STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP
EMU RIVER CATCHMENT MODEL CALIBRATION

REPORT

MARCH 2023

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Project Tasmanian Strategic Flood Map Emu River Catchment Model Calibration	Project Number 120038
Client STATE EMERGENCY SERVICE	**Client's Representative** Chris Irvine
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Revision History

Revision	Description	Distribution	Authors	Reviewed by	Verified by	Date
0	Draft report for review	Luke Roberts, SES	Sarah Blundy, Daniel Wood, Evmen Wong	Fiona Ling	Mark Babister	DEC 21
1	Updated in response to review comments	Luke Roberts, SES	Sarah Blundy, Daniel Wood, Evmen Wong	Fiona Ling	Mark Babister	DEC 21
2	Report with minor revisions	Chris Irvine, SES	Sarah Blundy, Daniel Wood, Evmen Wong	Fiona Ling	Mark Babister	MAR 23

Cover image: river road rail bridge in June 2016 floods

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ALS	Airborne Laser Scanning
AMS	Annual Maximum Series
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff
ATP	Areal Temporal Patterns
AWAP	Australian Water Availability Project
AWS	Automatic Weather Station
Bureau/BoM	Bureau of Meteorology
C	Lag parameter in WBNM
CFEV	Conservation of Freshwater Ecosystem Values (DPIPWE)
CL	Continuing Loss
DEM	Digital Elevation Model
DPIPWE	Department of Primary Industries, Water and Environment
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
FFA	Flood Frequency Analysis
FLIKE	Software for flood frequency analysis
FSL	Full Supply Level
GIS	Geographic Information System
GEV	Generalised Extreme Value distribution
GPS	Global Positioning System
HSA	Human Settlement Area
ICM	Infoworks ICM software (Innovyze)
IDW	Inverse Distance Weighting
IL	Initial Loss
IFD	Intensity, Frequency and Duration (Rainfall)
LiDAR	Light Detection and Ranging
mAHD	meters above Australian Height Datum
PERN	Catchment routing parameter in RAFTS
Pluvi	Pluviograph – Rain gauge with ability to record rain in real time
QAQC	Quality assurance and quality control
R	Channel routing parameter in WMAWater RAFTS WBNM hybrid model
RAF	Rafts Adjustment Factor; sub-catchment calibration parameter in ICM
RAFTS	hydrologic model
SCE	Shuffled Complex Evolution
SES	State Emergency Service
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydrodynamic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

1. INTRODUCTION

Flooding occurs regularly throughout Tasmania; the Bureau of Meteorology describes numerous major flood events that have occurred since the early 1800s. Following the 2016 Tasmanian floods, the need for state and local governments, communities, and emergency response agencies to better understand flooding in Tasmania was identified. Improved flood intelligence would allow for targeted and appropriate investment in flood recovery and increased community resilience to future flood events. The Independent Review into the Tasmanian Floods of June and July 2016 found that there were gaps in flood studies and flood plans over Tasmania, both in comprehensiveness and currency.

The objectives of the Tasmanian Strategic Flood Mapping Project are to assist flood affected communities to recover from the 2016 floods through a better understanding of flood behaviour, and to increase the resilience of Tasmanian communities to future flood events. The targeted outcomes of the project are that post-flood recovery will be informed by up-to-date flood risk information, ownership of flood risk is appropriately allocated, flood risk can be included in investment decisions, and responsibility for flood mitigation costs can be appropriately allocated.

The Tasmanian Flood Mapping Project aims to address the objectives and outcomes by:

- providing communities with access to a high resolution digital terrain model that can be used for flood modelling, through collection of LiDAR data over Tasmania
- developing state-wide Strategic Flood Maps to support flood risk assessment and post event analysis and
- partnering with Local Government to deliver detailed flood studies and evacuation planning for communities with highest flood risk that do not have a current flood study.

This project addresses the second component of the Tasmanian Flood Mapping Project, the development of state-wide Strategic Flood Maps.

This report describes the calibration of hydrologic and hydrodynamic flood models for the Emu River study area.

2. STUDY AREA

The Emu study area is located in the north-west of Tasmania. The study area includes the Cam River, Emu River and Blythe River, as well as smaller creeks including Cooee Creek, Chasm Creek, Heybridge Rivulet, Sulphur Creek, and Penguin Creek. The Emu study area has an area of 916 km^2. The rivers flow in a generally north easterly direction and discharge into Bass Straight. The largest towns in the Emu study area are Burnie and Penguin.

The Emu River rises at St Valentines Peak and discharges into Emu Bay at Burnie. The majority of the upper catchment is forested, with agricultural areas lower in the catchment. Major tributaries of the Emu River include the Pet River and Guide River. Both of these major tributaries are dammed and the Pet and Guide reservoirs are operated by TasWater for the purpose of water supply.

Another dam in the catchment, South Riana Dam, is operated by Tasmanian Irrigation as part of the Dial Blythe Irrigation Scheme. The dam is filled via both natural inflows from a small creek and pumping from the Blythe River. The scheme supports production of potatoes, vegetables, poppies, berries, and pasture for livestock finishing and dairy.

The area was significantly impacted by the June 2016 floods. River Road in Wivenhoe was inundated by the Emu River. Logs and tree debris were carried down the river and built up behind the railway bridge in this area, blocking the mouth of the river. Penguin was also impacted by the 2016 floods, as Penguin Creek flooded into Hiscutt Park and surrounding areas.

The Emu River study area is shown in Figure 1 and land use over the study area is shown in Figure 2.

3. AVAILABLE DATA

3.1. Historic Flow Data and Level Data

There are seven flow gauges with data available in the Emu River study area, as shown in Table 1. These gauges are owned by DPIPWE, Tasmanian Irrigation and Tas Water, the timeseries supplied for this project were downloaded by SES from DPIPWE's data portal (DPIPWE 2020), and ratings and gaugings were sourced directly from DPIPWE for some sites. Some of the sites gauge only small creeks, such as Chasm Creek and Sulphur Creek. The gauge on the Emu River was located on the upper reaches of the river and closed in 1996. There was a gap in the data at this gauge which included the 1970 event.

Table 1: Flow gauges

Gauge attribute	CAM RIVER U/S SOMERSET WS	CHASM CREEK U/S BASS HIGHWAY	SULPHUR CREEK 1.5KM U/S MOUTH	PET RIVER U/S BURNIE WS	SOUTH RIANA DAM INFLOW	BLYTHE RIVER US SOUTH RIANA RD BR	EMU RIVER D/S COMPANION
Gauge number	14212-1	14261-1	14206-1	14203-1	14266-1	14264-1	14219-1
Gauge abbreviated name	Cam River gauge	Chasm Creek gauge	Sulphur Creek gauge	Pet River gauge	South Riana Dam inflow	Blythe US South Riana	Emu DS Companion
Start date	20/03/1968	20/06/2008	23/01/1964	28/11/1963	12/10/2015	24/03/2015	31/08/1967
End date	current	current	current	19/06/1995	current	current	16/04/1996
Latitude	-41.057	-41.068	-41.105	-41.172	-41.228	-41.236	-41.306
Longitude	145.837	145.963	146.029	145.829	145.947	145.930	145.742
Rating quality	Poor to fair. Rating extended with hydraulic modelling	Poor to fair	Poor to fair	Not known	Not known	Not known	Not known
Used for calibration	Yes	No	No	No	No	Yes	No
Used for FFA	Yes	No	No	Yes	No	No	Yes
Catchment area (km^2)	225	21	23	11	5.3	166	25
Assumed local datum 0m in AHD	4.6	6.3	32.0	n/a	n/a	260.0	n/a
Highest gauging (m local datum)	3.0	0.5	0.5	0.4	Not known	Not known	Not known
Highest recorded stage height (m local datum)	6	1.5	0.7	1.3	0.1	5.9	1.5
Highest recorded flow (m^3/s)	171	6	5	21	2	182	22
Highest recorded flow date	14/01/2011	14/01/2011	14/01/2011	28/04/1974	08/10/2020	6/06/2016	28/04/1974

3.1.1. Calibration Event Data Availability

Significant flows were recorded in the Emu study area for 3 of the 13 flood events selected by the Bureau as calibration events for this project (Table 2). The 1970 event has not been used in calibration as there was only sparse rainfall data available for this event and the AEP of the event was only between around 10% and 20% at the flow gauges that were operational at this time.

An investigation of the flow records, water licences and imagery in the catchments of Sulphur Creek and Chasm Creek gauges found that there are many extractions from the creeks as well as small instream dams upstream of these gauges, that impact on the flows. Licenced extractions from the creeks can be taken only when flows in the creeks are above a given threshold. These extractions and small dams are not modelled in detail for this regional flood model and therefore the data at these gauges was found to be of very limited value for model calibration. Flow data during large events was quality coded by DPIPWE as “estimated” or “unknown” at both gauges. Given this, these gauges were not used in model calibration.

The January 2011 event was the largest on record at all gauges that were operating during the event and had an AEP between 1% and 5% at the Cam River gauge.

The 2016 event was the largest event on record at the Blythe u/s South Riana gauge, however the quality is coded as “unknown”. The Cam River gauge was damaged in the 2016 flood and ceased recording on the rising limb of the event, however it had almost reached the flow of the January 2011 by this time so would have been the largest on record here if the hydrograph was fully recorded. The South Riana Dam inflow gauge has no data for the peak of the 2016 event.

Table 2: Summary of the largest events in the Emu study area, selected from the 13 calibration events supplied for the project

Event name	Used in calibration	Event peak flow (m^3/s) (location)
1970_Aug	No	93 (Cam River gauge)
	No	6 (Pet River gauge)
	No	4 (Sulphur Creek gauge)
2011_Jan	Yes	171 (Cam River gauge)
	No	6 (Chasm Creek gauge)
	No	6 (Sulphur Creek gauge)
2016_Jun	Yes	182 (Blythe US South Riana)
	No	Gauge damaged on rising limb at ~170 (Cam River gauge)
	No	4 (Chasm Creek Gauge)
	No	Unknown - recording cut off at 1 (South Riana Dam inflow)
	No	2 (Sulphur Creek gauge)

3.1.2. Rating Curve Quality

Cam River u/s Somerset WS has limited gaugings within the channel. The rating curve is extrapolated to high flows. The rating at this site was extended using a local hydraulic model (WMAwater 2021c). There was a clear shift in the rating after this gauge was reinstated following damage to the gauge in the June 2016 floods (Diagram 1). The rating prior to June 2016 was fitted through the lower set of gaugings highlighted in yellow in Diagram 1, however this rating curve was not provided by DPIPWE. The extended rating is based on the current gauge datum and is therefore only applicable for the period post June 2016. The original flows provided from the DPIPWE database were therefore used for the 2011 calibration event. These use the DPIPWE rating which was extrapolated to high flows, and has a very high degree of uncertainty.

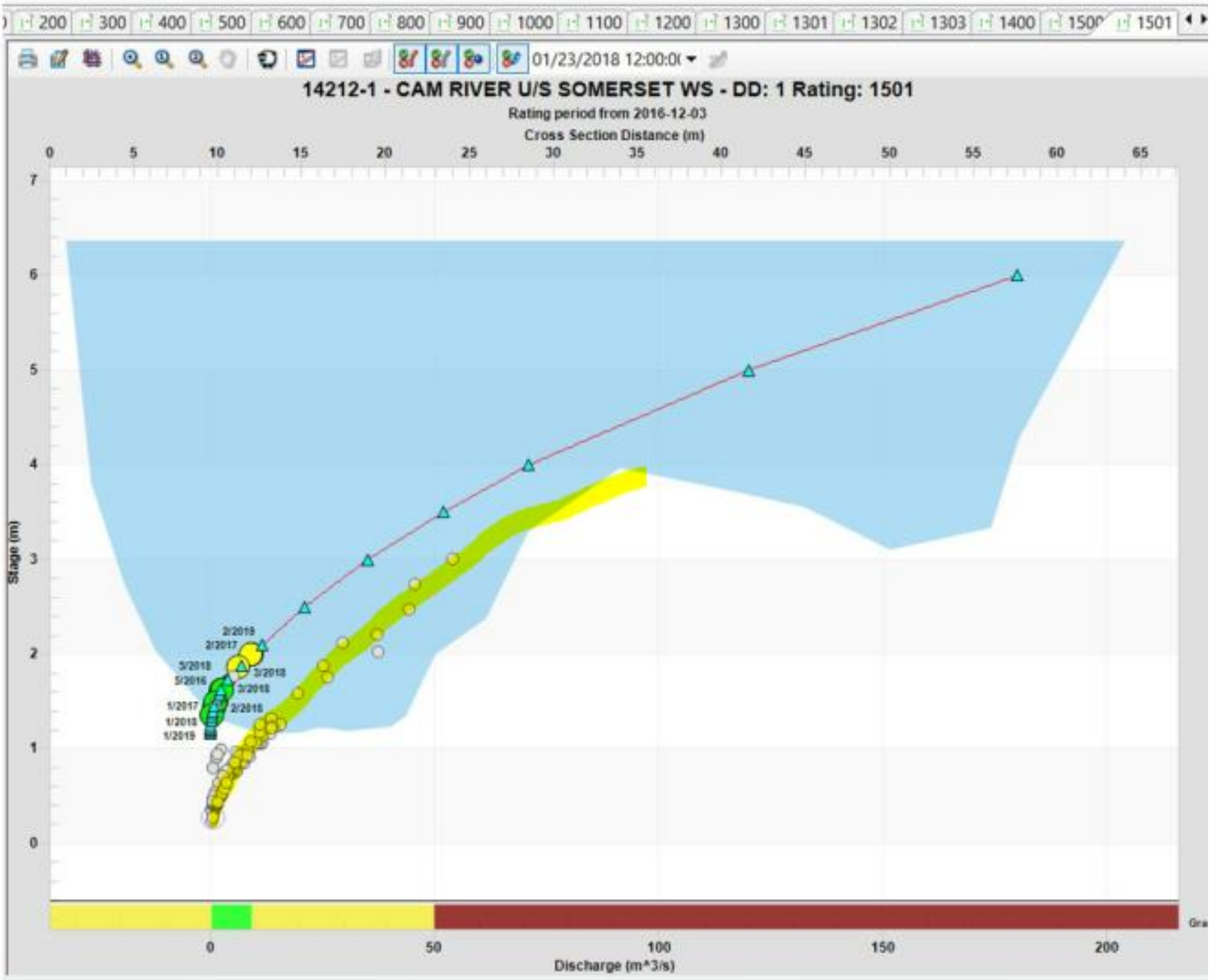

Diagram 1: Cam River u/s Somerset WS gaugings and rating. Current rating (post June 2016) shown as red line. Gaugings prior to June 2016 highlighted in yellow.

Chasm Creek u/s Bass Highway gauge has only low flow gaugings and the rating is extrapolated to higher flows. Data for high flow events is quality coded by DPIPWE as “unknown”. Sulphur Creek 1.5km u/s mouth has only low flow gaugings and the rating is extrapolated to higher flows. The ratings for all other gauges were not available.

3.2. Historic Rainfall Data

Rainfall data was provided by Bureau of Meteorology as part of the initial project data. The data provided included sub-daily rainfall timeseries data from four different sources: Automatic Weather

Station (AWS) data, pluvio data, rolling accumulated rainfall from the Bureau's flood warning network, and 10 minutely accumulation from the Bureau's flood warning network. The datasets were in different formats and required processing to a common format before they could be used to produce rainfall inputs to the model. Rainfall data was provided for 13 events identified by the Bureau of Meteorology for use as calibration events for this project, although not all 13 events have data available or were significant events in the Emu study area (see Data Review Report WMAwater (2020a) for details on calibration events).

The AWS and pluvio data were found to be more consistently reliable. Where multiple data sources were available at the same site, AWS or pluvio data were prioritised for use over the event or accum data. Data that was recorded less frequently than at 3 hour intervals was excluded from the analysis.

There are five sub-daily rain gauges within the Emu study area, however there was only one gauge operating for January 2011 event and none for June 2016 event. Sub-daily gauges in surrounding areas were also used to inform temporal patterns for events. The gauges in and around the Emu study area, are shown in Figure 1 and Table 3.

Table 3: Available Rainfall Information for selected calibration events

Statistic	Jan 2011	Jun 2016
Number of Sub-daily stations available within the study area	1	0
Number of daily stations available within the study area*	6	5
Number of subdaily surrounding gauges ~15km	1	1
Number of daily surrounding gauges ~15km	3	3
Rainfall Totals within study area	160-300 mm	140-310 mm
Approximate duration of rainfall event	48	36

*The number of daily gauges does not include daily gauges co-located with an active sub-daily gauge

The daily and sub-daily rain gauge data were used to create rainfall surfaces for the 2011 and 2016 calibration events using an inverse distance weighting method. The method is described in detail in WMAwater (2021a) and is summarised below.

1. Daily rainfall data from all gauges within Tasmania was extracted for each of the seven calibration events from 2007 – 2018
2. Rudimentary QAQC and infilling of daily record was undertaken
3. Daily rainfall surfaces for each event were fitted using all daily and available pluviograph data, using Inverse Distance Weighting (IDW)
4. Sub-catchment rainfall depths were calculated from all grid cells within the sub-catchment using areal weighted averages
5. Daily data in each sub-catchment was disaggregated using the temporal pattern from gauge assigned using Thiessen polygon method.

There are steep rainfall gradients across the catchment for both events with coastal gauges in the region receiving between 100 and 150mm and inland gauges receiving up to 350mm in both events. The rainfall surfaces for the selected calibration events are shown in Figure 3 to Figure 4.

3.3. Dam Information

There are three significant dams in the Emu study area. South Riana Dam is owned by Tasmanian Irrigation, and Pet and Guide Reservoirs are owned by TasWater. Details are shown in Table 4.

Table 4: Dam information

Name	Storage Volume (ML)	Full Supply Level (mAHD)	Crest Length (m)	Spillway Width (m)
South Riana Dam	4100	302.0 (assumed)	260	16.7
Pet Reservoir	4320	267.4	360	24.4
Guide Reservoir	1800	393.2	130	8.0

4. METHODOLOGY OVERVIEW

The hydrological and hydrodynamic model calibration methodology has been outlined in the Hydrology Methods Report (WMAwater, 2021a) and the Hydrodynamic Methods Report (WMAwater 2021b). Details on the methods are only included in this report where they deviate from the methods described in these reports or are specific for this catchment.

The modelling method includes the following steps:

- Data preparation
  - Extraction and collation of rainfall data for identified calibration events
  - Gridding rainfall data across each catchment
  - Extraction of flow data for identified calibration events at each flow site, and assessment of suitability of this data for calibration
- Hydrologic modelling
  - Identification of flow gauge locations
  - Identification of dam and diversion locations
  - Sub-catchment delineation in GIS
  - Inclusion of dam storage and spillway ratings where required and available
  - Event calibration for routing and losses using automated external RAFTS modelling tool. Output event sub-catchment rainfalls, routing parameters and event losses for input to ICM model
  - Running event calibration through ICM RAFTS model to provide sub-catchment pickups for direct input into ICM hydrodynamic model
  - As required, revise hydrologic parameters within ICM-RAFTS to obtain good match to historic flood information provided
  - Once a good match is achieved, provide ICM-RAFTS modified hydrologic parameters back to the external hydrologic model to ensure consistency
  - As required, confirm the response between the external hydrologic model and ICM hydrodynamic model is consistent to enable design event analysis
- Hydrodynamic modelling in ICM
  - Importing base DEM
  - Setting roughness values, referencing calibrated PERN value from hydrologic model
  - Meshing
  - Incorporation of structures
  - Setting up rainfall inputs (depth and temporal pattern), losses and dam/diversion outflows from the hydrologic model
  - Calibration model runs
  - Compare model results with hydrologic model runs and calibration points
- Model iteration (if necessary)
  - Adjust routing parameters values in both external and ICM RAFTS hydrologic model if necessary, based on results of hydrodynamic model calibration
  - Rerun hydrologic models for calibration events
  - Set roughness values in hydrodynamic model
    Rerun hydrodynamic model for calibration events

5. HYDRODYNAMIC MODEL SETUP

5.1. Digital Elevation Model (DEM)

The base dataset that was used for the digital elevation model (DEM) of the hydrodynamic model was the SES state-wide 10 m DEM merged with 2 m DEM subsets at the gauges (where available). 2 m DEM subsets were available at six of the seven gauges in the study area, with the SES state-wide 10 m DEM used at the remaining gauge (Emu River d/s Companion). The merged DEM was then clipped to the study area with a buffer zone to ensure 100% active mesh area in the model. Where no terrain information was available in the tidal zones, a ground level of -10 mAHD was applied in GIS to the clipped DEM. The resulting DEM is shown in Diagram 2.

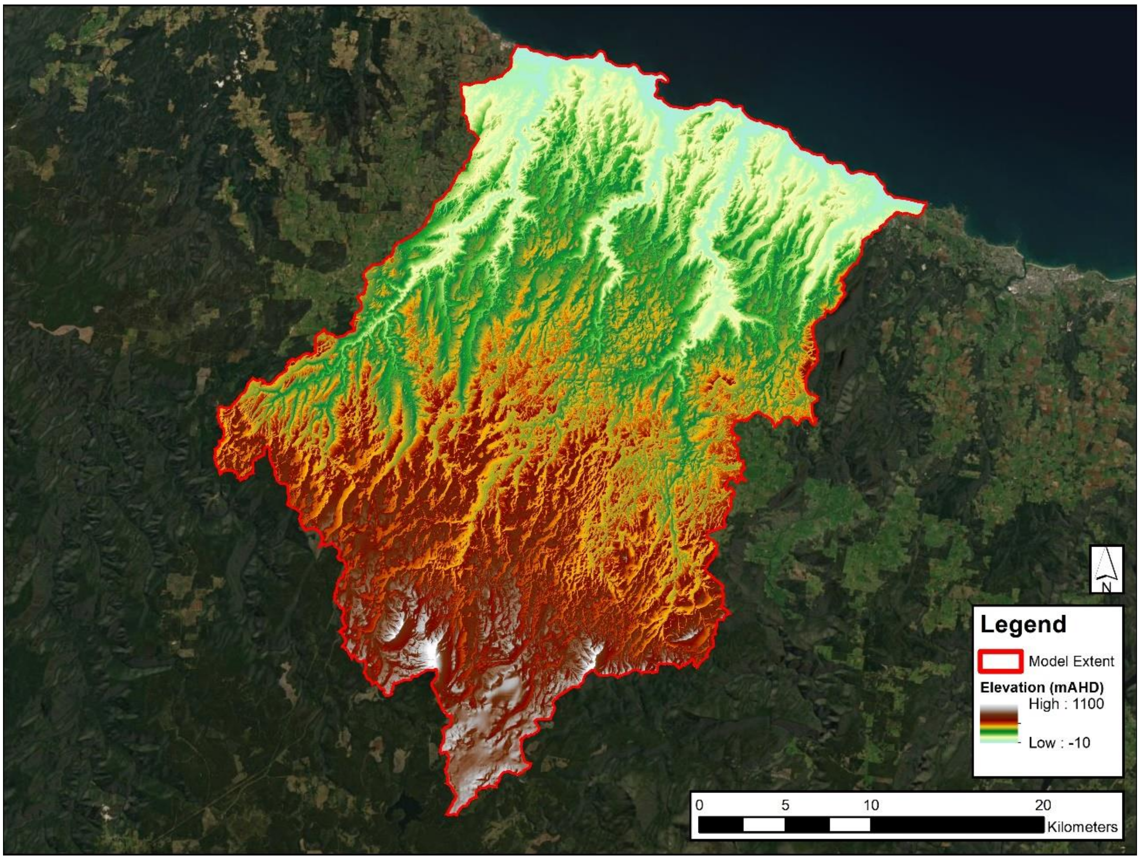

Diagram 2: DEM of the Emu study area

The SES state-wide 10 m DEM consists of a ‘Default DTM’ that is state-wide and a ‘LiDAR DTM’ that covers the areas where LiDAR data was available at the time. It is understood that the ‘Default DTM’ was constructed from primarily photogrammetric contour data, which is likely to be a poor representation of the true topography of the area.

Areas within the Emu study area that are covered by the ‘Default DTM’ include the very upper reaches of the Emu and Blythe Rivers as shown in Diagram 3.

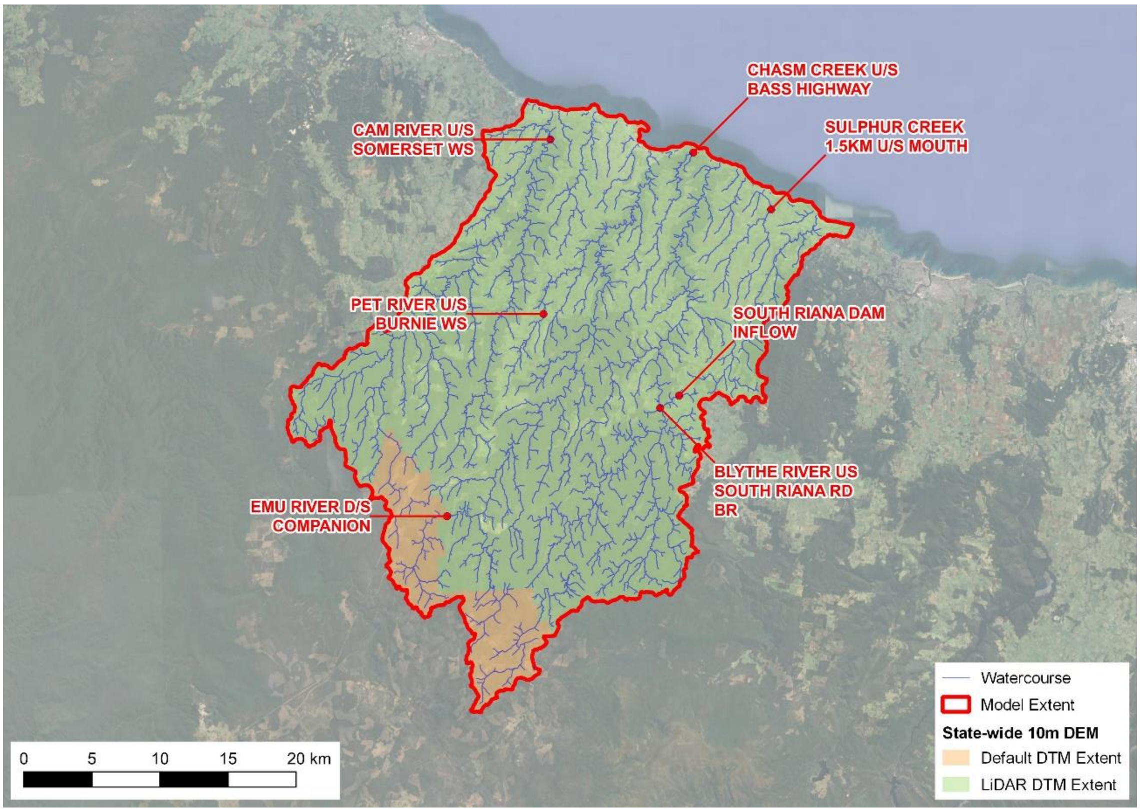

Diagram 3: ‘Default DTM’ extents for the Emu study area

During the calibration process, it was identified that some bespoke modifications to the DEM were required. Notably, this included modifications to the bathymetry near the mouth of Emu River to improve the match to the calibration flood marks in the area. In this location the DEM supplied did not incorporate the constriction formed by the beach spit.

5.2. Roughness

The base dataset that was used for the roughness of the hydrodynamic model was the SES state-wide roughness grid. This dataset was converted to a set of polygons for each land use and linked to a corresponding friction value (as detailed in the Hydrodynamic Modelling Methods Report). The polygons were then cleaned in GIS to ensure that the geometry was valid before being imported into the hydrodynamic model.

It is noted that, at this stage, the roughness values for streams vary greatly with sections of Manning’s n of 0.1 crossing streams in many locations. This issue is an artefact of the simplification of the roughness layer when it is converted into triangles. Where the issue was severe, a continuous zone of single roughness of 0.05 for all upper streams was utilised.

The resulting roughness layer is shown in Diagram 4.

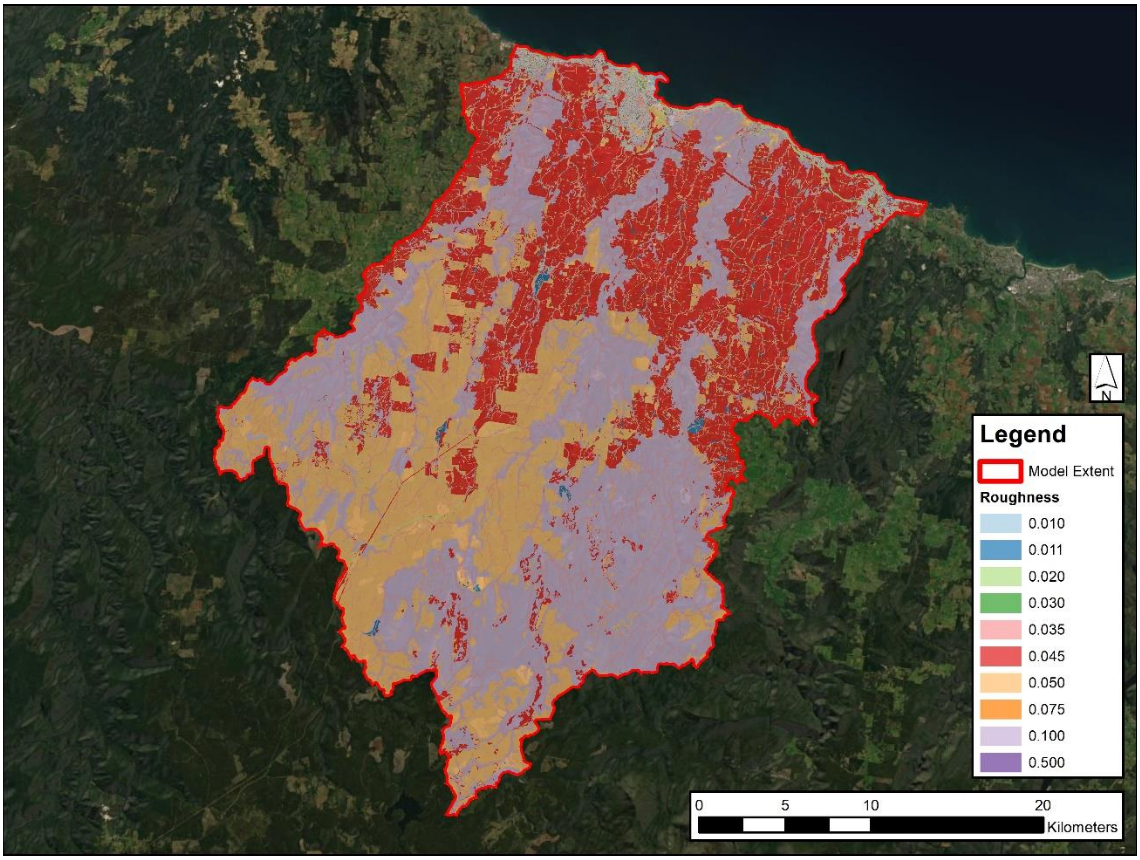

Diagram 4: Roughness layer for the Emu study area

5.3. Meshing

Meshing in the hydrodynamic model was undertaken using mesh zones, with the following rules:

- Base mesh zone – the default mesh size, set to a maximum of 2500 m^2 and a minimum of 400 m^2
- Stream mesh zones – set as an independent mesh zone with a maximum mesh size of 400 m^2 and a minimum of 100 m^2
- Upper stream mesh zones – streamlines of strahlar order 2-5 and strahlar order 6-8 were buffered by 10 m and 20 m either side of the centre line. These zones were then set to a maximum mesh size of 150 m^2 and a minimum of 100 m^2. This process was done to ensure that the meshing process did not result in artificial blocking of the flow paths along the upper streams.
- Human Settlement Areas and other areas of interest – set as an independent mesh zone with a maximum area of 100 m^2 and a minimum of 25 m^2

The resulting mesh zones are shown in Diagram 5.

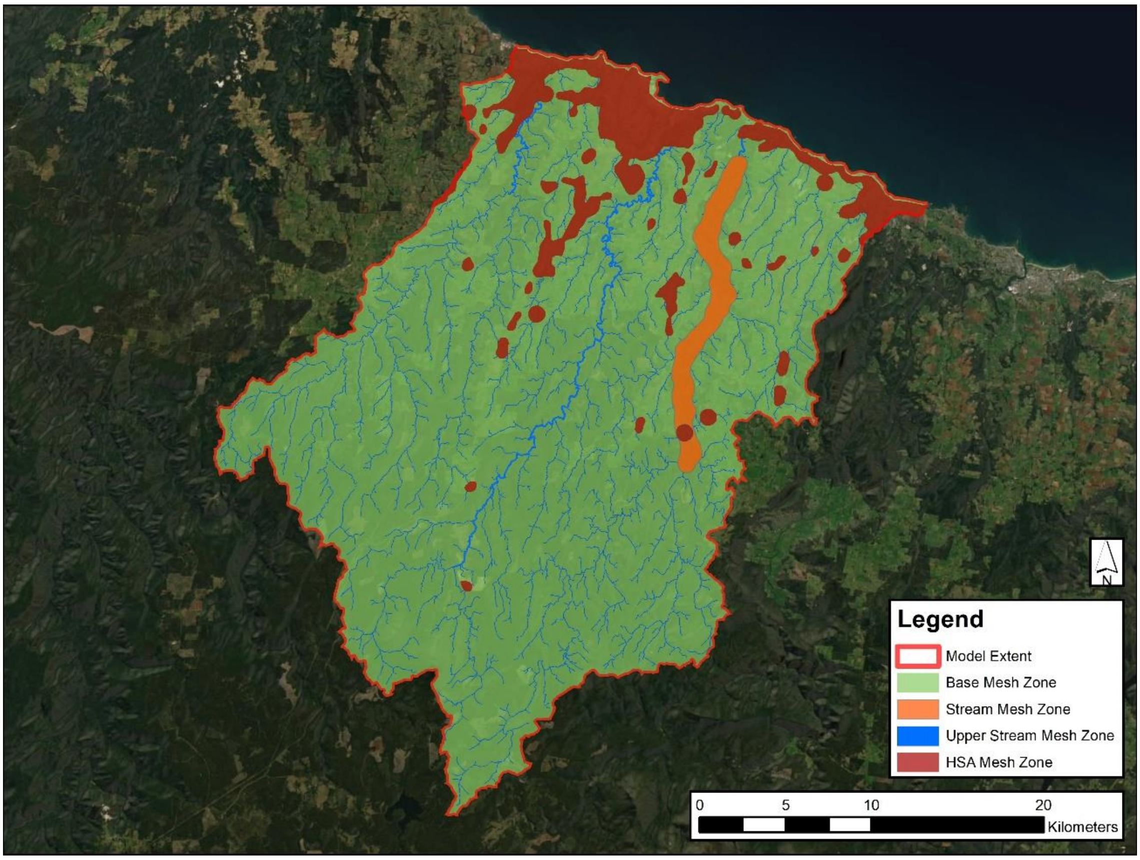

Diagram 5: Mesh zones for the Emu study area

5.4. Structures

Within the study area, six significant bridges were identified from the SES state-wide bridge database and these were modelled in the hydrodynamic model in the 2D domain using linear 2D bridge structures. Further discussion on this process is provided in the Hydrodynamic Modelling Methods Report.

The bridges modelled included:

- Bass Highway at Cam River
- Fern Glade Road at Emu River
- Pipeline at Emu River
- Railway at Emu River
- Bass Highway at Emu River
- Bass Highway and railway at Blythe River

Within the study area, three significant culverts were identified and were modelled in the hydrodynamic model in the 1D domain (linked to the 2D domain). As detailed drawings were not available at the time, the dimensions and inverts of the culverts were estimated from aerial and street imagery (where possible) and the DEM.

The details of the culverts are as follows:

- Bass Highway at Heybridge Rivulet – assumed to be a 1/2700x2700 RCBC

- Bass Highway at Sulphur Creek – assumed to be a 1/3300x3300 RCBC
- Bass Highway at Penguin Creek – assumed to be a 3/3600 RCP

Finally, a weir along Emu River (downstream of Fern Glade Road) was added to the 2D domain of the hydrodynamic model due to its proximity to a number of calibration flood marks. Data on this weir was not available, so the weir was modelled assuming a sharp-crested weir (based on available imagery), with the crest of the weir at an assumed level of 3.6 mAHD.

The resulting structures are shown in Diagram 6.

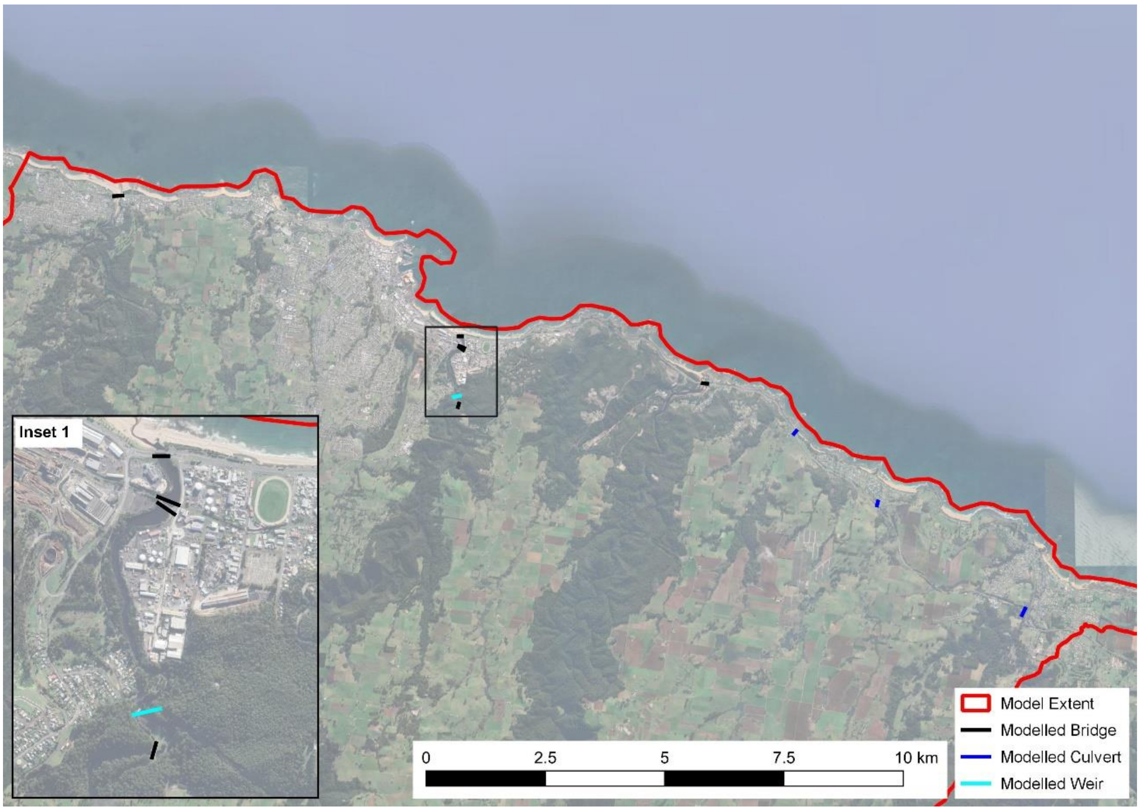

Diagram 6: Modelled structures in the Emu study area

5.5. Dams

The three significant dams in the study area were modelled in the hydrodynamic model in the 2D domain, assuming initial conditions at the full supply level of the dams. As detailed drawings were not available for this study, the dimensions of the spillways were estimated from available photography and the spillways were modelled assuming a broad-crested weir.

5.6. Downstream Boundaries

Downstream boundaries were applied at the base of the model to provide the interaction with the tidal zone. Given the proximity of the Emu study area to the Burnie Tide Gauge, real tide data was able to be extracted for this study area. This data was extracted at 60-minute time increments from the Bureau of Meteorology Australian Baseline Sea Level Monitoring Project Portal and was imported into the hydrodynamic model as a time varying boundary condition.

Diagram 7 shows an example of the tide data that was extracted for the June 2016 event.

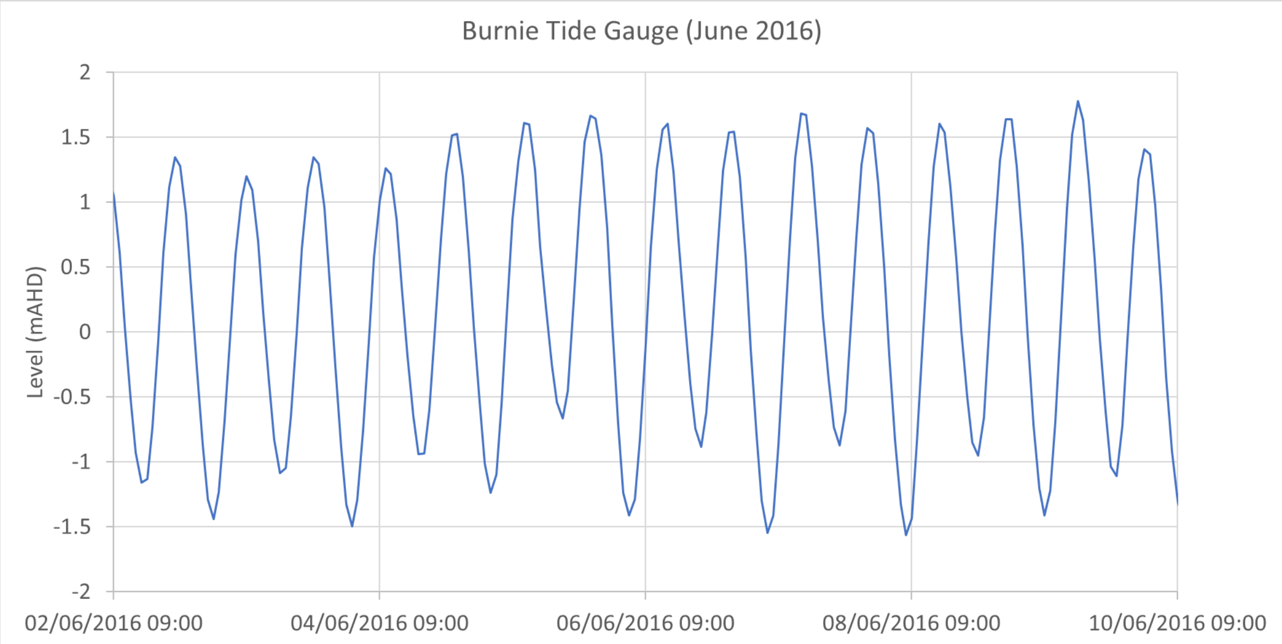

Diagram 7: Burnie Tide Gauge (June, 2016)

5.7. Flow Application for Hydrodynamic Modelling

Two approaches were used for application of flow in ICM:

- ICM-RAFTS sub-catchment routing, applied to each sub-catchment in the model at the downstream end of the sub-catchment
- Direct rainfall to model overland flow (short duration events).

The reason for using two approaches is to enable the model to be run efficiently for longer durations by limiting the number of cells wet, focusing on the major tributary flooding while also ensuring the local areas in the upper tributaries are mapped for short duration flooding.

The two flow scenarios sit within the same ICM hydrodynamic model as alternative flow condition scenarios (base and direct rainfall). For the calibration events, only the ICM-RAFTS approach is used, where the rainfall information is derived from rainfall files created by the hydrologic model.

For the design events, an envelope of the ICM-RAFTS approach and the design rainfall approach will be used. Rainfall and temporal pattern information derived from the ARR datahub will be used to establish the design rainfall and temporal pattern information for the ICM-RAFTS approach and a synthetic, duration independent storm will be used to assess a range of storm durations and temporal patterns in a singular rainfall event for the design rainfall approach.

5.7.1. ICM-RAFTS Sub-catchment Routing

For the ICM-RAFTS sub-catchment routing, the RAFTS model within ICM was used to calculate the hydrologic routing at each sub-catchment. Rainfalls, model information and model parameters developed through the external hydrologic model were imported into ICM through the open data input tool.

The information imported into ICM included:

- Sub-catchment name
- Slope
- PERN
- RAF
- Initial and Continuing Loss
- Sub-catchment rainfalls (for calibration events)

Each sub-catchment is connected directly to the 2D mesh surface at the downstream end of the catchment. The resulting RAFTS sub-catchment model setup is shown in Diagram 8. Figure A 1 and Figure A 2 show the hydrological soil groups used to distribute the CL and the average PERN used for each sub-catchment.

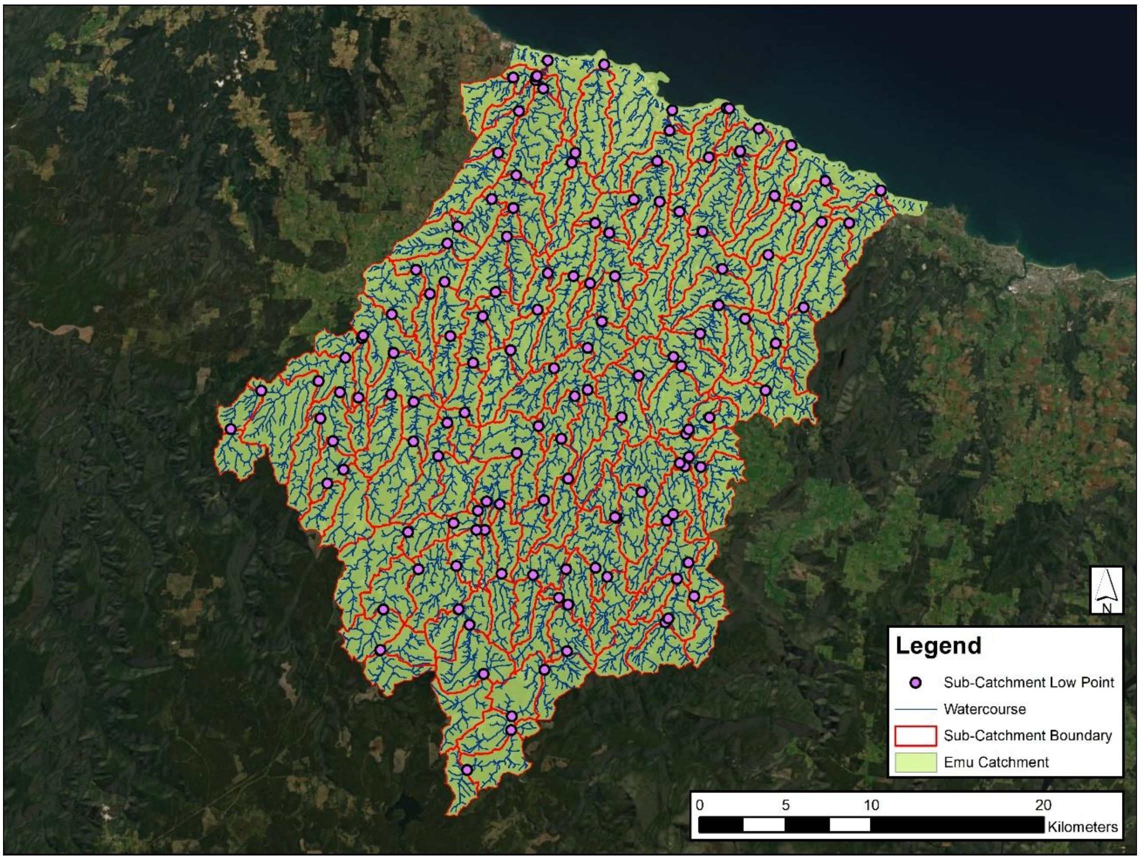

Diagram 8: RAFTS sub-catchment model setup for the Emu study area

6. CALIBRATION RESULTS

6.1. Sub-catchment Routing and Loss Parameters

The ICM model was run with the routing and loss parameters derived from the external hydrologic model and the calibration process was undertaken for each calibration event. A spatially varying sub-catchment routing parameter was not found to be necessary to achieve a reasonable calibration to the locations of interest and a single sub-catchment routing parameter was used (RAF of 2.5).

A RAF of 2.5 was assumed based on initial model runs which indicated that the routing within the sub-catchment component of the model was faster than the recorded catchment responses. Noting the presence of several large waterfalls and other significant grade variations in the catchment, it is likely the average slope of a number of catchments is over estimated, resulting in a need to offset this with a larger RAF factor.

A comparison of the selected RAF factor of 2.5 and a RAF factor of 1.0 at two key gauges in the Emu study area are shown in Diagram 9 and Diagram 10.

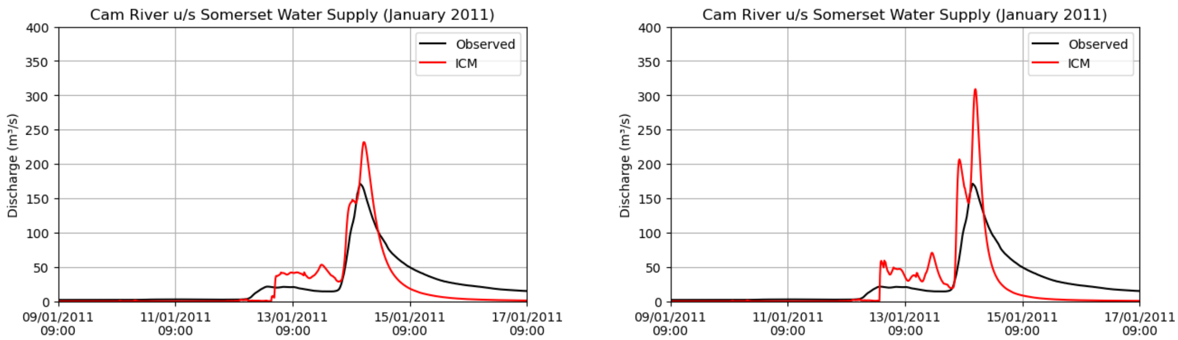

Diagram 9: Flow comparison at Cam River u/s Somerset WS (left: RAF 2.5, right: RAF 1.0)

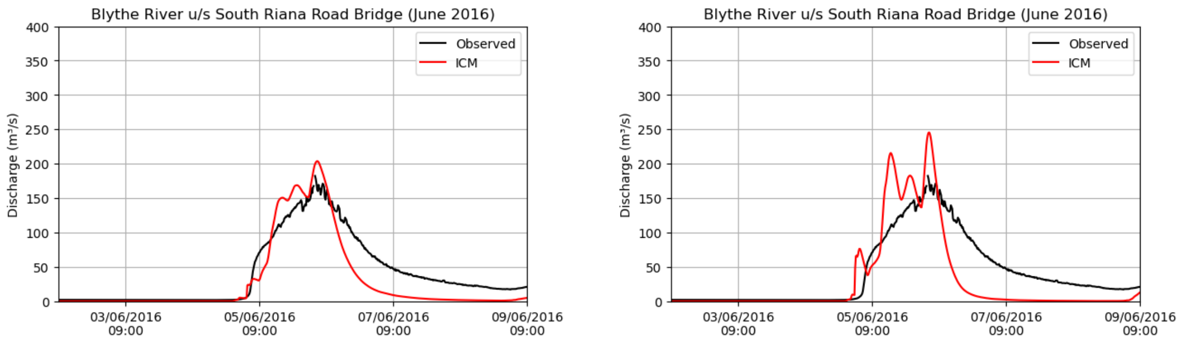

Diagram 10: Flow comparison at Blythe River u/s South Riana Road Bridge (left: RAF 2.5, right RAF 1.0)

Upon completion of the calibration process, the external hydrologic model and the ICM model were compared to ensure that the modelled flows are comparable. This is shown in Appendix C.

6.2. Initial Conditions

Prefilling of the ICM model was not found to be necessary to achieve a reasonable calibration to the locations of interest. On occasion it is necessary to prefill hydraulic models to manage the loss of flood volume due to local depression storage. This scenario however may result in filling of floodplain storage and as such should only be considered where necessary. To ensure there was no incidental filling of floodplain storage in this model it has been run without prefilling.

6.3. Gauge Results

There are two gauges within the catchment where historic event information was available for the selected calibration events (Cam River gauge and Blythe River gauge). The remaining five of the seven gauges within the catchment were not used due to the following reasons:

- Closed prior to the calibration events (Pet River gauge and Emu River DS Companion gauge) or
- Being of limited value to the model calibration (Chasm Creek gauge, Sulphur Creek gauge, and South Riana Dam Inflow).

The Chasm Creek and Sulphur Creek gauges provided limited information for model calibration due to the presence of the extractions and small dams that have insufficient information to be considered, and also a lack of high flow gaugings at Chasm Creek. The model results at the locations have been reviewed. The results at these gauges are presented in Appendix D.

Due to the limited number of events available for assessment it is considered that, while the model looks to respond appropriately, there is insufficient information to provide a high level of confidence in the model calibration. The model is considered to be valid based on the information available.

Mapping of the peak flood depths from the calibrated ICM model for each calibration event is shown in Figure 6 to Figure 7.

6.3.1. Cam River u/s Somerset WS

Initial calibration of model at the Cam River u/s Somerset WS gauge indicated that unreasonable parameters were required in order to match recorded flows. Given the high level of uncertainty in the rating curve at high flows for the January 2011 event, it was considered appropriate to use a reasonable set of parameters to inform the initial run of the hydrodynamic model, and subsequently review level rather than flow.

The Cam River gauge was damaged during the 2016 event and was not able to be used as a calibration point for the June 2016 event. The results however have been presented to provide a reference frame for this event.

The modelled peak level for the January 2011 event at the Cam River gauge shows a good match to the recorded peak level (Table 5). The water level response in the ICM model also shows a good match to the timing and shape of the recorded levels, as shown in Diagram 12.

It is noted that a gauge zero for the Cam River gauge was not available from the DPIPWE database, so an assumed gauge zero of 4.6 mAHD was used. This gauge zero was inferred from the DEM of the hydrodynamic model.

Table 5: Calibrated parameters and results at Cam River u/s Somerset WS

Statistic	2011 January	2016 June
IL (mm)	60	20
Average CL (mm/h)	5.1	7.8
RAF	2.5	2.5
Modelled Peak (m^3/s)	232	438
Observed Peak (m^3/s)	171	Gauge damaged on rising limb at ~170
Peak % difference	+36%	n/a
Modelled Volume (ML)	14,996	16,881
Observed Volume (ML)	17,040	n/a
Volume % difference	-12%	n/a
Modelled peak (mAHD)	10.59	11.63
Observed peak (mAHD)	10.63	Gauge damaged on rising limb at ~10.56
Peak difference (m)	-0.04m	n/a

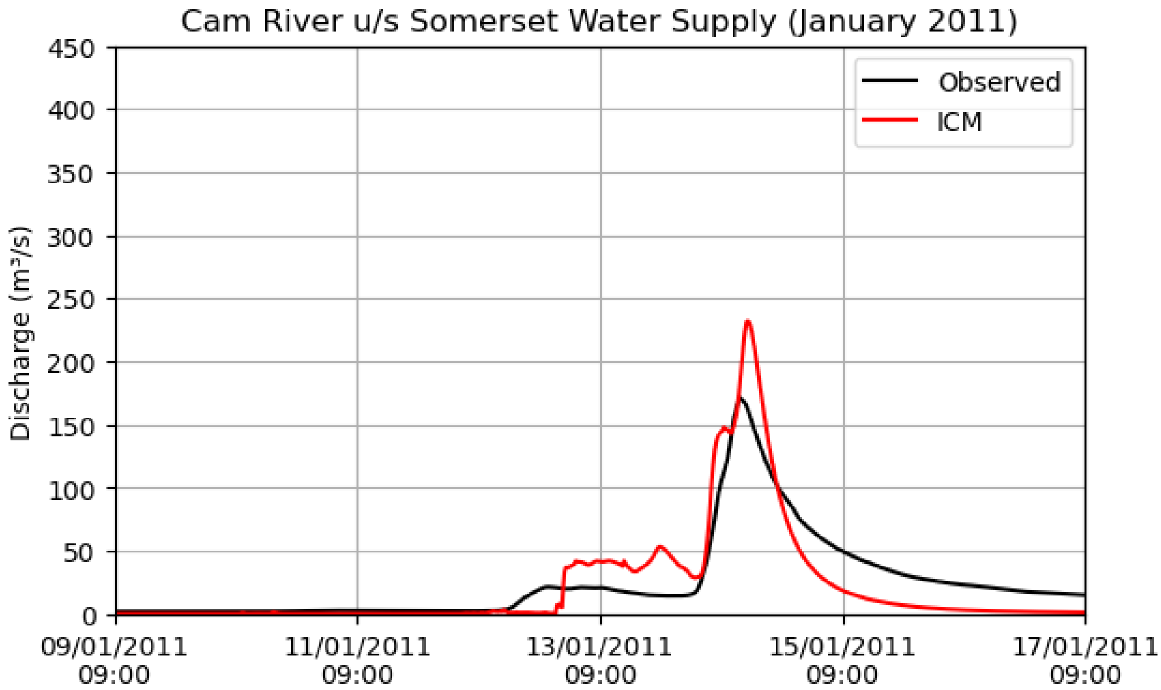

Diagram 11: January 2011 flow comparison at Cam River u/s Somerset WS

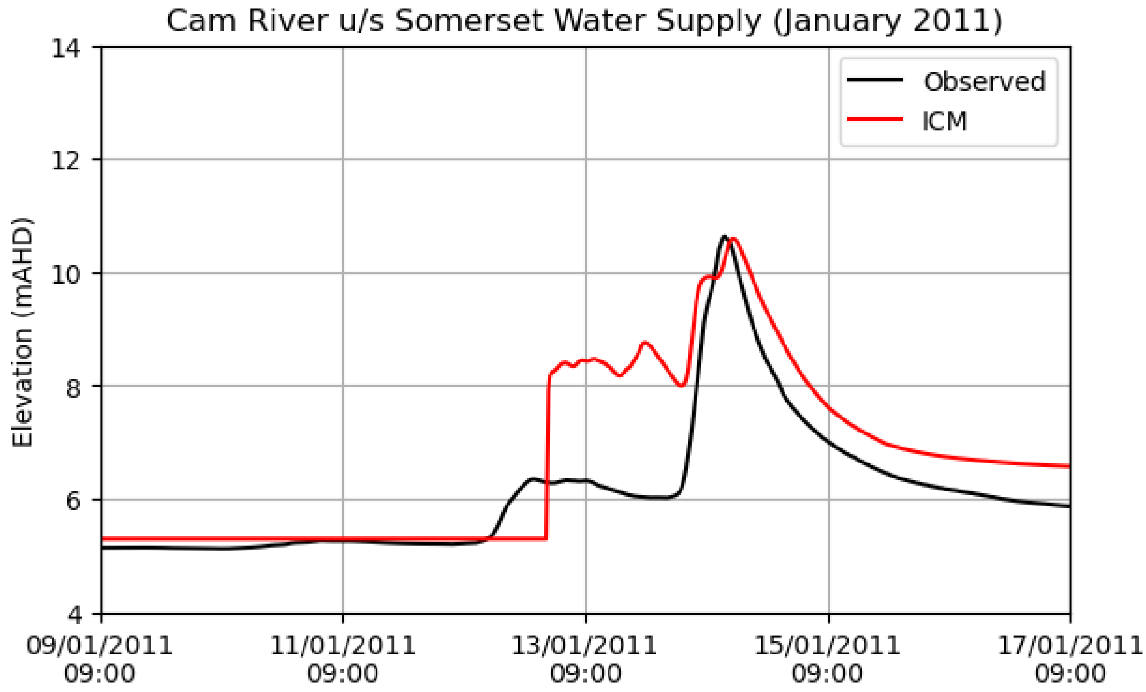

Diagram 12: January 2011 water level comparison at Cam River u/s Somerset WS

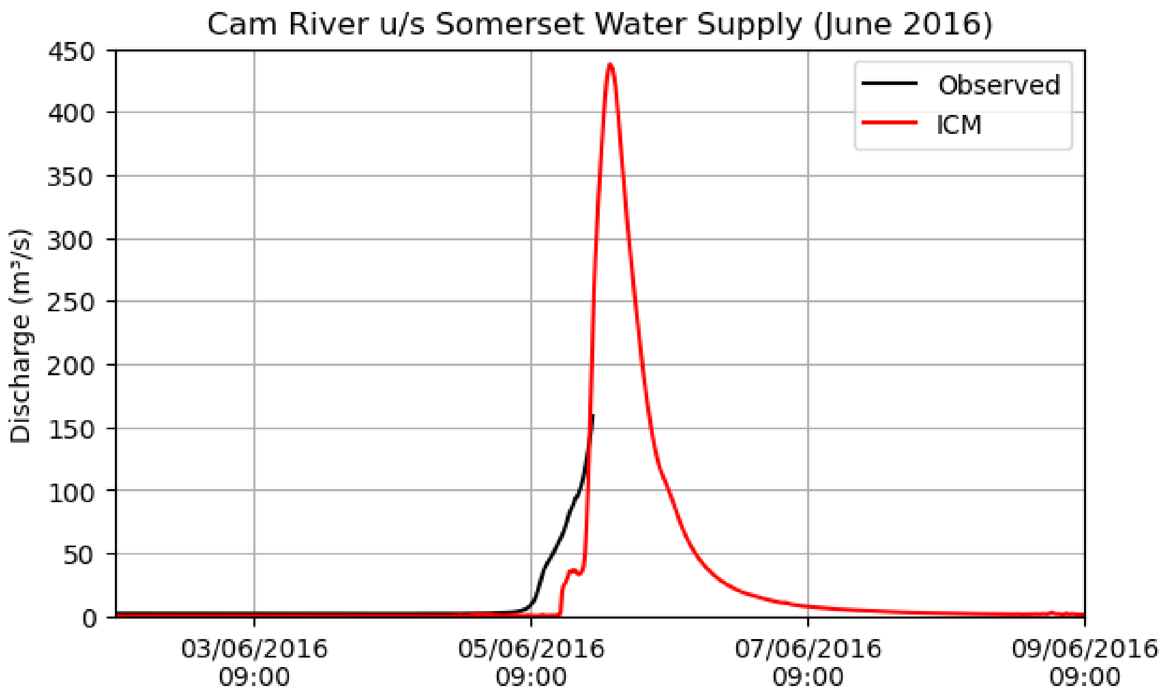

Diagram 13: June 2016 flow comparison at Cam River u/s Somerset WS

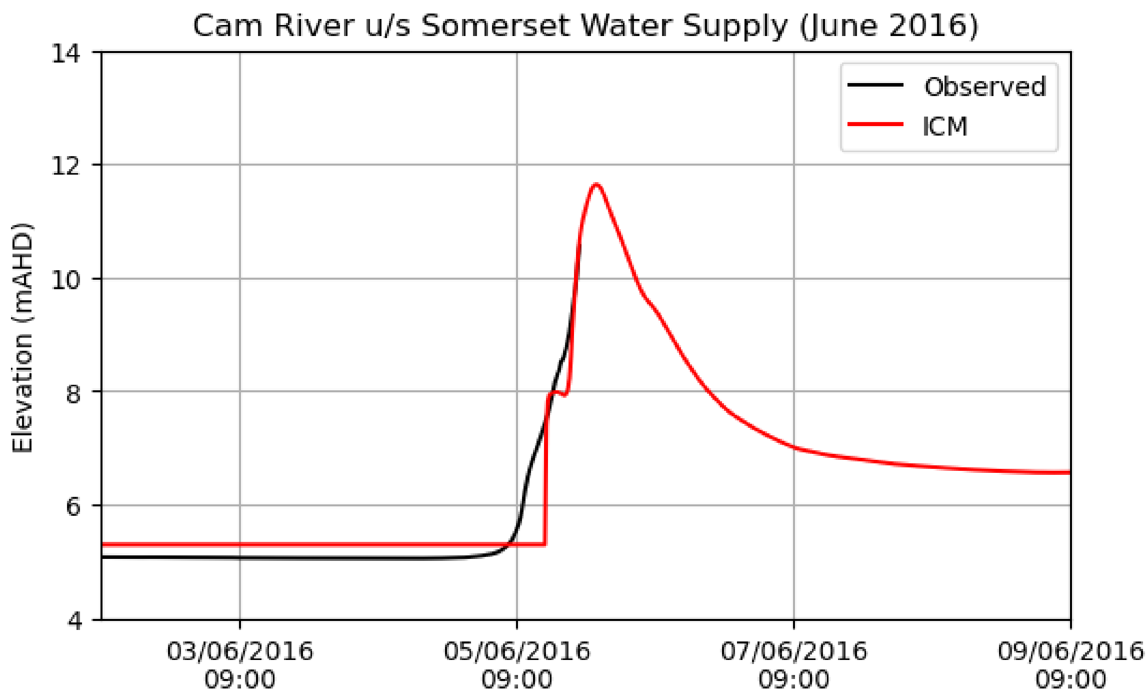

Diagram 14: June 2016 water level comparison at Cam River u/s Somerset WS

6.3.2. Blythe River u/s South Riana Road Bridge

The Blythe River gauge was opened in March 2015 and thus was not able to be used as a calibration point for the January 2011 event.

The modelled peak flow and level for the June 2016 event at the Blythe River gauge shows a good match to the recorded peak flow and level (Table 6). The modelled hydrograph and water level response also shows a good match to the timing and shape of the recorded flows and levels, as shown in Diagram 15 and Diagram 16.

It is noted that a gauge zero for the Blythe River gauge was not available for the DPIPWE database, so an assumed gauge zero of 260.0 mAHD was used. This gauge zero was inferred from the DEM of the hydrodynamic model.

Continuing losses for the June 2016 event were high, especially once the locally calibrated losses were distributed based on the soil types to the remainder of the study area (Figure A 1). These were set to balance peak flows and levels but do lead to an underestimation of event volume, mostly during the recession. These high losses may be partially offsetting uncertainty in the observed rating curve and rainfall, and may not be a true reflection of the catchment state.

Table 6: Calibrated parameters and results at Blythe River u/s South Riana Road Bridge

Statistic	2016 June
IL (mm)	20
Average CL (mm/h)	5.4
RAF	2.5
Modelled Peak (m^3/s)	204
Observed Peak (m^3/s)	182
Peak % difference	+12%
Modelled Volume (ML)	17,723
Observed Volume (ML)	24,622
Volume % difference	-28%
Modelled peak (mAHD)	265.77
Observed peak (mAHD)	265.96
Peak difference (m)	-0.19m

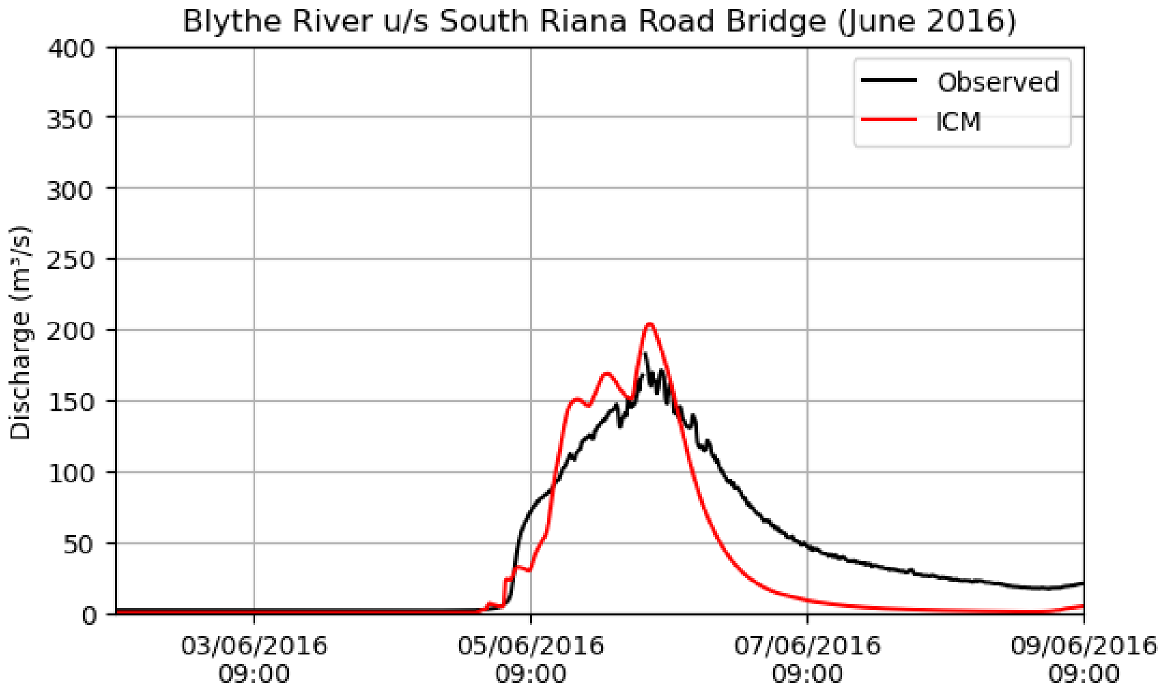

Diagram 15: June 2016 flow comparison at Blythe River u/s South Riana Road Bridge

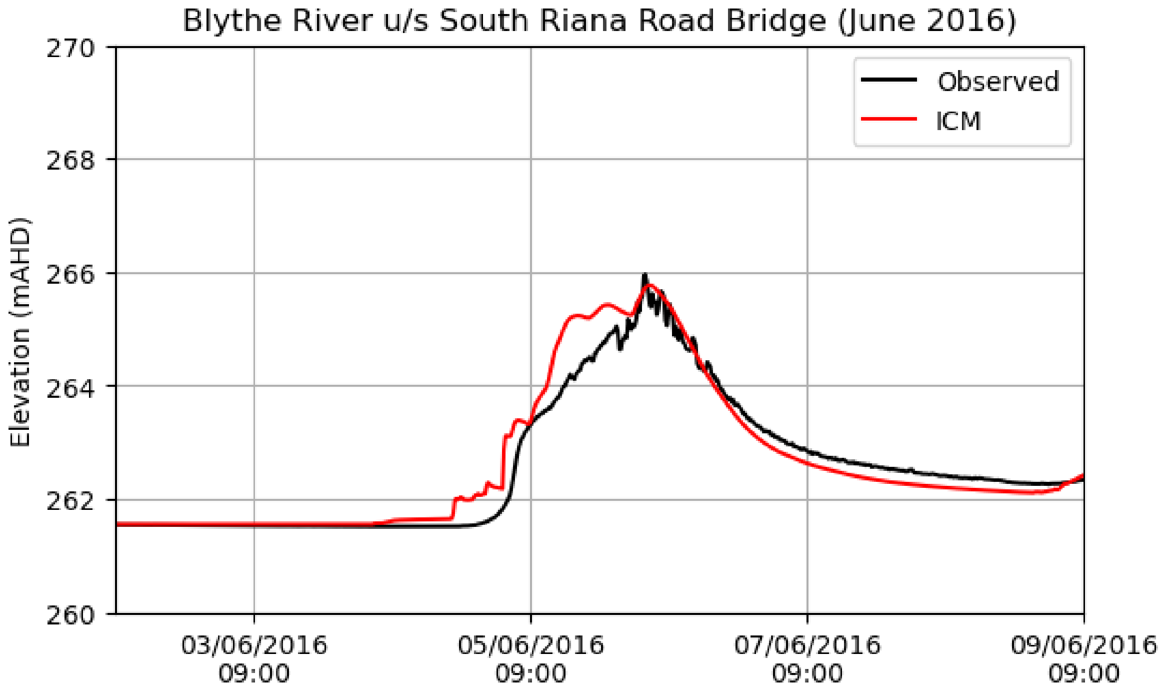

Diagram 16: June 2016 water level comparison at Blythe River u/s South Riana Road Bridge

6.4. Comparison to June 2016 Flood Survey

As part of the Tasmanian flood recovery program following the 2016 floods, the Tasmanian Government collected flood extents survey around impacted areas of Tasmania. The survey utilised damage locations, debris marks and witness accounts to survey the full extent of the June 2016 flood.

Figure 5 shows the modelled and surveyed flood extents for the June 2016 event across the Emu River study area. Survey information was available in the areas around the mouth of Emu River at Burnie. It should be noted that almost all the survey provided around the bridges is classified as approximated, identifying limited confidence in the actual levels provided.

Diagram 18 and Diagram 19 shows the modelled and surveyed flood extent around the mouth of Emu River at Burnie, along with the surveyed levels and a comparison of the modelled and surveyed levels (positive values indicate that the modelled levels are greater than the surveyed levels). Diagram 17 shows a profile of the DEM and the modelled levels from the weir downstream of Fern Glade Road to the mouth of Emu River.

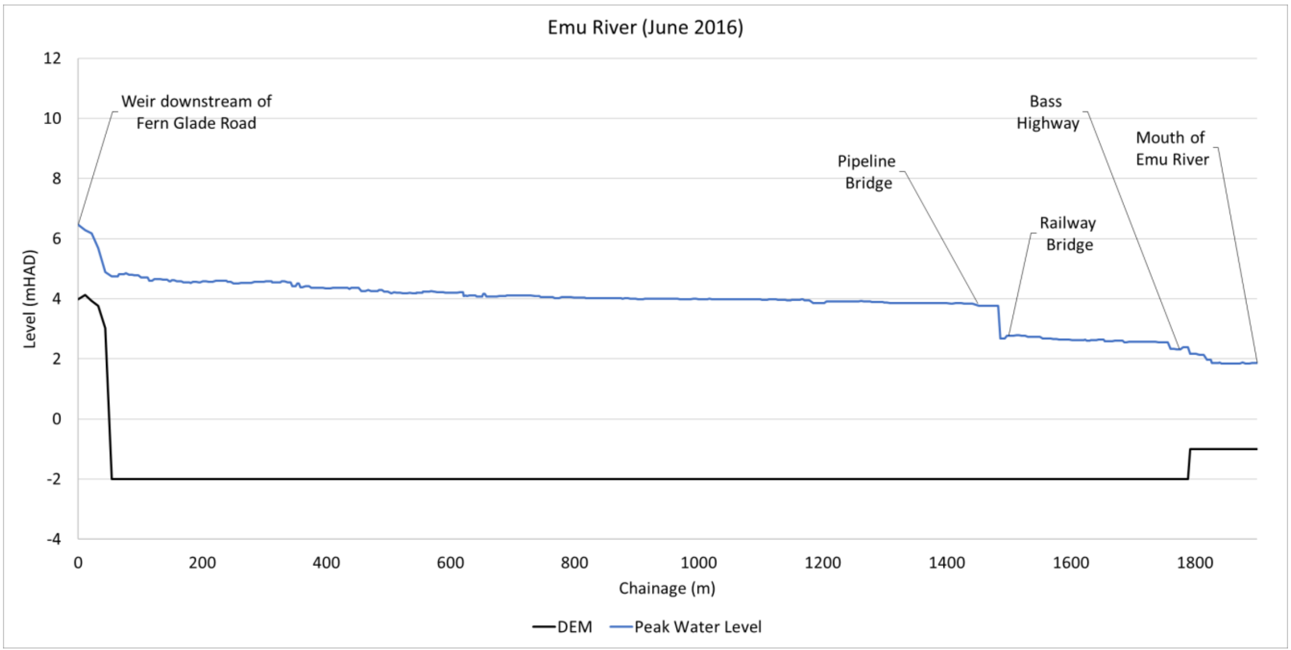

Diagram 17. DEM and June 2016 peak water level along Emu River

It is considered that a reasonable match to the surveyed flood levels has been achieved for a regional model. Key locations include:

- At the railway bridge (Diagram 18), where flood reports and photos of the June 2016 event indicated a large volume of debris load on the bridge – a fair match to the survey was achieved, with the model in the order of 0.5 m of the survey upstream of the bridge. It was identified that a blockage in the order of 80% on the modelled bridge was required. It is believed that the survey levels downstream of the bridge are erroneous, as the surveyed levels are lower than the surveyed levels at the mouth of Emu River. The levels however indicate there was a significant drop in levels across the bridge systems.

- At the mouth of Emu River (Diagram 18) – a fair match to the survey was achieved, with the model in the order of 0.5 m of the survey – it was identified that the following bathymetry modifications were required:
    - Reinforcing the constriction formed by the sand bars in the DEM, which appeared to have been processed out of the LiDAR capture of the DEM during its processing, and
    - Lowering the base of the channel from approximately 2 mAHD (erroneous due to the limitations of the LiDAR capture of the DEM) to -1 mAHD downstream of the Bruce Highway and to -2 mAHD upstream of the Bruce Highway (noting the sand bar)
- Along River Road east of the river and south of the train line (Diagram 18), a fair match to the survey was achieved, with the model in the order of 0.5 m of the survey. It was identified that a higher estuary roughness of 0.025 was required (from the default roughness of 0.011), and this is proposed to become the default for all estuaries and
- At Fern Glade Road (Diagram 19), where flood reports of the June 2016 event indicated a small volume of debris load on the bridge. A fair match to the survey was achieved, with the model in the order of 0.5 m of the survey. It was identified that a blockage on the modelled bridge was not required
- Downstream of the rail bridge within the industrial estate is under estimated by the provided survey. Plate 1 shows a much larger area of inundation through this zone, consistent with the modelling outcomes.

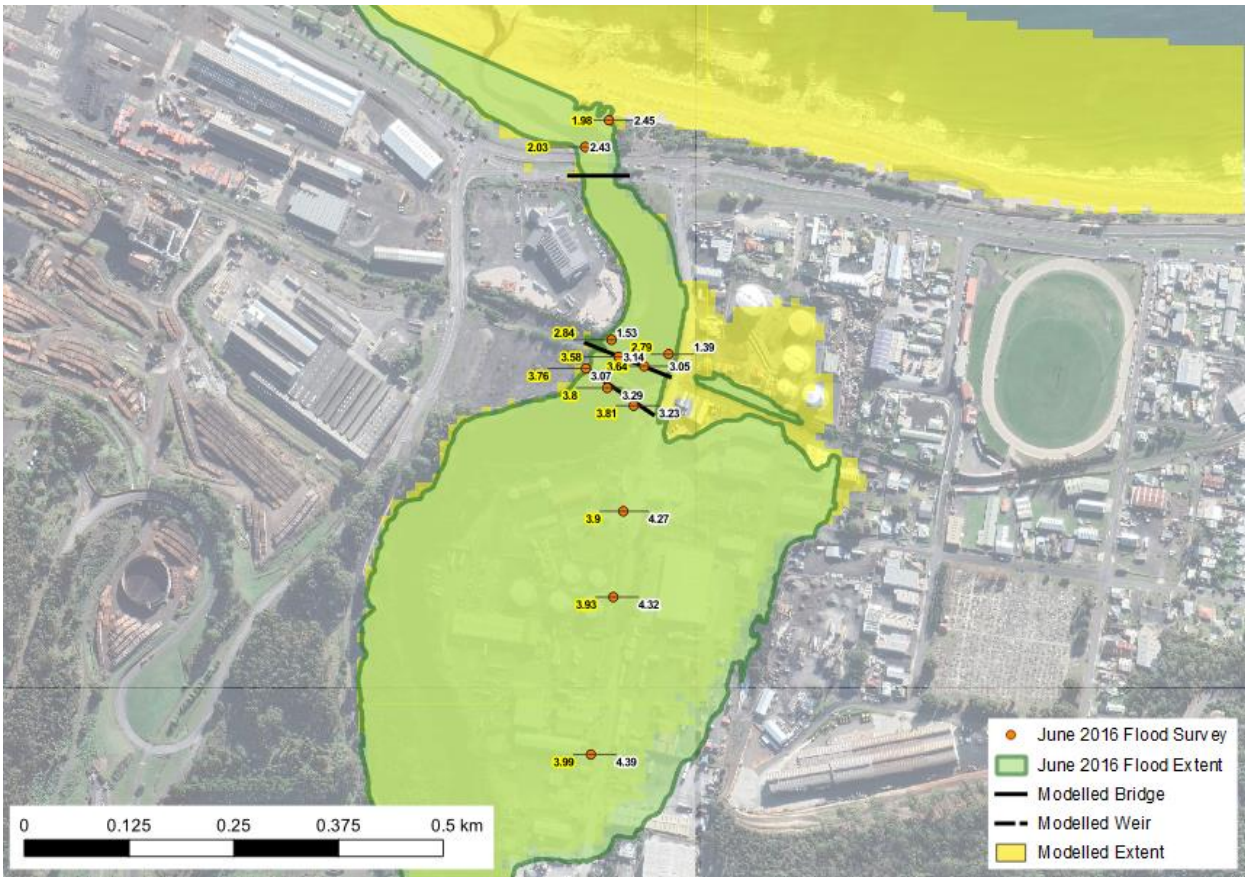

Diagram 18: Comparison to June 2016 flood survey at the mouth of Emu River at Burnie

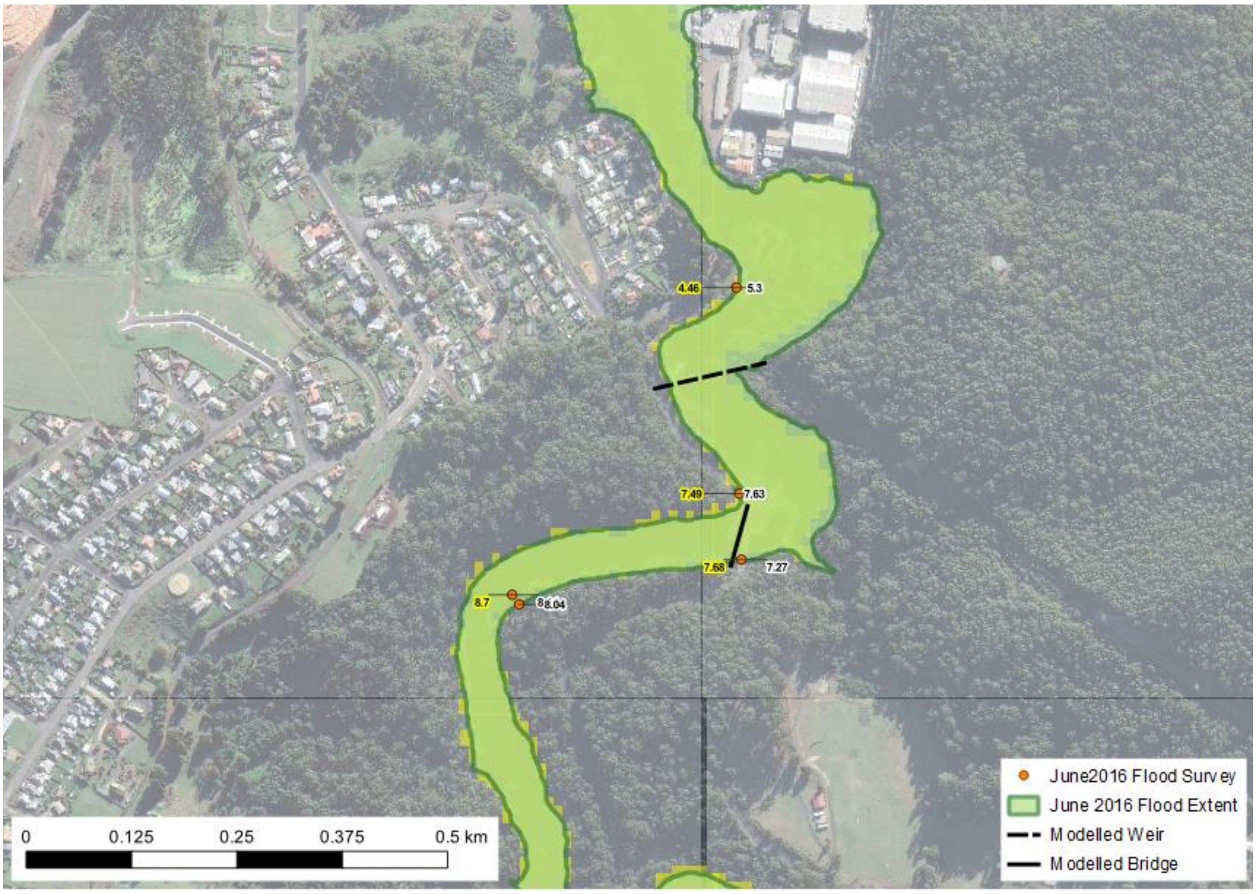

Diagram 19: Comparison to June 2016 flood survey upstream of the mouth of Emu River at Burnie

Plate 1 – Flood Area Downstream of the Rail Bridge in June 2016 Event (Entura, 2018)

To ensure a consistent methodology across the study area, similar bathymetry and estuary roughness modifications were made to the mouth of the Cam and Blythe Rivers as a starting point for the future modelling of these areas. If detailed analysis of these areas is undertaken in future, then these modifications will need to be validated to local bathymetric survey and/or flood survey information.

6.4.1. Summary of Survey Levels

Diagram 20 presents the outcomes of the comparison of the surveyed levels at all locations within the model extent. The upper and lower limits are based on the confidence levels provided with the survey points, with the exception of levels that are commented as approximate. In these scenarios an uncertainty of 1m has been applied.

The majority of points fall within approximately ±0.5 m variance from surveyed levels, two of the four locations outside of the limits are downstream of the bridge and considered erroneous (lower than the tide / entrance levels).

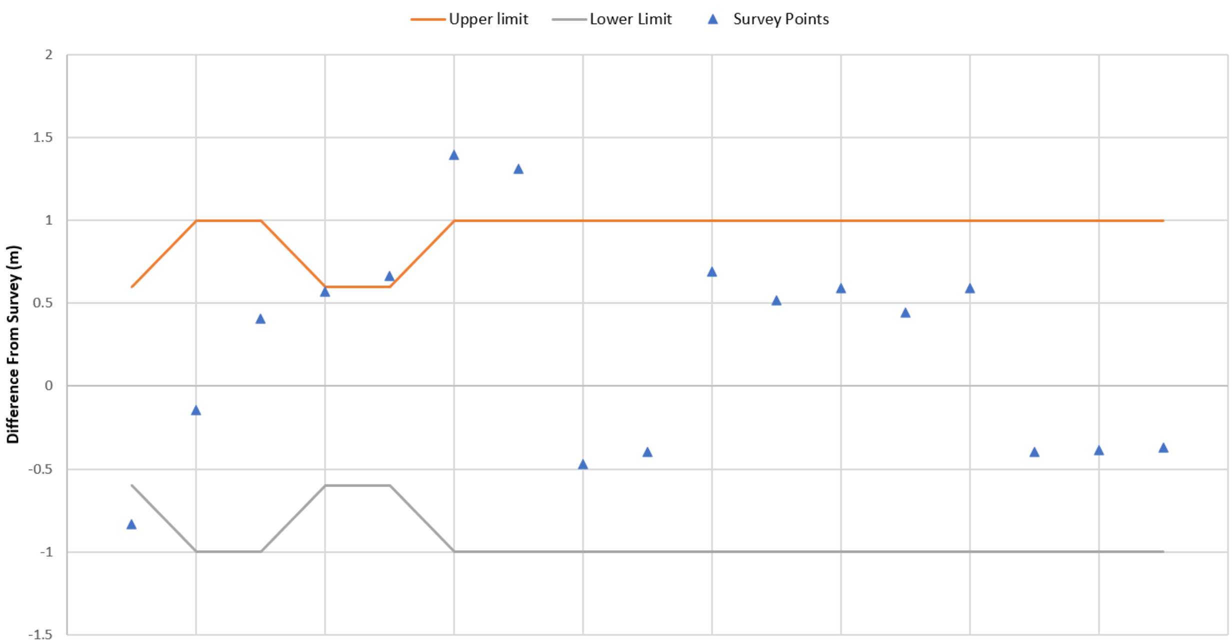

Diagram 20: June 2016 Level Results – Difference from Recorded Level

6.5. Comparison to Previous Studies

6.5.1. Emu River

Burnie City Council commissioned Entura (2018) to undertake a flood study for the lower reaches of the Emu River in Wivenhoe, following the June 2016 flood event. Entura calibrated hydrologic models to the Emu River at Hampshire and Cam River u/s Somerset WS gauges. A detailed local hydraulic model was developed for the Wivenhoe area and this was calibrated to the June 2016 flood event, with validation against the January 2011 flood event.

A review of the modelling indicated a large discrepancy between the peak estimated flow of the 2016 flood event between this study and Entura's study. This discrepancy was due to the large difference in continuing loss assumed (Entura 2.2 mm/hr, WMAwater 7.3 mm/hr catchment average). This results in a flow discrepancy of around 200 m^3/s (220 m^3/s in ICM vs 450 m^3/s in Entura report). The rainfall spatial pattern used over the catchment for the June 2016 event is not presented in the Entura report and it is not known whether the pattern used included the higher rainfalls in the south of the catchment. Figure 6.2.3 of the Entura report shows a hyetograph that looks to present similar rainfalls to those observed at the Burnie pluviograph, however it is not clear whether this is catchment average rainfalls. It is also noted that data from Burnie pluviograph was used in the Entura study, however when this data was supplied by the Bureau for the current study it was given a quality code of “suspect” and was thus not used to derive catchment rainfalls or temporal patterns. The relatively high continuing loss of 7.3 mm/hr in the current study is based on calibration to the available flow gauge during the June 2016 flood event, and distribution of losses over the catchment is based on the supplied hydrological soils group mapping, using the method outlined in WMAwater (2021a).

The Entura report highlights that, for this event, the primary constriction is the outlet of the river to the ocean rather than the bridges. This assumption does not correlate to the surveyed levels provided by SES for the purposes of this study, which indicate a large drop across the structures. The Entura model did, however, provide a better match to levels upstream of the bridges along River Road compared to this study.

6.5.1.1. Emu River – Calibration Parameter Comparison

To confirm the function of the models was relatively similar, a model scenario was run within ICM using the losses as specified within the Entura (2018) report. The model was also updated to have the same blockage factor (50%) on the rail bridge as in the Entura model.

Comparison of the ICM modelled hydrograph with a continuing loss of 2.2 mm/hr to the Entura hydrograph at the outlet of Emu River is shown in Diagram 21. The results confirm the hydrologic response of the models are generally consistent, with a discrepancy of 20 m^3/s in the peak flows. Comparison of the modelled and surveyed levels at the mouth of Emu River with this continuing loss is shown in Diagram 22.

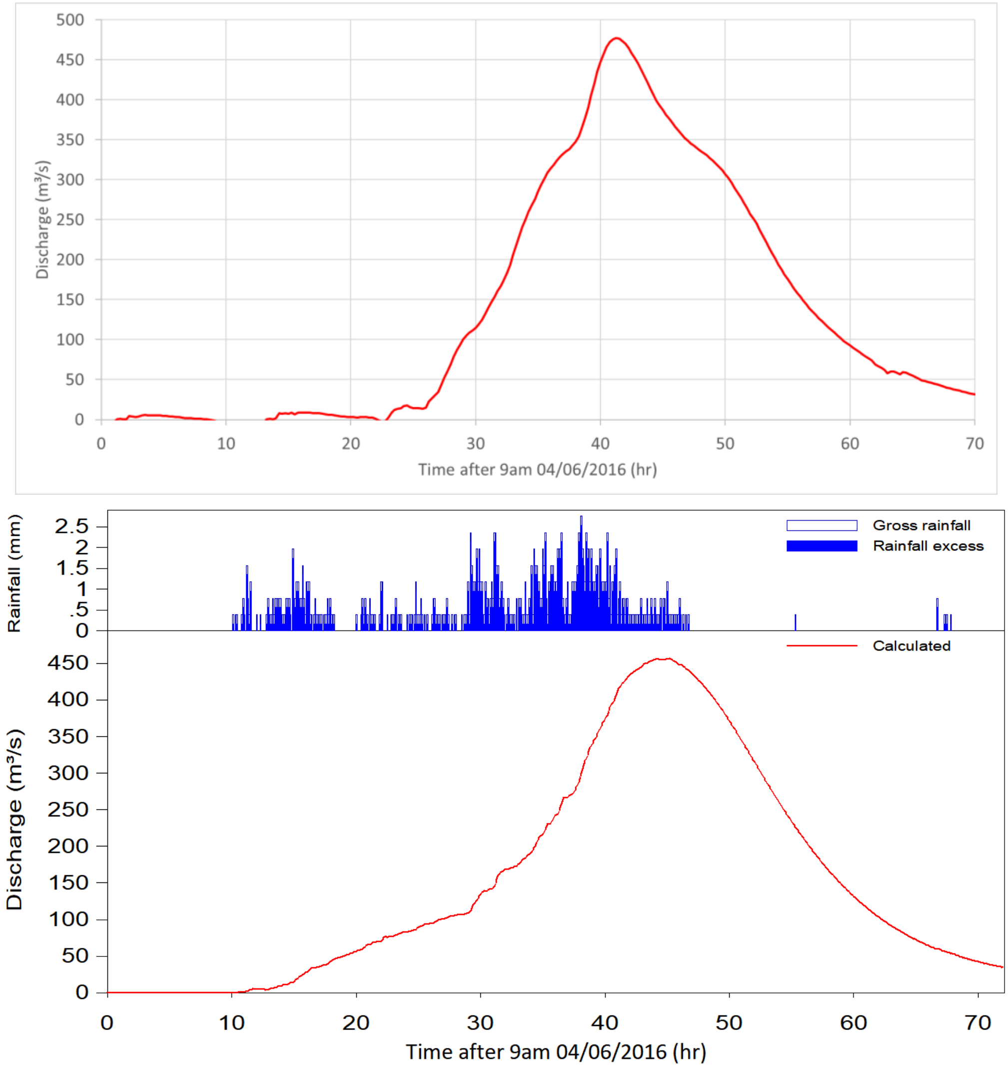

Diagram 21: June 2016 hydrograph at the outlet of Emu River in ICM with continuing loss of 2.2 mm/hr (top) compared to the Entura hydrograph (bottom)

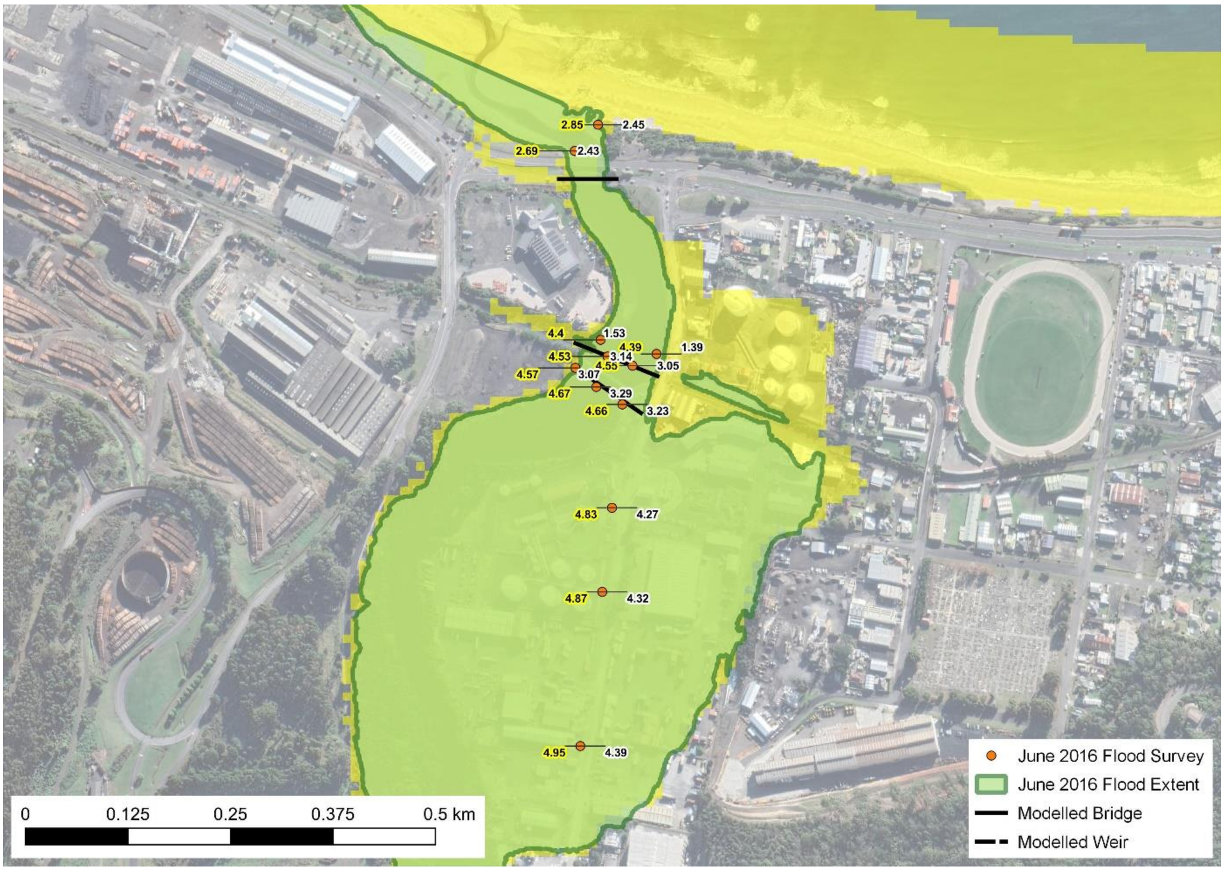

Diagram 22: Comparison to June 2016 flood survey at the mouth of Emu River with continuing loss of 2.2 mm/hr

The results indicate a relatively similar response within the ICM model when compared to the Entura (2018) model. It confirms the increased flow changes the hydraulic control location from the bridge to downstream at the entrance. This mechanism is consistent with the Entura findings. The discrepancy in levels is due to the limited representation of the entrance system and the bathymetry in the area. The Entura model utilised an assumed entrance condition to replicate levels, however this information is not readily available for incorporation into the ICM model. Prior to design runs it is recommended minor adjustments are made to the entrance to try and improve its representation, if data is available.

Noting the similarities in model results it is considered that the performance of the ICM model is comparable to the performance of the Entura (2018) model through this region.

6.5.2. Cooee Creek

Burnie City Council commissioned Entura (2011) to undertake a flood study of Cooee Creek. It is understood that the modelling was not calibrated to a historic event and therefore, a comparison of the modelling undertaken to the flood study was not undertaken. It is noted however that survey of Cooee Creek and its structures was undertaken as part of the flood study and may be of use if future detailed analysis is undertaken.

6.6. Identified Issues

Through the review of the calibration results at the gauges and the comparisons to the June 2016 flood survey and to previous studies, the following issues were identified which should be investigated further if future detailed analysis is undertaken:

- Uncertainties in the DEM in the very upper reaches of the Emu and Blythe Rivers, which was modelled based on the 'Default DTM' to LiDAR
  Review of the 10 m DEM in these areas showed the potential for flows to be trapped within the 'Default DTM' as shown in Diagram 23.

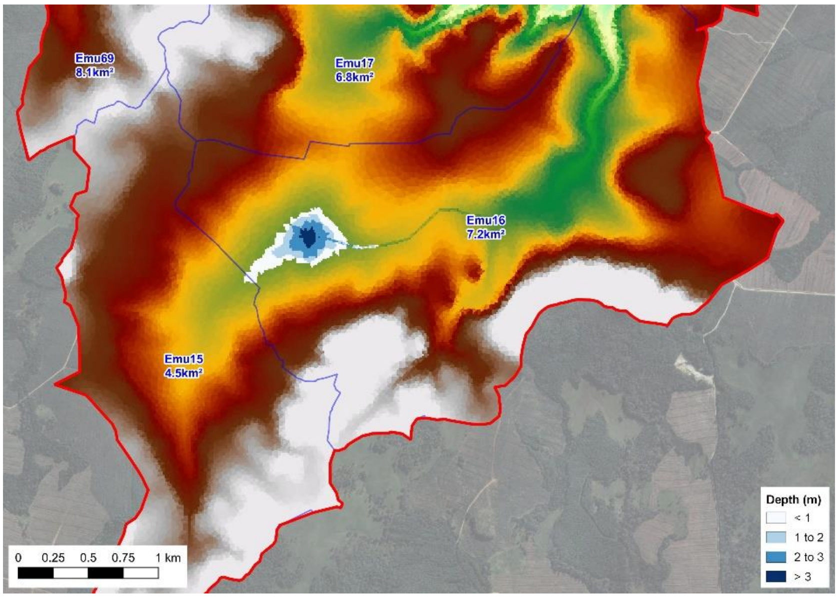

Diagram 23: Flows trapped within the 'Default DTM' in the very upper reaches of Blythe River

- Due to the limited number of events available for calibration it is considered that, while the model looks to respond appropriately, there is insufficient information to provide a high level of confidence in the model calibration. The model is considered to be valid based on the information available, however any future detailed assessments could attempt calibration of other events to improve the confidence in the model.
- Updates are required to dimensions of the culverts through the Bass Highway and the weir along Emu River (downstream of Fern Glade Road), based on survey information, rather than estimated parameters currently used within the model.
- If available, representation of river entrances in the catchment should be updated with bathymetry. The areas are currently based on estimated levels derived from the 2018 Emu River Flood Study.
- If available, the geometry of the entrance of the Emu River should be updated to improve definition. In the supplied DEM, the entrance control was not present. If sufficient data exists, this should be incorporated into the design model, noting that at higher flows this may result in changes to modelled in water level in the river.
- Several of the gauges have poor or no quality information. Future works may consider improving gauges in the area to ensure higher quality data is available for future flood events.

7. UNCERTAINTY ASESSMENT

Significant flows were recorded at gauges within the Emu River study area for three of the study calibration events: August 1970, January 2011, and June 2016. Due to lack of rainfall data for the 1970 event, only the January 2011 and June 2016 events were used in model calibration. These events were each recorded at one gauge in the study area, where they were the largest events on record. The ratings at both the gauges used in the calibration are considered to be poor, with a high degree of uncertainty in high flows. No gauge zero levels were supplied and these were inferred from the DEM.

Surveyed flood levels were available for the June 2016 event. There were inconsistencies in the surveyed levels, which were classified as “approximated” in some areas.

There is a high level of uncertainty in the DEM definition of river entrances in the catchment. This results in uncertainty in the hydrodynamic model control in the lower reaches of the modelled rivers.

The uncertainty assessment for the modelling is shown in Table 7. Detail of the uncertainty assessment in provided in Appendix B.

Table 7: Uncertainty assessment for Emu River study area model

Category	Quality statement
Hydrology – rainfall input quality	The rainfall quality for the calibration events is generally good, with at least 1 sub-daily rainfall gauge within or close by the study area, providing information for each calibration event, and 5 to 6 daily rainfall gauges within the catchment.
Hydrology – observed flows	One flow gauge was operating for each of the January 2011 and June 2016 calibration events within the catchment. These gauges are located on the Cam River and the Blythe River. The rating at the Cam River gauge for the January 2011 event is considered to be poor with the rating extrapolated to high flows. The rating at the Blythe River site was not available.
Hydrology – calibration events	The January 2011 and June 2016 events are the largest on record at the respective gauges operating for the events. The June 2016 event was also likely to be the largest event at the Cam River gauge, however the gauge was destroyed during the event.
Hydrology – calibration results	The modelled hydrograph was considered to provide a poor match to peak flows at the Cam River gauge for the January 2011 event, which likely reflects the uncertainty in the high flow rating. The hydrograph volume and shape for this event were considered to be good. The modelled hydrograph showed a very good match to peak flows at the Blythe River gauge for the June 2016 event, and a fair match to volume.

Category	Quality statement
DTM definition	Base dataset for the digital elevation model (DEM) was the SES state-wide 10 m DEM merged with 2 m DEM subsets at the gauges (where available). There is a high level of uncertainty in the DEM definition of river entrances in the catchment. There is also a high level of uncertainty in the DEM in the upper reaches of the Emu and Blythe rivers, which was modelled based on the 'Default DTM'.
DTM waterways	No bathymetric data was available and waterway definition was based on the LiDAR to water surface.
Hydrodynamic – observed flood depths	Surveyed flood levels were available for the June 2016 event. There were inconsistencies in the surveyed levels, with some levels classified as "approximated".
Hydrodynamic – calibration results, peak levels	Calibration results within the hydrodynamic model showed an excellent match to peak flows at the gauges for the calibration events, with modelled peaks within 0.2 m of recorded peaks.
Hydrodynamic – calibration results, flood extents	The comparison of modelled extents to the 2016 flood extents was generally good. There is a discrepancy in one area close to the mouth of the Emu River in Wivenhoe area, where photos of the event indicate that the supplied flood extent is not accurate.
Hydrodynamic – calibration results, flood depths	Comparison to the surveyed flood depths shows that modelled levels are generally within ±0.5 m. There is a high degree of uncertainty in the hydrodynamic model in area around the mouth of the Emu River due to the lack of bathymetric information to inform the DEM at the river entrance.

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Figures

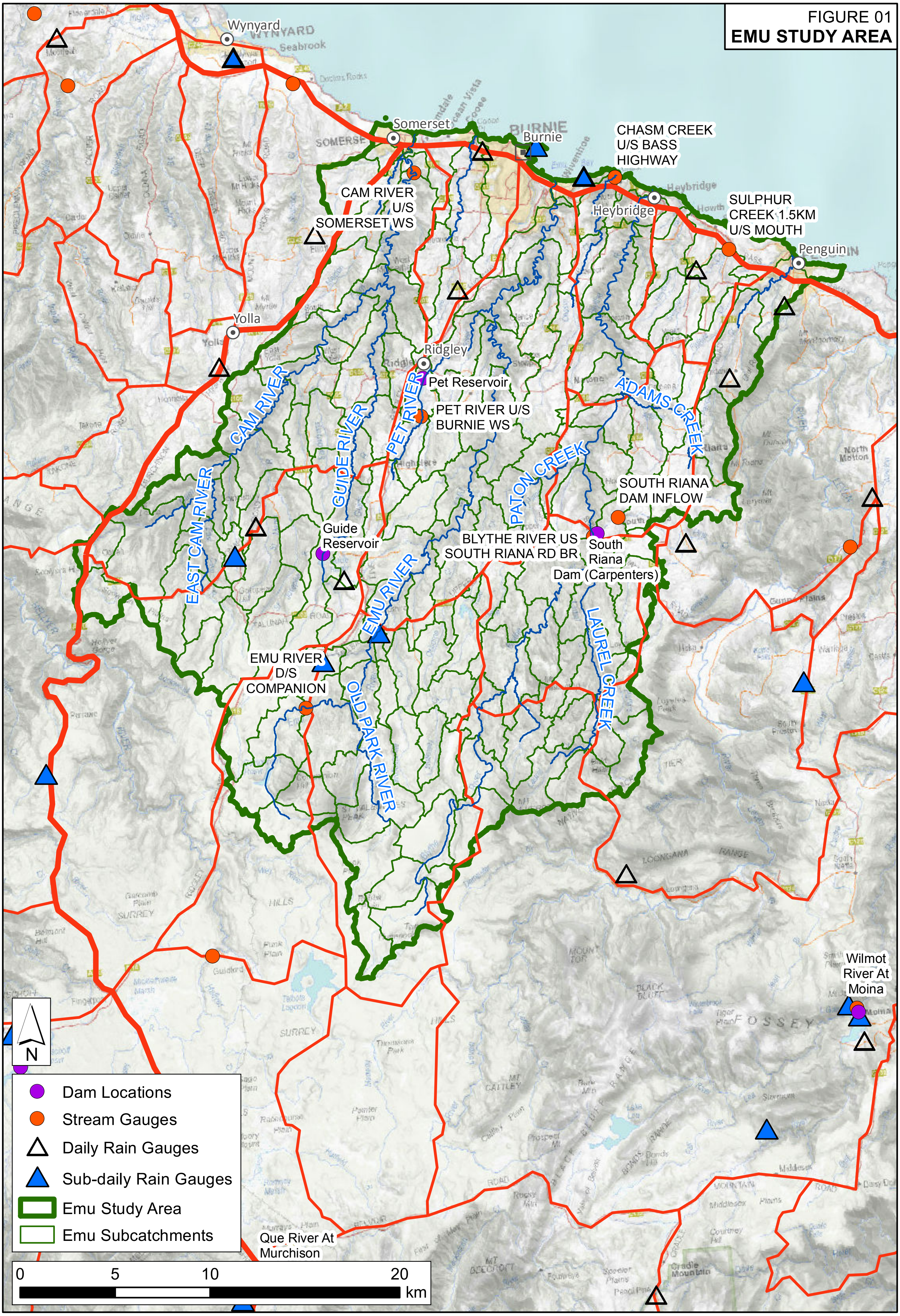

FIGURE 01
EMU STUDY AREA

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EMU CATCHMENT LAND USE

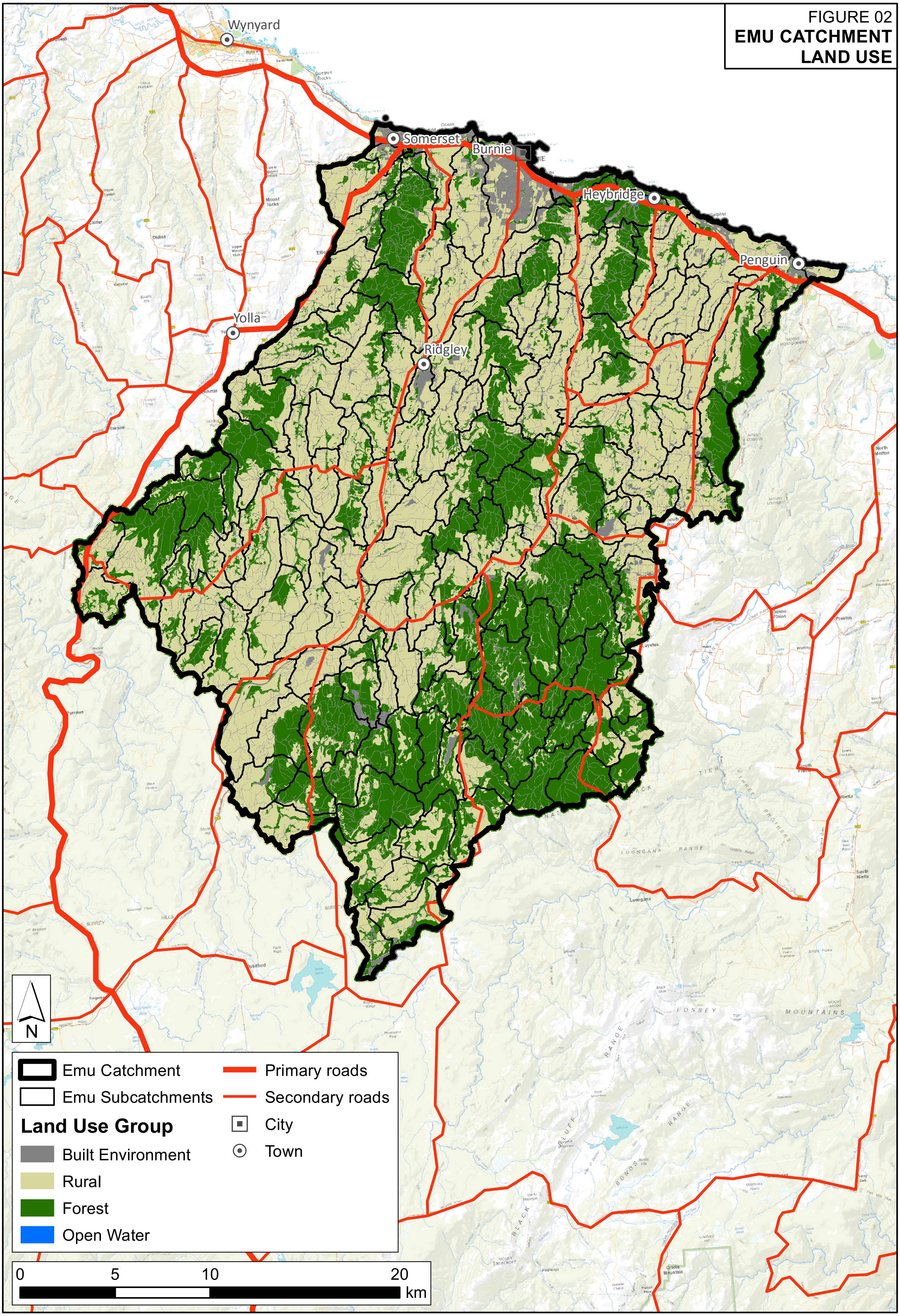

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FIGURE 3

EMU STUDY AREA

RAINFALL 2011_JAN

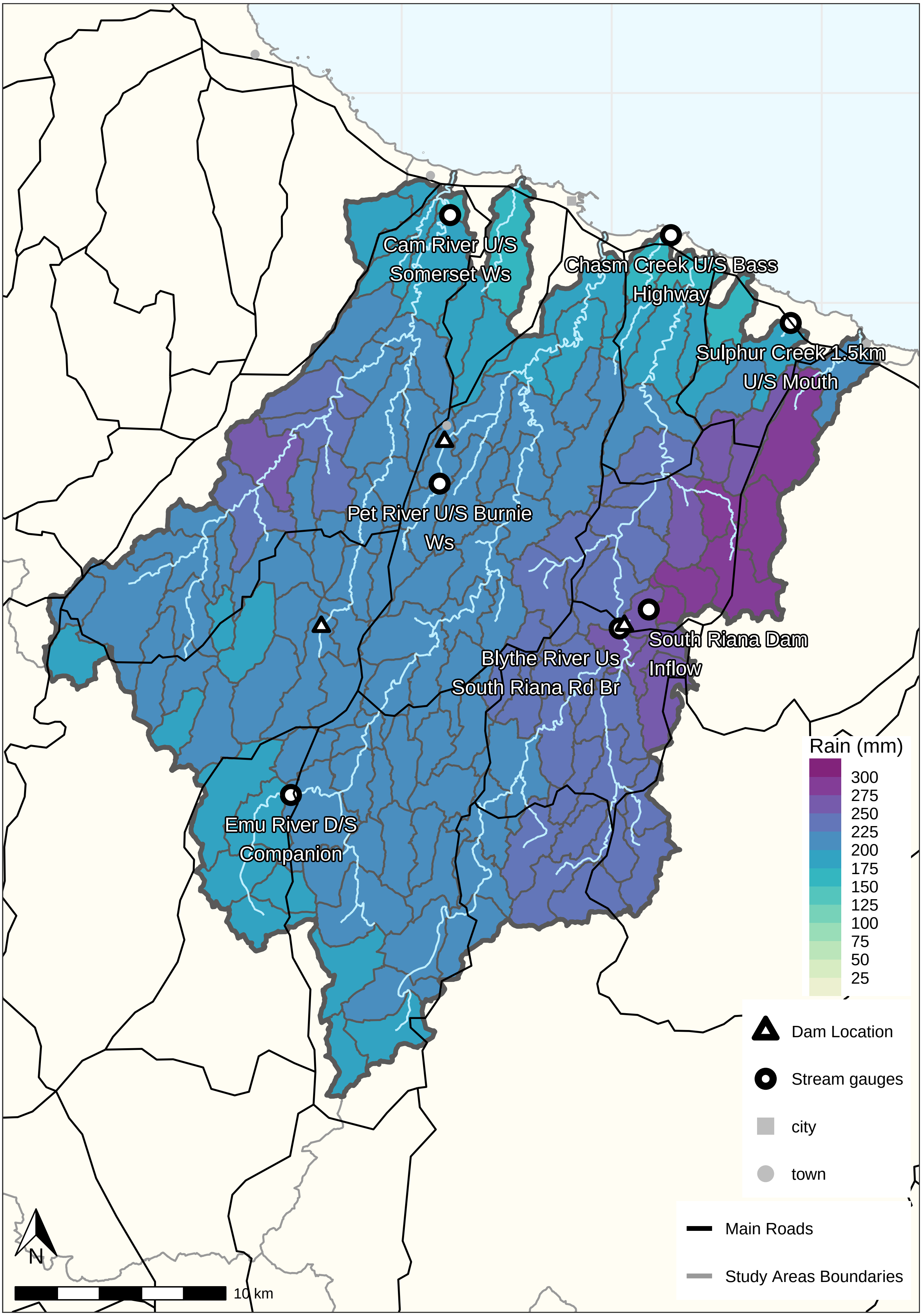

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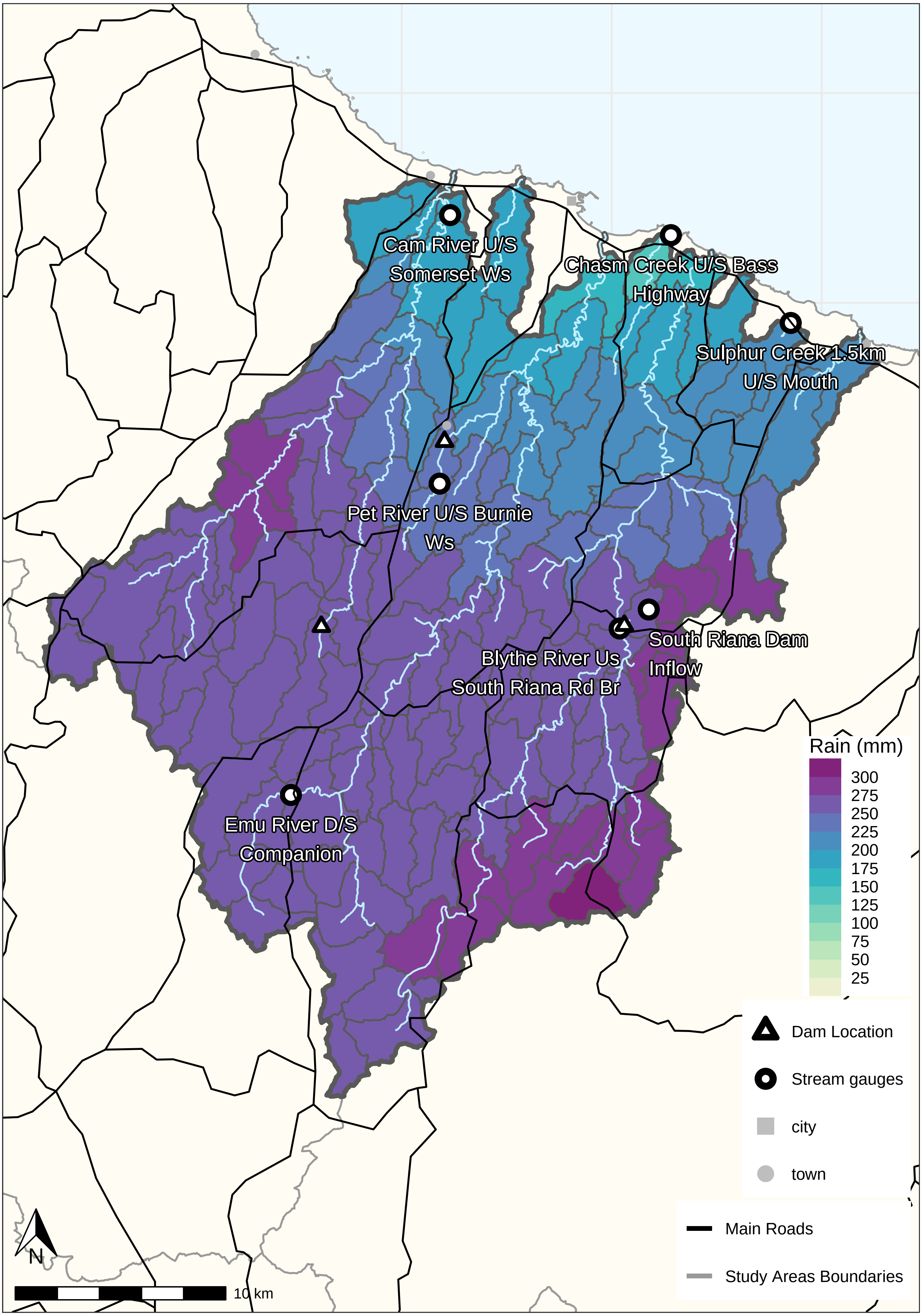
FIGURE 4
EMU STUDY AREA
RAINFALL 2016_JUN



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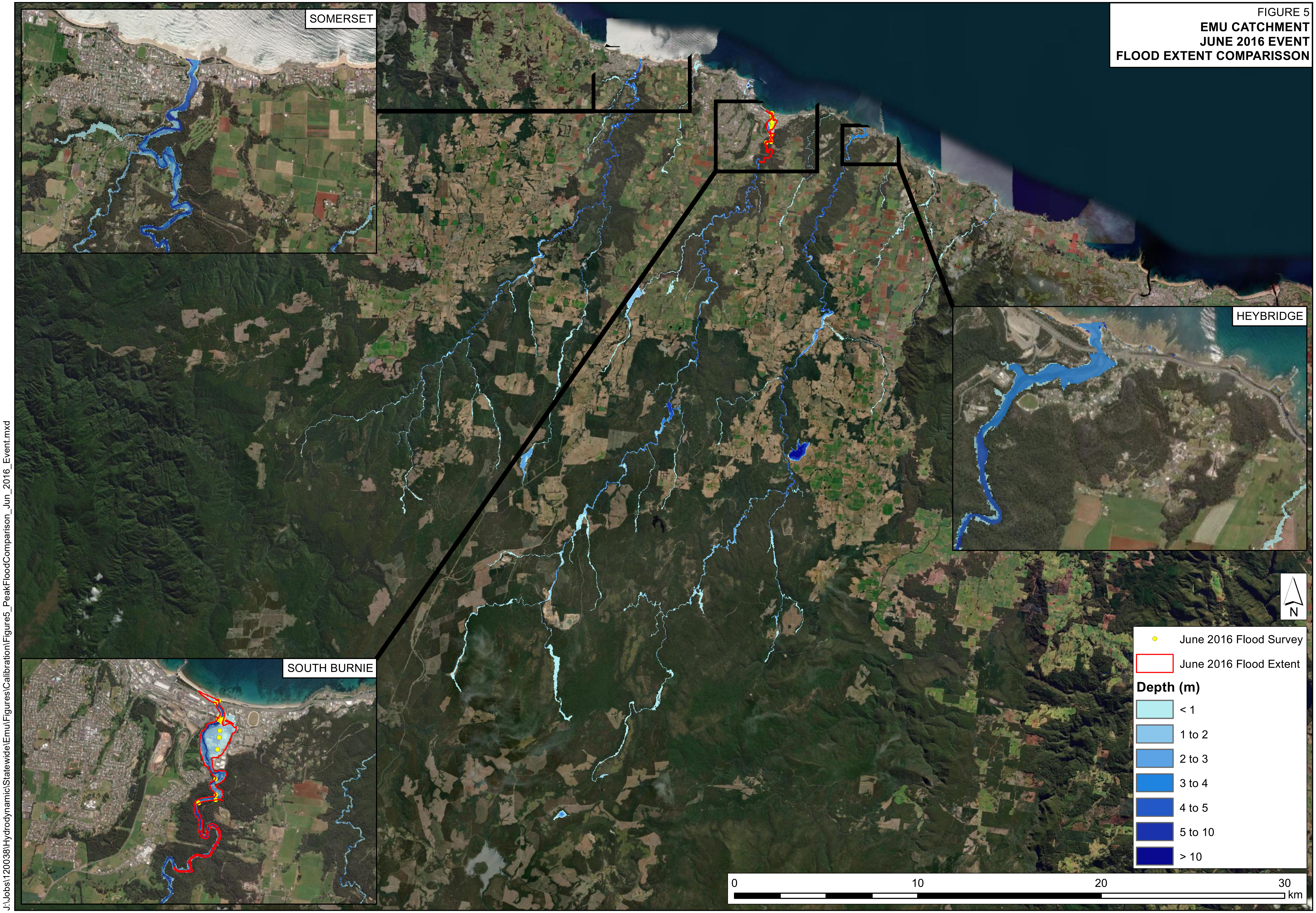
FIGURE 5
EMU CATCHMENT
JUNE 2016 EVENT
FLOOD EXTENT COMPARISSON
SOMERSET
HEYBRIDGE
SOUTH BURNIE
N
June 2016 Flood Survey
June 2016 Flood Extent
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
10
20
30
km
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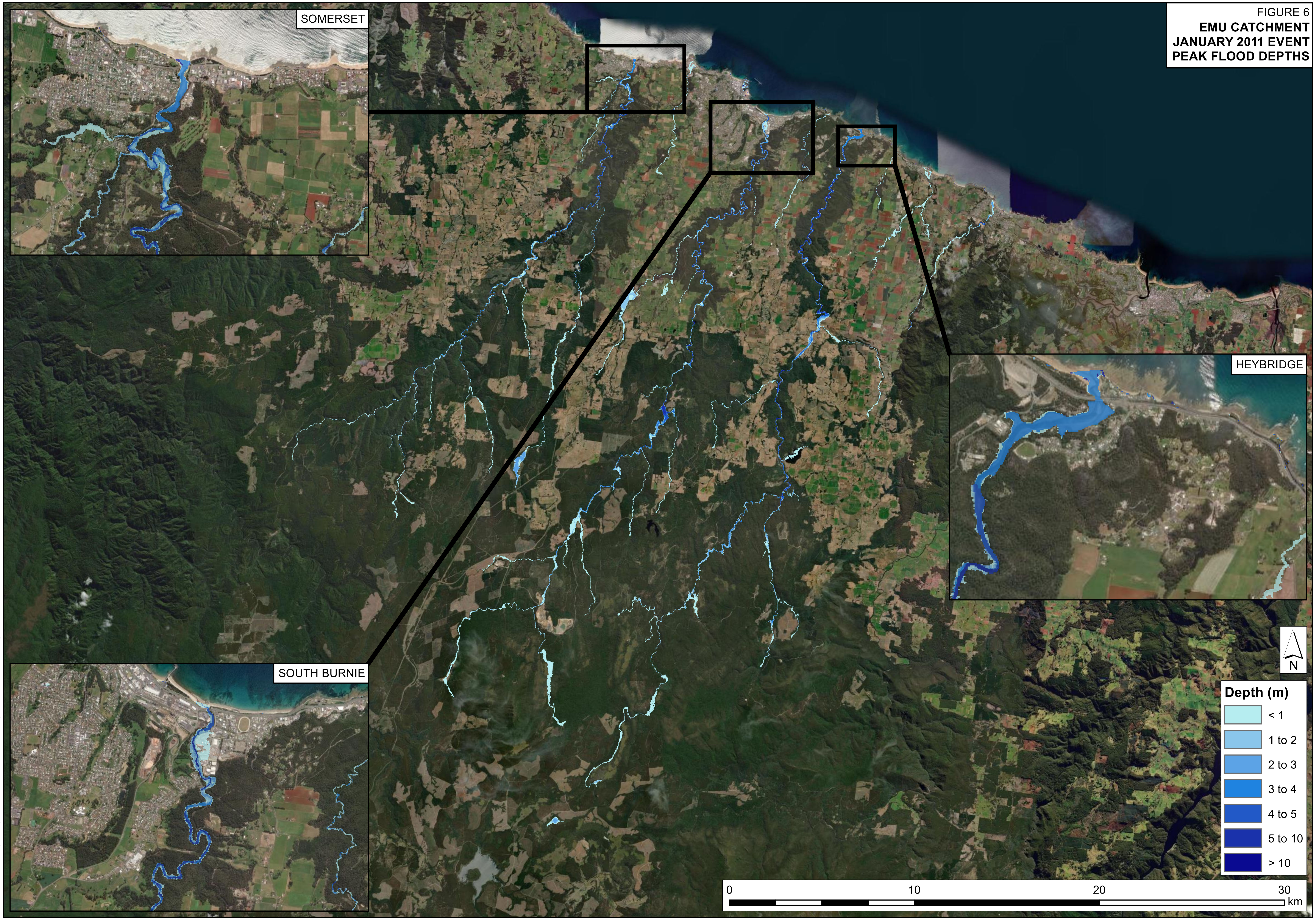

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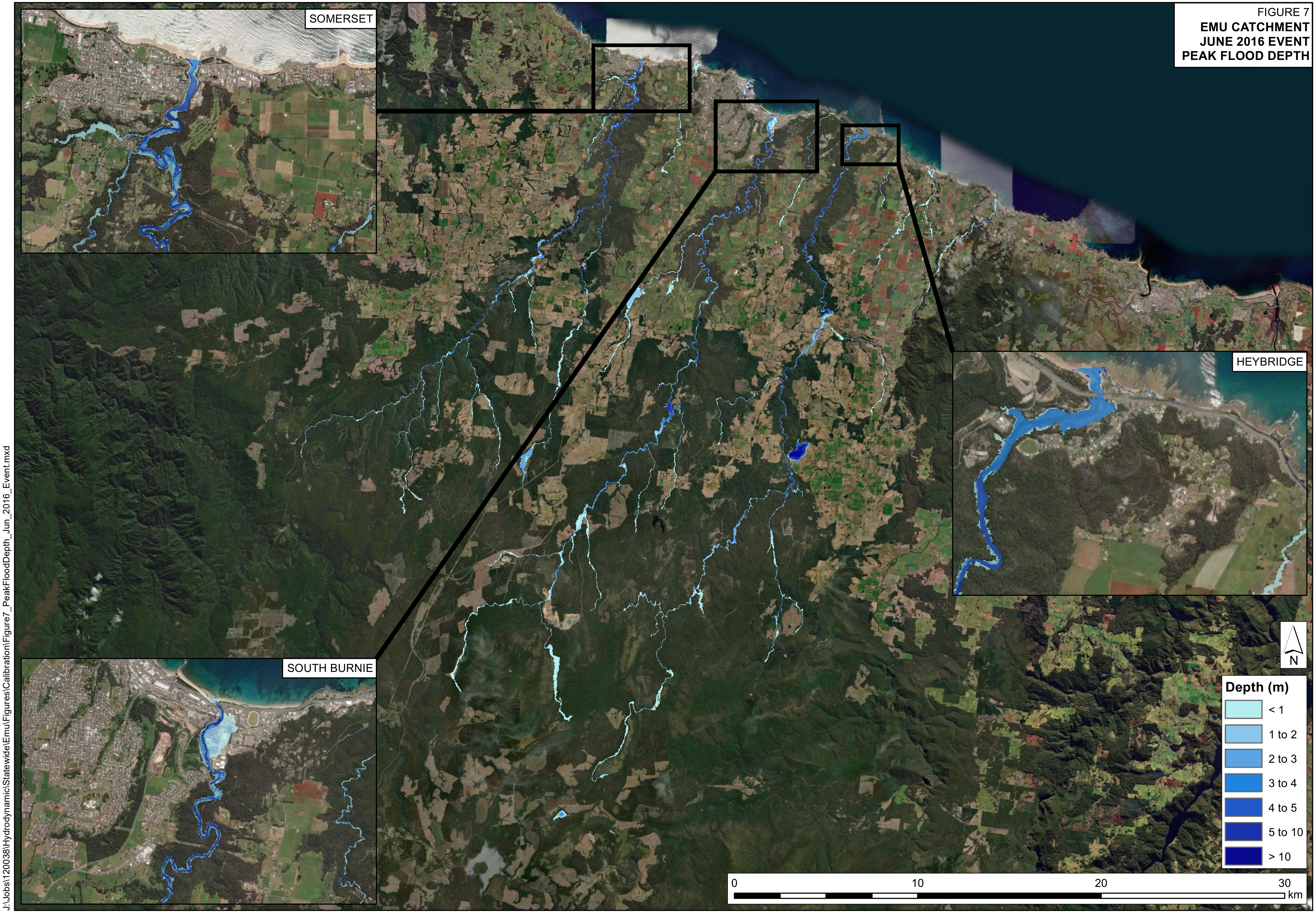

FIGURE 7
EMU CATCHMENT
JUNE 2016 EVENT
PEAK FLOOD DEPTH
SOMERSET
SOUTH BURNIE
HEYBRIDGE
N
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
10
20
30
km
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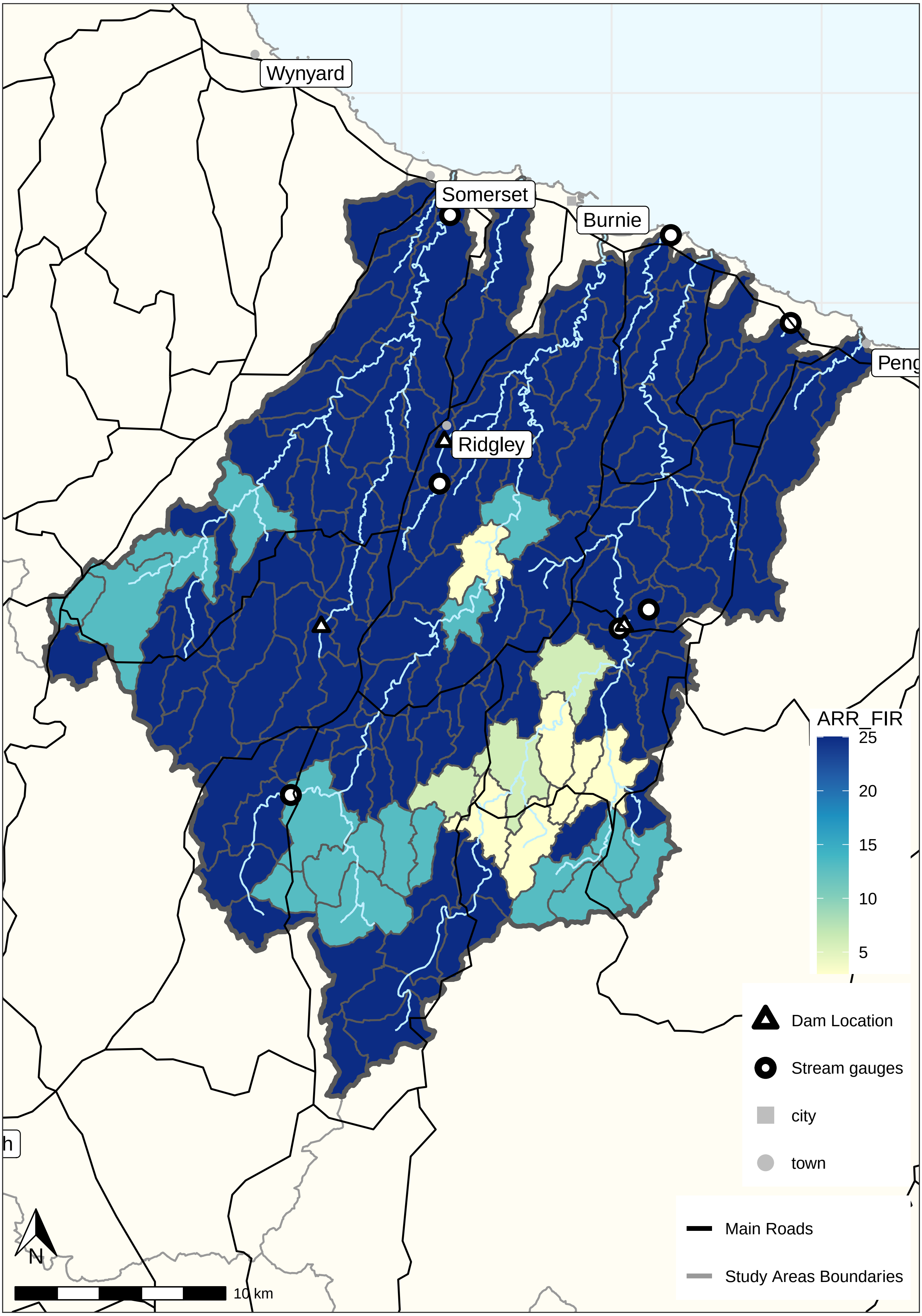
Appendix A

APPENDIX A. AVALIABLE DATA

A.1. Sub catchment Data

FIGURE A1
HYDROLOGICAL SOIL GROUP MAPPING
DOMINANT SUBCATCHMENT SOIL INFILTRATION RATE



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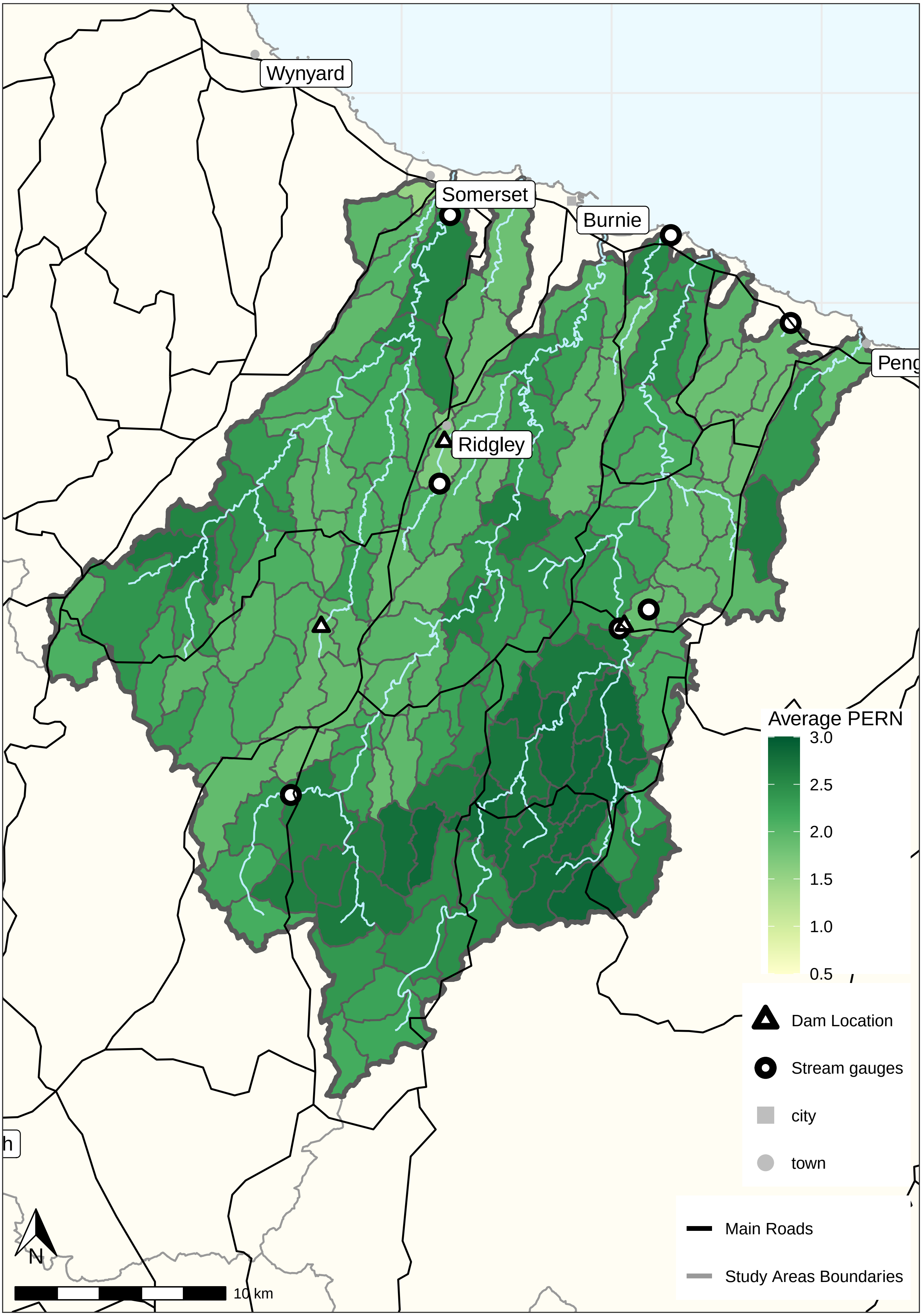
J:/Jobs/120038/Hydrology/Statewide/Calibration/Emu/Subcatchment_rainfalls/Figure_A1_Emu_SoilTypesReport.pdf

FIGURE A2
EMU STUDY AREA
SUBCATCHMENT AVERAGE PERN



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Appendix B

APPENDIX B. UNCERTAINTY ANALYSIS

B.1. Hydrologic Model Uncertainty

Table B 1 shows the calibration event rating with relevant statements highlighted in green. For observed flows Cam River u/s Somerset WS is shown in green shading for the January 2011 event. Gaugings and ratings were not provided for the Blythe River us South Riana Rd gauge.

Table B 1: Hydrology calibration event rating

Category	Rating				
	Poor	**Fair**	**Good**	**Very good**	**Excellent**
Rainfall input quality	Nearest pluvi > 15 km from catchment in unrepresentative location	Nearest pluvi > 15km from the catchment in similar climate area	Pluvi within the catchment or within 15km	1 pluvi within or very near catchment for each 300km2 of catchment area	1 pluvi within catchment for each 150km^2 of catchment area (spaced out)
	No daily rainfall sites within 15 km of catchment	No daily rainfall sites within 10 km of catchment	One daily rainfall site within 10 km of catchment in similar climate area	multiple gauges within 15km in different directions	multiple gauges within 10km in different directions
	Known high rainfall gradients (from BoM or investigation of surrounding gauges)	Known rainfall gradients for calibration events	No known large spatial variation in event rainfall relative to gauges	Event rainfall known to be generally spatially uniform if catchment is large, or well represented by raingauges	Event rainfall known to be spatially uniform if catchment is large, or well represented by raingauges
Observed flows	Highest gauging within channel and flow breaks out of channel at high flows.	Rating or gauging info unavailable, but flow contained in channel.	Calibration event is out of channel, good set of gaugings but no gaugings out of channel	Calibration event is out of channel, site has been gauged out of channel during different rating period (with changes at top end)	Calibration event is out of channel, site has been gauged during applicable rating period out of channel
	Rating extrapolated with no consideration for shape of cross section	Rating extrapolated with no consideration for shape of cross section	Rating shows consideration to shape of cross section	Rating shows consideration to shape of cross section	Rating shows consideration to shape of cross section
Calibration events	Smaller than 20% AEP	Between 20% and 10%	Between 10% and 5%	Between 5% and 2% AEP	Larger than 2% AEP or

		AEP	AEP	or within largest 4 events on record	within largest 2 events on record

Table B 2 shows the hydrology calibration quality rating. The following shading is used to highlight relevant statements:

- Calibration at Cam River gauge for January 2011 event is shown with blue shading
- Calibration at Blythe River gauge for June 2016 event is shown with orange shading

Table B 2: Hydrology calibration quality rating

Category	Rating				
	Poor	**Fair**	**Good**	**Very good**	**Excellent**
Hydrology calibration results – peak flow	Peak varies by more than 30%	Peak within 30% of observed	Peak within 20% of observed	Peak within 15% of observed	Peak within 10% of observed
Hydrology calibration results – hydrograph volume	Volume varies by more than 30%	Volume within 30% of observed	Volume within 20% of observed	Volume within 15% of observed	Volume within 10% of observed
Hydrology calibration results – hydrograph shape	Poor match to shape – modelled event routing does not match observed	Modelled and observed hydrographs have some similarities in shape	General characteristics of the modelled and observed hydrograph shape match in either rising limb or falling limb	Shape of the event generally matches well in rising and falling limbs	Shape of the event matches well including rising and falling limbs and recession

B.2. DTM Uncertainty

The overall study area DTM quality rating is shown in Table B 3 with green shading.

Table B 3: DTM rating

Category	Rating				
	Poor	Fair	Good	Very good	Excellent
DTM definition	Low resolution	Low resolution	High resolution at HSA/gauges	High resolution in HSA	High resolution in >60% of catchment
	Minimal Ground Control Points (GCP)	Minimal GCP	Reasonable GCP coverage	Good GCP coverage	Good GCP coverage
DTM waterways	Bathymetrical data unavailable	Bathymetrical data poor – e.g. LiDAR with estimated bathymetric information	Bathymetrical data reasonable	Bathymetrical data good	Detailed bathymetrical survey data available

B.3. Hydrodynamic Modelling Uncertainty

The hydrodynamic calibration event rating is shown in Table B 4, with general statements highlighted in green.

Table B 4: Hydrodynamic calibration event rating

Category	Rating				
	Poor	Fair	Good	Very good	Excellent
Calibration flood levels	Water level gauge data not available	Water level gauge data available	Water level gauge data available	Water level gauge data available	Water level gauge data available
		gauge zero level inferred	gauge zero level is known	gauge zero level is known	gauge zero level is known
		Sporadic water level gauge data available for event, low confidence in data	Reasonable confidence in gauged levels based on review of historic data	Good confidence in gauged levels based on review of historic data	Gauge is known to be regularly calibrated and of good quality (e.g. BOM flood warning sites)
Calibration flood depths	No survey extent available	Survey extent available with high uncertainty – few survey points and mostly interpolated	Survey extent available with medium uncertainty – survey points in critical areas, significant areas interpolated	Survey extent available with reasonable certainty – many survey points and limited interpolation	Survey extent available with survey points in all critical areas and limited interpolation

The hydrodynamic calibration event rating is shown in Table B 5 with relevant statements highlighted in green.

Table B 5: Hydrodynamic calibration quality rating

Category	Rating				
	Poor	Fair	Good	Very good	Excellent
Hydrodynamic calibration - peak levels at gauges	Peak level > +/- 1m of observed	Peak level within +/- 0.5m of observed	Peak within +/-0.5m of observed	Peak within +/-0.3m of observed	Peak within +/- 0.3m of observed
Hydrodynamic calibration – flood extents	Extent > 50m difference from observed	Extent lies within +/- 50m of recorded	Extent lies within +/- 20m of recorded	Extent lies within +/- 10m of recorded	Extent lies within +/- 5m of recorded
Hydrodynamic calibration - depths	Depth within > +/- 1m of Survey	Depth within +/- 1 m of Survey	Depth within +/- 0.5m of Survey	Depth within +/- 0.3m of Survey	Depth within +/- 0.3m of Survey

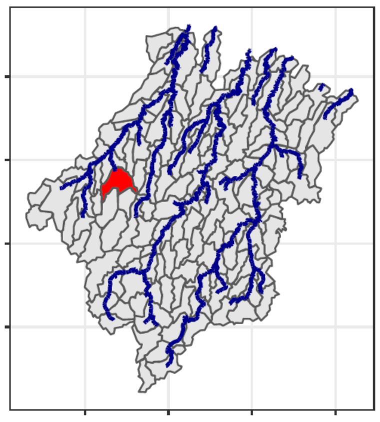
Appendix C

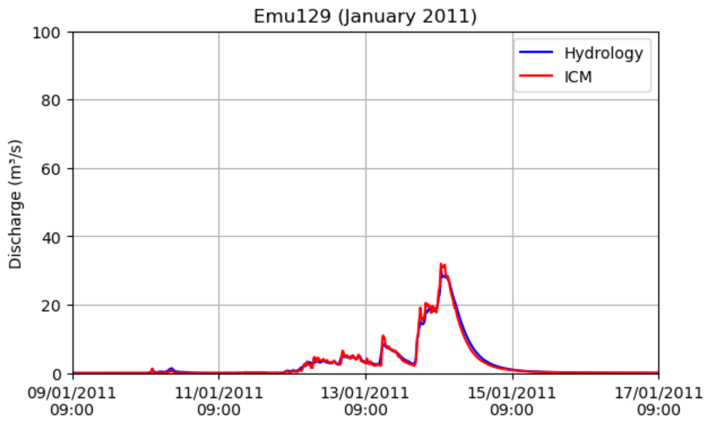
APPENDIX C. EXTERNAL HYDROLOGY MODEL AND ICM HYDRODYNAMIC MODEL COMPARISON

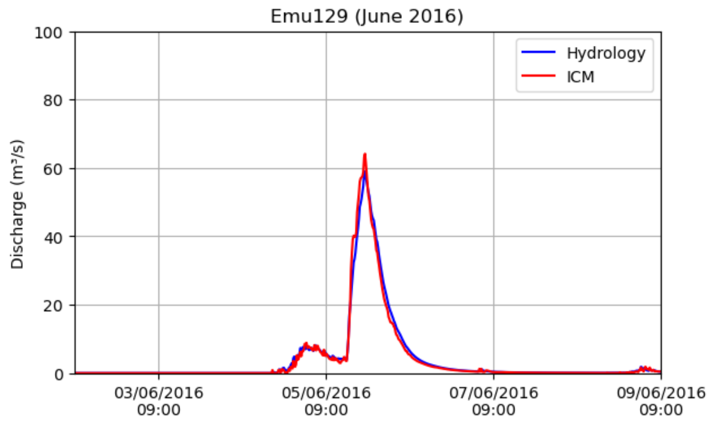
Figure C 1: Event hydrographs

Catchment	January 2011	June 2016

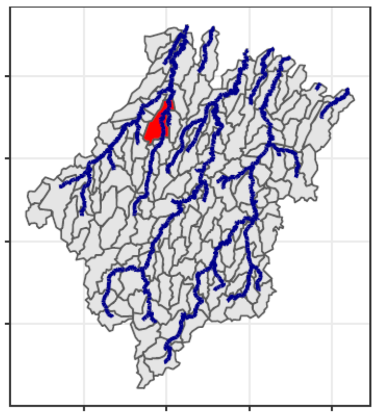
Emu129

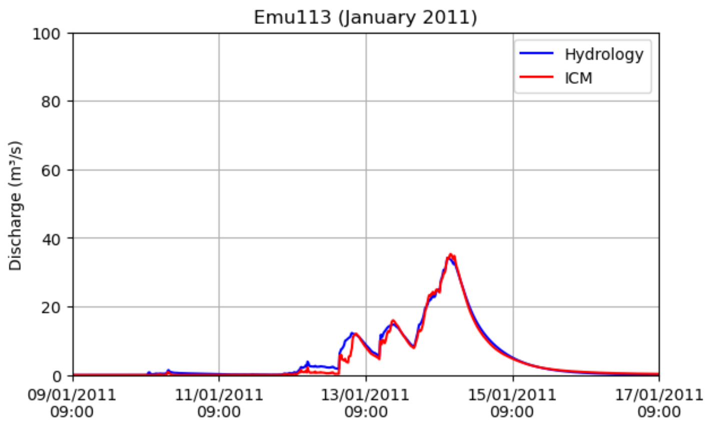


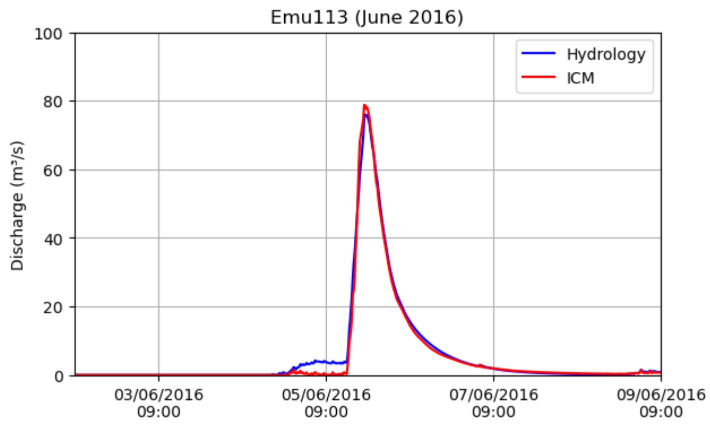




Emu113







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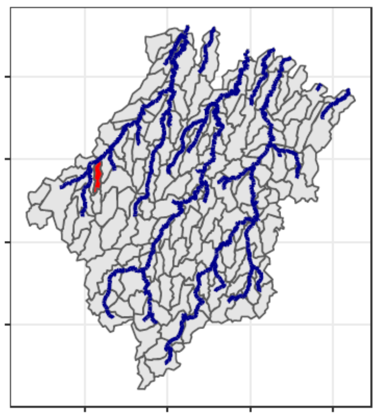
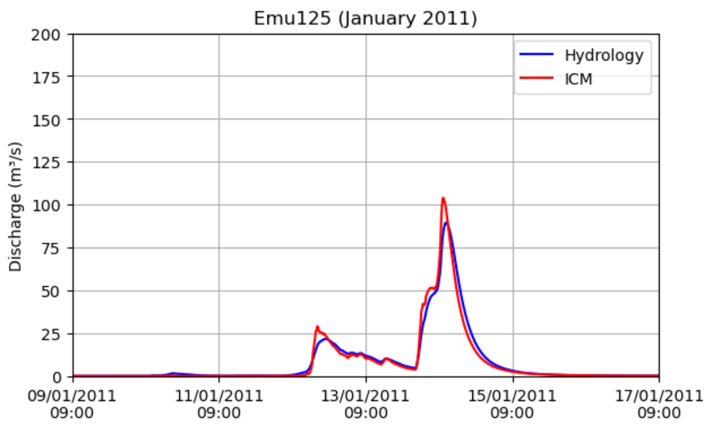
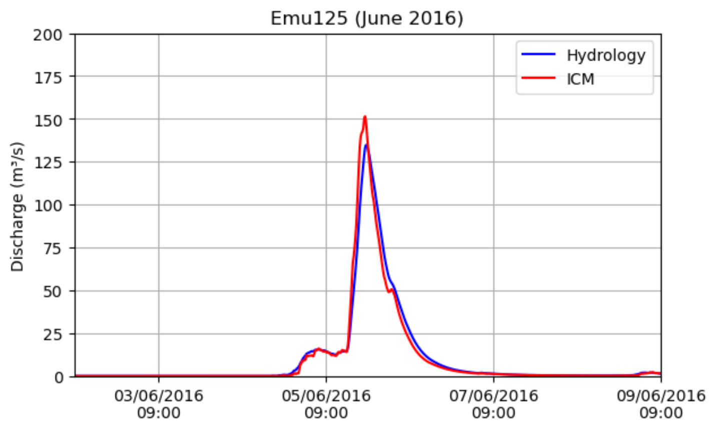
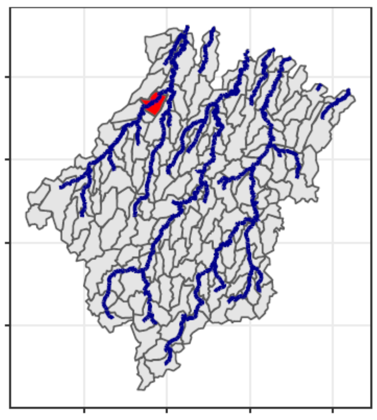
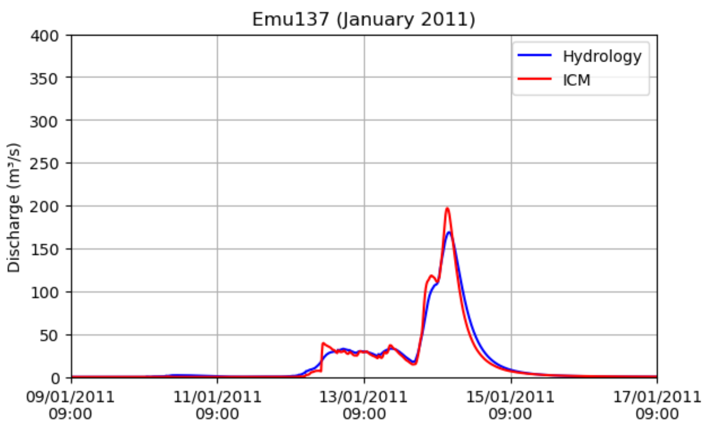


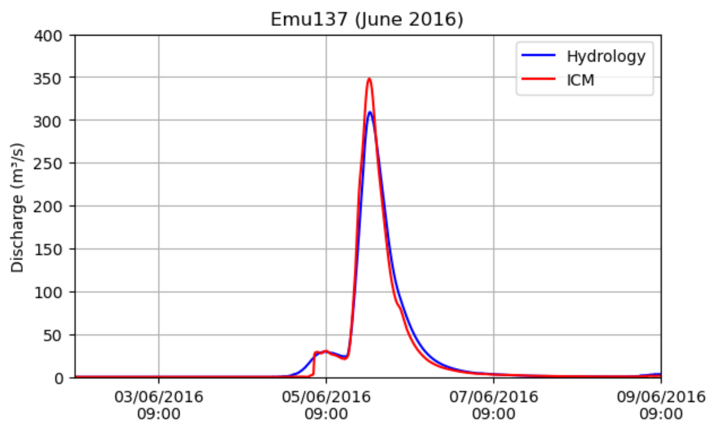




Emu137







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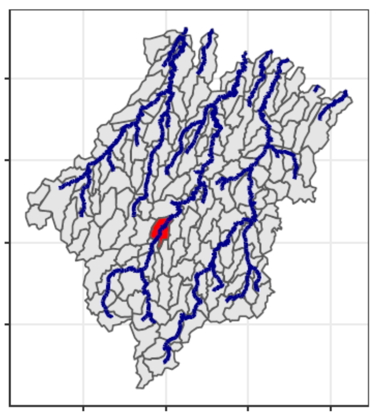

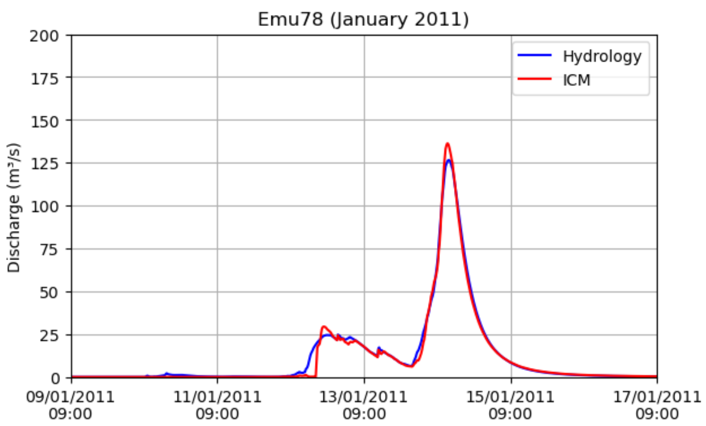

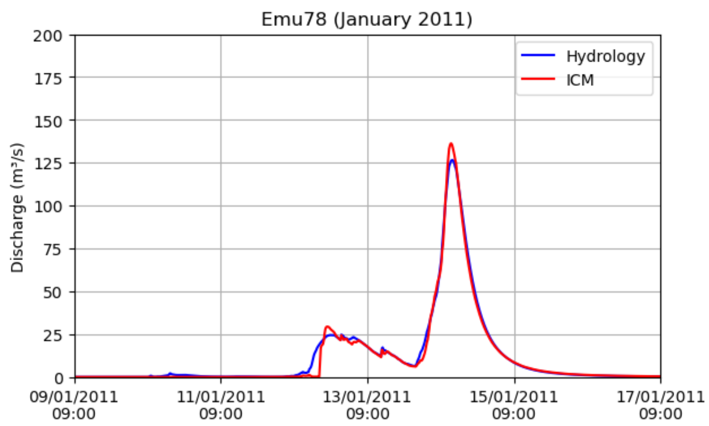

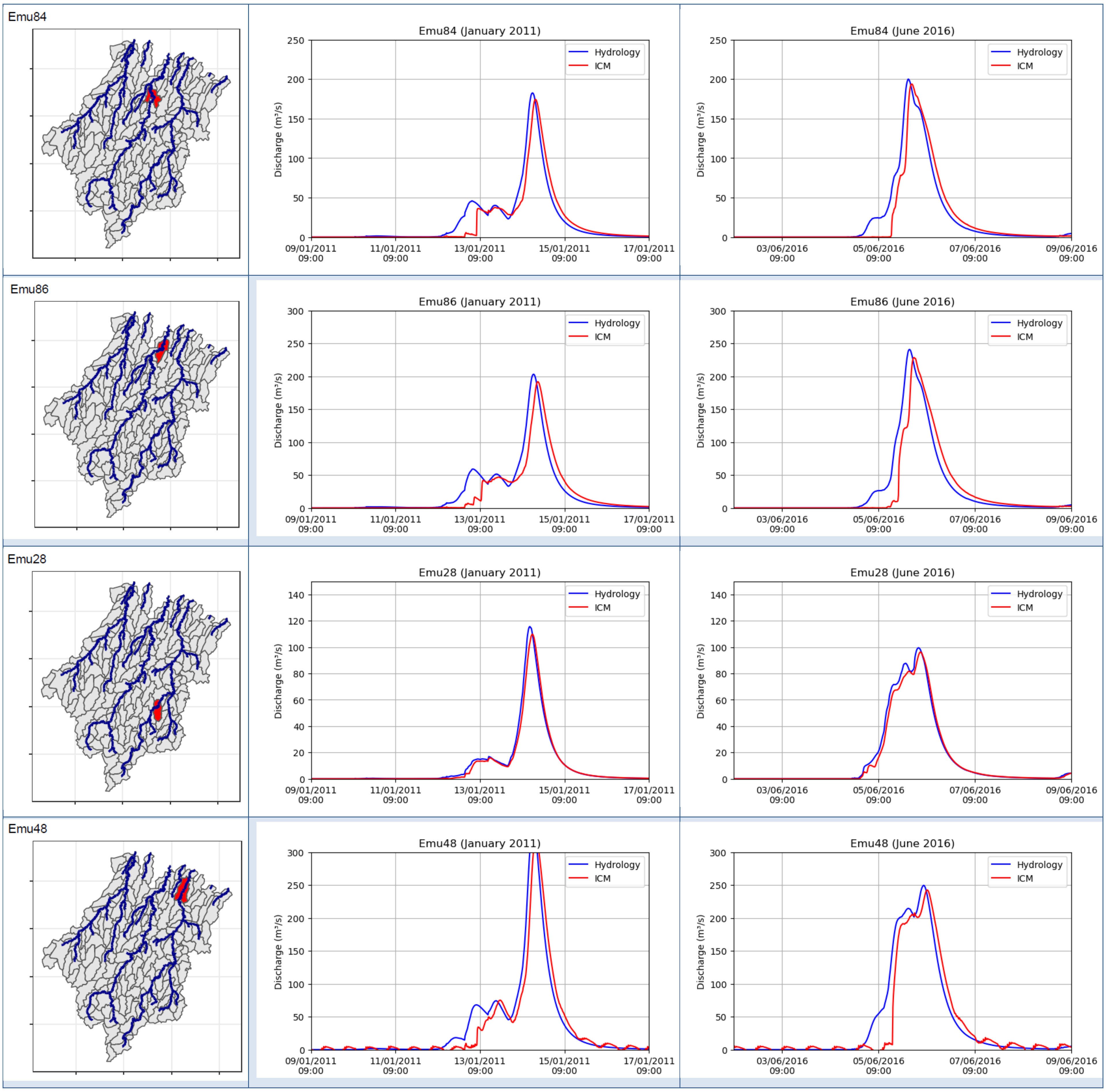
Emu84
Emu84 (January 2011)
Emu84 (June 2016)
Emu86
Emu86 (January 2011)
Emu86 (June 2016)
Emu28
Emu28 (January 2011)
Emu28 (June 2016)
Emu48
Emu48 (January 2011)
Emu48 (June 2016)
Hydrology
ICM
Discharge (m³/s)
09/01/2011 09:00
11/01/2011 09:00
13/01/2011 09:00
15/01/2011 09:00
17/01/2011 09:00
03/06/2016 09:00
05/06/2016 09:00
07/06/2016 09:00
09/06/2016 09:00

Appendix D

APPENDIX D. OTHER LOCATIONS

The Chasm Creek and Sulphur Creek gauges were of limited value to the model calibration due to extractions from the creeks and small dams in the catchment, that have insufficient information to be included in the model. The results at these locations, however, have been presented here to demonstrate this limitation of the modelling. Model calibration at these locations was not undertaken.

D.1. Chasm Creek u/s Bass Highway

The modelled flows and levels for the Chasm Creek gauge are shown in Table D 1 and Diagram D 1 to Diagram D 2. A gauge zero was not available, so an assumed gauge zero of 6.3 mAHD was used.

Table D 1: Results at Chasm Creek u/s Bass Highway

Statistic	2011 January	2016 June
Modelled Peak (m^3/s)	8.2	8.3
Observed Peak (m^3/s)	5.9	4.2
Peak % difference	+39%	+98%
Modelled Volume (ML)	854	535
Observed Volume (ML)	1130	782
Volume % difference	-24%	-32%
Modelled peak (mAHD)	7.63	7.64
Observed peak (mAHD)	7.77	7.44
Peak difference (m)	-0.14m	+0.20m

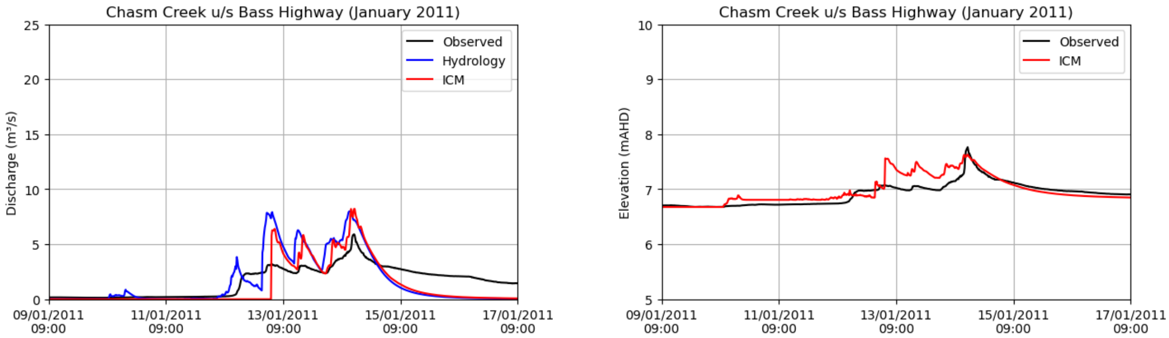

Figure D 1: January 2011 results at Chasm Creek u/s Bass Highway (left: flows, right: levels)

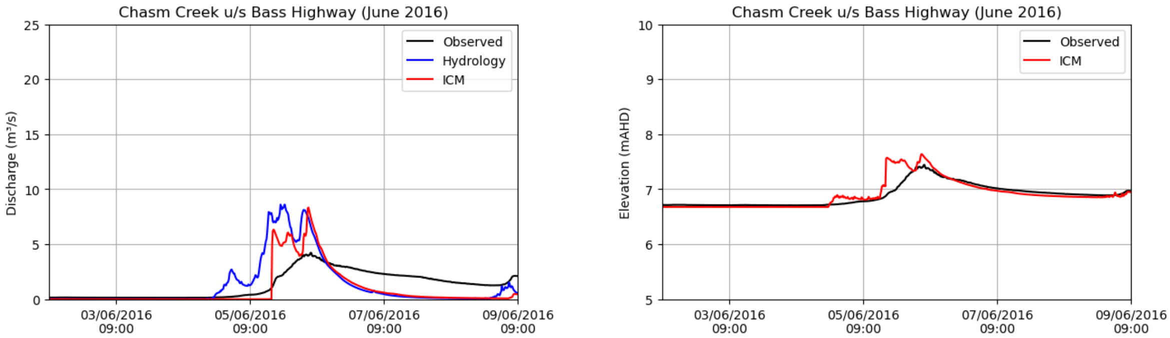

Figure D 2: June 2016 results at Chasm Creek u/s Bass Highway (left: flows, right: levels)

D.2. Sulphur Creek 1.5km u/s Mouth

The modelled flows and levels for the Chasm Creek gauge are shown in Table D 2 and Diagram D 3 to Diagram D 4. A gauge zero was not available, so an assumed gauge zero of 32.0 mAHD was used.

Table D 2: Results at Sulphur Creek 1.5km u/s Mouth

Statistic	2011 January	2016 June
Modelled Peak (m^3/s)	13.5	9.2
Observed Peak (m^3/s)	5.1	2.4
Peak % difference	+165%	+283%
Modelled Volume (ML)	1519	701
Observed Volume (ML)	822	560
Volume % difference	+85%	+25%
Modelled peak (mAHD)	33.22	33.12
Observed peak (mAHD)	32.70	32.42
Peak difference (m)	+0.52m	+0.70m

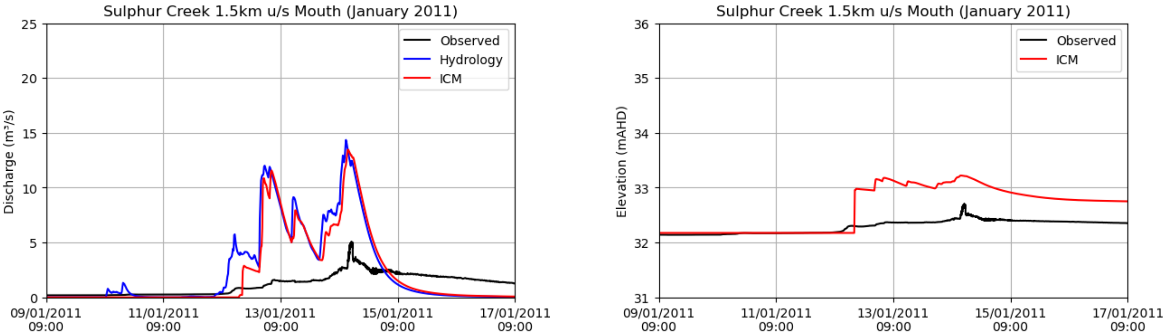

Figure D 3: January 2011 results at Sulphur Creek 1.5km u/s Mouth (left: flows, right: levels)

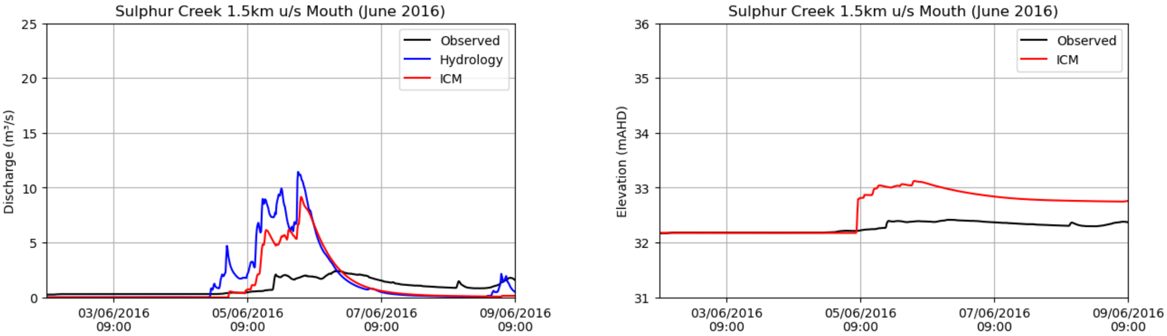

Figure D 4: June 2016 results at Sulphur Creek 1.5km u/s Mouth (left: flows, right: levels)