimum flood hazard
- Minimum ponded area

0 100 200 300 400 metres

Coordinate System: GDA 1994 MGA Zone 55
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Figure 5.
Captain Cook Creek Flood depth for 2050 1% AEP with 2 m tailwater

Flood Depth (m)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- >2
- Property boundary
- Flood extent for 2100 1% AEP with 3 m tailwater

Data Acknowledgement

Base data is from TheLIST © State of Tasmania

Notes

To be read in conjunction with the Captain Cook Creek Flood Study - Inundation Risk Modelling and Mapping report.

Peak flood conditions have been derived by calculating the envelope of maximum values across a range of storm durations, with subsequent filtering by applying the following criteria:
- Minimum flood depth
- Minimum flood hazard
- Minimum ponded area

0 100 200 300 400 metres

Coordinate System: GDA 1994 MGA Zone 55
Scale 1:10,000 A3 paper size

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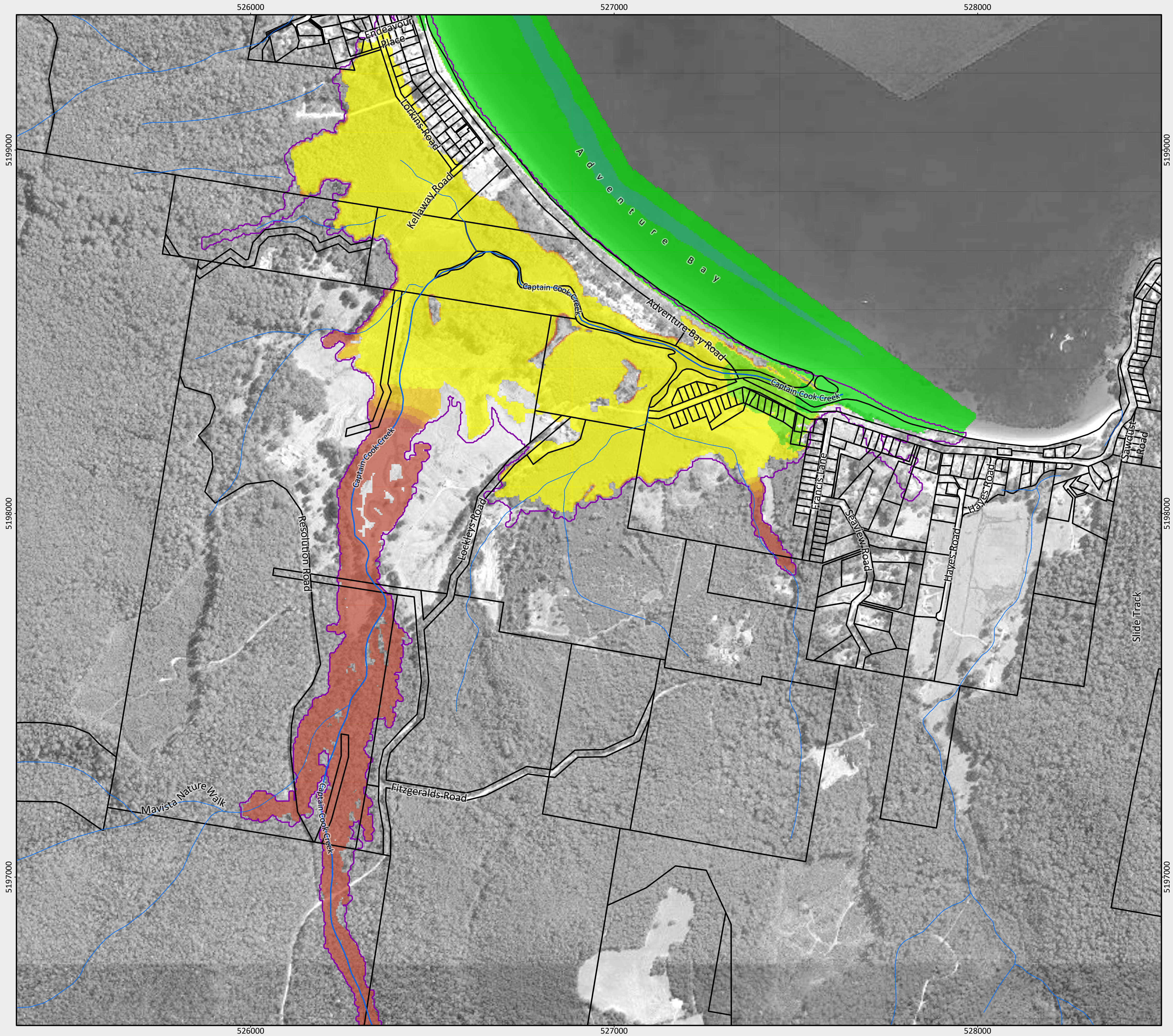

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Figure 6.
Captain Cook Creek Flood level for 2050 1% AEP with 2 m tailwater

Flood Level (m AHD)

- ≤ 1.25
- 1.25 - 1.50
- 1.50 - 1.75
- 1.75 - 2.00
- 2.00 - 2.25
- 2.25 - 2.50
- 2.50 - 2.75
- 2.75 - 3.00
- 3.00 - 3.25
- 3.25 - 3.50
- > 3.50

- Watercourse
- Property boundary
- Flood extent for 2100 1% AEP with 3 m tailwater

Data Acknowledgement

Base data is from TheLIST © State of Tasmania

Notes

To be read in conjunction with the Captain Cook Creek Flood Study - Inundation Risk Modelling and Mapping report.

Peak flood conditions have been derived by calculating the envelope of maximum values across a range of storm durations, with subsequent filtering by applying the following criteria:
- Minimum flood depth
- Minimum flood hazard
- Minimum ponded area

0 100 200 300 400 metres

Coordinate System: GDA 1994 MGA Zone 55
Scale 1:10,000 A3 paper size

Locality

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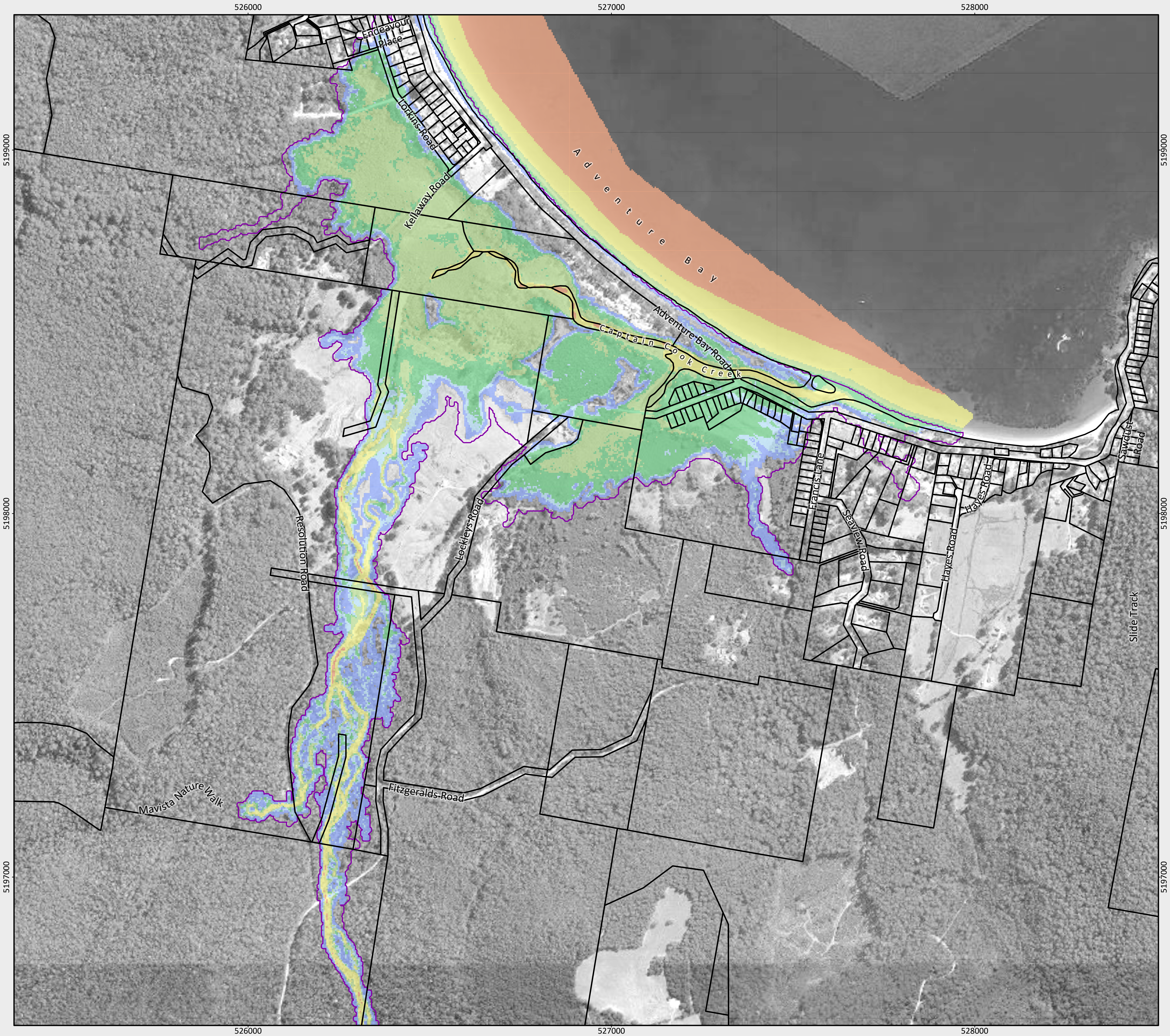

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Title

Figure 7.
Captain Cook Creek Flood hazard for 2050 1% AEP with 2 m tailwater

Flood Hazard Categories

- **H1** Generally safe for people, vehicles and buildings.
- **H2** Unsafe for small vehicles.
- **H3** Unsafe for vehicles, children and the elderly.
- **H4** Unsafe for vehicles and people.
- **H5** Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
- **H6** Unsafe for vehicles and people. All building types considered vulnerable to failure.

Property boundary

Flood extent for 2100 1% AEP with 3 m tailwater

Data Acknowledgement

Base data is from TheLIST © State of Tasmania

Notes

To be read in conjunction with the Captain Cook Creek Flood Study - Inundation Risk Modelling and Mapping report.

Peak flood conditions have been derived by calculating the envelope of maximum values across a range of storm durations, with subsequent filtering by applying the following criteria:
- Minimum flood depth
- Minimum flood hazard
- Minimum ponded area

N
0 100 200 300 400 metres

Coordinate System: GDA 1994 MGA Zone 55
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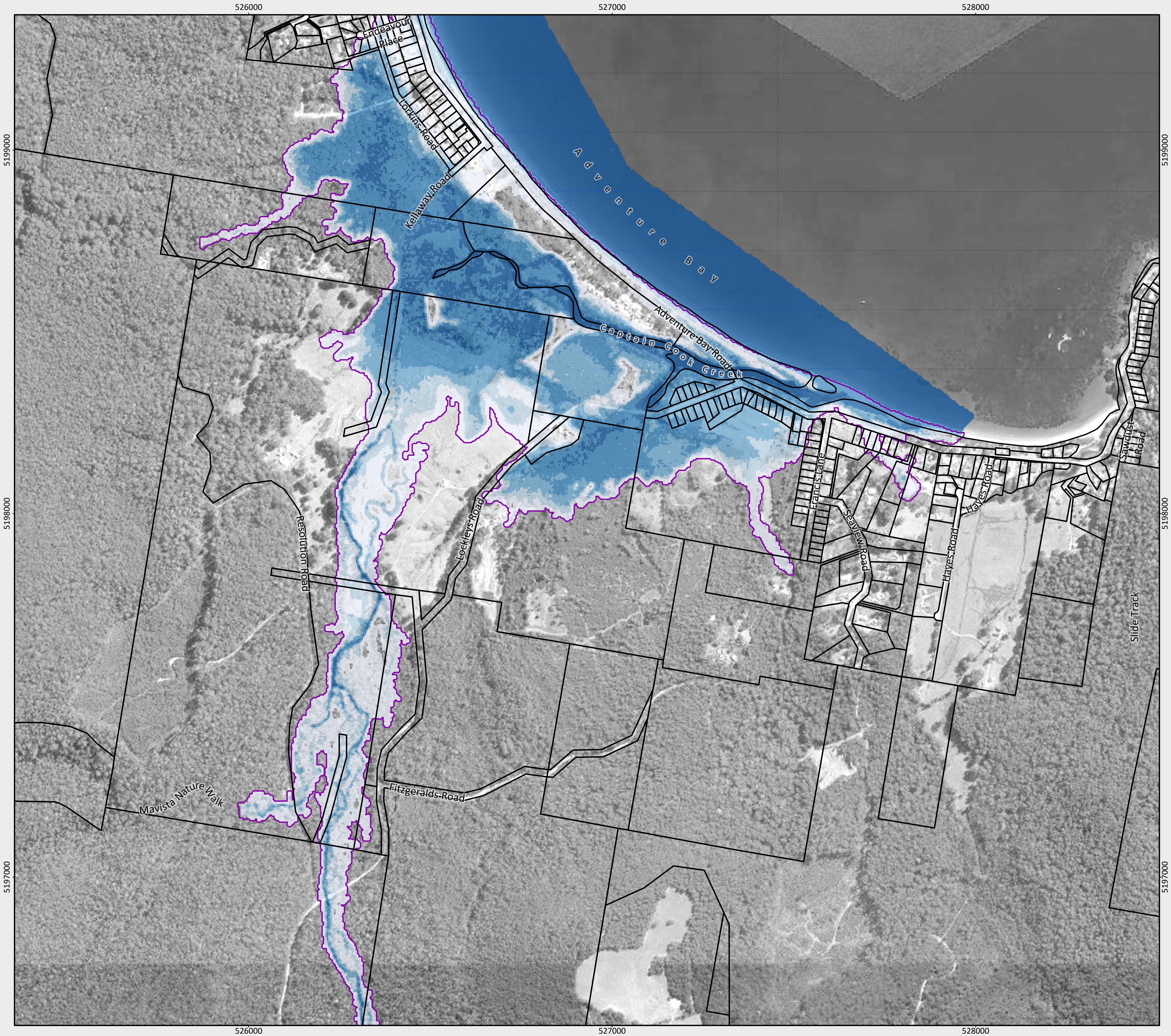

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Figure 8.
Captain Cook Creek Flood depth for 2100 1% AEP with 3 m tailwater

Flood Depth (m)

- ≤ 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- >2

- Property boundary
- Flood extent for 2100 1% AEP with 3 m tailwater

Data Acknowledgement

Base data is from TheLIST © State of Tasmania

Notes

To be read in conjunction with the Captain Cook Creek Flood Study - Inundation Risk Modelling and Mapping report.

Peak flood conditions have been derived by calculating the envelope of maximum values across a range of storm durations, with subsequent filtering by applying the following criteria:
- Minimum flood depth
- Minimum flood hazard
- Minimum ponded area

0 100 200 300 400 metres

N

Coordinate System: GDA 1994 MGA Zone 55
Scale 1:10,000 A3 paper size

Locality

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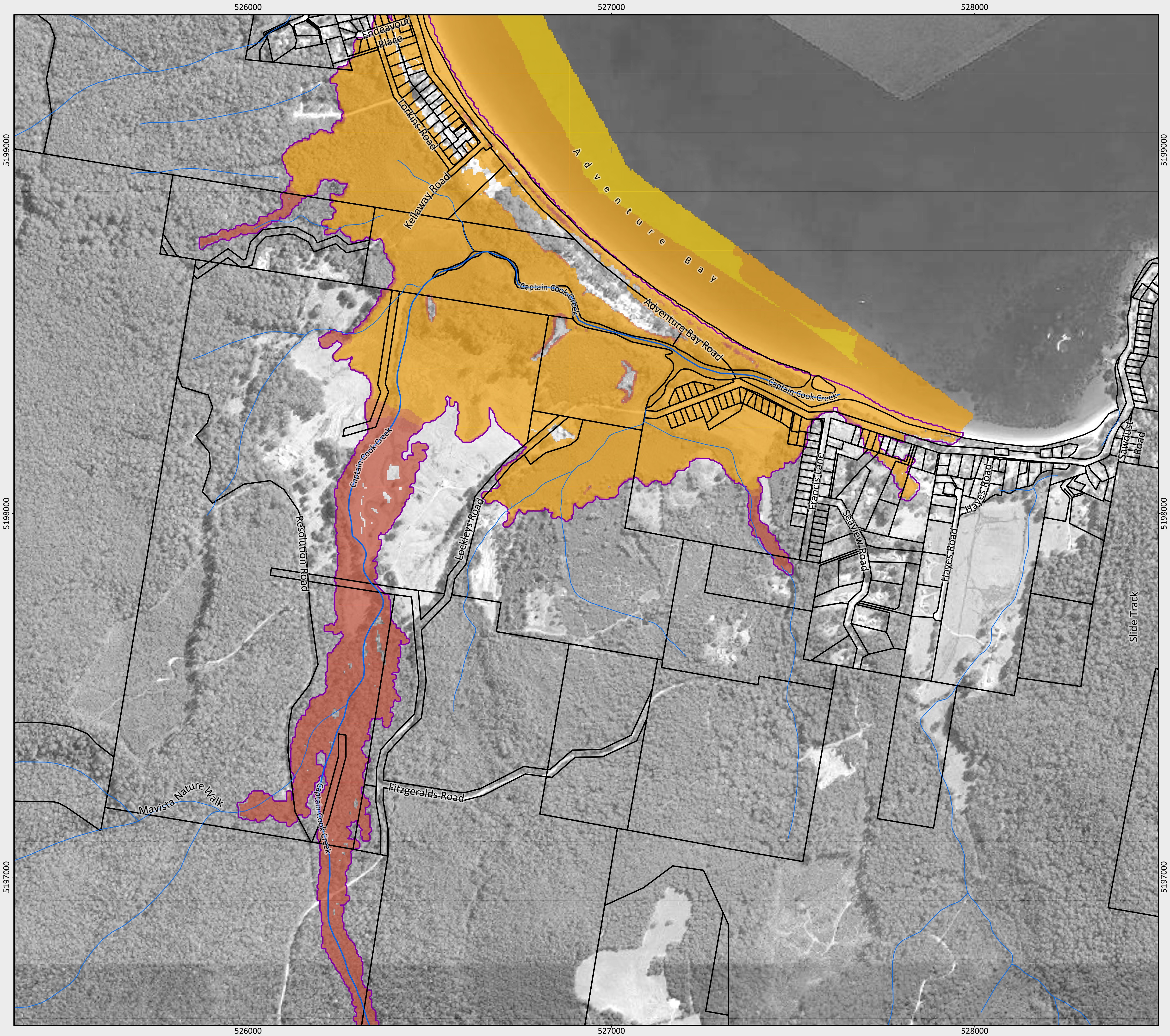

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Figure 9.
Captain Cook Creek Flood level for 2100 1% AEP with 3 m tailwater

Flood Level (m AHD)

- ≤ 1.25
- 1.25 - 1.50
- 1.50 - 1.75
- 1.75 - 2.00
- 2.00 - 2.25
- 2.25 - 2.50
- 2.50 - 2.75
- 2.75 - 3.00
- 3.00 - 3.25
- 3.25 - 3.50
- > 3.50

- Watercourse
- Property boundary
- Flood extent for 2100 1% AEP with 3 m tailwater

Data Acknowledgement

Notes

To be read in conjunction with the Captain Cook Creek Flood Study - Inundation Risk Modelling and Mapping report.

Peak flood conditions have been derived by calculating the envelope of maximum values across a range of storm durations, with subsequent filtering by applying the following criteria:
- Minimum flood depth
- Minimum flood hazard
- Minimum ponded area

0 100 200 300 400 metres

Coordinate System: GDA 1994 MGA Zone 55
Scale 1:10,000 A3 paper size

Locality

entura

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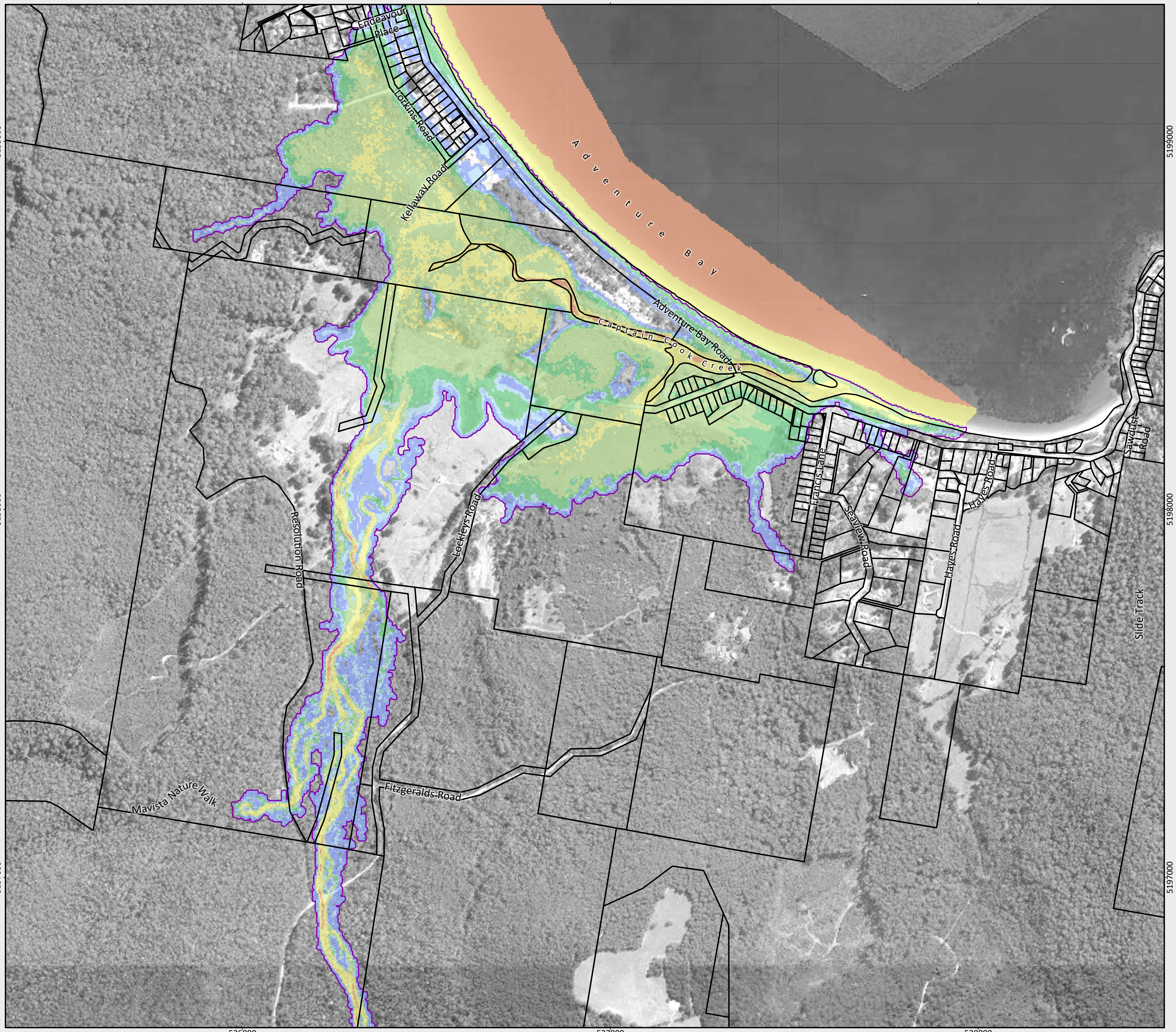
Plot date: 11 Feb 2020

Doc path: P:\Project\ConsultDM\E307xxx\E3076xx\E307686\P515370\GIS\CaptainCook\CaptainCook.aprx



Project number E307686 - P515370

Document title Captain Cook Creek Flood Study Inundation Risk Modelling and Mapping

Title

Figure 10.
Captain Cook Creek Flood hazard for 2100 1% AEP with 3 m tailwater

Flood Hazard Categories

- **H1** Generally safe for people, vehicles and buildings.
- **H2** Unsafe for small vehicles.
- **H3** Unsafe for vehicles, children and the elderly.
- **H4** Unsafe for vehicles and people.
- **H5** Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
- **H6** Unsafe for vehicles and people. All building types considered vulnerable to failure.
- Property boundary
- Flood extent for 2100 1% AEP with 3 m tailwater

Data Acknowledgement

Base data is from TheLIST © State of Tasmania

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