STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP
PIPERS STUDY AREA MODEL CALIBRATION

REPORT

MARCH 2023

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Project Tasmanian Strategic Flood Map Pipers Study Area Model Calibration	**Project Number** **120038**
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Revision History

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Cover image: From Visit Northern Tasmania -https://visitnortherntasmania.com.au/experience/pipers-river-board-walk

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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
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 Pipers study area.

2. STUDY AREA

The Pipers River study area is situated in the northern Tasmania. It is located approximately 10-30 km east of the Tasman Estuary. The major river in the study area is the Pipers River starting on the slopes of Mt Arthur and the Eaglehawk Tiers in the south east of the study area. The main other rivers are the Back Creek and Pipers Brook, which both flows into the Pipers Estuary, and Curries River in the west of the catchment. There are also a number of small creeks in the study area which discharge directly into Bass Strait.

The study area includes large forested areas, cleared areas used for grazing and cropping, and forestry plantations. The catchment includes numerous rural centres in the study area generally with populations less than 400 people. These include: Lilydale, Lebrina, Karoola, Lanena, Lalla and Pipers River as well as some small coastal towns including Weymouth, Bellingham, Lulworth and Beechford. Curries River Dam in the far west of the study area is a 12,000 ML storage used for water supply.

The Pipers study area has an area of 753 km^2. The Pipers River catchment (upstream of creeks flowing into its estuary) covers 465km^2. The Pipers study area and the available gauge information are shown in Figure 1. Landuse in the Pipers study area is shown in Figure 2.

3. AVAILABLE DATA

3.1. Historic Flow Data and Level Data

There are two flow gauges with data available in the Pipers study area, as shown in Table 1. These gauges are owned by DPIPWE, who supplied timeseries of flows, ratings and gaugings for these sites. Pipers River at Underwood has a very long record period however has several decades of missing flows between the late 1960s and late 2000s, with only about 10 years of data available over this period. The data at Pipers d/s Yarrow is largely complete across its period of record. Both gauges are still operational.

The gauge at Pipers River at Underwood is in the upper reaches of the catchment, covering approximately 1/5th of the catchment area of Pipers d/s Yarrow.

Table 1: Flow gauges

Gauge attribute	Pipers River D/S Yarrow Ck	Pipers River at Underwood
Gauge number	19204-1	116-1
Gauge abbreviated name	Pipers d/s Yarrow	Pipers at Underwood
Start date	26/04/1972	03/04/1952
End date	Current	Current
Latitude	-41.06	-41.29
Longitude	147.11	147.20
High flow rating quality	Fair – some higher flow gaugings, with some inconsistency. Rating extrapolated to high flows.	Original DPIPWE rating considered poor for high flows. Theoretical rating developed using local hydraulic model.
Used for calibration	Yes	Yes
Assumed local datum 0m in AHD	13.00	227.28
Highest Gauged Level (m local datum)	2.70	0.96
Highest recorded stage height (m local datum)	3.5	1.9
Highest recorded flow (m^3/s)	449	67
Highest recorded stage height date	06/06/2016	25/07/1988
Highest recorded flow date	06/06/2016	25/07/1988

3.1.1. Calibration Event Data Availability

Despite being on the same river, many events are only significant at one of the two gauges on the Pipers River. There can be steep rainfall gradients, which means that there can be larger events in the upper catchment around the Underwood gauge, that are not significant at the D/S Yarrow Creek gauge. There can also be widespread events over the whole catchment where there are not high rainfalls in the Underwood gauge catchment. For calibration, significant flows were recorded in the catchment area for only one of the 13 flood events selected by the Bureau as calibration events for this project (Table 2). This was June 2016 which was the largest on record at Pipers d/s Yarrow (approximately AEP between 1% and 2%), as Pipers at Underwood gauge ceased recording on the rising limb of this event. To provide a second calibration event, an additional event was selected (WMAwater 2021d). This was the August 2013 event. This event was the 6th largest on record at Pipers at Underwood and while it was only the 9th largest at Pipers d/s Yarrow it was the largest event available with nearby sub-daily rainfall data, and was approximately a 20% AEP event at both gauges.

Table 2: Summary of the largest events in the Pipers study area

Event name	Used for calibration	Event peak flow (m^3/s) (location)
2013_Aug	Yes Yes	156 (Pipers d/s Yarrow) 40 (Pipers at Underwood)
2016_Jun	Yes No, but used as verification	449 (Pipers d/s Yarrow) 41 (Pipers at Underwood) *

* Gauge cut out on the rising limb

3.1.2. Rating Curve Quality

The high flow rating curve at Pipers d/s Yarrow appears to be entirely pinned on two gaugings taken on one day in 1992 (Diagram 1). These gaugings, along with 5-6 gaugings taken in the 1980s which plot significantly off the rating curve, are the only gaugings at the site above the confines of the weir. Therefore the quality of the high flow rating is highly uncertain at this site. DPIPWE has given a quality coded of "unknown" for the flows for the June 2016 event at this site and given a quality code of good for the August 2013 event.

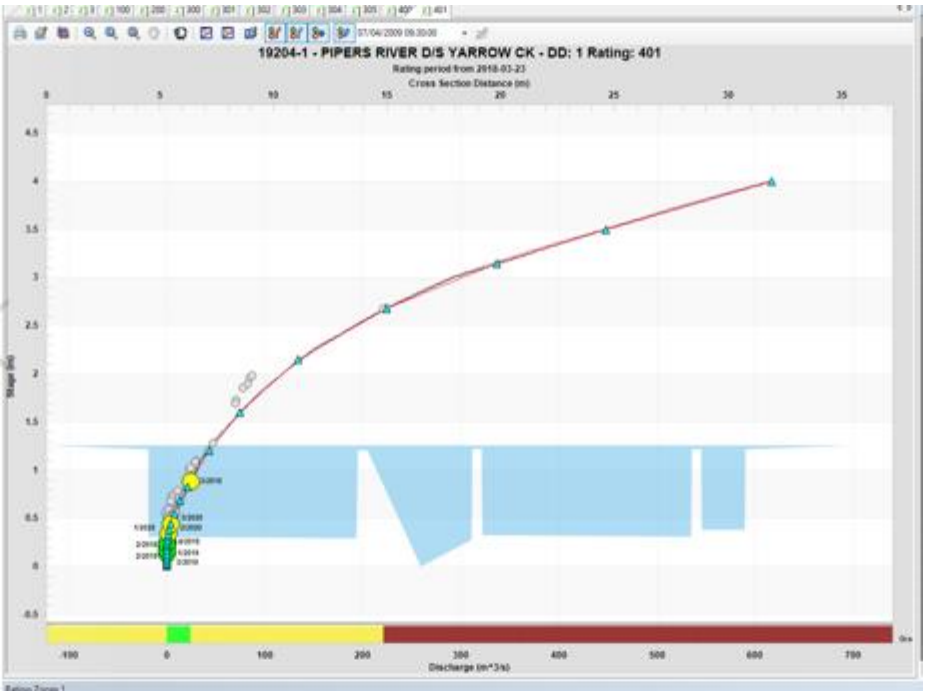

Diagram 1: Pipers River d/s Yarrow Creek rating

The DPIPWE rating for Pipers at Underwood gauge was extrapolated to high flows and does not appear to account for the shape of the cross section. To improve the quality of the high flow rating for Pipers at Underwood, a theoretical rating was developed using a local hydraulic model (WMAwater, 2021c). This rating has been used in calibration (Diagram 2).

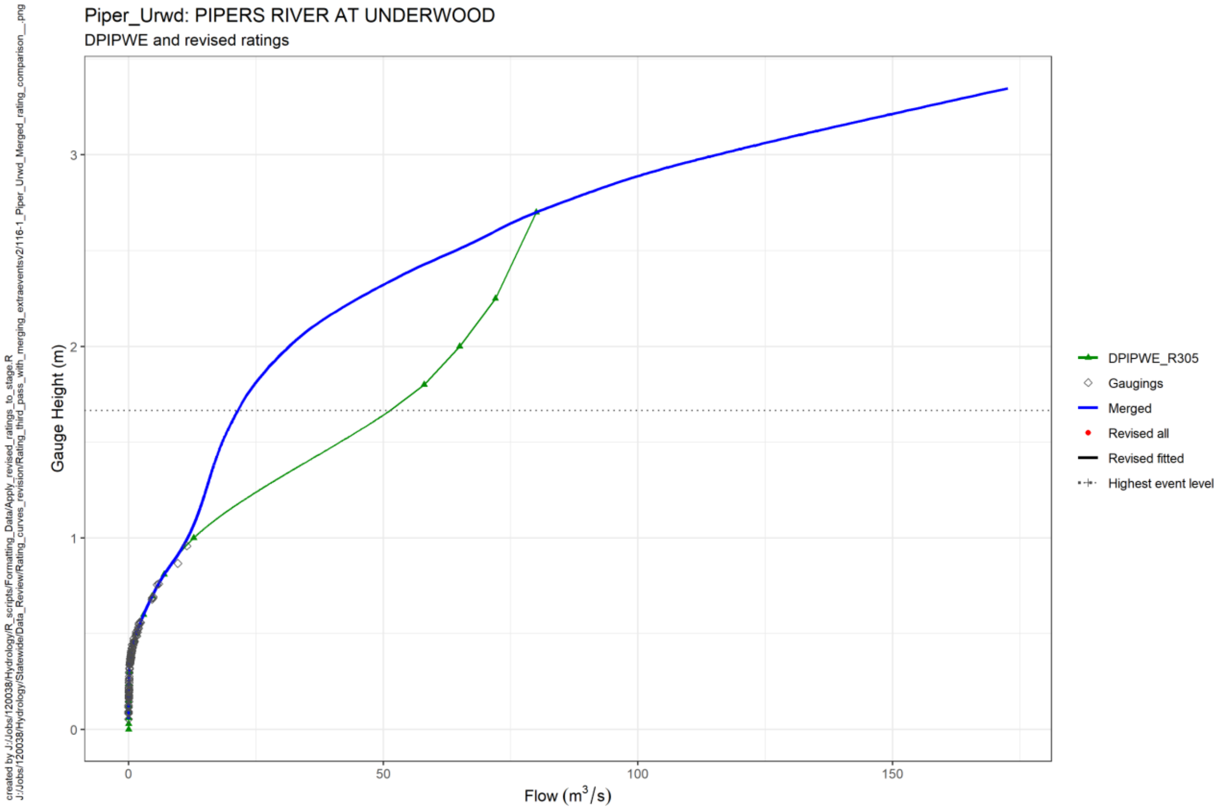

Diagram 2: Pipers at Underwood - revised rating

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 Pipers study area (see Data Review Report WMAwater (2020) for details on calibration events). The 2013 calibration event at this site was selected as an additional event for calibration (WMAwater, 2021d).

The AWS and pluvio data were found to be the most consistently reliable data. 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.

A summary of the rain gauges and rainfall totals for this study area is shown in Table 3. There are two sub-daily rain gauges in the Pipers catchment, however the gauge at the Pipers d/s

Yarrow site only has data available for the June 2016 event. There is good coverage of gauges in the surrounding catchments. The gauges in and around the Pipers study area are shown in Figure 1.

Table 3: Available Rainfall Information

	August 2013	June 2016
Number of Sub-daily Stations Available within the study area	1	2
Number of daily Stations Available within the study area	1	5
Number of sub-daily surrounding gauges ~15km	8	6
Number of daily surrounding gauges ~15km	9	11
Rainfall Totals	40-90 mm	90-160 mm
Approx duration of rainfall event (hours)	36	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 each of the selected calibration events using an inverse distance weighting method. The method is described in detail in WMAwater 2021 and is summarised below.

1. Daily rainfall data from all gauges within Tasmania was extracted for each of the seven calibration events from 2000 – 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.

The rainfall surfaces for the selected calibration events are shown in Figure 3 to Figure 4.

3.3. Dam information

There is one significant dam in the Pipers study area, operated by TasWater. Curries River Dam is located in the west of the study area on the Curries River, which flows into Bass Strait west of Pipers River. Curries River Reservoir is a large Dam (12,000 ML) on a relatively small catchment (~17 km^2). Spillway and storage rating curves were provided by TasWater for this project.

3.4. Flood Levels and Extents

There was no information on flood levels or extents provided for this study area.

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 both of the gauges used for calibration in the catchment, with the SES state-wide 10 m DEM used for a small part of the study area around Curries River Dam and in the far eastern area. 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 (Diagram 3), was then imported into ICM via the grid import interface.

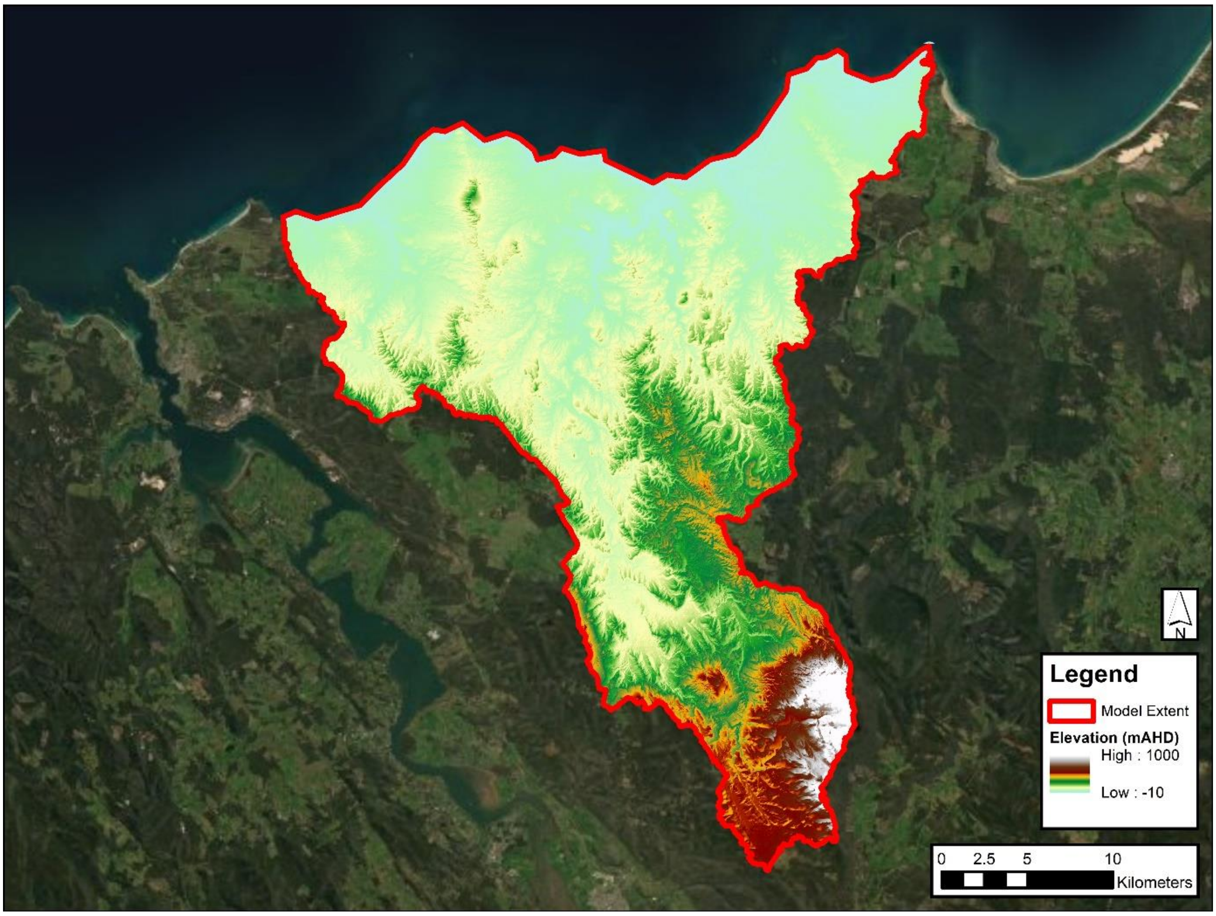

Diagram 3: DEM of the Pipers study area

The ‘Default DTM’ is understood to be comprised primarily of photogrammetric contour data, and this is the basis of the DEM in the north east corner of the catchment (Diagram 4). The ‘Default DTM’ is likely to be a poor representation of the topography of the area. Additionally, it is understood that the ‘Default DTM’ provided for the modelling was pre-processed to include the estimated bathymetry of watercourses.

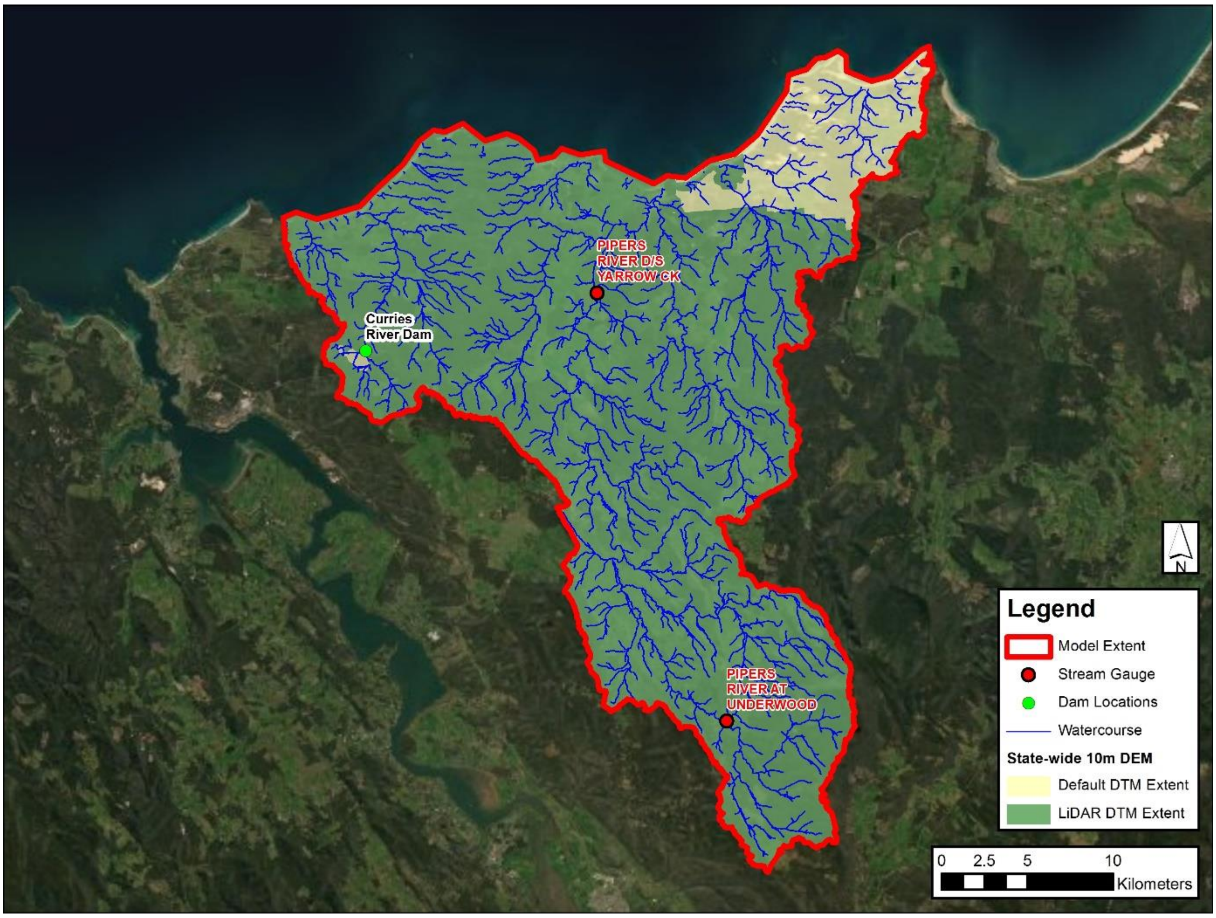

Diagram 4: 'Default DTM' extents for the Pipers study area

5.2. Roughness

The base information for the roughness grid was the roughness raster provided by SES for this project. The whole of state dataset was converted to a set of polygons for each land use zone in GIS, and the dataset was cleaned to ensure that the geometry was valid. This data was then exported as a csv file to link land use to friction values.

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 30 m buffered zone of single roughness of 0.05 for all upper streams was utilised. 0.05 was selected as in the upper reaches the computation of levels in triangles also results in artificial attenuation of flow, and thus a slightly lower value than the norm was utilised.

This change will be revised on a case-by-case basis in future assessments as it is managing a very specific issue. The values derived are shown in the 'Hydrodynamic Modelling Report' (WMAwater, 2021b). The roughness layer in ICM is shown in Diagram 5.

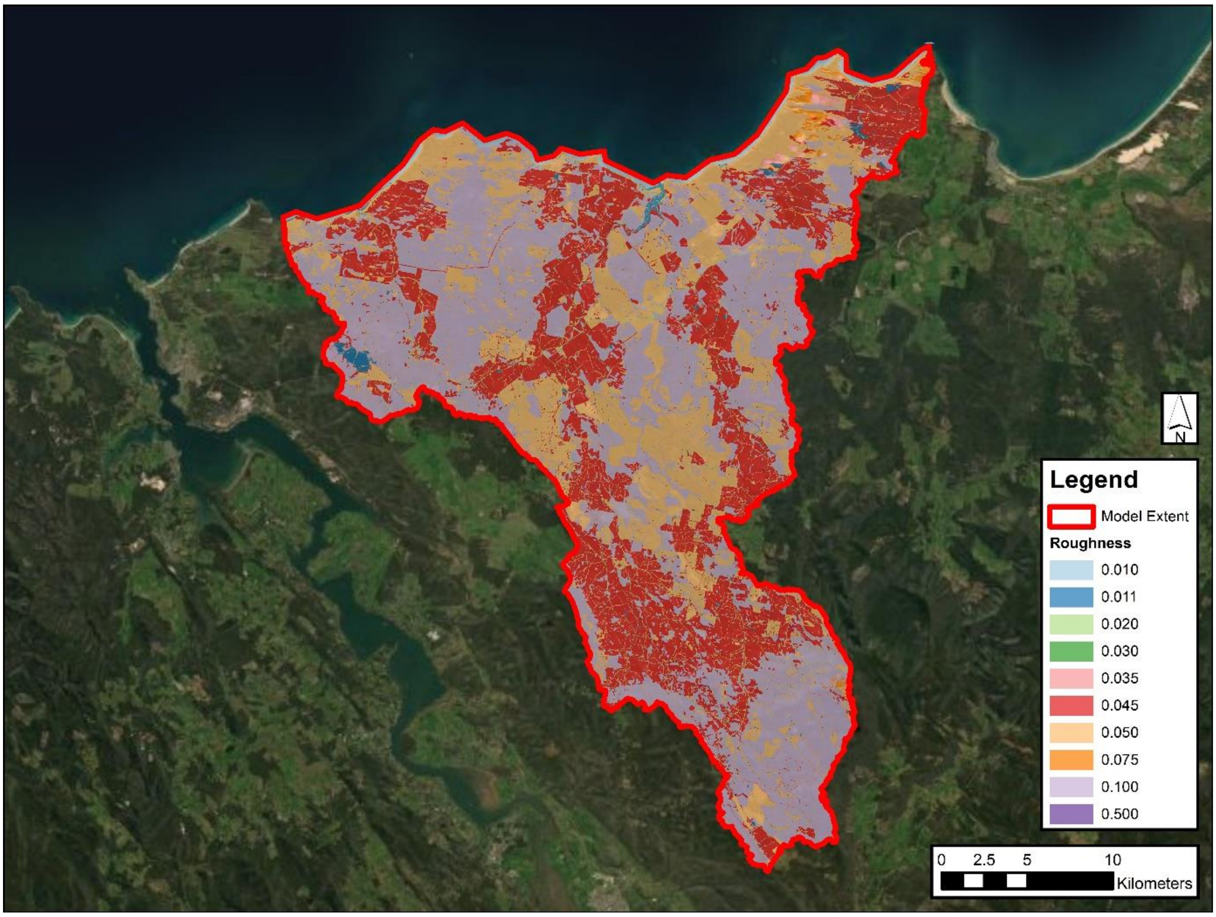

Diagram 5: Roughness layer for the Pipers study area

5.3. Meshing

Meshing in ICM was undertaken using zones, with the following rules:

- Base 2D zone – regional extent mesh size set to a maximum of 2500 m^2 with a minimum of 400 m^2
- Stream zone – set as an independent area with a maximum mesh size of 400 m^2 and a minimum of 100 m^2
- Human Settlement Area – set as an independent mesh zone with a maximum area of 100 m^2 and a minimum of 25 m^2
- Upper stream reaches – streamlines of Strahler order 2-5 were buffered by 10 m either side of the centre line with Strahler order 6-8 buffered by 20 m either side of the centre line and incorporated into the hydrodynamic model as a mesh zone. The mesh zones had a maximum area of 150 m^2. This process was to ensure that the meshing process did not result in artificial blocking of the flow paths along main stream lines.

The lower gauge is located within the base stream mesh zone. Noting this zone is of lower resolution than the upper stream mesh zone, the model in this area was updated to incorporate a mesh resolution consistent with the upper stream mesh zones. The resulting mesh zones for the Pipers study area are shown in Diagram 6.

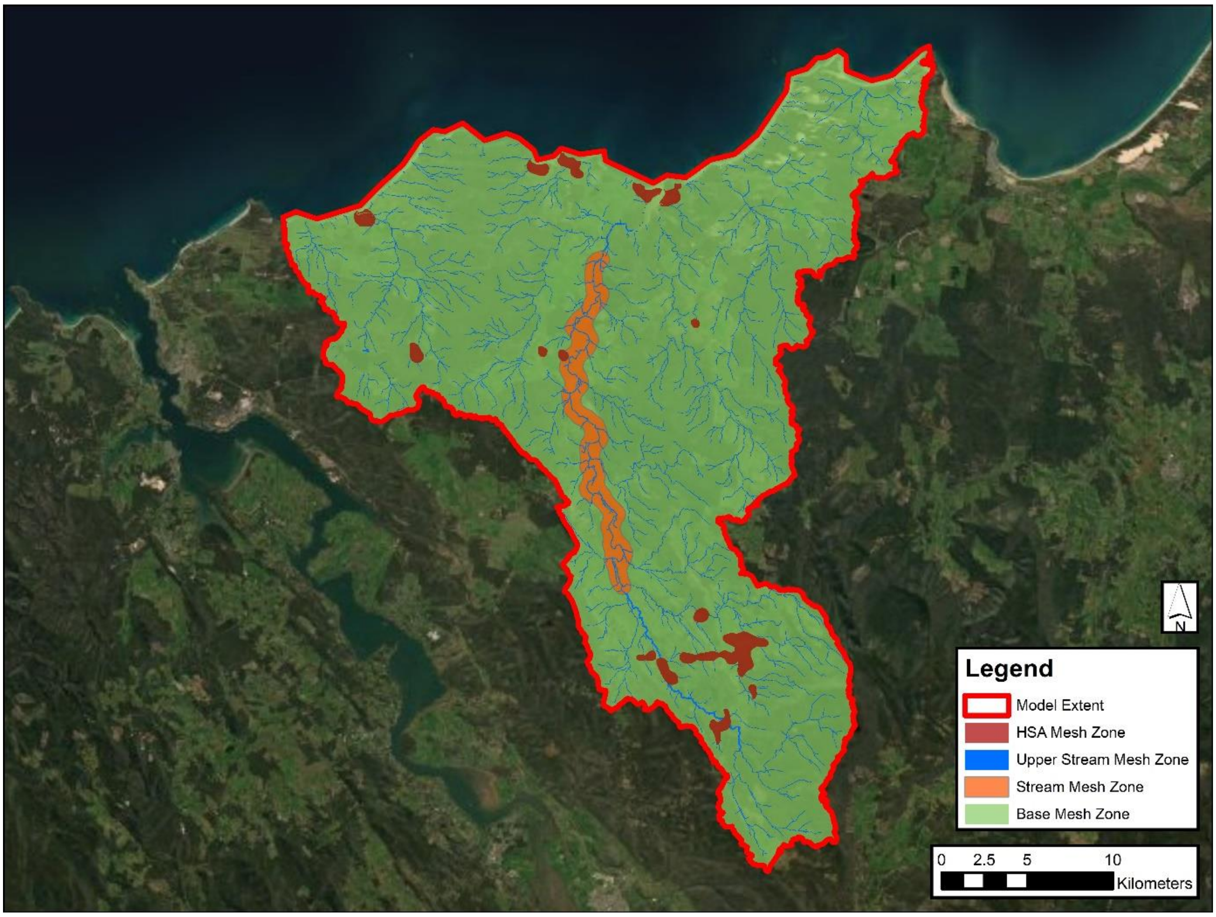

Diagram 6: Mesh zones for the Pipers study area

5.4. Structures

Bridges are represented within the ICM model as linear 2D bridge structures, using the SES state-wide bridge database for location and reach of associated structures.

For the Pipers study area only one bridge longer than 30 m was identified and imported into the hydrodynamic model. This bridge was location at Pipers River at Bridport Road. Further discussion on this process is provided in the Hydrodynamic Modelling Methods Report (WMAwater, 2021b). No major culverts were identified.

5.5. Dams and Storage areas

Curries Dam spill was modelled using a head dependent discharge table in ICM to replicate TasWater's spillway curve. The storage area was modelled utilising the 2-dimensional surface to represent the storage available.

5.6. Downstream Boundaries

Downstream boundaries were applied at the base of the model to provide interaction with the tidal zone. Synthetic tide data was provided by the Bureau of Meteorology (BOM) for the original 13 calibration events and was used to set a varying tide level for the calibration events. This data was extracted off the coast of the Lulworth at 10 min time increments and was imported into ICM as a time varying boundary condition. Synthetic tide data was not available for the August 2013 event as it was selected as a calibration event at a later stage (Section 3.2), therefore observed tide data from the Burnie gauge was used for this event (BOM 2021). Diagram 7 and Diagram 8 show examples of the observed and synthetic tide data that was extracted for the calibration events.

Note there is no calibration information to verify the function of the tailwater condition, thus no allowance for local storm effects has been undertaken. It is considered the observed and synthetic tide data are reasonable estimations of tailwater levels for the purposes of calibration assessment.

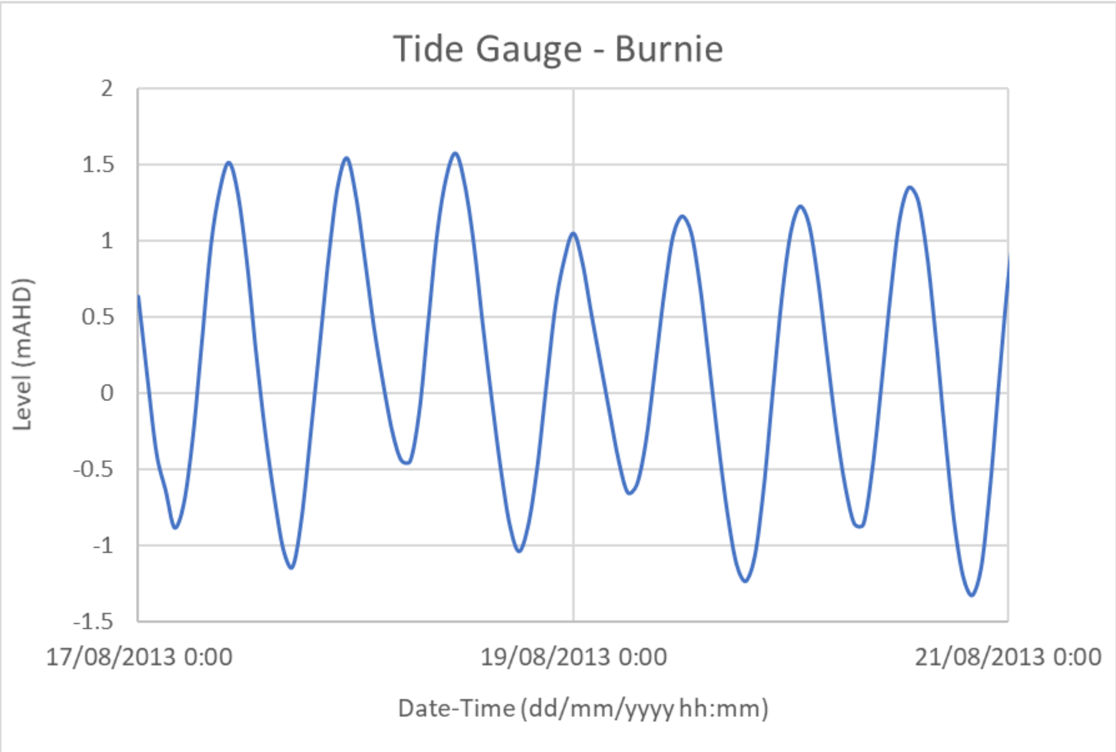

Diagram 7: Observed tide data from the Burnie tide gauge for the August 2013 calibration event

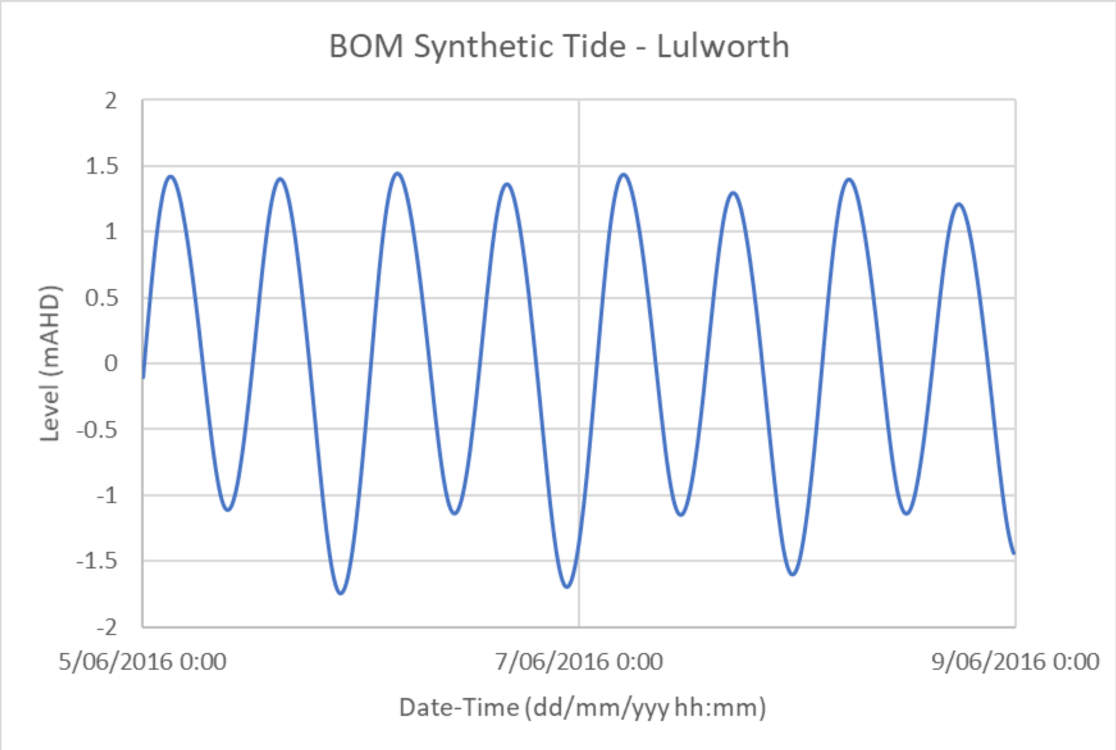

Diagram 8: Synthetic tide data off the coast of the Lulworth for the June 2016 calibration event

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, 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 RAFTS sub-catchment model setup in ICM for the Pipers study area is shown in Diagram 9. 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.

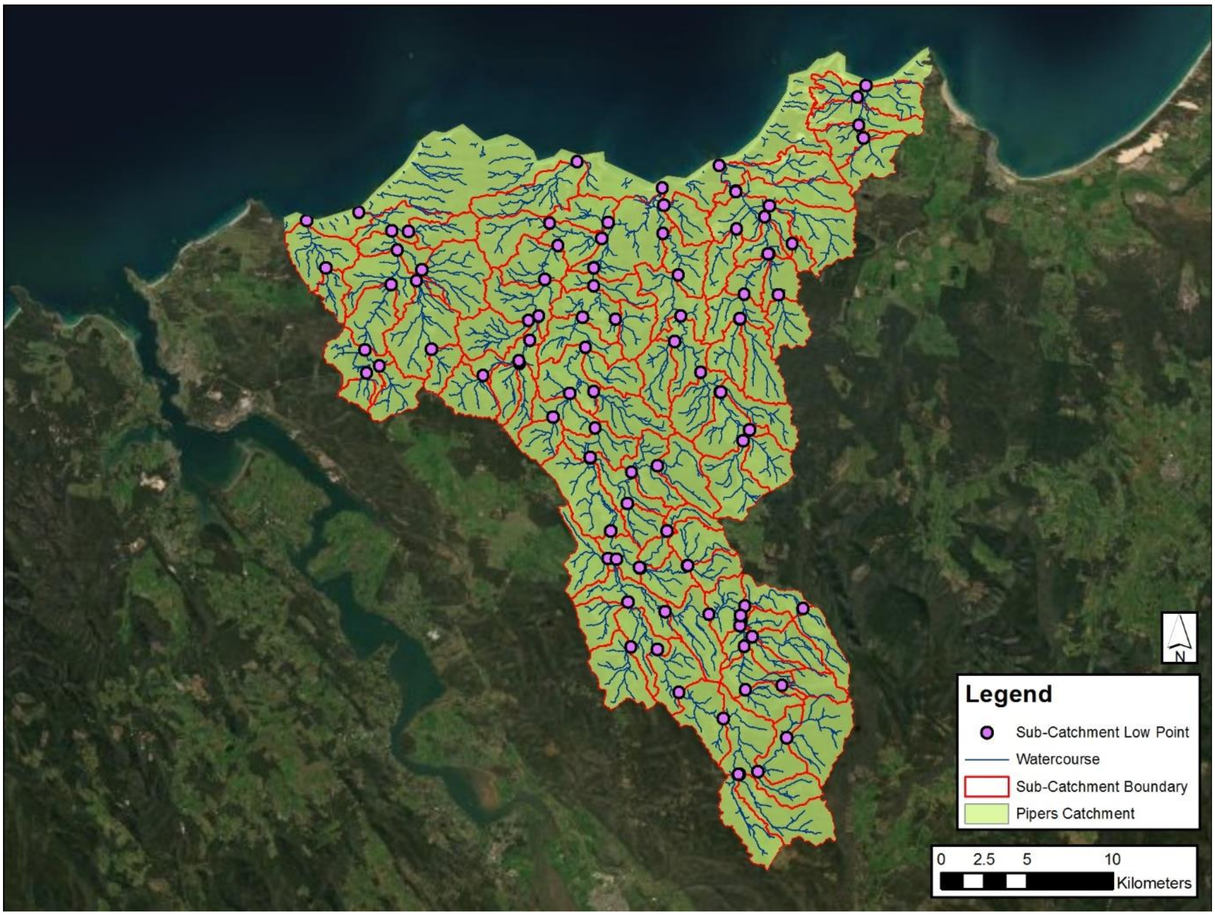

Diagram 9: RAFTS sub-catchment model setup in ICM for the Pipers study area

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 for each calibration event.

The calibrated loss parameters were consistent at all gauges for each event and are summarised in Section 6.3. An RAF of 2 was selected after reviewing the fit of modelled to observed. Upon completion of the calibration assessment, the external hydrologic model and the ICM model flow results were compared to ensure results were comparable. A summary of this review is presented in Appendix C.

6.2. Initial Conditions

Prefilling of the model has not been undertaken for this study area. It is not proposed to pre-fill the model for design events based on the outcomes of this assessment. Without prefilling, some artificial depression storage can occasionally occur to lumpiness in the DTM. This may result in no flow at the beginning of each event and then a sudden response. This response is not identified as significant for this study area.

6.3. Gauge Results

In general, it is considered that a reasonable calibration has been achieved at both gauges, with good response to flow and reasonable response to level achieved. Mapping of the peak flood depths from the calibrated ICM model for each calibration event is shown in Figure 5 and Figure 6.

6.3.1. Pipers River d/s Yarrow CK

The modelled peak flows for the August 2013 and June 2016 calibration events at the Pipers River d/s Yarrow CK gauge are presented in Table 4. Diagram 10 and Diagram 11 show flow hydrograph response for both events. The model provides a good replication of peak flow in the August 2013 event. In the June 2016, the model underestimates peak flow at the gauge however has a similar volume.

Diagram 12 and Diagram 13 show the water level response for the calibration events at the gauge for the August 2013 and June 2016 events. A gauge zero was not available from the DPIPWE database so an assumed gauge zero of 13 mAHD was used, based on the DEM in the area. The results indicate slight over estimation of levels at the gauge for both events. For the higher flow June 2016 event, the calculated levels are higher than the observed and the flows are lower. This result indicates a poor match between the modelled and the supplied rating curve at higher flows. Given there is a high level of uncertainty in the DPIPWE high flow rating at this site (Section 3.1.2) this outcome is not unexpected. A comparison of the gauge rating and ICM results is shown in Appendix D.

Table 4: Calibrated parameters and discharge at Pipers River d/s Yarrow CK

Statistic	2013 Aug	2016 Jun
IL	5	24
Average CL	0.67	0
Modelled Peak (m^3/s)	149.44	360.68
Observed Peak (m^3/s)	155.61	448.89
Peak % difference	-4%	-20%
Modelled Volume (ML)	11,591	30,027
Observed Volume (ML)	14,656	31,430
Volume % difference	-21%	-4%
Modelled peak (mAHD)	15.54	16.96
Observed peak (mAHD)	15.28	16.50
Peak difference (m)	0.26	0.45

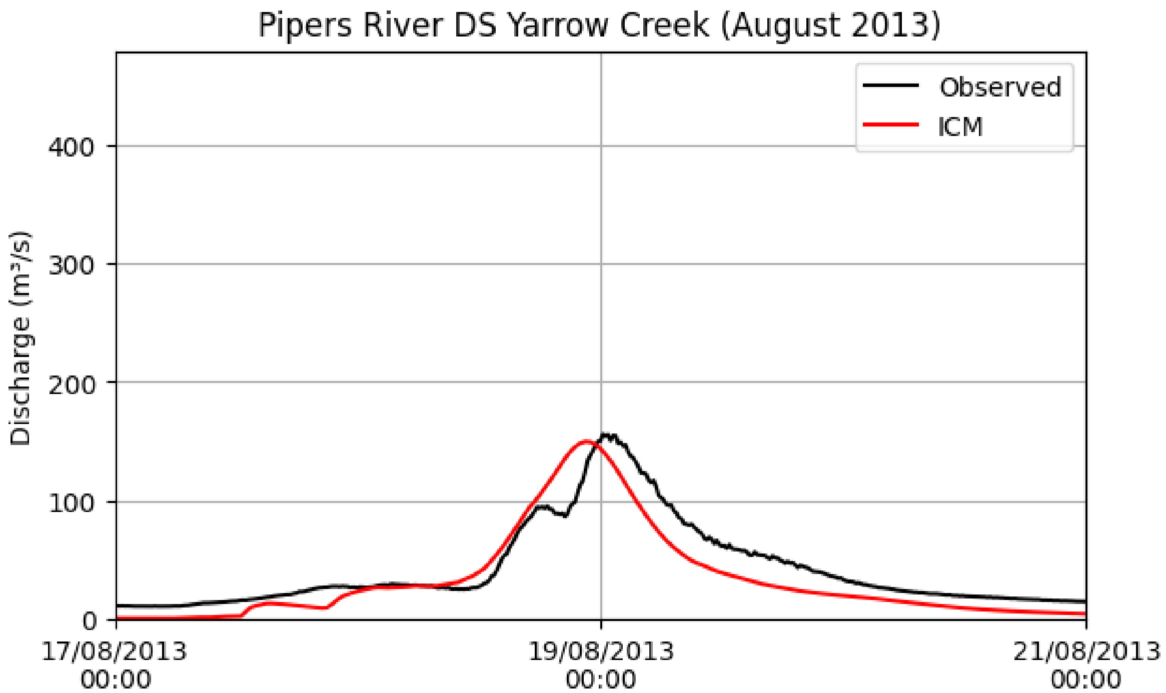

Diagram 10: August 2013 flow comparison at Pipers River d/s Yarrow CK

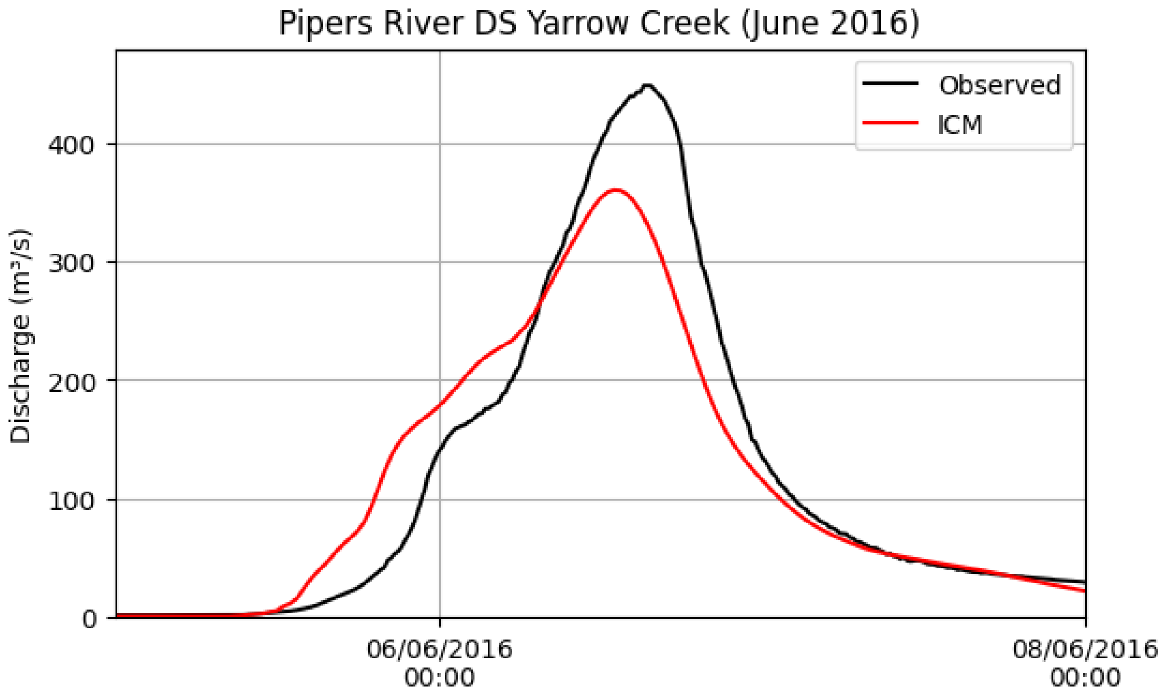

Diagram 11: June 2016 flow comparison at Pipers River d/s Yarrow CK

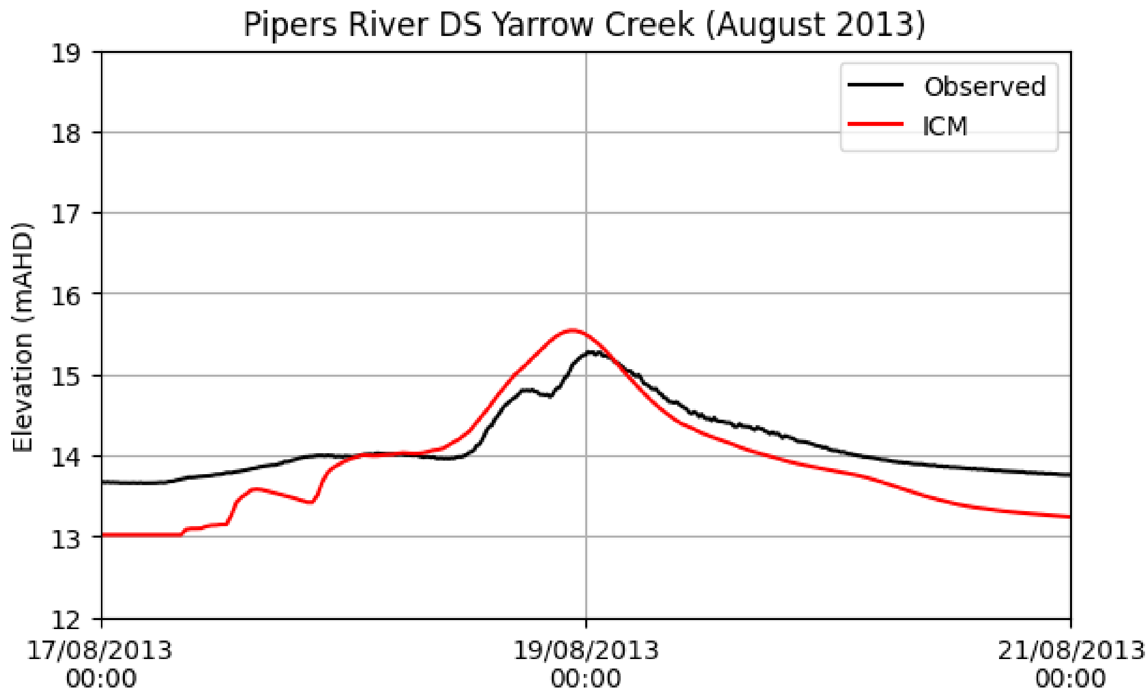

Diagram 12: August 2013 water level comparison at Pipers River d/s Yarrow CK (assumed gauge zero)

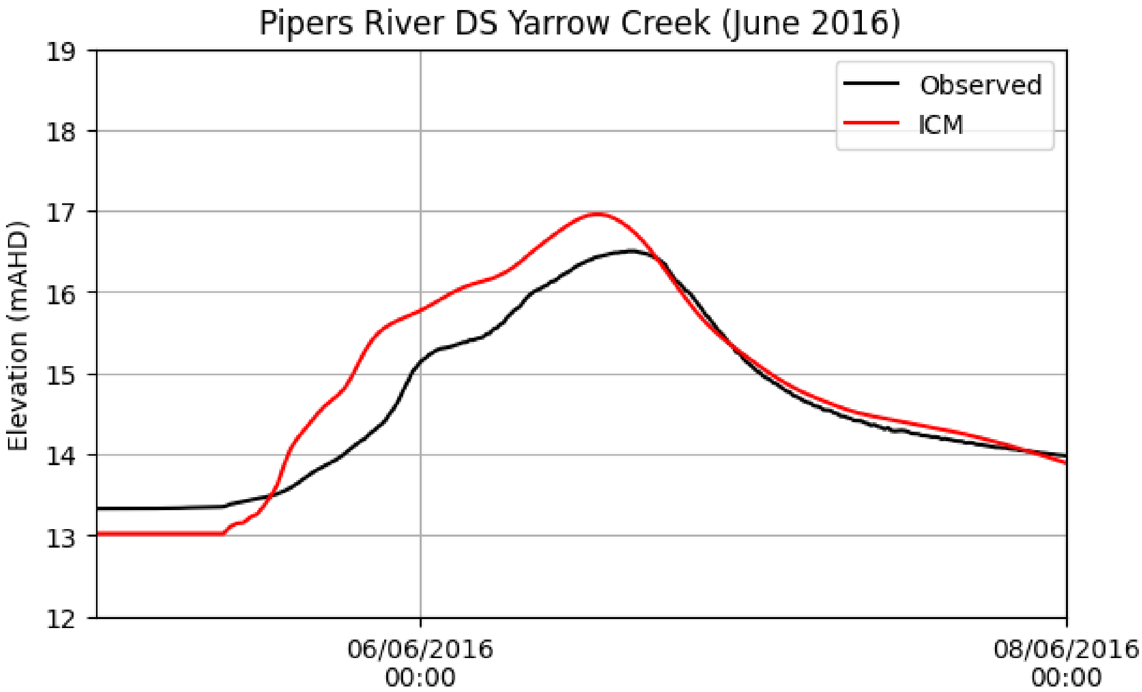

Diagram 13: June 2016 water level comparison at Pipers River d/s Yarrow CK (assumed gauge zero)

6.3.2. Pipers River at Underwood

At this gauge, data was available for one calibration event, August 2013. The modelled peak flow shows a good match to the recorded peak flow, noting the low flows present. The modelled hydrograph volume is less than half of the observed however. The rising limb of the flow hydrograph is well replicated in the model and the modelled levels provide a good match to the observed levels over the whole event (Diagram 14). It is possible that there is some hysteresis in the rating at this site, which is not well represented by a simple rating curve. The water level response recorded vs the modelled looks to somewhat confirm this.

A summary of the flows and water levels for the August 2013 event is shown in Table 5. There is a good agreement between the modelled and observed peak flows and levels. Diagram 15 compares the observed to the modelled water level results. At the start of the event the levels recorded are higher than the observed, which indicates a poor representation of the channel at low flows, which is expected given the location of the gauge in the upper reaches of the catchment. This can be seen in a comparison of the gauge rating and ICM results is shown in Appendix D.

Table 5: Calibrated parameters and discharge at Pipers River at Underwood

Statistic	2013 Aug
IL	5
Average CL	0.67
Modelled Peak (m^3/s)	29.73
Observed Peak (m^3/s)	21.35
Peak % difference	39%
Modelled Volume (ML)	2,107
Observed Volume (ML)	2,899
Volume % difference	-27%
Modelled peak (mAHD)	228.87
Observed peak (mAHD)	228.94
Peak difference (m)	-0.07

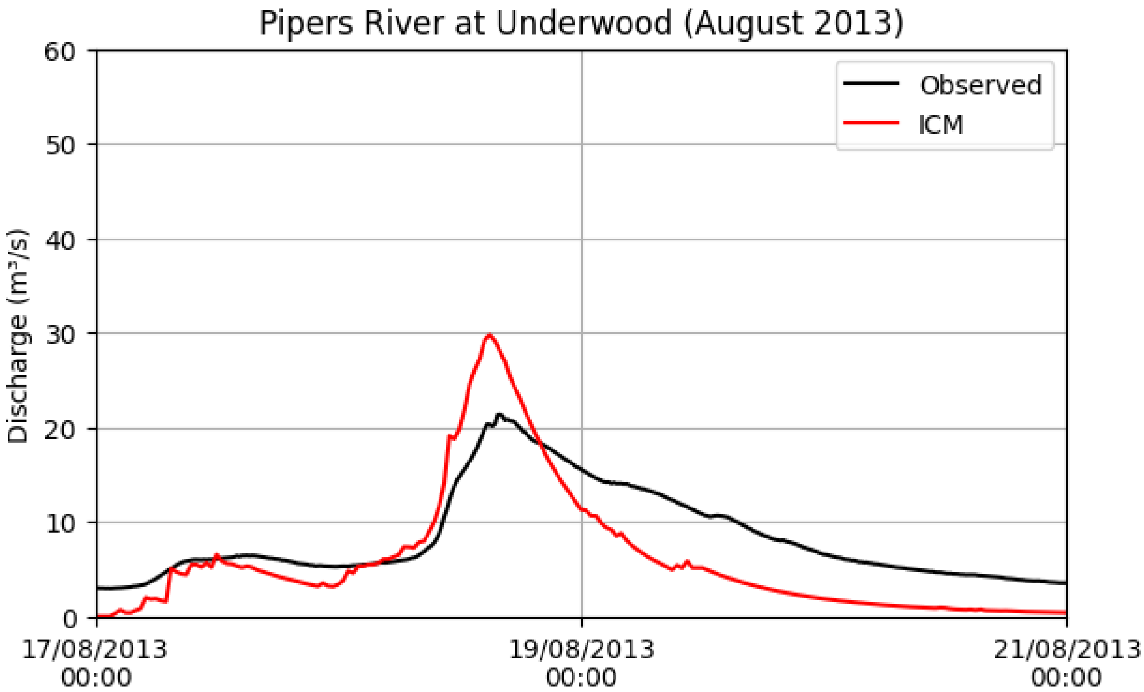

Diagram 14: August 2013 flow comparison at Pipers River at Underwood

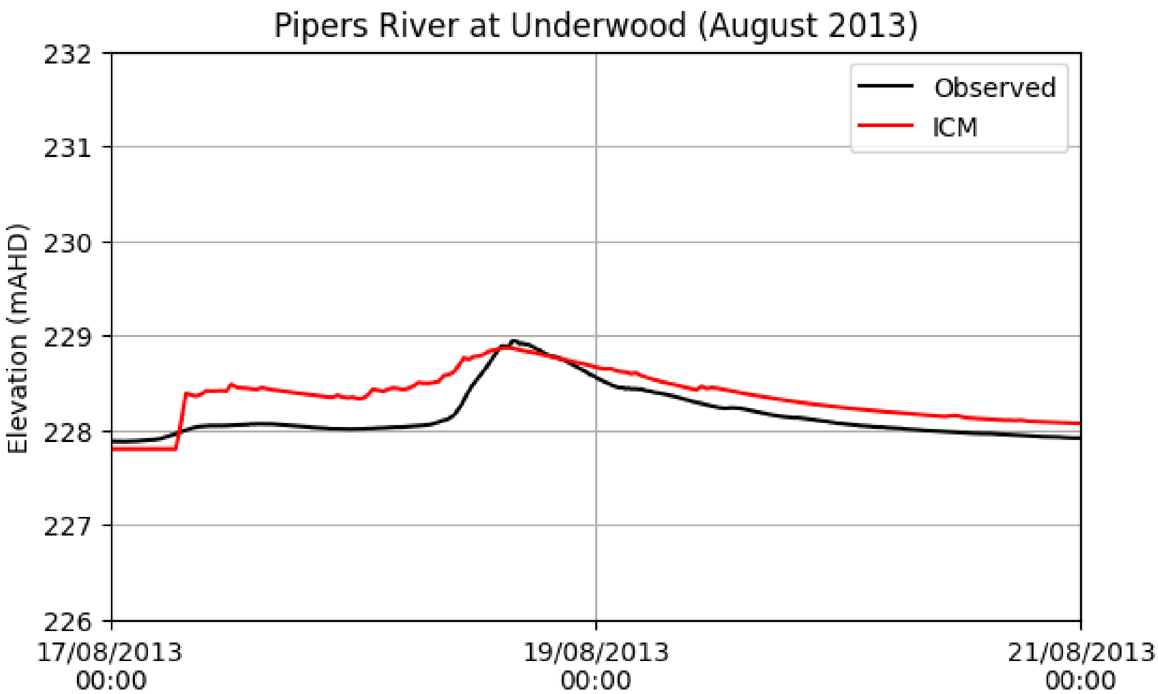

Diagram 15: August 2013 water level comparison at Pipers River at Underwood

6.4. Identified Issues

A high-level review of the modelled flood extents for the calibration events was undertaken to identify limitations of the modelling.

The following issues and limitation were identified, which should be investigated further if future detailed analysis is undertaken:

- The DEM in an area in the north east of the catchment is limited to the 'Default DTM' of the state-wide 10 m DEM. It is expected that there will be a poor representation of flooding through these areas.
- It is possible that there is some hysteresis in the rating at the Pipers River at Underwood gauge. This does not objectively alter the outcomes of the assessment however it should be kept in mind when reviewing volumes at the location.
- There is a high level of uncertainty in the high flow rating at the Pipers River d/s Yarrow Creek site. Future assessments may consider a review of the rating curve for high flows to confirm if appropriate.
- There is limited sub-daily rainfall information available for the calibration events. This may result in derived rainfalls over the study area not well representing the actual rainfall for these events.

7. UNCERTAINTY ASESSMENT

Significant flows were recorded in the catchment area for one of the 13 flood events selected by the Bureau as calibration events for this project, in June 2016. An additional event in August 2013 was also used for calibration.

Flow data was available at two gauges for the August 2013 calibration event, and one gauge for the June 2016 event.

There were no flood extents or depths available in this catchment.

The uncertainty assessment for the modelling is shown in Table 6 and Appendix B.

Table 6 Uncertainty assessment for Pipers River catchment model

Category	Quality statement
Hydrology – rainfall input quality	The quality of the rainfall data is generally fair to good. There is one sub-daily rain gauge within the Pipers study area that was operating for both events and two gauges operating for the June 2016 event. There is only one daily rainfall gauge within the catchment for the August 2013 event and 5 gauges for the June 2016 event. There is good coverage of rain gauges in surrounding catchments.
Hydrology – observed flows	At all sites gaugings are within the river channel and are lower than the highest recorded stage height. The calibration events are at flows that are in the area of extrapolated DPIPWE rating curves at both sites. A theoretical rating was developed using a local hydraulic model at Pipers River at Underwood and this rating has been used in calibration. The rating curve for Pipers River d/s Yarrow Creek was considered to be poor.
Hydrology – calibration events	June 2016 event was the largest on record at the Pipers at Underwood gauge. Pipers d/s Yarrow Creek gauge ceased recording on the rising limb of the June 2016 event. The August 2013 event is the 6th largest on record at Pipers at Underwood and 9th largest at Pipers d/s Yarrow Creek.
Hydrology – calibration results	The hydrology calibration was considered to provide a very good match to peak flows. Hydrograph volume was well represented in the model for the June 2016 event, however volume was underestimated for the August 2013 event, giving a poor match to volumes.
DTM definition	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. The “default DTM” was used in a small area in the north-east of the catchment and is likely to be a poor representation of the topography of the area
DTM waterways	No bathymetric data was available and waterway definition was based on the LiDAR to water surface.
Hydrodynamic – overall calibration results	Calibration results generally indicate a fair to good correlation between recorded and modelled levels at the gauges. There is uncertainty in the gauge zero values at both gauges, and these were derived from the DTM.
Hydrodynamic – calibration results, peak levels	Model calibration to peak levels at Pipers River d/s Yarrow Creek was considered to be fair to good, and an excellent fit to peak levels was achieved at Pipers River at Underwood gauge.

Category	Quality statement
Hydrodynamic – calibration results, flood extents	No flood extents were available in this study area
Hydrodynamic – calibration results, flood depths	No flood depths were available in this study area

8. REFERENCES

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WMAwater (2021c): Tasmanian Strategic Flood Map, Flow Gauge Rating Revision, May 2021.

WMAwater (2021d): Tasmanian Strategic Flood Map, Addition Calibration Event Rainfalls, Nov 2021.

Figures

FIGURE 01
PIPERS STUDY AREA

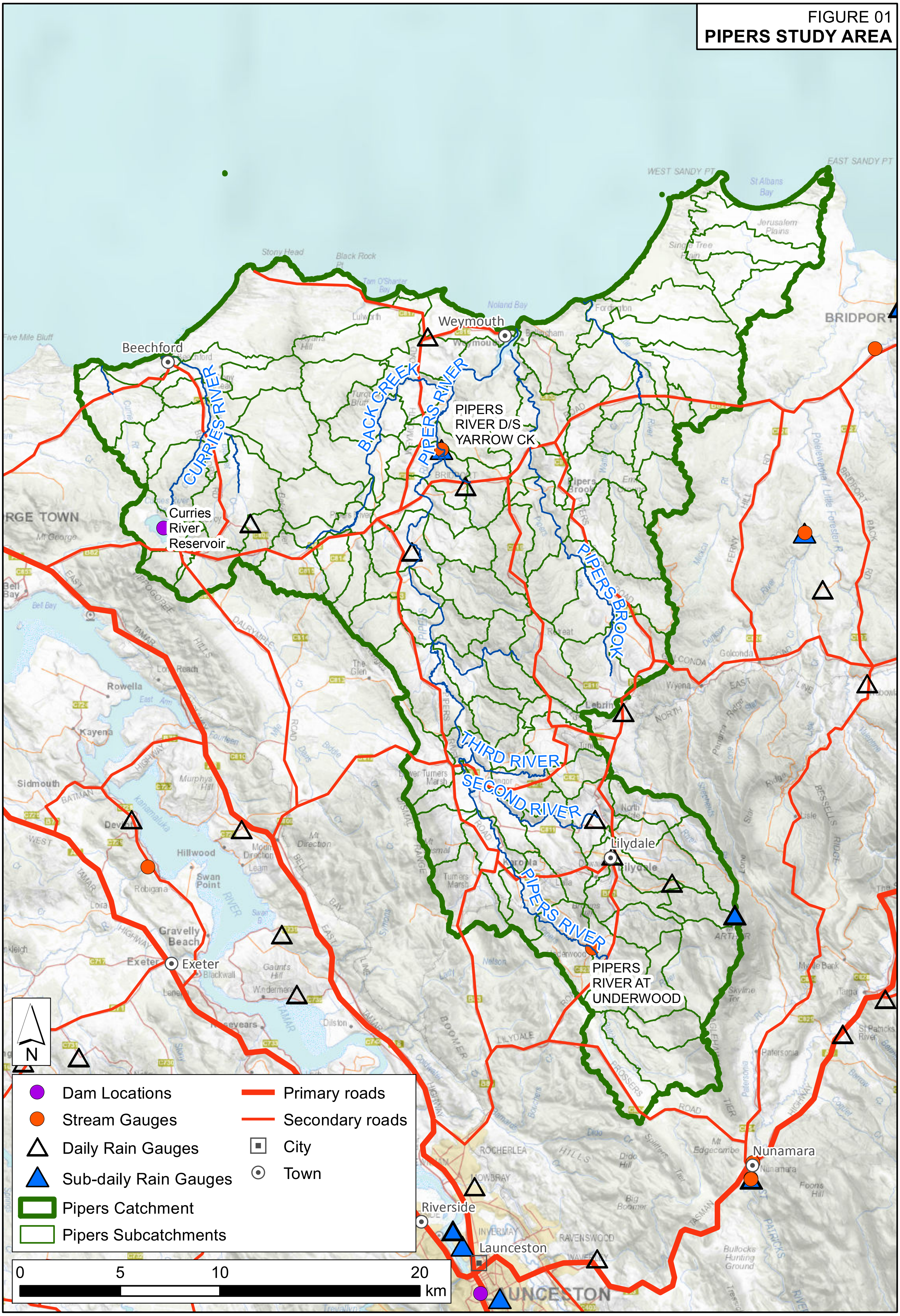

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FIGURE 02
PIPERS STUDY AREA LAND USE

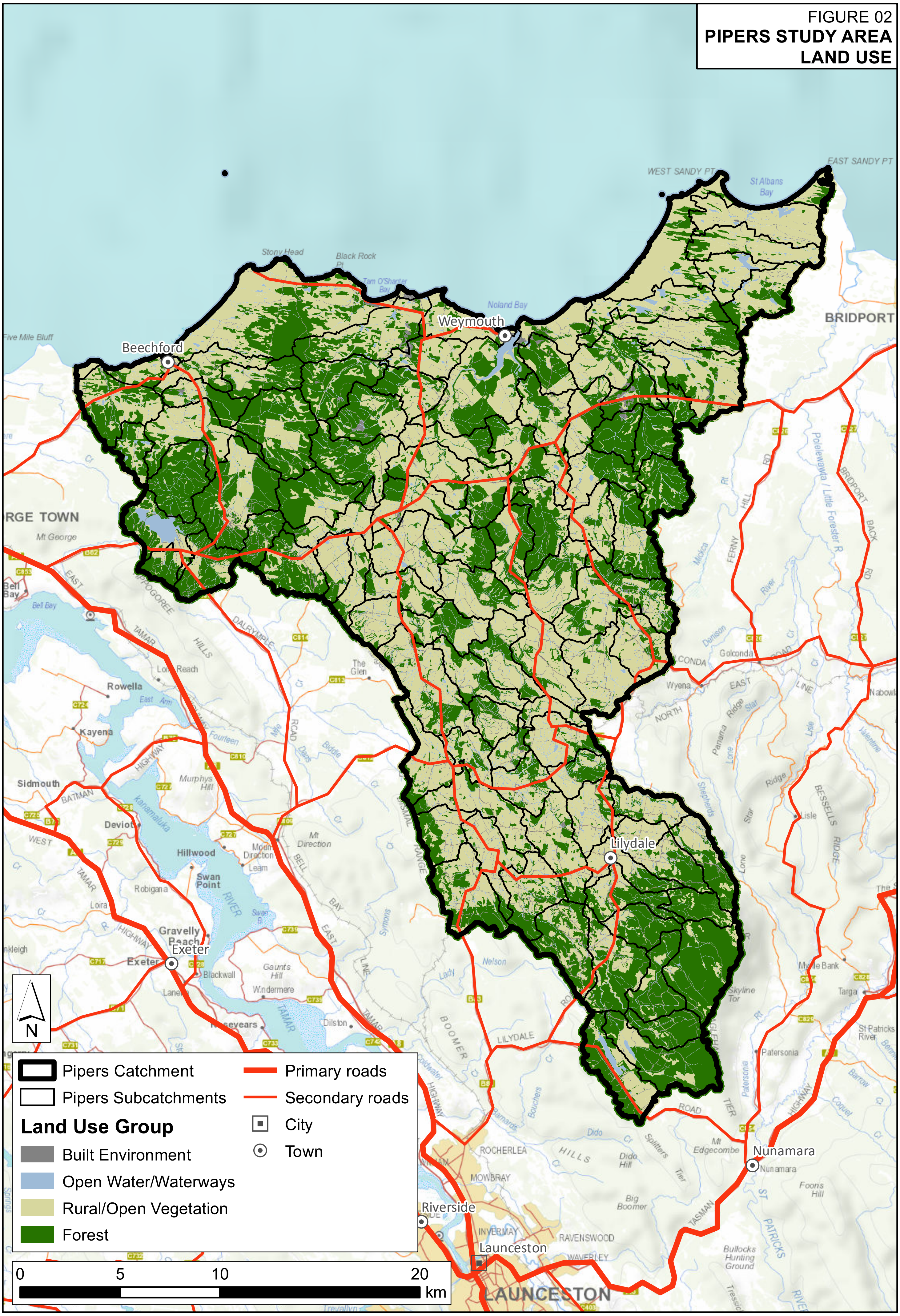

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FIGURE 03
PIPERS STUDY AREA
RAINFALL 2013_AUG

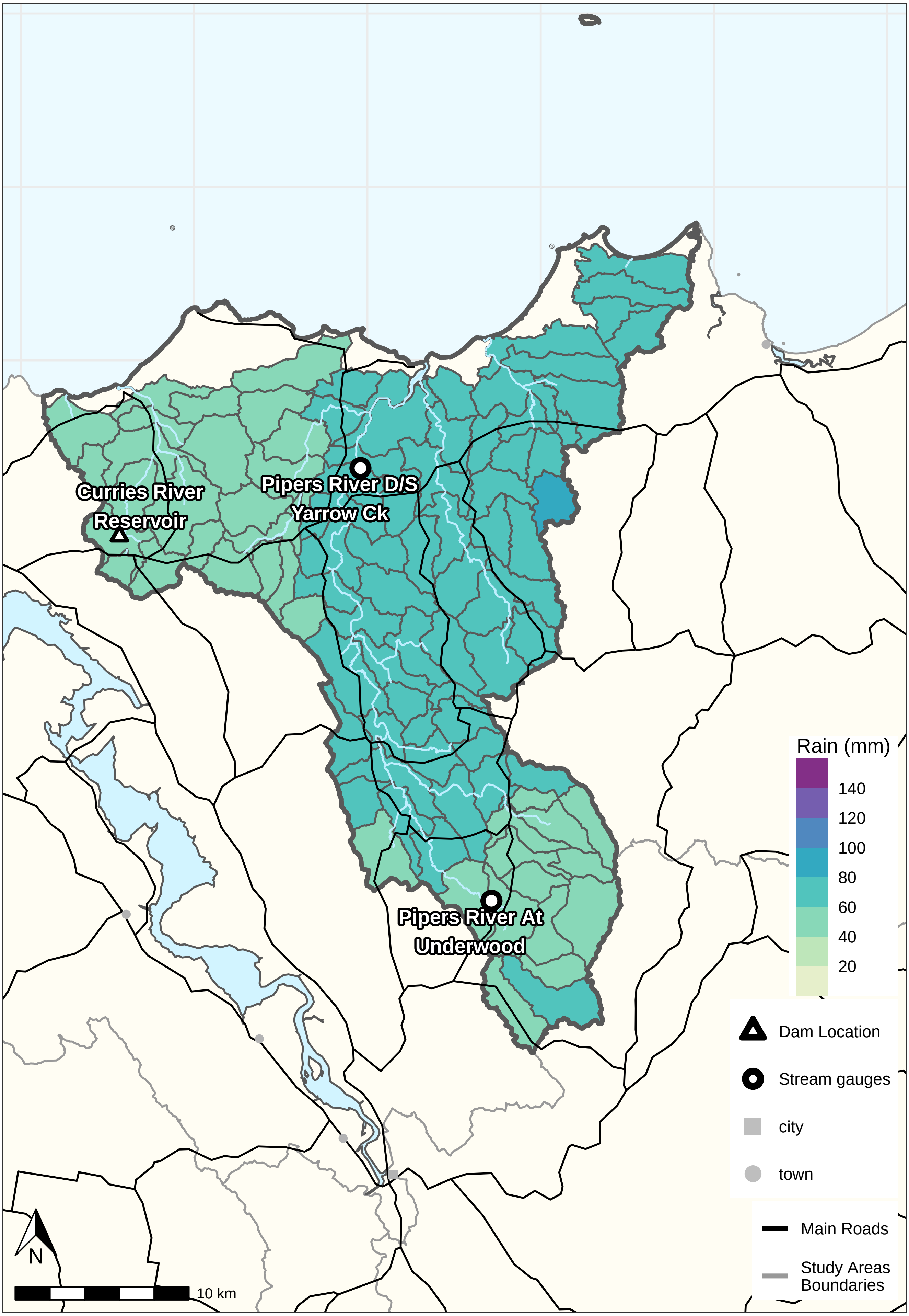

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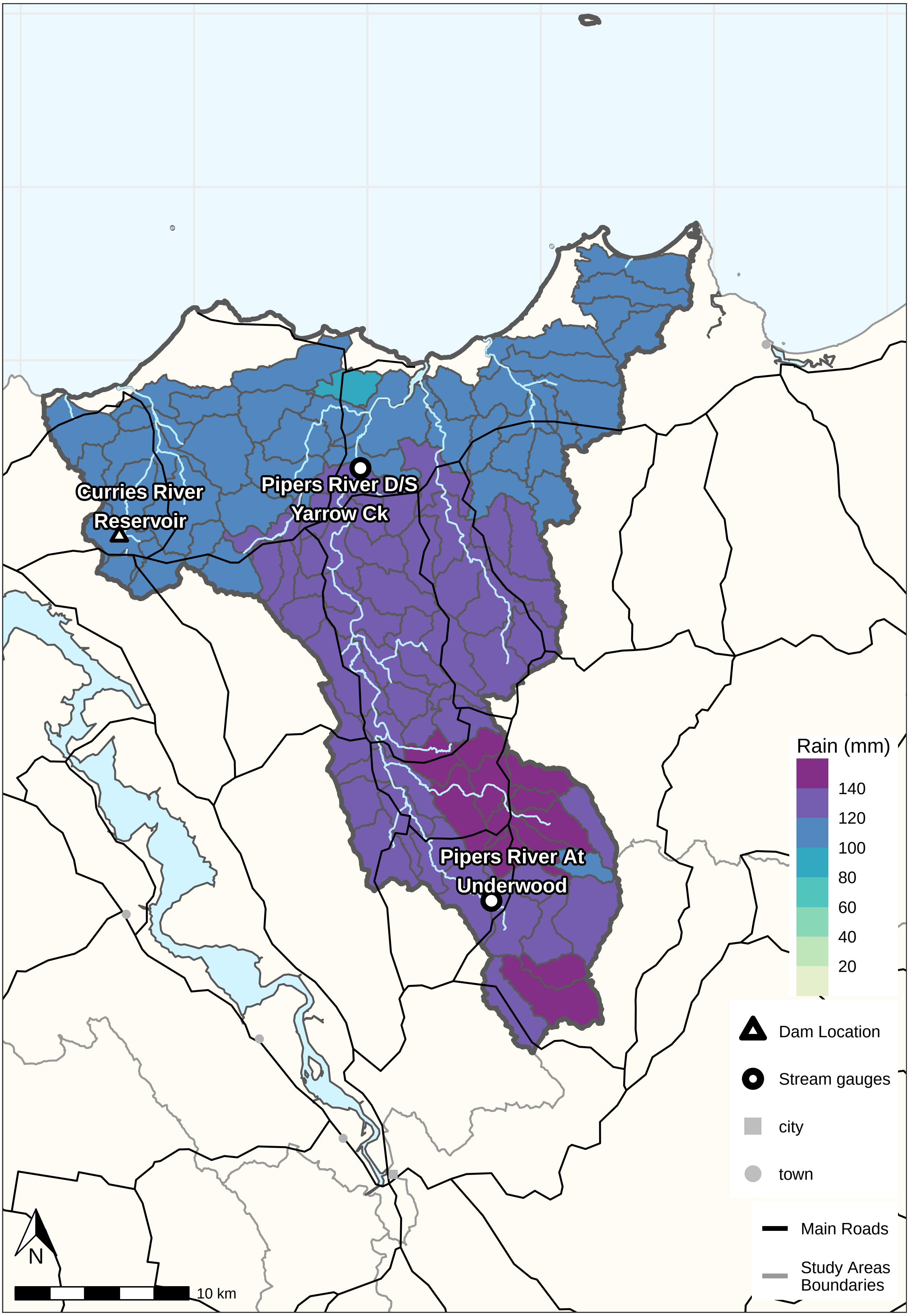
FIGURE 04
PIPERS STUDY AREA
RAINFALL 2016_JUN



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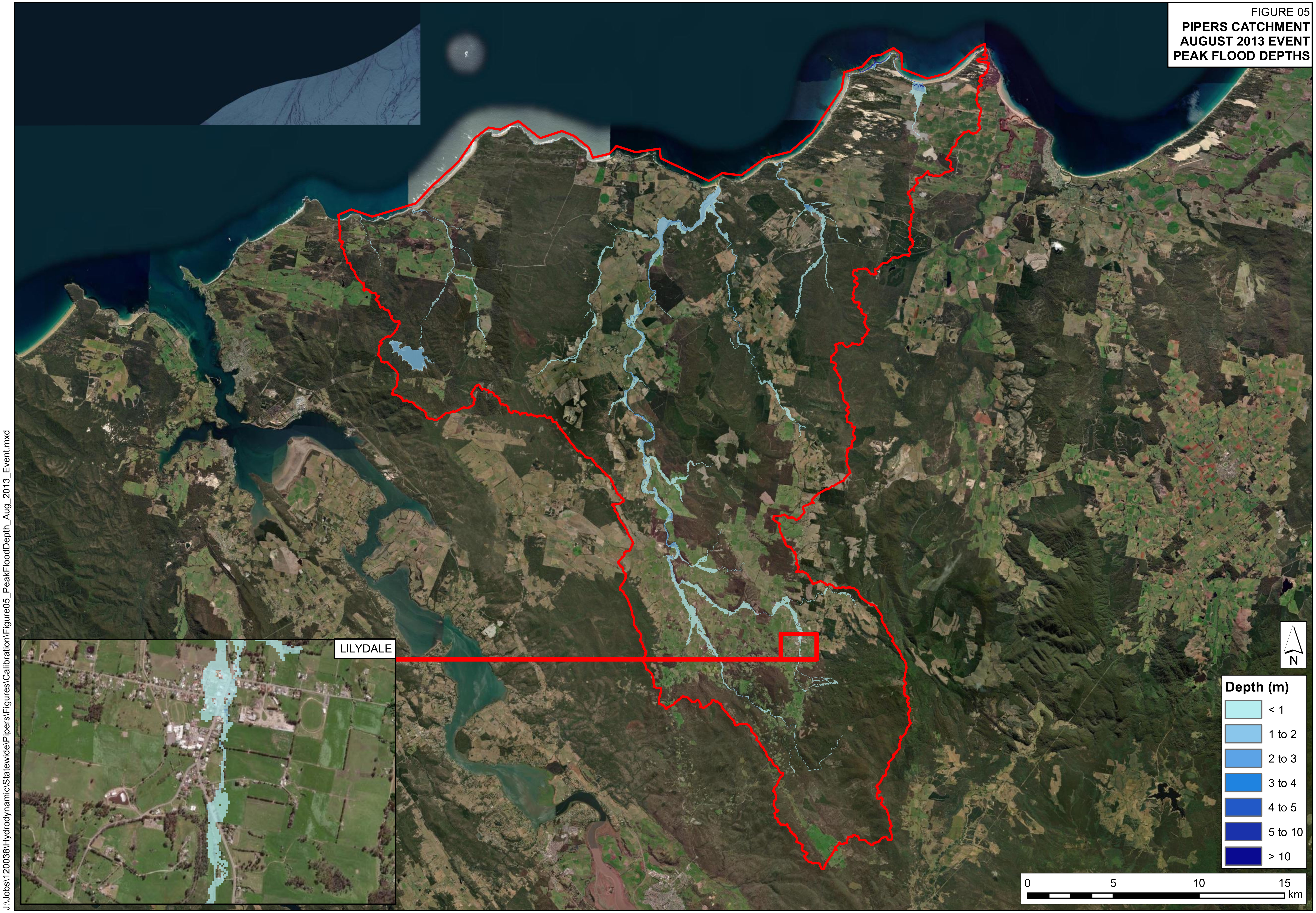
FIGURE 05
PIPERS CATCHMENT
AUGUST 2013 EVENT
PEAK FLOOD DEPTHS
LILYDALE
N
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
5
10
15
km
J:\Jobs\120038\Hydrodynamic\Statewide\Pipers\Figures\Calibration\Figure05_PeakFloodDepth_Aug_2013_Event.mxd

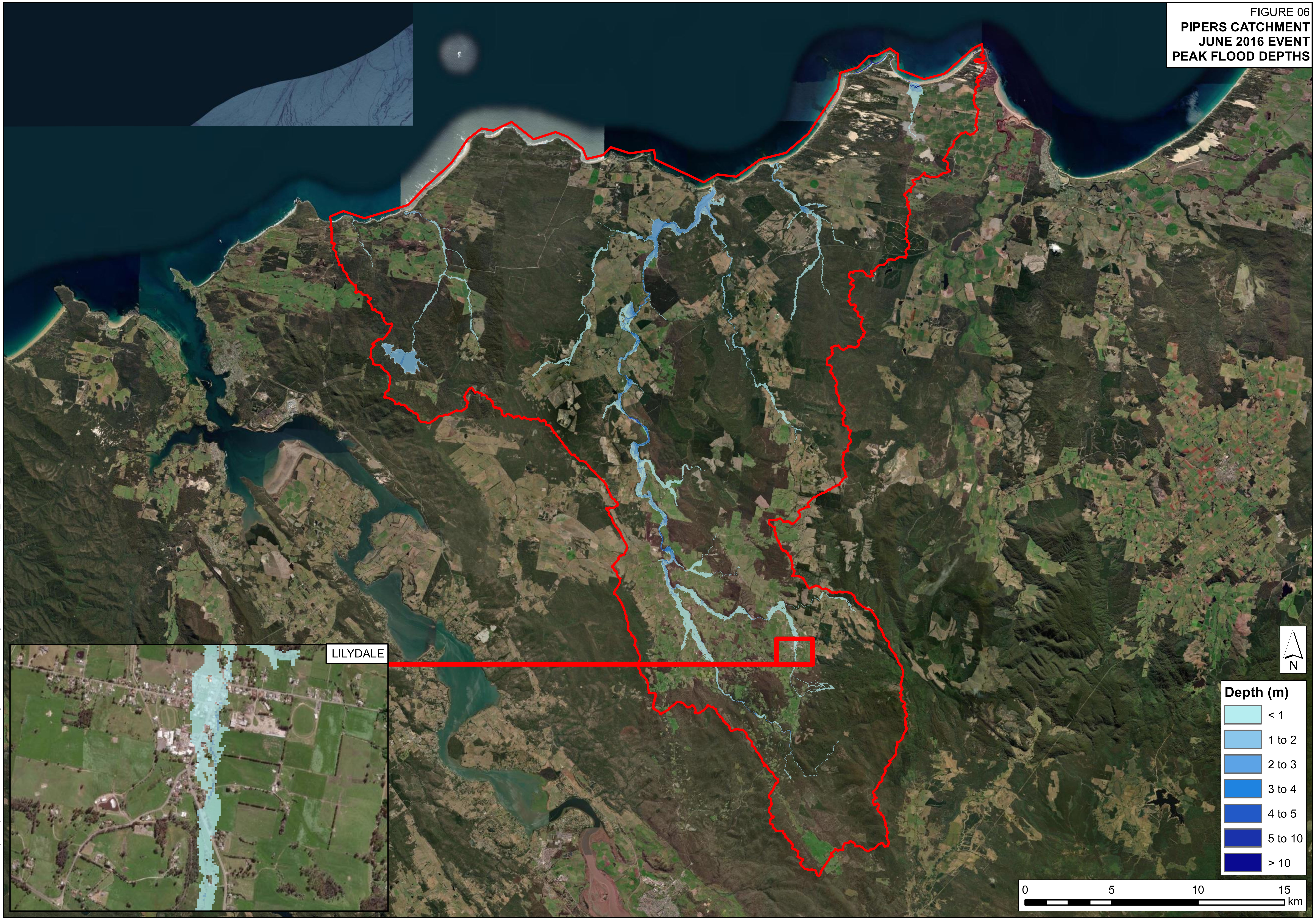

FIGURE 06
PIPERS CATCHMENT
JUNE 2016 EVENT
PEAK FLOOD DEPTHS

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Appendix A

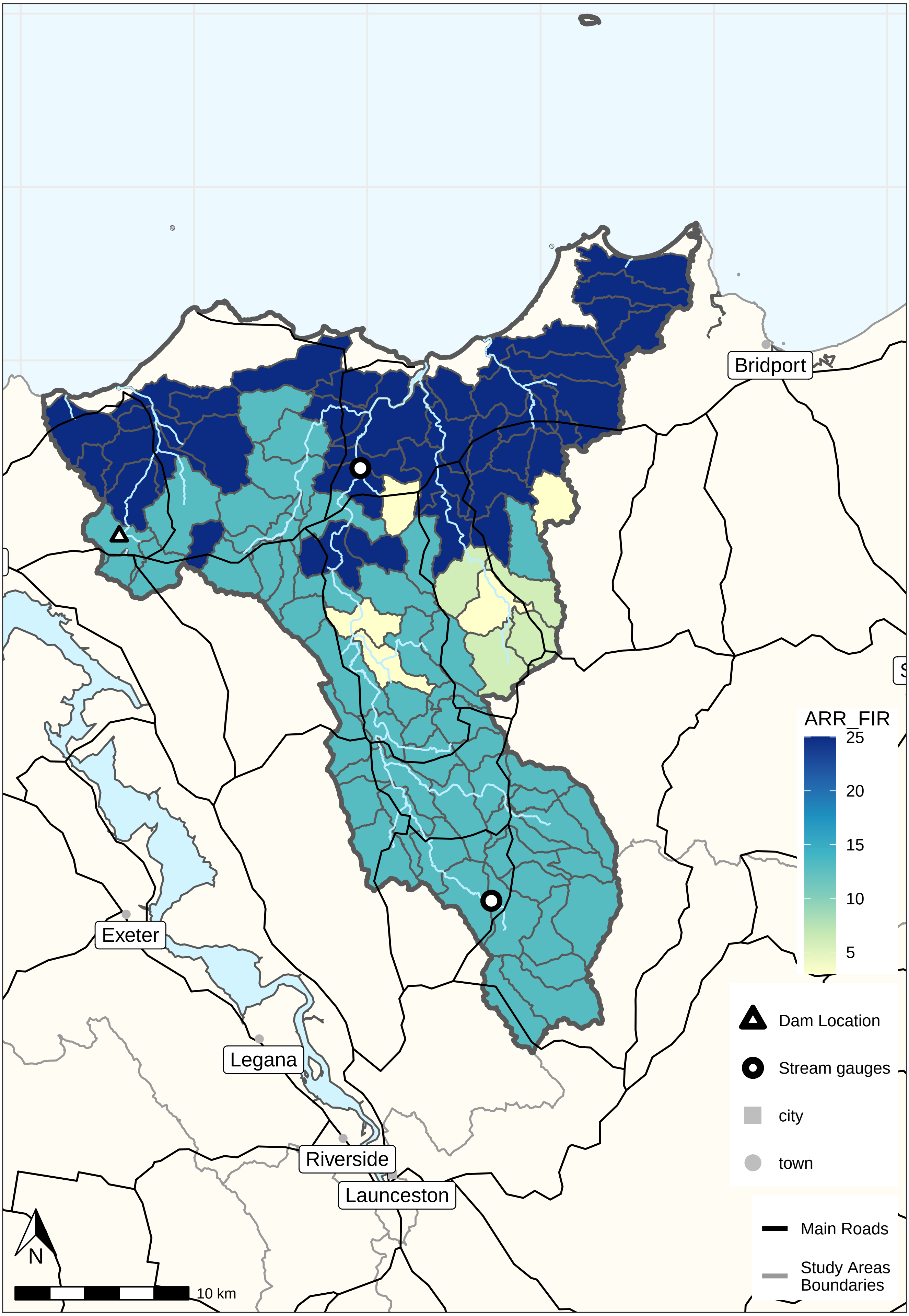
APPENDIX A. AVALIABLE DATA

A.1. Sub catchment data

FIGURE A1

HYDROLOGICAL SOIL GROUP MAPPING

DOMINANT SUBCATCHMENT SOIL INFILTRATION RATE



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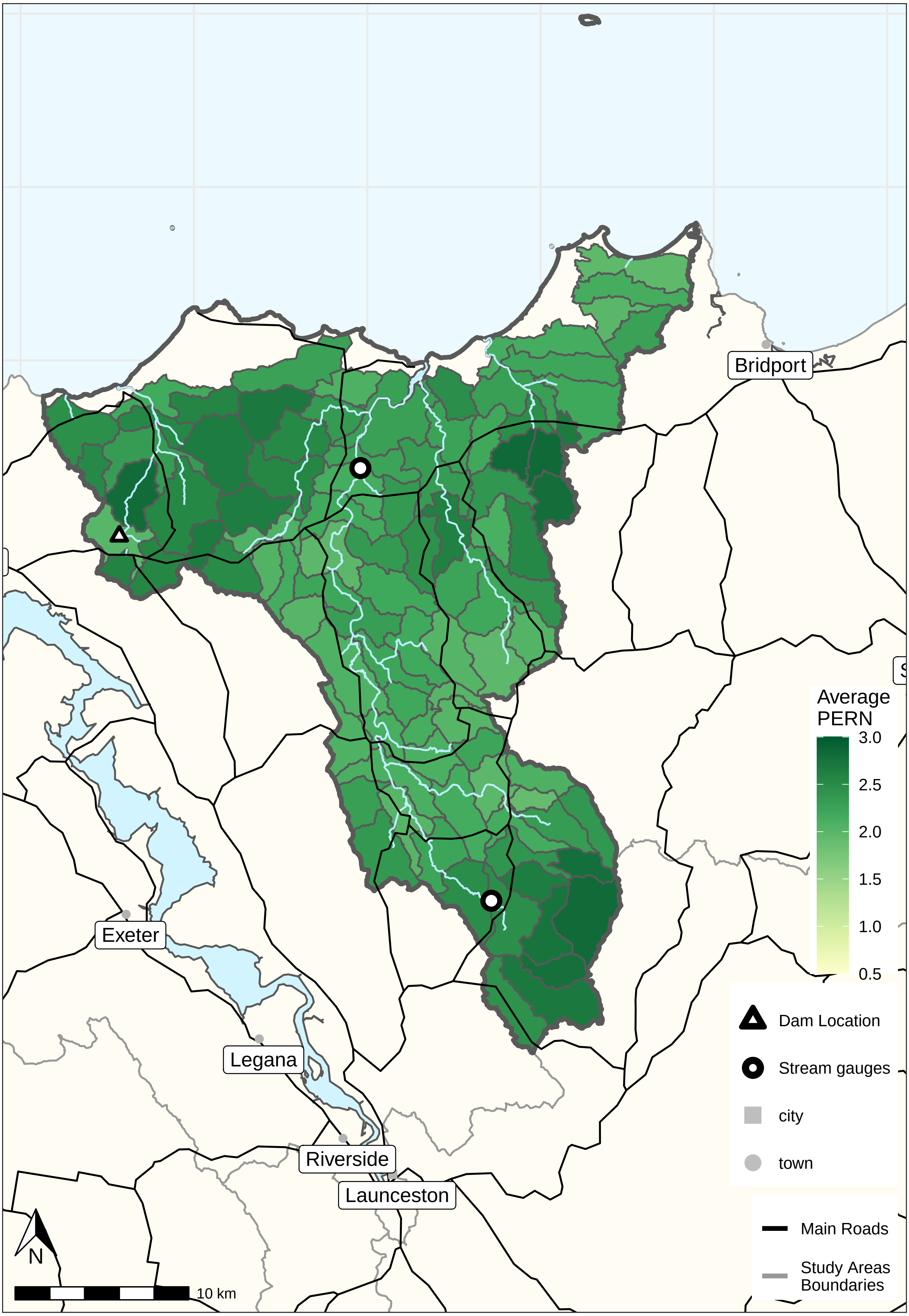
J:/Jobs/120038/Hydrology/Statewide/Calibration/Pipers/Subcatchment_rainfalls/Figure_A1_Pipers_SoilTypesReport.pdf

FIGURE A2

PIPERS 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. Green shading is used to highlight relevant statements where applicable to all gauges or events. In other cases, the following shading is used to highlight relevant statements:

- For observed flow rating description, Pipers River at Underwood is shown in blue shading, Pipers River d/s Yarrow Creek is shown in orange shading.
- For calibration events August 2013 is shown in purple shading, June 2016 in yellow shading.

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% AEP	Between 10% and 5% AEP	Between 5% and 2% AEP or within largest 4 events on record	Larger than 2% AEP or within largest 2 events on record

Table B 2 shows the hydrology calibration quality rating. Green shading is used to highlight relevant statements where applicable to all gauges or events. In other cases, the following shading is used to highlight relevant statements:

- August 2013 is shown in orange shading, June 2016 in blue shading
- Pipers River @ Branxholm WS shown in blue 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, with orange shading for the area in the north east of the catchment.

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 relevant 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. Orange shading is used to highlight relevant statements for Pipers River d/s Yarrow Creek gauge, with blue shading used for Pipers River at Underwood gauge. No flood extents or survey points were available for comparison.

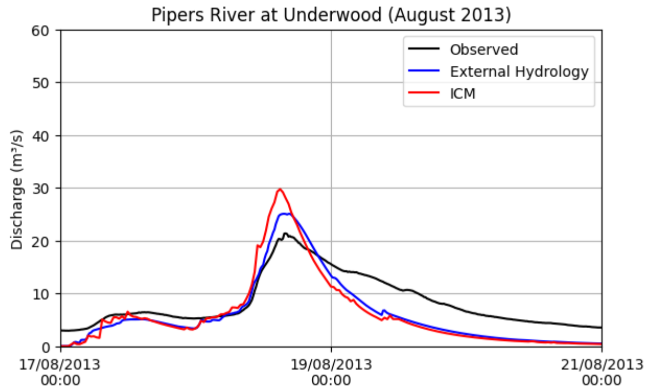
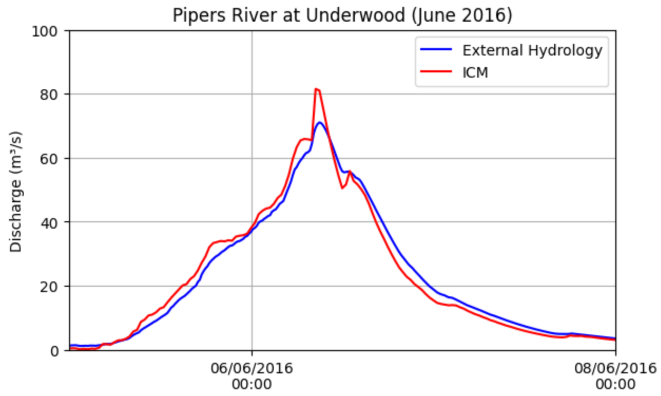
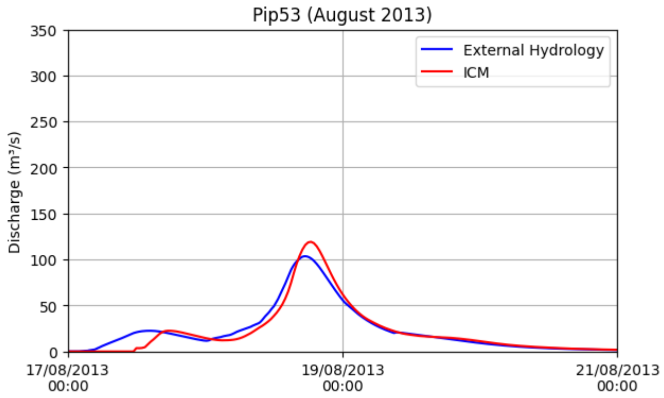
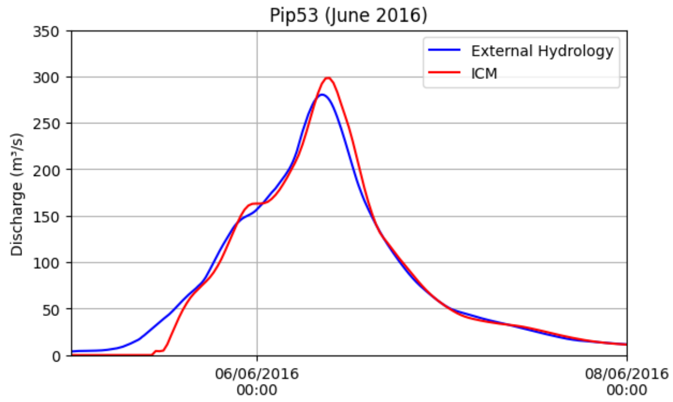
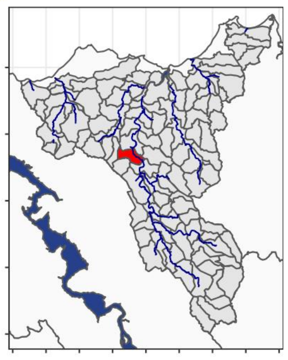
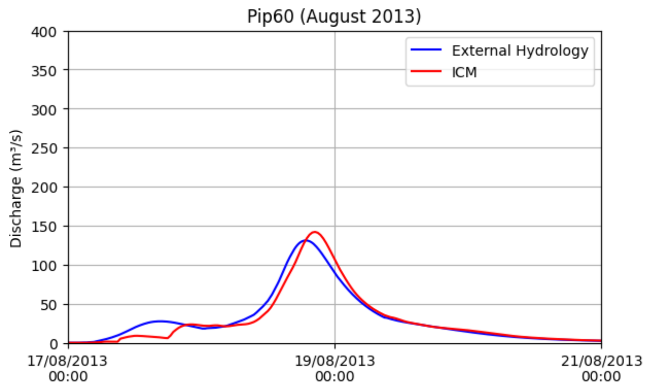
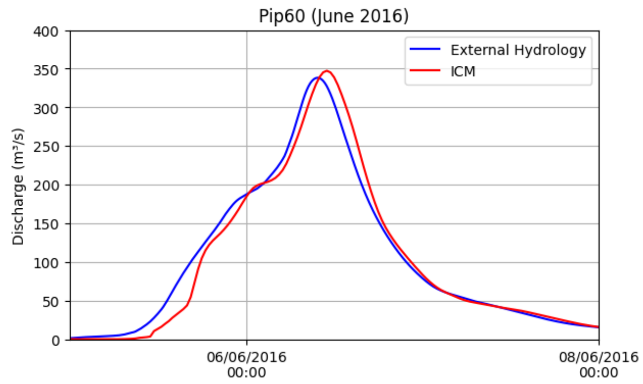
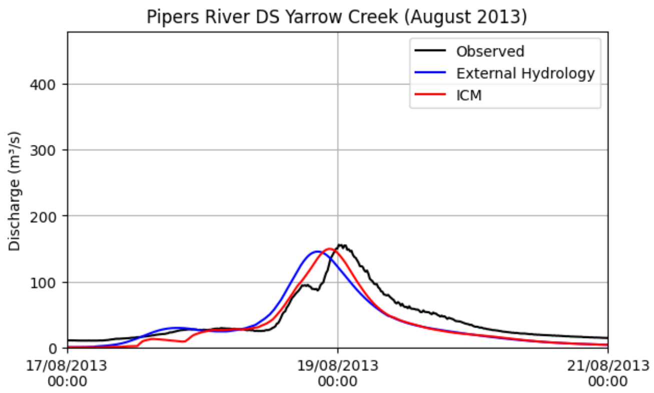
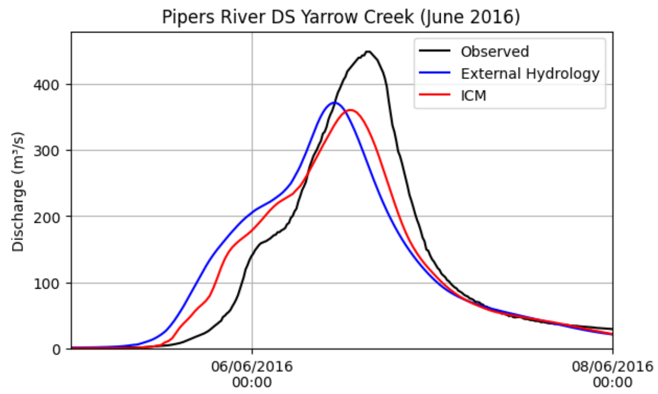
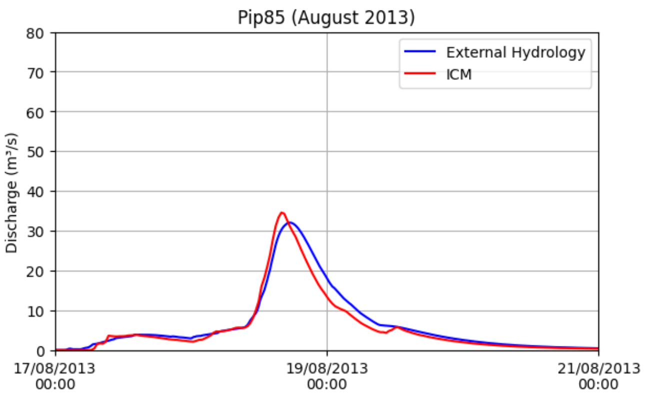
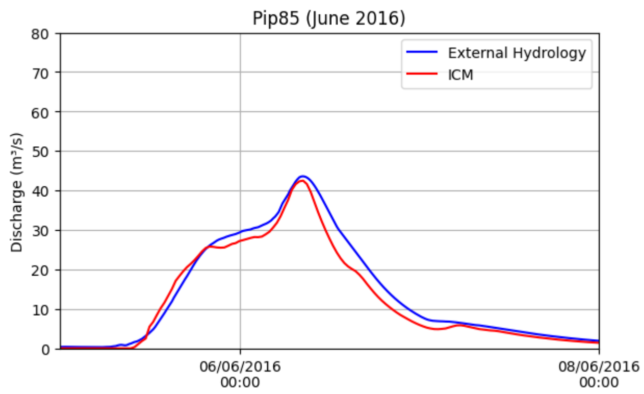
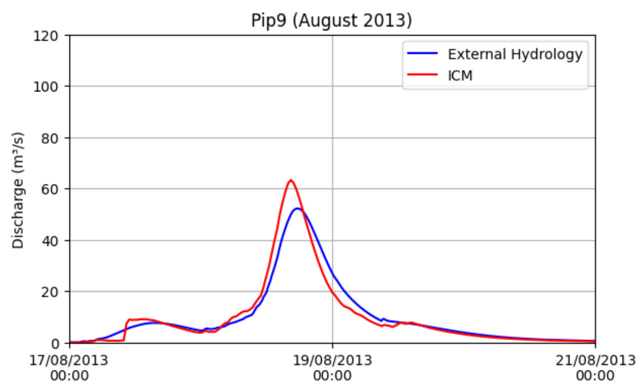
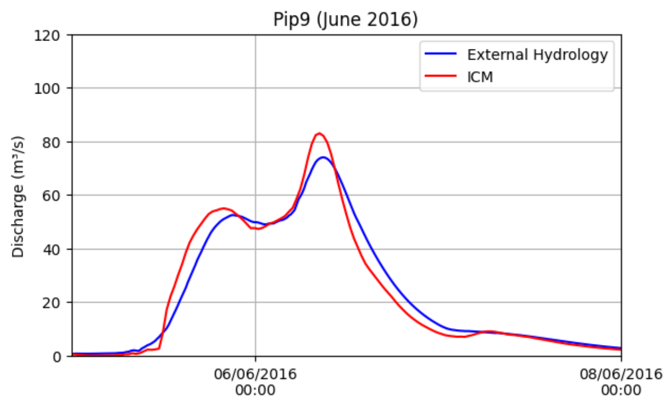
Table B 5: Hydrodynamic calibration quality rating

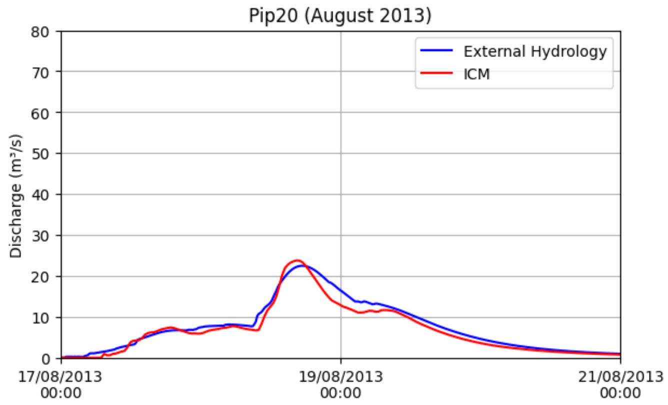
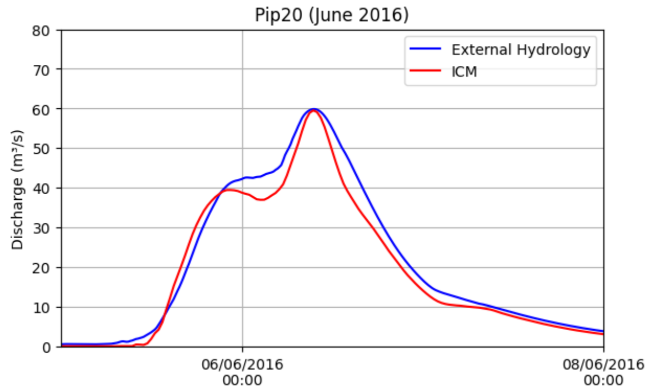
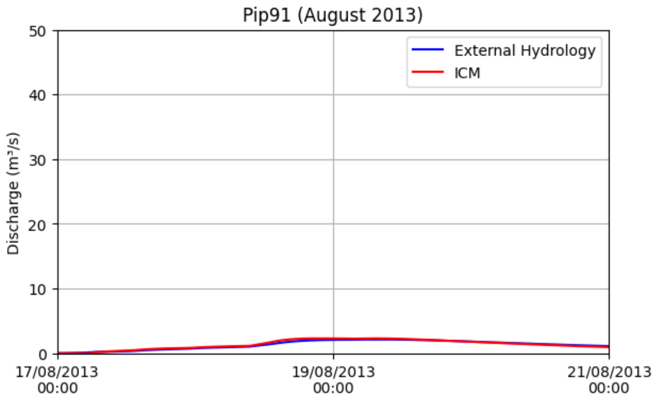
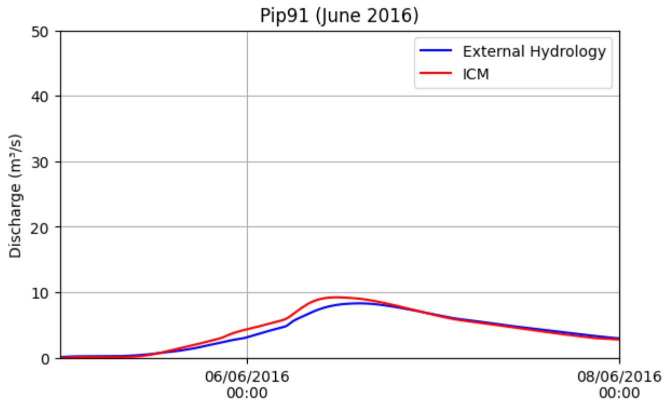
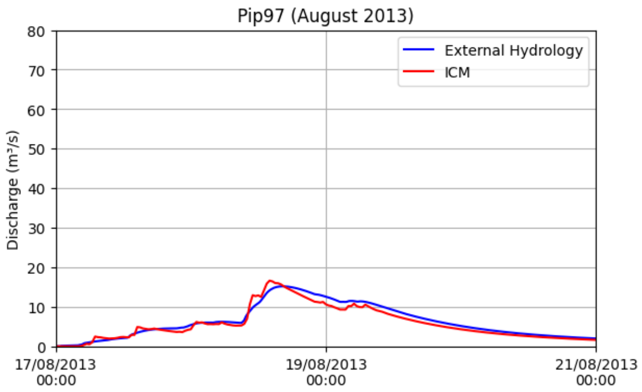
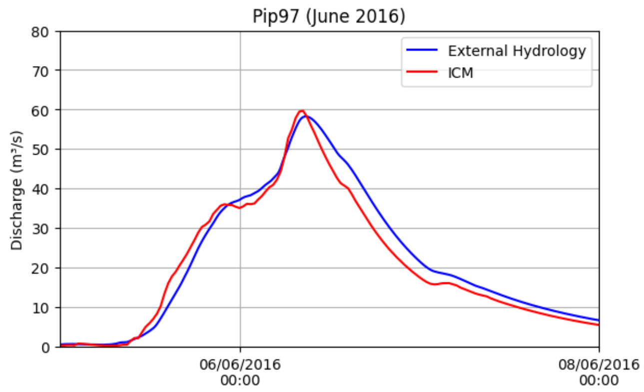
Category	Rating				
	Poor	**Fair**	**Good**	**Very good**	**Excellent**
Hydrodynamic calibration - peak levels	Peak level > +/- 1m of observed	Peak level within +/- 0.5m of observed	Peak within +/-0.5m of observed	Peak within +/-0.3m of observed	Peak within +/- 0.3m of observed
Hydrodynamic calibration – 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 TO ICM HYDRAULIC MODEL COMPARISON CHARTS

Figure C 1 Event hydrographs

Catchment	August 2013 Event	June 2016 Event
Piper_Urwd 		
Pip53 		
Pip60 		
Piper_Yrrw 		
Pip85 		
Pip9 		

Pip20 		
CurriesRes 		
Pip97 		

Appendix D

APPENDIX D. RATING CURVE COMPARISON

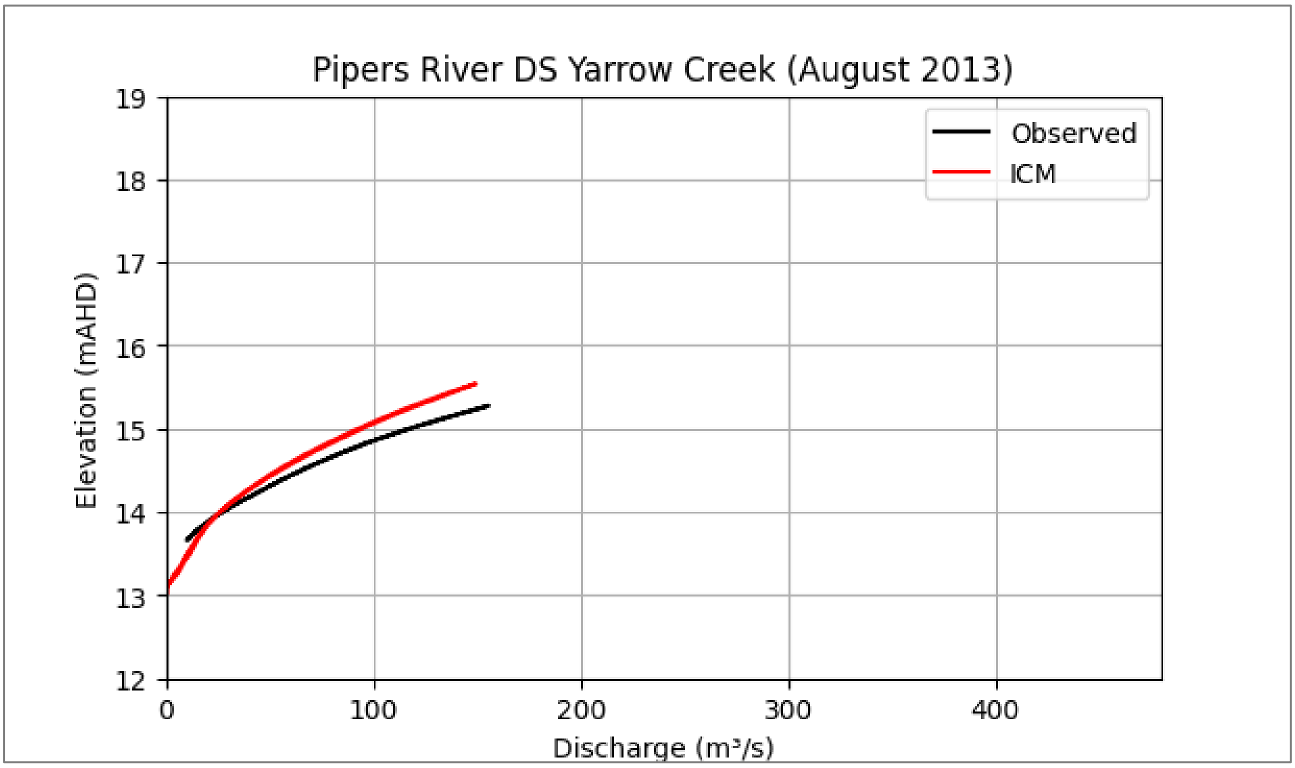


Figure D 1: Comparison of ICM results to rating curve – Pipers River DS Yarrow Creek, August 2013

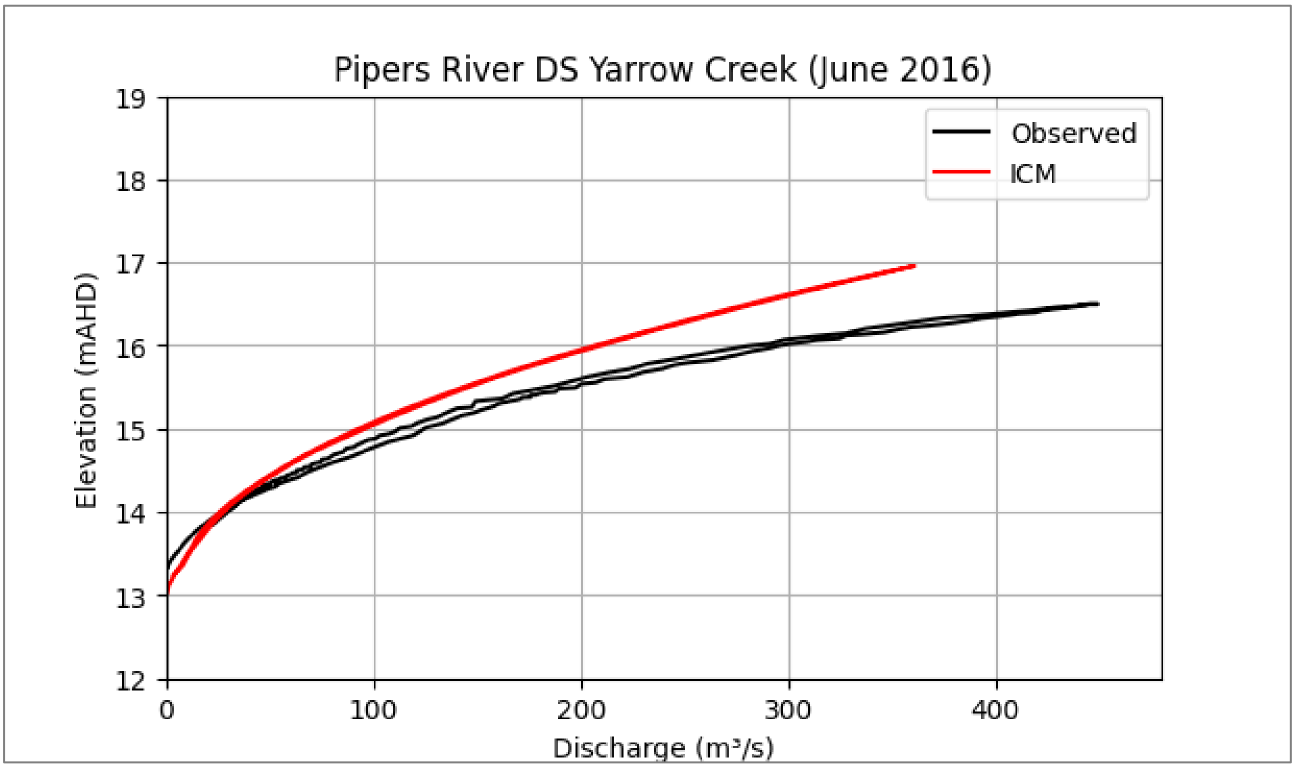


Figure D 2: Comparison of ICM results to rating curve – Pipers River DS Yarrow Creek, June 2016

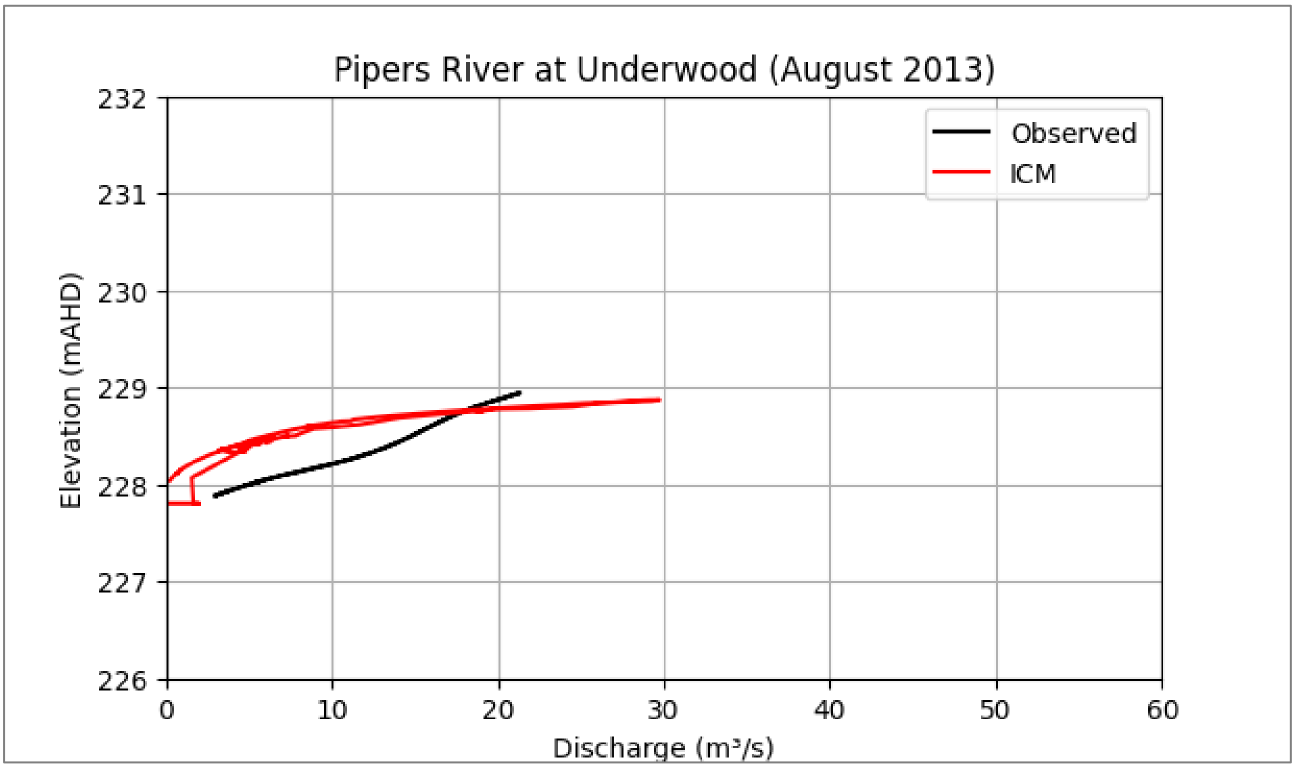


Figure D 3: Comparison of ICM results to rating curve – Pipers River at Underwood, August 2013