STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP
MEANDER RIVER CATCHMENT
MODEL CALIBRATION

REPORT

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AUGUST 2021

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Project Tasmanian Strategic Flood Map Meander River Catchment Model Calibration	**Project Number** **120038**
Client STATE EMERGENCY SERVICE	**Client's Representative** Luke Roberts
Project Manager Fiona Ling	

Revision History

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1	Revised draft report for review	Luke Roberts, SES	Sarah Blundy, Audrey Lau	Daniel Wood, Fiona Ling	Mark Babister	JUN 21
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TASMANIAN STRATEGIC FLOOD MAP
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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
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 (typically used to mean design rainfalls provided by BOM)
LiDAR	Light Detection and Ranging
LP3	Log Pearson Type 3 distribution
mAHD	meters above Australian Height Datum
mRL	meters reduced level
PERN	Catchment routing parameter in RAFTS
Pluvi	Pluviograph – Rain gauge with ability to record rain in real time
PTP	Point Temporal Patterns
QAQC	Quality assurance and quality control
R	Channel routing parameter in WMAWater RAFTS WBNM hybrid model
RAFTS	hydrologic model
SCE	Shuffled Complex Evolution
SES	State Emergency Service
TP	Temporal Patterns
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 of the Meander River catchment. This catchment is one of two validation catchments used to validate methods and data for the project.

2. STUDY AREA

The Meander River is situated in the central-eastern area of Tasmania. The Meander River catchment has an area of approximately 1,600 km^2. The Meander River originates in the Great Western Tiers and flows into the South Esk River 12km southwest of Launceston. The South Esk River drains a large part of central-east Tasmania and discharges into the Tamar Estuary at Launceston. The Meander Dam was built on the Meander River in 2007 upstream of Meander Township. The dam impounds Huntsman Lake, which is owned and operated by Tasmanian Irrigation and is used to supply irrigation water and generate electricity through the Huntsman Lake Power Station. The catchment lies within the South Esk Hydro-electric Water District and its water contributes to generation of electricity at Trevallyn Power Station. The towns within the Meander River catchment include Deloraine, Westbury and Meander. The catchment is shown in Figure 1. The land use groups across the catchment are shown in Figure 2.

3. AVAILABLE DATA

3.1. Historic Flow Data and Level Data

There are seven flow gauges with available data in the Meander catchment area, however some of these are on very small tributaries.

There are two main gauges on the Meander River itself and three additional gauges on tributaries that have some value for calibration (Table 1). All gauges are owned and operated by DPIPWE, other than Meander River at Deloraine which is owned by Hydro Tasmania. DPIPWE and Hydro Tasmania supplied timeseries of flows, and ratings and gaugings for Deloraine, Strathbridge and Liffey sites.

Review of data for the calibration events shows that two of the gauges on the Liffey River and the gauge on Western Creek do not appear to be able to record high flow levels (Diagram 1). This is likely due to higher levels being beyond the instrument range, as the same behaviour as shown in Diagram 1 is observed in the level data. One of these gauges is named Liffey River upstream Storage Pond, however this is an off-stream storage and so should not impact the flows, however it is also possible that there is an unknown hydraulic control that could impact on higher flows, rather than being a limitation of the recording equipment at these sites.

Table 1: Flow gauges information

Gauge attribute	Meander River @ Deloraine	Meander River at Strathbridge	Western Creek @ Bankton Rd Bridge	Jackeys Creek @ Jackeys Marsh	Liffey River A/B Carrick Br
Gauge number	162-1 541-1^	852-1	3395-1	18221-1	164-1
Gauge abbreviated name	Deloraine	Strathbridge	Western Creek	Jackeys Marsh	Liffey A/B Carrick
Current gauge owner	Hydro Tasmania	DPIPWE	DPIPWE	DPIPWE	DPIPWE
Start date	01/09/1954^	28/08/1985	19/04/2007	01/04/1982	01/01/1982
End date	Remains open	Remains open	Remains open	Remains open	Remains open
Latitude	-41.524	-41.487	-41.589	-41.674	-41.535
Longitude	146.659	146.906	146.537	146.657	147.003
Rating quality	Very good	Very good	Poor	Poor	Very good
Used for calibration events	2011_Jan 2016_Jun 2016_Jul	2011_Jan 2016_Jun*			2011_Jan 2016_Jul
Used for FFA	Y	N	N	N	N
Assumed local datum 0m in AHD	228.52m# 226.86 mRL####	133.33m##	-	458.78m###	137.34m##

Gauge attribute	Meander River @ Deloraine	Meander River at Strathbridge	Western Creek @ Bankton Rd Bridge	Jackeys Creek @ Jackeys Marsh	Liffey River A/B Carrick Br
Highest recorded date	09/10/1992 (541-1) 06/06/2016 (162-1)	07/06/2016	15/05/2013	06/06/2016	25/07/1988
Highest recorded stage height (m local) datum)	4.89 (541-1) 3.83 (162-1)	9.27	3.19	2.33	3.31
Highest recorded flow (m^3/s)	433 (541-1) 405 (162-1)	555	24	49	247
Date Highest recorded flow	25/08/1970 (541-1) 06/06/2016 (162-1)	24/09/1998	15/05/2013	06/06/2016	25/07/1988

* The peak flow at Strathbridge for June 2016 was estimated as the site was washed out during this event

^ The records at two gauges have been combined to give flows at Deloraine – data from the Hydro Tasmania gauge Meander at Deloraine Bridge (162-1), which has a data gap from 1975 until 1991, was combined with the DPIPWE gauge Meander below Deloraine (541-1), located approximately 2km downstream with no major tributaries in between, where data was available.

The local datum was provided by DPIPWE

The local datum is assumed based on the cease-to-flow level.

The local datum is assumed based on the mesh level in ICM.

The local datum is assumed based on recorded 2016 flood levels.

A combined record was created from the Hydro Tasmania gauge Meander at Deloraine Bridge (162-1) and DPIPWE gauge Meander below Deloraine (541-1) as there is a data gap in the Hydro Tasmania record from 1975 until 1996. Meander below Deloraine is located approximately 2km downstream of the Hydro Tasmania gauge with no major tributaries in between. While there was not a period of overlapping high quality data there are extensive comments in the Hydro Tasmania data files that indicate the sites have been used together within Hydro Tasmania. There is some overlapping data with only intermittent data at site 162, this shows that the general flows appear to match well, even if the old 162 data is no use for calculating event peaks (Diagram 2).

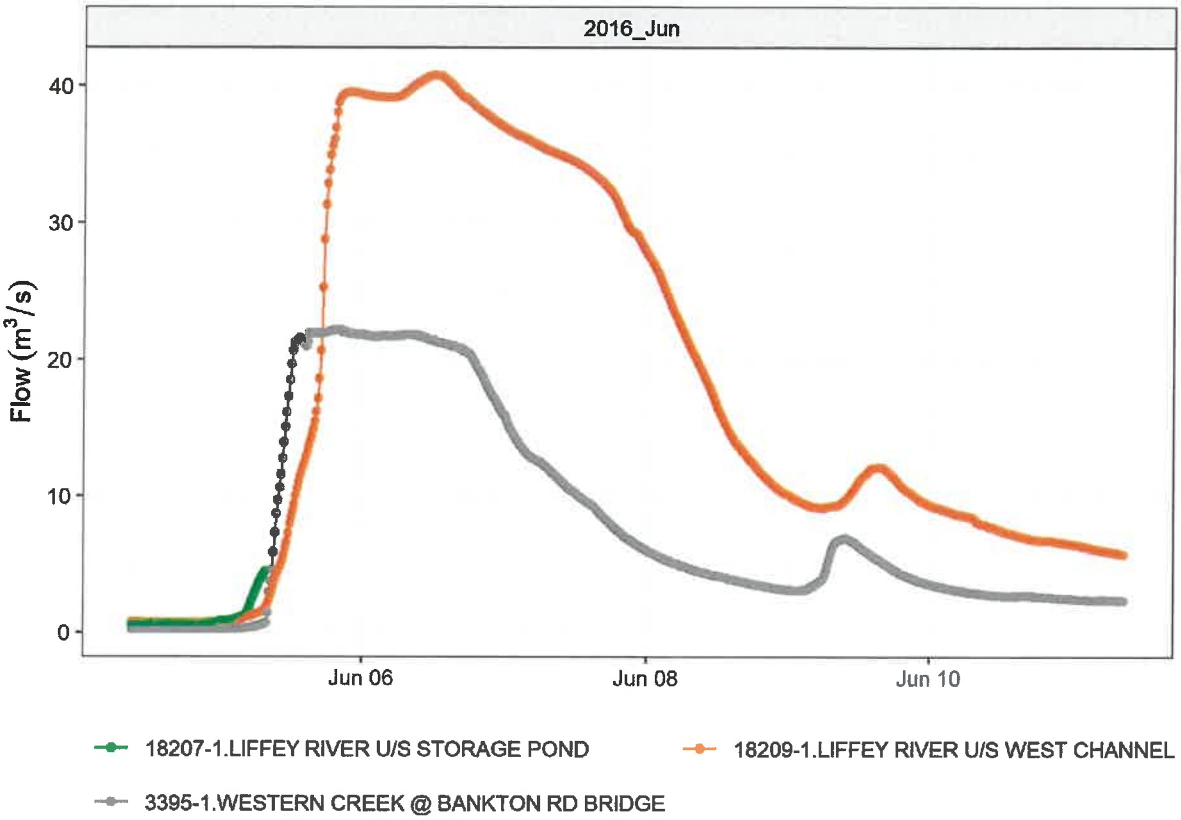

Diagram 1: Example of gauges excluded from calibration where the hydrograph is cut off (18207-1) or is unrealistically flat at the top (18209-1, 3395-1)

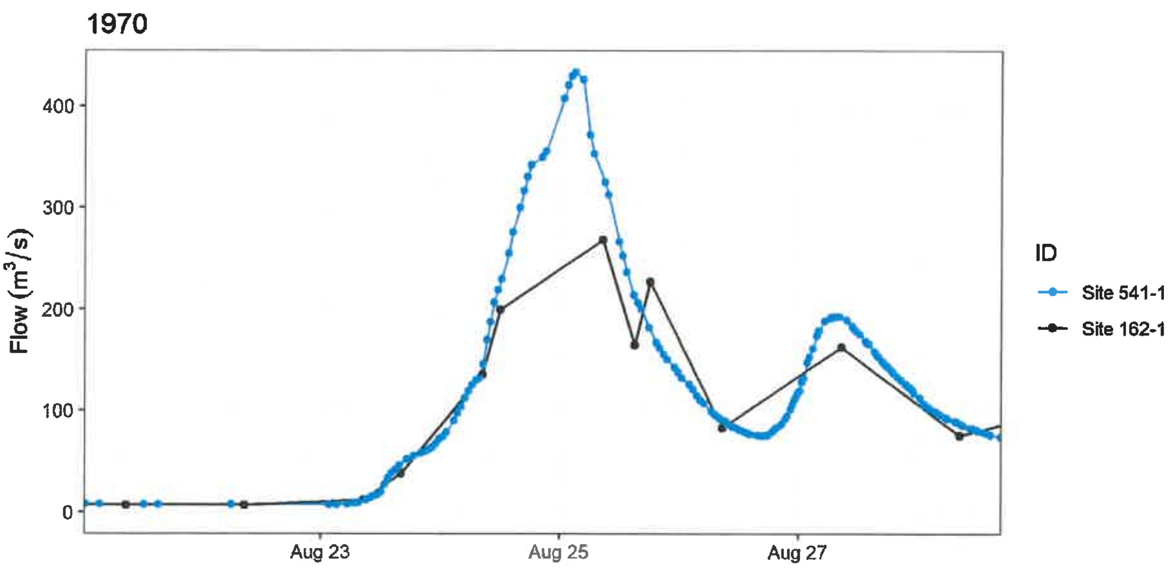

Diagram 2 Comparison of August 1970 flood data at DPIPWE's site 541-1 (near continuous) and Hydro Tasmania gauge 162-1 which at this time was only read approximately daily. This shows good fits at times with a data point in site 162-1 but clearly would not match event peaks.

3.1.1. Calibration Event Data Availability

Of the 13 flood events selected by the Bureau as calibration events for this project, only four had any significant flows (> 50% AEP) recorded in the Meander River. August 1970 and June 2016 were the largest two events on record at Deloraine, however widespread, high quality, sub-daily rainfall data is not available for the 1970 event. Therefore, this event was not included as a calibration event, but will be run when the full suite of historical events is run. The January 2011 and July 2016 events were between a 20% AEP and 50% AEP flow for the Meander River.

3.1.1.1. 162-1 Meander at Deloraine Bridge

There is data available for all three calibration events (Jan 2011, June 2016 and July 2016) at Meander at Deloraine Bridge. Comments and quality ratings in the archive suggest that these flows were at the very upper end of the stage to flow rating curve for Jan 2011 and June 2016. The site was visited during the June 2016 event and all the gauge boards were underwater. Hydro Tasmania was unable to provide their ratings in a user-friendly format, however a screen shot of the ratings available on Water Data Online (Bureau of Meteorology, 2021) was provided by SES. This suggests that the highest gauging is at approximately 3.5 m, only 0.3 m below the highest level recorded during the June 2016 event. This gives some confidence in the rating curve in the range of flows of relevance for calibration.

3.1.1.2. 852-1 Meander River at Strathbridge

Complete data is only available for the January 2011 event at the Meander River at Strathbridge gauge. A flow data time series is available on DPIPWE's data portal for June 2016. This is largely estimated as it is believed that the site was washed out during the rising limb of the hydrograph. Data remained unavailable for several months after June 2016 meaning there is also no data available for July 2016. Even with an estimated peak, June 2016 is the third largest event on record at the Strathbridge gauge, almost equal to the second largest event in 2005. The rating information provided by DPIPWE at this site only included a screen shot of the rating from October 2016 to present, so the rating quality for any of the calibration events is unknown. The information supplied shows that there are several high flow gaugings from events in 1988, 1992 and the recession of the June 2016 event after the site was washed out. These gaugings show significant variability, with very similar flows recorded at almost 0.8 m stage height difference. This could be due to uncertainty in gauging flow during large flood events, or natural change to flow characteristics over 30 years. Hysteresis may also be a factor, with the 1988 gauging taken before the peak, 1992 gaugings taken almost at the peak and the 2016 gauging taken on the recession.

3.1.1.3. 164-1 Liffey River above Carrick Bridge

The Liffey River above Carrick Bridge site has data for all three calibration events. However, flows and levels for the June 2016 event show a surprisingly flat section at the top of the hydrograph that suggests that the level recorded reached the top of its reliable range, which precluded its use for this event. The rating curve at the Liffey River site appears to be good, showing good consistency with the hydraulic rating curve reviews undertaken as part of this project (WMAwater, 2021a).

3.1.1.4. 18221-1 Jackeys Creek at Jackeys Marsh

Data was available for all three calibration events at Jackeys Creek at Jackeys Marsh, however the rating curve at this site is considered unreliable as the highest gauging is only at about 8 m^3/s while the highest recorded flow in June 2016 was almost 50 m^3/s. Additionally this site is located directly downstream of Jackeys Marsh which acts as a detention basin in the lower flow events in 2011 and July 2016, resulting in this site being difficult to model in a hydrologic model alone as the hydraulic effects will not be accounted for. As such, this gauge has not been used in model calibration or verification.

3.1.1.5. 3395-1 Western Creek @ Bankton Rd Bridge

Stage and flow data was available at Western Creek for all three calibration events, however the two larger events (January 2011 and June 2016) clearly overtopped the instrument range with almost flat lines at the top of the hydrograph (Diagram 1). Therefore, only data for the July 2016 event from this gauge was available. This gauge is located on a section of the creek that acts as an irrigation canal with the satellite imagery showing the channel forming a very orderly straight line. The resolution of the hydrodynamic model limits the ability to review the results of the hydrodynamic model at this location. The total width of the channel at the location of the gauge is less than 5 m, which is smaller than the resolution of the model. As such, this gauge has not been used in model calibration or verification.

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 Meander catchment (see Data Review Report WMAwater (2020a) for details on calibration events).

There are multiple daily and sub-daily gauges available in and around the catchment for all calibration events. The gauges in and around the Meander catchment are shown in Figure 1. The sub-catchment rainfall depths for the selected calibration events are shown in Figure 3 to Figure 5. This shows the highest rainfall in the far south west of the catchment, with the lowest rainfalls near the outlet, downstream of the Strathbridge and Liffey above Carrick gauges. This is consistent with the "typical" extreme rainfall in the area, seen in the IFD rainfall depths (Figure A 1 to Figure A 3).

Table 2 – Available Rainfall Information

	January 2011	June 2016	July 2016
Number of sub-daily stations available within the catchment	4	7	6
Number of daily stations available within the catchment	19	20	19
Number of subdaily surrounding gauges ~15km	10	10	9
Number of daily surrounding gauges ~15km	15	7	7
Rainfall Totals	60-210 mm	87-280mm	36-120mm
Approx duration of rainfall event	54 hours	36 hours	48 hours

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 2021b 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.

3.3. Meander Dam

The Meander Dam was built on the Meander River in 2007, upstream of Meander Township. The dam impounds Huntsman Lake, which is owned and operated by Tasmanian Irrigation and is used to supply irrigation water and to generate electricity through the Huntsman Lake Power Station.

Tasmanian Irrigation did not provide any information on the dam configuration of Meander Dam for this study. Some information was available from the List Map from the Dam Permit Locations (DPIPWE 2009) layer and the LIST Hydrographic Areas layer (DPIPWE 2014), however information about the spillway width or length was not available (Table 3).

For the hydrological model calibration and design runs, the external hydrologic model was run assuming the dam had "glass walls" (fixed surface area above full supply level). In the external hydrologic model and the hydrodynamic model, the spillway was modelled using a simple broad crested weir equation, with a spillway width of 50 m estimated from aerial photography, satellite imagery and LiDAR information.

Table 3 Meander Dam information from List Map (DPIPWE 2009 and DPIPWE 2014)

Dam ID	8345
Easting	468424
Northing	5384378
Dam Status	Existing
Dam Type	Irrigation
Height (m)	50
Capacity (ML)	43000
Crest Width (m)	3.5
Crest Length (m)	402
Spillway Width	N/A
Spillway Length	N/A
Year Built	2007
Surface Area (hectares)	372

3.4. Flood Levels and Extents

Flood survey levels and extents within Meander catchment were available following the 2016 surveyed flood extents program conducted after the June 2016 flood event. This information was used to verify the results of the June 2016 event.

Besides that, a drone video ("Flooded Deloraine") was taken in the township of Deloraine in June 2016. It was uploaded by Rod How on YouTube. However, the time of the video taken is not recorded.

No other information was provided to enable verification of other rainfall events for the catchment.

3.5. Previous Flood Studies

A previous flood study of Deloraine was provided as part of the project (Hydrodynamica, 2015). The study utilised the 1992 flood event to validate the model, with observed flood levels within Deloraine used to benchmark the model performance. The model utilised the same LiDAR set as is used for this version of the model, coupled with bathymetry of the river. The bathymetry was not provided within our study.

The model also estimated a 1% AEP peak flow and extent. The model however used a hydrograph derived from the 1992 event to estimate the level rather than a design hydrograph. Additionally, this hydrograph is not presented anywhere to understand the shape or function.

A review of the report identified several challenges in correlating the current assessment to the previous modelling completed including:

- No hydrograph was provided to enable comparison of the flows within the model to either current modelling or the recorded flows at Deloraine.
- The gauge at Deloraine for this event was deemed to be inaccurate and as such the flows are not available for review as part of this project.

- No details of the cross section of the channel are provided to enable an estimate of the channel shape in lieu of obtaining the bathymetry.
- No discussion of the weir or weir definition is present in the report (or any other structure). It is unclear how the system represented the weir; and
- The model seems to have utilised a recorded flow at the gauge as an upstream inflow, placing the flow at the upstream end of a large storage area. Without the comparison of inflows between the recorded and modelled it is difficult to ascertain the impact of this decision.

Ultimately it is considered the focussed Deloraine modelling undertaken will likely provide a better estimation of flood levels based purely on the presence of the bathymetry in the stream alone. Reference between the models however should be undertaken with caution noting the large discrepancies in approach and data availability.

3.6. Design Event Data

The design inputs (Intensity Frequency Duration (IFD) depths, losses, pre-burst rainfalls, Areal Reduction Factors and temporal patterns) were obtained through the ARR Data Hub (Babister et al, 2016) or the Bureau of Meteorology website (Bureau of Meteorology, 2019).

3.6.1. Design Rainfall Depths and Spatial Pattern

Intensity Frequency Duration (IFD) information was sourced from the Bureau of Meteorology website (Bureau of Meteorology, 2019). IFD information was sourced for each individual sub-catchment to give a spatial pattern across the catchment. Examples of sub-catchment rainfalls are shown in Figure A 1 to Figure A 3.

3.6.2. Temporal Patterns

ARR 2016 Book 2 Chapter 5 (Ball et. al. 2019) recommends the use of areal temporal patterns for catchments greater than 75 km^2. Therefore, for flood frequency analysis at the Deloraine gauge, the areal temporal patterns relevant to this location were downloaded from the ARR Data Hub. An example of the temporal patterns is shown in Figure A 4.

For selection of the final design runs applicable to the entire catchment, areal and point temporal patterns were downloaded from the ARR Data Hub. When assessing the reference critical flow for each sub-catchment (as described in the Hydrology Methods Report, 2021b), areal temporal patterns (ATP) were used for sub-catchments with an upstream area greater than 75 km^2 and point temporal patterns (PTP) were used for sub-catchments with an upstream area of less than 75 km^2. PTP were also used to assess shorter storms if the critical duration on a larger catchment was identified as 12 hours (the shortest duration available with areal temporal patterns).

3.6.3. Pre-burst

Pre-burst depths were taken from the ARR Data Hub as a ratio of the IFD depths. The median pre-burst depth was used in a sensitivity run with a pre-burst temporal pattern derived from historic storms within Tasmania. The temporal patterns used are described in the Hydrology Methods Report (WMAwater, 2021b).

3.6.4. Losses

Initial values for sub-catchment initial loss (IL) and continuing loss (CL) were derived from the unpublished Hydrologic Soil Groups of Tasmania data that was provided for use in this project (DPIPWE 2019) (Figure A 5).

3.6.5. Baseflow

Baseflow was calculated for each calibration event and found to be less than 5% of the event peaks, except for July 2016 which was approximately 5%. In line with ARR 2016 Book 5 Chapter 4 (Ball et. al. 2019) baseflows less than 5% are considered a small component compared to runoff, and a simplified approach to baseflow calculations was therefore undertaken. The July 2016 event is the smallest calibration event and is much smaller than the AEPs of interest for design mapping. As baseflows will be an even smaller component for the AEPs of interest (2%, 1% and 0.5%) it was determined that this catchment does not have significant baseflow and therefore this was not included.

3.6.6. Climate Change

3.6.6.1. Rainfall Factors

ARR climate change factors are the same across all of Tasmania, these were downloaded for the entire state from the ARR Data Hub. ARR recommends the use of the RCP4.5 and RCP8.5 values, however the Tasmanian Planning Scheme recommends the use of RCP8.5 and this has been adopted for this project. Using RCP8.5 results for the year 2090 gives a rainfall scaling factor of 16.3% increase to IFDs.

3.6.6.2. Boundary Conditions

Meander River catchment flows into the South Esk River at Hadspen. As the South Esk River catchment above the confluence has not been modelled, a 2000m^3/s passing through the confluence of the Meander River in the South Esk River is applied for the current and future design events. However, this can be updated once the South Esk River catchment is modelled in the future.

4. HYDROLOGIC MODEL METHODOLOGY

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

The following is an overview of the hydrologic modelling method.

- 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
  - Fitting FFA to suitable flow records
  - Extraction of design data – IFDs, temporal patterns, pre-burst rainfalls from ARR DataHub (automated in the modelling process)
- 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
  - After running initial run-through of ICM hydrodynamic model, adjust routing parameters values in both external and ICM-RAFTS hydrologic model if necessary, for better agreement between the models
  - Calibration of design losses to FFA using automated external hydrologic model
  - Running design events in the external hydrologic model, with design data, calibrated routing parameters and design losses. Outputs design sub-catchment rainfalls for selected design event for input to ICM combined hydrologic and hydrodynamic model
  - Run design events through ICM RAFTS model to provide sub-catchment pickups for direct input into ICM hydrodynamic model

In this catchment, changes were required to the relationship between the routing parameter, R, and slope to increase routing, in order to better match observed flood hydrographs within the catchment. The relationship used in this catchment is shown in Diagram 3. The R values were then increased further for some sub-catchments upstream of Deloraine. This is described in Section 7.1.1.

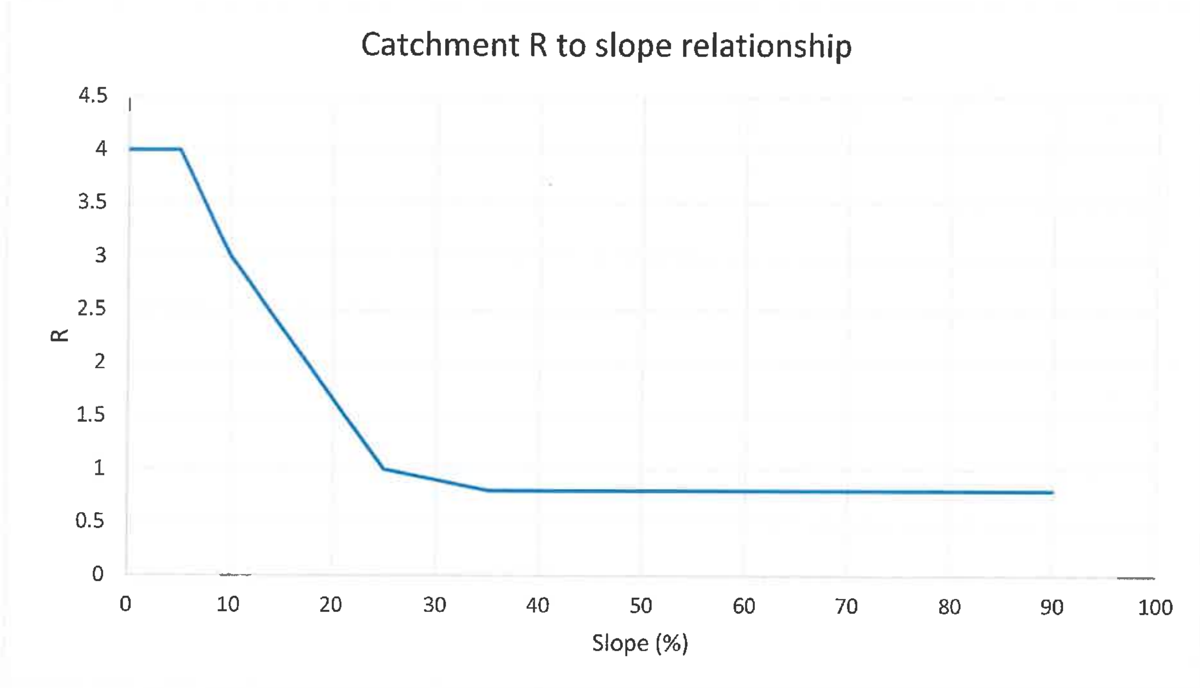

Diagram 3 R vs slope relationship for Meander catchment

PERNs are calculated for each individual land use group (shown in Figure 2) as described in the Hydrodynamic Methods Report (WMAWater 2021c) for the ICM model. Sub-catchment PERNs for the external hydrologic model were calculated from the areal weighted PERNs per sub-catchment.

5. HYDRODYNAMIC MODEL TERRAIN SETUP AND MESHING

5.1. Base DEM Management

The base dataset used was the SES state-wide 10 m DEM (including bathymetry) only. The 2 m DEM is not used in this catchment because it does not improve the 10 m DEM in critical areas such as the stream gauge locations, due to issues with representation of the channels. Examples of the issue with representation of the channels through Deloraine are shown in Diagram 4 and Diagram 5.

Diagram 4: Meander River through Deloraine - cross-sections.

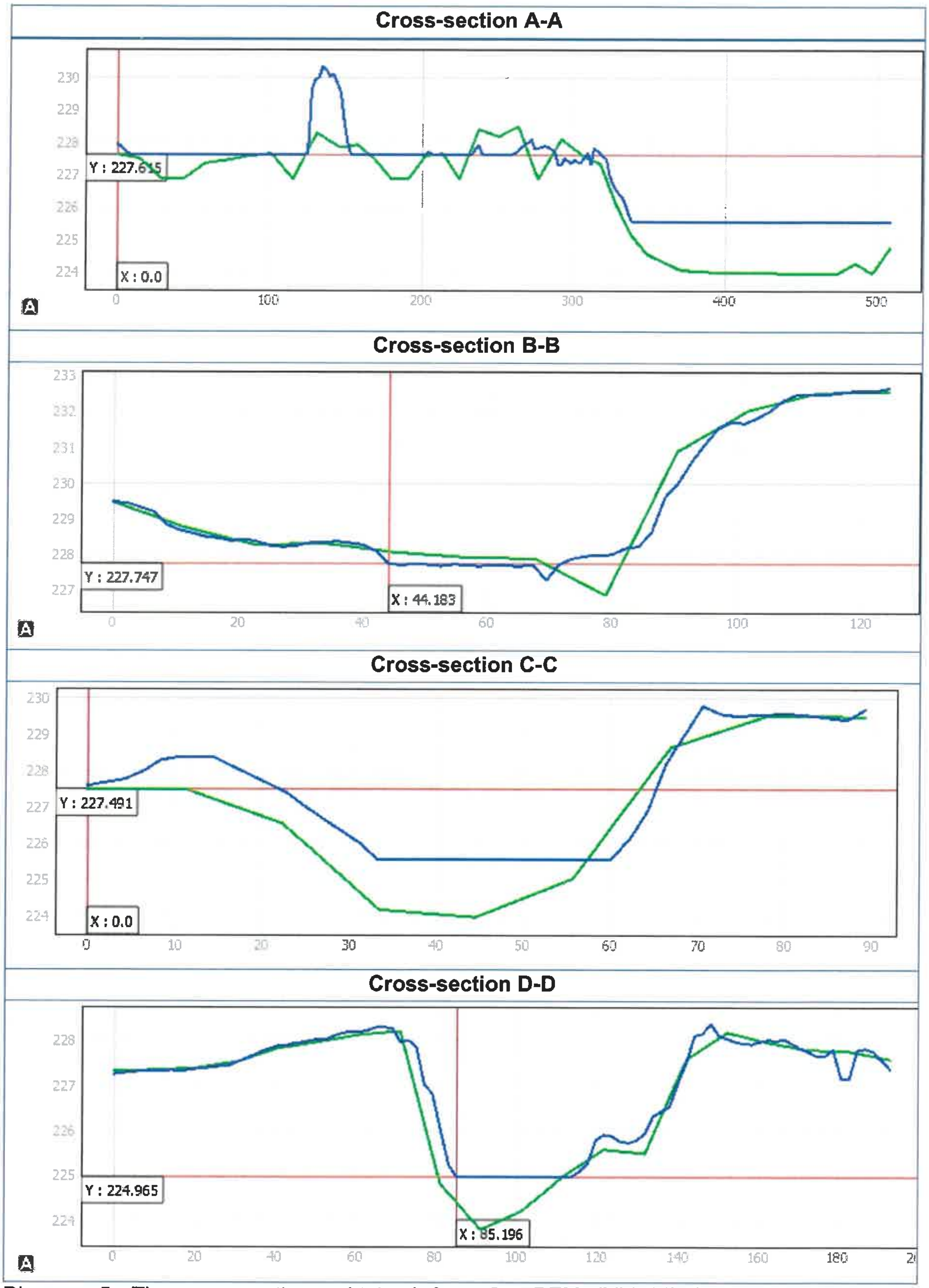

Diagram 5: The cross-sections obtained from 2m DEM (MV_14) (Blue) and 10m DEM (DEM_breached) (Green).

The 10m DEM was clipped to the study area with a buffer zone to ensure 100% active mesh area in the model. The study area was extended downstream of Meander catchment to include the confluence of Meander and South Esk at Hadspen.

The DEM was successfully imported to ICM via the grid import interface (Diagram 6).

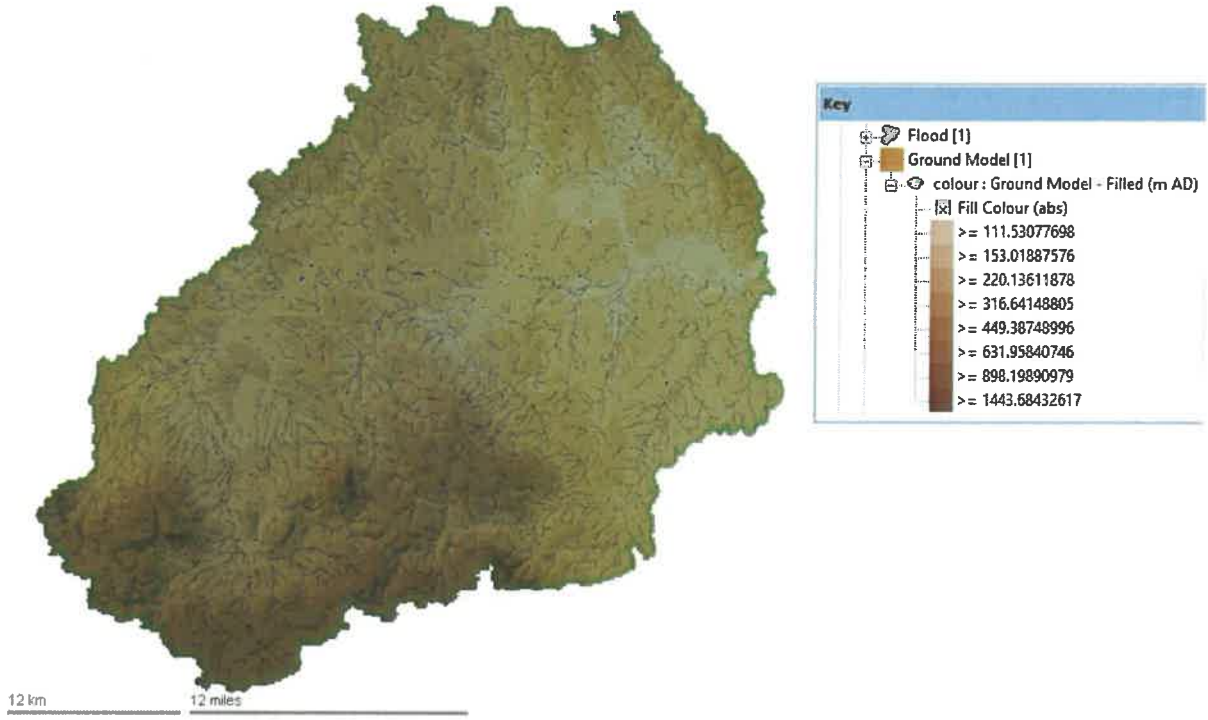

Diagram 6: Meander River catchment imported to ICM

The DEM at two of the bridges between Deloraine gauge and Strathbridge gauge was modified manually by adding polygons, in order to set reasonable levels. This was necessary as the 10m DEM does appropriately define the actual channel width that can be observed in the 1 m Hillshade. Since the geometry of the bridges is not provided, the width of the channel was obtained from the aerial image, and the invert level of the bridge was obtained from the lowest mesh cell level in ICM.

The modification of the DEM was deemed necessary in this location because the modelled level was higher than the 2016 flood survey level due to the backwater caused by the narrow channel under the bridges when the unmodified DEM was used.

5.2. Roughness Grid

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 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 10m buffered zone of single roughness of 0.035 for all upper streams was utilised. 0.035 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'. The roughness layer in ICM is shown in Diagram 7.

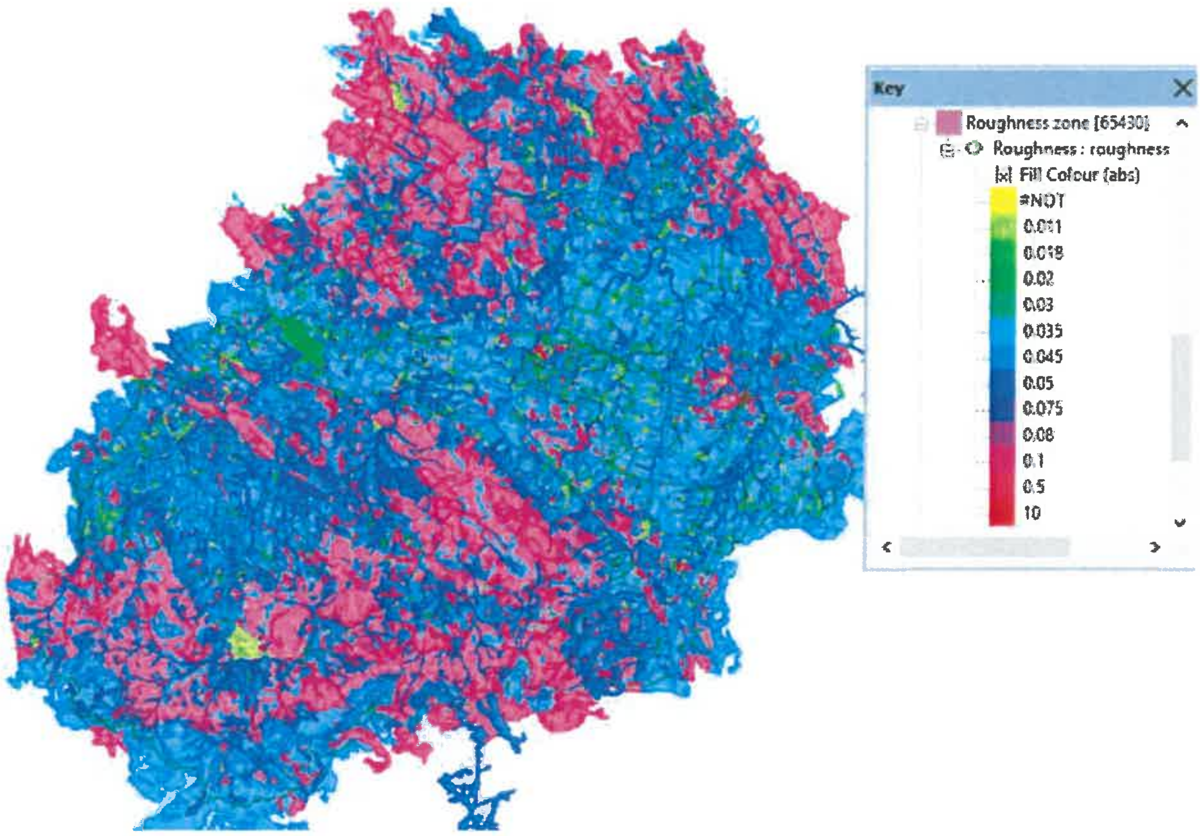

Diagram 7: ICM roughness layer for Meander River catchment

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 resulting mesh zones for the Meander catchment are shown in Diagram 8.

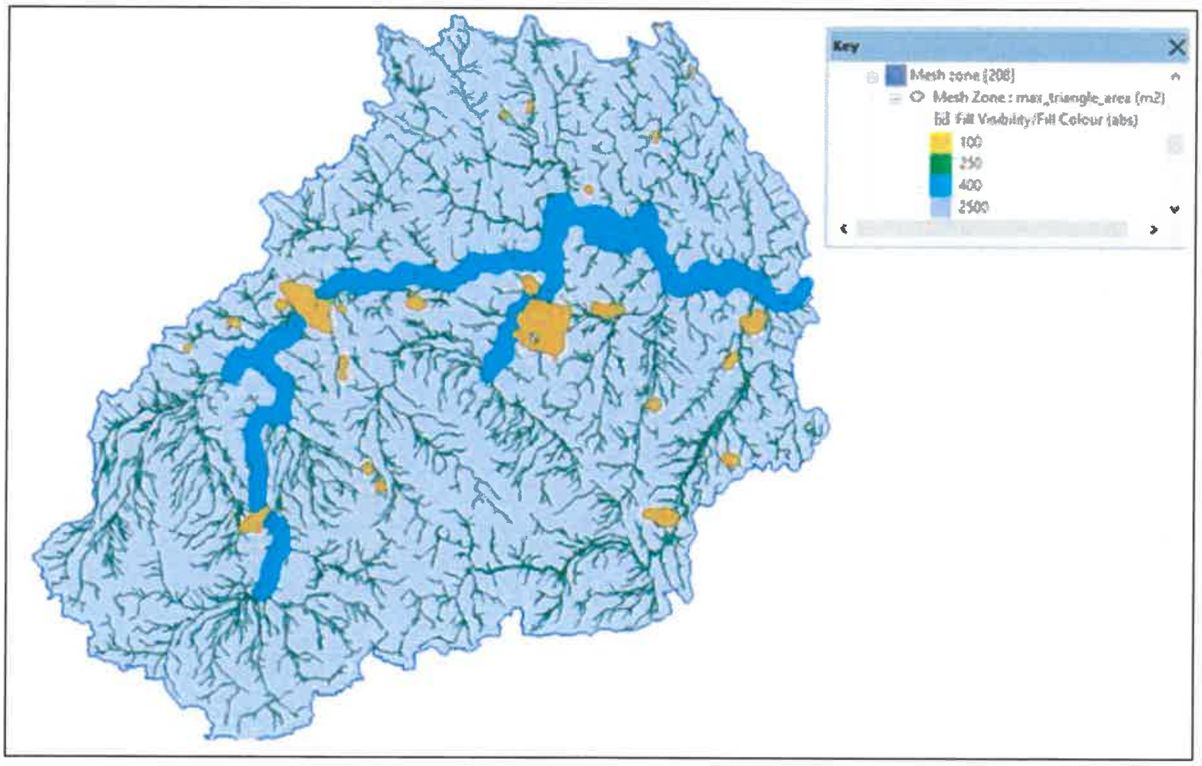

Diagram 8: Mesh Zones. Human Settlement Areas shown in brown.

5.4. Structures

5.4.1. Bridges

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

For the Meander River catchment, a total of 56 bridges longer than 30 m were identified and imported into the validation model. Two bridges were modified manually to represent a realistic opening of the bridge.

A further discussion on this process is provided in the Hydrodynamic Methods Report (WMAwater 2021c).

5.4.1. Culvert

A major culvert was identified near the junction of Bass Highway and Oaks Road as a significant 1D structure to be included in the model. The culvert posed a major obstruction to creek flow that resulted in water ponded at the upstream of the highway. No data was supplied on the dimensions of the culvert, so assumptions were made on the size, length and grade of the culvert based on available aerial and DEM data. The culvert was assumed to be of rectangular shape approximately 3 m wide by 1.2 m high. Further site visits to obtain the exact size should be undertaken to inform any future detailed studies.

5.4.2. Dam

Meander Dam was modelled with an initial water level of 402 m, which is the full supply level, as no historical dam storage level data was provided. The weir was modelled as a broad crested weir with a spillway length of 50 m and 3 m height, and the crest elevation of 405 m. These measurements were based on the supplied DEM and aerial photography. The modelled initial water extent of Lake Huntsman is shown in Diagram 9.

Diagram 9: The modelled initial water extent of Lake Huntsman (Meander Dam).

5.5. Downstream Boundaries

Downstream boundaries were applied at the base of the model to provide interaction with the flow from the South Esk River. For the calibration events, the hydrographs of stream gauge 181 South Esk River at Perth, 733 Macquarie River at Cressy Pump and 18219 Back Creek at Wilmores Lanes were combined and used as the flow at the tailwater boundary of Meander River in the South Esk River. Diagram 11 to Diagram 13 show tailwater boundaries that were used in the model.

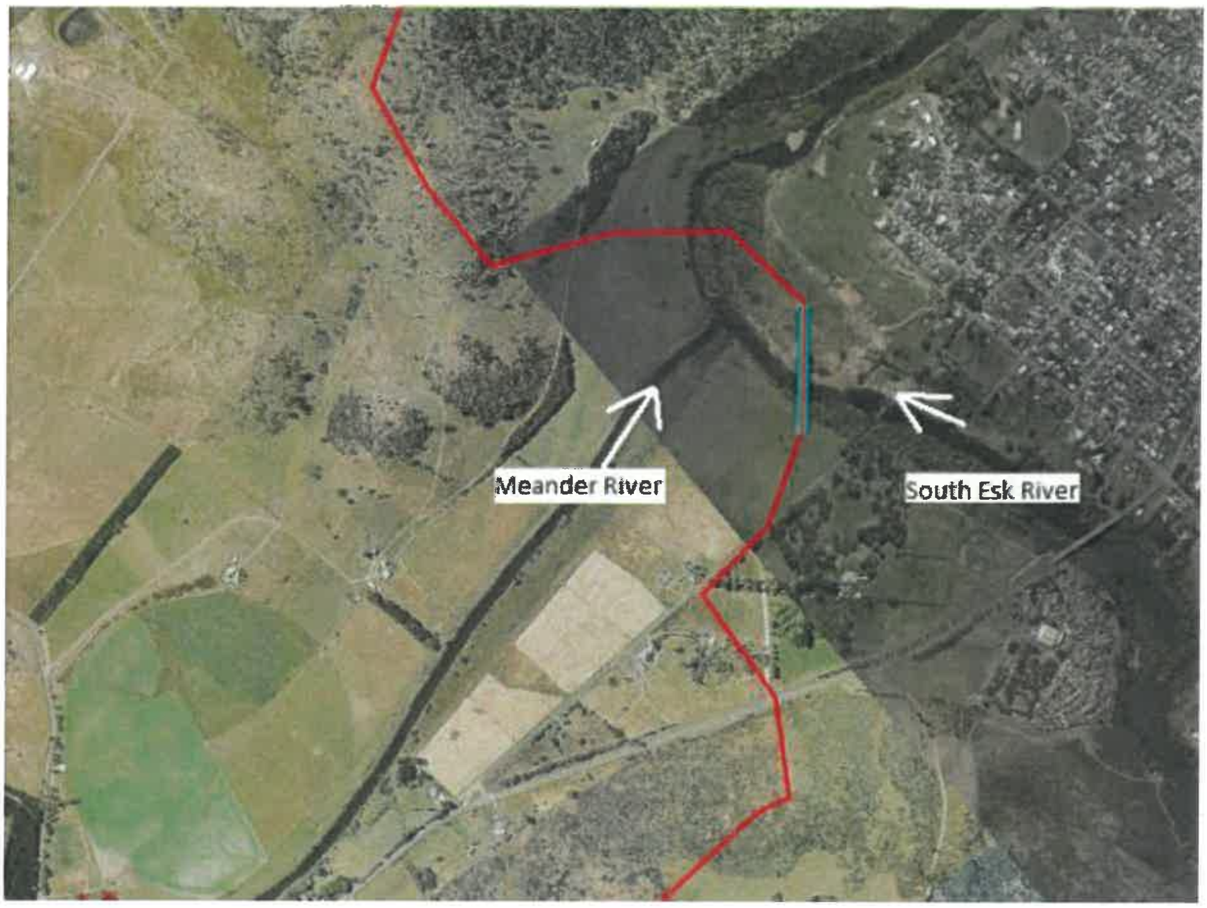

Diagram 10: The inflow boundary (blue) from South Esk River and the Meander catchment boundary (red) which is set as normal condition of the outflow.

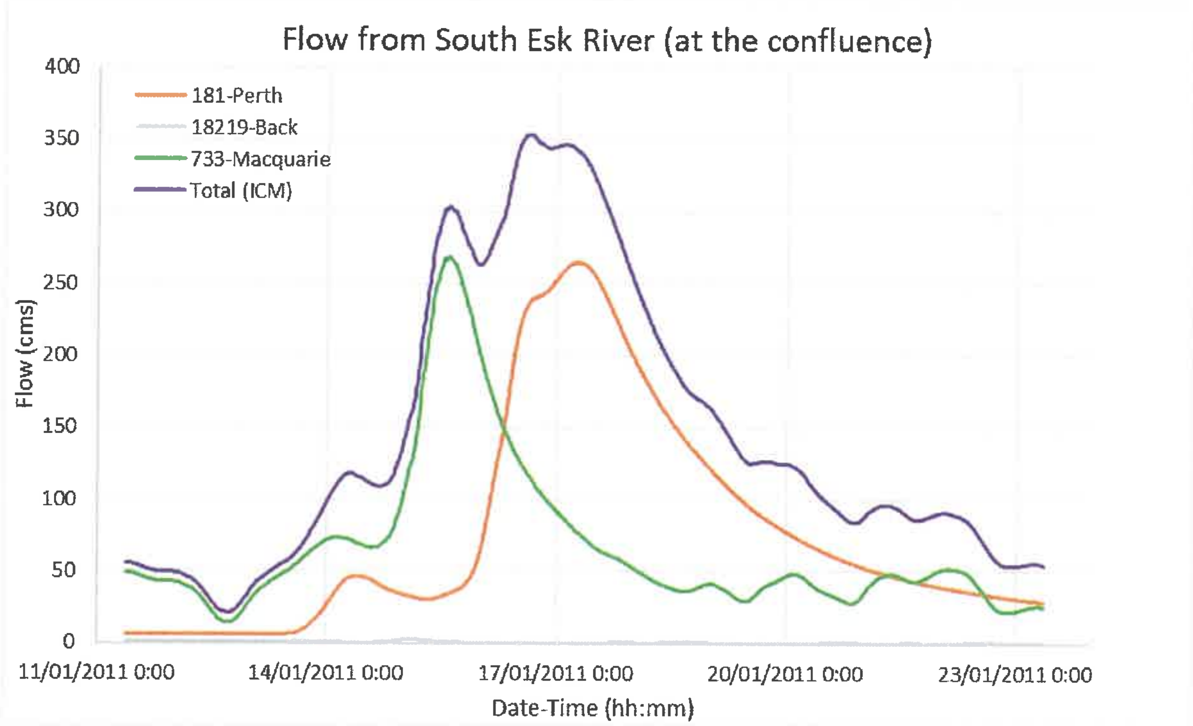

Diagram 11: The flow in the South Esk River at the tailwater boundary of Meander River in January 2011 event.

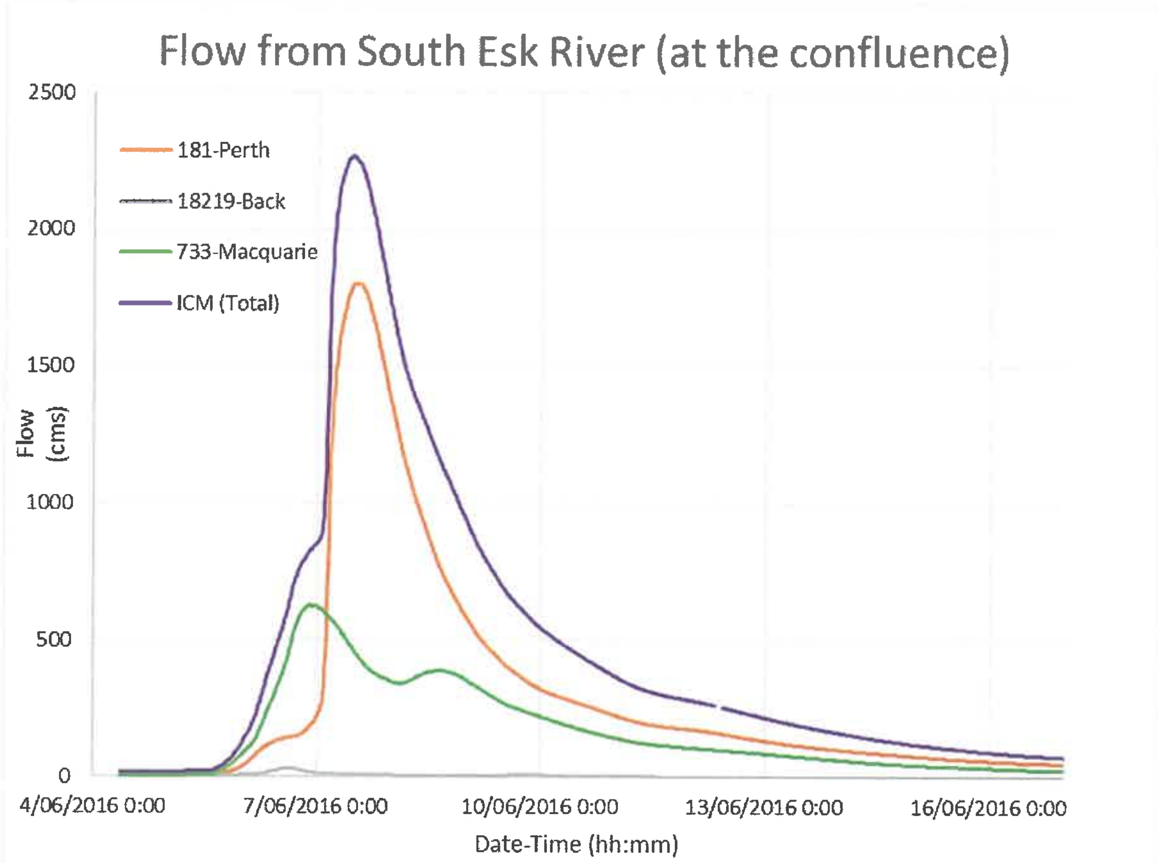

Diagram 12: The flow in the South Esk River at the tailwater boundary of Meander River in June 2016 event.

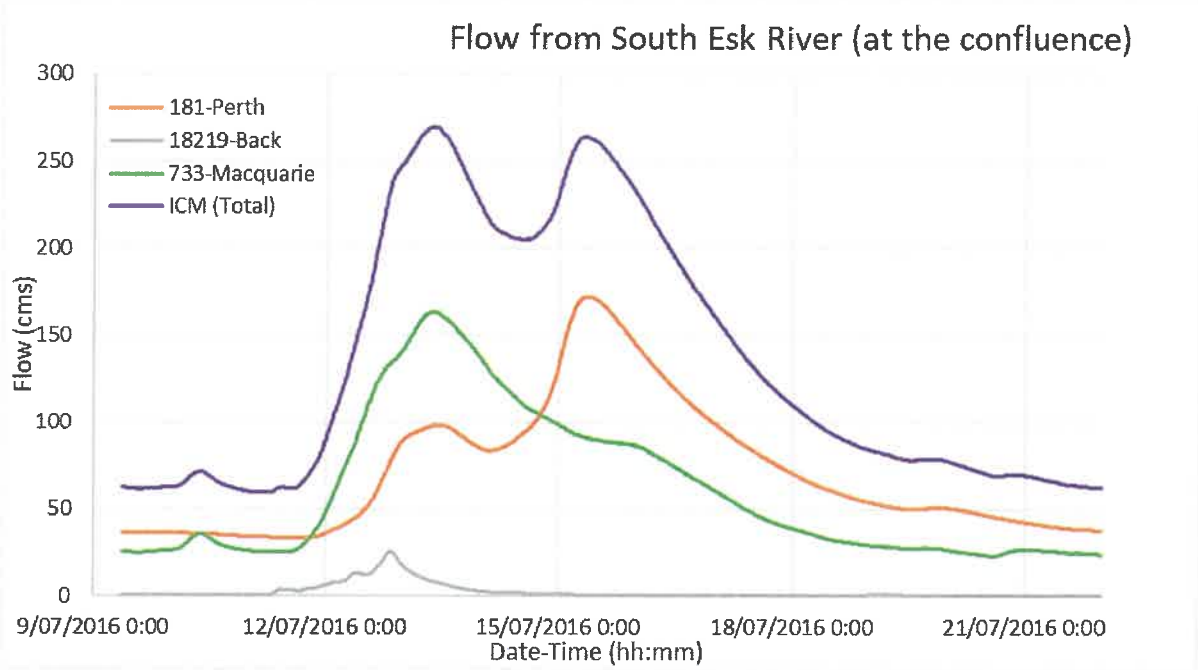

Diagram 13: The flow in the South Esk River at the tailwater boundary of Meander River in July 2016 event.

For the design events, an inflow of 2000 m³/s from South Esk River was applied at the downstream boundary. This will be updated once South Esk River is modelled.

5.6. Flow Application for Hydrodynamic Modelling

Two approaches were used for application of flow in ICM:

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

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, focussing on the major tributary flooding while also ensuring the local areas in 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 direct rainfall modelling, a synthetic, duration independent storm event is used to assess the areas for a range of storm durations and temporal shapes in a singular rainfall event.

For traditional RAFTS modelling, the rainfall information is derived from rainfall files created by the external hydrologic model (in the scenario of a calibration event) or via the internal ARR2019 rainfall approach within ICM (for a design event scenario).

5.6.1. Direct Rainfall

A requirement of the brief is to assess flow paths over the entirety of the catchment. A lumped inflow approach applying flow at the downstream end of each sub-catchment captures the majority of flow paths, however it is not capable of assessing flow paths in headwater catchments. Headwater catchments are shown in Diagram 35.

For these zones, an alternative approach of direct rainfall was utilised. This model enabled rainfall excess to be applied directly to all active mesh elements within the hydrodynamic model, thus enabling flow path representation of the overland flow paths present in the zone.

To use direct rainfall, the model was setup to enable rainfall to be applied to all mesh elements in the model. The sub-catchment layer was used to spatially vary the rainfall in the model, with a different rainfall temporal pattern and depth able to be applied for each sub-catchment. The files were input automatically with a flag linking the rainfall to the spatial zone in the model. The intent of the direct rainfall component is to model only the uppermost regions of catchments with a higher resolution.

Noting the time constraints of the project, an alternating block storm approach, rather than an ensemble storm approach was used, for the direct rainfall zones. The use of the alternating block enables the assessment of a range of durations to be undertaken within a single temporal pattern. This approach provides a reasonable estimation of peak flow (and thus level and hazard) for a range of storms within the area of interest but is not capable of producing realistic hydrographs. A detailed description of the alternating block temporal pattern is included in the Hydrodynamic Modelling Methods Report (WMAwater 2021c).

5.6.2. Traditional RAFTS Sub-catchment Routing

For traditional RAFTS sub-catchment routing, the RAFTS model within ICM is used to calculate the hydrologic routing in each sub-catchment. Rainfalls, model information and model parameters developed through in the RAFTS model in the WMAwater framework external hydrologic model, were input into ICM through the open data input tool.
The information input to ICM includes:

- Sub-catchment name
- Slope
- PERN
- 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 Meander River catchment is shown in Diagram 14.

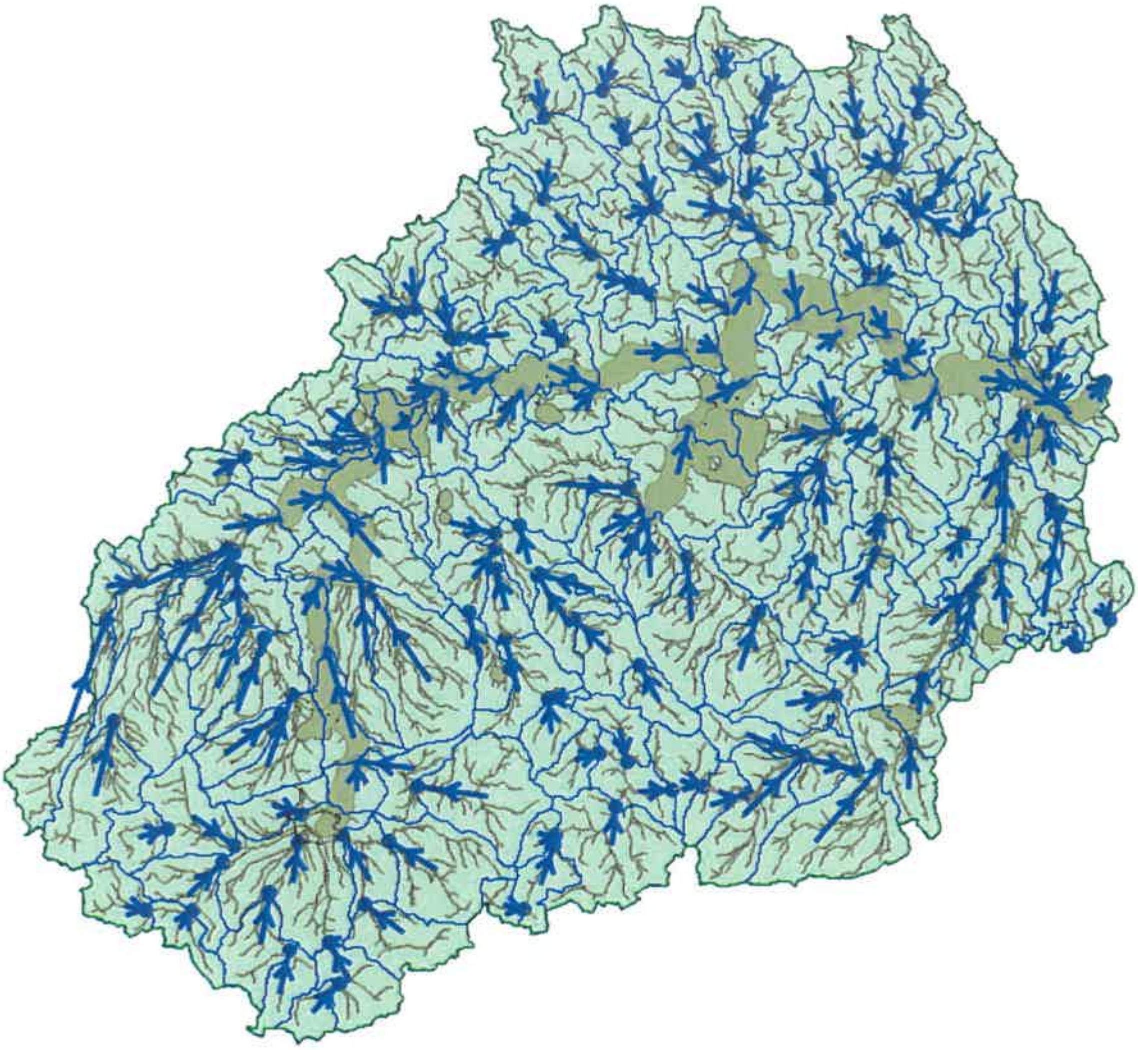

Diagram 14: ICM RAFTS traditional sub-catchment model setup for the Meander River catchment.

6. LIMITATIONS

One of the aims of the Tasmanian Strategic Flood Mapping project is to develop state-wide Strategic Flood Maps to support flood risk assessment and post event analysis. This is a regional flood mapping study and the methodology has been developed to provide mapping at a state-wide scale, as distinct from undertaking detailed flood studies over particular areas. The SES and local government can use the regional mapping to identify areas where further detailed flood studies would be beneficial. Limitations and assumptions were required in order to produce state-wide strategic flood maps within a reasonable timeframe and budget. The following are some of the limitations and assumptions in the data and the methodology.

- The scope of the project, as defined by SES, included thirteen calibration events. These events were selected by Bureau of Meteorology as significant events over Tasmania. Investigation of flow data at gauge sites has shown that, in many catchments, there are more significant flood events than those selected, that would be more suitable for model calibration. In the Meander study area, only four of the selected events had any significant flows (> 50% AEP) recorded in the Meander River. Widespread, high quality, sub-daily rainfall data was available for three events.
- There is no surveyed gauge zero for the Deloraine gauge, and a lack of other data to provide an exact conversion from the gauge local datum to mAHD
- The base dataset used for raw data was the SES state-wide 10 m DEM (including bathymetry) merged with available 2 m DEM subsets. The 2 m DEM was unable to be used for bathymetry due to issues with breaching. The DEM at the Deloraine township within the channel is poorly defined and this limits the ability of the hydrodynamic model to match surveyed levels.
- The surveyed extent of June 2016 event is based on very limited data points in several locations, and should be assumed to have a low level of accuracy.
- Due to the absence of the details of the dam in the calibration events, it is assumed to be at full supply level. Future assessments should aim to obtain further information on the dam and its storage level during rainfall events.
- Design events are selected by running design rainfalls through the hydrological model across the entire study area with a range of ARFs to select representative ARFs, storm durations and temporal patterns to be run through the hydrodynamic model. The selection of these four ARF-duration-TP sets per AEP does introduce error compared to running each sub-catchment's ideal ARF-duration-TP set through the hydrodynamic model, however running thousands of runs of the hydrodynamic model is clearly not feasible for a state-wide study. Enough ARF-duration-TP sets are used in order to keep the error within agreed bounds.
- In the headwater catchments, direct rainfall was defined as the dominating event. Direct rainfall was also applied to all sub-catchments, however the critical duration of the primary flow path was not defined by this scenario. In the direct rainfall zones, an alternating block storm approach, rather than an ensemble storm approach was used. The use of the alternating block enables the assessment of a range of durations to be undertaken within a single temporal pattern. This approach provides a reasonable estimation of peak flow (and thus level and hazard) for a range of storms within the area of interest, but is not capable of producing realistic hydrographs. Whilst this method has the potential to

overestimate flows, this was not considered to be an issue for the modelling, as the direct rainfall is only used for mapping purposes and not as an input to downstream sub-catchments.

- The coarse definition of the hydrodynamic model does not allow for the detailed assessment of low flow hydraulic features. This means that modelled water levels at gauges for lower flows will not necessarily compare well with observed water levels.
- 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.

7. CALIBRATION RESULTS

7.1. Hydrologic Model Calibration

The external hydrologic model was largely calibrated to the gauge at Meander River at Deloraine Bridge with some consideration of the Meander River at Strathbridge gauge. The Deloraine gauge was chosen as the Meander River at Strathbridge gauge had no data for July 2016, and levels were only estimates for the peak of June 2016, leaving only one calibration event for which data was available at this gauge. Other gauges on the smaller tributaries were used for only for verification of the parameters chosen and typically confirmed the validity of the catchment-wide parameter set.

The Meander River is a slow moving river with significant flood storage. This was evident in the observed records at Deloraine and Strathbridge and also in initial hydrodynamic model runs. It was necessary to undertake a joint calibration of the external hydrologic model and the ICM combined hydrologic and hydrodynamic model, to revise the external hydrologic model routing parameters. This ensured the external model was adequately reflecting the ICM model so that it could be used to inform parameter and design run selection. Therefore, channel routing parameters obtained from the initial hydrologic model calibration on the Meander River were increased slightly in the sub-catchments upstream of Deloraine and increased by a greater amount from Deloraine to the base of the catchment, based on the results of the hydrodynamic modelling. This was done as part of joint calibration of the hydrological model and hydrodynamic model, and resulted in the external hydrologic model results better fitting the observed flows.

7.1.1. Meander River at Deloraine Bridge

The model calibration resulted in reasonable fits for all three events at Meander River at Deloraine Bridge gauge. The modelled peak flows were within 3% of the observed and the modelled hydrographs generally showed similar timing and shape, but were narrower and had less volume than the observed hydrographs. For the Meander catchment, the routing parameter (R) to slope relationship was changed from the standard relationship to account for additional routing observed in the catchment. This was done to attempt to better match the shape of the observed hydrographs. This resulted in R values of up to 4 in large parts of the catchment. Once the hydrodynamic model had been run the R values in the three sub-catchments upstream of Deloraine on the main Meander River were increased further to 4.25 to give better consistency between the two models. The calibration results are shown in Figure B 1 to Figure B 3. The baseflow for the July 2016 event was on our threshold of 5% of the event peak. Therefore, it was removed for event calibration and added back into the hydrologic model for the final external hydrologic model results. However, as the baseflow was relatively small and was likely fully contained within the channel, it was not added separately into the hydrodynamic model, as the hydrodynamic model already has some wetted extent within the channel inherent to using LiDAR flown at an unknown time.

Table 4: Deloraine calibration event losses, routing parameters and fit statistics with individual routing parameters for each event.

Statistic	2011 Jan	2016 Jun	2016 Jul
IL	80	110	20
CL	1.05	0.52	0.26
BX	1	1	1
External hydrological modelled peak (m^3/s)	301	415	194
Observed peak (m^3/s)	310	405	195
External hydrological modelled volume (GL)	22.8	45.8	38.2
Observed volume (GL)	26.8	66.7	45.2
Peak % difference	-2.8%	2.5%	-0.5%
Volume % difference	-15.1%	-31.3%	-15.5%

7.1.2. Meander River at Strathbridge

Modelled and observed flows were compared at Strathbridge, however there was limited information available at this site, with reliable information available for the 2011 event only. The June 2016 event is included, however the observed peak is estimated only. Flows were also compared to the hydrodynamic model to investigate the reasonableness of modelling of the channel routing along the main Meander River in the external hydrological model. Channel routing parameters along the main channel from Deloraine to Strathbridge were increased significantly to a R value of 6.1 in the hydrologic model to provide similar flood attenuation between Deloraine and Strathbridge as seen in the observed and hydrodynamic models. This is a higher R value than would typically be expected in many parts of Tasmania, however there is significant flood plain storage in this part of the catchment and the match to the observations and hydrodynamic model results gives confidence that this is reasonable. Even with these high R values the hydrological model slightly overestimates peak (by 6%) for the Jan 2011 event. However, these parameters resulted in a reasonable fit for the hydrodynamic model results and therefore this routing parameter was adopted. For the June 2016 events, the external hydrologic model results provide a good match to the peaks of the estimated observed and hydrodynamic model results, but the volume is underestimated. The calibration results are shown in Figure B 4 and Figure B 5

Table 5: Strathbridge calibration event losses, routing parameters and fit statistics with individual routing parameters for each event.

Statistic	2011 Jan	2016 Jun
IL	80	110
CL	1.05	0.52
BX	1	1
External hydrological modelled peak (m^3/s)	263	471
Observed peak (m^3/s)	249	471
External hydrological modelled volume (GL)	40	38.6
Observed volume (GL)	47.9	53.2
Peak % difference	5.8%	-0.2%
Volume % difference	-16.6%	-27.4%

7.1.3. Validation Gauges

Comparison of modelled and observed hydrographs at Liffey at Carrick gauge show reasonable agreement for the January 2011 and July 2016 events (Figure B 6 and Figure B 7).

7.1.4. Calibration of Design Losses

Flood Frequency Analysis (FFA) was undertaken at Deloraine using the combined record at the Meander at Deloraine Bridge gauge (162-1) and Meander below Deloraine (541-1), providing a continuous data period from 1966 to 2019 (51 years). Meander Dam was constructed in 2007 so flood behaviour may be changed after this date. To account for this, the losses were calibrated using the external hydrologic model with the dam removed, and calibrating to the FFA based only on the years prior to dam construction (38 years). These losses were then used for design modelling, with the dam added back into to the model.

The best fit to the data was achieved with a LP3 distribution using the Bayesian fitting technique in FLIKE (Figure 6).

Table 6 Fitted flood frequency - Deloraine prior to 2007

AEP	Peak flow (m^3/s)	90% confidence interval (m^3/s)	
		Lower	Upper
50%	192	168	218
20%	276	242	317
10%	330	287	394
5%	382	325	481
2%	447	368	607
1%	495	395	721
1 in 200	543	418	853

The calibrated external hydrologic model was run through the solver and the initial and continuing loss that best matched the curve were estimated. As the events of relevance to this study are of 2% AEP or larger, the results were weighted to this end of FFA curve. The catchment-average loss was distributed across the catchment using the hydrological soil group final infiltration rates. The adopted values of losses were an initial loss of 0 mm and continuing losses shown in Table 8. The resulting FFA is shown in Figure 6. As the calibrated IL was 0mm a sensitivity run was undertaken using the median pre-burst depths with temporal patterns derived from Tasmanian storms. This resulted in changes to the peak flow of less than 1% so the pre-burst was deemed insignificant, and no pre-burst was used for the design event runs. The slope of the modelled FFA is significantly different to the observed FFA with modelled flows outside the confidence interval up to around 5% AEP. The modelled and observed flows are within 5% at 2% AEP and match well at 1% AEP. There is a significant change in shape of the modelled curve at the 1% AEP which is clearly evident in the IFDs in this region.

Table 7 Fitted flood frequency for Meander River at Deloraine (observed) and modelled peaks prior to Meander Dam construction

AEP	Observed peak flow (m^3/s)	Modelled peak flow (m^3/s)	Percent difference
50%	192	135	-30%
20%	276	218	-21%
10%	330	276	-16%
5%	382	332	-13%
2%	447	423	-5%
1%	495	497	0%
1 in 200	543	644	18%

Table 8: Adopted continuing loss for each soil type

Continuing Loss (mm/h)			
Soil Type A	Soil Type B	Soil Type C	Soil Type D
3.65	1.90	0.88	0.44

It is noted that initial losses in the calibration models are of much higher magnitude that the design losses. This is not uncommon, as calibration events were modelling complete storms rather than only the most intense burst. Often there is significant rainfall in the lead up to the most intense burst that may be largely removed by initial loss in the calibration events. The calibration events for the Meander catchment have at least 2 days of rainfall while the design critical duration is 24 hours for the 1% AEP. As an example, from ARR DataHub (Babister et.al., 2016), the 90% pre-burst depth for a 1% AEP design event of 24 hours duration in this study area is 56 mm. The initial loss calibrated for the June 2016 event was larger than the 90% pre-burst depth and thus supports the use of zero initial loss for design bursts.

The design model was rerun with the dam in the external hydrologic model to give some idea of the impact the dam would have on the FFA flows used for this project. This was undertaken using the modelling assumptions that the dam level starts at FSL, and with no provided storage or spillway rating curves for the model so is only to see how the dam changes the FFA in this model and cannot be used to infer the true impact Meander Dam has had on downstream flooding. For the AEPs of interest in this study the modelled flows with the dam present are approximately 20% lower than with no dam (Table 9).

Table 9 Modelled flood frequency peak flows at Meander River at Deloraine with and without the Meander Dam in the model.

AEP	Modelled peak flow (m^3/s)		Percent difference
	No dam	With dam	
50%	135	97	-28%
20%	218	162	-26%
10%	276	207	-25%
5%	332	253	-24%
2%	423	330	-22%
1%	497	400	-20%
1 in 200	644	520	-19%

7.2. Calibration Event Hydrodynamic Modelling

The ICM model was run with rainfall and parameter inputs derived from the external hydrologic model at each sub-catchment for each calibration event.

The modelled depths for all calibration events for the catchment are shown in Figure 9 to Figure 11.

7.2.1. Results Comparisons at Gauges

A comparison of recorded information against the hydrologic and hydraulic model response has been undertaken for Deloraine and Strathbridge, which are to two main gauges in the catchment.

Liffey River above Carrick Bridge and Jackeys Creek at Jackeys Marsh hydraulic response has been reviewed at a high level where information was available. Due to uncertainties in the rating and gauge response, only water level has been reviewed at these locations to confirm hydraulic response is reasonable. Western Creek @ Bankton Rd Bridge sits on an irrigation channel which is 5 m wide. This channel is not captured in the model and as such the site has not been assessed.

Table 10 shows a comparison of hydrodynamic and hydrologic modelled results and observed levels and flows at the Deloraine gauge. While level comparisons are presented, during the course of the assessment it was identified that there is no confidence in the gauge zero provided by DPIPWE for the site, with the level being erroneous when compared to surveyed levels captured during the June 2016 flood event. A similar issue is present at Strathbridge, with no gauge zero present.

To provide a frame of reference, the recorded levels at Deloraine gauge were adjusted so the peak of the level at the gauge matched a local survey level recorded during the June 2016 event. The subsequent estimated gauge zero (226.857 mRL) has been applied across other events for consistency. The results of the assessment are presented in Diagram 15 to Diagram 17 using this assumed RL.

Peak flows compare well to the external hydrologic model results for all three calibration events. A good match to the general shape of the events is also present. In all events the water level is over estimated through Deloraine, which is attributed to the poor channel definition in the model. This issue is further discussed in Section 7.2.2.2.

Table 10: 2D model calibration event results at Deloraine gauge.

Statistic	2011 Jan		2016 June		2016 July	
	Flow	Level	Flow	Level	Flow	Level
Hydrodynamic model peak	306.6 m^3/s	230.8 mAHD	406.4 m^3/s	231.4 mAHD	196.70 m^3/s	230.3 mAHD
Hydrology model peak	300.9 m^3/s		415.1 m^3/s		193.6 m^3/s	
Observed peak	309.5 m^3/s	230.1 mRL	405.2 m^3/s	230.7 mRL	194.7 m^3/s	229.3 mRL
Peak flow difference to hydrology	1.9%		-2.1%		1.6 %	
Peak difference to observed	1.0%	0.7 m	0.3%	0.7 m	1.0%	0.9 m

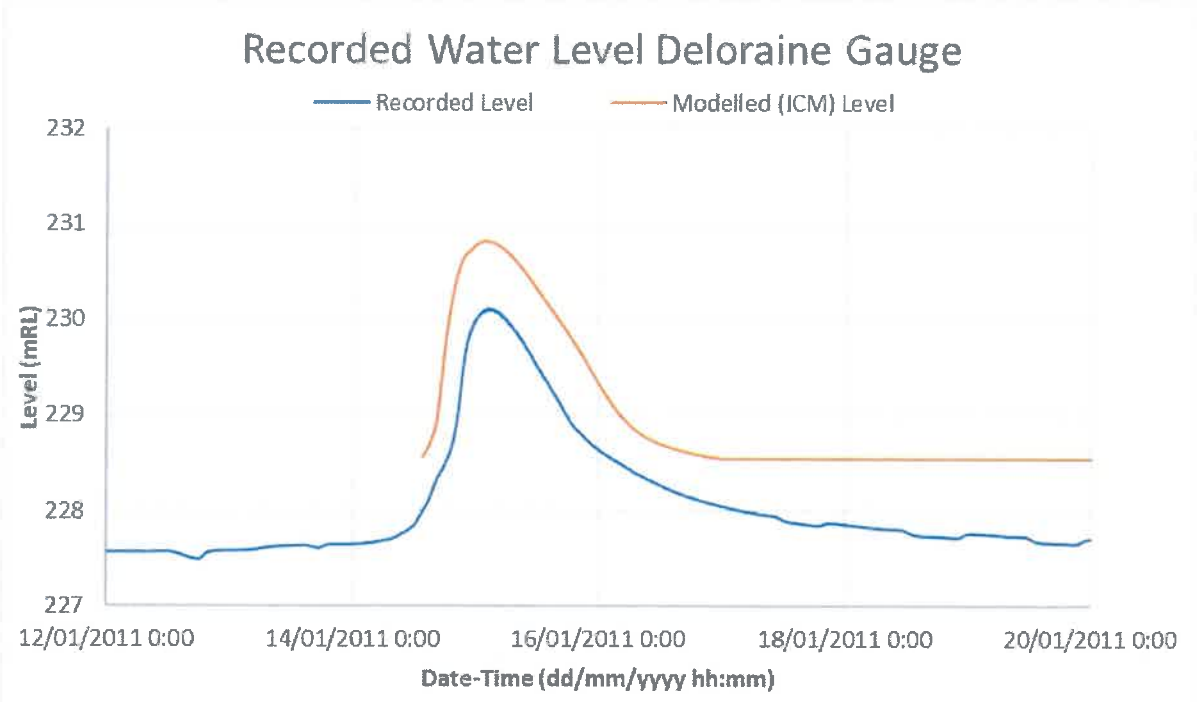

Diagram 15: January 2011 water level comparison at Deloraine.

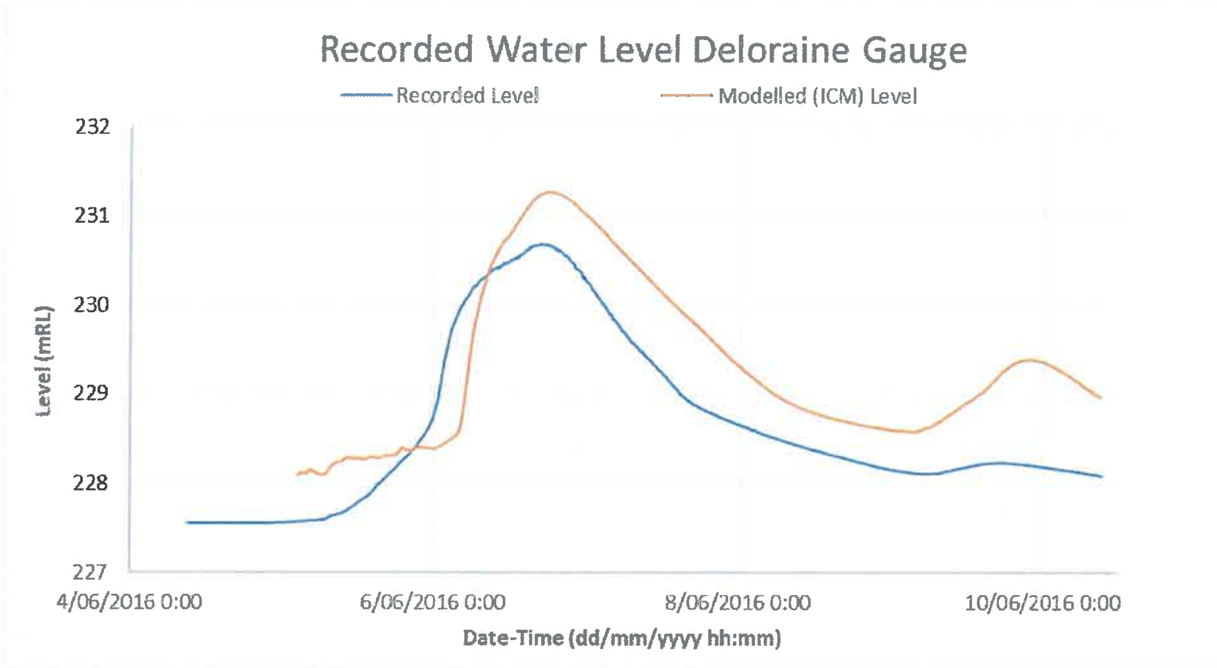

Diagram 16: June 2016 water level comparison at Deloraine

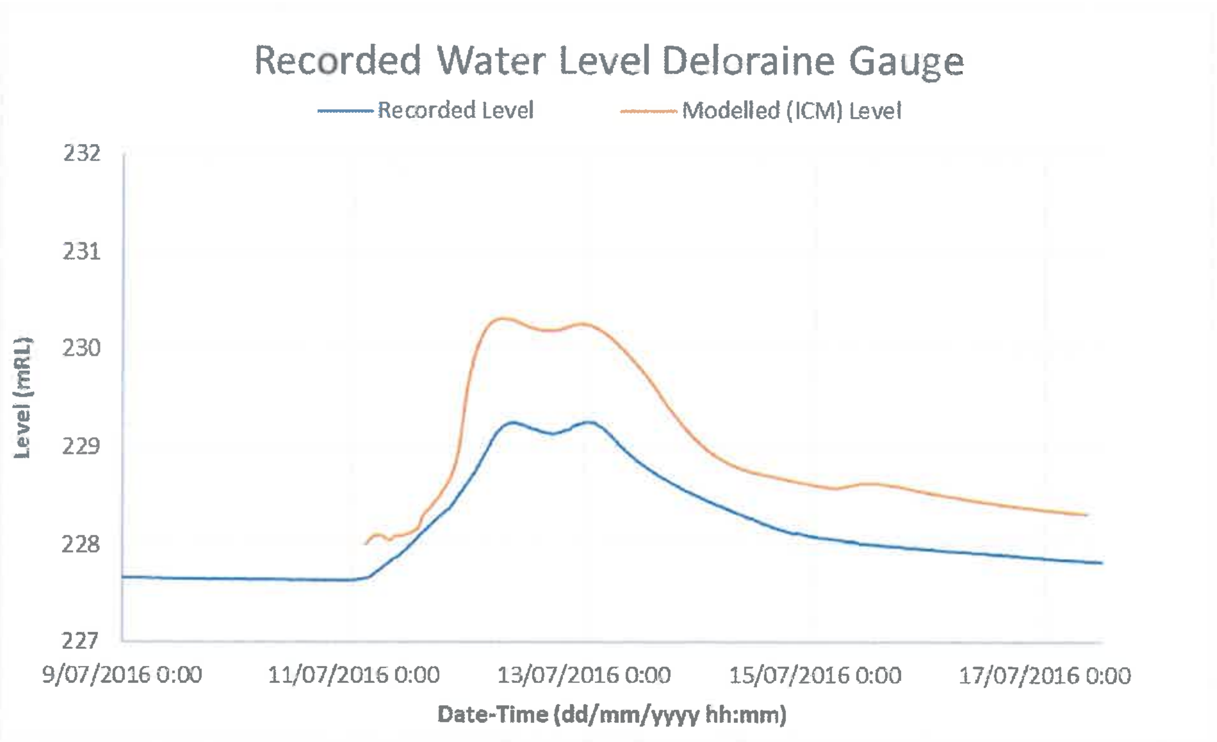

Diagram 17: July 2016 water level comparison at Deloraine

Table 11 presents the results of the calibration at Strathbridge gauge. The calibration results show a good match to observed peak levels for the January 2011 event with approximately 300 mm difference between modelled and observed levels. In the June 2016 event, there is more than 1 m difference between the observed and modelled peak levels. This is discussed further in Section 7.2.2.6.

Table 11: 2D model calibration event results at Strathbridge gauge.

Statistic	2011 Jan		2016 June	
	Flow	Level	Flow	Level
Hydrodynamic model peak	267.3 m^3/s	140.33 mAHD	453.4 m^3/s	141.37 mAHD
Hydrology model peak	263.1 m^3/s		470.5 m^3/s	
Observed peak	248.8 m^3/s	140.1 mAHD	471.4 m^3/s	142.60 mAHD
Peak flow difference to hydrology	1.6%		-3.6%	
Peak difference to observed	7.4%	0.23m	-3.8%	-1.22m

Diagram 18 and Diagram 19 show the water level responses for the January 2011 and June 2016 events. As previously discussed, the gauge zero was not provided for this location and has been estimated. Similarly, the recorded water level present for the 2016 event was estimated and does not correlate well to surveyed levels, which are 1 m lower than the presented level.

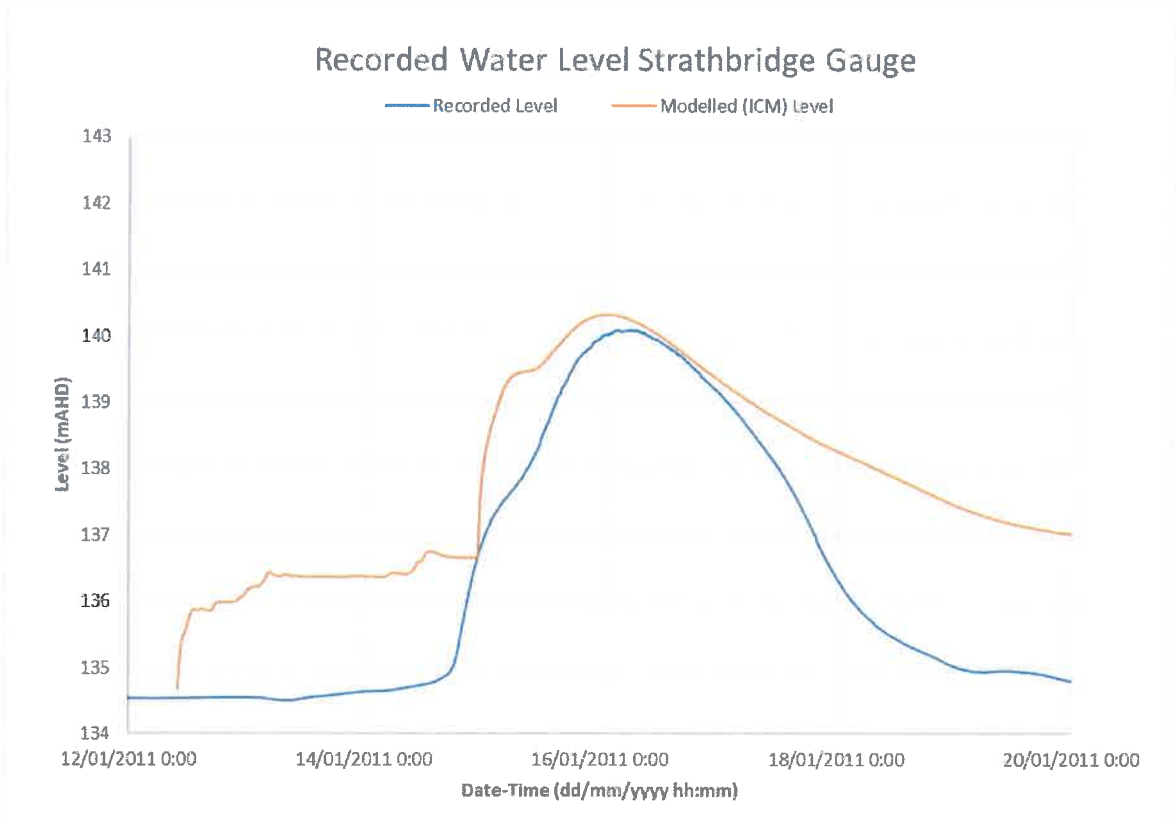

Diagram 18: January 2011 water level comparison at Strathbridge

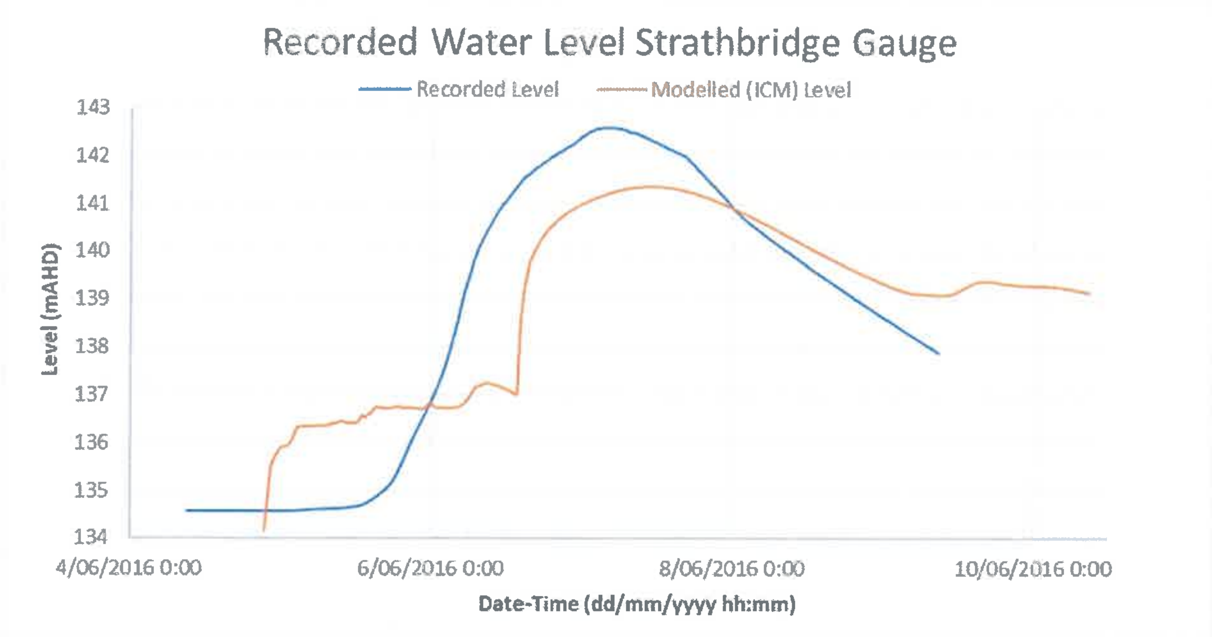

Diagram 19: June 2016 water level comparison at Strathbridge.

A review of water level at Liffey River @ Carrick Bridge and Jackeys Creek, is shown in Diagram 20 to Diagram 25. At both locations in the 2011 event the hydraulic model is dramatically over estimating level, indicating a poor correlation between actual and model response in this event. In the June 2016 event however, at both locations a good match to timing and level is present, noting that the gauge appears to have malfunctioned at the Liffey River site. In the July 2016 event both locations show an over estimation of level, indicating the model does not replicate the lower flow response at the gauge well.

The results indicate there is uncertainty with regard to the functionality of the model in regions that do not have similar characteristics to the regional river response. The ability of the model to replicate the June 2016 event well however indicates that the issue may lie within the use of regional loss rates to assess catchments with independent characteristics.

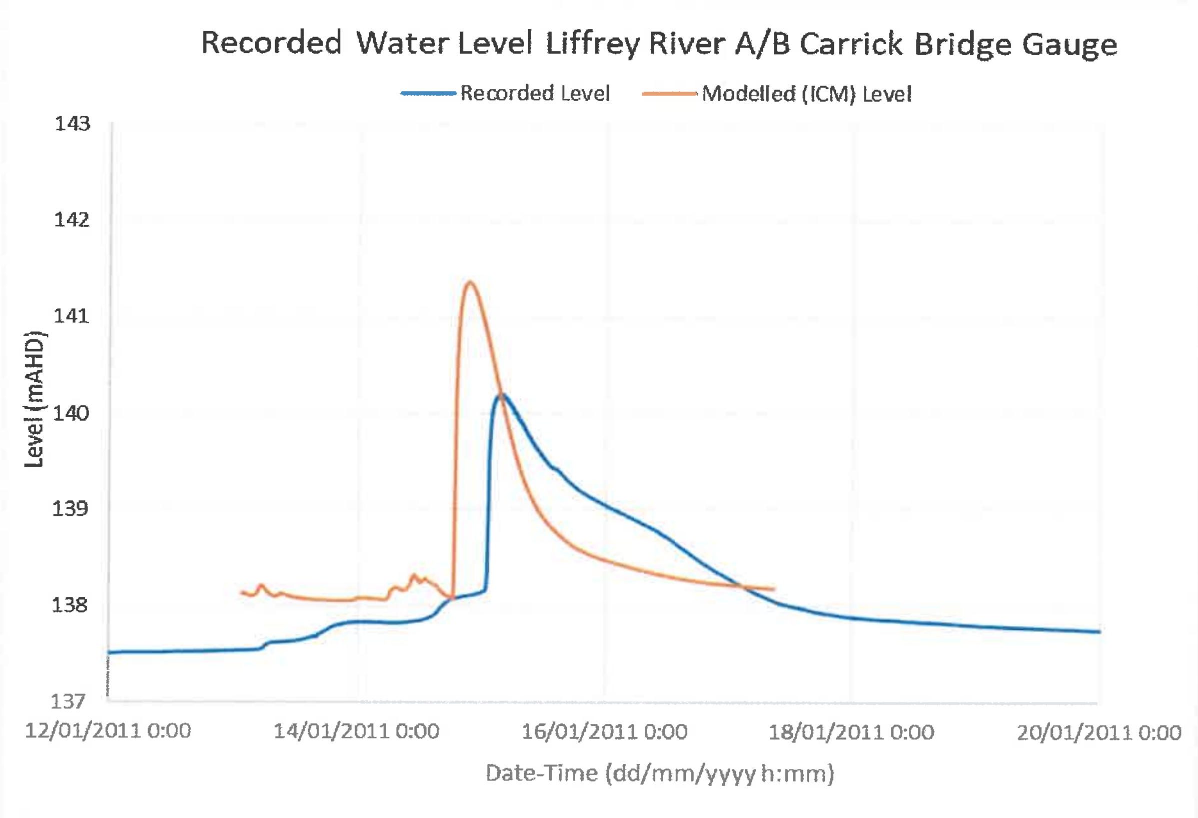

Diagram 20: January 2011 water level comparison at Liffey River A/B Carrick Bridge.

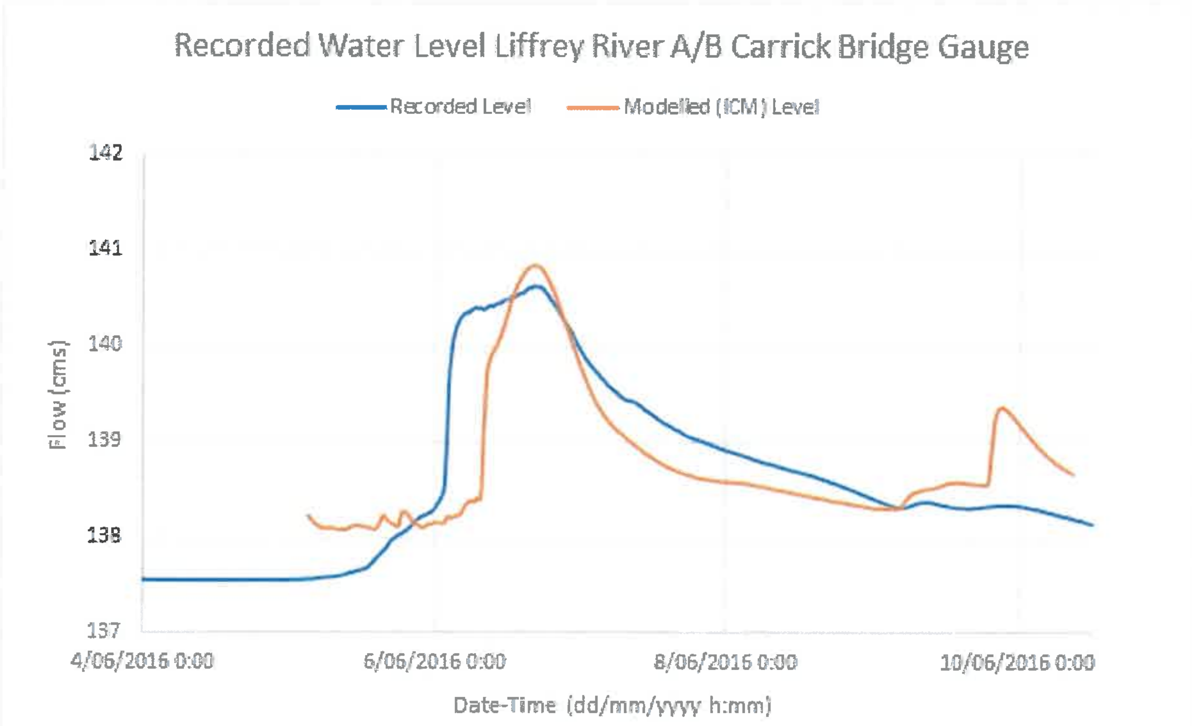

Diagram 21: June 2016 water level comparison at Liffey River A/B Carrick Bridge.

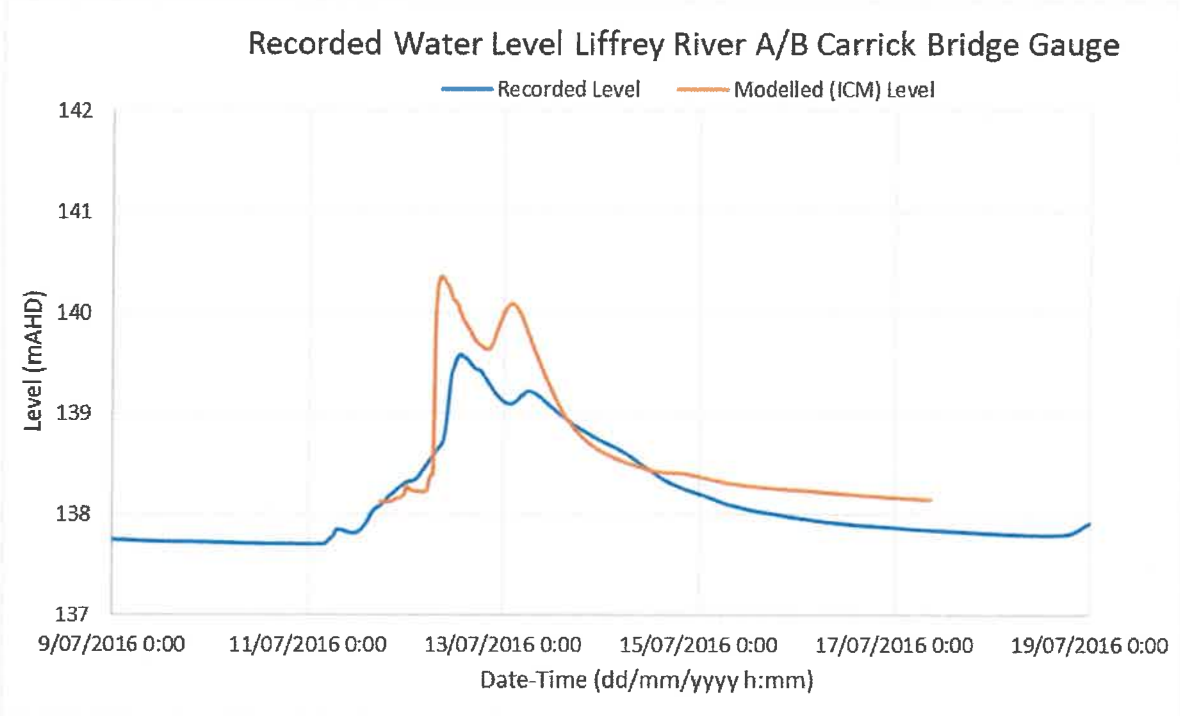

Diagram 22: July 2016 water level comparison at Liffey River A/B Carrick Bridge.

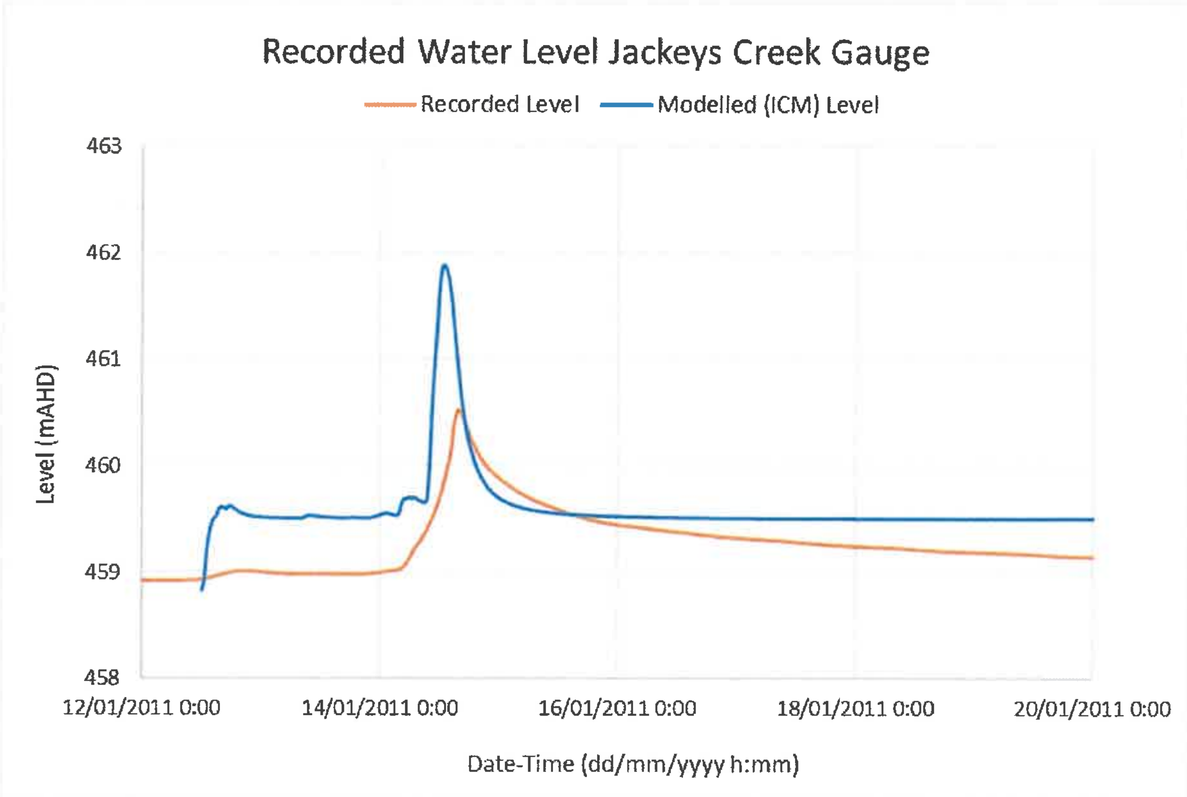

Diagram 23: January 2011 water level comparison at Jackeys Creek.

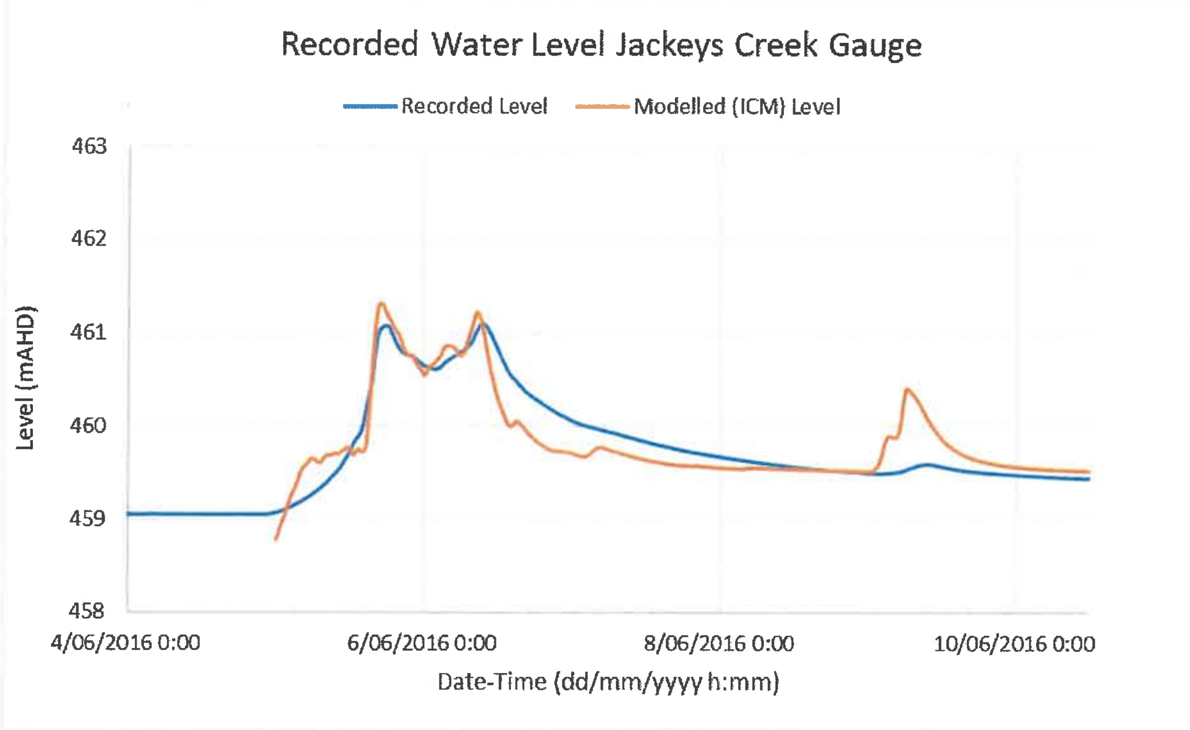

Diagram 24: June 2016 water level comparison at Jackeys Creek.

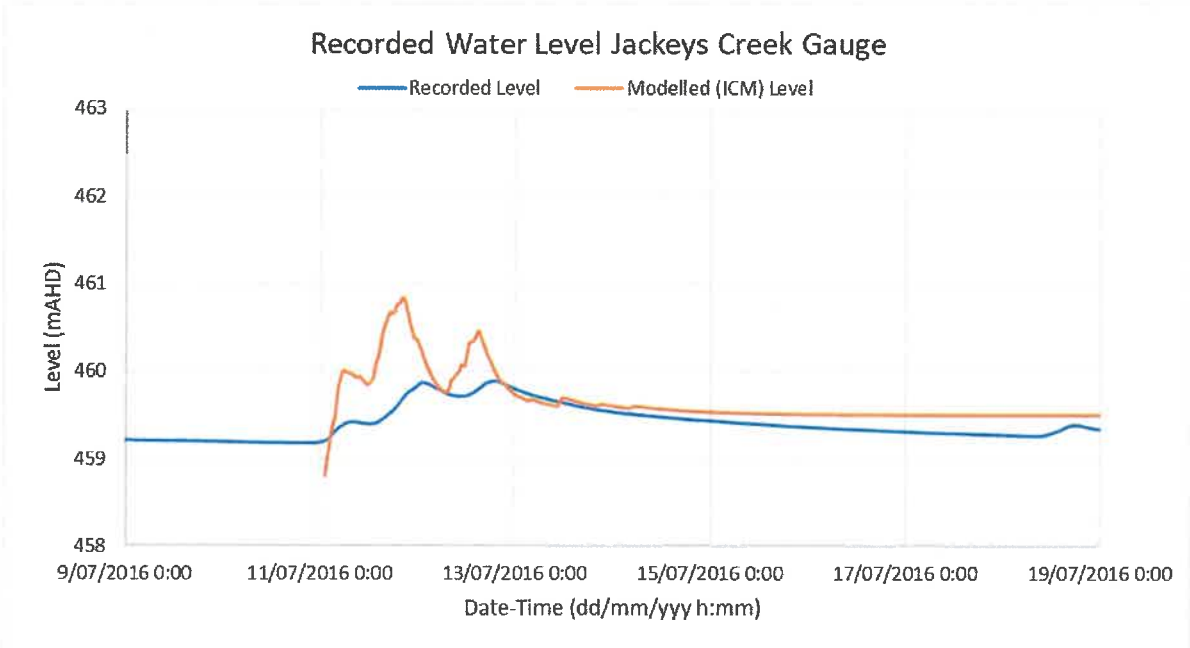

Diagram 25: July 2016 water level comparison at Jackeys Creek.

7.2.2. Verification Against June 2016 Flood Survey

As part of the Tasmanian flood recovery program following the 2016 floods, the Tasmanian Government collect 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. This information is compared to the flood extents developed by this validation model using the June 2016 event as a validation event.

7.2.2.1. Flood Extent Review

During the review process it was identified that there was a significant variance between the match to levels and the extent. As part of the process of reviewing the dataset it was identified that in a large number of locations the extent was being informed by a small number of data points, resulting in flood extent shapes that are unlikely to be representative of the event.

Based on this, while the review has included consideration of the extent, it was deemed to be of insufficient resolution to inform the assessment.

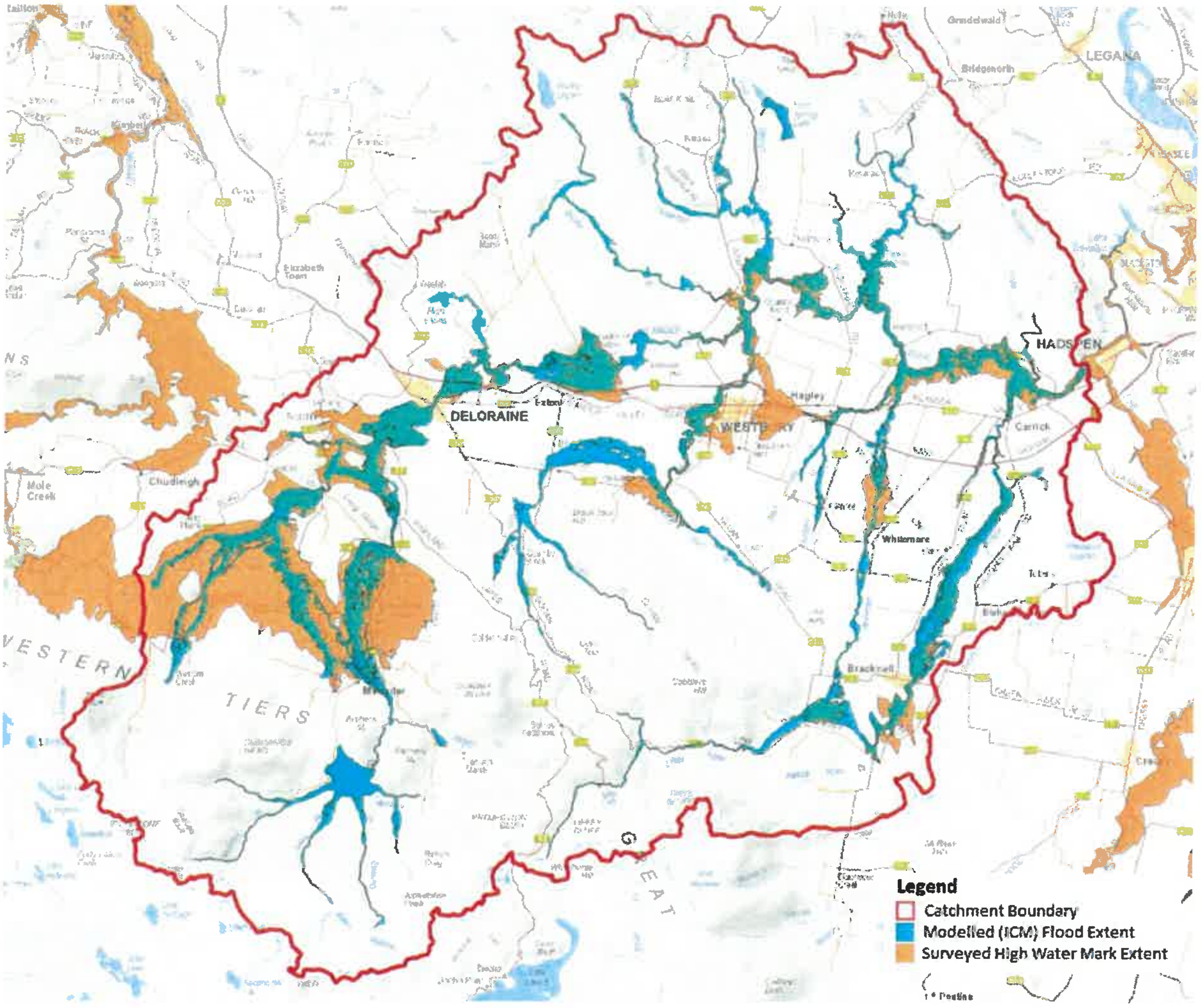

Diagram 26: The flood extent derived from model results overlain by the outline June 2016 flood extent surveyed after the fact and digitised to GIS.

7.2.2.2. Review of Deloraine Flooding

During the initial stages of the assessment it was identified that while the model in general was replicating the surveyed levels well, through Deloraine the levels were being overestimated throughout.

Diagram 27 shows a comparison of modelled flood extent and levels surveyed in the June 2016 event. The surveyed extent is smaller than the modelled extent, and the modelled level is higher than the surveyed level. The absence of river bathymetry in this area makes a good level match in the area difficult to achieve, however the presence of higher levels both upstream and downstream of the Deloraine township indicates other factors may be influencing the results.

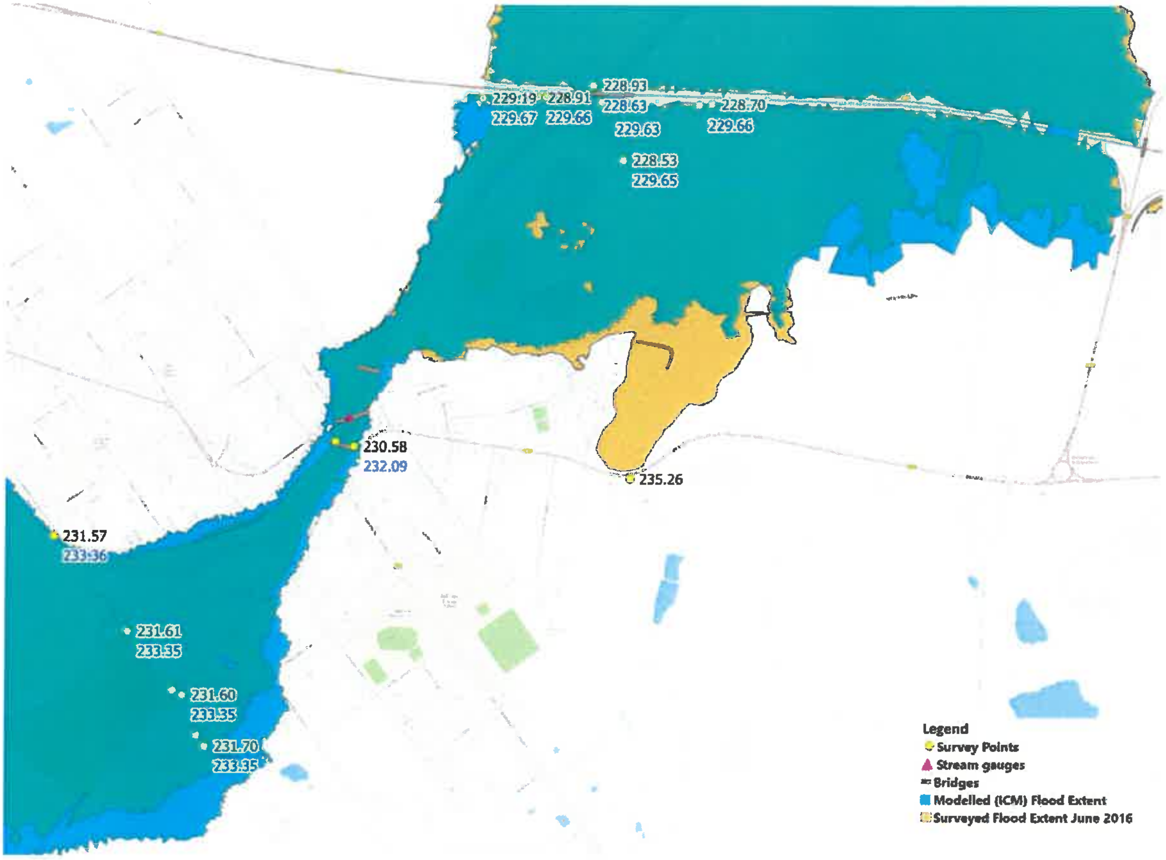

Diagram 27: The surveyed flood level (black), modelled level (blue); surveyed extent (brown) and ICM modelled extent (aqua) in June 2016 event.

To further understand the issues present, a review of other available information was undertaken to determine if the model was acting in a reasonable manner. This has been undertaken by using the video "Flooded Deloraine" posted by Rod How on YouTube (How, 2016) and from photography present on The Examiner Website (Dolan, C, 2017). Noting the peak of the event occurred at 6 pm, which is full darkness in June, the levels present in the images are unlikely to represent the peak of the event however are deemed to be representative given the information available.

Through the town, specifically focussed on the main bridge, the modelled flood extent is larger compared to the image in the video which is consistent with the understanding of the model overestimating the levels through the township. Diagram 28 presents the comparison through this area.

Photo 1: Image taken from the “Flooded Deloraine” video posted by Rod How on YouTube (How, R 2016).

Diagram 28: The surveyed flood level (black text), ICM modelled level heights (blue text); surveyed extent (brown transparent – appears green) and ICM modelled extent (light blue) in June 2016 event.

A review of levels downstream of the weir has also been undertaken, focussing on the footbridge. Within the hydraulic model a recorded flood level of 231.2 mAHD is present at the footbridge. Based on photography provided, the water level at the footbridge looks to be 200-400 mm below the soffit (Photo 2). While no survey of the footbridge is present, it is estimated to be of a similar level to Racecourse Drive to the east of the structure, which is roughly 231.4 mAHD in the provided DEM. Based on this information the levels look generally appropriate.

Photo 2: Deloraine Footbridge – Flood Level (www.examiner.com.au)

Photo 3: Deloraine Footbridge and Racecourse Road – Streetview

Another location where a significant amount of surveyed data was available was along the Porters Bridge Road near the junction of the Bass Highway. A review of the extent of the backwater was undertaken. Based on the imagery available, the provided flood extent looks to overestimate the level in this location and the model is also over estimating at the Bass Highway. In general, the model extent and the surveyed extent provide a good match. As the structure at the Bass Highway controls all discharge through the area, the absence of bathymetry may be contributing to the over estimation of levels in the model.

Photo 4: taken from the "Flooded Deloraine" (How, R 2016).

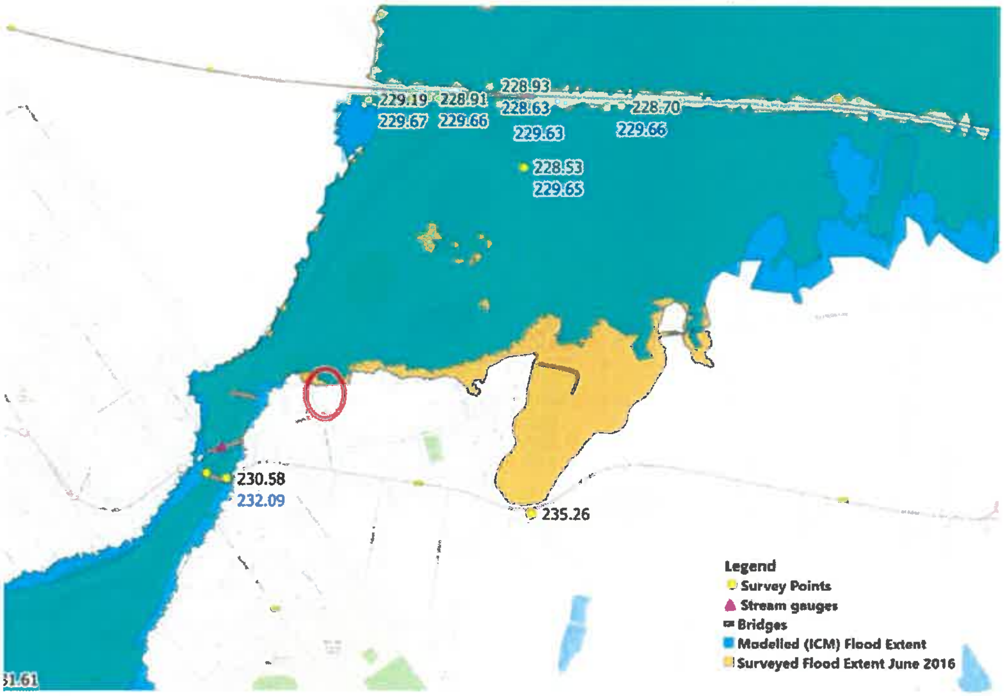

Diagram 29: The circled (red) area shows the location of the sports centre. Surveyed flood level (black text), ICM modelled level (blue text), surveyed extent (brown transparent – appears green where overlaps ICM), and ICM modelled extent (light blue).

Upstream of Deloraine is a large flood storage area. In this location the model also looks to be over estimating level. The main bridge in the township results in a significant flow constriction in the model, which is likely to contribute to the higher levels modelled.

Overall, the absence of an appropriate bed definition through the town looks to be resulting in an under estimation of the channel capacity in the model.

7.2.2.3. Deloraine Sensitivity Checks

While it is not possible to develop a bathymetric surface for the channel, a sensitivity check of other potential controls in the model was undertaken. This included:

- Check of the structure losses (reduction of losses) and
- Incorporation of friction values consistent with current flood study information.

Both of these sensitivity tests were undertaken independently. The bridge losses resulted in negligible changes to levels while the roughness change resulted in level drops of approximately 100 mm. These checks indicated the model was not particularly sensitive to these parameters.

Based on the outcomes of the checks it is considered that the most likely cause of variance is the poor representation of the channel due to lack of definition of channel bathymetry.

7.2.2.4. Westbury and Carrick Township

Other human settlement areas where surveyed data is available are along tributaries of the Meander River at Westbury and Carrick. Diagram 30 shows the comparison of surveyed against modelled results of Quamby Brook Creek near Westbury. Levels recorded are within 200 mm of the surveyed levels.

At Carrick (Diagram 31) the surveyed levels are more variable however a good match is still present. In general, a good match to the flood level is evident in these tributaries that join the Meander River upstream and downstream of the Strathbridge gauge.

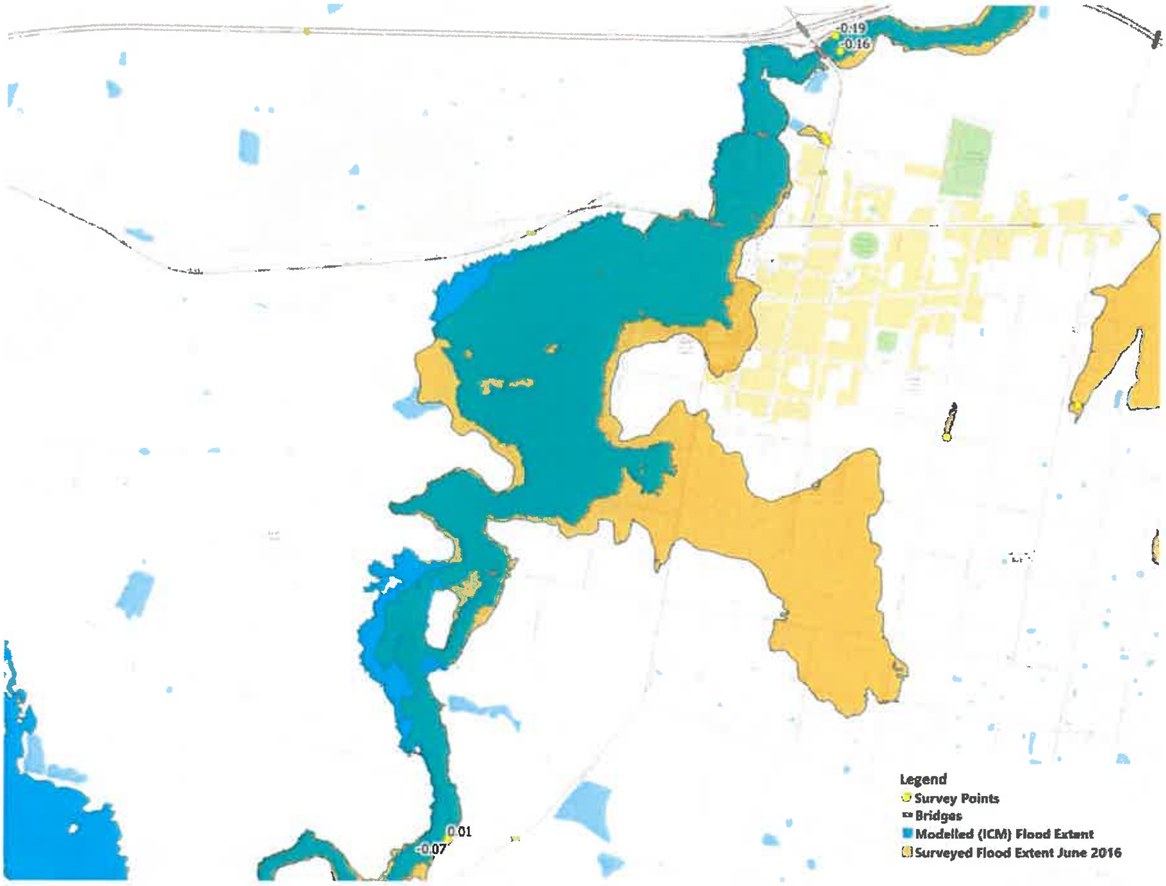

Diagram 30: Westbury township – Survey Level Comparison (m)

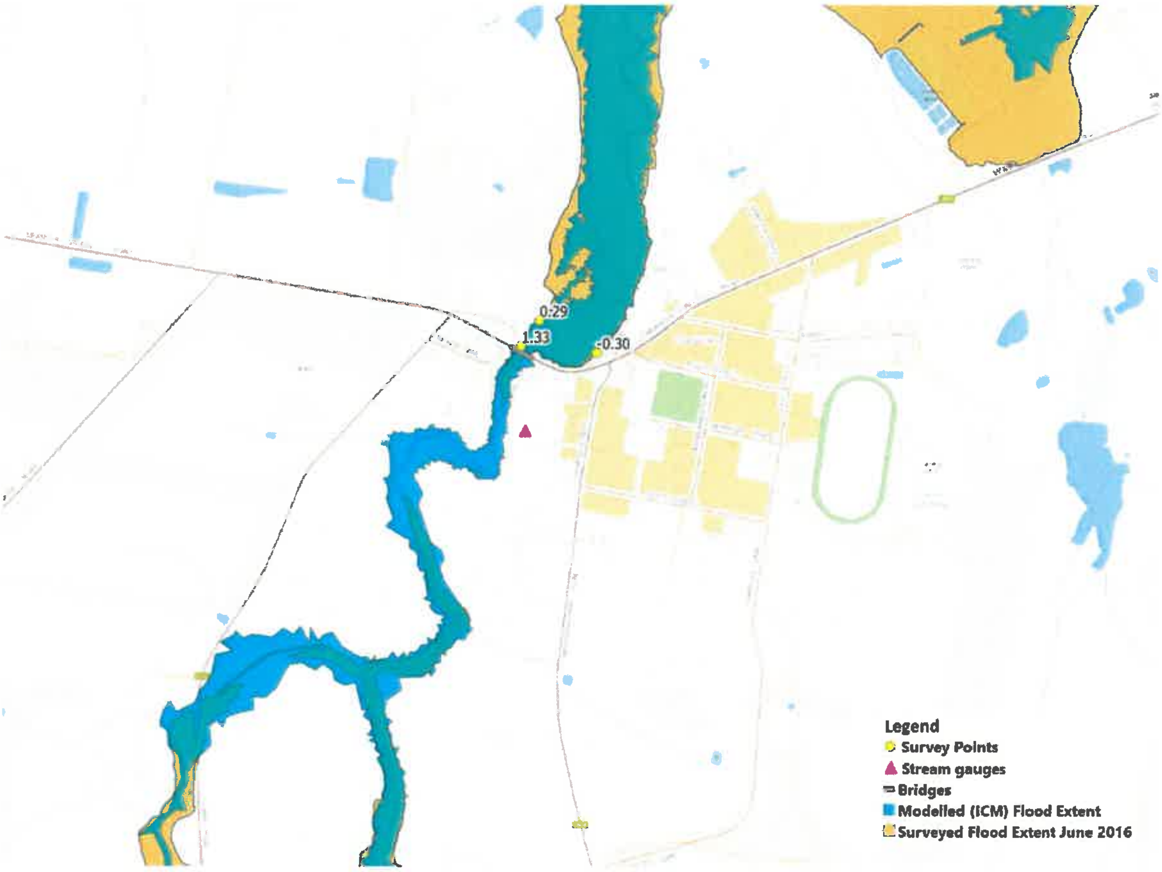

Diagram 31: Carrick township – Survey Level Comparison (m)

7.2.2.5. Porters Bridge Road

Diagram 32 shows the comparison of surveyed against modelled results in this location. In general, a good match is shown in the levels, but not to the provided flood extent.

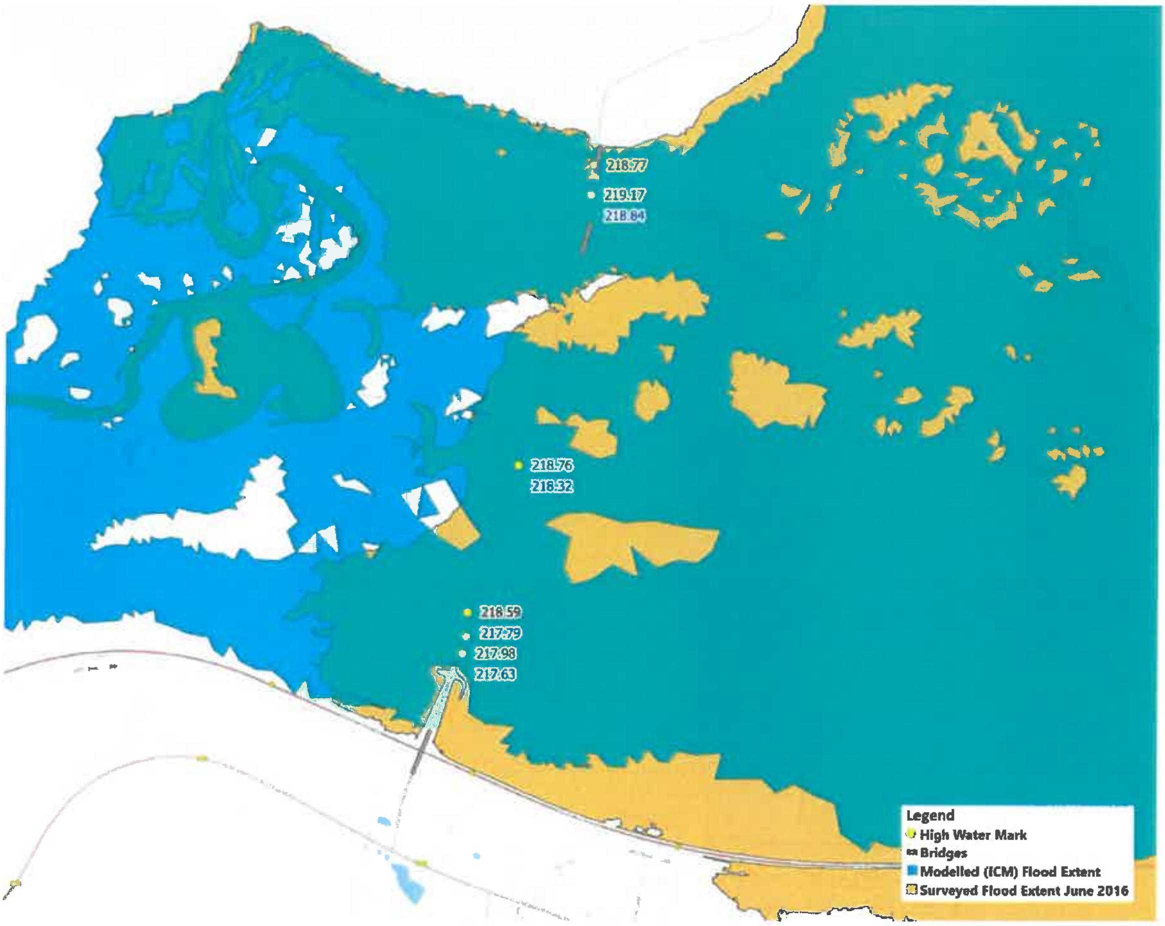

Diagram 32: The surveyd flood level (black), modelled level (blue) in June 2016 event.

7.2.2.6. Strathbridge Gauge

At Strathbridge, a good match to water level (within 150-400 mm) and flood extent is present (Diagram 33) for the 2016 flood event. Noting the likelihood that the gauge during the 2016 event was compromised, the survey levels at this location have been used in preference to the estimated gauge readings.

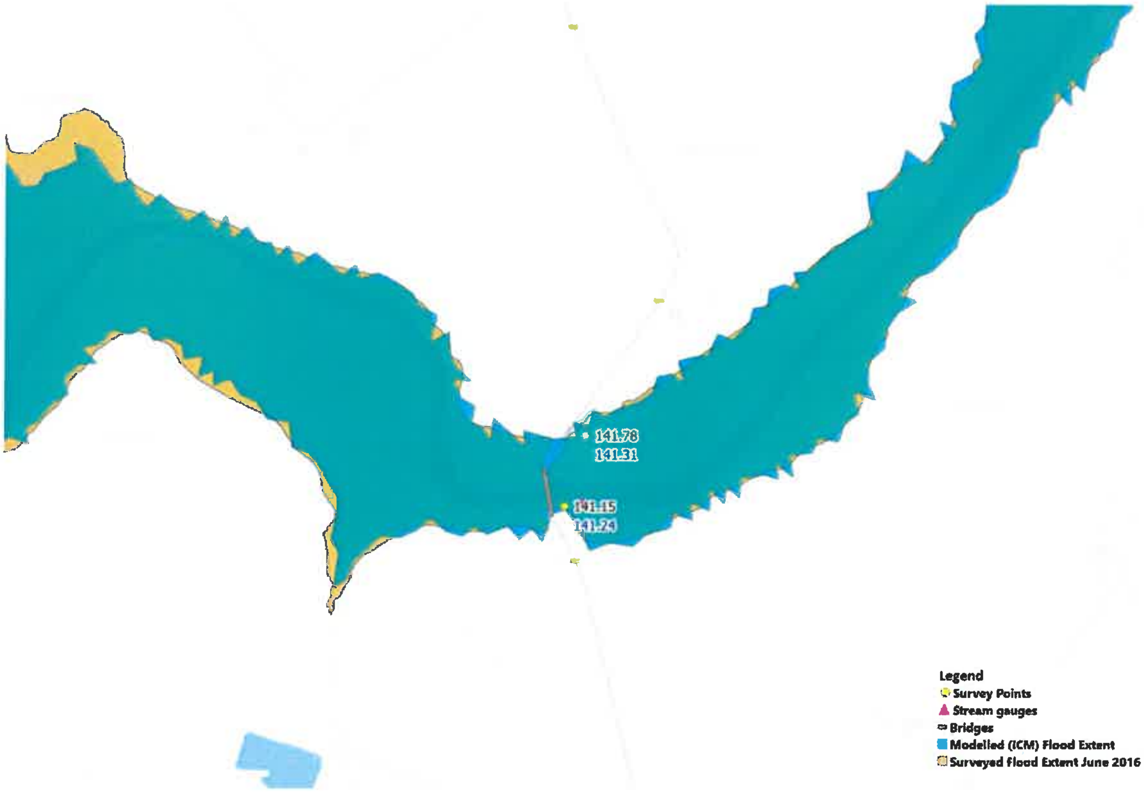

Diagram 33: Flood level surveyed (black) and modelled level (blue) in June 2016 event.

7.2.2.7. Remainder of the Catchment Review

Diagram 21 presents the outcomes of the comparison of the surveyed levels at all locations within the model extent, with the confidence bands given with the survey data shown as upper and lower uncertainty. The uncertainty attempts to capture the limitations of the surveyed points alongside the uncertainty in the accuracy of the surface information. While not a standard approach of determining appropriateness, given the nature of the assessment and the survey that has been completed it is considered reasonable to ensure a fair representation of model accuracy is presented. Apart from the previously discussed levels in the vicinity of Deloraine township (circled in red), the calibration results are considered reasonable for the scope of the project.

Throughout the remainder of the catchment, the majority of surveyed levels fell within the expected confidence bands present within the supplied data. This indicates that in areas that are not sensitive to the capacity of the channel, the model is performing well.

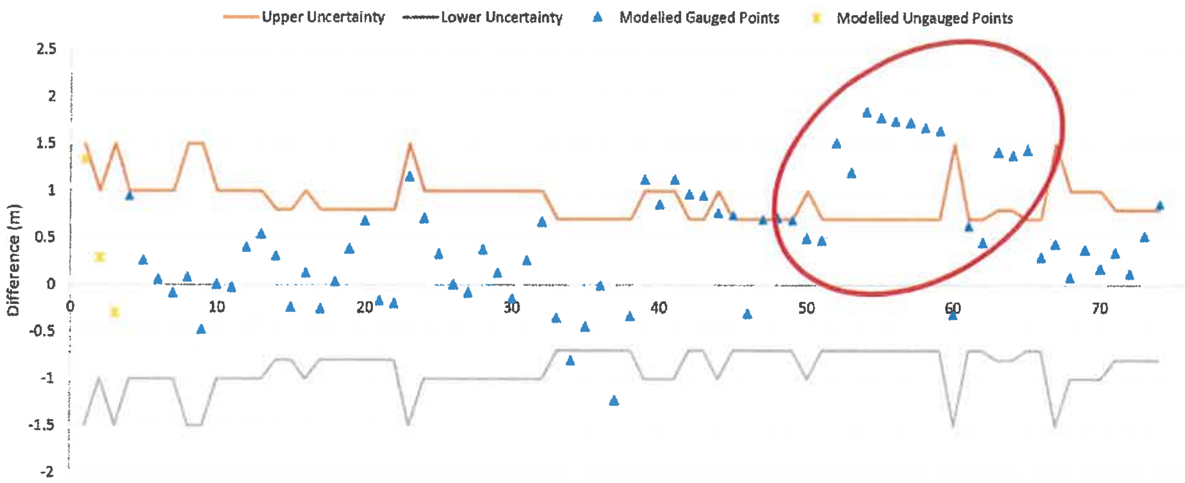

Diagram 34: June 2016 Level Results – Difference from Recorded Level.

7.2.2.8. Identified Issues

Through the level and extent review the following issues were identified within the model:

- The use of regionalised approaches within the model to ensure appropriate representation of the Meander River catchment results in some issues being present on smaller, faster responding catchments. Future assessments should aim to improve the local response in these areas by undertaking localised catchment calibrations.
- The DEM at the Deloraine township within the channel is poorly defined. Therefore, it is very challenging to match the June 2016 modelled level with the surveyed level. Future iterations of the model should attempt to obtain bathymetric data of the Meander River channel for at least the area between East Moriarty Street to downstream of the Bass Highway. At the same time the definition of key structures in the area should also be reviewed and updated with surveyed information.
- There is no surveyed gauge zero for the Deloraine gauge. Future analysis should consider review of the gauge datum to ensure comparison can occur.
- The surveyed extent of June 2016 event doesn't match with the extent in the model due to the limited data points in several locations. This information has been used for reference only, and only where sufficient information is present for it to be of use.
- The water ponding behind highways (such as Porters Bridge Road and Bass Highway) or bridges with narrower openings, could result in misrepresentation of the flood extent and level in the model. This could potentially be improved in a future detailed flood study by adding some conveyance structures such as culverts and small bridges in the model.
- Due to the absence of the details of the dam in the calibration events, it is assumed to be at full supply level. Future assessments should aim to obtain further information on the dam and its storage level during rainfall events.
- For the June 2016 event, the survey points next to Strathbridge gauge show level differences of less than 200 mm. However, the difference between hydrodynamic and observed peak levels at the gauge is more than 1 m.

8. DESIGN EVENT MODELLING

8.1. Design Event Selection

Design inputs were run through the external hydrological model across the entire catchment with a range of ARFs to select representative ARFs, storm durations and temporal patterns to be run through the hydrodynamic model using methods described in the Hydrology Methods Report (2021b). The selected storms, and the number of sub-catchments best represented by each, are shown in Table 12. The temporal patterns for each selected run are shown in Figure A 4. Diagram 35 shows the ARF-duration-TP set used to give representative flows for each sub-catchment for 1% AEP. Figure A 6 to Figure A 8 show the percentage errors in the peak flows for every sub-catchment created by using the four selected patterns across the catchment instead of using individual reference patterns at each sub-catchment.

Table 12: Selected storms for each AEP with the number of sub-catchments best represented by each set

AEP	Storm duration (min)	ARF bin	TP	# sub-catchments
2%	270	45	TP6777	22
2%	540	45	TP6867	43
2%	720	120	TP6931	16
2%	1440	450	ATP7344	21
1%	270	45	TP6777	21
1%	540	45	TP6867	41
1%	720	120	TP6931	16
1%	1440	450	ATP7344	24
0.5%	270	45	TP6777	22
0.5%	540	45	TP6867	40
0.5%	720	120	TP6931	14
0.5%	1440	450	ATP7344	26

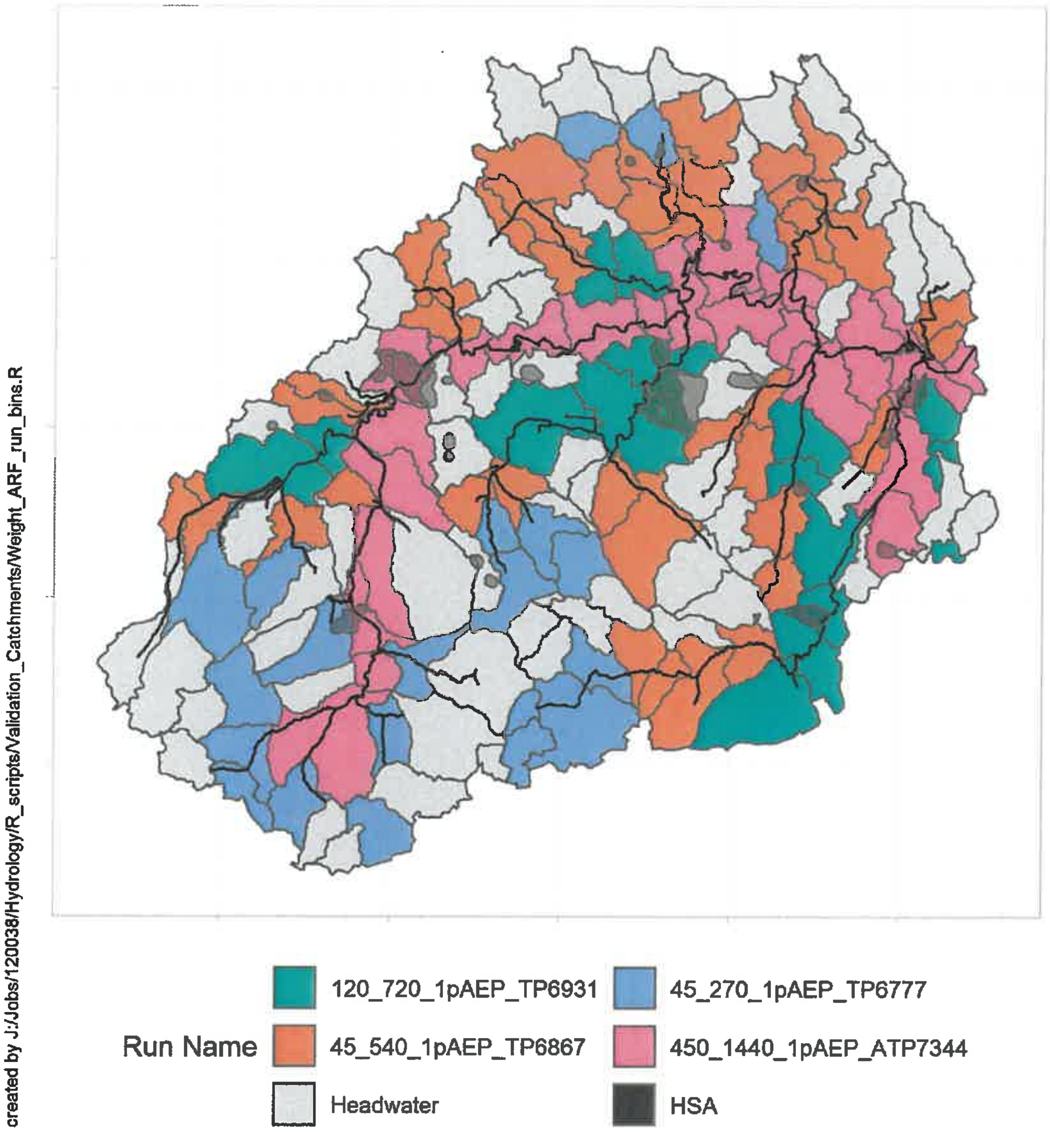

Diagram 35: ARF set relevant for each sub-catchment for the 1% AEP event

The selection of these three ARF-duration-TP sets per AEP does introduce error compared to running each sub-catchment's ideal ARF-duration-TP set through the hydrodynamic model, however running thousands of runs of the hydrodynamic model is clearly not feasible. A summary of the magnitude of the errors introduced is shown in Table 13. Each sub-catchment's absolute percentage error is calculated using the following equation:

$SC\_Q\_Peak_{ref}$ = Sub-catchment peak flow run with ARF from that sub-catchment's ARF bin, with critical duration calculated at this gauge, and TP above the mean selected.

$SC\_Q\_Peak_{sel}$ = Sub-catchment peak flow run with ARF, storm duration and TP from the selected pattern which give peak closest to $SC\_Q\_Peak_{ref}$

$$\text{Absolute subcatchment percentage error} = \left| \frac{(SC\_Q\_Peak_{sel} - SC\_Q\_Peak_{ref})}{SC\_Q\_Peak_{ref}} \right| \times 100$$

Table 13: Sub-catchment errors using the ARF-TP-duration sets shown in Table 12 for each AEP

AEP	Absolute sub-catchment error		
	Mean across sub-catchments	90th %ile across sub-catchments	Max of all sub-catchments
2%	2.8%	7.6%	11.9%
1%	2.6%	7.0%	12.3%
0.5%	3.0%	8.4%	13.5%

8.2. Design Event Hydrodynamic Modelling

Within the main human settlement area of Deloraine, the primary flooding experienced is volume driven, with the channel through the township ultimately controlling the peak flow that can traverse the system. Similar storage controls are located throughout the Meander River system, with the resultant flood being slow moving.

However other local tributaries, such as Liffey River, which passes through Carrick, are more peak flow dominated. The large variance between the response and function of the primary river system compared to smaller local systems pose a challenge to modelling when trying to simplify the general parameters used for a regional study. In this case the primary focus has been on ensuring the response within the model is representative of the majority of locations while acknowledging the limitations where present.

Results of design event modelling are shown in Figure 12 to Figure 27. A critical duration plot is also provided of the 1% AEP event to enable comparison to the hydrologic model outputs Figure 28. In general, there is a good match to the critical durations. Given the regionalised nature of the analysis, some variance is not unexpected, but checks to ensure reasonable levels are present should be undertaken. In some smaller channel reaches there are some discrepancies due to local characteristics, however ultimately the level differences between the critical hydrology and hydrodynamic model are minor with less than 50 mm level variance present at interrogated locations.

8.2.1. Review of Design Event Results at Deloraine

The results of the hydrodynamic design event modelling were compared to flows derived from the external hydrologic model peak flows at Deloraine (Table 14). The estimated peak flows from the external hydrologic model are slightly (approximately 3%) higher than those presented in Section 7.1.4, as these flows are from the catchment-wide selected design event runs instead of being individually calibrated to the Deloraine location shown in Table 9. The modelled design events produce a reasonable fit to the estimated post dam flows at the gauge with a slight over estimation, attributed to the Meander Dam functioning differently between the models.

Table 14: Estimated peak flow comparison at Deloraine

Event	Hydrodynamic model peak flow (m^3/s)	Estimated Peak Flow (external hydrologic model) (m^3/s)	Peak flow difference (%)
2% AEP	385	340	13
1% AEP	465	410	13
0.5%AEP	610	540	13

8.2.2. Review of Design Event Results at Strathbridge

The results of the hydrodynamic design event modelling were compared to flows derived from the external hydrologic model design flow estimates at Strathbridge (Table 15). Peak flows are slightly higher in the hydrodynamic model.

Table 15: Flow comparison at Strathbridge

Event	Hydrodynamic model peak flow (m^3/s)	Hydrologic Peak Flow (m^3/s)	Peak flow difference (%)
2% AEP	445	415	7
1% AEP	545	510	7
0.5%AEP	730	680	7

8.3. Comparison to Previous Flood Study

There is a previous flood study available for the Meander River at Deloraine, "Deloraine Flood Plain Mapping Review for Meander Valley Council 2015" (Hydrodynamica, 2015). This flood study included results from previous flood studies undertaken by Entura and HEC. A discussion on the validity of comparing the two models is provided in Section 3.5. This study generally produces higher levels when compared to the existing flood study. This outcome is consistent with the findings of the calibration through this zone, with the 2016 flood levels also being over estimated.

It is considered that without the incorporation of improved bathymetry into the state-wide flood model, at this location the model will tend to overestimate levels modelled.

Table 16: Comparison to previous flood studies

AEP (%)	Previous Study Modelled Level (@ Gauge) mAHD	State-wide Study Modelled (ICM) Level (@ Gauge) mAHD
2	230.4	231.2
1	230.5	231.5
0.50	230.7	232.0

9. UNCERTAINTY ASESSMENT

Three of the study calibration events had sufficient rainfall data for model calibration and were significant in the Meander study area: January 2011, June 2016 and July 2016 events.

Flood extents were available for the June 2016 floods, and a previous flood study was also available. The DEM at the Deloraine township within the channel is poorly defined. This impacts the ability of the model to reproduce surveyed levels for the June 2016 event, and generally results in overestimation of levels in this area. The use of regionalised approaches within the model to ensure appropriate representation of the Meander River catchment results in uncertainty in modelling of smaller, faster responding catchments.

There is no surveyed gauge zero for the gauges in mAHD, so no exact conversions from the gauge local stage heights to mAHD were possible.

The uncertainty assessment for the modelling is shown in Table 17. The method for uncertainty assessment is described in WMAwater (2021c), and further details on the uncertainty assessment are included in Appendix C. The uncertainty assessment descriptors and quality assessments are based on consideration of the regional nature of this state-wide modelling study. The uncertainty assessment is not reflective of an equivalent detailed flood study for a specific area.

Table 17: Uncertainty assessment for Meander River study area model

Category	Quality statement
Hydrology – rainfall input quality	The rainfall quality for the calibration events is very good, with 4 or more sub-daily gauges available for each event and more than 19 daily rainfall gauges within the study area.
Hydrology – observed flows	There are five flow gauges that were operating during at least one calibration event and used for calibration within the study area. The ratings at Meander at Deloraine, Meander at Strathbridge and Liffey above Carrick gauges are considered to be very good. The ratings at Jackeys Creek and Western Creek are considered poor.
Hydrology – calibration events	The June 2016 event is the largest event on record at Meander at Deloraine. The January 2011 and July 2016 events have AEPs of between 20% and 50% in the catchment. Meander at Deloraine was the only gauge with reliable data for the June 2016 event.
Hydrology – calibration results, peak flows	The hydrology calibration was considered to provide an excellent match to peak flows, with differences of less than 3% between modelled and observed peaks.
Hydrology – calibration results, hydrograph volume	The modelled hydrograph match to observed hydrograph volumes was considered to be fair to good for the January 2011 and July 2016 events, but was poor for the June 2016 event.
Hydrology – calibration results, hydrograph shape	The modelled hydrograph shapes were generally good.
DTM definition	The base dataset used was the SES state-wide 10 m DEM (including bathymetry) only. The 2 m DEM is not used in this catchment because it does not improve the 10 m DEM in critical areas such as the stream gauge locations, due to issues with representation of the channels. The DTM

	definition was considered to be good.
DTM waterways	Representation of waterways in the DTM was considered to be poor as no bathymetric data was available, and this was a major source of uncertainty in the modelling, particularly around Deloraine.
Hydrodynamic – observed flood levels	The gauge zero level provided for the Meander at Deloraine gauge is not consistent with the model results or surveyed water levels in June 2016 flood event. No gauge zero levels were provided for other gauges and these were inferred based on cease to flow levels.
Hydrodynamic – observed flood depths	Surveyed flood levels were available for the June 2016 flood event. In many areas, the extent was informed by a small number of data points, resulting in flood extent shapes that are unlikely to be representative of the event.
Hydrodynamic – overall calibration results	Calibration results within the hydrodynamic model show an excellent match to hydrologic model peak flows. The match to gauge levels is poor, with significant uncertainty around the gauge datums. The match to surveyed levels is poor around Deloraine and fair to good in other areas.
Hydrodynamic – calibration results, peak flows	The model calibration to peak flows at Deloraine was excellent, with hydrodynamic model flows within 1 % of the observed peak flows for all calibration events. At Strathbridge, the modelled peak flows were within 8% of observed peak flows for available calibration events.
Hydrodynamic – calibration results, peak levels	Model calibration to peak levels at Deloraine and Strathbridge was considered to be poor with comparisons limited by the uncertainty in the gauge datums.
Hydrodynamic – calibration results, flood extents	There was a poor to fair match to flood extents. Due to the fact that the flood extent shapes that are unlikely to be representative of the event, it was generally deemed to be of insufficient resolution to inform the assessment.
Hydrodynamic – calibration results, flood depths	Modelled flood depths were compared to the surveyed depths for the 2016 flood event. Other than in the area around Deloraine, the flood levels were generally within the confidence of the surveyed levels, and was considered to be fair to good. Around Deloraine, the modelled flood depths overestimated levels and the match was poor. This is considered to be due to the lack of definition of the channel bathymetry in the model.

10. CONCLUSIONS AND LEARNINGS

One of the aims of the Tasmanian Strategic Flood Mapping project is to develop state-wide Strategic Flood Maps to support flood risk assessment and post event analysis. This is a regional flood mapping study and the methodology has been developed to provide mapping at a state-wide scale, as distinct from undertaking detailed flood studies over particular areas. The SES and local government can use the regional mapping to identify areas where detailed flood studies would be beneficial.

The Meander River study area was modelled as one of two validation catchments to validate methods and data for the overall project. The methods and data used are generally suitable for state-wide modelling, noting the limitations discussed in Section 6. The following points are noted for the state-wide modelling, based on modelling in this validation catchment.

- The thirteen calibration events provided for this project will not necessarily provide significant events for calibration in all study areas state-wide.
- There is a lack of information or a high degree of uncertainty in some gauge datums and locations. This includes gauges on the Meander River.
- Information on significant structures may not be available for some study areas. In these cases, structure dimensions have been assumed, and this has potential to impact on the model results in these areas. These structures will be identified as requiring additional information where this is likely to result in improved model results.
- During the process, issues with the 2 m DEM, specifically associated with the breaching process, were identified. This is a state-wide issue. State-wide runs will use the 10 m DEM as the base information with the 2 m DEM used to inform higher detail around key structures. Prior to incorporation, the 2 m DEM in the area will be reviewed to ensure errors are not present. The lack of definition in the channel bathymetry impacted on the quality of the results of the hydrodynamic modelling.
- The coarse definition of the hydrodynamic model does not allow for the detailed assessment of low flow hydraulic features. This means that modelled water levels at gauges for lower flows will not necessarily compare well with observed water levels.
- The surveyed extents for June 2016 event should be reviewed as they may be based on very limited data points in some locations.

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Figures

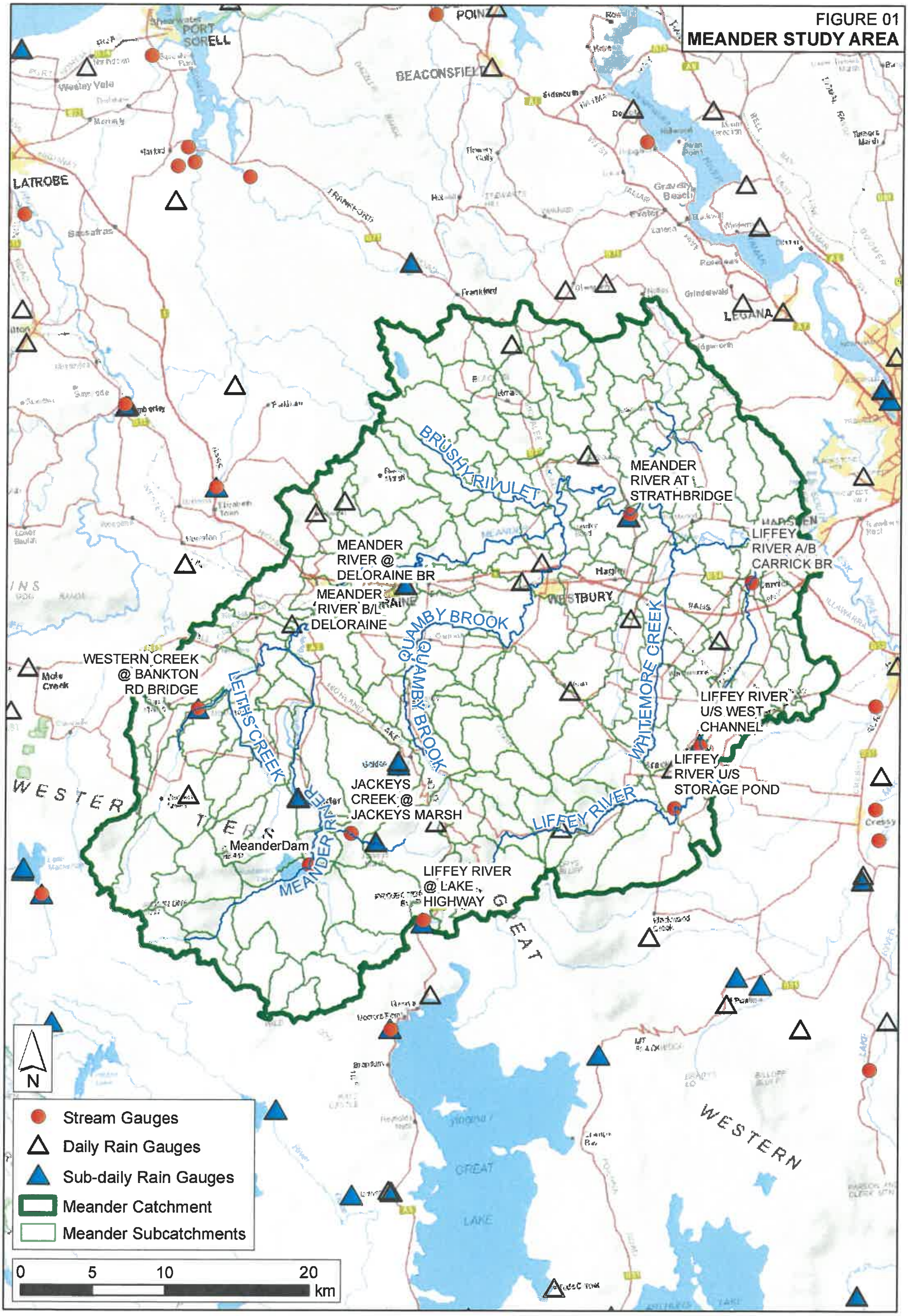
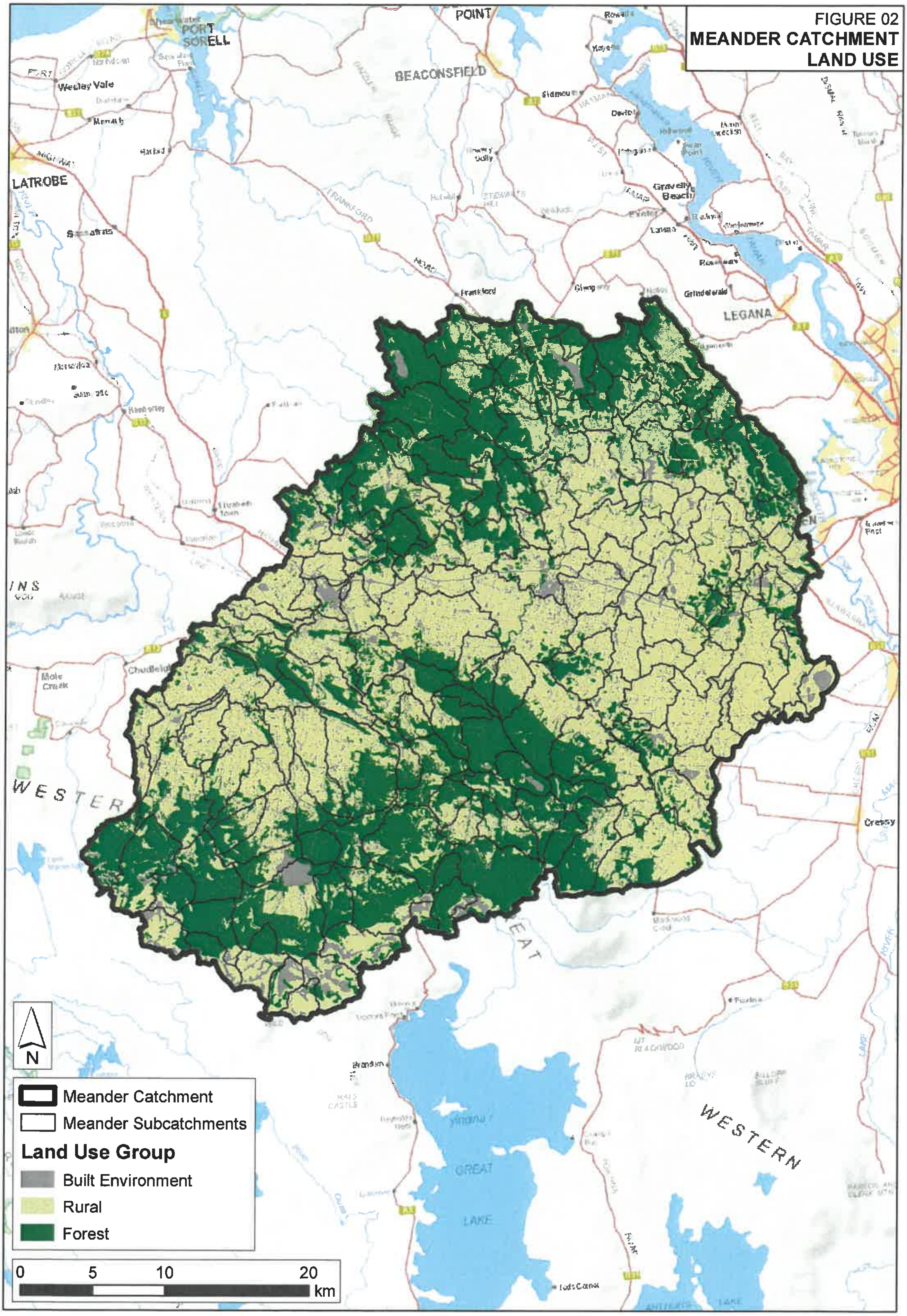


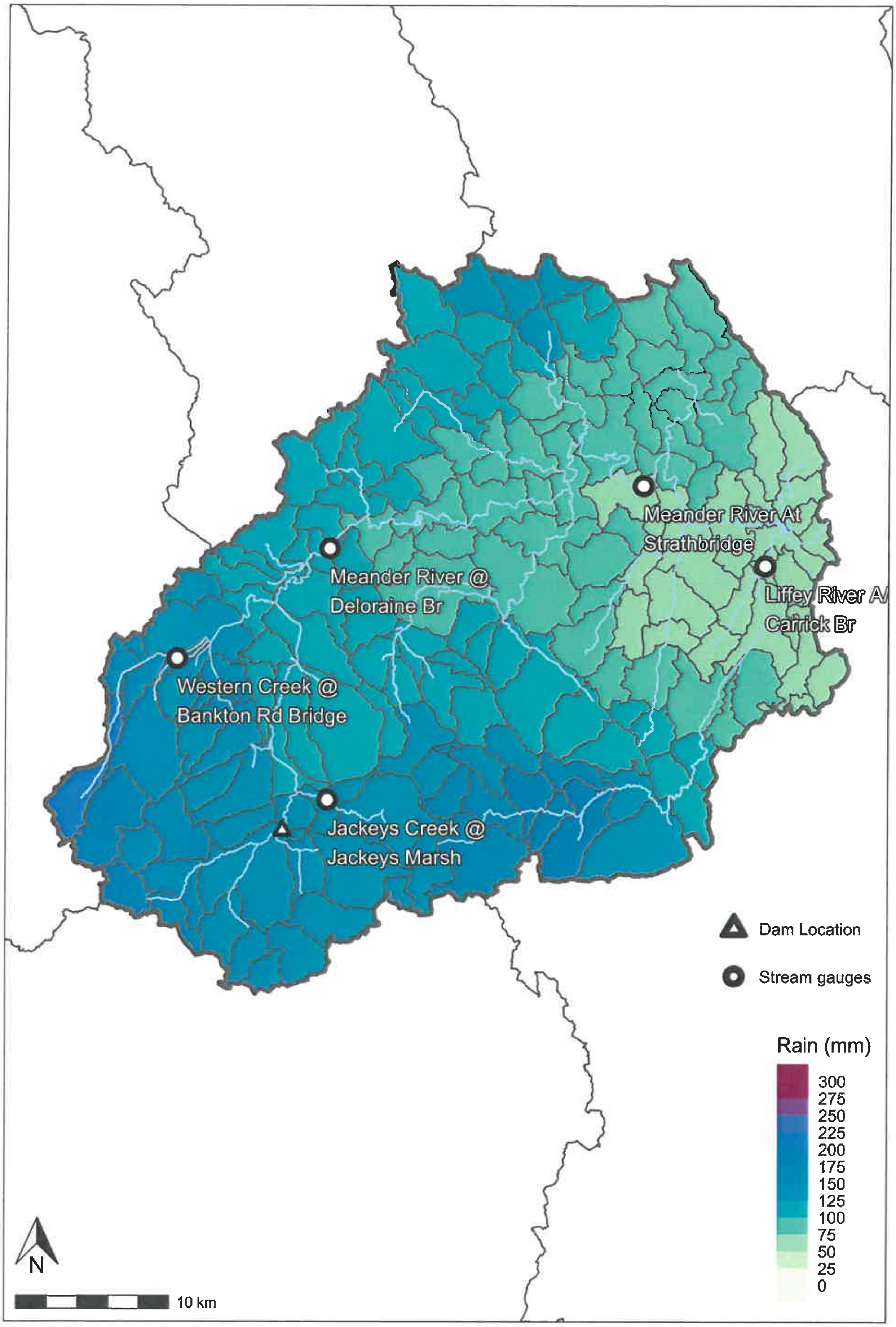
FIGURE 01
MEANDER STUDY AREA

J:\Jobs\120038\GIS\hydrology\Map\Validation_Catchments\Meander\Figure01_Meander_Study_Area.mxd



J:\Jobs\120038\GIS\hydrology\Map\Validation_Catchments\Meander\Figure02_Meander_Catchment_Land_Use_SubOutline.mxd

FIGURE 3
MEANDER
WHOLE_CATCHMENT 2011_JAN



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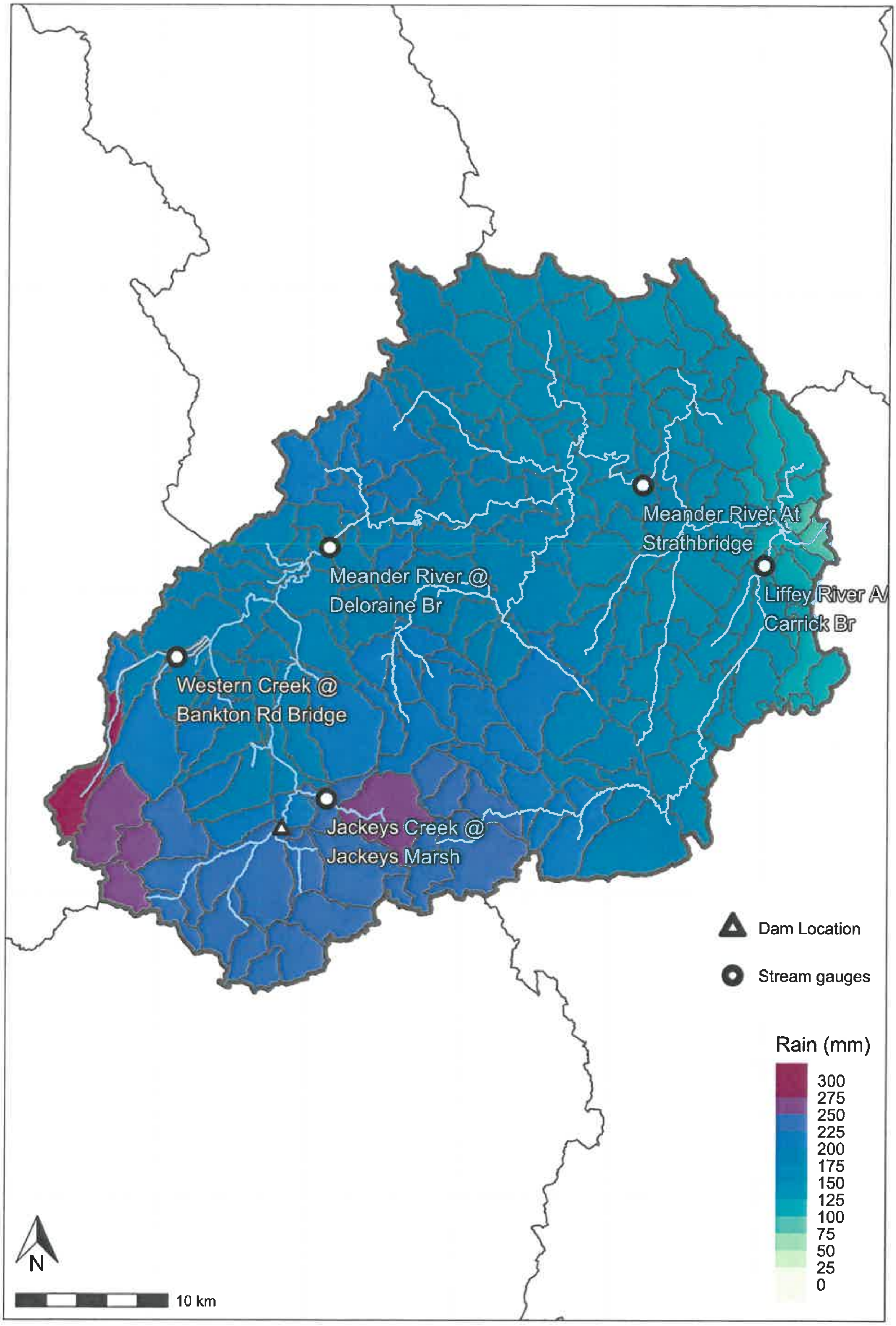
J:/Jobs/120038/Hydrology/Validation_Catchments/Calibration/Meander_recode_7km2_postRainfallVariation/Subcatchment_rainfalls/Figure3Rain_Whole_catchment 2011_Jan.pdf

FIGURE 4
MEANDER
WHOLE_CATCHMENT 2016_JUN



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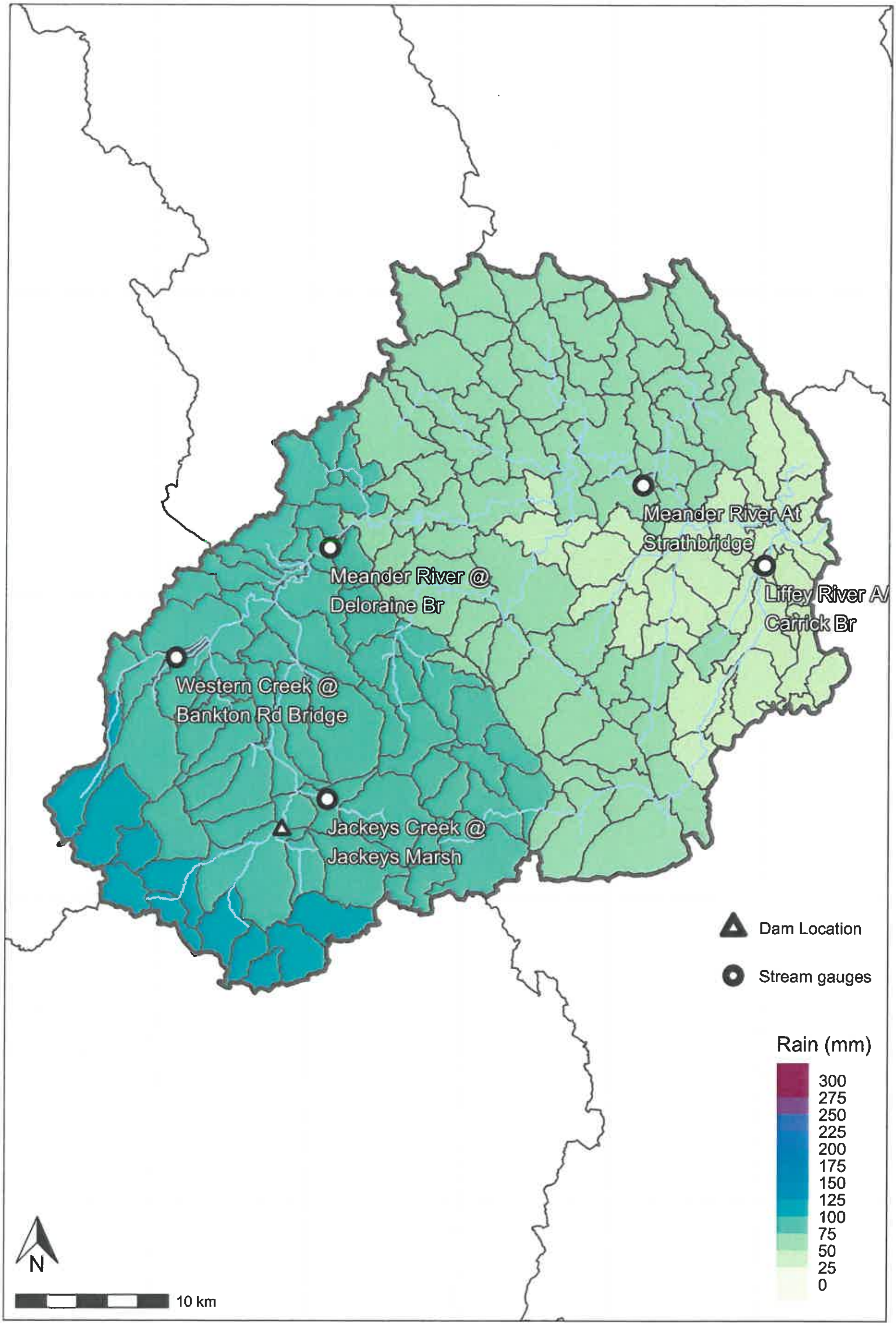
J:/Jobs/120038/Hydrology/Validation_Catchments/Calibration/Meander/Subcatchment_rainfalls/Figure4Rain_Whole_catchment 2016_Jun.pdf

FIGURE 5
MEANDER
WHOLE_CATCHMENT 2016_JUL



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J:/Jobs/120038/Hydrology/Validation_Catchments/Calibration/Meander/Subcatchment_rainfalls/Figure5Rain_Whole_catchment 2016_Jul.pdf

FIGURE 6

MEANDER RIVER AT DELORAINE FFA

PRE-MEANDER DAM

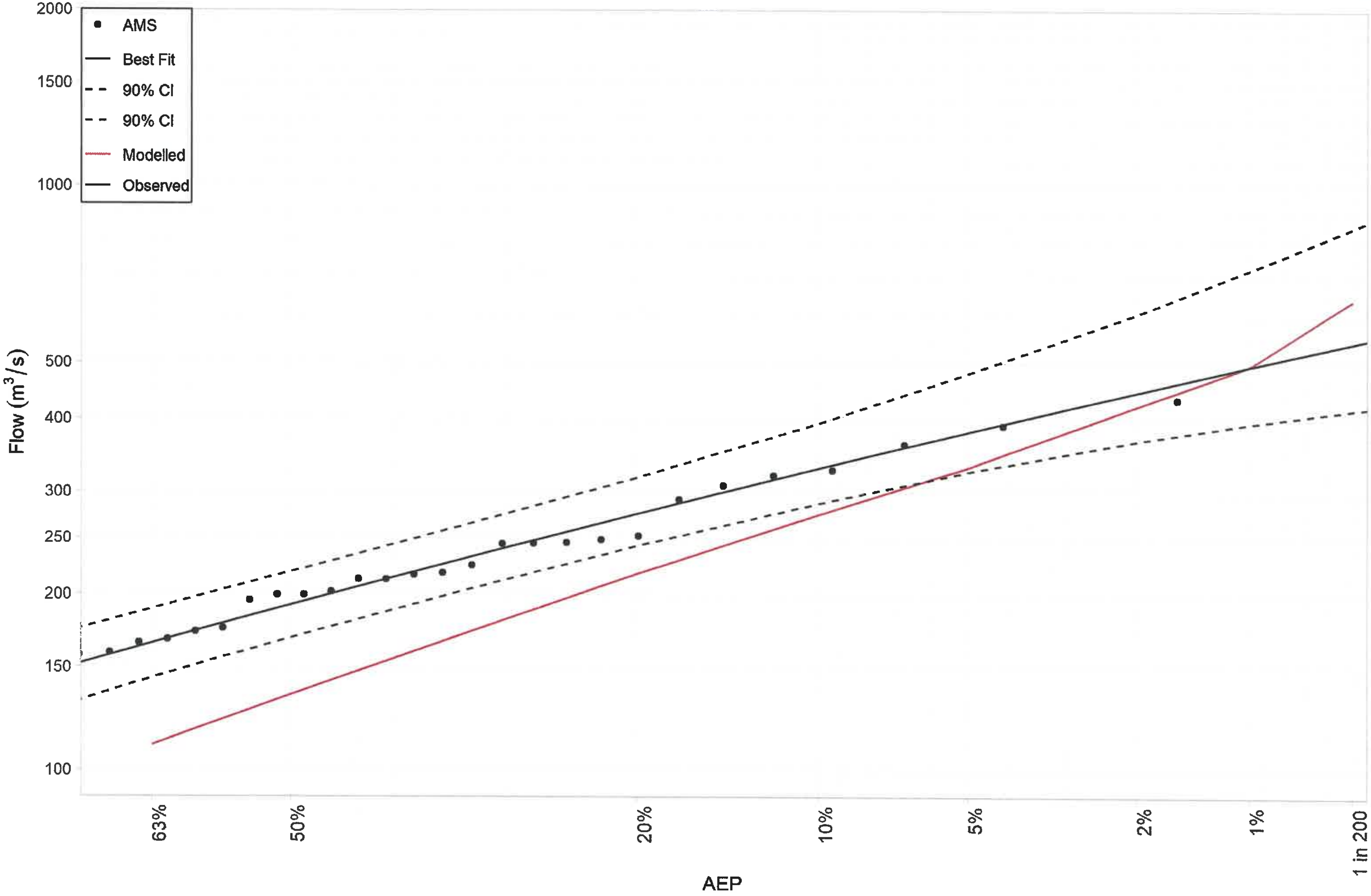

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FIGURE 7

SELECTED DESIGN TEMPORAL PATTERNS ALL AEPS BY STORM DURATION AND ARF AREA

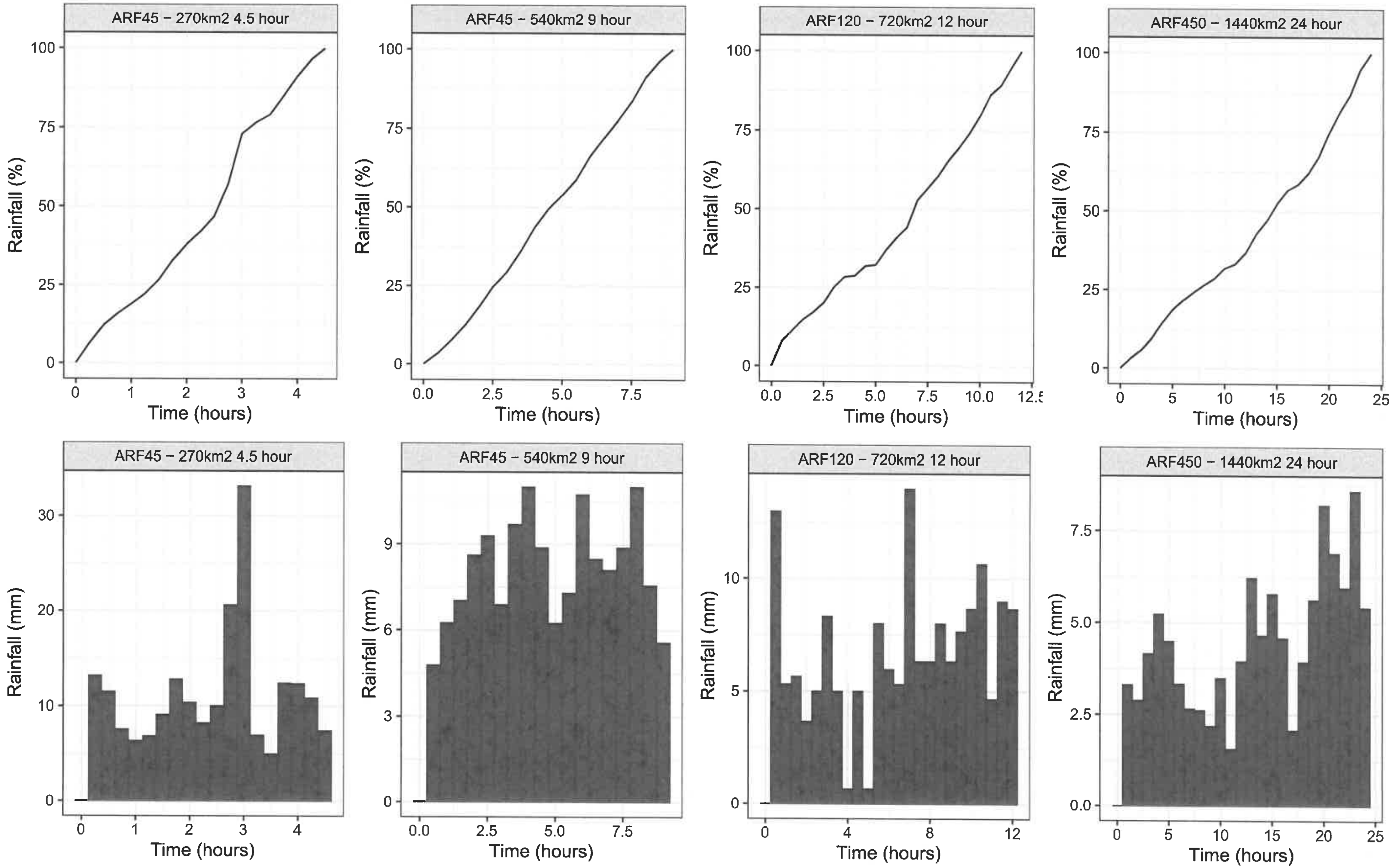
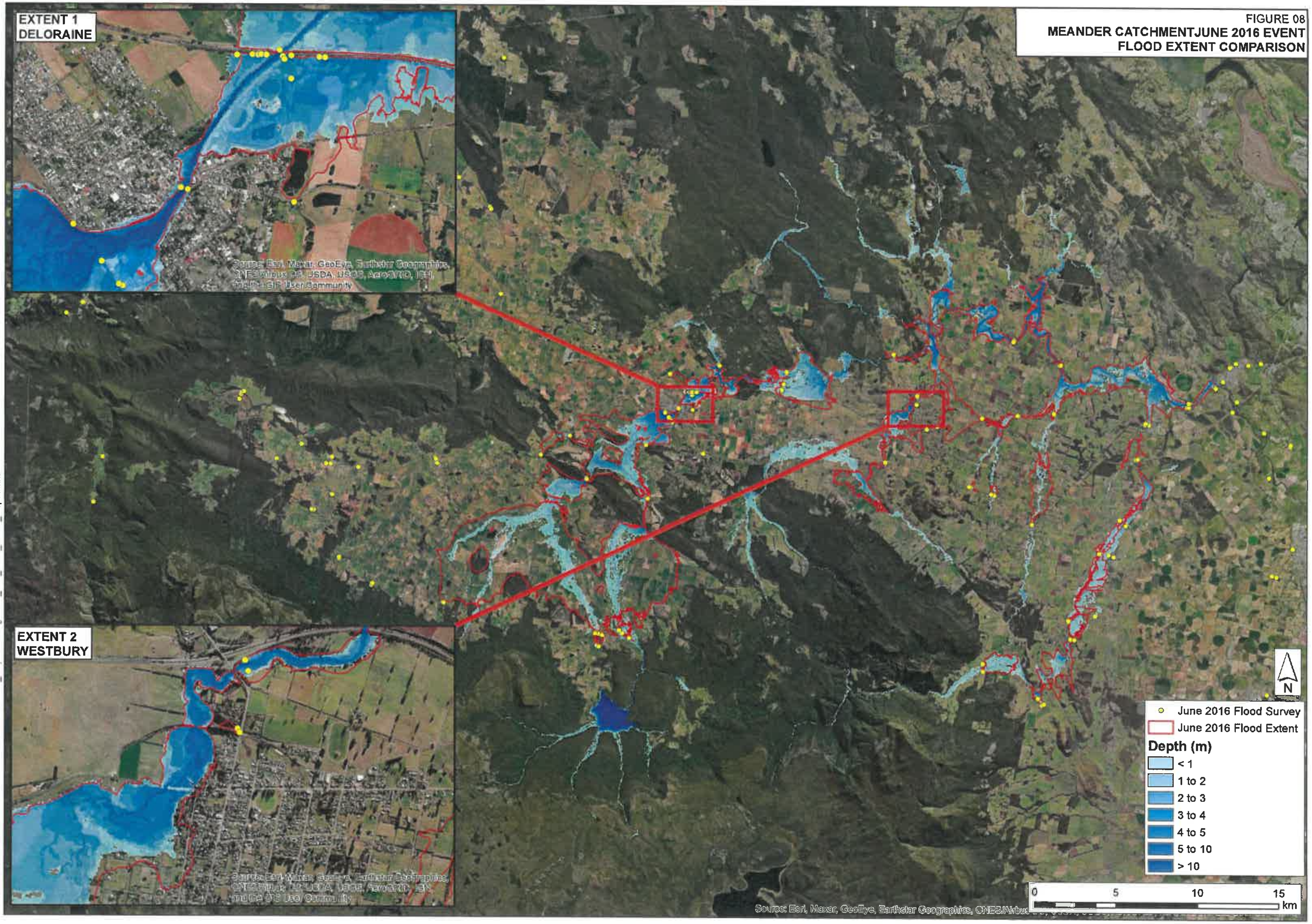
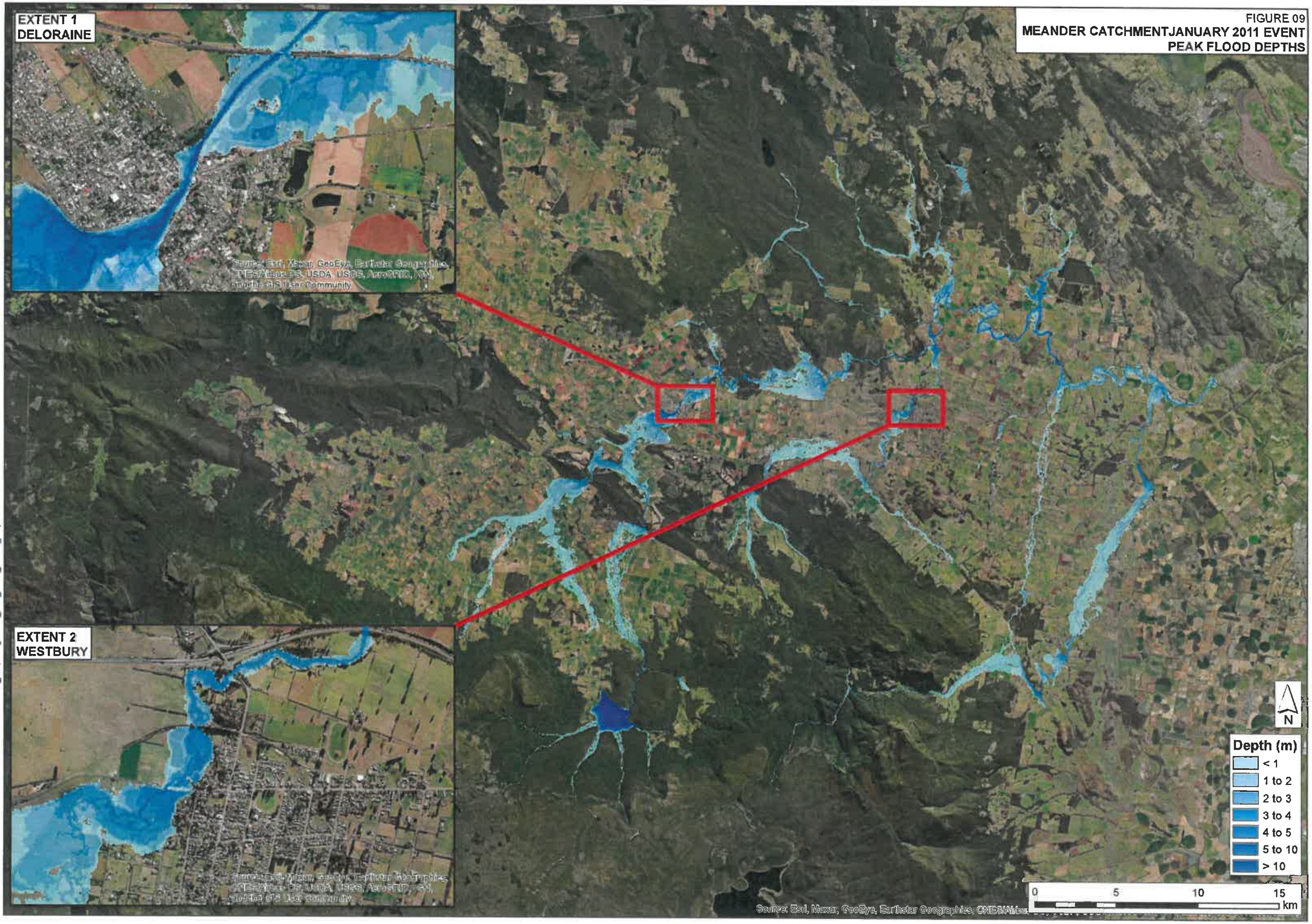


FIGURE 08
MEANDER CATCHMENTJUNE 2016 EVENT FLOOD EXTENT COMPARISON



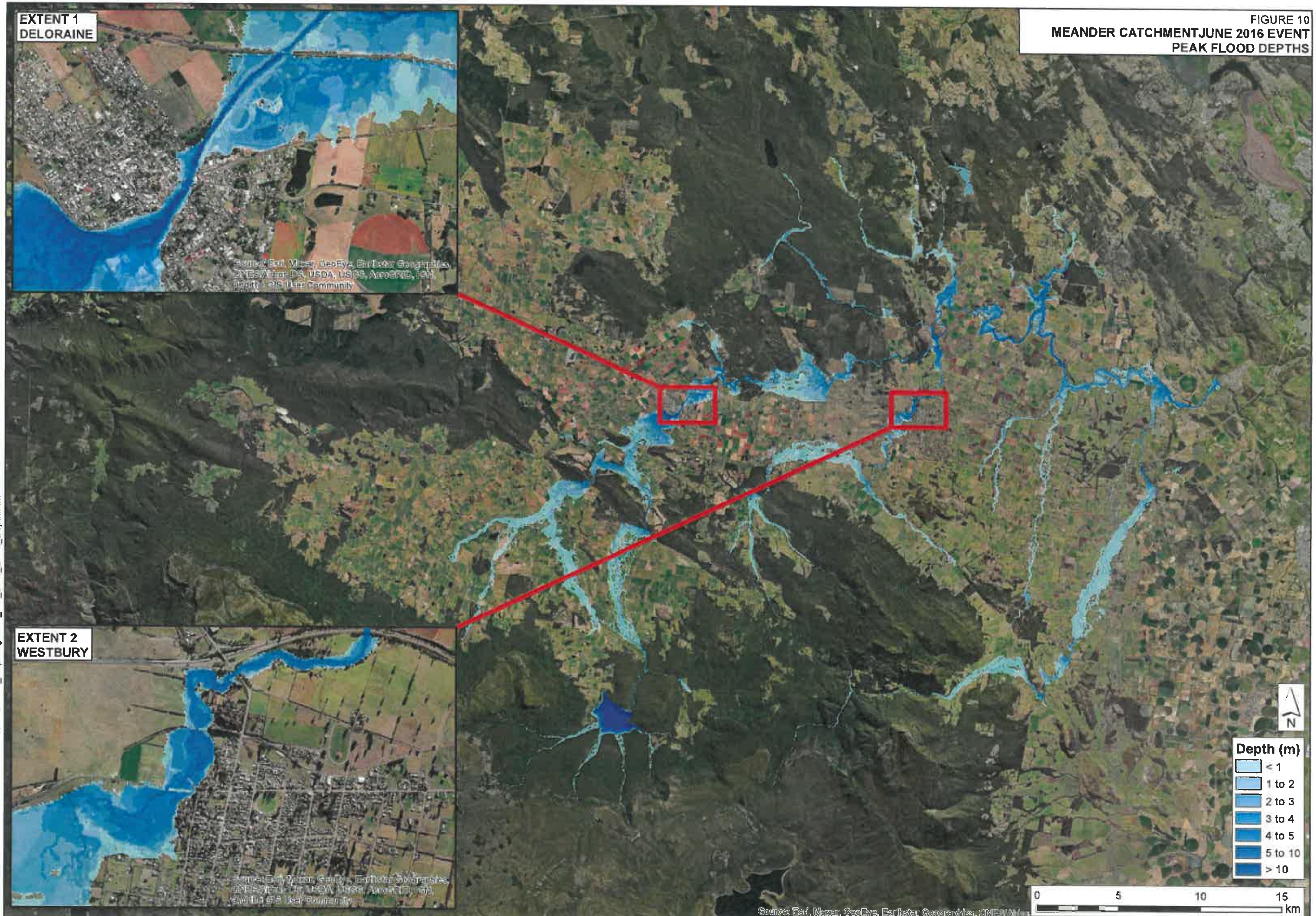
J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\com\Figure08_Jun_2016_Event_Depth.mxd

FIGURE 09
MEANDER CATCHMENTJANUARY 2011 EVENT
PEAK FLOOD DEPTHS



J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure09_Jan_2011_Event_Depth.mxd

FIGURE 10
MEANDER CATCHMENTJUNE 2016 EVENT
PEAK FLOOD DEPTHS



J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure10_Jun_2016_Event_Depth.mxd

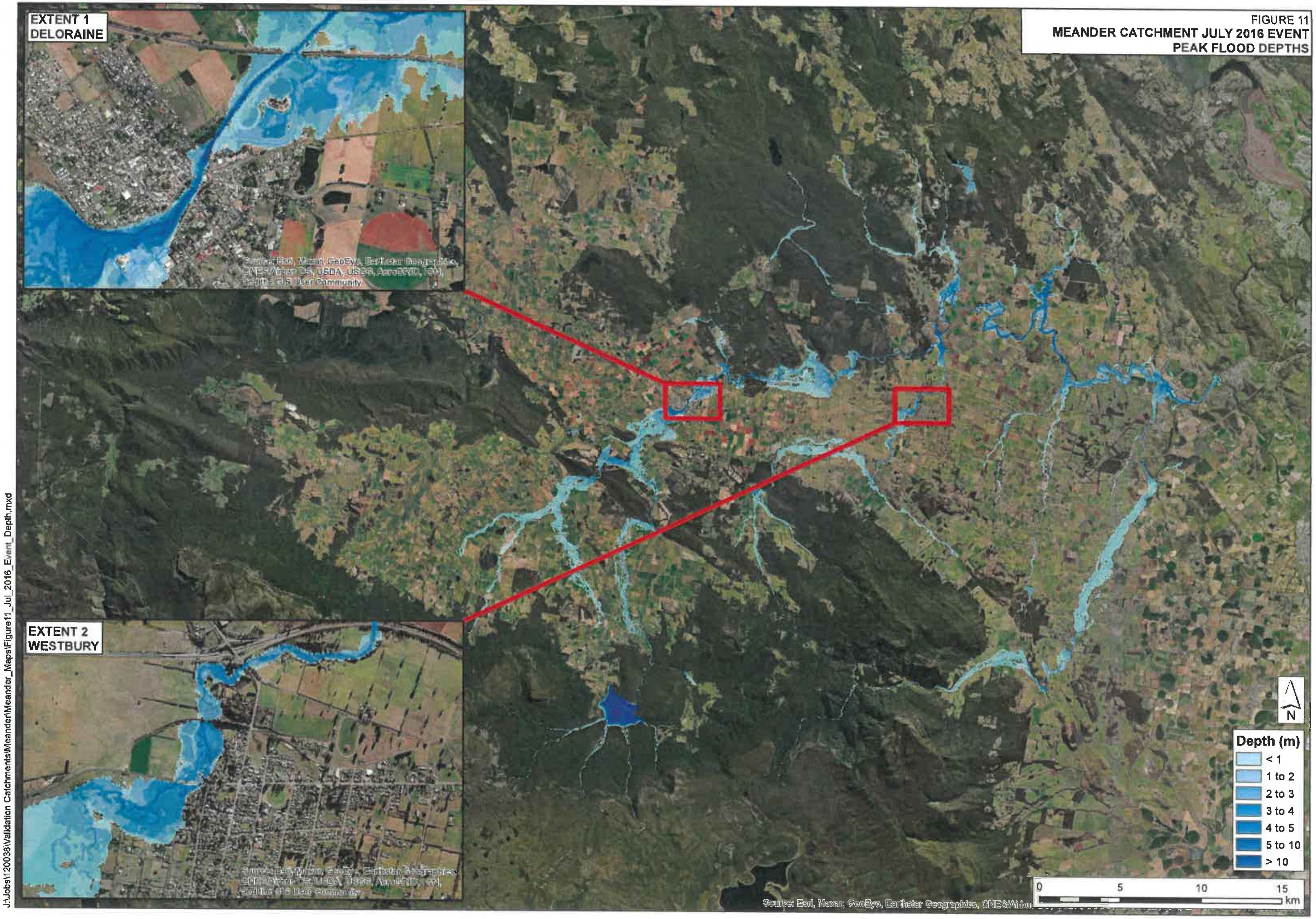
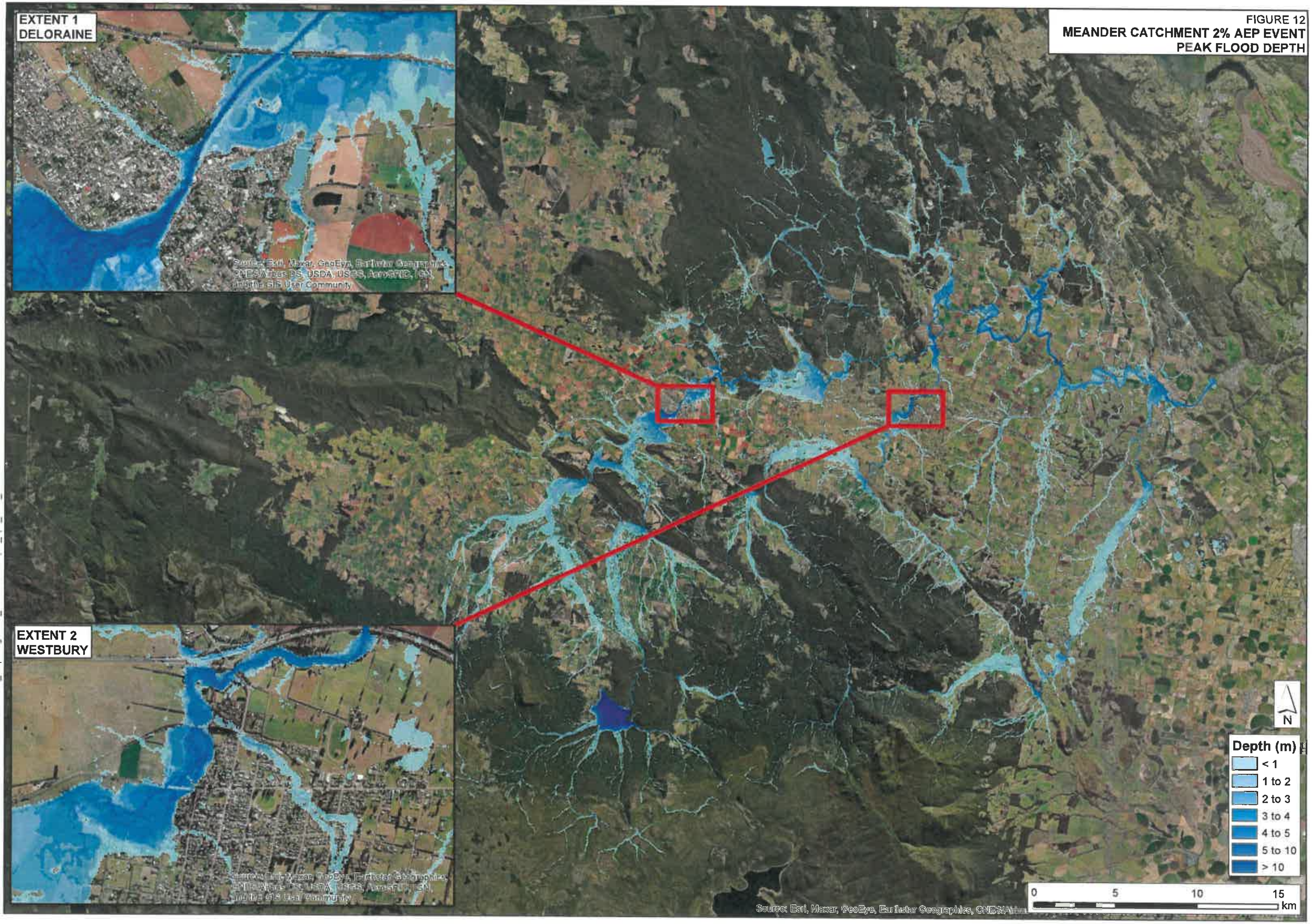


FIGURE 11
MEANDER CATCHMENT JULY 2016 EVENT
PEAK FLOOD DEPTHS
EXTENT 1
DELORAINE
EXTENT 2
WESTBURY
N
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
5
10
15
km

FIGURE 12
MEANDER CATCHMENT 2% AEP EVENT
PEAK FLOOD DEPTH



J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure12_PeakFloodDepth_2pc_AEP_Event.mxd

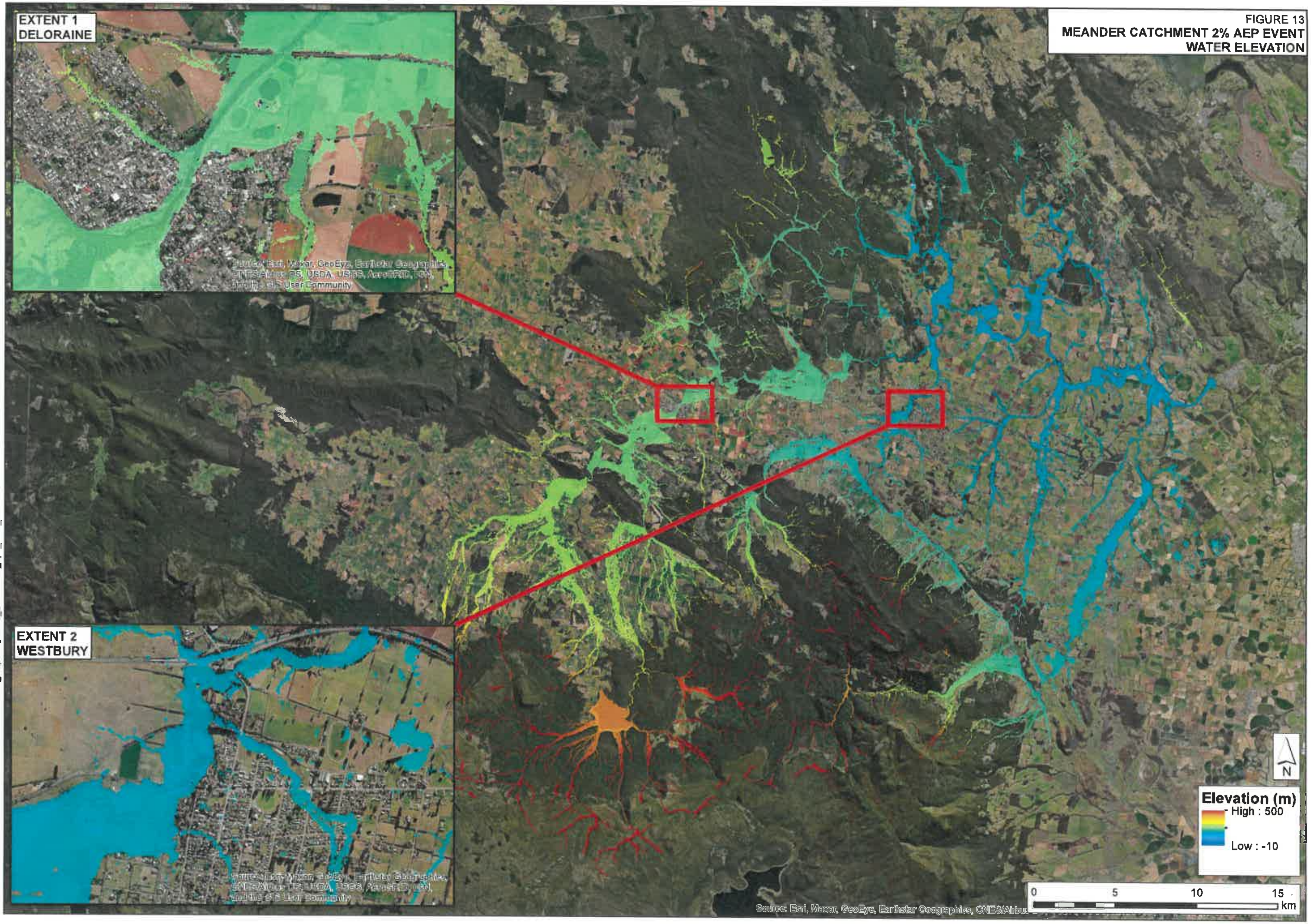
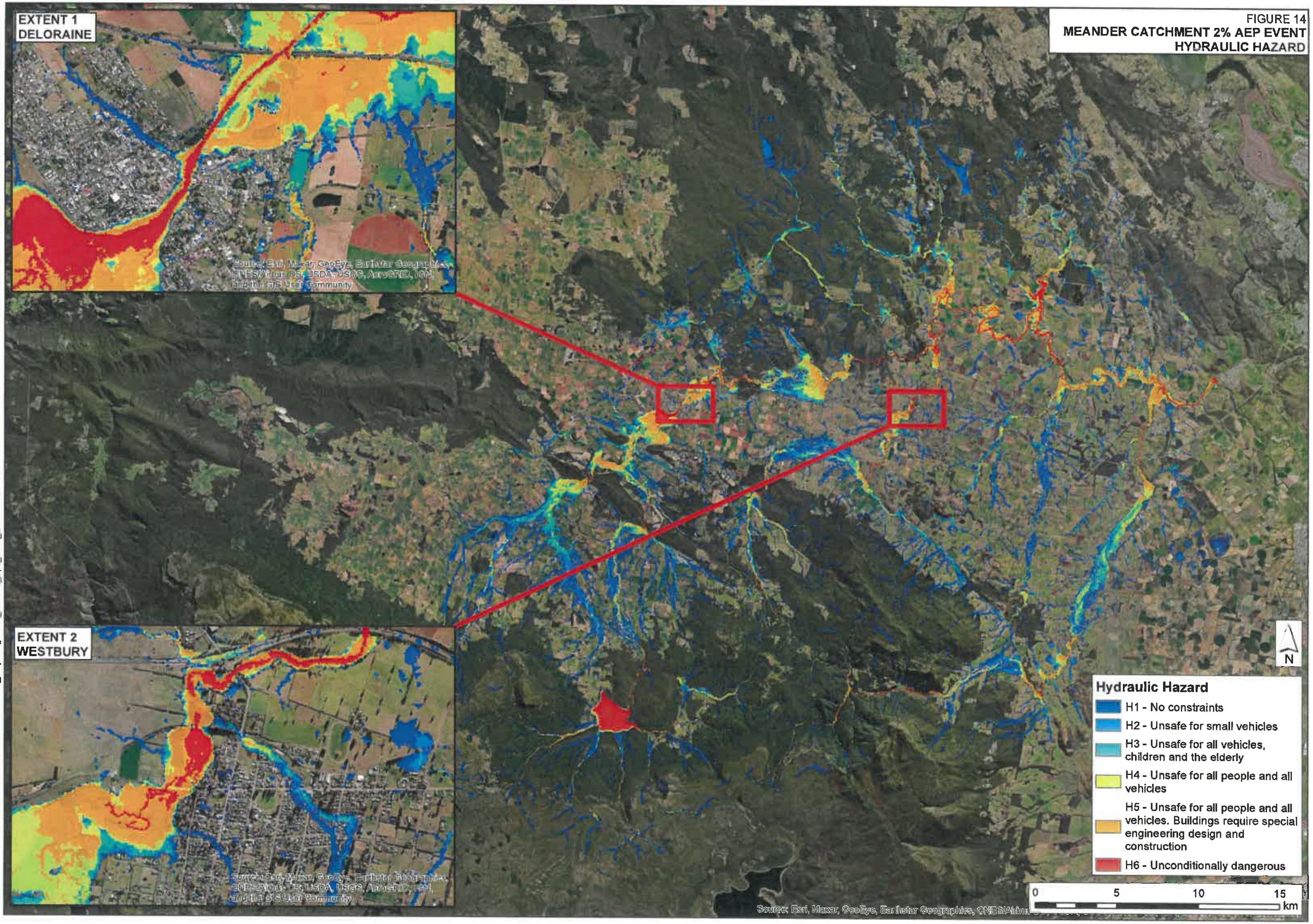
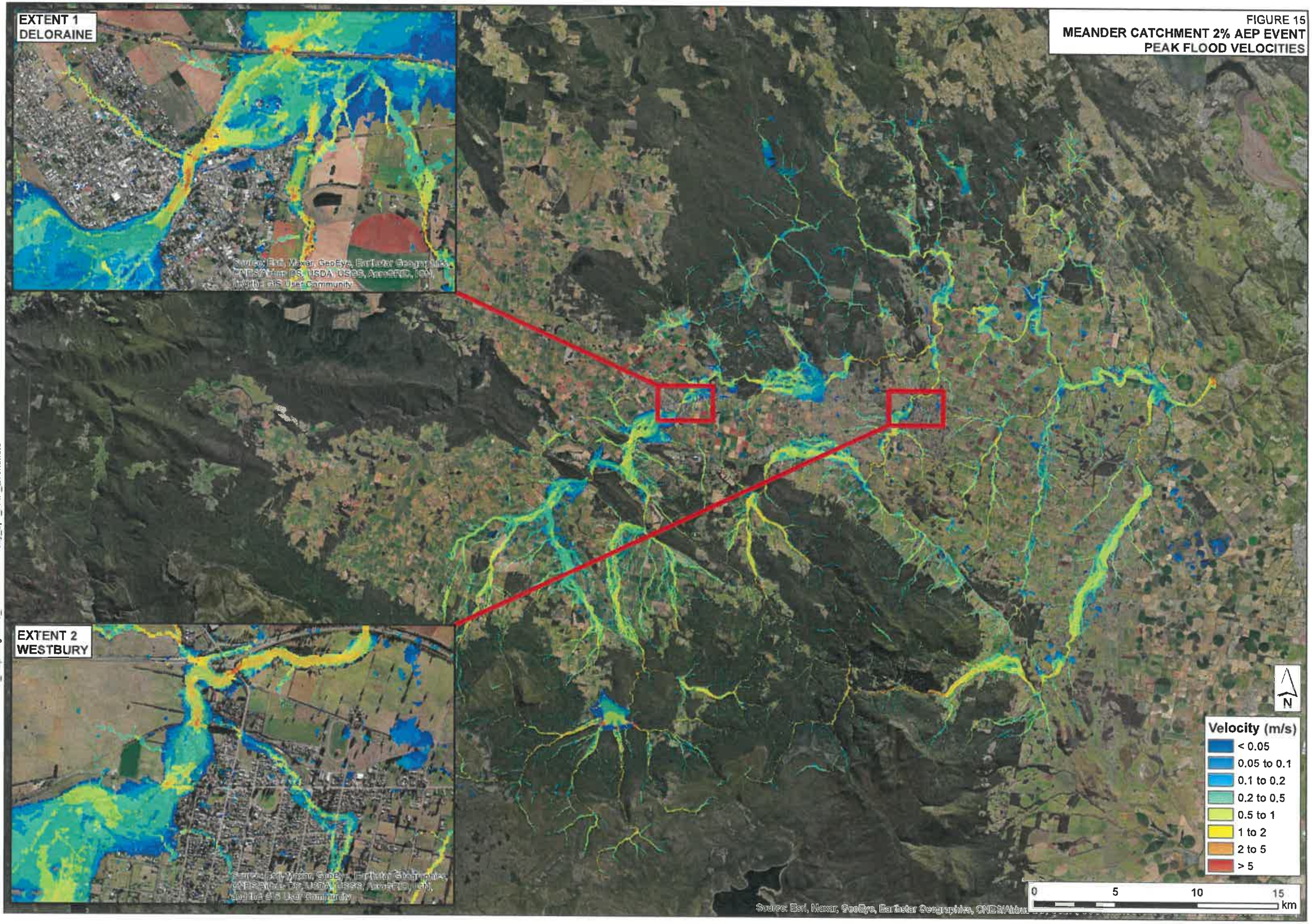


FIGURE 13
MEANDER CATCHMENT 2% AEP EVENT
WATER ELEVATION

J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure13_Elevations_2pc_AEP_Event.mxd



J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure14_Hazard_2pc_AEP_Event.mxd



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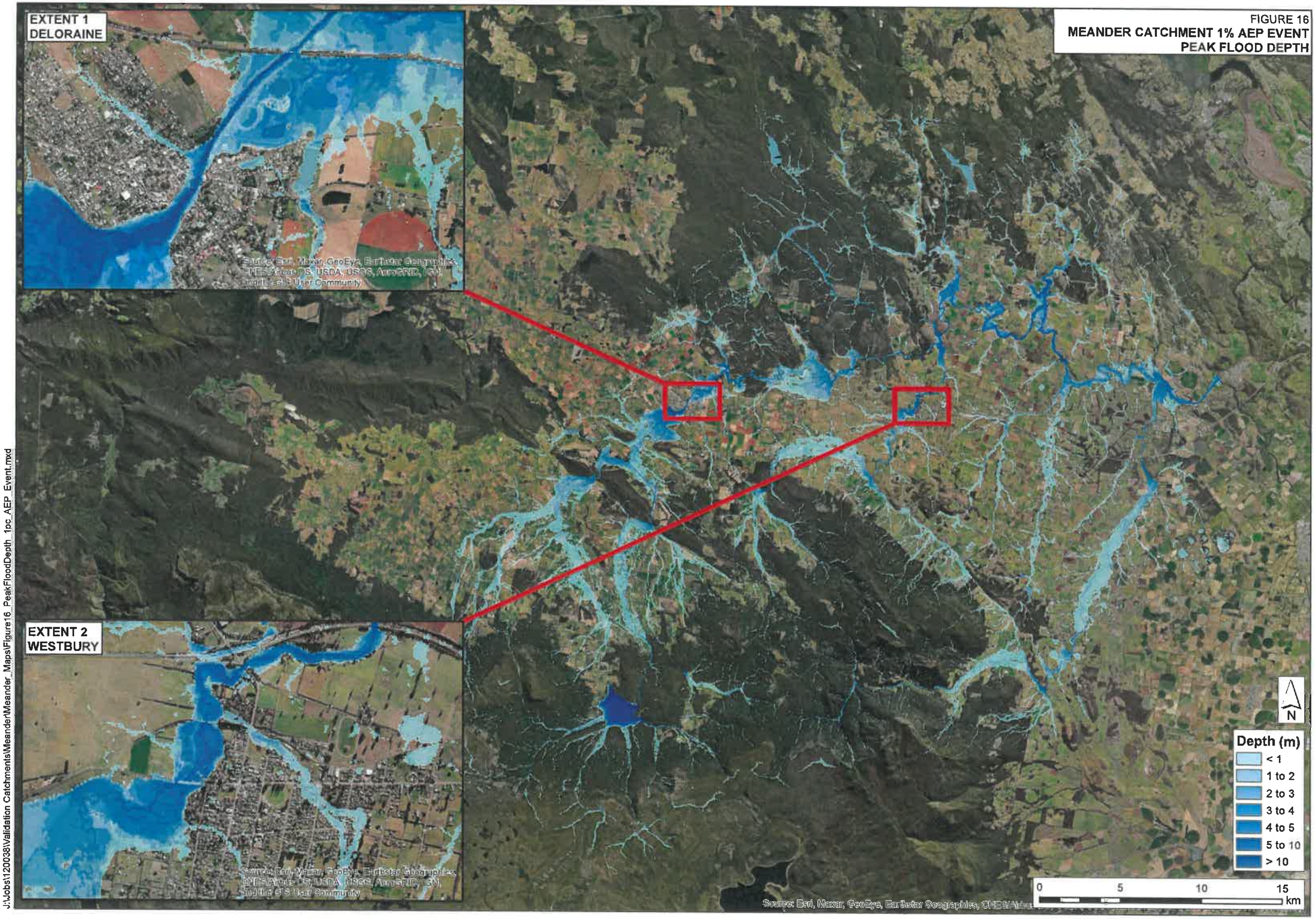
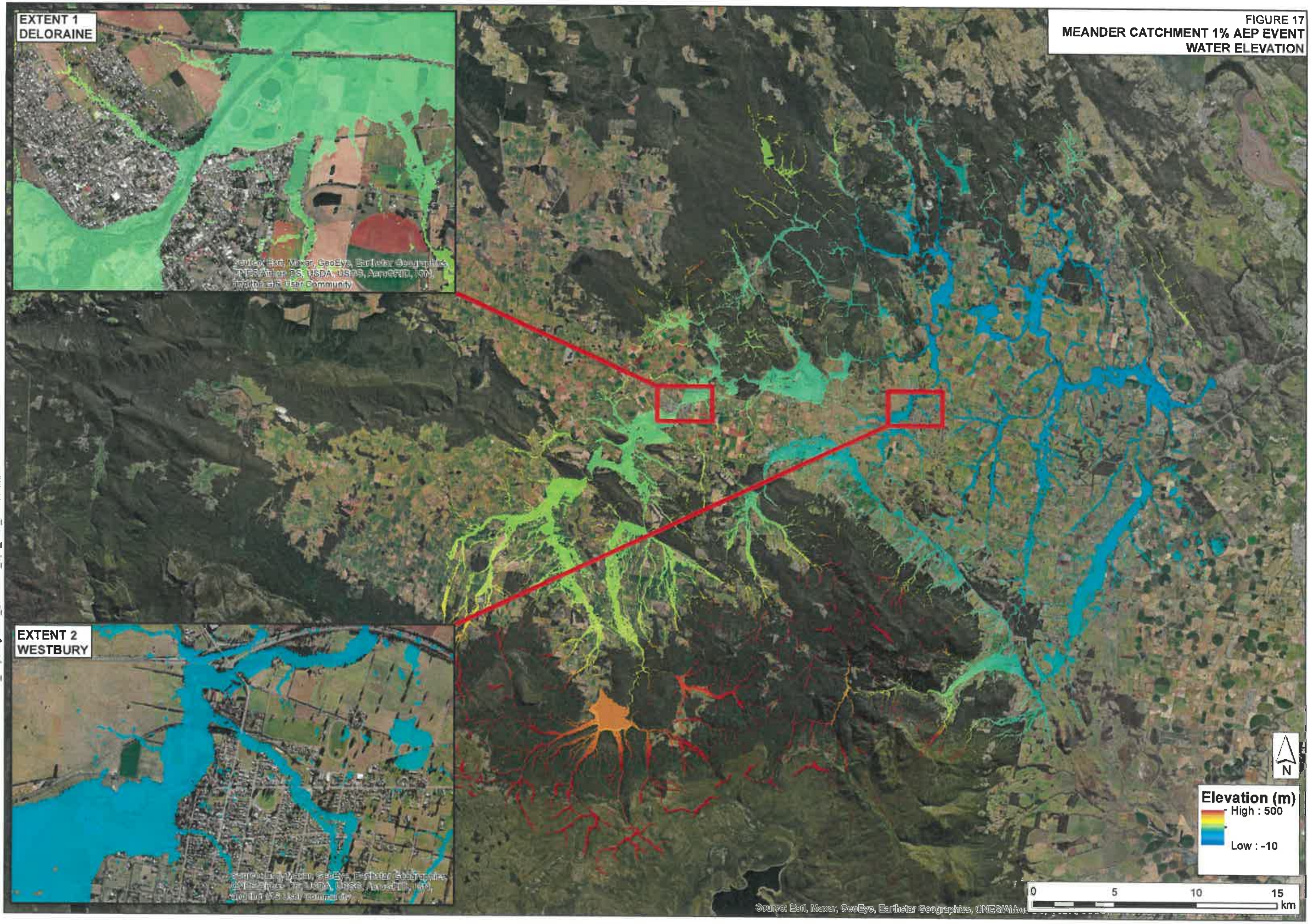


J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure16_PeakFloodDepth_1pc_AEP_Event.mxd

FIGURE 17
MEANDER CATCHMENT 1% AEP EVENT WATER ELEVATION



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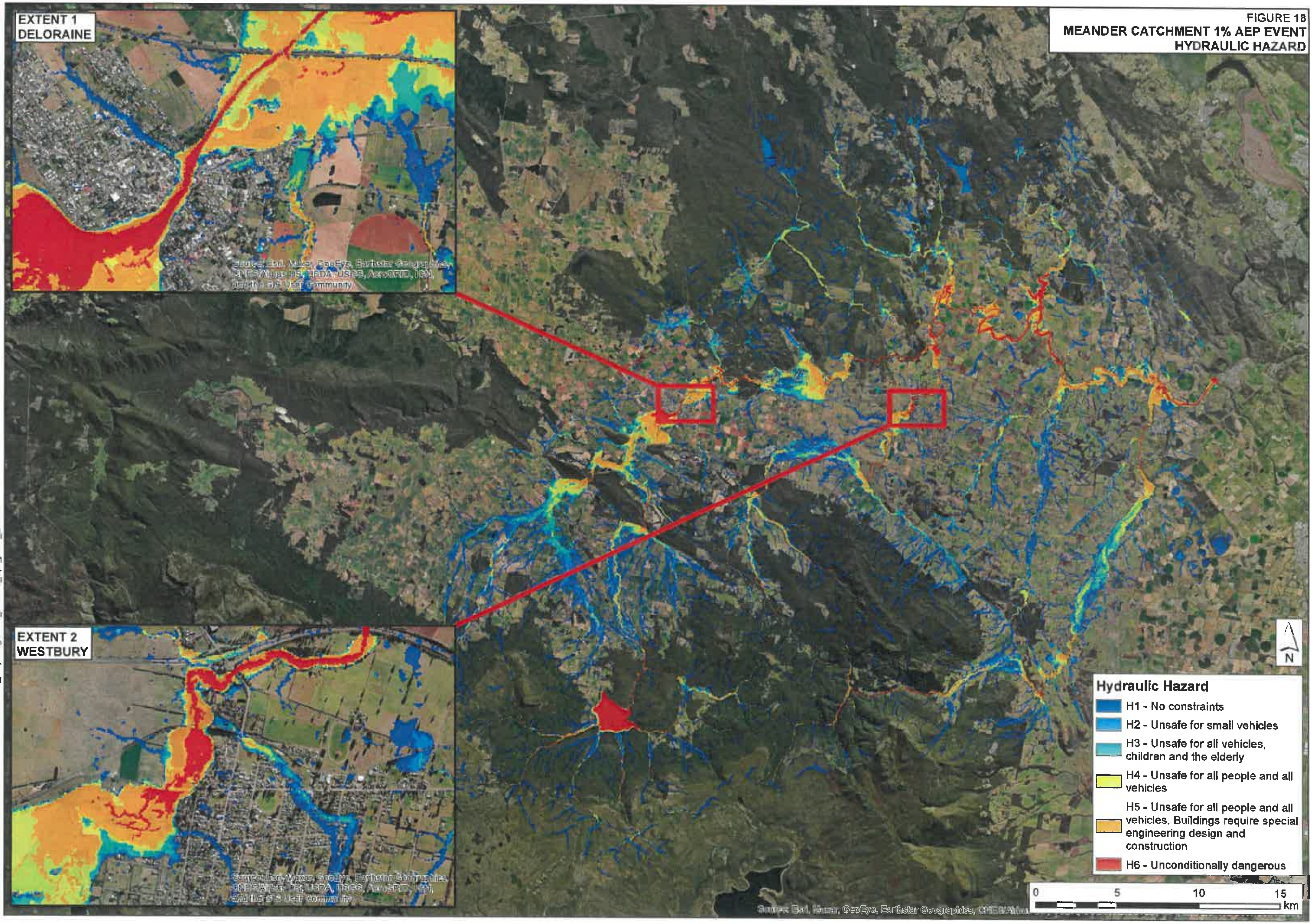

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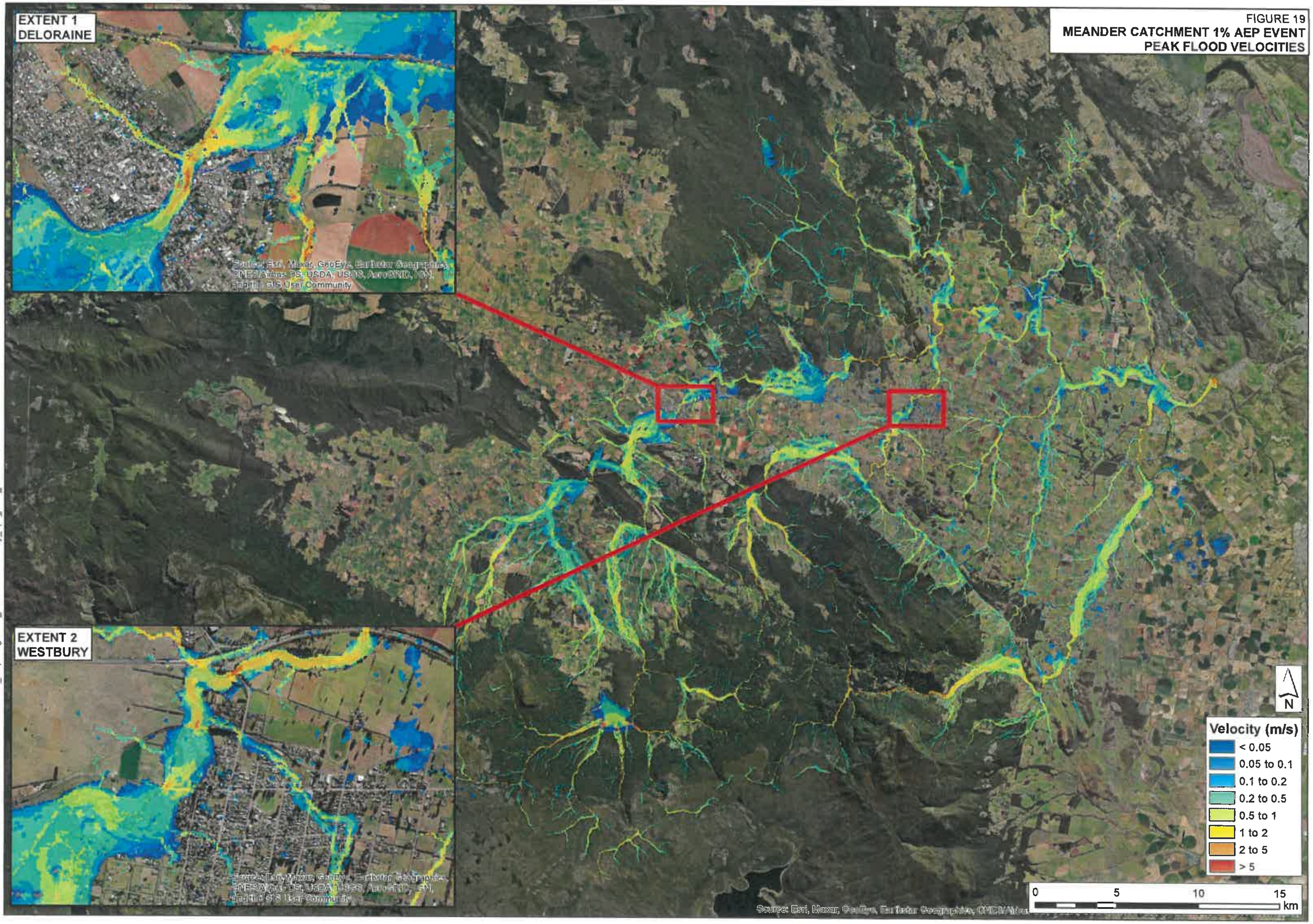
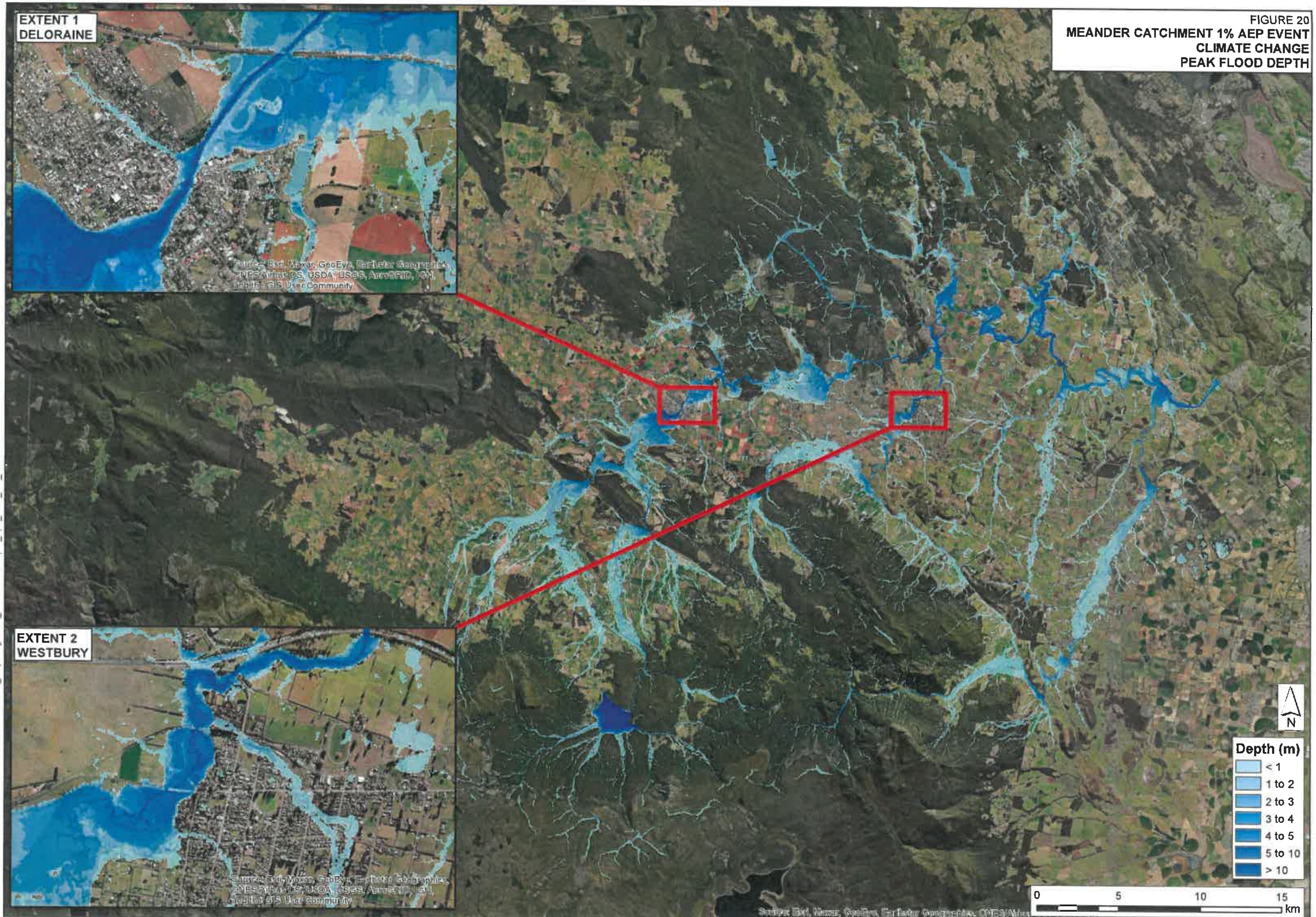
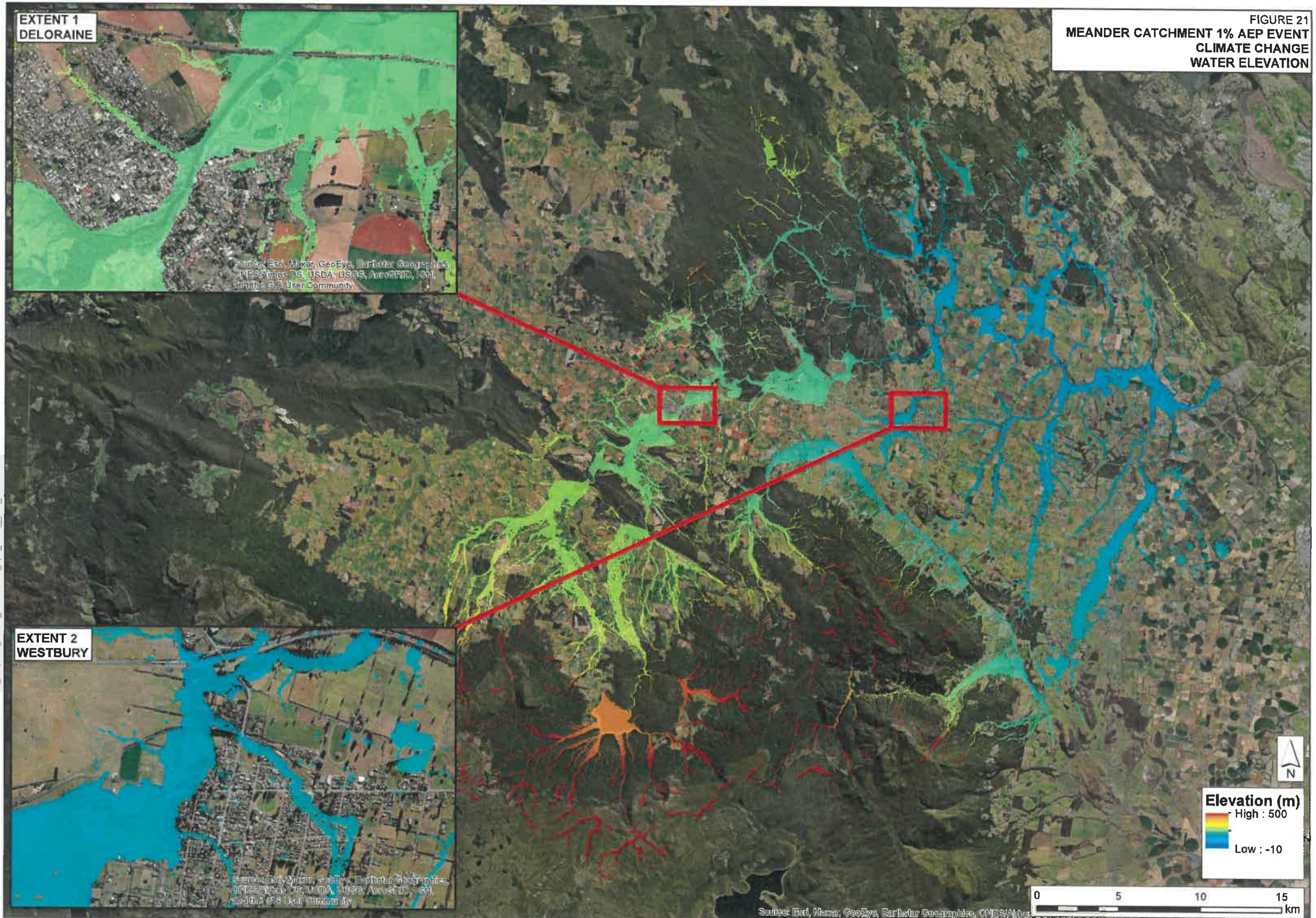


J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure19_PeakFloodVelocity_1pc_AEP_Event.mxd

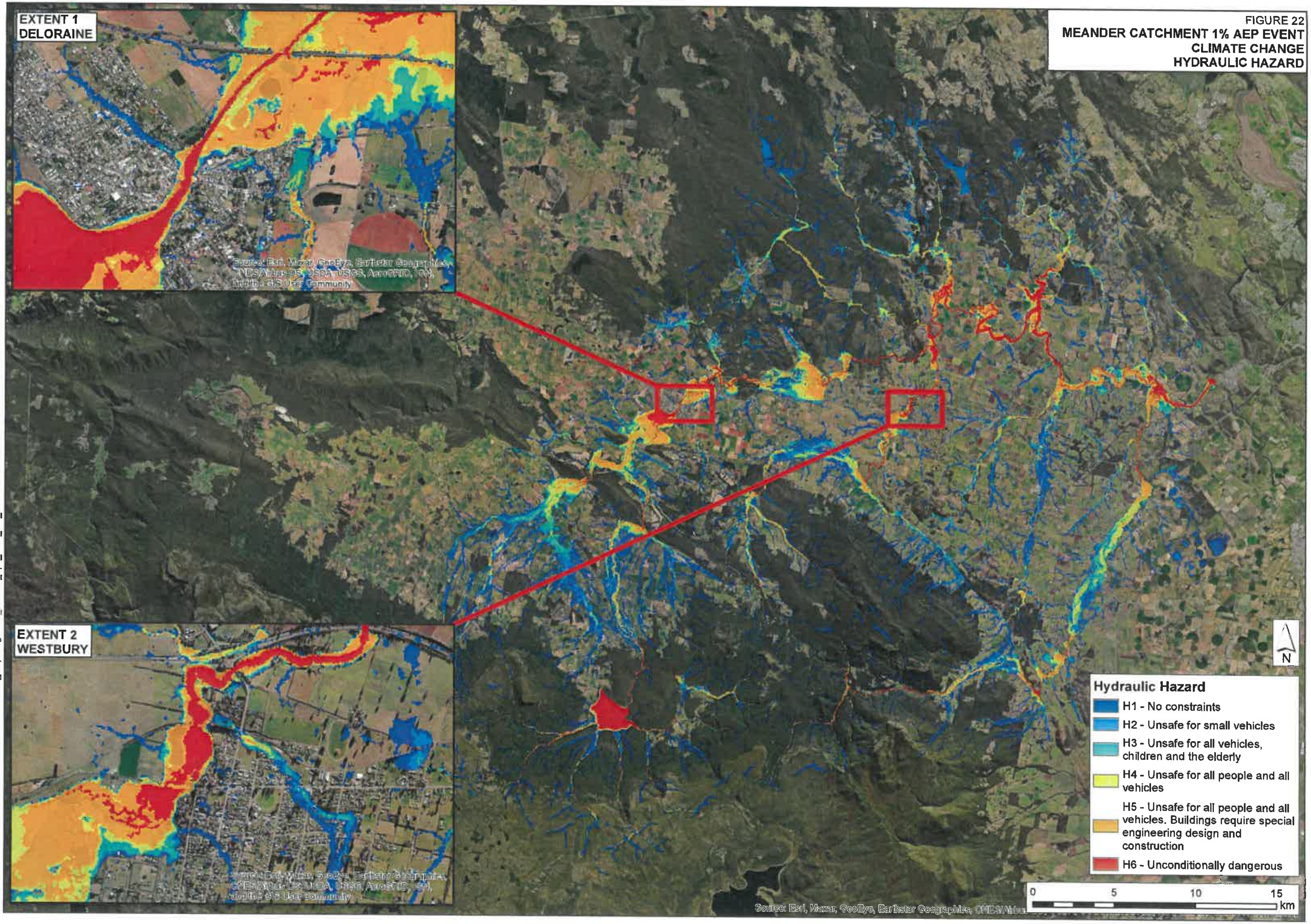


J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure20_PeakFLoodDepth_1pc_AEP_CC_Event.mxd



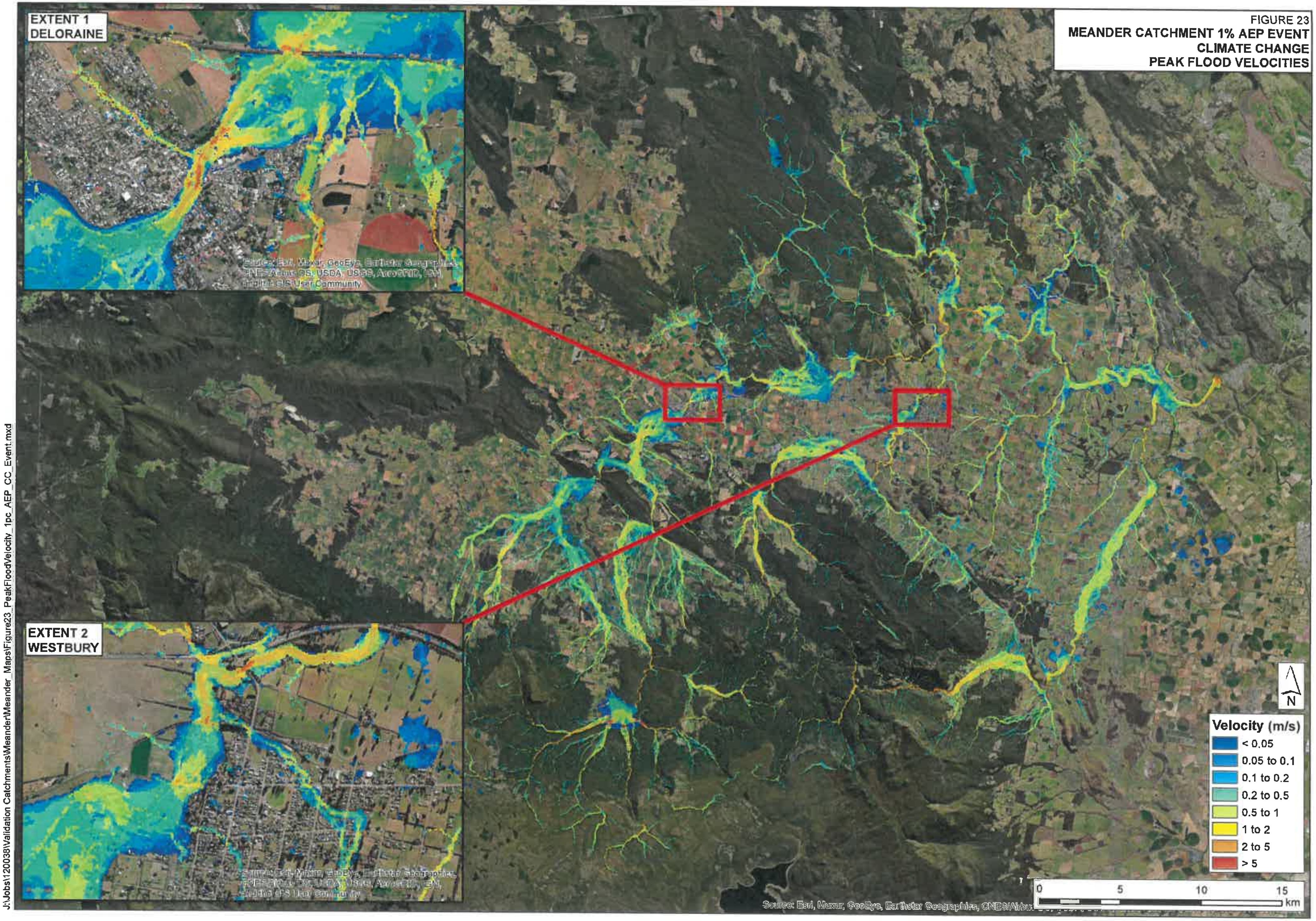
J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure21_Elevations_1pc_AEP__CC_Event.mxd

FIGURE 22
MEANDER CATCHMENT 1% AEP EVENT
CLIMATE CHANGE
HYDRAULIC HAZARD



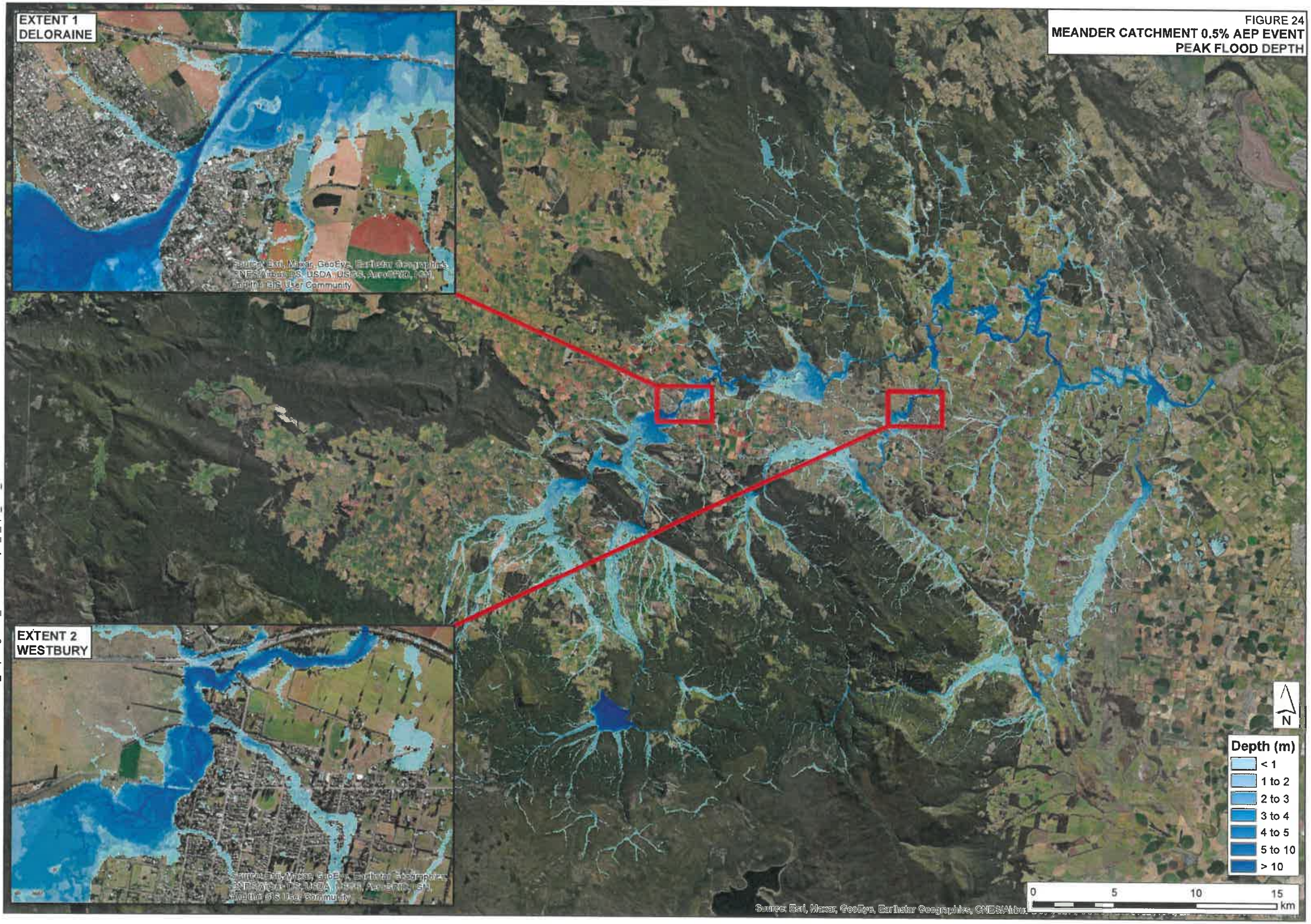
J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure22_Hazard_1pc_AEP_CC_Event.mxd

FIGURE 23
MEANDER CATCHMENT 1% AEP EVENT CLIMATE CHANGE PEAK FLOOD VELOCITIES

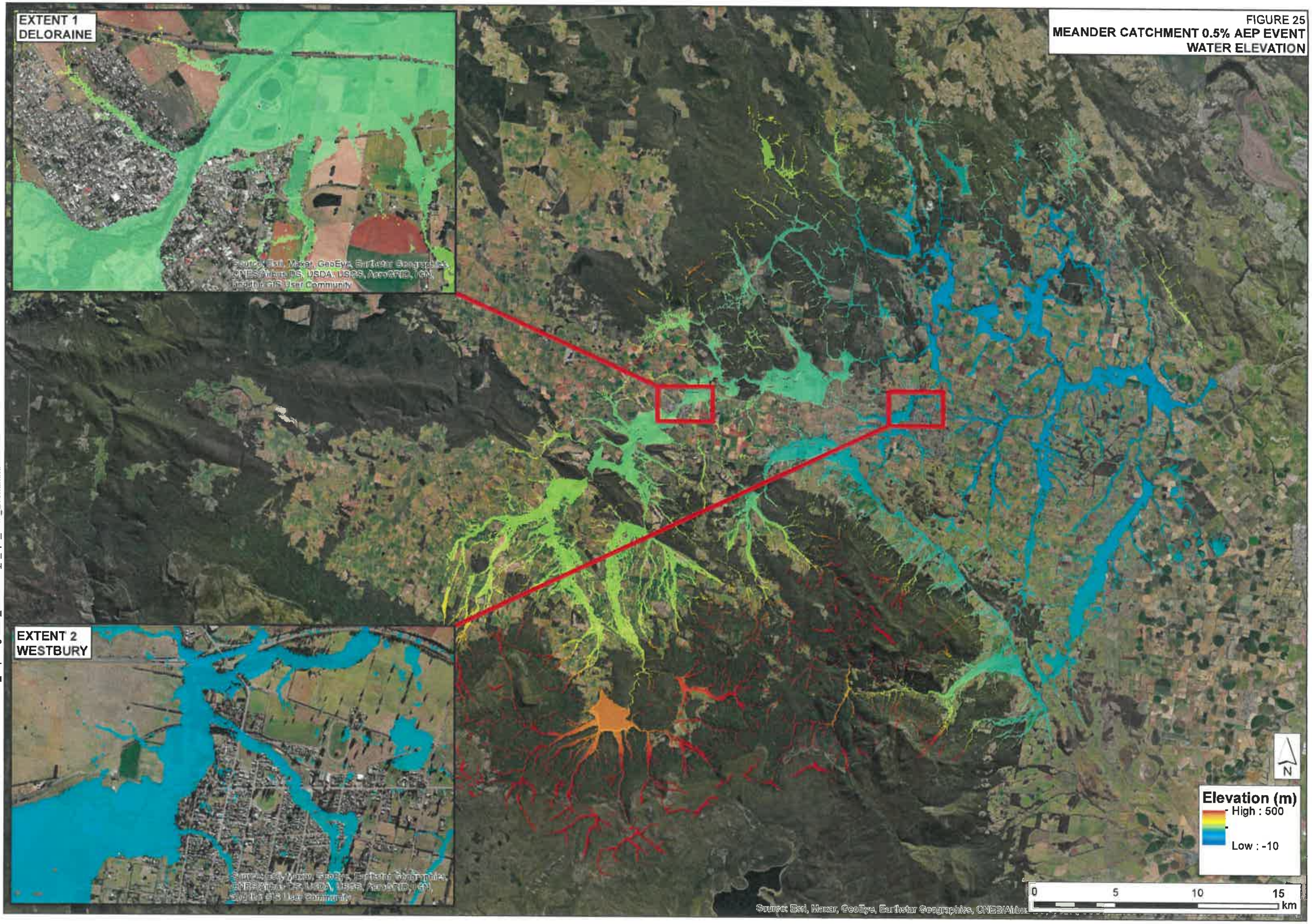


J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure23_PeakFloodVelocity_1pc_AEP_CC_Event.mxd

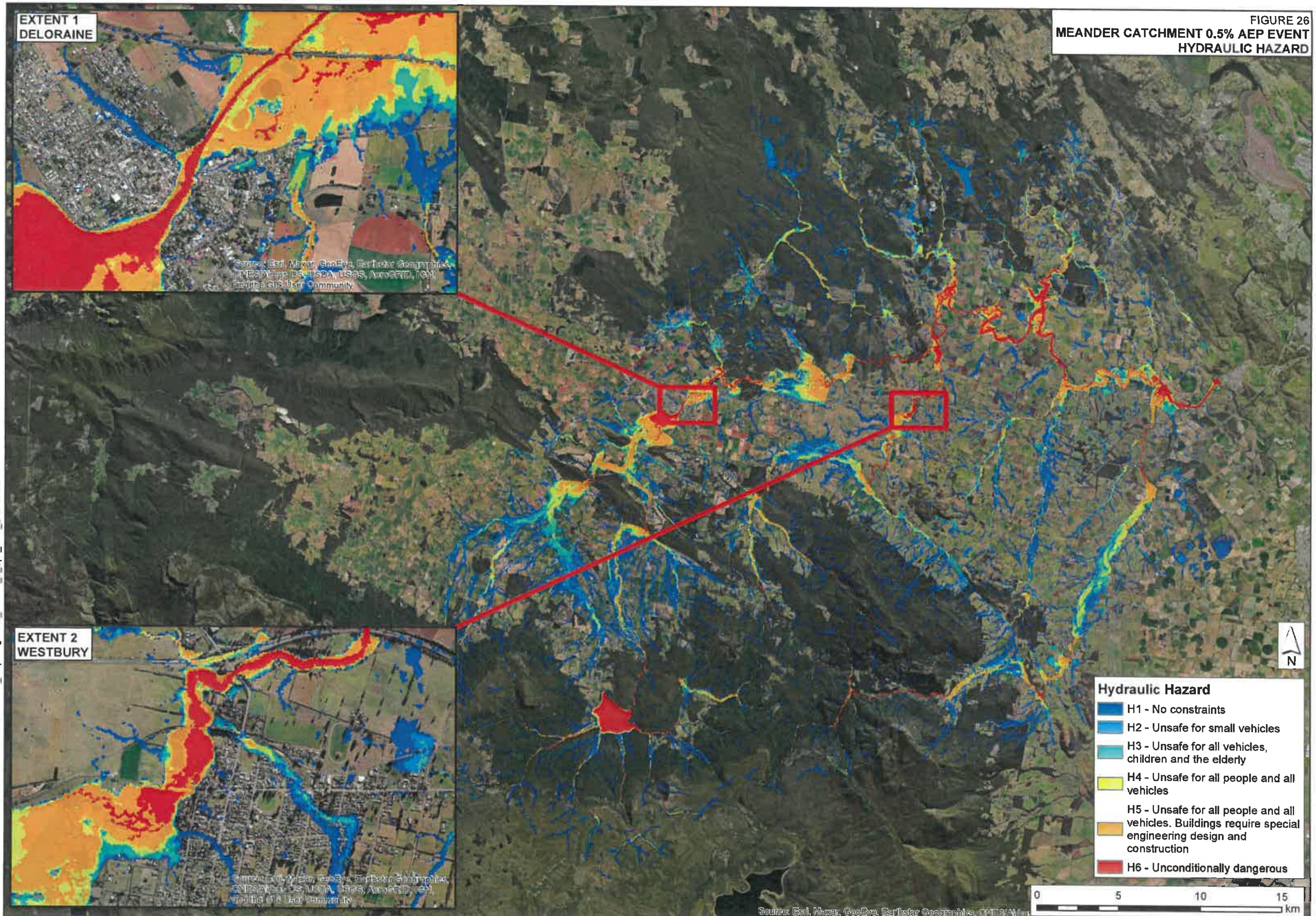
FIGURE 24
MEANDER CATCHMENT 0.5% AEP EVENT
PEAK FLOOD DEPTH



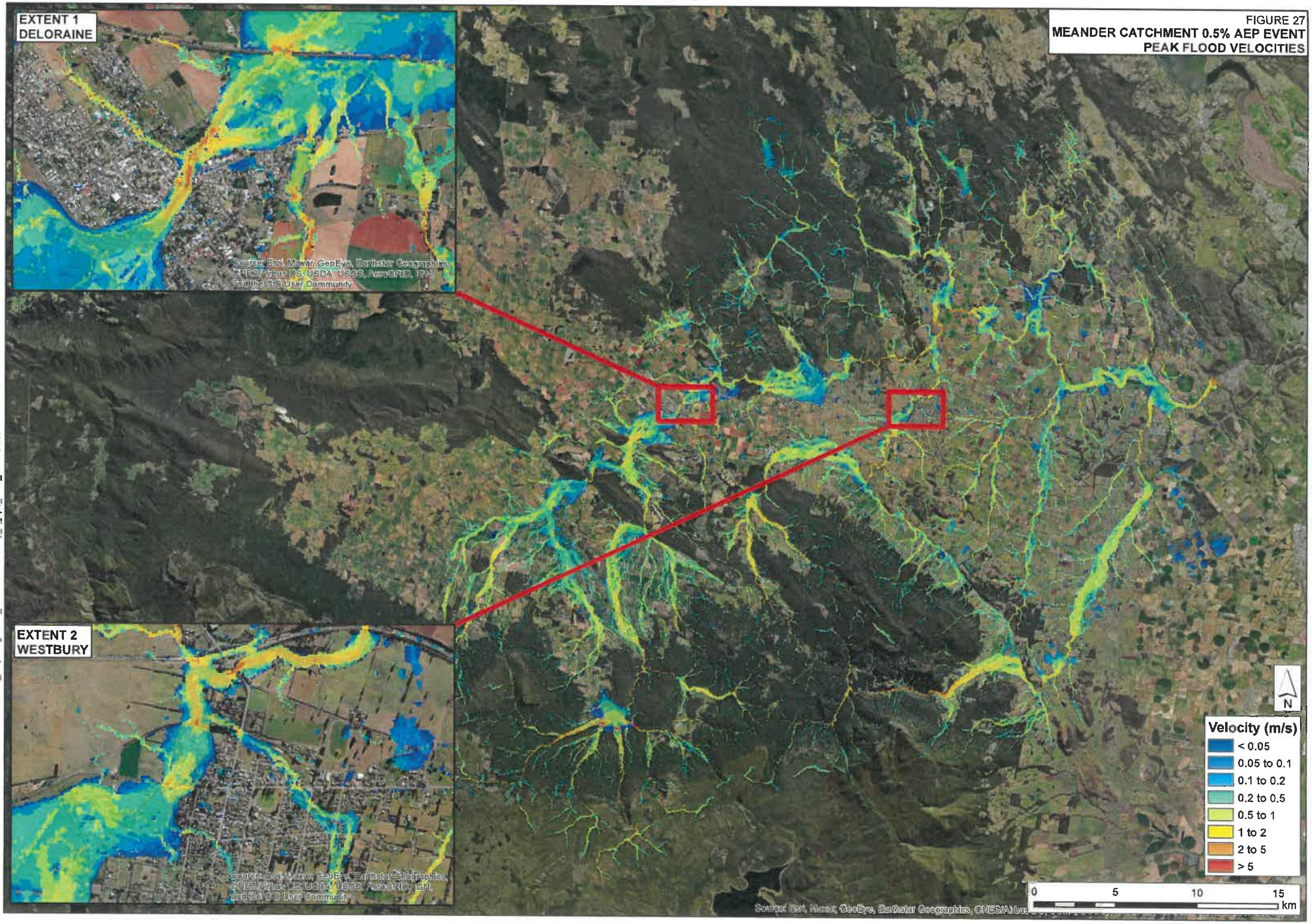
J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure24_PeakFloodDepth_0_5pc_AEP_Event.mxd



J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure25_Elevations_0_5pc_AEP_Event.mxd



J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure26_Hazard_0_5pc_AEP_Event.mxd



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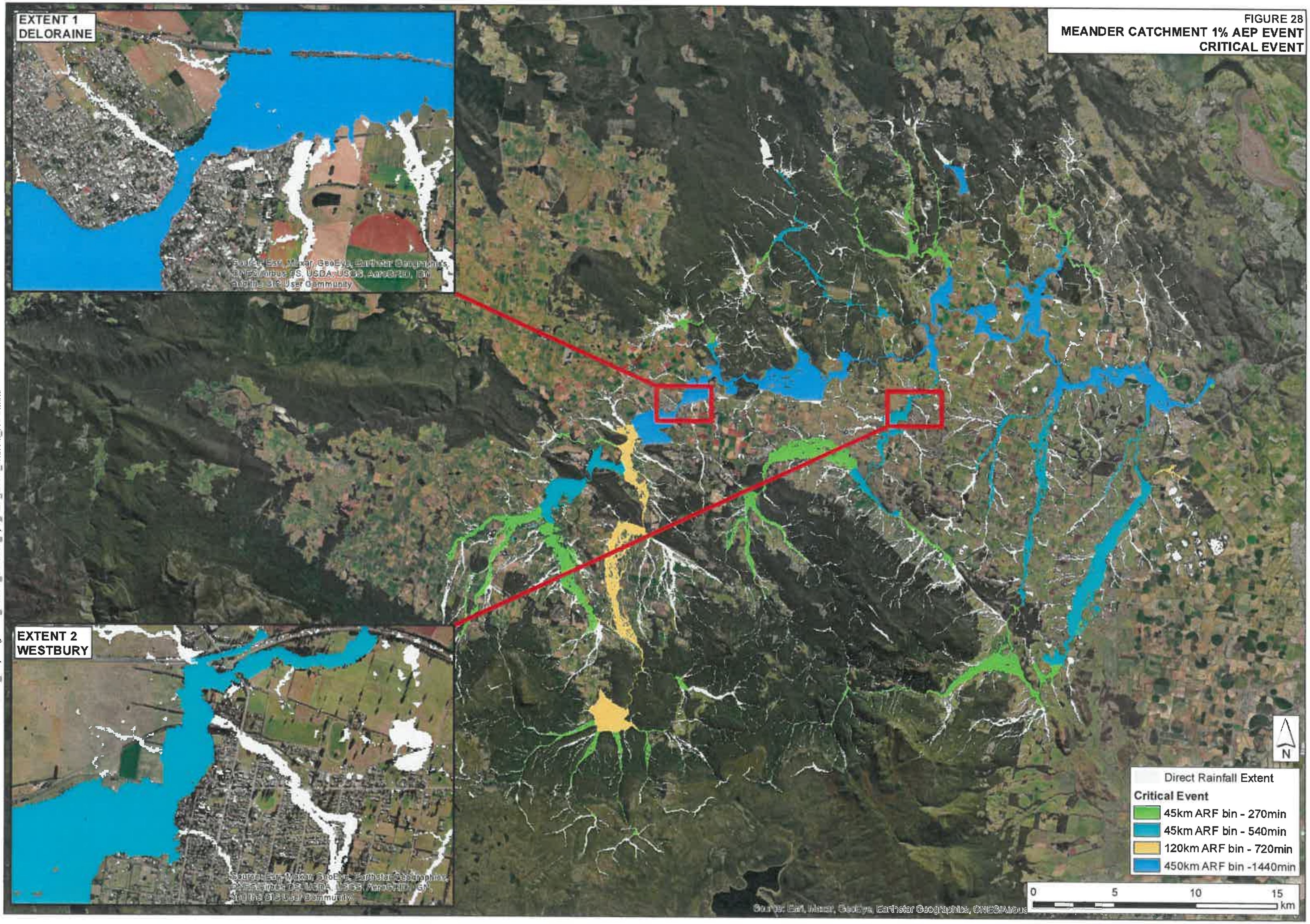


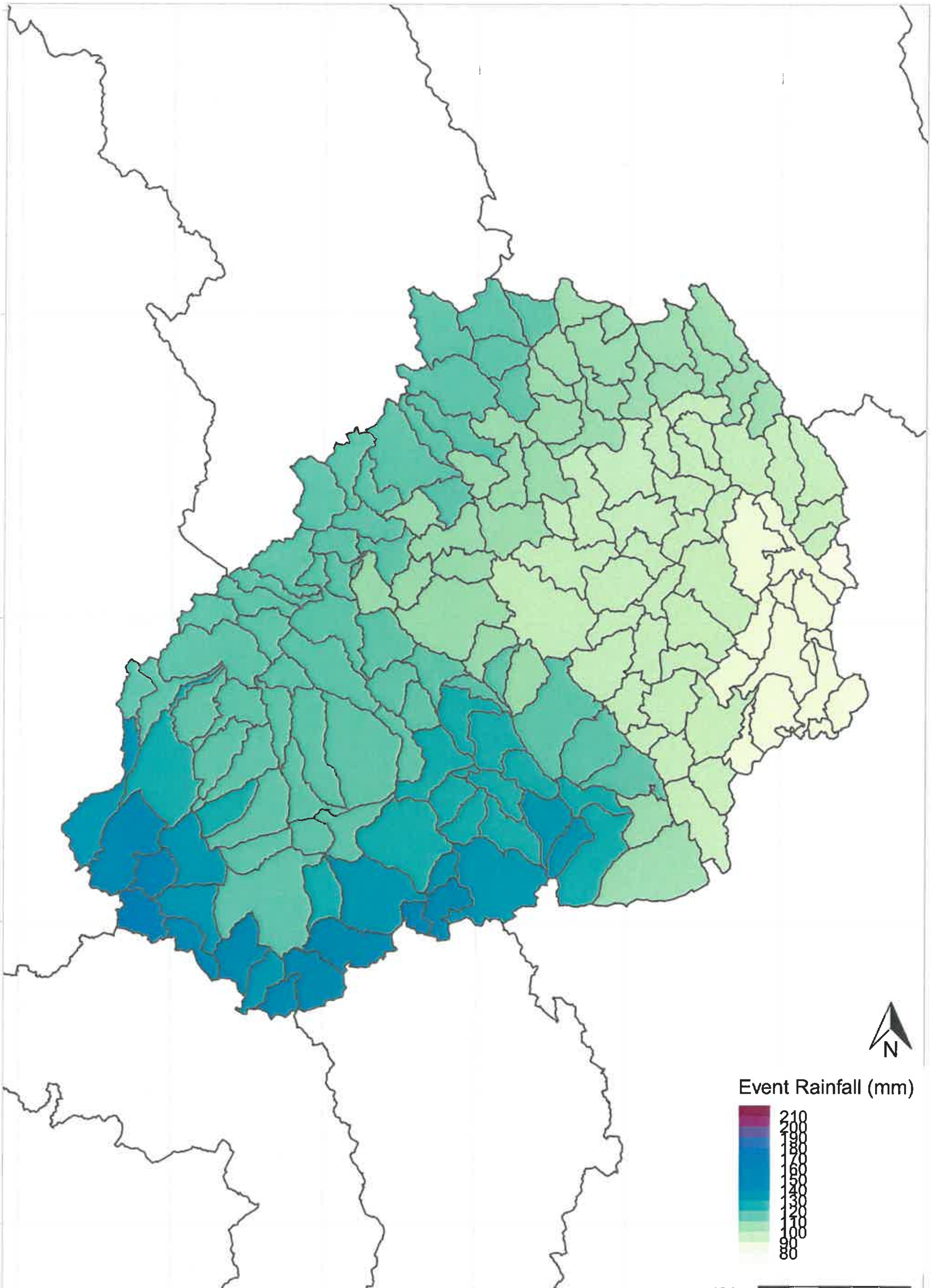
J:\Jobs\120038\Validation Catchments\Meander\Meander_Maps\Figure28_Critical_Duration_1pc_AEP_Event_without_ROG.mxd

Appendix A

APPENDIX A. AVALIABLE DATA

A.1. Design Event Data

FIGURE A1
DESIGN RAINFALL DEPTHS
1440MIN 2%AEP



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J:/Jobs/120038/Hydrology/Validation_Catchments/DesignRuns/Meander_recode_7km2/Design_Rainfall_Full_Catchment_ARF/report_maps/FigureA1dur14402pAEP_same_scale.pdf

FIGURE A2
DESIGN RAINFALL DEPTHS
1440MIN 1%AEP

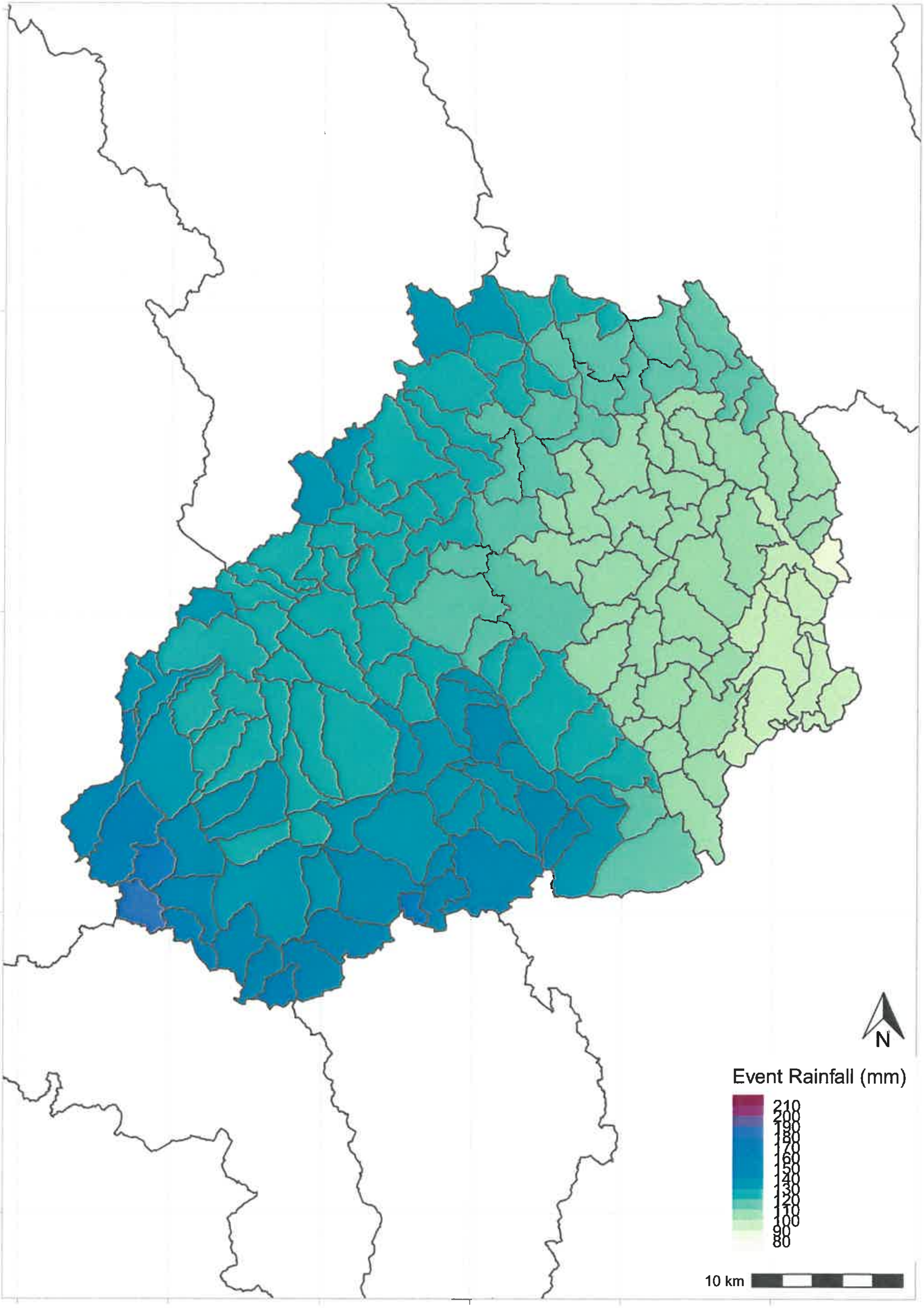

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FIGURE A3
DESIGN RAINFALL DEPTHS
1440MIN 1IN200AEP

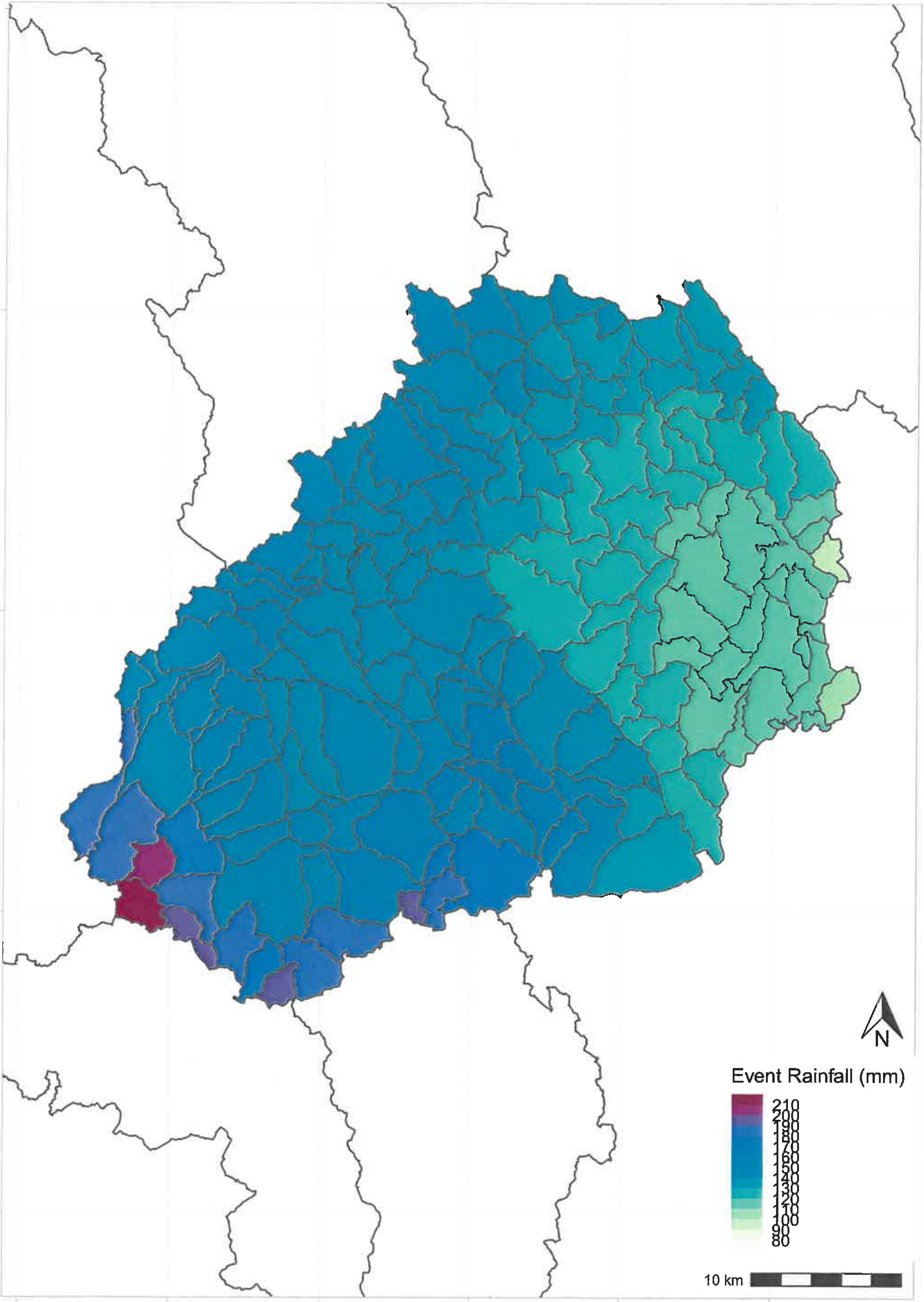

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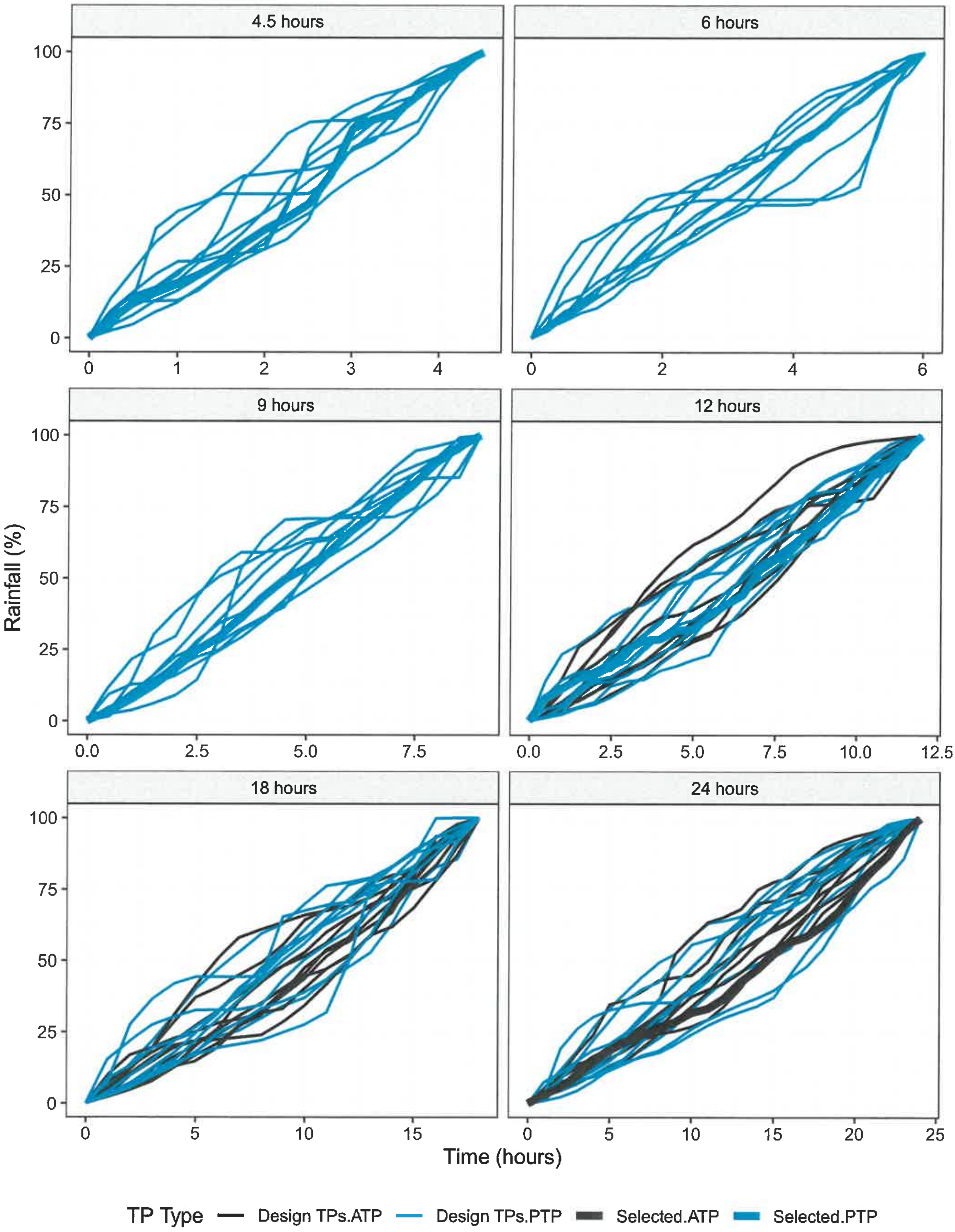
FIGURE A4
DESIGN AREAL TEMPORAL PATTERNS
DURATIONS FROM 1 TO 12 HOURS

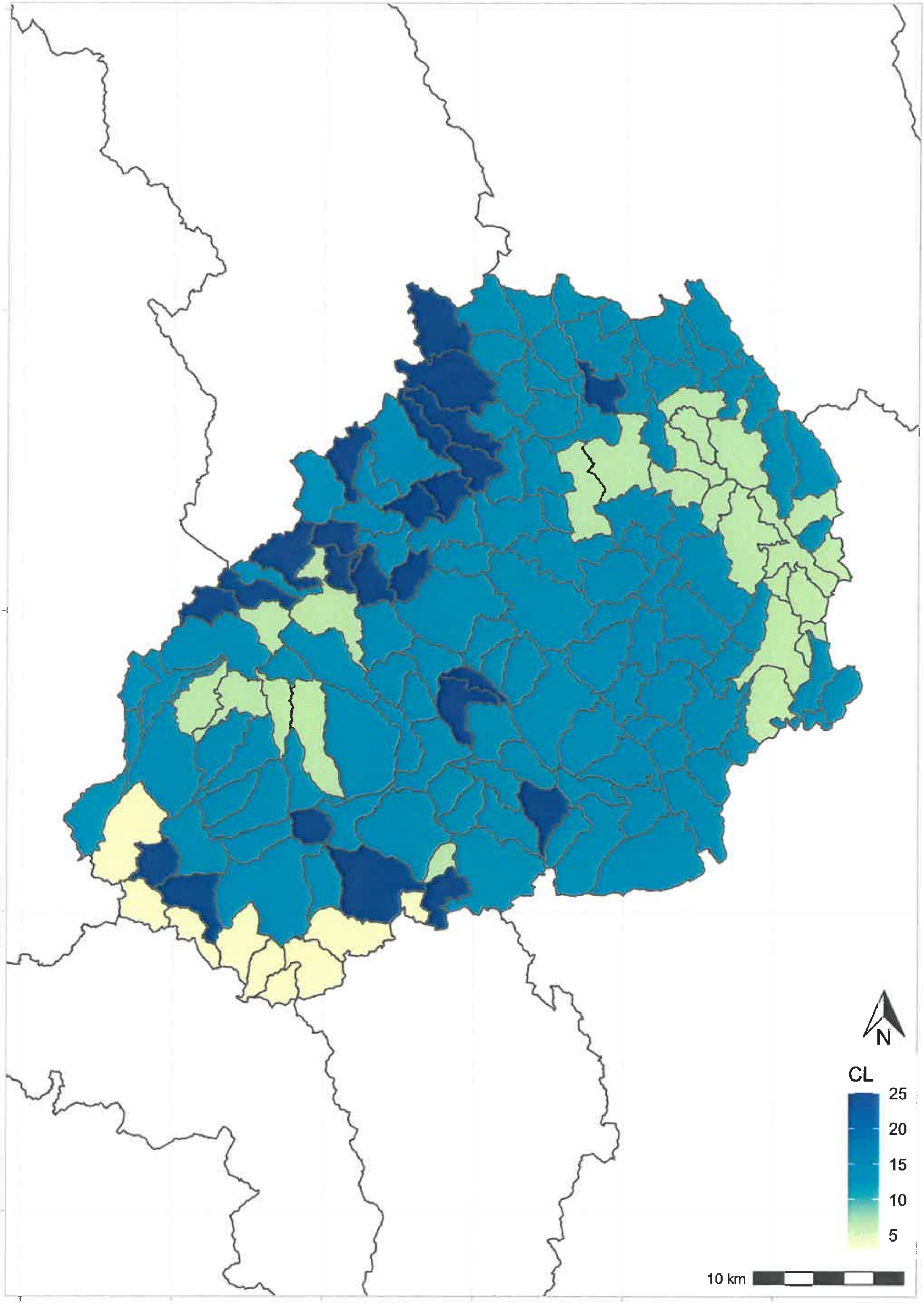


created by J:/Jobs/120038/Hydrology/R_scripts/Validation_Catchments/Design_Report_Plots_Meander.R

FIGURE A5

HYDROLOGICAL SOIL GROUP MAPPING

DOMINANT SUBCATCHMENT SOIL INFILTRATION RATE



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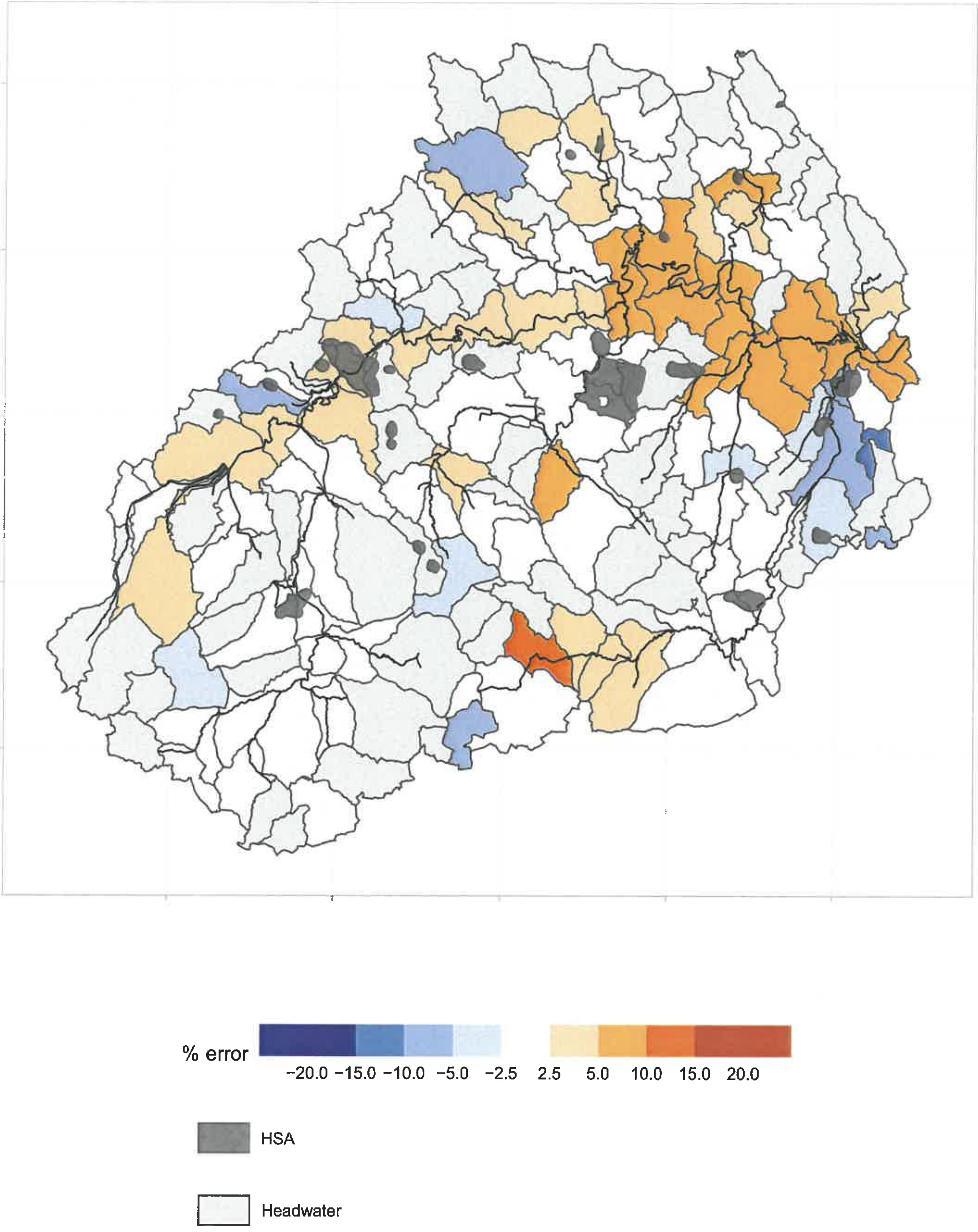
J:/Jobs/120038/Admin/Reports/Validation catchment reports/Meander_Figures/Figure_A5_Soil_types.png

Figure A6

Meander Catchment

Percentage error in peak flows using selected runs

2% AEP



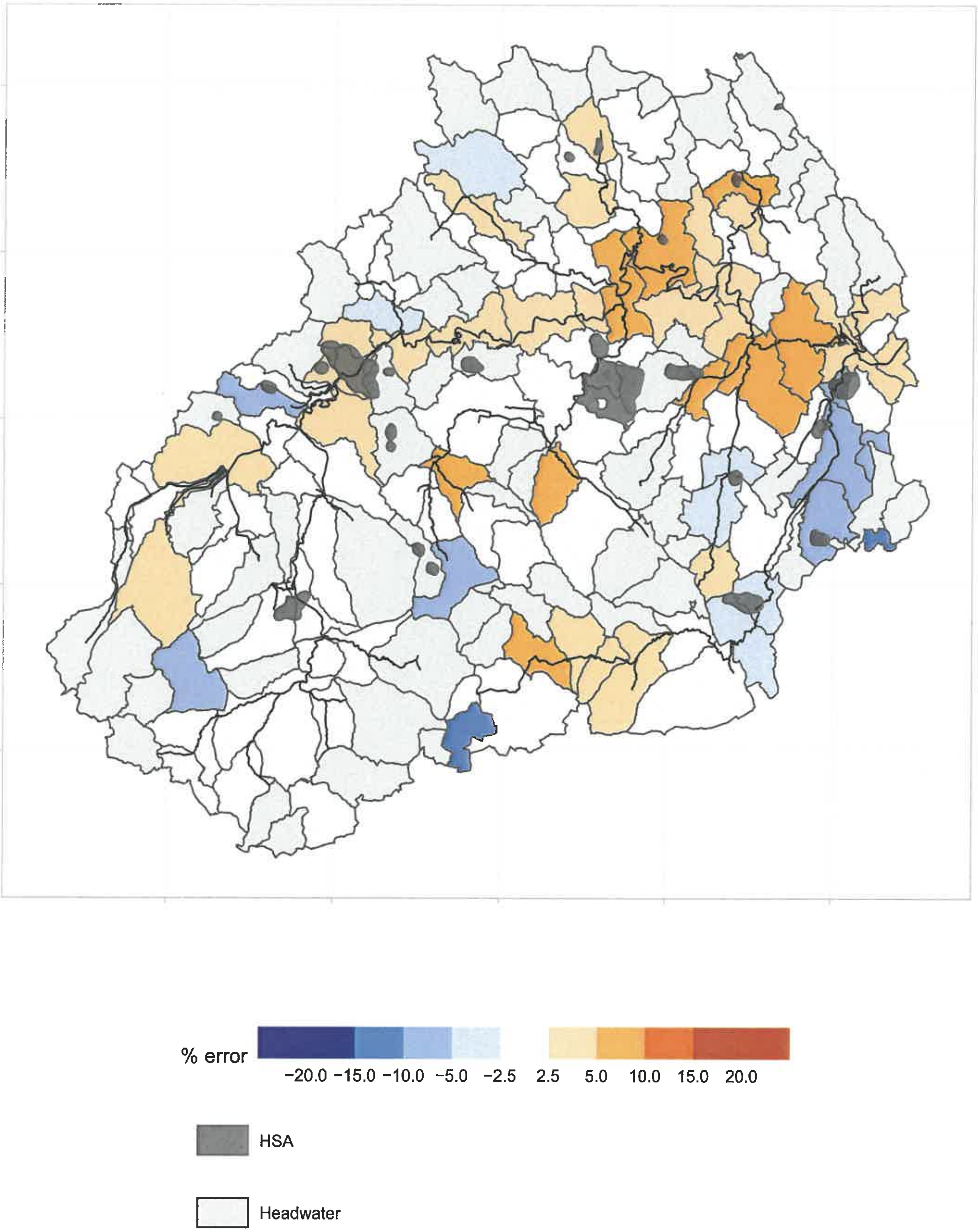
created by J:/Jobs/120038/Hydrology/R_scripts/Validation_Catchments/Weight_ARF_run_bins.R

Figure A7

Meander Catchment

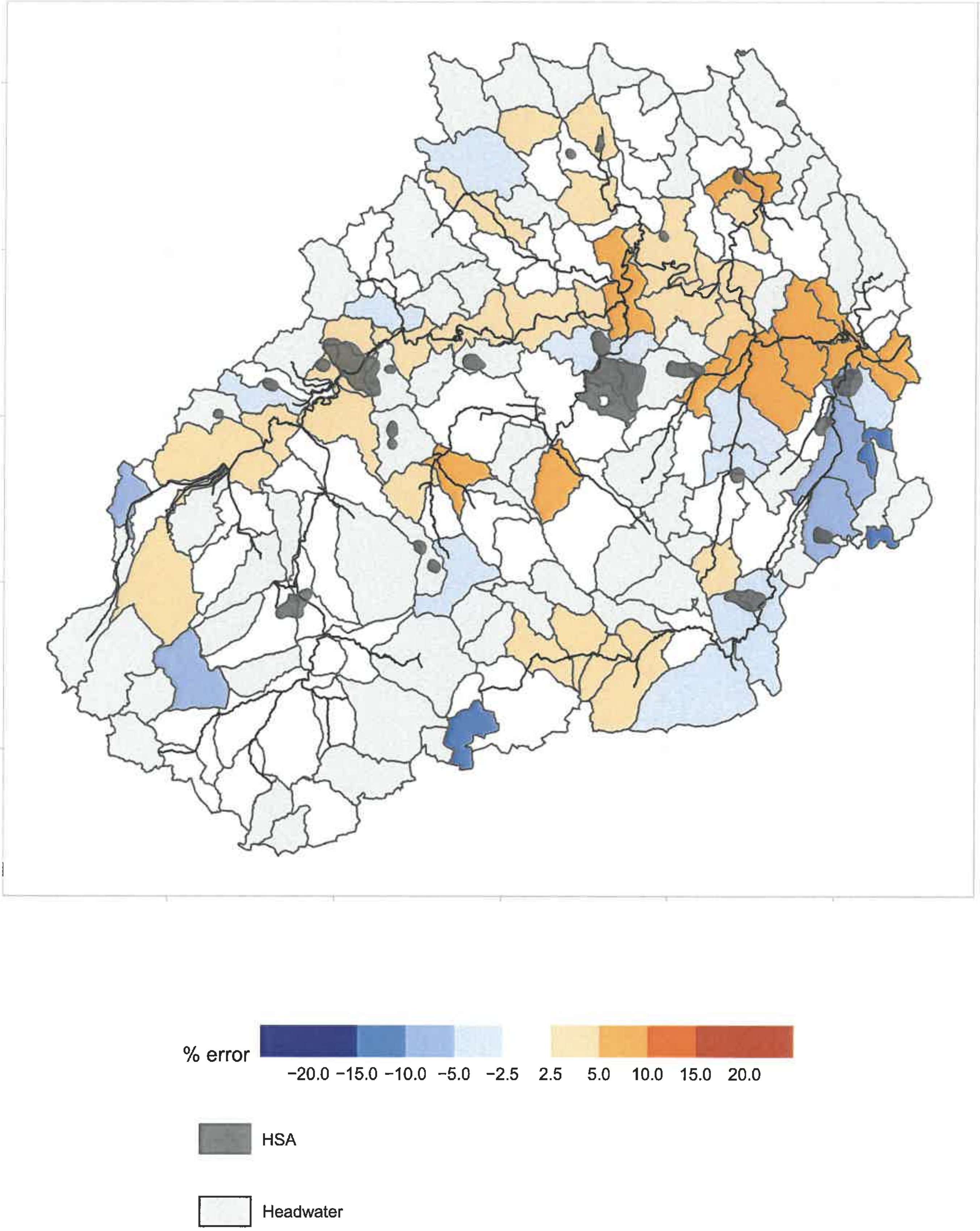
Percentage error in peak flows using selected runs

1% AEP



created by J:/Jobs/120038/Hydrology/R_scripts/Validation_Catchments/Weight_ARF_run_bins.R

Figure A8
Meander Catchment
Percentage error in peak flows using selected runs
1in200AEP



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Appendix B

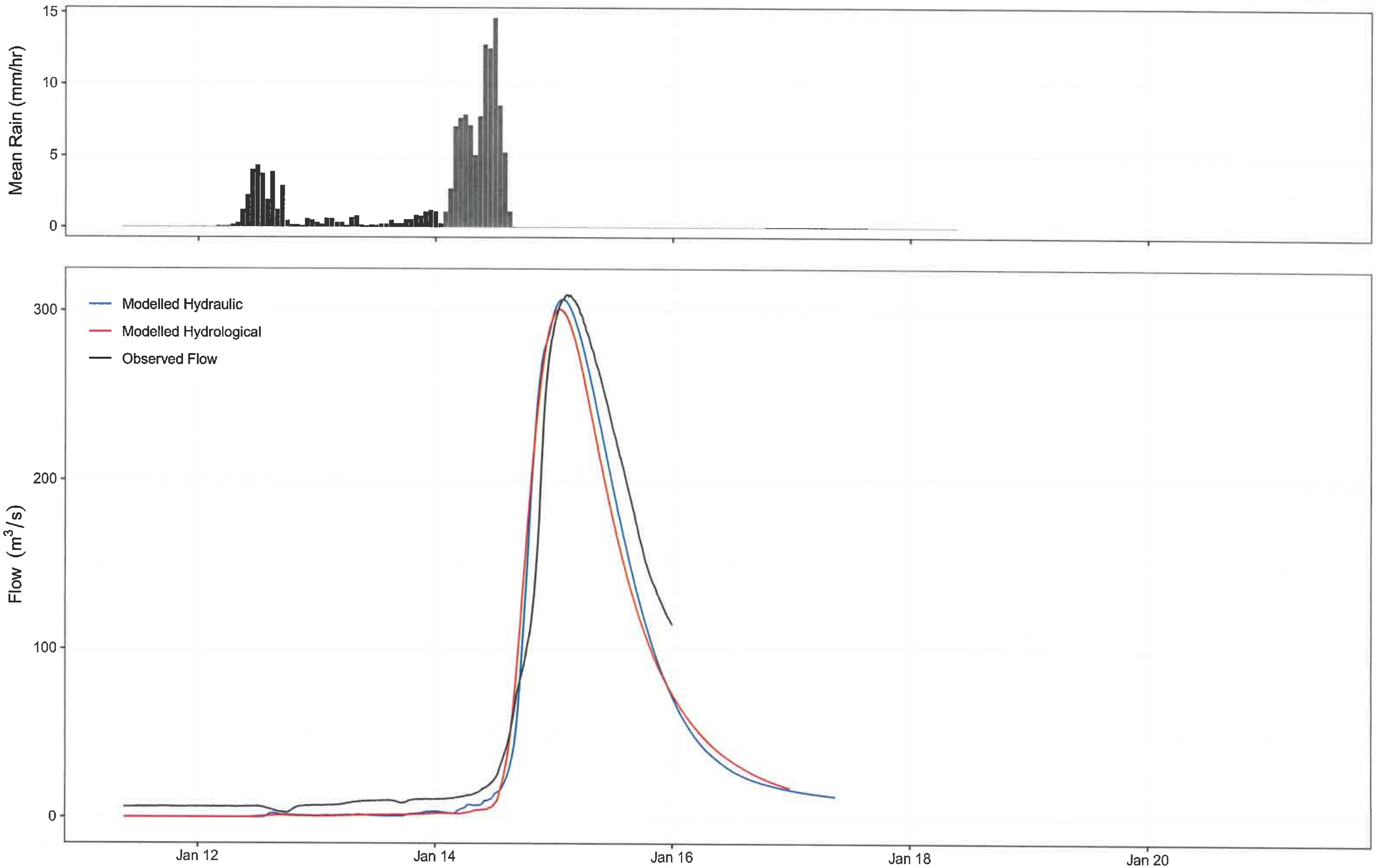
APPENDIX B. EVENT HYDROGRAPHS

FIGURE B01

MEANDER RIVER @ DELORAINE BR

2011 JAN

MEAN LOSSES IL=80 CL=1.05



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J:\Jobs\120038\Hydrology\Validation_Catchments\Calibration\Meander_recode_7km2_postRainfallVariation\collate_results\Report_plots__2021_06_28/FigureB01_Mnder_DlrnH 2011 Jan.pdf

FIGURE B02

MEANDER RIVER @ DELORAINE BR

2016 JUN

MEAN LOSSES IL=110 CL=0.52

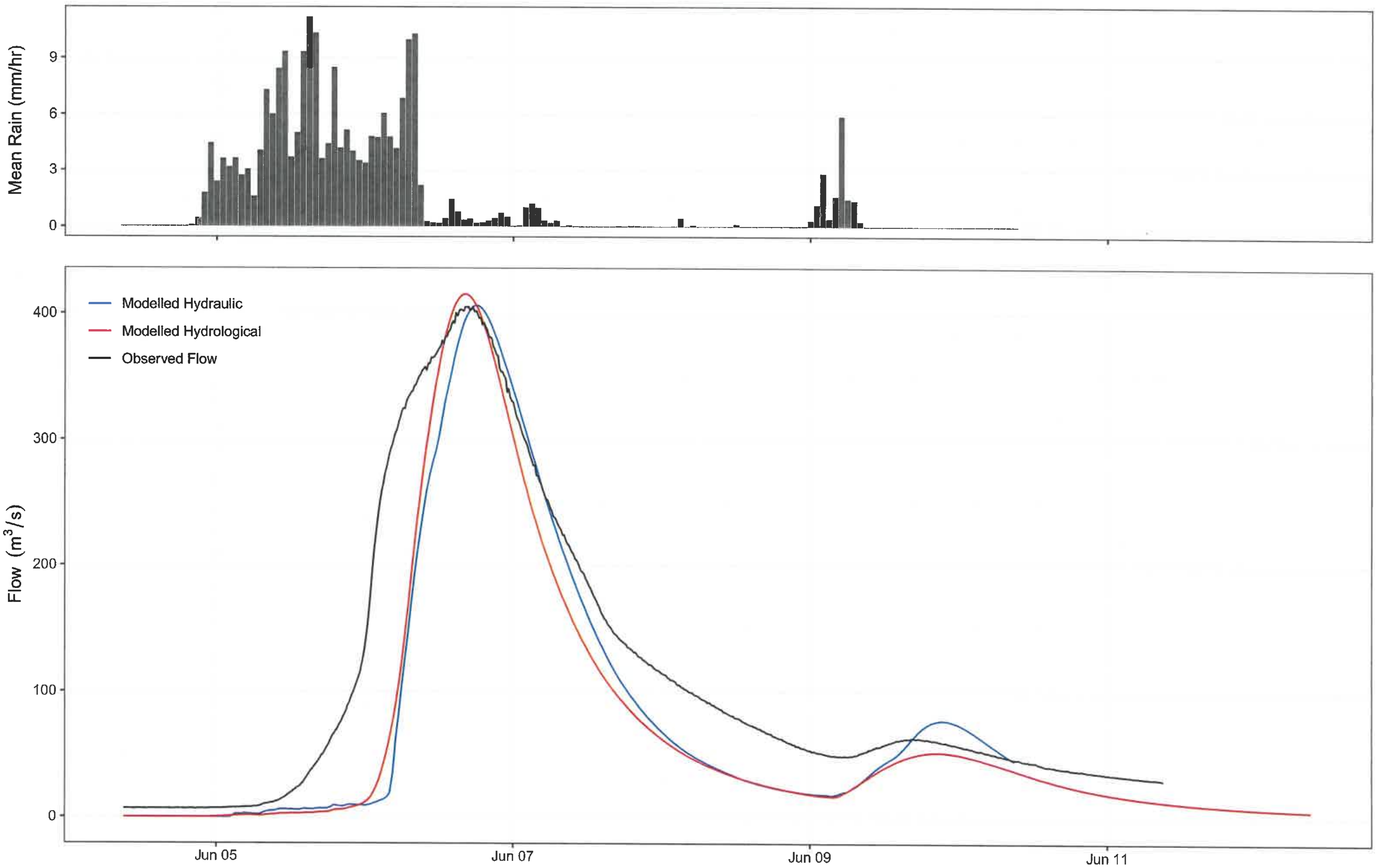

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FIGURE B03

MEANDER RIVER @ DELORAINE BR

2016 JUL

MEAN LOSSES IL=20 CL=0.26

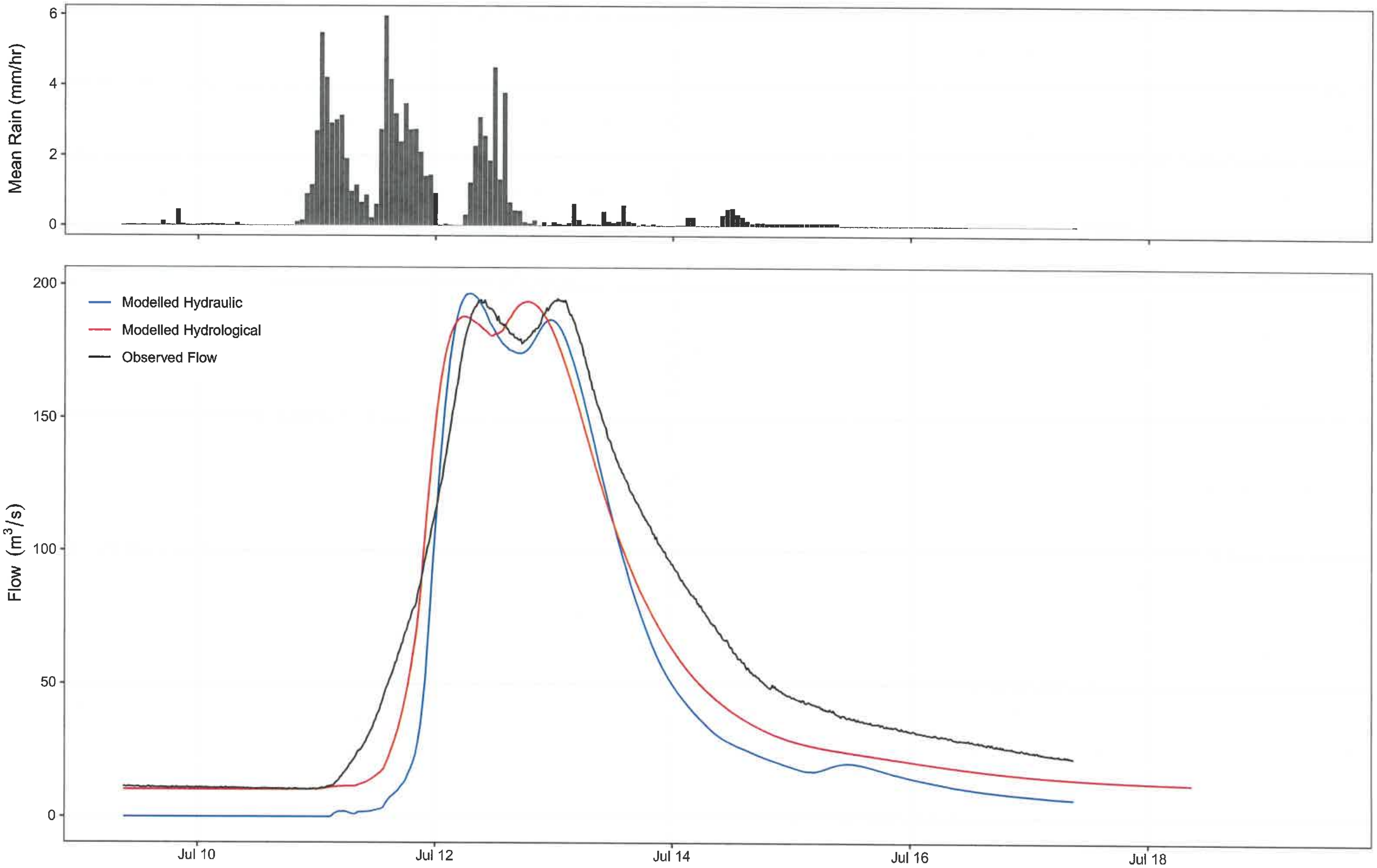

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FIGURE B04

MEANDER RIVER AT STRATHBRIDGE

2011 JAN

MEAN LOSSES IL=80 CL=1.05

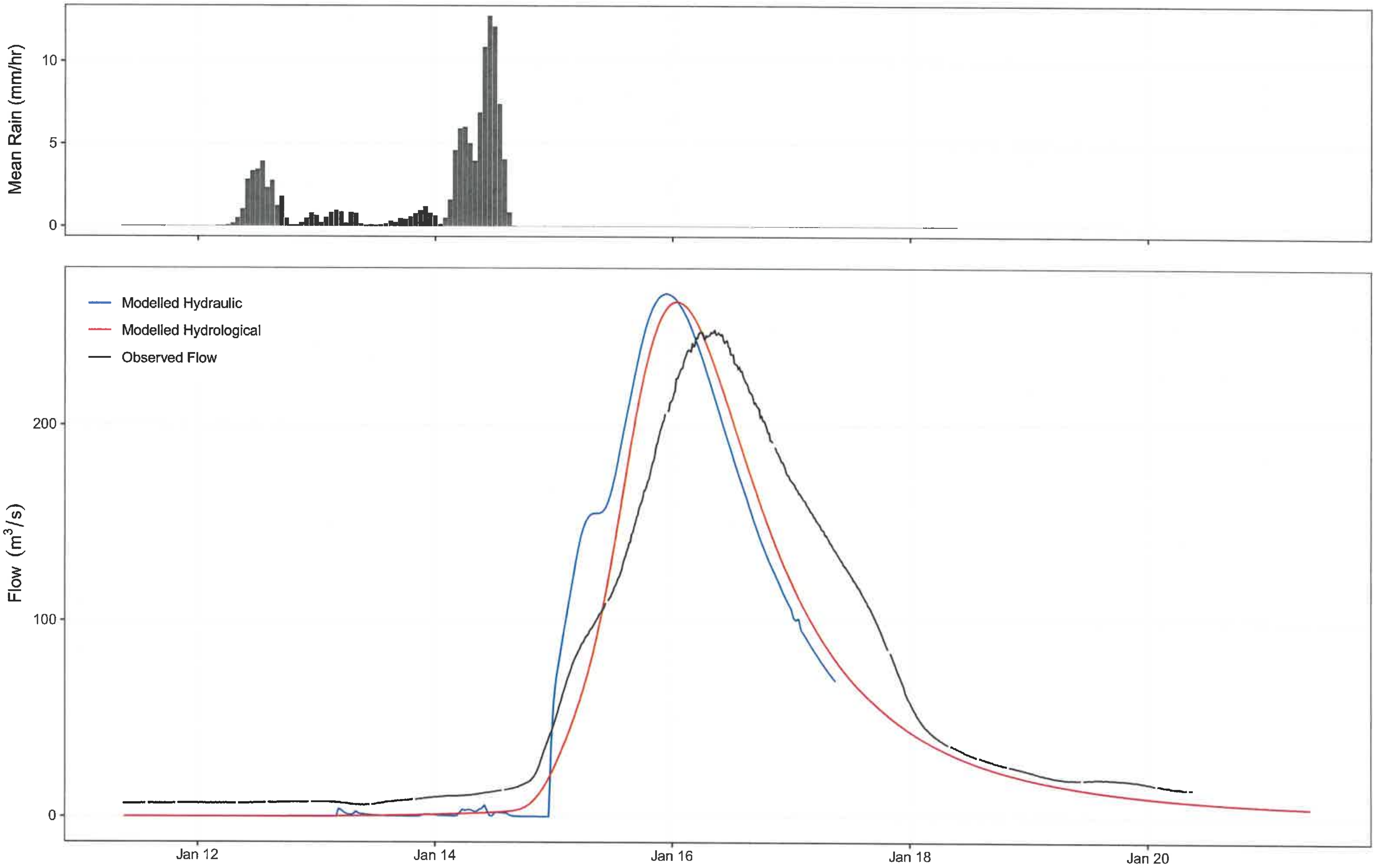

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FIGURE B05

MEANDER RIVER AT STRATHBRIDGE

2016 JUN

MEAN LOSSES IL=110 CL=0.52

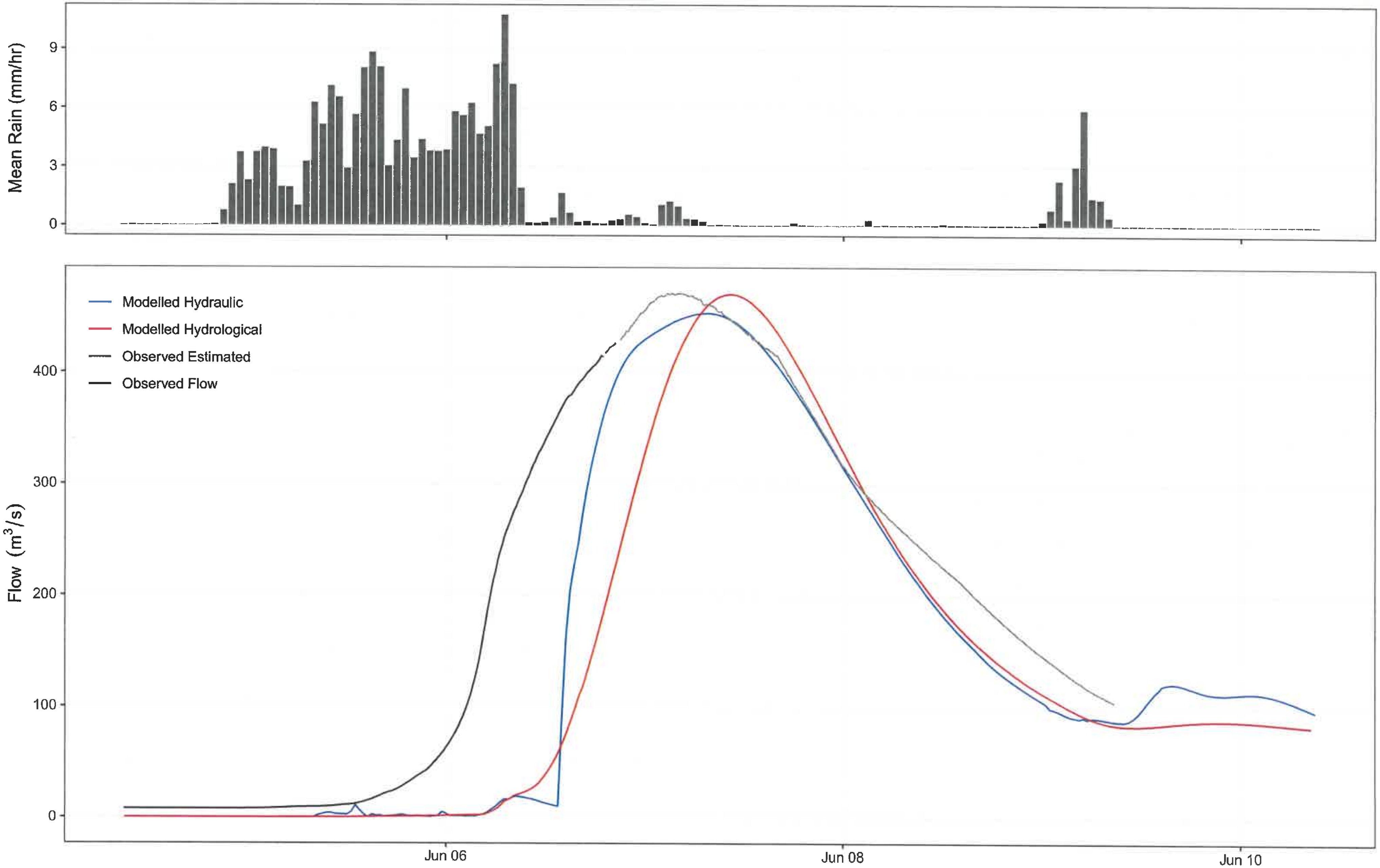

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FIGURE B06

LIFFEY RIVER A/B CARRICK BR

2011 JAN

MEAN LOSSES IL=80 CL=1.05

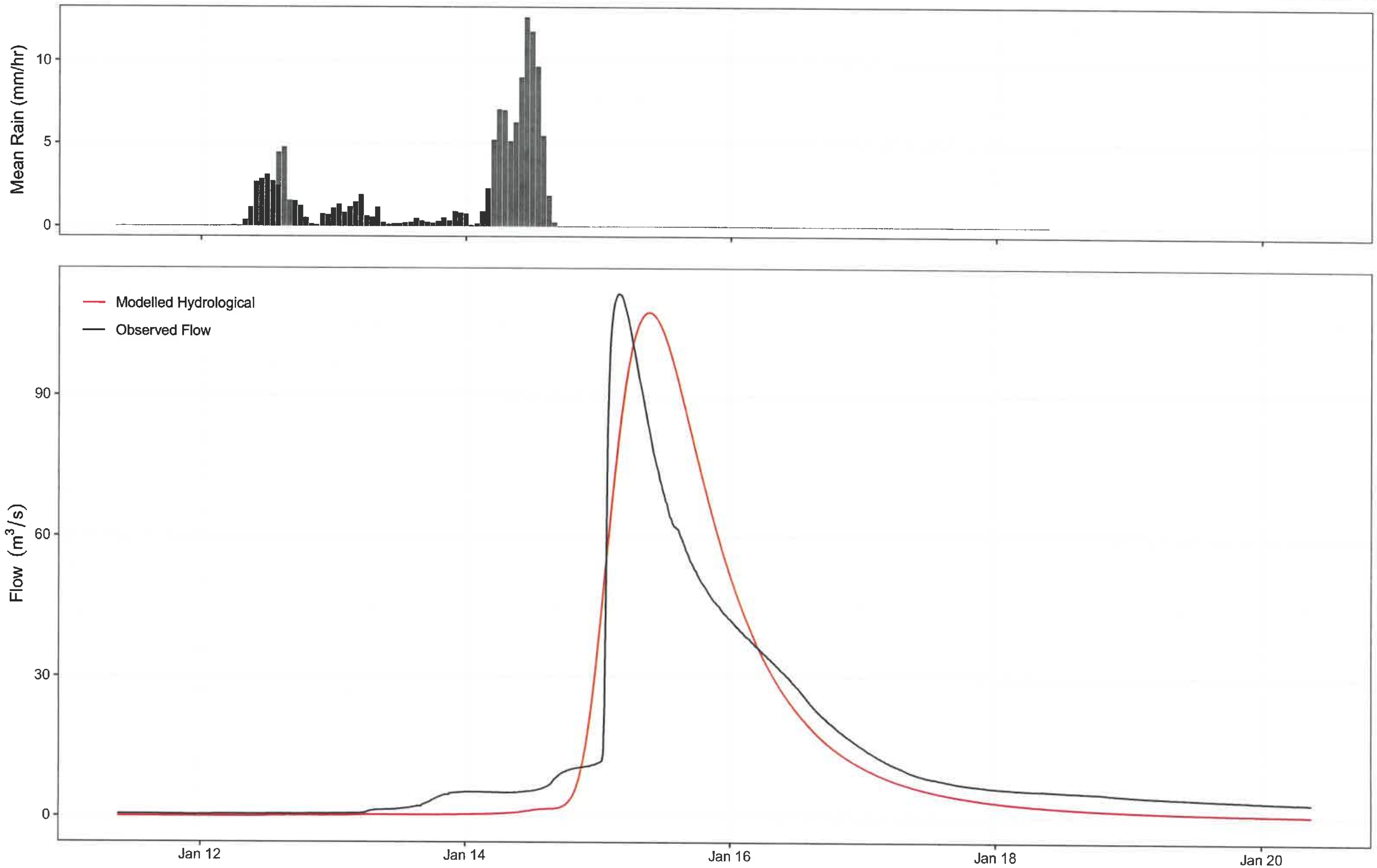

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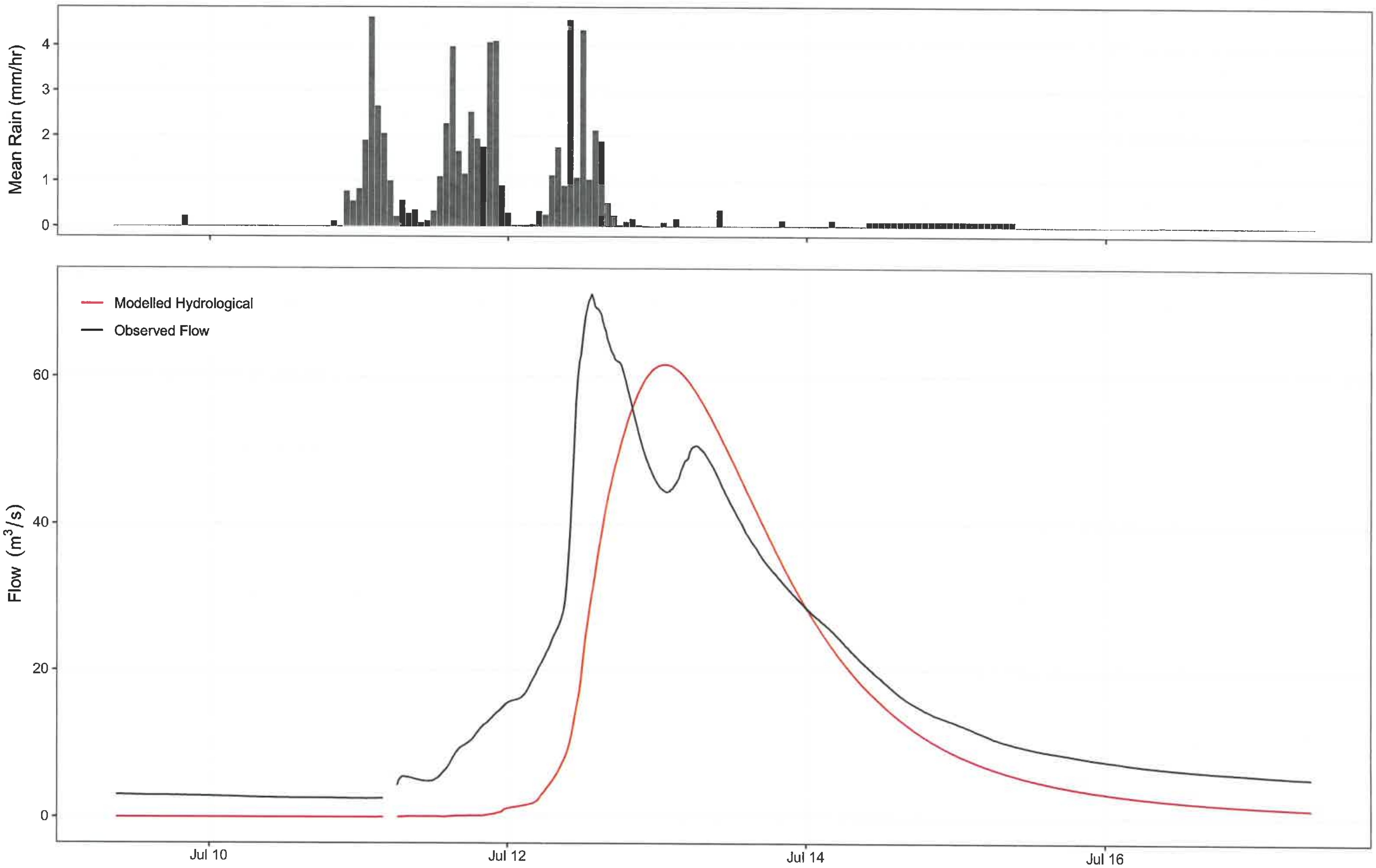
FIGURE B07

LIFFEY RIVER A/B CARRICK BR

2016 JUL

MEAN LOSSES IL=20 CL=0.26



created by J:/Jobs/120038/Hydrology/R_scripts/Validation_Catchments/Calibration_report_plots_Meander.R
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Appendix C

APPENDIX C. UNCERTAINTY ANALYSIS

C.1. Hydrologic Model Uncertainty

Table C 1 shows the calibration event rating. The following shading is used to highlight relevant statements:

- For observed flows Liffey above Carrick, Meander at Deloraine and Meander at Strathbridge in orange shading, Jackeys Creek and Western Creek gauge in grey shading.
- For calibration events June 2016 is shown with blue shading, January 2011 and July 2016 with yellow shading.

Table C 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	Rating extrapolated with	Rating shows	Rating shows	Rating shows

	no consideration for shape of cross section	no consideration for shape of cross section	consideration to shape of cross section	consideration to shape of cross section	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 C 2 shows the hydrology calibration quality rating for Meander at Deloraine. The following shading is used to highlight relevant statements:

- For hydrograph volumes, June 2016 is shown in grey. July 2016 and January 2011 are shown in yellow.

Table C 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

C.2. DTM Uncertainty

The DTM quality rating is shown in Table C 3 with orange shading.

Table C 3: DTM rating

Category	Rating				
	Poor	Fair	Good	Very good	Excellent
DTM definition	Low resolution	Low resolution	High resolution in HSA	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

C.3. Hydrodynamic Modelling Uncertainty

The hydrodynamic calibration event rating is shown in Table C 4, highlighted in orange. The calibration flood depths are considered fair in some areas and good in others.

Table C 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 C 5. The following shading is used to highlight relevant statements:

- Peak flows and levels are comparisons at Deloraine and Strathbridge gauges
- For calibration depths, green is used for areas around Deloraine, and yellow for other areas.

Table C 5: Hydrodynamic calibration quality rating

Category	Rating				
	Poor	Fair	Good	Very good	Excellent
Hydrodynamic calibration - peak flow	Peak flow not within 20% of hydrology	Peak flow within 20% of hydrology	Peak flow within 15% of hydrology	Peak flow within 15% of hydrology	Peak flow within 10% of hydrology
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