STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP TAMAR-ESK STUDY AREA DESIGN FLOOD MODELLING

ADDENDUM TO CALIBRATION REPORT

MARCH 2025

Level 1, 119 Macquarie Street
Hobart, TAS, 7000

Tel: (03) 6111 1726
Fax: (02) 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

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Project Tasmanian Strategic Flood Map Tamar-Esk Study Area Design Flood Modelling	**Project Number** 120038
Client State Emergency Service	**Client's Representative** Chris Irvine
Project Manager Fiona Ling	

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
AMS	Annual Maximum Series
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff
ATP	Areal Temporal Patterns
Bureau/BoM	Bureau of Meteorology
CC	Climate Change
CFEV	Conservation of Freshwater Ecosystem Values (DPIPWE/DNRE)
CL	Continuing Loss
DEM	Digital Elevation Model
DPIPWE	Department of Primary Industries, Water and Environment
DNRE	Department of Natural Resources and Environment Tasmania (formerly DPIPWE)
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
FFA	Flood Frequency Analysis
FLIKE	Software for flood frequency analysis
FSL	Full Supply Level
GIS	Geographic Information System
GEV	Generalised Extreme Value distribution
HAT	Highest Astronomical Tide
HSA	Human Settlement Area
ICM	Infoworks ICM software (Innovyze)
IL	Initial Loss
IFD	Intensity, Frequency and Duration (Rainfall)
LiDAR	Light Detection and Ranging
mAHD	meters above Australian Height Datum
NTC	National Tide Centre
PERN	Catchment routing parameter in RAFTS
Pluvi	Pluviograph – Rain gauge with ability to record rain in real time
PTP	Point Temporal Patterns
R	Channel routing param in WMAWater RAFTS WBNM hybrid model
RAF	RAFTS Adjustment Factor
RAFTS	hydrologic model
RCP	Representative Concentration Pathways (RCPs) (CC scenarios)
RORB	RORB hydrological modelling software
SES	State Emergency Service
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydrodynamic model)
TP	Rainfall Temporal Patterns

1. INTRODUCTION

This report is an addendum to the Tasmanian Strategic Flood Map Tamar-Esk Study Area Calibration Report (WMAwater, 2023). The study area, available data, model calibration, limitations and uncertainty statements are provided in the calibration report.

This report outlines the data, methodology and the results of modelling the design flood events for the Tamar-Esk Study Area.

2. DATA

2.1. Previous Flood Studies

Previous flood studies in the study area were provided to WMAwater as part of the project data library. The studies that include modelling areas within the Esk and Tamar are listed in Table 1.

Table 1: Previous flood studies

Flood study name	Study year	Study area	Design data available
Perth-Longford Flood Plain Study (HEC)	1992	South Esk River from Evandale to Longford	Design flood levels and flood maps showing flood extents at different chainages for 5%, 2% and 1% AEP events at Perth and Longford.
Longford and Hadspen Flood Hydrology (Entura)	2015	Meander and South Esk River catchment with towns of interest at Longford and Hadspen.	Design flood hydrographs for Back Creek, Macquarie River at Cressy Pumps, South Esk River at Hapsen, Liffey River at Carrick, South Esk River at Longford, South Esk River at Perth, Meander River at Strathbridge, South Esk River at Trevallyn Dam Upstream Inflow, and Meander River at Westwood.
Longford Hadspen 2D Flood Mapping Plan (JMG and Hydrodynamica)	2016	South Esk River at Trevallyn Dam to Meander River at Westwood Bridge, South Esk River at Perth and Macquarie River at Cressy Pumps.	Design flood levels and flood maps showing flood extents for 5%, 2%, 1% and 1% CC AEP events at Longford and Hadspen.
Flood Study Report: St Marys Flood Risk Investigation (Water Technology)	2018	Newmans Creek, St Marys Rivulet and St Patricks Creek at St Marys.	Flood maps for 20%, 10%, 5%, 2%, 1%, 0.5% and PMP events showing depth, level, hazard and flood function.
North Esk and South Esk Rivers Flood Modelling and Mapping Update (BMT)	2019	Tamar River, North Esk and South Esk River at Launceston.	Flood maps for existing, 2050 and 2100 climates for 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2%, 0.1% and 0.05% AEP events showing flood, level, depth, velocity and hazard.
Campbell Town and Ross Design Flood (Entura)	2020	Macquarie River at Ross and Elizabeth River at Campbell Town.	Design flood hydrographs for Elizabeth River at Campbell Town WTP, Edgar Street Campbell Town local upstream catchment, Macquarie River upstream Ross, Downs Creek, Tacky Creek, Macquarie River at Ross Left Bank, Macquarie River downstream Ross and Macquarie River downstream of Elizabeth River.
Ross and Campbell Town Flood Plain Mapping (Hydrodynamica)	2022	Macquarie River at Ross and Elizabeth River at Campbell Town.	Design flood levels extent maps for 5%, 2%, 1% and 1% CC AEP events at Ross and Campbell Town.

2.2. Flow Data

Flood Frequency Analysis (FFA) was performed on annual maximum series (AMS) from flow gauges within the catchment. The gauges used for FFA are shown in Table 2. The other gauges in the study area were not included in the FFA due to insufficient record length, being highly influenced by upstream dams, inconsistent datasets and/or unreliable rating curves. Gauges for FFA calibrated were selected to try and balance data quality and coverage of a large proportion of the study area. More detail on the quality of the rating curves and gauge data is provided in the calibration report (WMAwater, 2023).

A local hydrodynamic model was used to create theoretical rating curves at the South Esk at Perth and North Esk at Ballroom gauges (WMAwater, 2021d). These ratings were largely similar to the more recent DNRE ratings however varied significantly from historical rating curves. As the 1969 calibration event was one of the largest events at both sites the logic applied in the calibration report was applied for all historical events at each site; i.e. at South Esk at Perth the theoretical rating curve was applied to events since 1980 with original ratings kept before this, and at North Esk at Ballroom all historical events were re-rated.

Table 2: Flow gauges used for FFA

Gauge number	Gauge name	River	Period of record	Number of points in AMS
150-1	South Esk at Llewellyn	South Esk	1954-2022	51
181-1	South Esk at Perth	South Esk	1957-2022	66
18217-1	Macquarie River At Trefusis	Macquarie River	1980-2022	43
18312-1	Macquarie River D/S Elizabeth	Macquarie River	1989-2022	33
76-1	North Esk River at Ballroom	North Esk	1923-2022	93
444-1	St Patricks River at Nunamara Offtake	St Patricks	1992-2022	18

2.3. Design Inputs

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

2.3.1. 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 study area. Examples of sub-catchment rainfalls are shown in Figure A 1 to Figure A 3.

2.3.2. 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 the flood frequency analysis, the areal temporal patterns relevant to this location were downloaded from the ARR Data Hub. An example of the temporal patterns downloaded from the Data Hub is shown in Figure A 4.

For selection of the final design runs applicable to the entire study area, areal and point temporal patterns were downloaded from the ARR Data Hub. Temporal patterns were filtered for embedded bursts and in some cases patterns with large, embedded bursts causing significant outliers were removed. When assessing the reference critical flow for each sub-catchment (as described in the Hydrology Methods Report (WMAwater, 2021a)), point temporal patterns were used for sub-catchments with an upstream area of less than 75 km^2 or 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).

2.3.3. Pre-burst

Pre-burst rainfall depths were taken from the ARR Data Hub as a ratio of the IFD depths. As Ils calibrated to the FFA were greater than 0 there was no need to include sensitivity to adding a pre-burst temporal pattern for this study area, as the pre-burst has effectively been removed from the IL with some IL depth remaining.

2.3.4. 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).

2.3.5. Baseflow

Baseflow was calculated for each calibration event and was found to be less than 5% of the event peaks. In line with ARR 2016 Book 5 Chapter 4 (Ball et. Al., 2019), where baseflows of less than 5% are considered a small component compared to runoff, a simplified approach to baseflow calculations was undertaken. Hydrodynamic modelling of the calibration events showed that large flood events in this study area were peak rather than volume driven. Baseflows will be a small component of the hydrograph for the AEPs of interest (2%, 1% and 0.5%) and therefore baseflow was not included in the design events.

2.3.6. Direct Rainfall

Two-hour direct rainfall storms were created using each sub-catchment's IFD depths using the method described in the Hydrodynamic Methods Report (WMAwater, 2021b).

2.3.7. Climate Change

2.3.7.1. Rainfall Factors

Climate change factors for the study area were downloaded from the ARR Data Hub. ARR recommends the use of the RCP4.5 and RCP8.5 values, however the Tasmanian Interim 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% to the IFDs.

2.3.7.2. Boundary Conditions

Sea level rise was included in the climate change scenario and was applied at the downstream boundary of the hydrodynamic model. The rise in water level was taken from the Tasmanian Local Council Sea Level Rise Planning Allowances, which uses sea level rise projections based on RCP 8.5 for 2100. This gave a rise in sea level of 0.82 m for the West Tamar Council area.

The levels from this document were deemed most appropriate to be consistent with best practise planning around Tasmanian Councils.

3. OVERVIEW OF METHODOLOGY

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

The modelling method for the design events includes the following steps.

- Data preparation
  - Fitting FFA to suitable flow records
  - Extraction of design data – IFDs, temporal patterns, pre-burst rainfalls from ARR DataHub (automated in the modelling process), derivation of direct rainfall storms
- Hydrologic modelling
  - Identification of flow gauge locations
  - Identification of dam and diversion locations
  - Sub-catchment delineation
  - Include dam storage and spillway ratings where required
  - Event calibration for PERN parameter and event losses, using automated WMAwater RAFTS modelling tool, IDW rainfall surfaces and available flow data.
  - Output event sub-catchment rainfalls, routing parameters and event losses for input to hydraulic model
  - Calibration of design losses to FFA using automated WMAwater RAFTS model
  - Run design events in WMAwater RAFTS modelling tool, with design data, calibrated routing parameters and design losses. Outputs design sub-catchment rainfalls for input to hydrodynamic model.
- Hydrodynamic modelling
  - Run design events and direct rainfall through the calibrated hydrodynamic model with the applicable downstream boundary levels and dam initial conditions.
  - Output design event and direct rainfall results for processing.
- Mapping
  - Convert design event and direct rainfall results to a grid format with a grid resolution of at least 10 m.
  - Envelope design event results to produce the maximum envelope of the inputs.
  - Filter direct rainfall results using a peak flood depth filter of 0.1 m. Clip direct rainfall results to the design event envelope.
  - Map the design event envelope and filtered direct rainfall results.

During the design event selection process, it was discovered that the standard selection process could not select a small number of patterns which were viable across the catchment without the patterns with small ARFs (i.e. higher rainfalls) drowning out all patterns with more appropriate ARF factors in the lower catchment. The selected patterns were therefore forcibly applied to their respective regions through the cropping of the design event results prior to the enveloping.

It is acknowledged that the cropping may result in abrupt changes in levels at the boundaries of the selected patterns in the design mapping. Where possible, the boundaries of the selected patterns were located away from human settlement areas and major infrastructure to minimise the impact of the cropping. Discontinuities in the design mapping in isolated areas should still be expected, however this was deemed to be an acceptable compromise in achieving a better representation in the design mapping across the remainder of the study area.

4. CALIBRATION OF DESIGN LOSSES

FFA was undertaken at the gauges identified in Table 2. The results of the FFA are shown in Figure 1 to Figure 6. The fitting method and distribution that provided the best fit to the data at each site is shown in Table 3. As the original fitted FFAs at the two South Esk River gauges were showing quite different fits to the rarest events the Bayesian prior information feature of FLIKE was used to use the skew of log Q at Perth to inform the shape of the fit at Llewellyn. This gave a closer fit to the largest AMS events at Llewellyn and resulted in similar shapes between the sites, which is required in order for the model to work across both locations.

Table 3: Fitting method and distribution used for FFA

Gauge number	Gauge name	Fitting method	Distribution
150-1	South Esk at Llewellyn	Bayesian	Log Pearson III
181-1	South Esk at Perth	Bayesian	Log Pearson III
18217-1	Macquarie River At Trefusis	Bayesian	Log Pearson III
18312-1	Macquarie River D/S Elizabeth	Bayesian	Log Pearson III
76-1	North Esk River at Ballroom	Bayesian	Log Pearson III
444-1	St Patricks River at Nunamara Offtake	Bayesian	Log Pearson III

The calibrated external hydrologic model for each study area was run through the solver and the initial and continuing losses 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 the FFA curve. The catchment-average continuing loss was distributed across the study area using the hydrological soil group final infiltration rates.

Losses were then compared across the different gauge areas to find a compromise across the entire study area, which was appropriate for a regional scale project. The percentage differences between the FFA and the modelled peak flow for the 2%, 1%, and 0.5% AEP events are shown in Table 4. Compromises were required in order to select losses that were acceptable across the entire area. The design events are underestimated at some gauges (South Esk at Llewellyn) and overestimated at others (Macquarie at Trefusis) but still sit comfortably within their confidence intervals.

However, at several gauges, the modelled design events deviate a long way from the observed FFAs, most notably North Esk River at Ballroom. To fit to the record to the 1% AEP at North Esk River at Ballroom, continuing losses roughly 10 times higher than had been fitted elsewhere were required (9-12 times higher, dependent on IL, but it is fairly insensitive to IL) and this still shows very poor fit to the shape of the FFA at this gauge. This suggests that there are more factors contributing to the poor fit at this gauge than the losses only. To give another point of comparison in the North Esk catchment the St Patricks River at Nunamara Offtake gauge was considered despite having a shorter record length than would normally be used. Surprisingly, this showed the opposite trend than the North Esk at Ballroom site. While little weight can be put on the specifics at St Patricks, it is enough to cast doubt on any changes which would effectively be more than halving the modelled flows in this catchment. Therefore, the North Esk has been left with the same losses as the rest of the study area despite this causing very significantly overestimation of flows compared to the FFA. It is strongly recommended that local studies are used in preference to regional studies in this area.

There is also significant variance between modelled and at-site FFAs at Macquarie D/S Elizabeth despite the modelled remaining within the confidence intervals of the at-site FFA. The at-site FFA flows for this gauge were only approximately 30% higher than at Macquarie at Trefusis despite a catchment over 5 times the area of the upstream gauge. This difference could not be explained by the rainfall, with average IFD rainfalls upstream of Trefusis are only approximately 25% higher, than the average above the Macquarie D/S Elizabeth gauge. Similarly, despite only having a 15% smaller catchment area to South Esk at Llewellyn at-site FFA peaks are between 5-6 times lower than peaks at Llewellyn. South Esk at Llewellyn does have higher IFD rainfalls with catchment averages almost 60% higher and flows are less attenuated than in the Macquarie, however, while this could explain some of the variation it is unlikely that it could explain differences in the order of 5-6 times lower flows. The record at Macquarie D/S Elizabeth is relatively short (33 years) and does not include key regional floods such as 1969 or 1986 (highest on record at Trefusis) therefore the at-site FFA here is assumed to be highly uncertain (which is already shown in broad confidence intervals) and this gauge was given little weighting in calibration.

As has been found across the state, the IFD curves increase in gradient at the 1% AEP rainfall in some cases and therefore the 0.5% AEP flows are overestimated. This is mainly true for the shorter duration IFDs (particularly shorter than 1 day), so this is only really relevant for upper parts of the catchments and, in particular, the gauges at Macquarie River at Trefusis and the North Esk, and St Patricks River gauges, however obviously this uncertainty was minor compared with the issues identified above in the North Esk catchment.

Table 4: FFA and modelled peak flows

Gauge	AEP	FFA peak flow (m^3/s)	Modelled peak flow (m^3/s)	Peak flow difference (%)
South Esk at Llewellyn	2% AEP	2,911	2,665	-8%
	1% AEP	3,561	3,178	-11%
	0.5% AEP	4,243	3,824	-10%
South Esk at Perth	2% AEP	2,500	2,557	2%
	1% AEP	3,000	3,008	0%
	0.5% AEP	3,503	3,556	2%
Macquarie River At Trefusis	2% AEP	425	422	-1%
	1% AEP	479	496	4%
	0.5% AEP	530	590	11%
Macquarie River D/S Elizabeth	2% AEP	593	954	61%
	1% AEP	643	1,150	79%
	0.5% AEP	682	1,349	98%

Gauge	AEP	FFA peak flow (m^3/s)	Modelled peak flow (m^3/s)	Peak flow difference (%)
North Esk River at Ballroom	2% AEP	231	573	148%
	1% AEP	262	668	155%
	0.5% AEP	293	808	175%
St Patricks River at Nunamara Offtake	2% AEP	564	440	-22%
	1% AEP	786	516	-34%
	0.5% AEP	1,082	629	-42%

The adopted loss values are shown in Table 5, and comparisons to site FFAs are shown in Figure 1 and Figure 6.

Table 5: Adopted losses

Initial Loss (mm)	Continuing Loss (mm/h)			
	Soil Type A	Soil Type B	Soil Type C	Soil Type D
50	1	0.52	0.24	0.12

5. DESIGN EVENT MODELLING

5.1. Design Event Selection

Design inputs were run 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 selected storms and the number of sub-catchments best represented by each are shown in Table 6. The temporal patterns for each selected run are shown in Figure 1 to Figure 6.

Due to the significant IL of 50 mm and the large variation in the IFDs in the catchment a range of storm durations was required for the 45 km^2 ARF bin, as the shorter design rainfall depths in parts of the catchment are not much larger than the IL, while these bursts were critical in higher rainfall areas. As almost half the (non-headwater) sub-catchments are in the 45 km^2 sub-catchment bin, or the bin either side of this, the need to have three different durations covering this area is reasonable. The total area covered by the 45 km^2 pattern is 3,360 km^2. The correlation between duration and IFDs can be seen in the rainfall and selected pattern maps in Diagram 1.

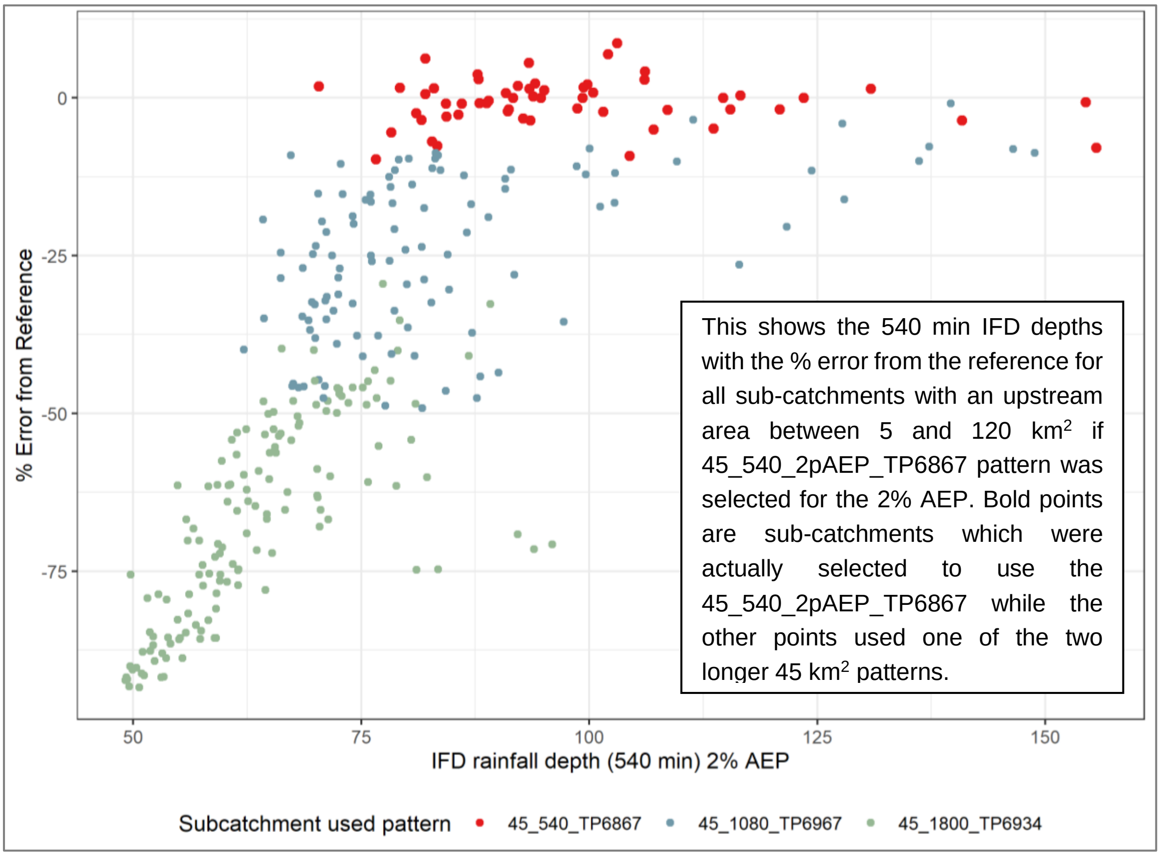

Diagram 1 Scatter plot, 2% AEP 540 minute events.

The remainder of the patterns behave more as expected with increasingly long storm durations used for larger ARF bins. While this has delivered catchment wide errors within tolerances and has typically worked very well for a regional study on such a wide scale, trying to regionalise temporal pattern selection on a study area of this scale means that localised errors in some locations may be quite high. This was particularly challenging due to the very long run time of this hydrodynamic model when trying to model the entire catchment, this is exacerbated by the large rainfall gradients across the catchment. Large rainfall gradients, and different catchment topography mean that the major rivers (i.e. the Macquarie and South Esk) have different reference critical durations for parts of the main river with similar upstream areas.

The Macquarie River naturally has longer critical durations with less intense rainfall gradients and flatter topography than the South Esk River. Therefore, combining these river basins, along with the North Esk and Meander does lead to increased local errors along both reaches. However, resolving this would have required many additional model runs which was not achievable within the project timeframes and was not required as average losses were within tolerance levels.

For this study area, in much of the catchment, the smaller ARF patterns were drowning out the more appropriate bins. Therefore, in some places the resulting grids were cropped to the appropriate areas, as detailed in Section 3.

Table 6: Selected storms for each AEP with the number of sub-catchments best represented by each set – Tamar-Esk study area

AEP	Storm duration (min)	ARF bin	# sub-catchments
2%	540	45	56
2%	1080	45	107
2%	1800	45	144
2%	1440	250	108
2%	2160	800	77
2%	4320	3600	46
2%	5760	4800	12
1%	540	45	79
1%	1080	45	124
1%	1800	45	104
1%	1440	250	114
1%	2160	800	71
1%	4320	3600	46
1%	5760	4800	12
0.5%	540	45	123
0.5%	1080	45	121
0.5%	1800	45	63
0.5%	1440	250	123
0.5%	2160	800	64
0.5%	4320	3600	44
0.5%	5760	4800	12

Diagram 2 shows which ARF-duration-TP set gives representative flows for each sub-catchment for the 1% AEP event. There are some areas with inconsistencies between the representative ARF-duration-TP set calculated from the external hydrology (Diagram 2) and the final selected ARF-duration-TP set from the hydrodynamic modelling (Figure 72 - Figure 75). Any significantly large areas with this discrepancy have been reviewed and show the two sets are in close alignment with very minor differences in extent or depth. Headwater sub-catchments where only direct rainfall is applied are also shown. In the headwater catchments, direct rainfall was defined as the dominating event, with the rainfall intensities factored to account for losses via a runoff coefficient. For this study area, a runoff coefficient of 35% was adopted. Although direct rainfall is applied to all sub-catchments, the mapping process detailed in Section 3 ensures that primary flow paths are not defined by this event.

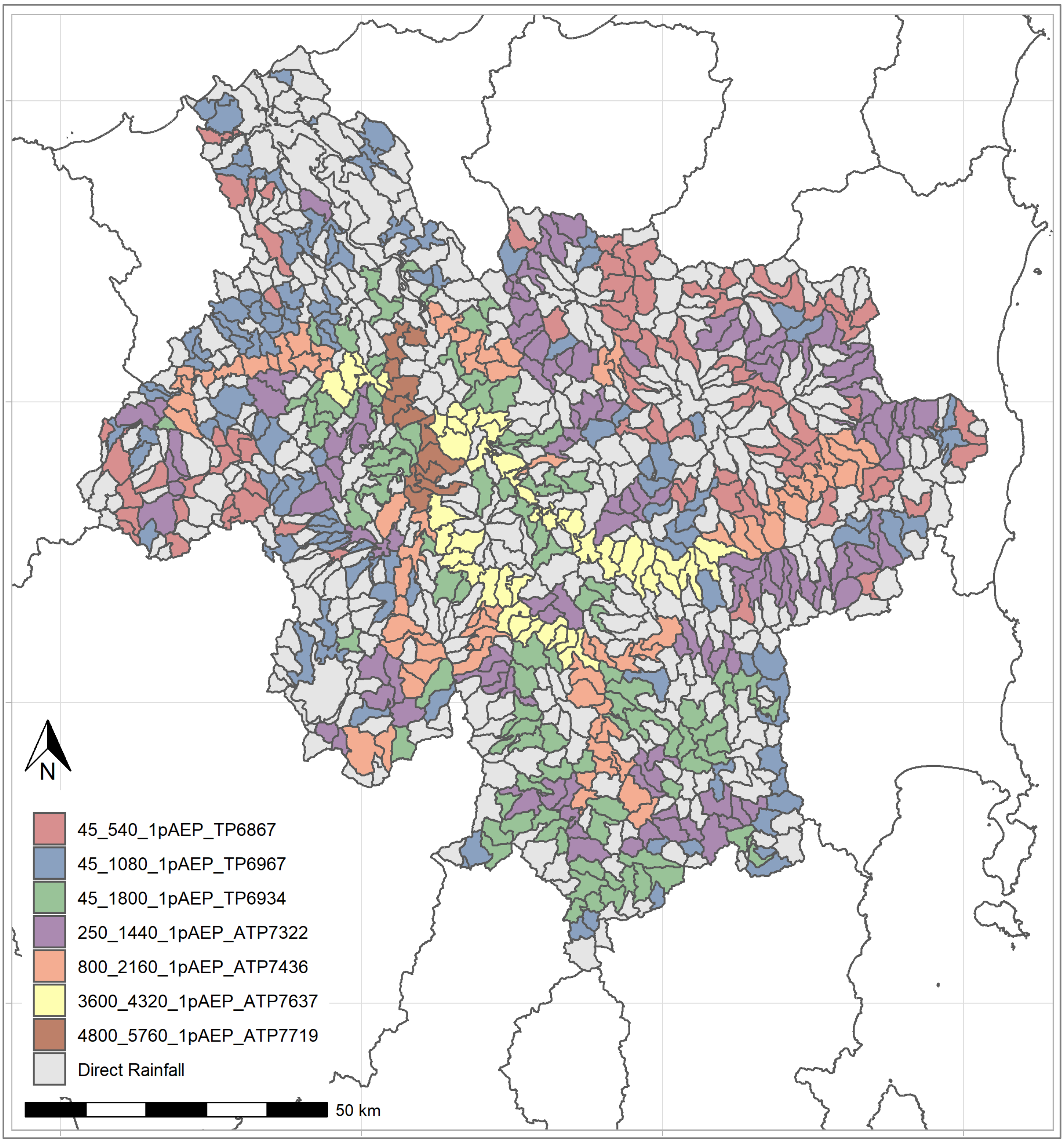

Diagram 2: ARF set relevant for each sub-catchment for the 1% AEP event

The selection of seven ARF-duration-TP sets per AEP does introduce errors when compared to running the ideal ARF-duration-TP set through the hydrodynamic model for each sub-catchment, however running thousands of runs of the hydrodynamic model is not computationally feasible. The percentage errors for each sub-catchment are shown in Figure B 1 to Figure B 3 and a summary of the magnitude of the errors is shown in Table 7. 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 as shown in Diagram 2

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

Table 7: Sub-catchment errors using the ARF-TP-duration sets shown in Table 6 for each AEP, these exclude sub-catchments in the Meander as they are covered in their own report

AEP	Absolute sub-catchment error		
	Mean across sub-catchments	**90th %ile across sub-catchments**	**Max of all sub-catchments**
2%	4%	10%	54%
1%	4%	9%	55%
0.5%	4%	8%	54%

The selected storms and direct rainfall were then run through the calibrated hydrodynamic model as documented in the calibration report (WMAwater, 2023). For the design event modelling, the downstream boundary adopts a static tailwater level set to the highest astronomical tide (HAT). This data was provided by the National Tide Centre (NTC) in 5 km² grid cells and was extracted in the Tamar Estuary.

Table 8 below summarises the downstream boundary levels and dam initial conditions for each design event for the Tamar-Esk study area. For the dams, the initial water level was set to the full supply level for all storages except Arthurs Lake.

Table 8: Downstream boundary levels and dam initial conditions for each AEP – Tamar-Esk study area

<table>
<tr><th>AEP</th><th>Downstream boundary</th><th>Huntsman Lake</th><th>Arthurs Lake</th><th>Woods Lake</th><th>Tooms Lake</th><th>Lake Leake</th><th>Trevallyn Lake</th></tr>
<tr><td>2%</td><td rowspan="3">HAT (1.85 mAHD)</td><td rowspan="4">FSL and IWL (402.00 mAHD)</td><td rowspan="4">IWL (951.98 mAHD)</td><td rowspan="4">FSL and IWL (737.77 mAHD)</td><td rowspan="4">FSL and IWL (466.00 mAHD)</td><td rowspan="4">FSL and IWL (571.00 mAHD)</td><td rowspan="4">FSL and IWL (126.49 mAHD)</td></tr>
<tr><td>1%</td></tr>
<tr><td>0.5%</td></tr>
<tr><td>1% CC</td><td>HAT + sea level rise (2.67 mAHD)</td></tr>
</table>

5.2. Design Event Results

The results of the design event modelling are shown in Figure 9 to Figure 71 in terms of peak flood level, depth, velocity, and hydraulic hazard for the 2%, 1%, 1% CC, and 0.5% AEP design events at the Macquarie-Lake, Meander, South Esk and North Esk-Tamar sub-areas. The results shown are of the design event envelope and filtered direct rainfall results, as detailed in Section 3. A critical event plot for the 1% AEP design event for each sub-area is provided in Figure 72 to Figure 75.

As has been discussed throughout this project, this is a regional study which does not take the place of local detailed design flood modelling. This is particularly important in heavily urbanised areas such as Launceston where existing flood studies have been undertaken which included detailed local information such as urban drainage networks, levees and structures. For these detailed studies modelling was targeted specifically at these areas, in particular in regard to choosing critical events, hydrodynamic model extents and grid resolution. Detailed studies also use more complete data for local structures which is shown to be highly influential in Launceston due to the incomplete levee data available for this project (discussed further in Section 5.3.1) Additionally, areas of Launceston not adjacent to the North or South Esk rivers are covered by direct rainfall modelling only in this strategic regional level modelling. This was done at a regional scale and does not include information on structures, including flood detention basins. There is a detailed Stormwater System Management Plan (2019b) and Urban Flood Layer (2019a) available which should be used in preference to the current study in urban areas of Launceston.

For direct rainfall only, in some areas the peak flow for headwater catchments was found to be higher in the hydrodynamic model than in the external hydrologic model. To ensure that the overestimation of these peak flows in the headwater catchments would not impact the design results, the direct rainfall results were clipped to the design event envelope.

The outcomes of the design event modelling have been reviewed against the gauge FFA and the previous flood studies.

5.2.1. Review of Results at South Esk at Llewellyn

A review of the design flows produced from the hydrodynamic model at South Esk at Llewellyn was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a fair match to the FFA peak flows at this location (Figure 1 and Table 9), with the model underestimating peak flows. This model underestimation appears to arise from the calibration of the design losses and the limited number of design events that could be used throughout the entire study area.

Table 9: Design flows at South Esk at Llewellyn

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	2,571	2,958	3,502	3,343
FFA peak flow (m^3/s)	2,911	3,561	n/a	4,243
Peak flow difference (%)	-12%	-17%	n/a	-21%

5.2.2. Review of Results at South Esk at Perth

A review of the design flows produced from the hydrodynamic model at South Esk at Perth was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a good estimation to the FFA peak flows at this location (Figure 2 and Table 10).

Table 10: Design flows at South Esk at Perth

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	2,635	3,026	3,574	3,409
FFA peak flow (m^3/s)	2,500	3,000	n/a	3,503
Peak flow difference (%)	+5%	1%	n/a	-3%

5.2.3. Review of Results at Macquarie River at Trefusis

A review of the design flows produced from the hydrodynamic model at Macquarie River at Trefusis was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a fair match to the FFA peak flows at this location (Figure 3 and Table 11), with the model slightly overestimating peak flows. This slight overestimation is aligned with the results from the calibration of design losses (refer to Section 4).

Table 11: Design flows at Macquarie River At Trefusis

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	453	517	617	591
FFA peak flow (m^3/s)	425	479	n/a	530
Peak flow difference (%)	+7%	+8%	n/a	+12%

5.2.4. Review of Results at Macquarie River D/S Elizabeth

A review of the design flows produced from the hydrodynamic model at Macquarie River downstream of Elizabeth River was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a poor match to the FFA peak flows at this location (Figure 4 and Table 12), with the model overestimating peak flows, however as discussed in Section 4 this may be at least partially due to uncertainty in the at-site FFA flows which seem very low compared with surrounding gauges.

Table 12: Design flows at Macquarie River D/S Elizabeth

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	946	1,161	1,488	1,368
FFA peak flow (m^3/s)	593	643	n/a	682
Peak flow difference (%)	+60%	+81%	n/a	+101%

5.2.5. Review of Results at North Esk River at Ballroom

A review of the design flows produced from the hydrodynamic model at North Esk River at Ballroom was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a very poor match to the FFA peak flows at this location (Figure 5 and Table 13), with the model greatly overestimating peak flows, however this error is aligned with the error seen in the calibration of design losses (refer to Section 4).

Table 13: Design flows at North Esk River at Ballroom

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	535	612	732	717
FFA peak flow (m^3/s)	231	262	n/a	293
Peak flow difference (%)	+132%	+134%	n/a	+145%

5.2.6. Review of Results at St Patricks River at Nunamara Offtake

A review of the design flows produced from the hydrodynamic model at St Patricks River at Nunamara Offtake was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a poor match to the FFA peak flows at this location (Figure 6 and Table 4), with the model underestimating peak flows, however this error is aligned with the error seen in the calibration of design losses (refer to Section 4).

Table 14: Design flows at St Patricks River at Nunamara Offtake

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m^3/s)	474	539	641	636
FFA peak flow (m^3/s)	564	786	n/a	1,082
Peak flow difference (%)	-16%	-31%	n/a	-41%

5.3. Comparison to Previous Flood Studies

In comparing the results of this regional study to the previous studies, it should be noted that the previous studies discussed in this section were detailed flood studies with model's setup to best represent the target areas of interest. This contrasts to the present study, which is a regional study which aims to give plausible flood extents over a large area. The detailed flood studies would have used detailed local survey and river bathymetry and finer details of urban features and modelling of stormwater systems which were not used in the present study.

Comparison of design flood results on the Meander River were not undertaken in this report as it has been covered within the more detailed Meander River Catchment Model Calibration Report (WMAwater, 2021c).

5.3.1. Tamar River, North Esk River and South Esk River

BMT completed a flood study of the North Esk and South Esk Rivers in 2019, calibrating the model to the 2016 flood event (BMT, 2019). As discussed in the Tamar-Esk calibration report (WMAwater, 2023), the levee data supplied for the current study was not comprehensive, requiring levee details to be inferred, using the highest elevation on the provided polyline of the levees in the DEM was to represent the height of the levees. Additionally, the levee data was not complete, resulting in levees that were not connected and had gaps in them. The gaps around Launceston were closed by adding additional polylines to the dataset and applying the elevation of neighbouring levees to these new polylines. This resulted in breakouts over the levee in the current study, where these were not seen in the BMT (2019) study where survey information on the levee system and the river channels were used in the modelling (Diagram 3). This highlights that the detailed flood modelling undertaken in previous studies should be used in urban areas of Launceston, rather than the results of the regional modelling study.

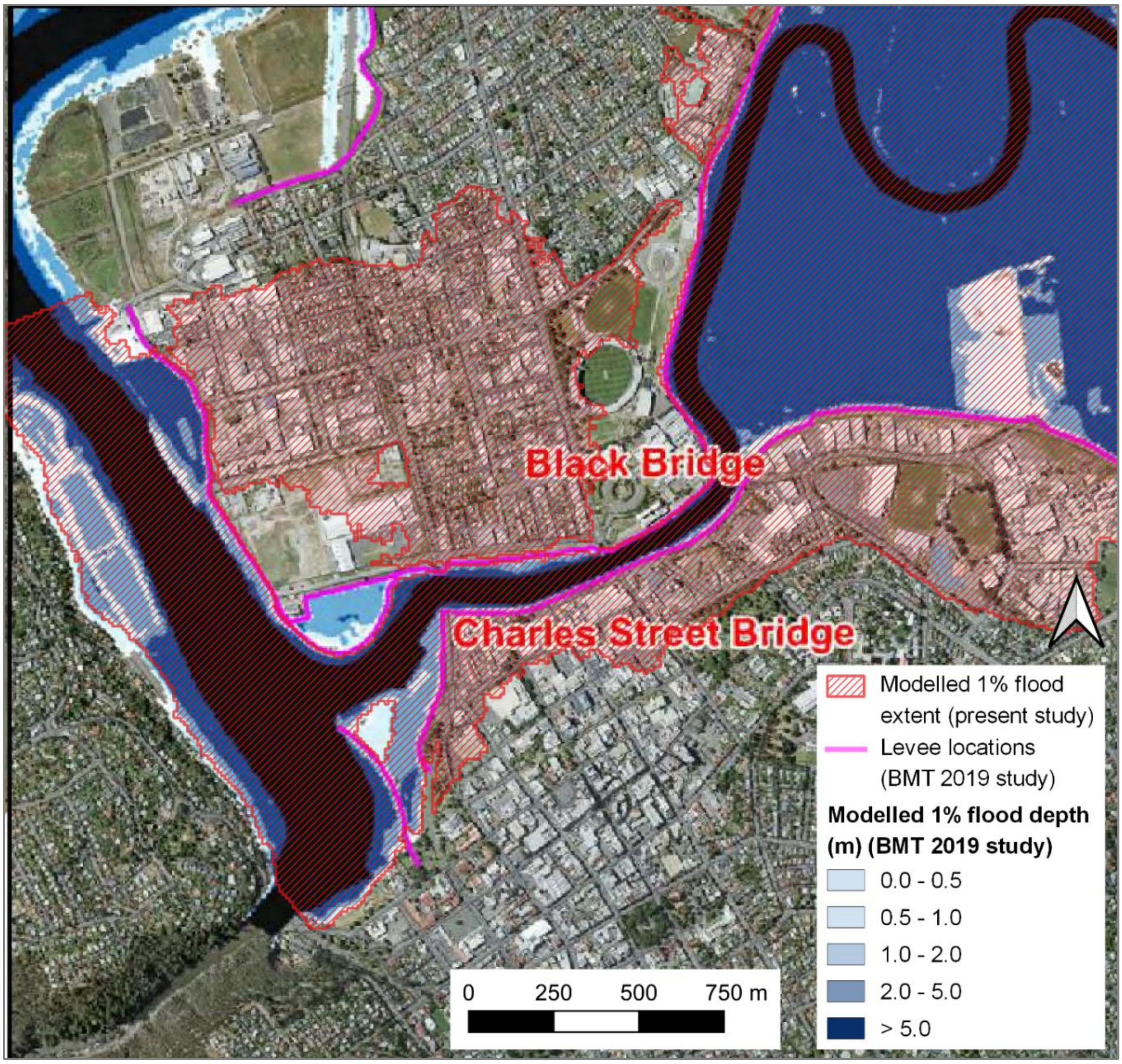

Diagram 3: BMT (2019) and present study flood extent for the 1% AEP design event through Launceston

5.3.2. St Marys

Water Technology completed a flood risk report for St Marys in 2018 (Water Technology, 2018). GIS flood layers were provided from the Water Technology study and were compared to the present study. Diagram 4 shows the comparison between the 1% AEP design event flood level from both studies. Four comparison points were chosen and the differences between the 1% AEP flood levels are shown in Table 15.

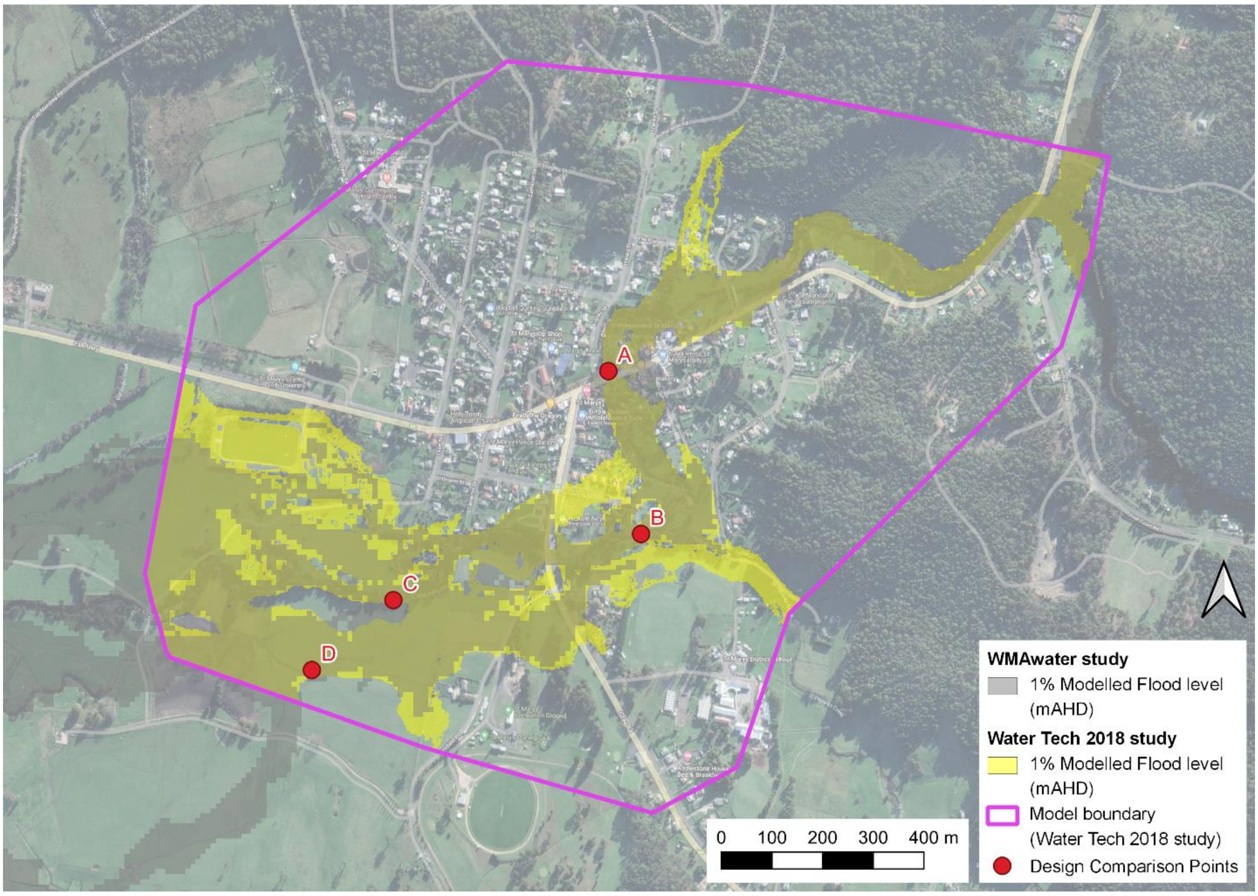

Diagram 4: Water Technology (2018) and present study flood levels for the 1% AEP design event through St Marys

Table 15: Design Level Comparisons at St Marys

Comparison Point	2018 Study 1% Flood level (mAHD)	Present Study 1% Flood level (mAHD)	Difference (m)
A	259.68	260.97	+1.31
B	257.73	257.66	-0.07
C	255.66	255.60	-0.06
D	254.09	254.06	-0.03

Table 15 shows that at Point A there is an overestimation in flood level from the present study, possibly due to a lack of information on the channel bathymetry and the bridge structure directly downstream. Points B, C and D show a close comparison between flood levels which gives some confidence in the present study's model. Overall, the present study's flood extent appears to be less than the Water Technology study due to the coarse DEM underlying the model.

5.3.3. South Esk River – Longford and Hadspen

JMG and Hydrodynamica completed a floodplain mapping study for Longford and Hadspen in 2016 (JMG, 2016) using design hydrology inputs derived by Entura (2015). A comparison of flood extents through Longford for the 1% AEP design event and the 2% AEP design event are shown in Diagram 5 and Diagram 6 respectively.

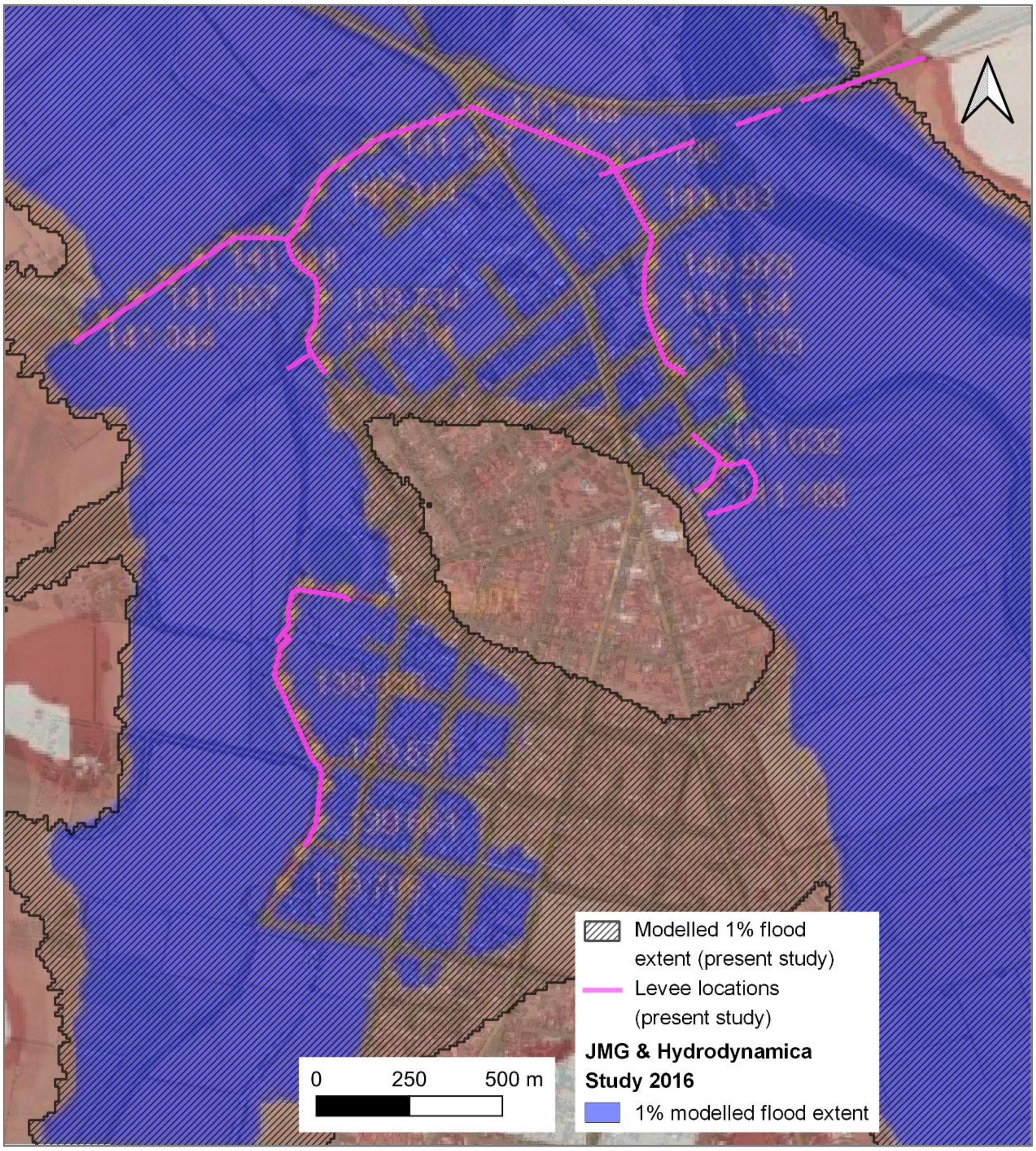

Diagram 5: JMG and Hydrodynamica (2016) study and present study flood extent for the 1% AEP design event through Longford

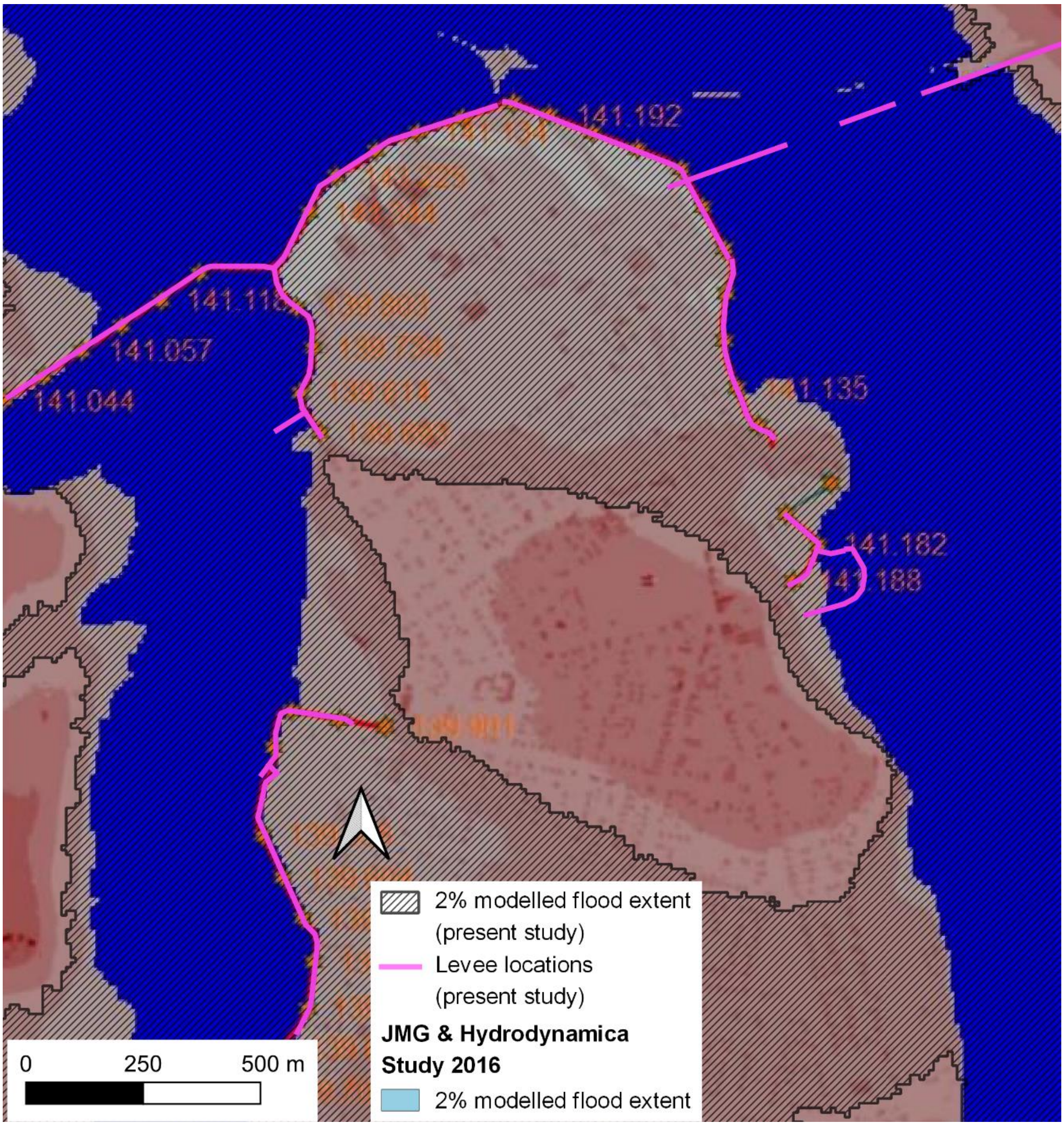

Diagram 6: JMG and Hydrodynamica (2016) study and present study flood extent for the 2% AEP design event through Longford

In both the present study's 1% AEP flood extent and 2% AEP flood extent, floodwaters are seen to not be stopped by the current flood levees in place, whereas in the JMG study, the 2% flood event is held by the flood levees from inundating the town of Longford. As was the case with the Launceston comparison, the levee data supplied for the current study was not complete. Additionally, the present study does not have information regarding the operation of flood gates that are on Back Creek whereas the JMG study takes into account flood gate operation. This highlights that the detailed flood modelling undertaken in previous studies should be used in the urban area of Longford, rather than the results of the present regional modelling study.

A comparison of flood extents through Hadspen for the 1% AEP design event is shown in Diagram 7. Hadspen is located at the confluence of the Meander and South Esk Rivers, so a comparison including the Meander has been undertaken in this report, despite the remainder of the Meander being compared in the Validation Report. Diagram 7 shows that the present study's flood extents through Hadspen match reasonably close to the JMG 2016 study, which provides some confidence in the present study's model. In the bottom left and the top middle of the figure the present study's extent is outside the JMG model's extent due to local tributary inflows upstream, however the difference between extents on the top left is on the main river (Meander River).

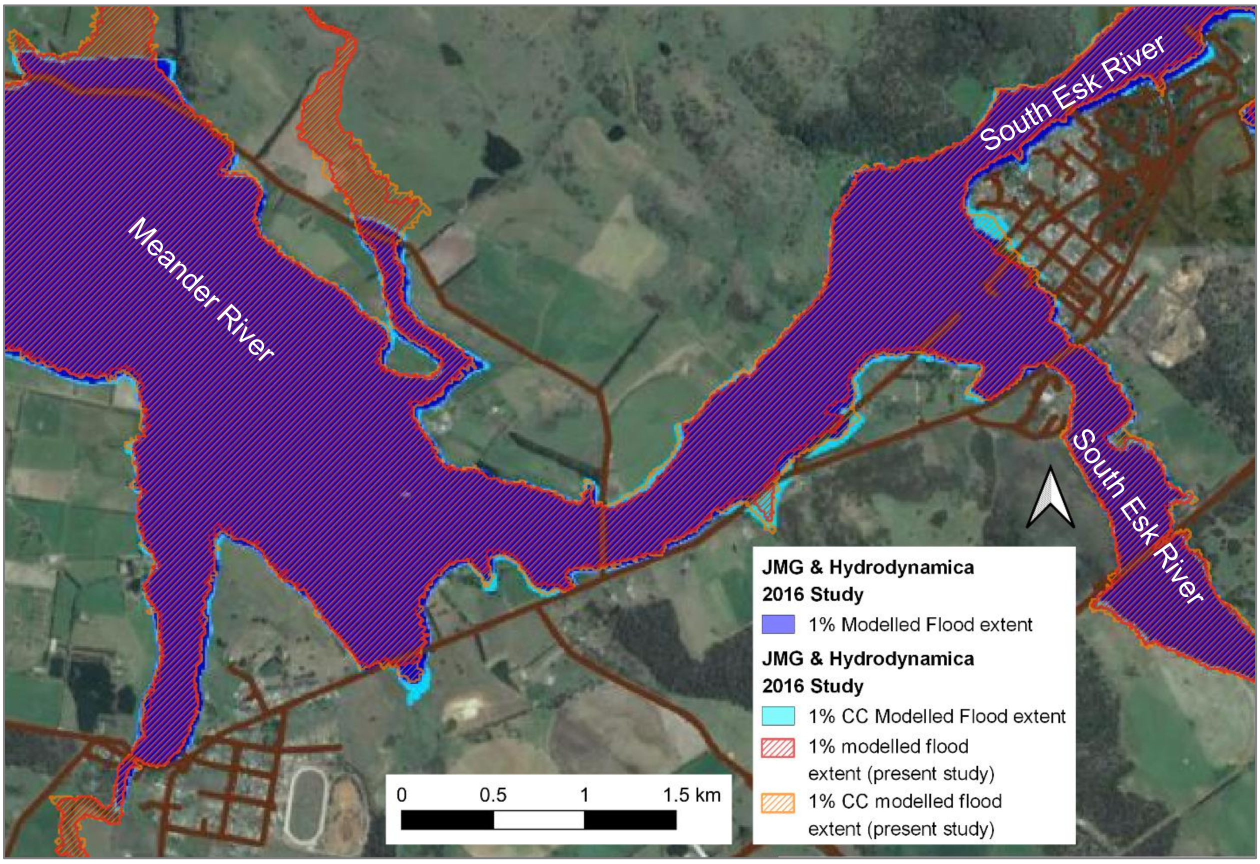

Diagram 7: JMG and Hydrodynamica (2016) study and present study flood extent for the 1% AEP design event through Hadspen

5.3.4. South Esk River at Perth

Hydro-Electric Commission (HEC) completed a flood plain study of Perth and Longford in 1992 (HEC, 1992). While there has been a recent flood study update to Longford (see Section 5.3.3), there was no other updated flood study found for South Esk River at Perth. Diagram 8 shows a comparison between the flood extents of the 1992 study and the present study for the 1% AEP design event.

As shown in Diagram 8, the flood extents of the South Esk River show a close match between both flood studies, which provides some confidence in the present study's model.

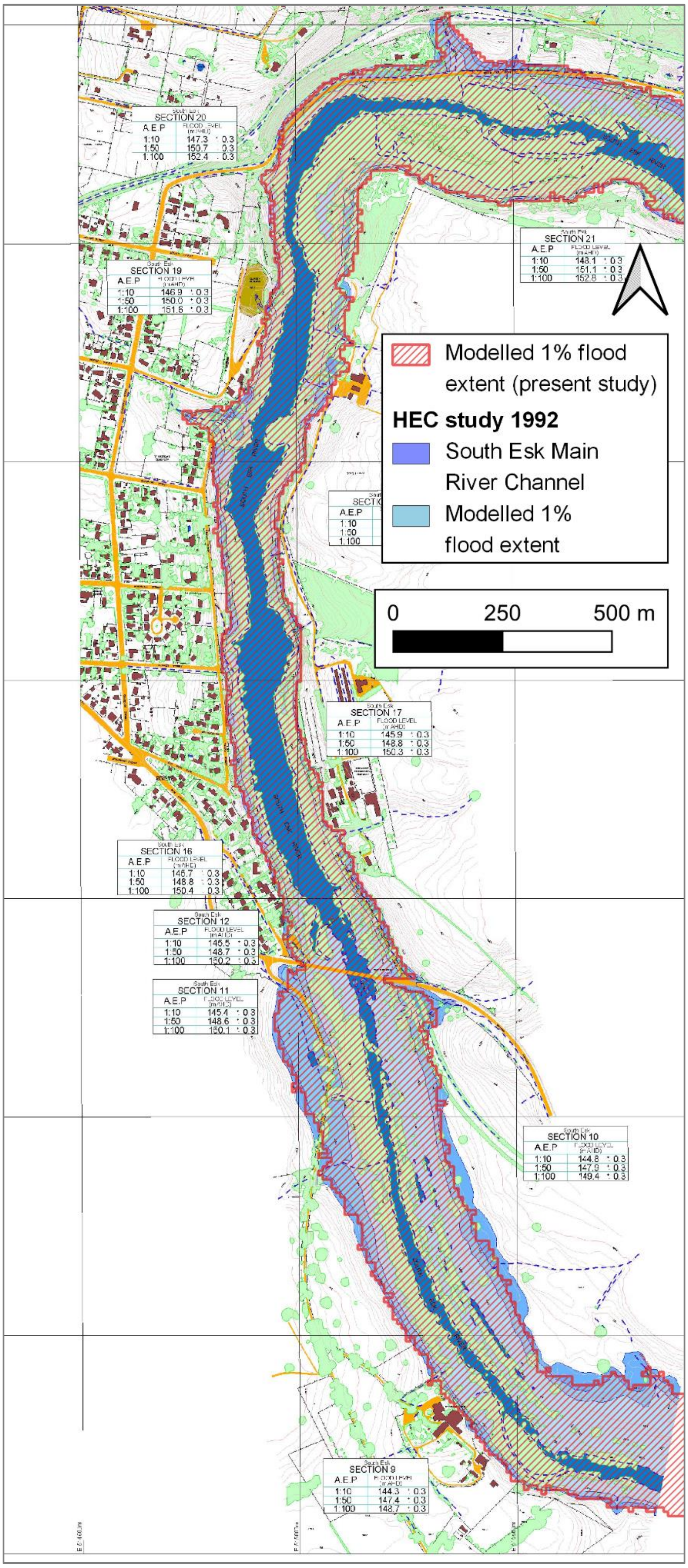

Diagram 8: HEC 1992 study and present study flood extent for the 1% AEP design event through Perth

5.3.5. Macquarie and Elizabeth River – Campbell Town and Ross

Hydrodynamica completed a flood plain mapping study for Ross and Campbell Town in 2022 (Hydrodynamica, 2022), using hydrology inputs from Entura (2020). A comparison of the 1% AEP flood extent through Campbell Town and Ross are shown in Diagram 9 and Diagram 10 respectively.

Diagram 9 and Diagram 10 show that the present study's 1% flood extents are slightly wider than the Hydrodynamica (2022) study. This was mainly due to higher modelled flows with 1% AEP modelled flows of 1,160 m^3/s for the current study at Macquarie River D/S Elizabeth gauge compared with 844 m^3/s in the 2020 study. Entura (2020) used this as the primary gauge for model calibration. As discussed in Section 4 and Section 5.2.4, the at-site FFA for this gauge appeared to be very low compared to other gauges in the area, and was therefore treated as highly uncertain. The design losses were calibrated to other gauges within the study area, with the resulting modelled FFA flows significantly higher than the FFA, and therefore higher than the 2020/2022 studies flows and levels.

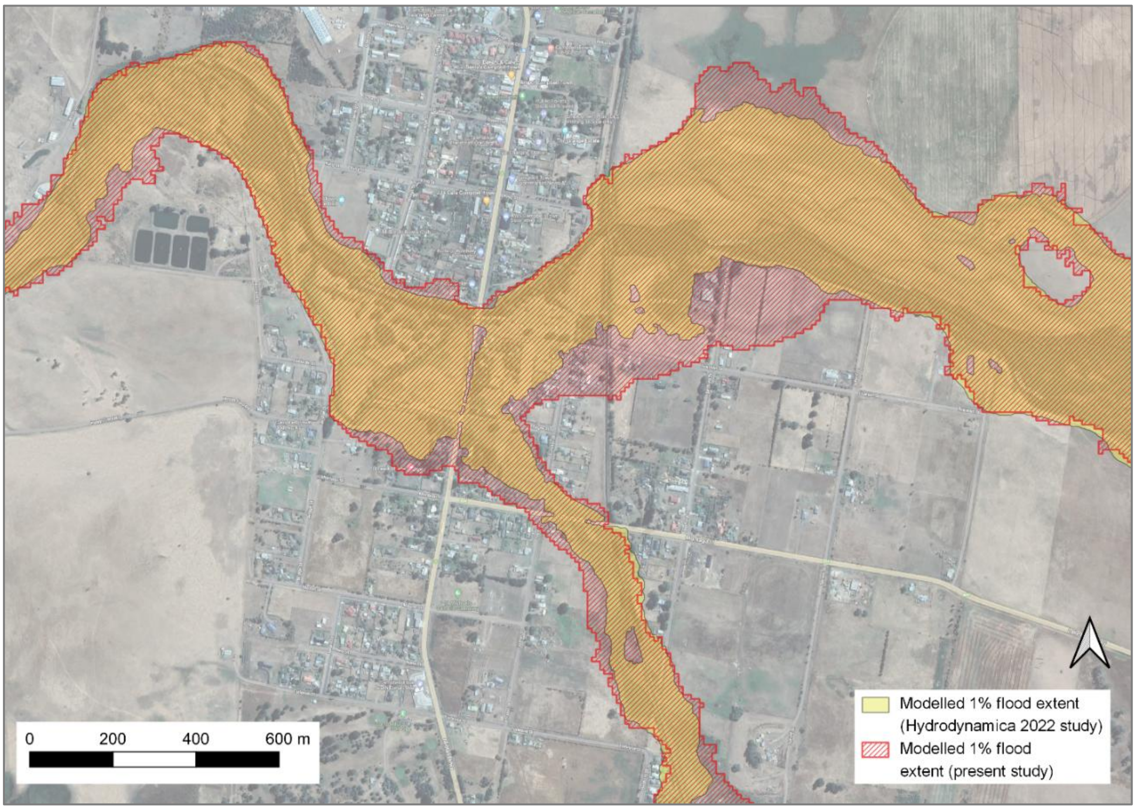

Diagram 9: Hydrodynamica (2022) study and present study flood extent for the 1% AEP design event through Campbell Town

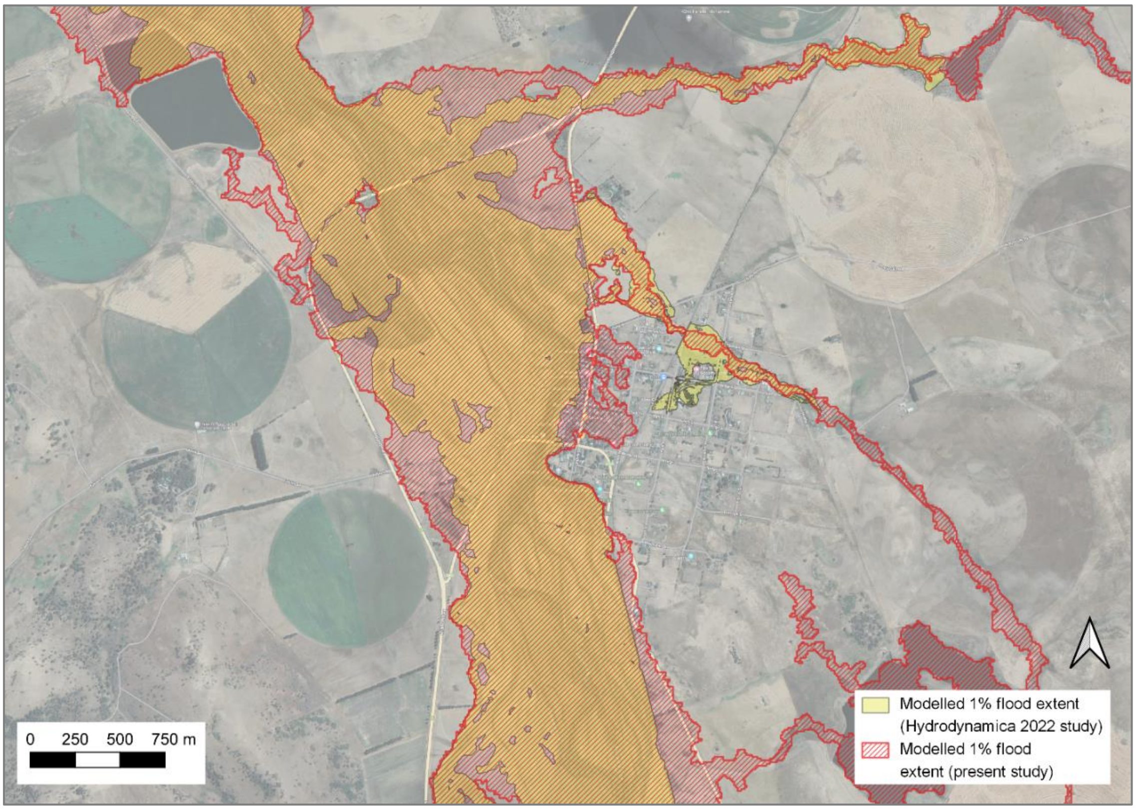

Diagram 10: Hydrodynamica (2022) study and present study flood extent for the 1% AEP design event through Ross

6. LIMITATIONS

A detailed uncertainty assessment of the data, hydrological calibration and hydrodynamic model is contained in the Tamar-Esk Calibration Report (WMAwater, 2023). In line with the calibration report there are some areas where the lack of bathymetry, levee data or LiDAR may have impacted the modelled flood levels. If LiDAR, levee data or bathymetry were made available this model would benefit from being re-run with this information.

The selection of limited duration-TP-ARF sets introduces some errors across the catchment as described in Section 5.1. This is appropriate for a regional method, however site-specific ARFs, critical durations and TP selection should be used for detailed design modelling at specific locations. This was particularly challenging for a study area as large as the Tamar-Esk, especially with two major rivers of similar size but differences in catchment behaviour.

As discussed in Section 0 there is some uncertainty introduced by the direct rainfall application on the headwater catchments. While the method used is appropriate for broad scale mapping, a full design event assessment should be undertaken for any future focussed studies in this area.

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Figures

FIGURE 1

South Esk at Llewellyn

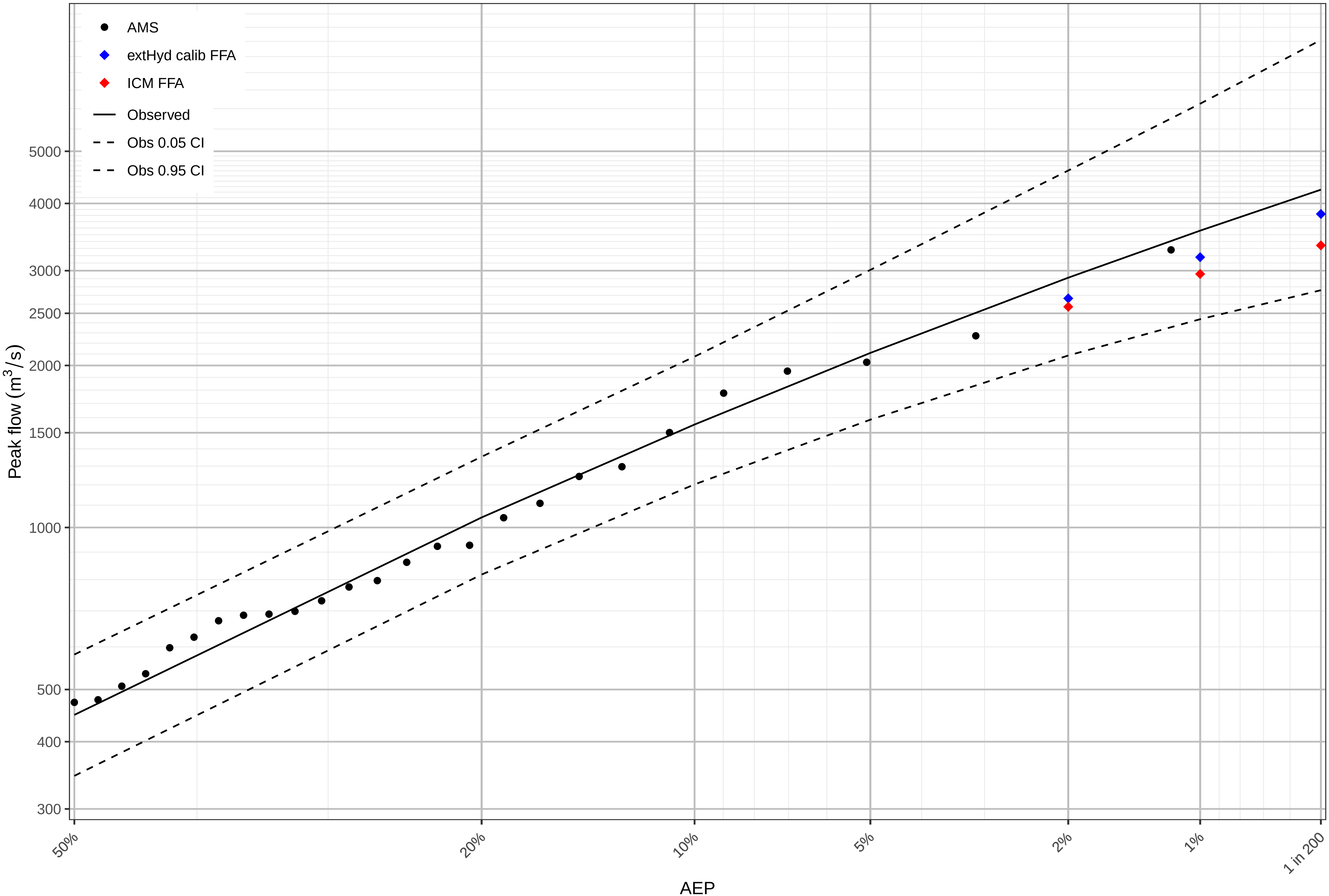

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FIGURE 2

South Esk at Perth

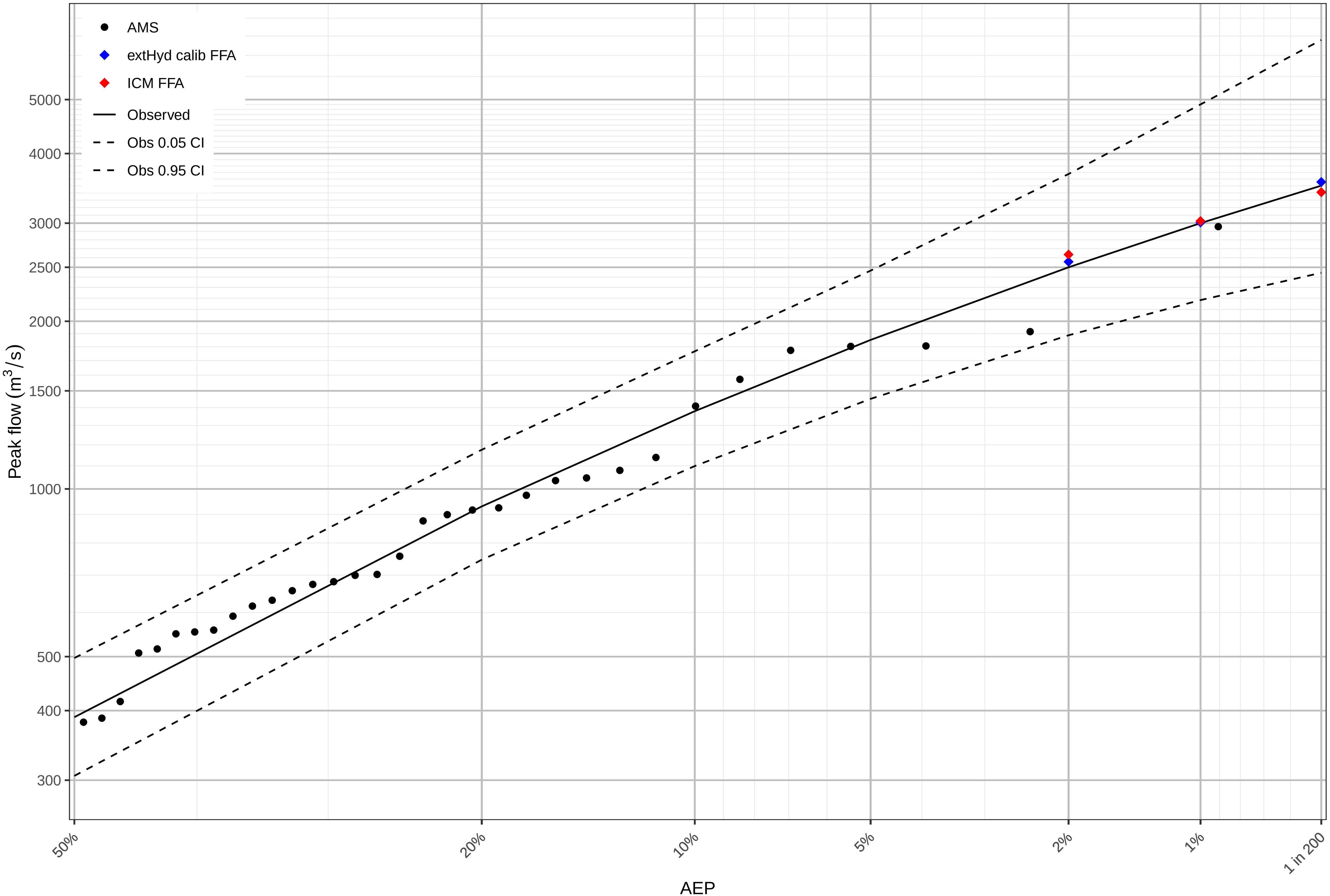

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FIGURE 3

Macquarie River at Trefusis

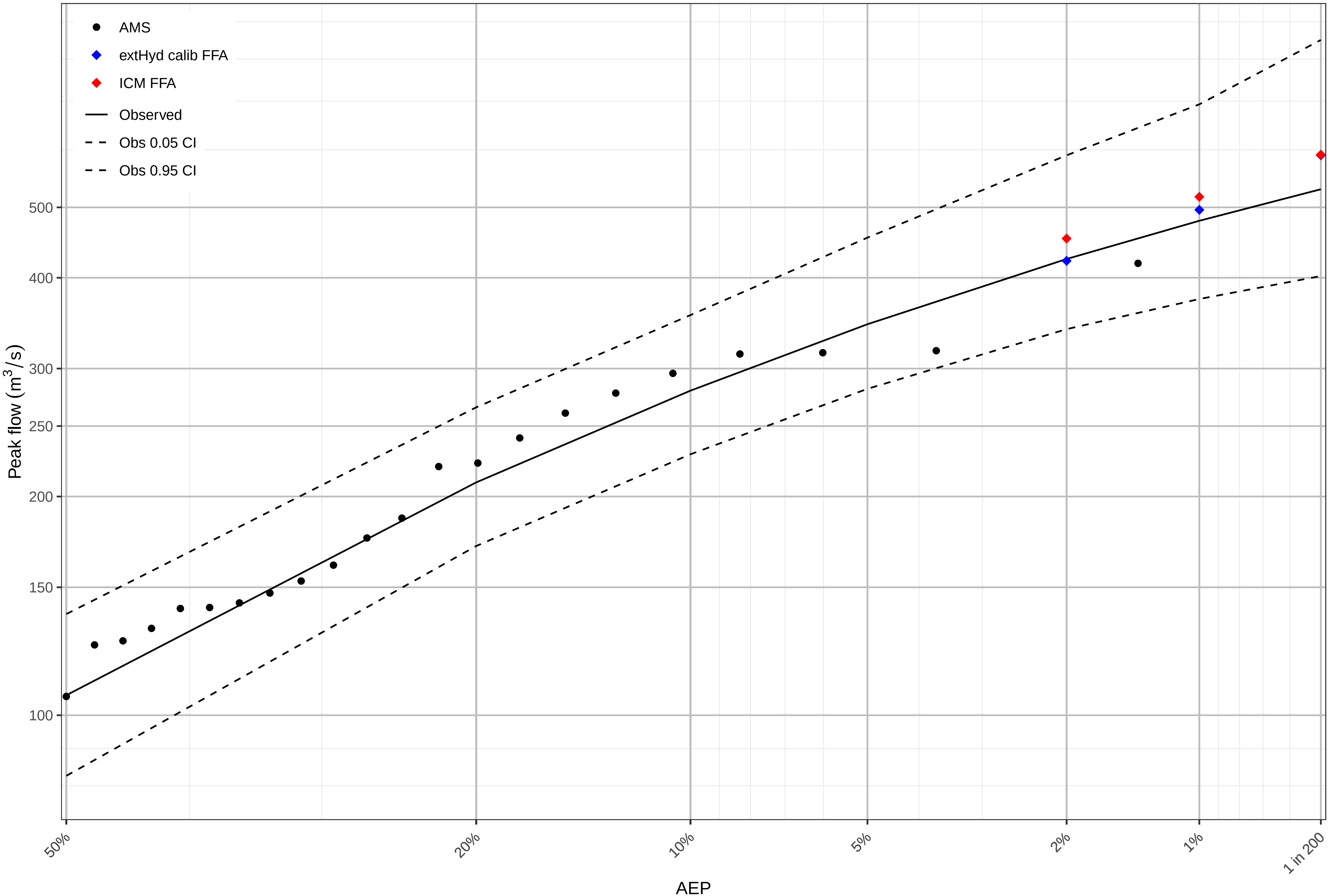

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FIGURE 4

Macquarie River D/S Elizabeth

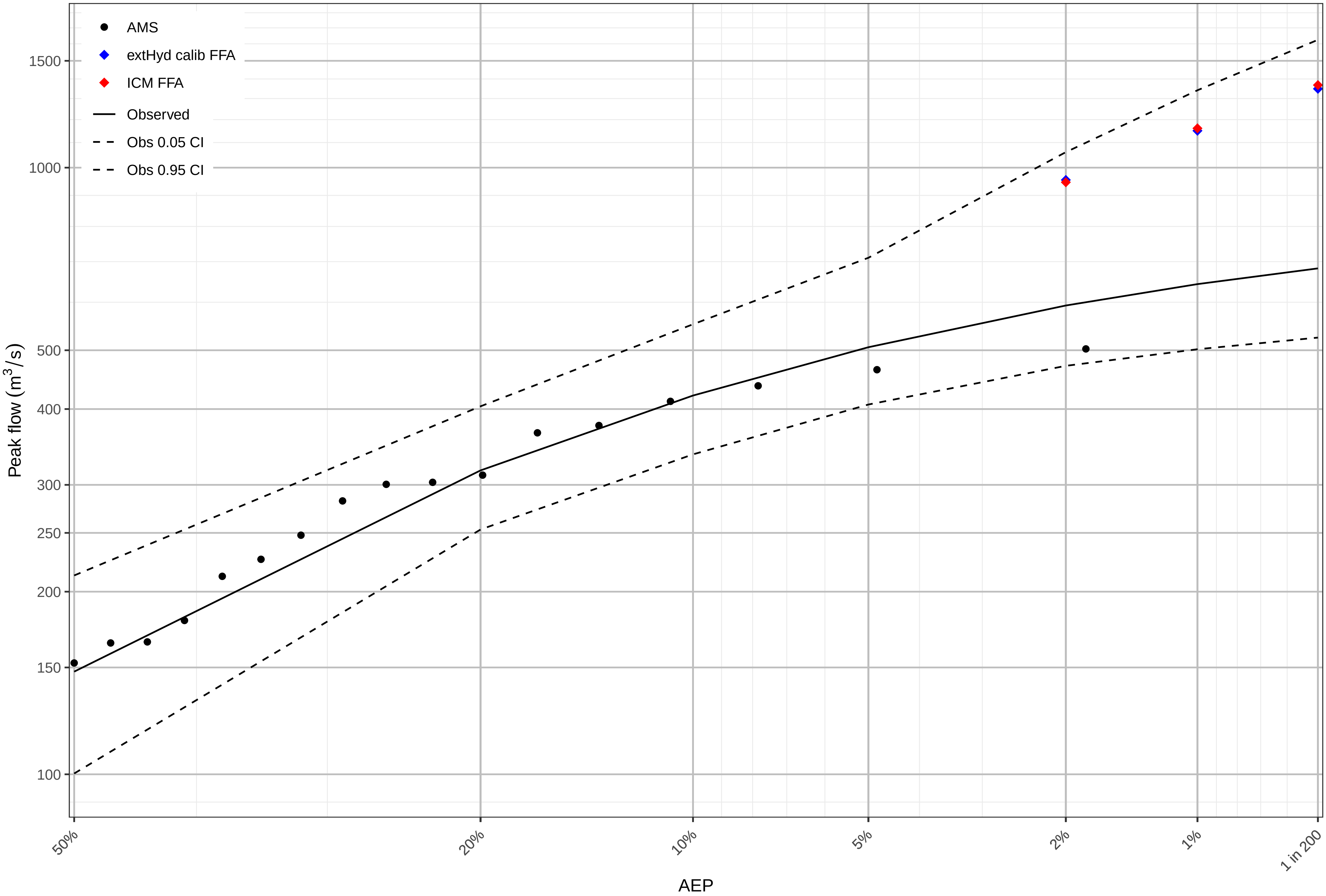

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FIGURE 5

North Esk at Ballroom

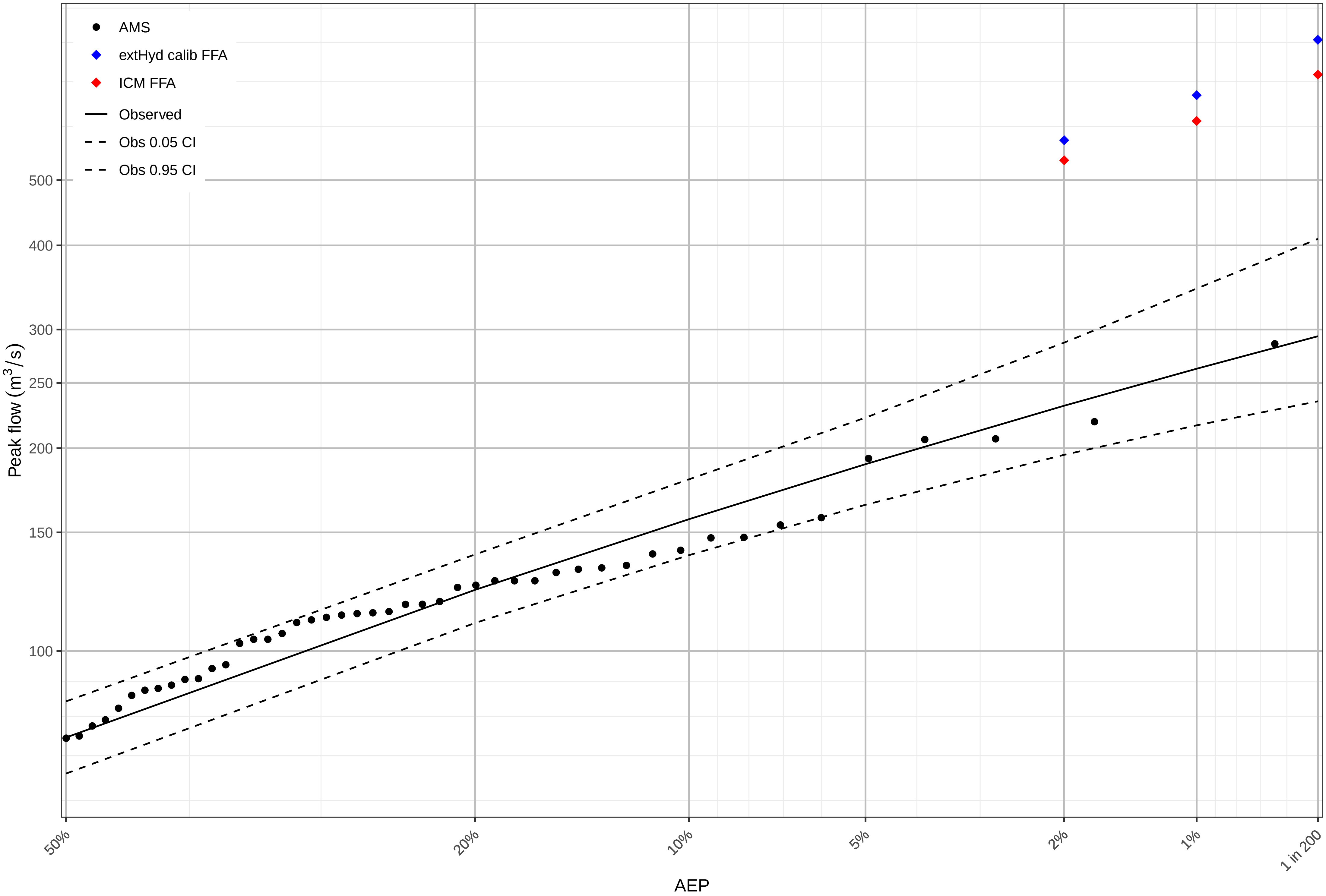

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FIGURE 6

St Patricks River at Nunamara Offtake

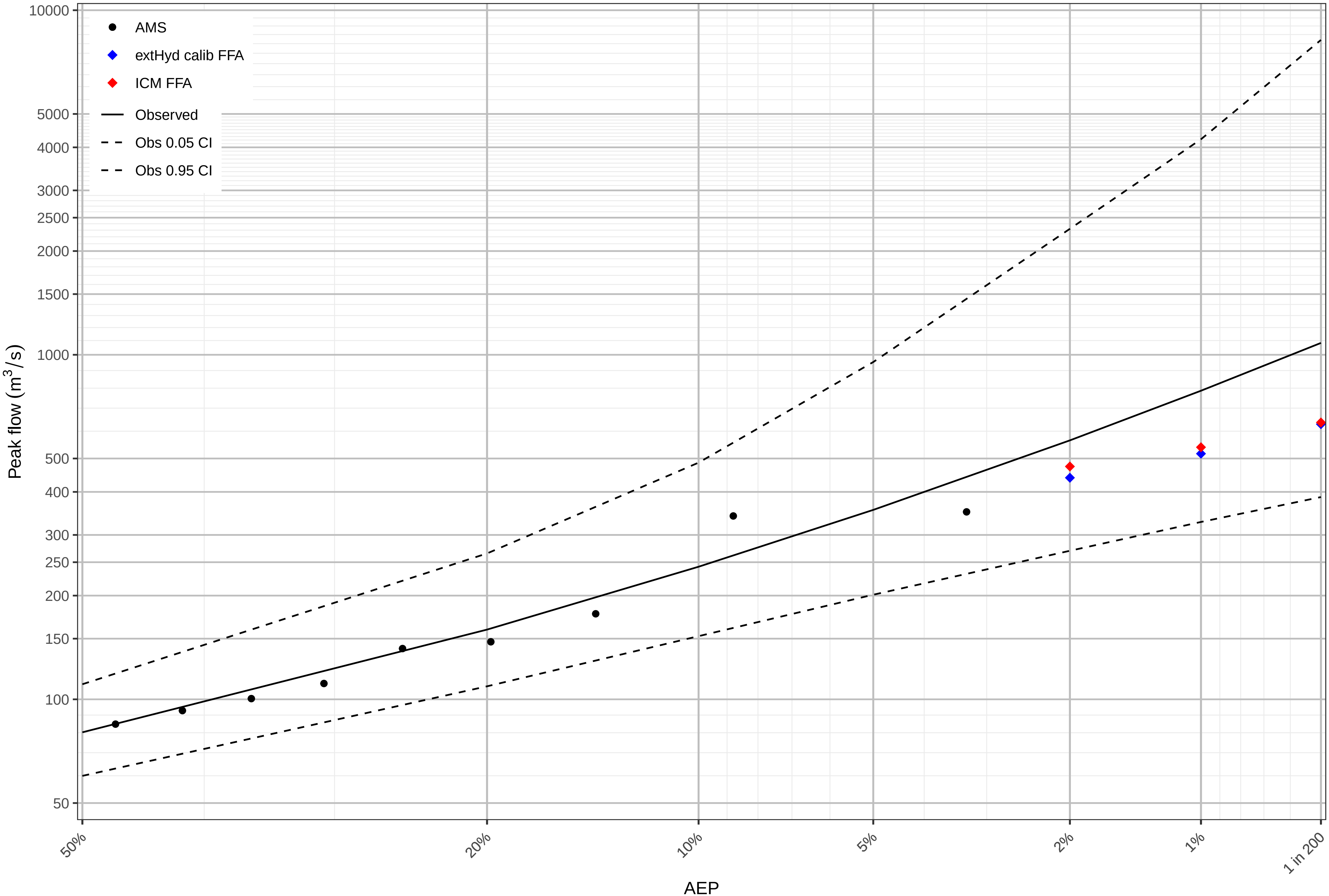

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FIGURE 7

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