4.2.1.4 July 2022 Results

The July 2022 event occurred from 29th June till 7th July 2022, reaching a peak of roughly 2,100 m^3/s at the Colo River at Upper Colo gauge. The event was estimated to be a 1 in 10 to 1 in 20 AEP event for the Colo catchment.

The comparison of the WBNM flows and the Upper Colo gauge record is shown in **Figure 4-7** and the comparison for the Glen Davis gauge is presented in **Figure 4-8**.

The Upper Colo model hydrograph is a reasonable match for the peak flow and timing with the gauged results. The receding limb of the model hydrograph acted faster than the gauged hydrograph. As noted with the previous events, this can be a result of the hysteresis at the rating curve representation.

The modelled outputs for the Glen Davis gauge generally follow the shape of the gauged hydrograph well and captures the twin peaks of the flood event at the gauge. The peak flow is an overestimate by 9% compared to the gauged peak. The model has a faster rate of rise causing the modelled peak to occur 6 hours prior to the gauged peak. The offset in timing increases over the course of the model with the second peak being 9 hours early.

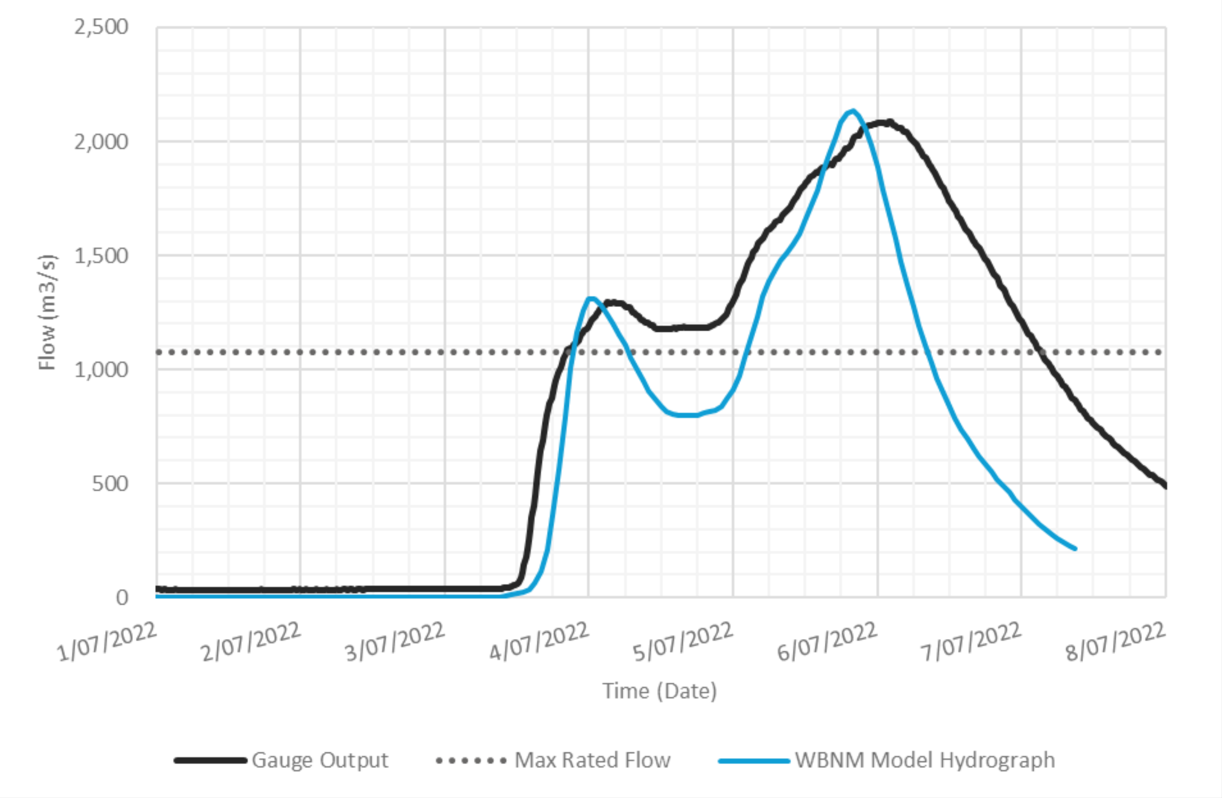


Figure 4-7 Upper Colo Gauge July-2022 calibration

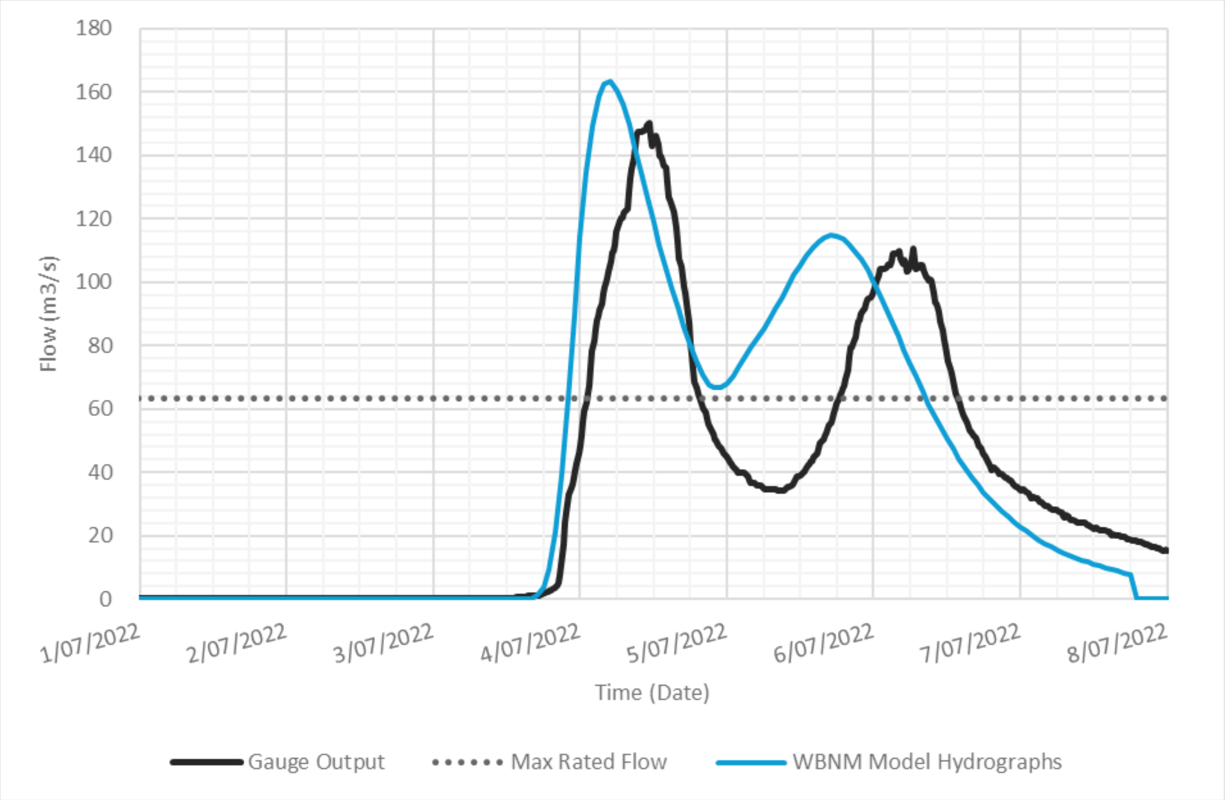


Figure 4-8 Glen Davis Gauge July-2022 calibration

4.2.1.5 March 2022 Results

The March 2022 event was approximately a 1 in 30 to 1 in 40 AEP flood event, reaching a peak of around 2,700m^3/s at the Colo River at Upper Colo gauge. The flood event occurred from 25th February to 15th March 2022.

The comparison of the WBNM flows and the Upper Colo gauge record is shown in **Figure 4-9** and the comparison for the Glen Davis gauge is presented in **Figure 4-10**.

The peak flow and timing from the modelled hydrograph for the Upper Colo gauge was a close match with the gauged record. The model reflected the rate of rise very well and highlighted the twin peak nature of the flood. The model underestimated the initial burst and overestimated the smaller first peak. The modelled result also shows a steeper receding limb compared with the gauged record.

The modelled hydrograph for the Glen Davis gauge was a much better match compared with the 1978 and 2020 calibrations, noting that the flows for Glen Davis were more significant in this event. The peak flows, twin peaks and rate of rise are all evident and reasonable in the modelled output.

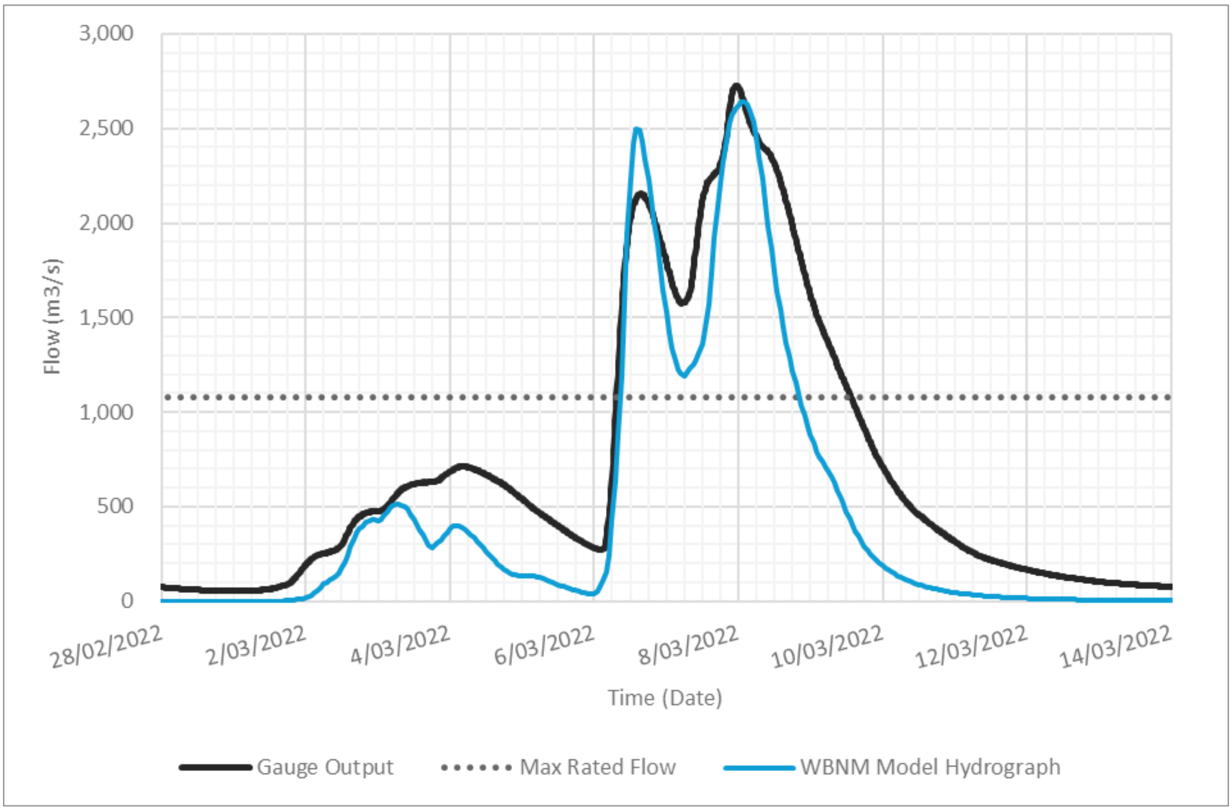


Figure 4-9 Upper Colo Gauge March-2022 calibration

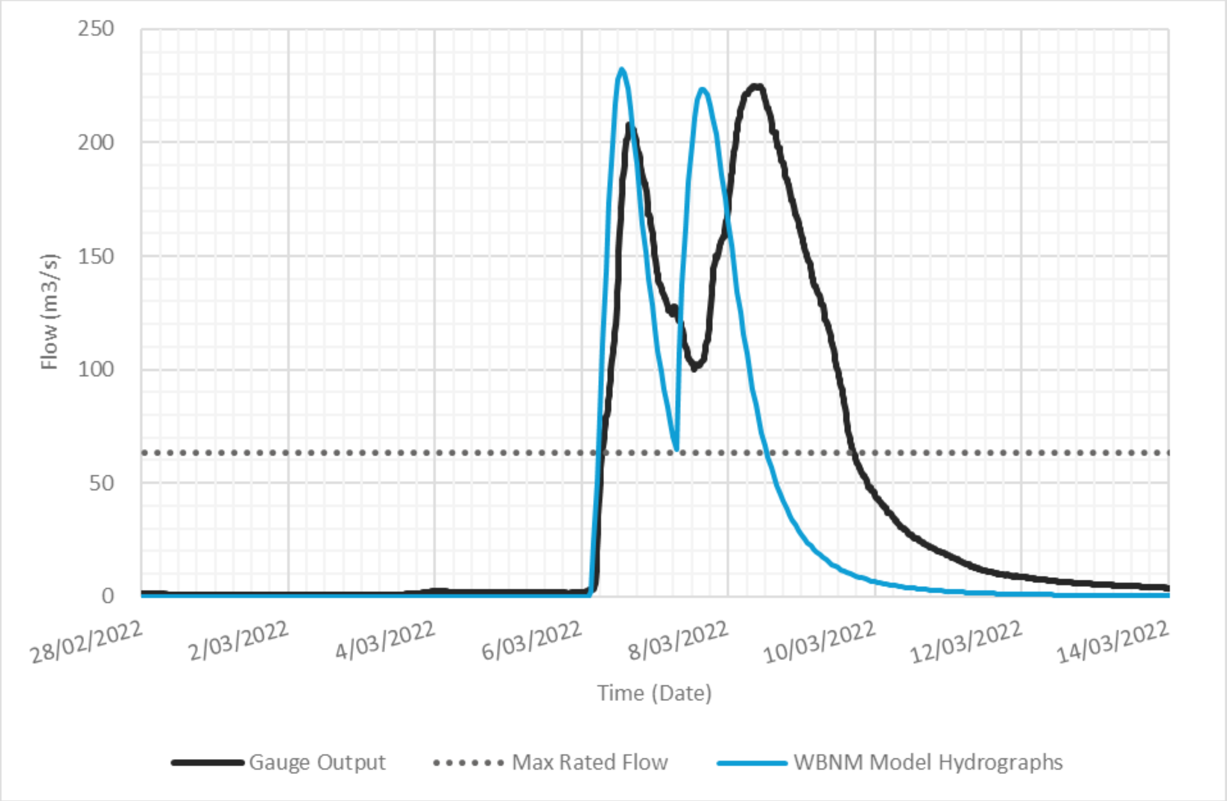


Figure 4-10 Glen Davis Gauge March-2022 calibration

4.2.1.6 2020 Results

The 2020 event commenced around the 5th of February and went through to around 12th February 2020, reaching a peak of approximately 2,400 m^3/s at the Colo River at Upper Colo gauge. The event was estimated to be between a 1 in 10 and 1 in 20 AEP event for the Colo catchment.

The comparison of the WBNM flows and the Upper Colo gauge record is shown in **Figure 4-11** and the comparison for the Glen Davis gauge is presented in **Figure 4-12**

The peak and timing of the 2020 Upper Colo gauge calibration event modelled flows are a close match to the gauged record. The shape of the hydrograph is also a reasonable fit, with the rate of rise being very similar, though delayed compared with the gauged record. The receding limb of the model hydrograph occurred at a faster rate than the gauged hydrograph. However, this can be due to the hysteresis in the rating. When these flows are run in the calibrated hydraulic model (where storage effects are better represented), the modelled receding limb more closely matches the gauge receding limb, as shown in **Appendix C**.

The modelled outputs at the Glen Davis gauge are similar to those in the 1978 event, with generally a poor match. As with the 1978 event, the poor coverage of rainfall data and the low flows make calibration to this gauge challenging. The peak flows based on the gauge represent less than 5% of the overall peak at the Upper Colo gauge. Further, the peak at the gauge occurs about 3 days after the Upper Colo gauge peak and would not have contributed to the peak flows at the Upper Colo.

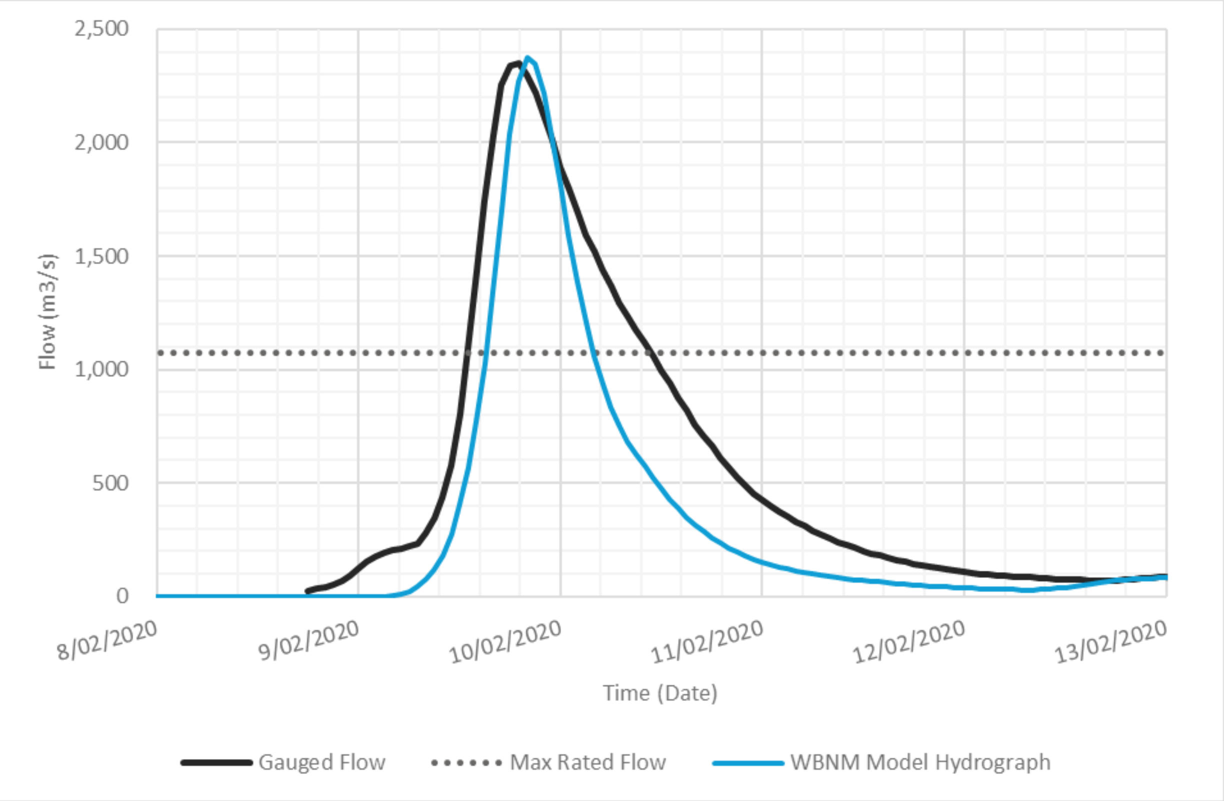


Figure 4-11 Upper Colo Gauge 2020 calibration

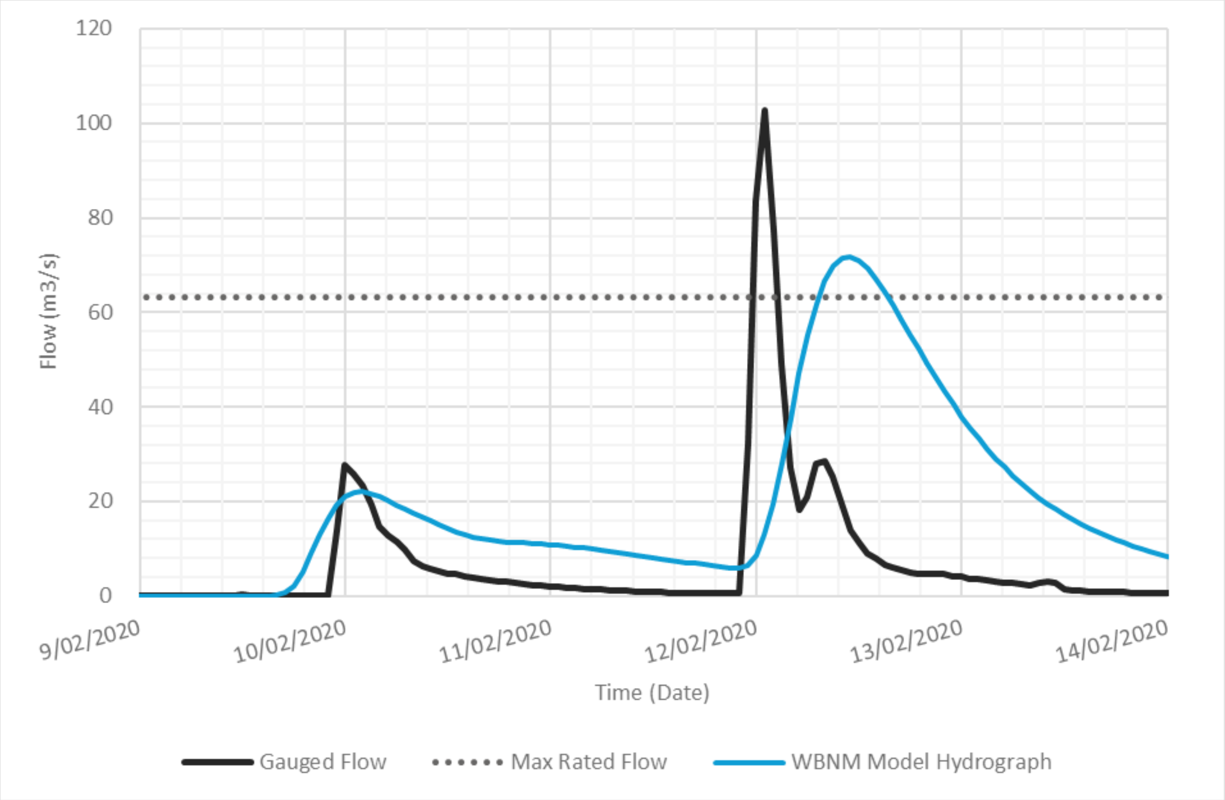


Figure 4-12 Glen Davis Gauge 2020 calibration

4.2.1.7 1978 Results

The 1978 event was the largest of the calibration events in the Colo River catchment. It reached a peak of approximately 3,800 m^3/s at the Colo River at Upper Colo gauge and was in the order of a 1 in 80 AEP flood event. The event occurred from 17th March through to 27th March 1978.

The WBNM model hydrograph and gauge hydrographs for the 1978 event at the Colo River at Upper Colo gauge are shown in **Figure 4-13**.

The model shows a good fit to the peak flow with the gauged record. The twin peaks were reflected in the results, albeit in a slightly different manner leading to a misalignment of the peak flows. The general shape of the hydrograph is a reasonable match, though the rate of rise is slower than the gauged data, whilst the rate of fall is faster than the gauged data.

The calibration to the Glen Davis gauge shown in **Figure 4-14** shows generally a poor alignment between model flows and gauge flows. This result suggests that the limited spatial and temporal rainfall data available for the Capertee River catchment was insufficient to capture the flood behaviour shown by the gauge for the 1978 flood event. It is worth noting that while the Capertee catchment represents nearly a quarter of the overall Colo River catchment, in this event the peak flows were less than 2% of the peak at the Upper Colo gauge, and therefore this part of the catchment contributed very little to the overall peak flows downstream.

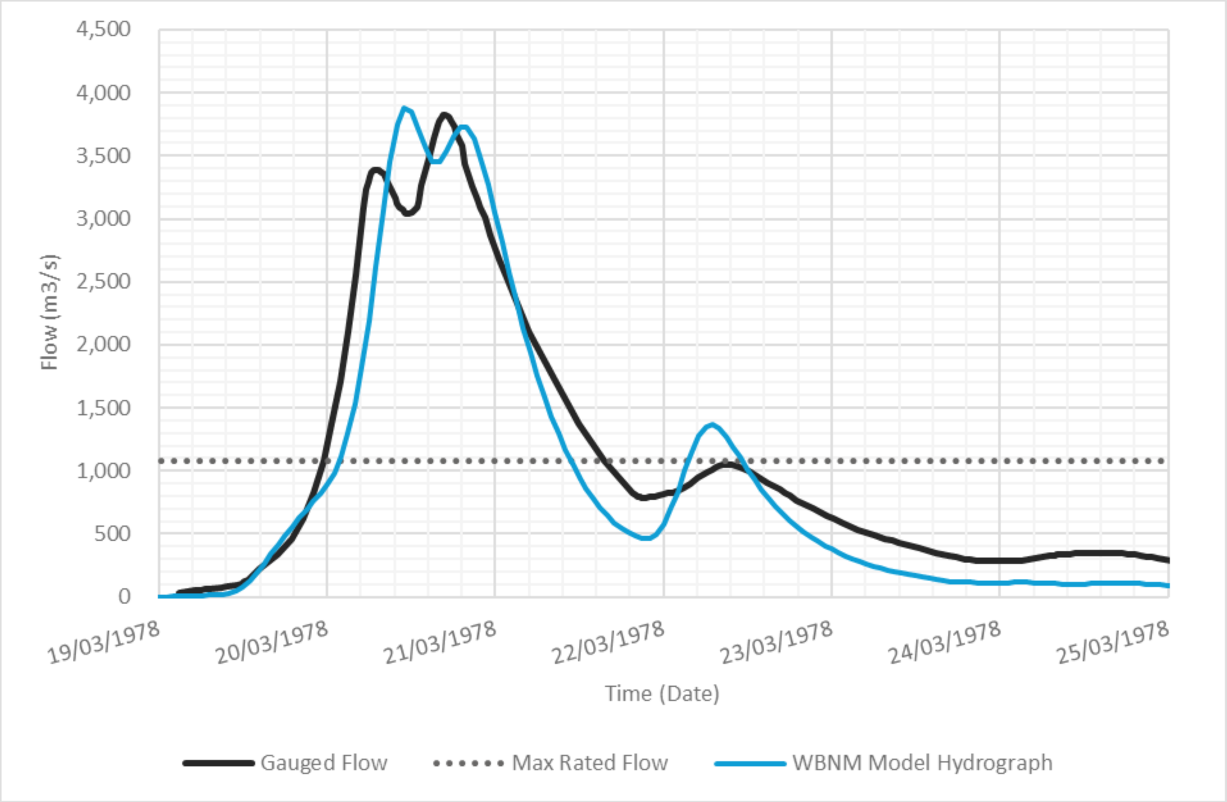


Figure 4-13 Upper Colo Gauge 1978 calibration

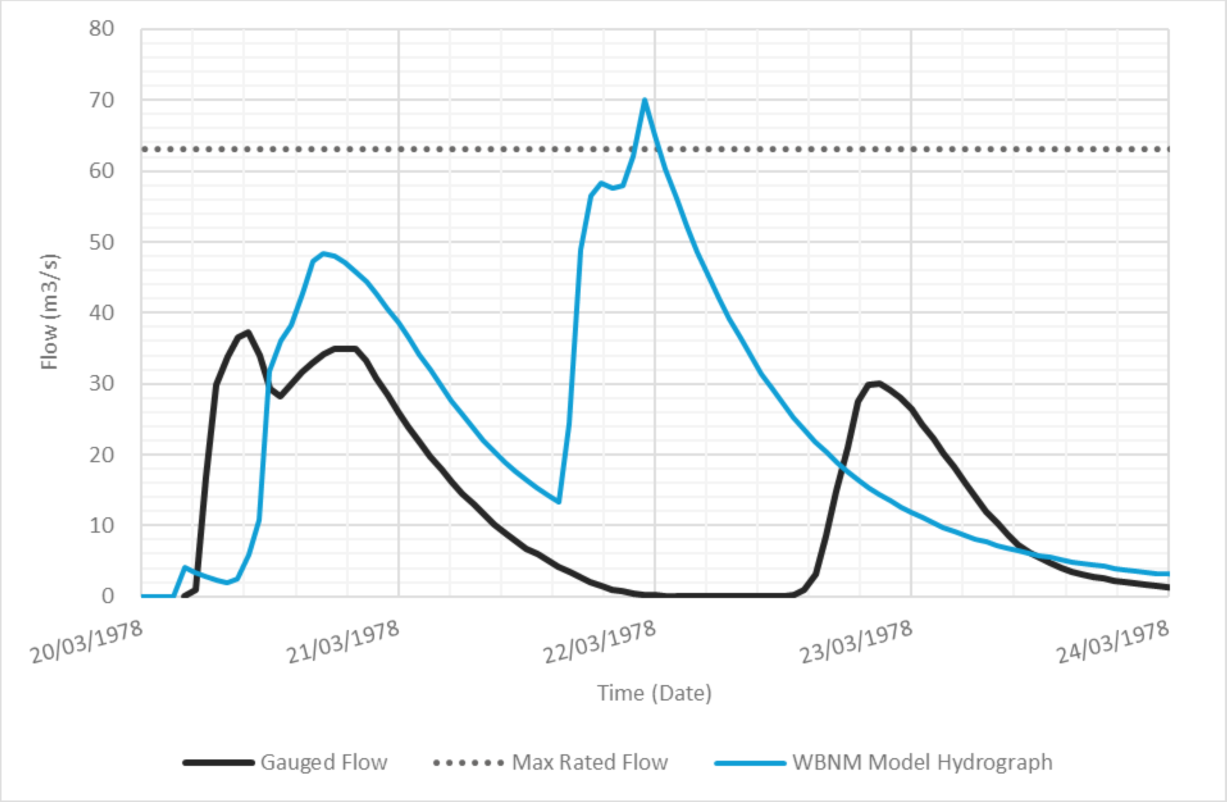


Figure 4-14 Glen Davis Gauge 1978 calibration

4.2.1.8 Calibration Outcome

The results of the above assessments indicated that the hydrological model is a reasonable representation of catchment hydrology. A summary of the peak flow differences is shown in **Table 4-6,** and a summary of the peak flow timing differences is shown in **Table 4-7.** As noted above, the key focus is on the Colo River at Upper Colo gauge, which is representative of the inflows to the study area. The Capertee River at Glen Davis gauge is further upstream in the catchment, and the rainfall in this area is generally lower and more difficult to represent due to the absence of gauges.

Table 4-6 Colo River catchment calibration peak flow difference summary

Catchment	Representative Gauge	1978 Peak flow difference	2020 Peak flow difference	March-2022 Peak flow difference	July-2022 Peak flow difference
Colo River	Upper Colo	-2%	1%	-3%	2%
Capertee River	Glen Davis	30%	-30%	-1%	9%

Table 4-7 Colo River catchment calibration peak flow timing difference summary

Catchment	Representative Gauge	1978 Peak flow timing difference (hr)	2020 Peak flow timing difference (hr)	March-2022 Peak flow timing difference (hr)	July-2022 Peak flow timing difference (hr)
Colo River	Upper Colo	2	1	3	-6
Capertee River	Glen Davis	7	10	-17	-6

A negative value refers to an early model and a positive value refers to a late model.

4.2.2 Macdonald River Calibration

4.2.2.1 Catchment Context

. The Macdonald River catchment areas and water level gauges are shown in **Figure 4-15**.

The total catchment area to the Macdonald River at St Albans gauge is 1740km^2. It is largely bushland with some rural areas primarily confined to the valley adjacent to the river. The catchment area to the Howes Valley gauge is approximately 20% of the area at St Albans, at around 300km^2

The gauge is located just downstream of the St Albans Bridge. This represents a reasonably confined part of the river, with high banks, as shown in **Figure 4-16**. While the riverbed is sandy in this location, which may affect lower flow estimates (due to geomorphic changes in the channel and the cross section), in higher flows the rating curve may be reasonable until flow overtops the bank on the St Albans village side. For the 1978 event, flow data for the St Albans gauge was reported in Webb McKeown & Associates (2004). This was digitised for the Hawkesbury-Nepean River Flood Study (2024) and included in the current study for the calibration.

A challenge in representation of the flows at St Albans gauge is the storage and conveyance characteristics upstream. For example, the large floodplain storage on Mogo Creek. These characteristics are represented in the TUFLOW hydraulic model, where routing and storage characteristics are better represented.

Similarly, immediately upstream of St Albans gauge (see **Figure 4-16**), the riverbank levels are lower and there is greater potential for the river to break its banks at lower levels and inundate the farmland on either side, as well as break out through St Albans township in larger events.

A further consideration is the potential backwater from the Hawkesbury River in larger flood events. In many of the historic events, the Hawkesbury River peaks after the Macdonald River, and can result in a much longer period with the gauge being elevated. This cannot be represented in the rating curve and is not included in the hydrology. Instead, these types of elevated characteristics are better represented in the hydraulic model.

However, as noted in **Section 5.3**, there are also some uncertainties in the gauge zero of the St Albans gauge. Therefore, there are some challenges with the hydraulic model calibration. Therefore, in undertaking the calibration, an iterative approach was undertaken by comparing results in both the hydraulic model (**Section 5.3**) and the hydrology model.

It is also noted that the Macdonald River is relatively sandy, and that the gauge is located in a relatively dynamic area. It is possible that after some of the larger historic events, that there may have been some change in the cross section either at, or upstream of, the gauge.

The catchment area to the Howes Valley gauge is approximately 20% of the area at St Albans, at around 300km^2.

The focus of the calibration was more on the St Albans gauge, given its proximity to the study area and hydraulic model boundary, rather than the Howes Valley gauge. However, a comparison of the hydrographs generally shows a reasonable representation of the Howes Valley gauged flows.

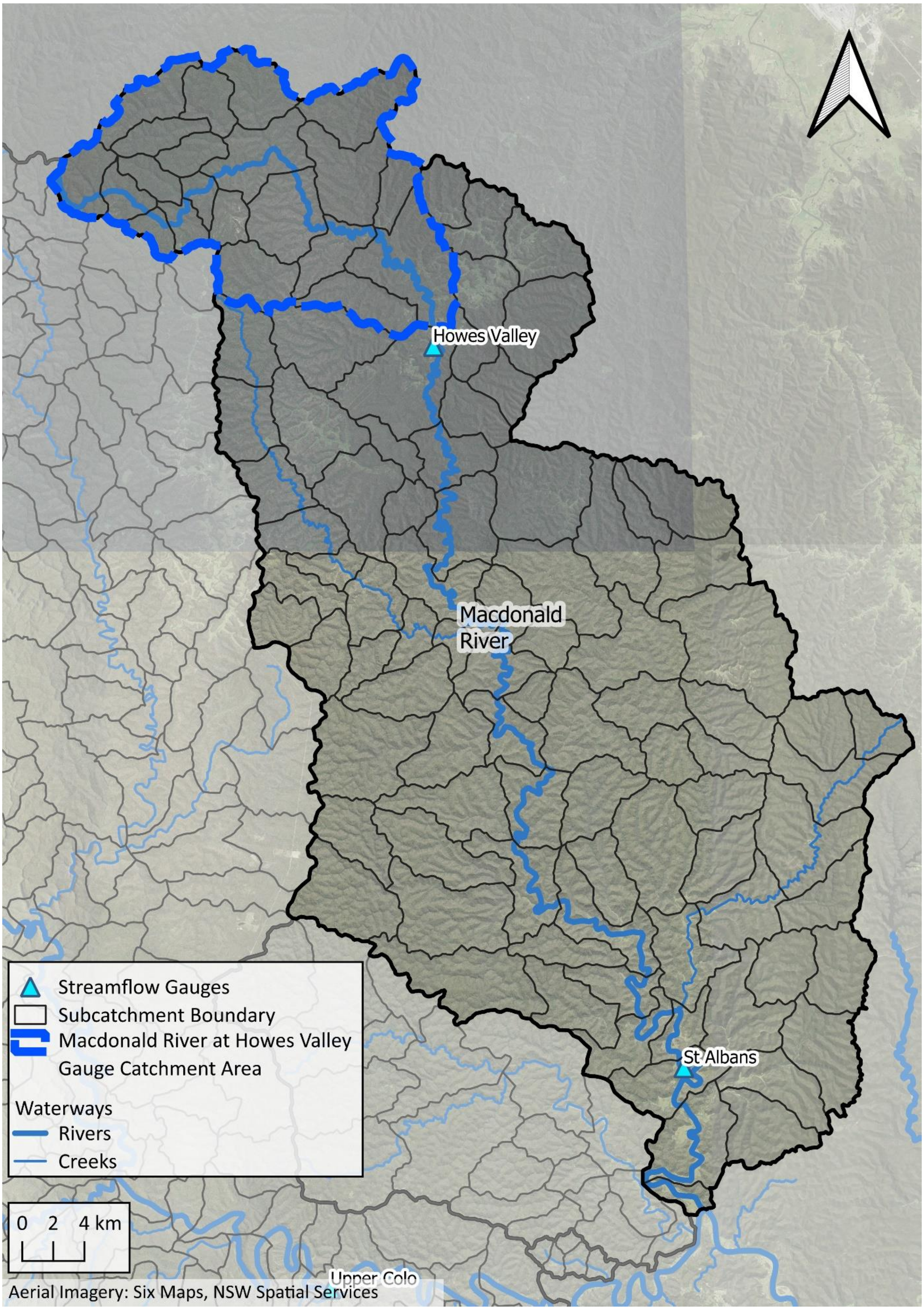


Figure 4-15 Macdonald River streamflow gauges and Howes Valley Gauge catchment area

Figure 4-16 Macdonald River near St Albans Gauge (top left – looking downstream at bridge, top right – looking upstream, approximately 300m upstream of bridge, bottom left – looking downstream of the bridge)

4.2.2.2 *Rainfall Losses*

The refinement of rainfall losses was undertaken to update the hydrological model calibration for the Macdonald River catchment. Initial and continuing loss combinations for the historical events were originally based on calibration losses used in the Hawkesbury-Nepean River Flood Study (2024). An iterative process which involved the testing of various initial and continuing loss combinations was undertaken to improve the match to historical streamflow gauge data. The result of this process found that the losses used in the Hawkesbury-Nepean River Flood Study (2024) provided a reasonable representation of the catchment behaviour for two out of four historical events (1978 and July 2022). Modifications were required for the 2020 and March 2022 event. For the 2020 event, the Macdonald River and Upper Macdonald River initial loss was changed to 205mm (from 185mm) and the continuing loss was changed to 1.9mm/hr (from 2.8mm/hr). For the March 2022 event, the Macdonald initial loss was changed to 110mm (from 80mm).

The adopted rainfall losses can be found in **Table 4-4**. These losses are much higher than the probability neutral burst losses from ARR Data Hub, particularly for the Macdonald River catchment which encompasses most of the total catchment (see **Figure 4-15**). For reference, the 5% AEP 72 hr probability neutral burst loss was 52.2mm for the Macdonald River. The ARR Data Hub losses were checked and found to be too low to provide a suitable match for the hydrological calibration at the St Albans gauge. The large difference in initial losses may be attributed to the long duration of the modelled rainfall events and associated antecedent moisture conditions associated with the calibration and validation events.

Table 4-8 Macdonald River hydrological calibration model rainfall losses

Catchment	Representative Gauge	1978		2020		March 2022		July 2022	
		IL	CL	IL	CL	IL	CL	IL	CL
Macdonald River – upper	Howes Valley	65	4	205	1.9	20	0	55	0
Macdonald River	St Albans	180	0.6	205	1.9	110	1	155	1.4

IL = Initial Loss (mm), CL = Continuing Loss (mm/hr)

4.2.2.3 Parameters

The adopted hydrological model inputs for the Macdonald River catchment are shown in **Table 4-9**.

Table 4-9 Macdonald River hydrological calibration model parameters

Parameter	Calibration Input
Rainfall Spatial Distribution	A total rainfall isohyet map was prepared for each event based on processed pluviograph and daily rainfall data from the Hawkesbury-Nepean River Flood Study (2024). These isohyets are the same isohyets adopted for the Colo River catchment. The isohyets and rainfall gauges used for each historical event are shown in **Figure 4-3** to **Figure 4-6**.
Temporal Pattern	The temporal pattern applied to the subcatchments in the model was adopted from the nearest pluviograph station. The stations used for each of the historical events are shown in **Figure 4-3** to **Figure 4-6**.
Runoff Routing (WBNM 'C' Parameter)	A 'C' parameter of 1.9 was adopted for each event, in line with the Hawkesbury-Nepean River Flood Study (2024).
Rainfall losses	Following an iterative process, variable rainfall losses were adopted across each calibration event. With the variance in catchment conditions between the Upper Macdonald River and Lower Macdonald River, adopted rainfall losses differed between the catchments. A summary of the rainfall losses adopted for each event is shown in **Table 4-8**

4.2.2.4 July 2022 Results

The July 2022 event was the largest of the calibrated events in the Macdonald River catchment. It reached a peak of approximately 1,100 m^3/s at the Macdonald River at St Albans gauge and was in the order of a 1 in 20 AEP event. The event occurred from 29th June till 7th July 2022.

The comparison of the WBNM flows and the St Albans gauge record is shown in **Figure 4-17** and the comparison for the Howes Valley gauge is presented in **Figure 4-18**.

The St Albans model hydrograph is a reasonable match for the peak flow timing with the gauged results from the July 2022 event. The peak flow itself was 28% higher than the gauged hydrograph and occurred in a rapid manner compared with the gauged record. However, this same effect is not observed in the TUFLOW hydraulic model, which may be better at representing the other routing characteristics upstream (Section 5.3).

The receding limb of the model hydrograph acted faster than the gauged hydrograph. However, in this event the Hawkesbury River at Wisemans Ferry was quite elevated and may have influenced the recession limb of the hydrograph. This is demonstrated in the better comparison between the TUFLOW model and the gauge in Section 5.3.

The modelled outputs for the Howes Valley gauge follow the shape of the gauged hydrograph well. In contrast to the St Albans gauge, the peak flow was an underestimate by 34% although it is noted that the flows are well above the maximum gauging, so there is a degree of uncertainty in the gauged flows at this level. The rate of rise and receding limb were closely matched.

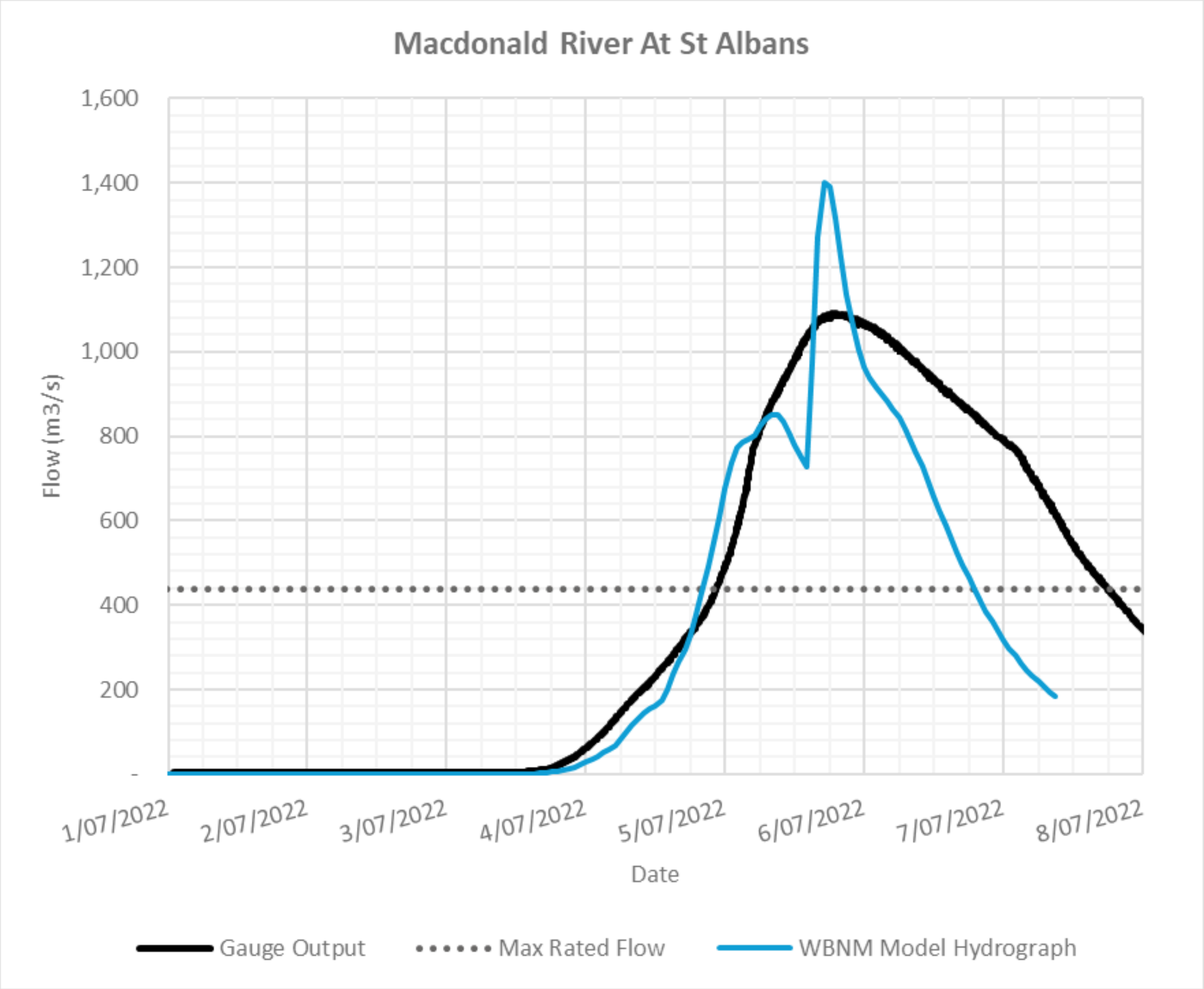


Figure 4-17 St Albans Gauge July-2022 calibration

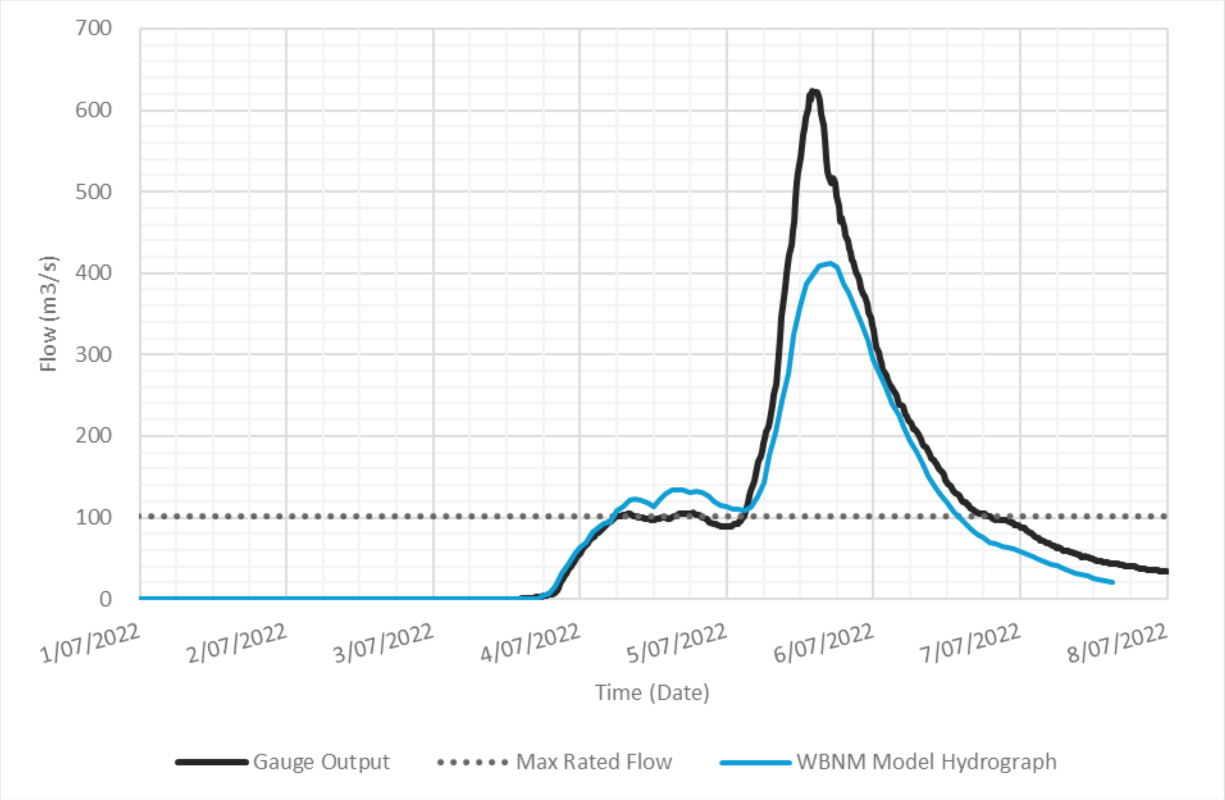


Figure 4-18 Howes Valley Gauge July-2022 calibration

4.2.2.5 *March 2022 Results*

The March 2022 event was approximately a 1 in 10 to 1 in 20 AEP flood event, reaching a peak of 900m^3/s at the Macdonald River at St Albans gauge. The flood event occurred from 25th February to 15th March 2022.

The comparison of the WBNM flows and the St Albans gauge record is shown in **Figure 4-19** and the comparison for the Howes Valley gauge is presented in **Figure 4-20**.

The peak flow and peak flow timing from the modelled hydrograph for the St Albans gauge was a reasonable match with the gauged record. The peak flow was lower by 9% and the timing was early by 4 hours. The model reflected the rate of rise very well. The sustained nature of the flooding was captured by the model, though a greater reduction in flows was witnessed over the course of the model run compared with the gauge data. The receding limb occurred early compared with the gauged record, but the rate of fall portrayed is similar.

While the model suggests that the volume of the event is underpredicted, the TUFLOW model results (Section 5.3), show that the modelled volume is a better fit (and potentially over-estimates).

The numerous peak flows and timings of the Howes Valley gauge record were suitably fitted by the modelled hydrograph. The 'spiky' nature of the gauged hydrograph was matched with modelled flows. The main differences arise from the increased flows early in the model run and decreased flows towards the end of the flood.

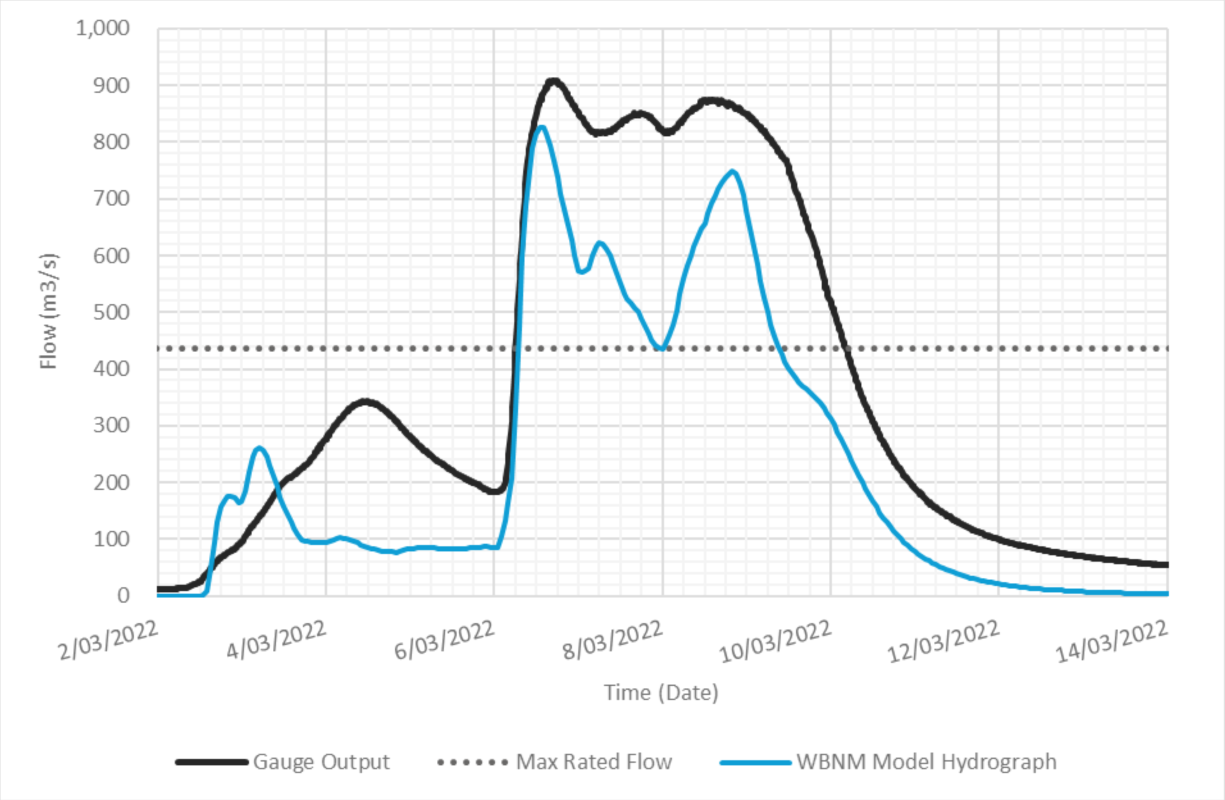


Figure 4-19 St Albans Gauge March-2022 calibration

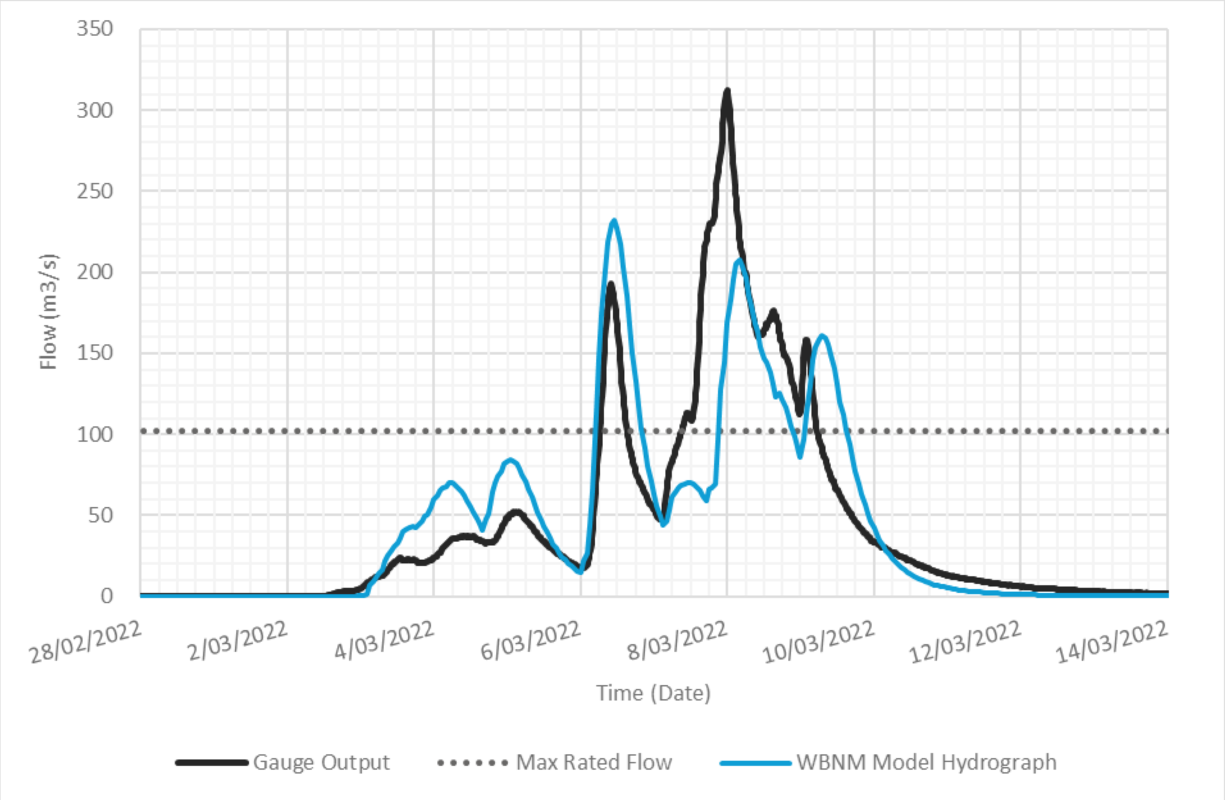


Figure 4-20 Howes Valley Gauge March-2022 calibration

4.2.2.6 2020 Results

The 2020 event commenced around the 5th of February and went through to 12th February 2020, reaching a peak of approximately 400 m^3/s at the Macdonald River at St Albans gauge. The event was estimated to be less than a 1 in 5 AEP event for the Macdonald River catchment.

The comparison of the WBNM flows and the St Albans gauge record is shown in **Figure 4-21**.

The general shape of the hydrograph reasonably matches the shape of the gauged record, with the rate of rise being similar, though the timing of the peak was early compared to the gauged record. While there is an underestimation of the volume for this event, this is not observed in the TUFLOW model calibration (Section 5.3).

The Howes Valley gauge did not provide suitable data for the 2020 calibration and the results of the calibration at the gauge were not considered.

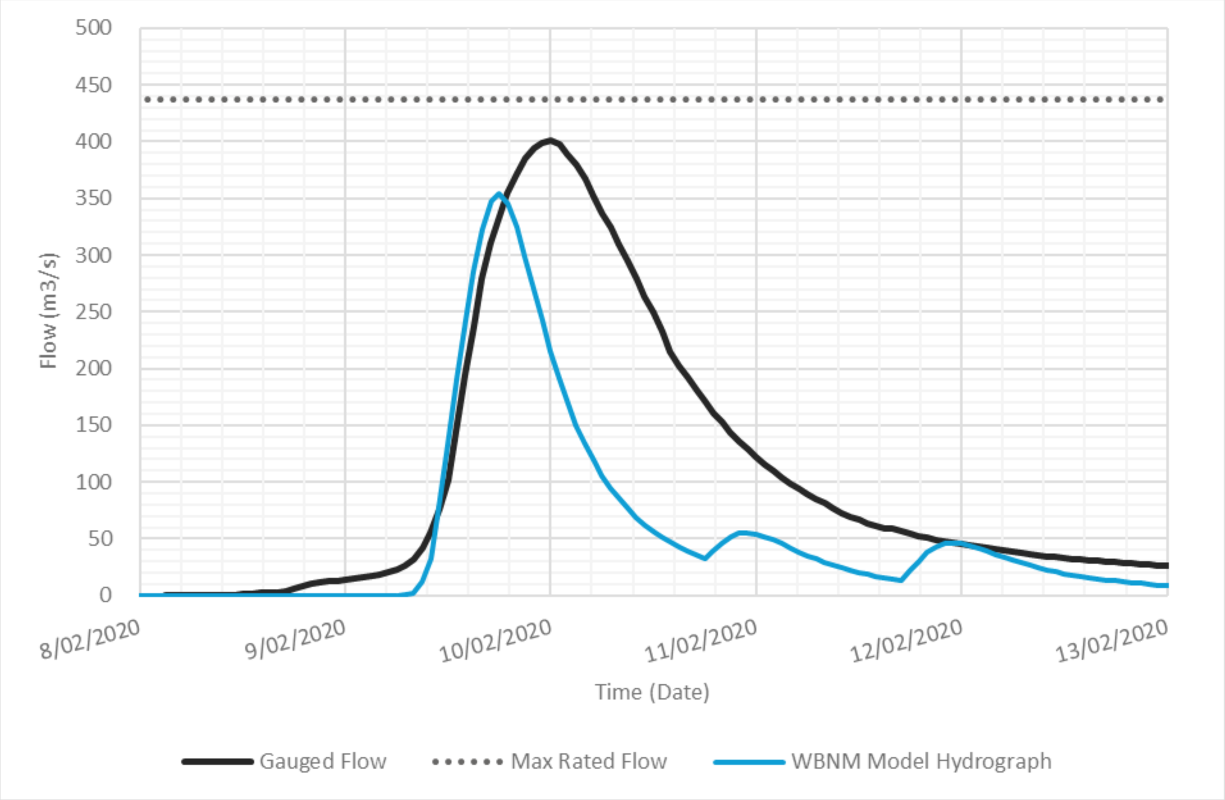


Figure 4-21 St Albans Gauge 2020 calibration

4.2.2.7 1978 Results

The 1978 event occurred from 17th March through to 27th March 1978, reaching a peak of roughly 930 m^3/s at the Macdonald River at St Albans gauge. The event was estimated to be between a 5% and 10% AEP event for the Macdonald catchment.

The comparison of the WBNM flows and the St Albans gauge record is shown in **Figure 4-22** and the comparison for the Howes Valley gauge is presented in **Figure 4-23**.

The peak flow and peak flow timing of the model matched very well with the St Albans gauge for the 1978 event. The rate of rise was similar to the gauged hydrograph, and the receding limb followed the shape of the hydrograph well, though responded faster compared with the gauged record.

The Howes Valley gauge also had a close fit for the peak flow and peak flow timing with the gauged record. The rate of rise was a close fit with the record, while the rate of fall was a good representation of the gauge.

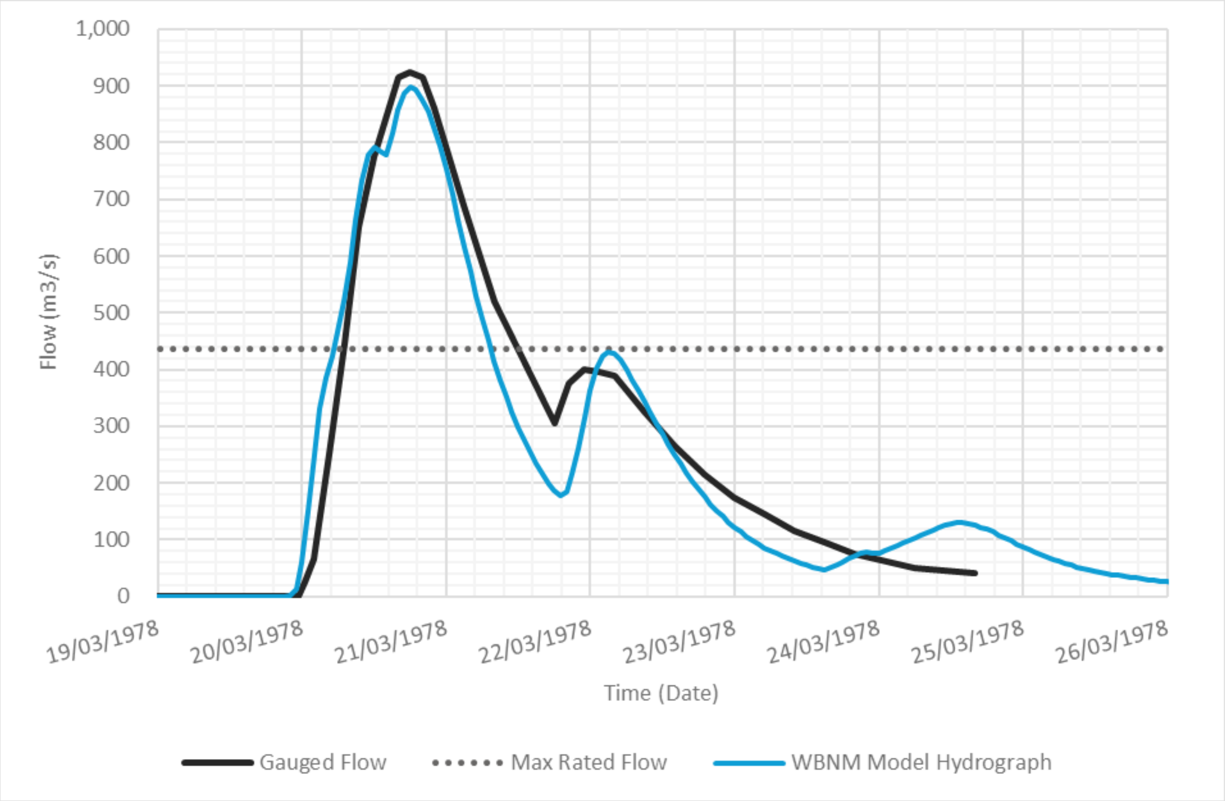


Figure 4-22 St Albans Gauge 1978 calibration

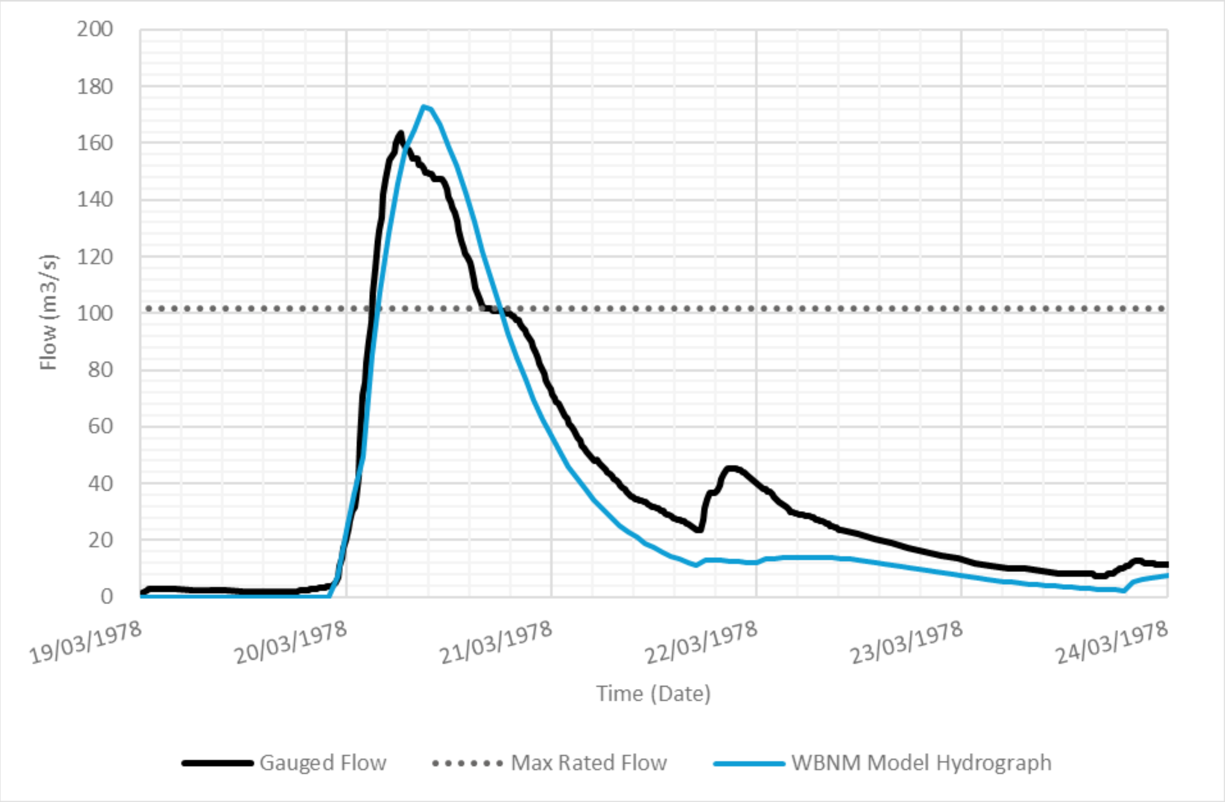


Figure 4-23 Howes Valley Gauge 1978 calibration

4.2.2.8 Calibration Outcome

The results of the above assessments indicated that the hydrological model is a reasonable representation of catchment hydrology. A summary of the peak flow differences is shown in **Table 4-10,** and a summary of the peak flow timing differences is shown in **Table 4-11.**

Table 4-10 Macdonald River catchment calibration peak flow difference summary

Catchment	Representative Gauge	1978 Peak flow difference	2020 Peak flow difference	March-2022 Peak flow difference	July-2022 Peak flow difference
Macdonald River	St Albans	-3%	-12%	-9%	28%
Macdonald River – upper	Howes Valley	6%	N/A	-34%	-34%

Table 4-11 Macdonald River catchment calibration peak flow timing difference summary

Catchment	Representative Gauge	1978 Peak flow timing difference (hr)	2020 Peak flow timing difference (hr)	March-2022 Peak flow timing difference (hr)	July-2022 Peak flow timing difference (hr)
Macdonald River	St Albans	0	-6	-4	-2
Macdonald River – upper	Howes Valley	3	N/A	4	3

A negative value refers to an early model and a positive value refers to a late model.

4.3 Flood Frequency Analysis

4.3.1 Colo River at Upper Colo FFA

A Flood Frequency Analysis (FFA) was completed for the Colo catchment using TUFLOW FLIKE. The annual maximum water level from the Upper Colo gauge was extracted and converted to a flow value using the AWACS (1997) rating curve. The use of the AWACS (1997) curve was based on the Colo River gauge review from **Section 3.3.3**. Annual maximum flows were estimated from a period spanning 134 years from 1889 to 2022.

The annual maximum flow time series used as the inputs for the Colo FFA are shown in **Figure 4-24** including threshold values.

For years where the water level or flow values were not known or highly uncertain, a threshold value was prescribed. The reasoning behind each threshold is as follows:

- >3830 m^3/s – Evidence from Rhelm CSS (2024) suggests the 1889 flood event exceeded the largest gauged flood event (1978) which had a gauge height water level of 19.2 m and a flow of 3830 m^3/s. The catchment was ungauged at the time of the event. Given the anecdotal nature of the estimate, this was included as a lower limit threshold value.
- >2000 m^3/s – The 1904 flood event was a large flood event with a flow exceedance estimate of roughly 2000m^3/s based on Rhelm CSS (2024). The catchment was ungauged at the time of the event. As the value is an estimate, a lower limit threshold was prescribed for the 1904 flood event.
- (<)2000 – For years between 1890 and 1908 (inclusive), the Upper Colo was ungauged resulting in large uncertainties regarding flow estimates for this period. The lack of historical records for these years suggests that another large flood event akin to the 1904 flood event did not occur during this time. Hence, an upper limit threshold of 2000 m^3/s was adopted for this duration.
- (<)500 – For the years 1934 to 1941, 1947 and 1960, gauge data was not available at the Upper Colo gauge. Given the lack of historical or anecdotal records during this time, it has been assumed that a large flood event did not occur during these years. As there is an increased likelihood in the fact a large flood event did not occur, an upper limit threshold of 500 m^3/s was adopted for this period.
- (<)103 – In addition to the other thresholds, FLIKE allows for the application of the Grubbs Beck test to the time series to identify Potentially Influential Low Flows. The application of the test identified 10 years with these low flows. Following guidance from Australian Rainfall and

Runoff (Ball et al, 2019), these flows were excluded from the series and represented with this threshold.

- (<)20 – For the years 1965, 1993, 1994 and 2006, a water level value was provided by the gauge but was too low for the applicability of the AWACS rating curve. For these years, a nominal upper limit threshold of 20m^3/s was prescribed.

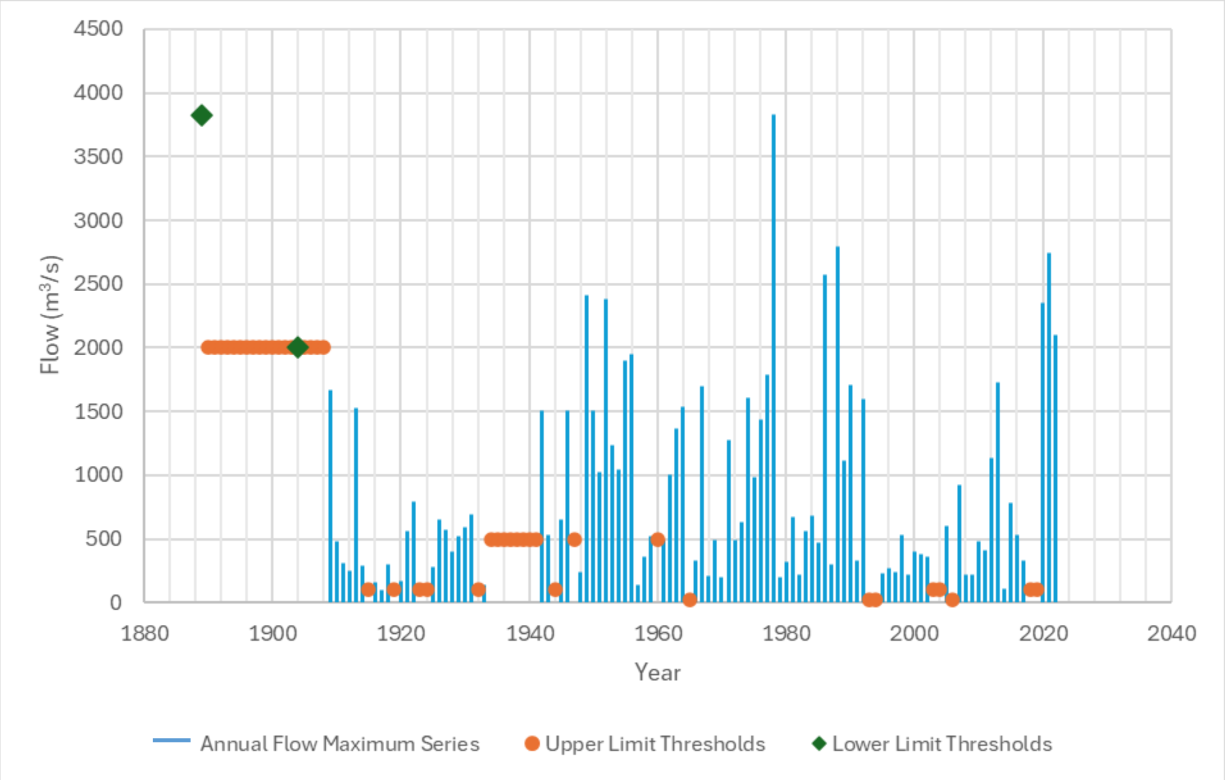


Figure 4-24 Colo River at Upper Colo Gauge annual maximum flow time series

With a Log-Pearson III probability model fit, the resultant flood frequency is shown in **Figure 4-25**. The curve expresses a close match to all the plotted points in the dataset, with all rarer record flows falling within the confidence limits. Caution should be applied with the application of the curve for events rarer than the 1 in 100 AEP.

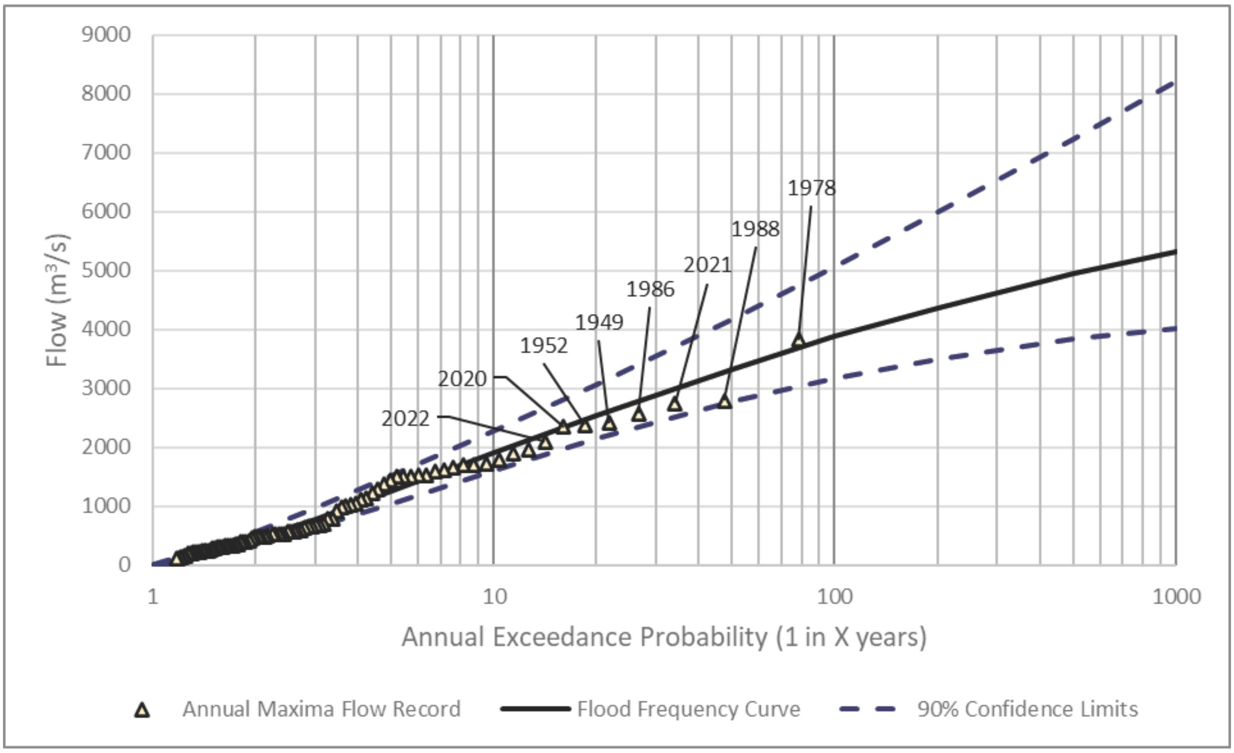


Figure 4-25 Colo River at Upper Colo flood frequency analysis

4.3.2 Macdonald River at St Albans FFA

As per the Colo catchment, the Flood Frequency Analysis (FFA) for the Macdonald River catchment used TUFLOW FLIKE. Flows were estimated for 156 years from 1867 to 2022 based on the reviewed rating curve adopted for this study (**See Section 3.3.3**).

For older events, the accuracy was treated with greater certainty than the Colo River catchment as historical records refer to specific locations near the gauge. Hence, the lower limit threshold approach for high flows used in the Colo FFA was not necessary for the Macdonald FFA.

The annual maximum flow time series and threshold values used as the inputs for the Macdonald River FFA are shown in **Figure 4-26**.

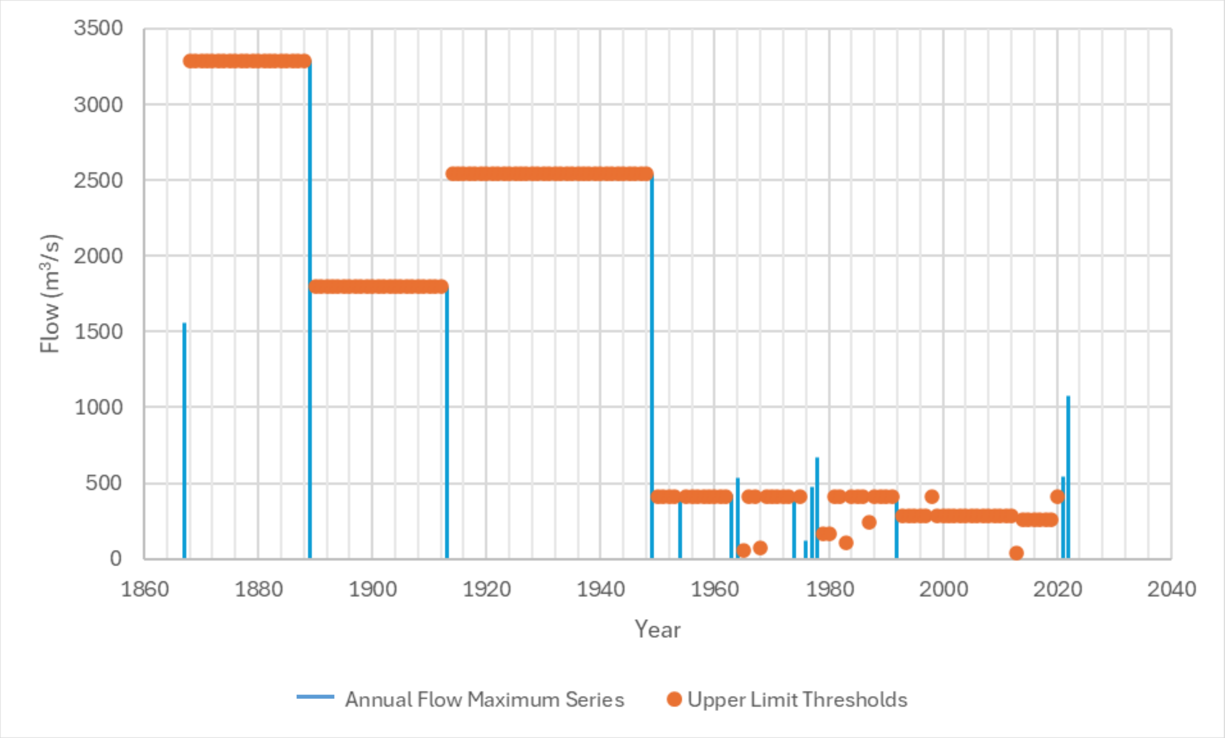


Figure 4-26 Macdonald River at St Albans Gauge annual maximum flow time series

Using a Log-Pearson III probability model fit, the flood frequency for the Macdonald River at St Albans is shown in **Figure 4-27**. The flood frequency curve is reasonable, and the plotted flow record is within the confidence limits for the events that were included in the FLIKE analysis. Given the nature of the thresholds applied, the match is an underestimate for the low flow records up to the 1 in 5-year AEP and the curve should be viewed with caution at this range. The application of the curve for events rarer than the 1 in 200 AEP should be treated with care.

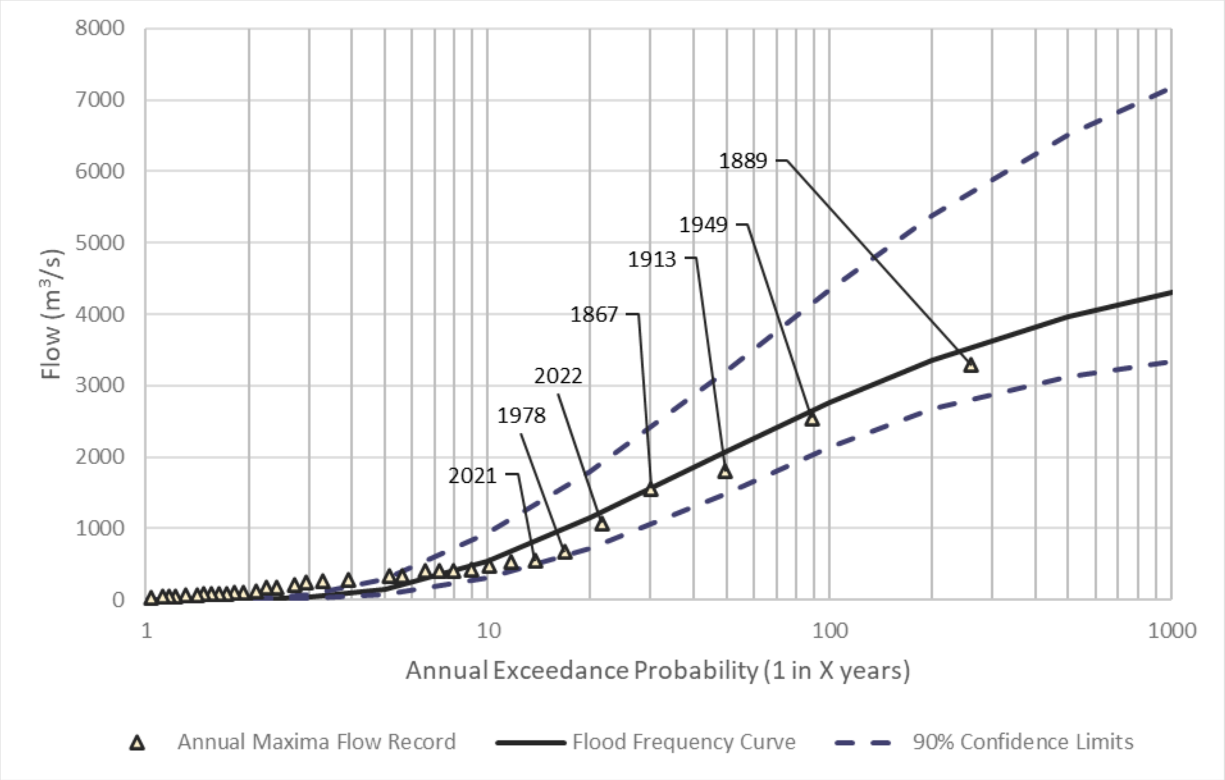


Figure 4-27 Macdonald River at St Albans flood frequency analysis

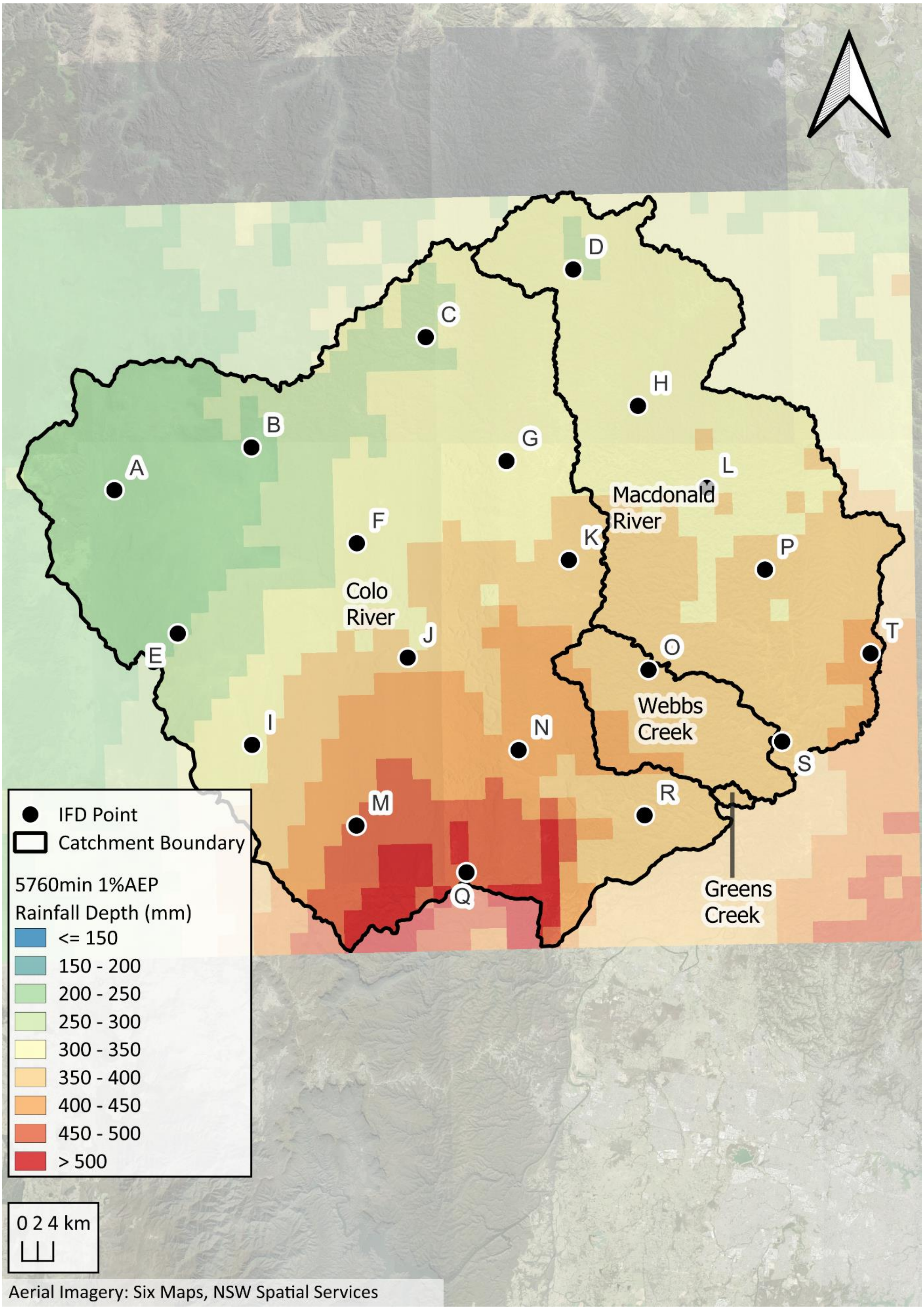
4.4 Hydrologic Design Modelling

Design hydrology for each of the four catchments was assessed using the Australian Rainfall and Runoff (Ball et al, 2019) guidelines and BOM IFD data.

To account for the spatial variation in rainfall across the catchments, 20 IFD Zones were selected across the four catchments. The IFD Zones with an example BoM IFD raster are shown in **Figure 4-28**. The zones were chosen based on the spatial variance exhibited by the BoM IFDs and were created to be evenly distributed across the four catchments. The rainfall information for each IFD Zone was applied to each subcatchment using the inverse distance weighting function of WBNM.

To ensure catchment-specific outcomes were met, the hydrology model was modified based on the information available for each catchment. In the case of the Colo and Macdonald River catchments, the completed flood frequency analyses (see **Section 4.3**) was used to inform the application of losses across design events. For the Greens and Webbs Creek catchments, the probability neutral burst losses from ARR (Ball et al, 2019) were used for the initial losses. For more information, refer to the catchment-specific sections below.

Whilst being catchment-specific, the four design hydrological models share common features as summarised in **Table 4-12**. The different features and outcomes of the design hydrological models are shown in the individual sections below.



Aerial Imagery: Six Maps, NSW Spatial Services

Figure 4-28 Design hydrology IFD zones with example BoM IFD event

Table 4-12 Design hydrological model input data

Parameter	Data Source
Subcatchment delineation	The subcatchments used for each model follow the same setup as shown in **Figure 4-1**. Note that the applicability of the model to a subcatchment is based on the underlying creek or river catchment. For example, the Macdonald hydrological model outputs should not be used to determine flow behaviour in a Colo River subcatchment.
Percentage impervious	The percentage impervious considerations for the design hydrology models are the same as described in **Table 4-2**.
Runoff Routing (WBNM 'C' Parameter)	A 'C' parameter of 1.55 was adopted for the Colo River catchment, and 1.9 was adopted for the Macdonald River and Webbs Creek catchments. For Greens Creek, a 'C' parameter of 1.9 was adopted. This follows the values used in the Hawkesbury-Nepean River Flood Study (2024) and the historical calibration process.
Rainfall Intensity-Frequency-Duration Information	Rainfall Intensity- Frequency- Duration (IFD) information is required in design hydrology to dictate the rainfall intensity to apply for a given AEP and storm duration. The information was sourced from BoM (2016). The IFDs were processed using the 20 points shown in **Figure 4-28**, and the WBNM inverse distance weighting function.

4.4.1 Colo River Design Modelling

The design hydrology modelling inputs that are specific to the Colo River are shown in **Table 4-13**.

Table 4-13 Colo River design hydrological model input data

Parameter	Design Model Input
Temporal Pattern	A series of ten areal temporal patterns with a reference area of 5000km^2 were assessed for the design event hydrology in the Colo River catchment. The ten temporal patterns assessed per event and duration were sourced from the ARR Data Hub (2016). The critical temporal pattern was the pattern which caused a peak flow closest to the mean peak flow (with a bias factor of 2 for patterns greater than the mean) for the Upper Colo gauge subcatchment.
Rainfall losses	Rainfall losses were formulated through an iterative process to match critical peak flows with the Colo River FFA reported in **Section 4.3.1**. Preliminary loss testing was originally undertaken in accordance using the loss hierarchy dictated by NSW Specific Data guidance from OEH (2019. The preliminary testing started with average calibration losses using a 110mm initial loss, and a 3mm/hr continuing loss. The average continuing loss (or near the average) was not used in any calibration event. A value of 3mm/hr was tested in place of the average. The design losses from the Hawkesbury-Nepean River Flood Study (2024) and the ARR Data Hub loss values (Probability Neutral Burst Loss with a 0.4 multiplication factor for the continuing loss) were also considered. The result of this preliminary testing is shown in **Figure 4-29**. From the preliminary results, the losses were found to be inadequate for a suitable match to the FFA. The losses from the Hawkesbury-Nepean River Flood Study were the closest match to the FFA and were used as a starting point for the iterative testing of various loss combinations. This process led to losses which differed by event and are shown in **Table 4-14**. It is noted that the trend of the continuing losses is increasing with AEP and is similar to the performance of proportional losses.

Parameter	Design Model Input
Areal reduction factors	Areal reduction factors were implemented using ARR2019. The factors were based on the following characteristics: • Region – SE Coast • Catchment Area – 4632km^2 • Duration – Differed based on the model run. • AEP – Differed based on the model run.
Probable Maximum Precipitation	The Generalised Southeast Australia Method (GSAM) was used to determine the Probable Maximum Precipitation (PMP) for the Colo River catchment. The GSAM parameters used to calculate the rainfall intensities were: • Moisture Adjustment Factor (Annual) – 0.91 • Moisture Adjustment Factor (Autumn) – 0.84 • Catchment-Average Topographical Adjustment Factor – 1.56 • Unfactored Rainfall Intensity – Uses rainfall intensities for catchments that are 4500km^2 or greater. The calculated rainfall intensities were used in conjunction with GSAM preburst and storm burst temporal pattern information for durations greater than and equal to 24 hours. The PMP model also differed in the following ways: • The spatial variance of rainfall was implemented by subcatchment-specific Topographical Adjustment Factors (TAF) which were added as a proportion of the catchment-average. For the variation of TAF across the catchment, see **Figure 4-30**. • The rainfall losses were: Initial Loss = 0 mm and Continuing Loss = 1mm/hr. This follows guidance from Australian Rainfall and Runoff (Ball et al, 2019). Based on this assessment, the critical duration of the PMP was determined to be 24 hours for the Colo River catchment.

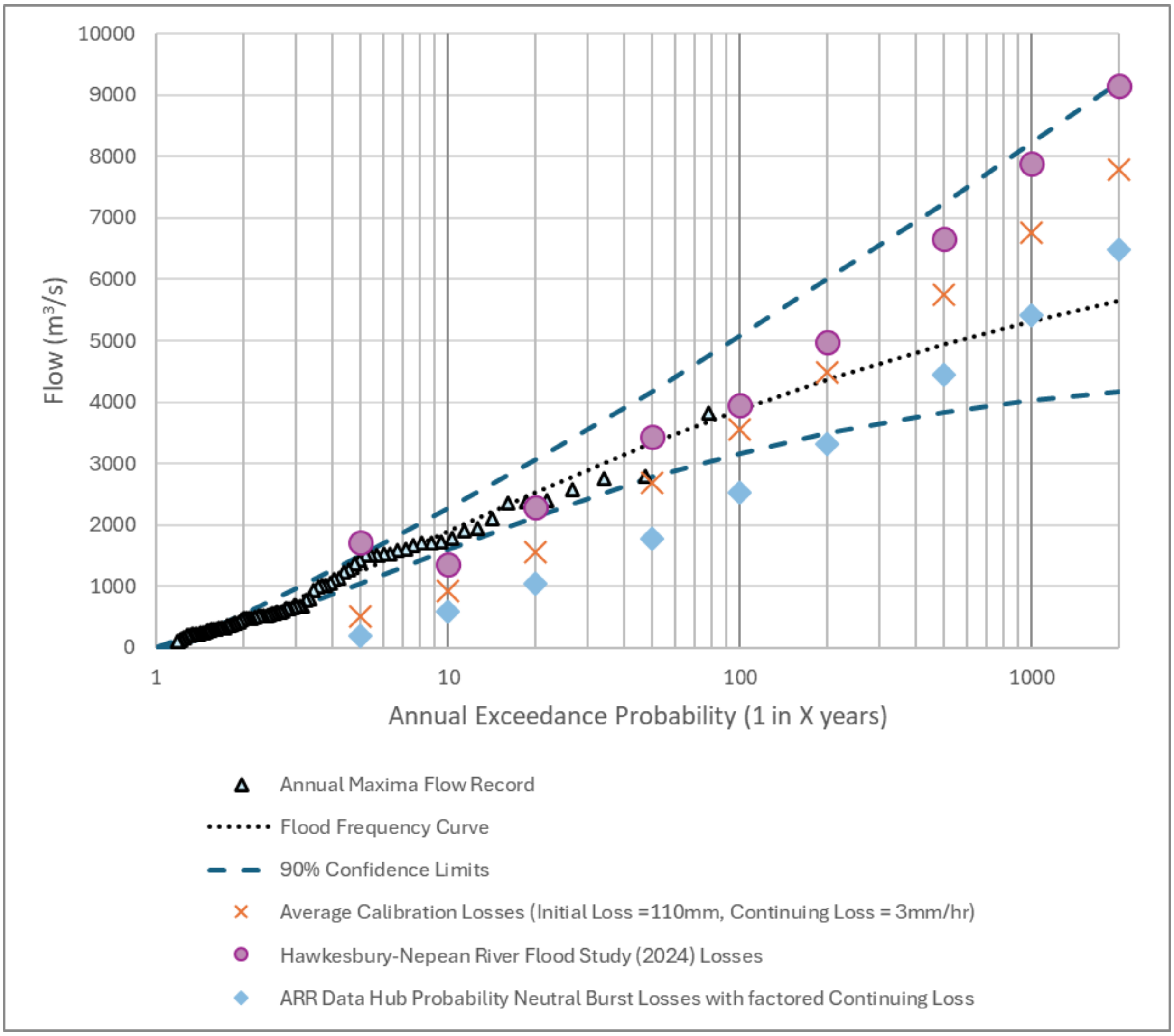


Figure 4-29 Upper Colo preliminary design model flow testing comparison with the FFA

Table 4-14 Colo River design rainfall losses

AEP	Initial Loss (mm)	Continuing Loss (mm/hr)
20% AEP	50	2.5
10% AEP	50	2.5
5% AEP	50	2.7
2% AEP	50	3
1% AEP	50	3
1 in 200	50	3
1 in 500	50	3
1 in 1000	50	3
1 in 2000	50	3
PMP	0	1

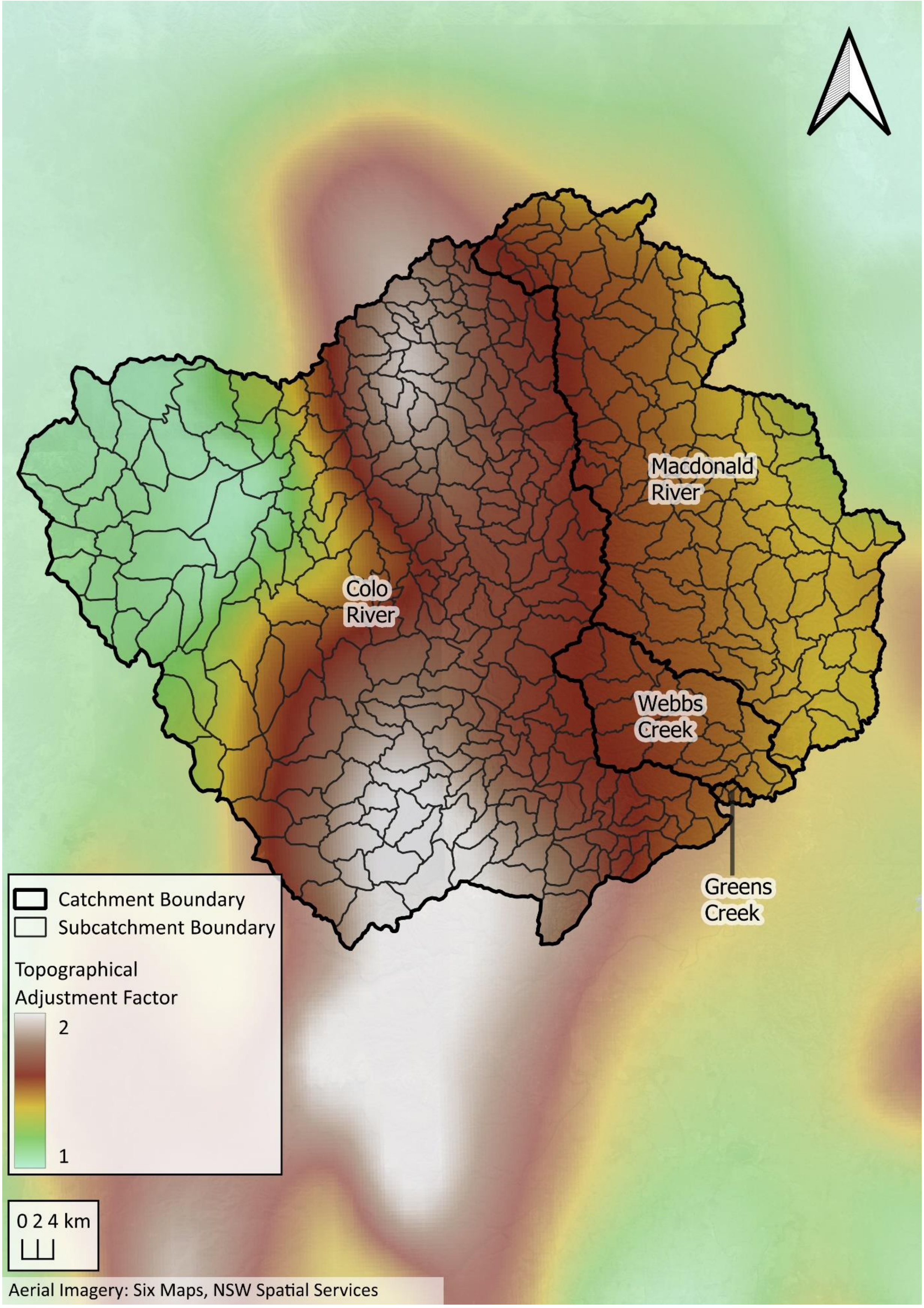


Figure 4-30 Topographical Adjustment Factor and GSAM rainfall spatial variance

Table 4-15 Colo River peak flow summary

AEP	Critical Duration at Upper Colo Gauge (hr)	Peak Flow at Upper Colo Gauge (m³/s)	Critical Duration at Outlet (hr)	Peak Flow at Outlet (m³/s)
20% AEP	96	1075	96	1120
10% AEP	96	1948	96	2073
5% AEP	96	2604	96	2770
2% AEP	96	3413	96	3641
1% AEP	96	3941	96	4157
1 in 200	96	4822	48	5292
1 in 500	48	6305	48	6753
1 in 1000	48	7846	48	8299
1 in 2000	48	9105	48	9641
PMP (GSAM)	24	43527	24	46167

A comparison of the design flows and the FFA at the upper Colo Gauge is provided in **Figure 4-31.** For the events ranging from a 1 in 5 AEP to a 1 in 200 AEP, the design events closely match the flood frequency curve. For the rarer events (1 in 500 to 1 in 2000 AEP), the design events are greater than the flood frequency curve, but within the confidence limits. It should be noted that there is a significant degree of uncertainty for design events greater than the 1 in 100 AEP at the Upper Colo gauge FFA.

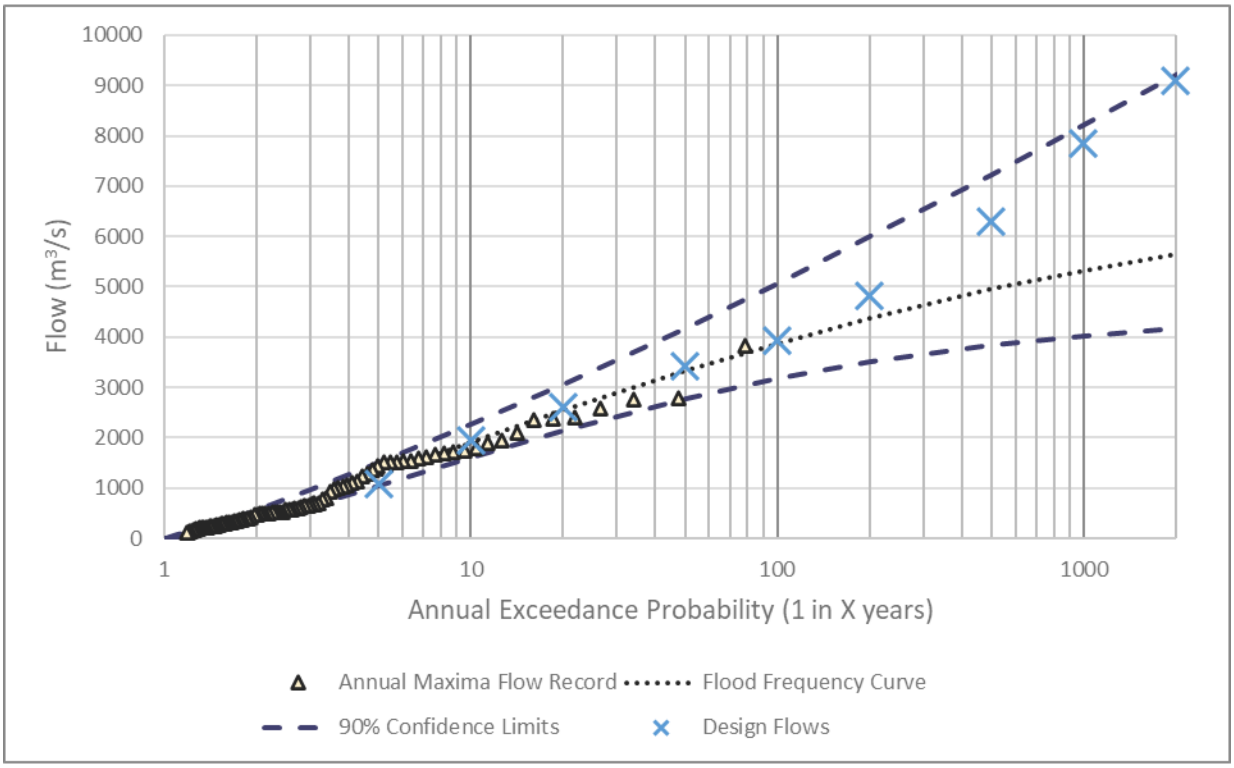


Figure 4-31 Upper Colo design model flow comparison with the FFA

4.4.2 Macdonald River Design Modelling

The design hydrology modelling inputs that are specific to the Macdonald River are shown in **Table 4-16**.

Table 4-16 Macdonald River design hydrological model input data

Parameter	Design Model Input
Temporal Pattern	Areal temporal patterns with a reference area of 2500km^2 were used for the Macdonald River catchment. Ten temporal patterns were assessed per event and duration. These were sourced from ARR Data Hub (2016). The critical temporal pattern was chosen as the pattern which caused a peak flow closest to the mean peak flow (with a bias factor of 2 for patterns greater than the mean) for the St Albans gauge subcatchment.
Rainfall losses	To match the Macdonald River FFA reported in **Section 4.3.2** with critical peak flows, an iterative process was used to determine rainfall losses. While the use of the Hawkesbury-Nepean River Flood Study (2024) losses as a starting point was envisioned akin to the Colo River testing (see **Table 4-13)**, the trend of increasing continuing losses for increased rainfall intensity was not reflected when fitting the FFA. In fact, the opposite was shown to be true after testing a single initial and continuing loss combination reflective of calibration testing (100mm initial loss with a 1.5mm/hr continuing loss). Further testing showed that both initial and continuing loss would require adapting to ensure that reasonable loss values can provide a suitable match with the FFA. Consistent with the Colo River testing, iteration was used to determine design rainfall losses. Using the calibration continuing losses (0.6-1.9mm/hr) and the Probability Neutral Burst losses (20-50mm) as a starting range, the match to the FFA was refined. A higher continuing loss than the initial range was required for frequent events. Some of the tested combinations are shown in **Figure 4-32**. The final losses differed by event and are shown in **Table 4-17**.
Areal reduction factors	Areal reduction factors were implemented based on the catchment characteristics. The factors were: • Region – SE Coast • Catchment Area – 1915km^2 • Duration – Differed based on the model run. • AEP – Differed based on the model run.

Parameter	Design Model Input
Probable Maximum Precipitation	The Generalised Southeast Australia Method (GSAM) was used to determine the Probable Maximum Precipitation (PMP) for the Macdonald River catchment. The GSAM parameters used to calculate the rainfall intensities were: • Moisture Adjustment Factor (Annual) – 0.92 • Moisture Adjustment Factor (Autumn) – 0.85 • Catchment-Average Topographical Adjustment Factor – 1.48 • Unfactored Rainfall Intensity – Linearly interpolated between rainfall intensities for catchments that are 1500km^2 and 2000km^2. The calculated rainfall intensities were used in conjunction with GSAM preburst and storm burst temporal pattern information for durations greater than and equal to 24 hours. The PMP model also differed in the following ways: • The spatial variance of rainfall was implemented by subcatchment-specific Topographical Adjustment Factors (TAF) which were added as a proportion of the catchment-average. The variation of the TAF across the catchment is shown in **Figure 4-30**. • The rainfall losses were: Initial Loss = 0 mm and Continuing Loss = 1mm/hr. This follows guidance from Australian Rainfall and Runoff (Ba;; et al, 2019). Based on this assessment, the critical duration of the PMP was determined to be 24 hours for the Macdonald River catchment.

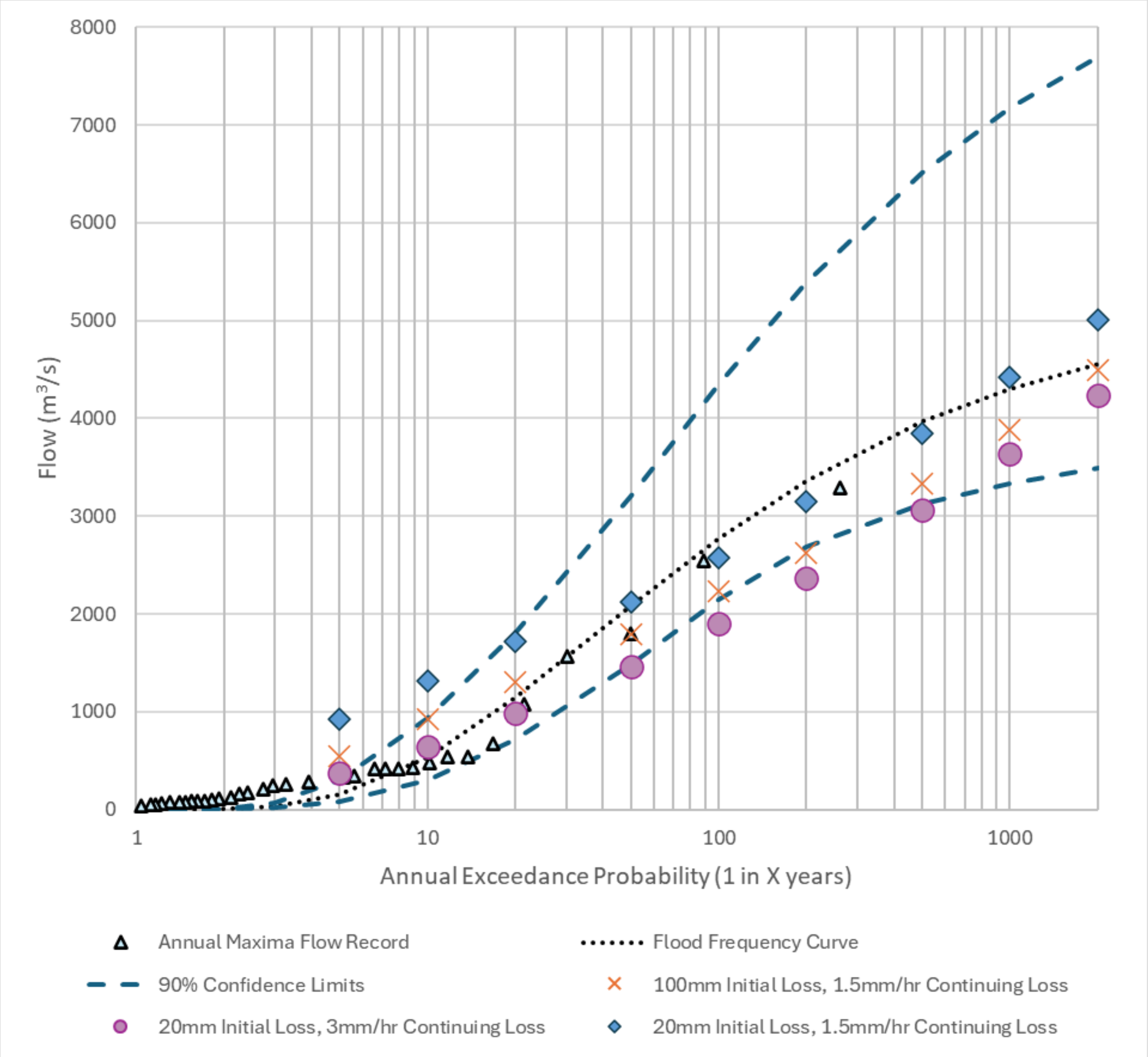


Figure 4-32 St Albans preliminary design model flow testing comparison with the FFA

Table 4-17 Macdonald River design rainfall losses

AEP	Initial Loss (mm)	Continuing Loss (mm/hr)
20% AEP	50	3
10% AEP	50	3
5% AEP	50	2.5
2% AEP	20	1.5
1% AEP	20	1.5
1 in 200	20	1.5
1 in 500	20	1.5
1 in 1000	20	1.5
1 in 2000	20	1.5
PMP	0	1

Table 4-18 Macdonald River peak flow summary

AEP	Critical Duration at St Albans Gauge (hr)	Peak Flow at St Albans Gauge (m^3/s)	Critical Duration at Outlet (hr)	Peak Flow at Outlet (m^3/s)
20% AEP	96	336	96	366
10% AEP	96	474	96	512
5% AEP	96	1044	96	1106
2% AEP	48	2105	48	2279
1% AEP	24	2555	48	2770
1 in 200	48	3134	48	3409
1 in 500	36	3828	48	4199
1 in 1000	36	4397	36	4812
1 in 2000	36	4992	36	5469
PMP (GSAM)	24	18280	24	19661

A comparison of the design flows and the FFA at the At Albans Gauge is provided in **Figure 4-33.** The design events generally match closely to the flood frequency curve. The 1 in 5 AEP design flows are slightly overestimated when compared to the frequency curve, however the estimate is within the confidence limits.

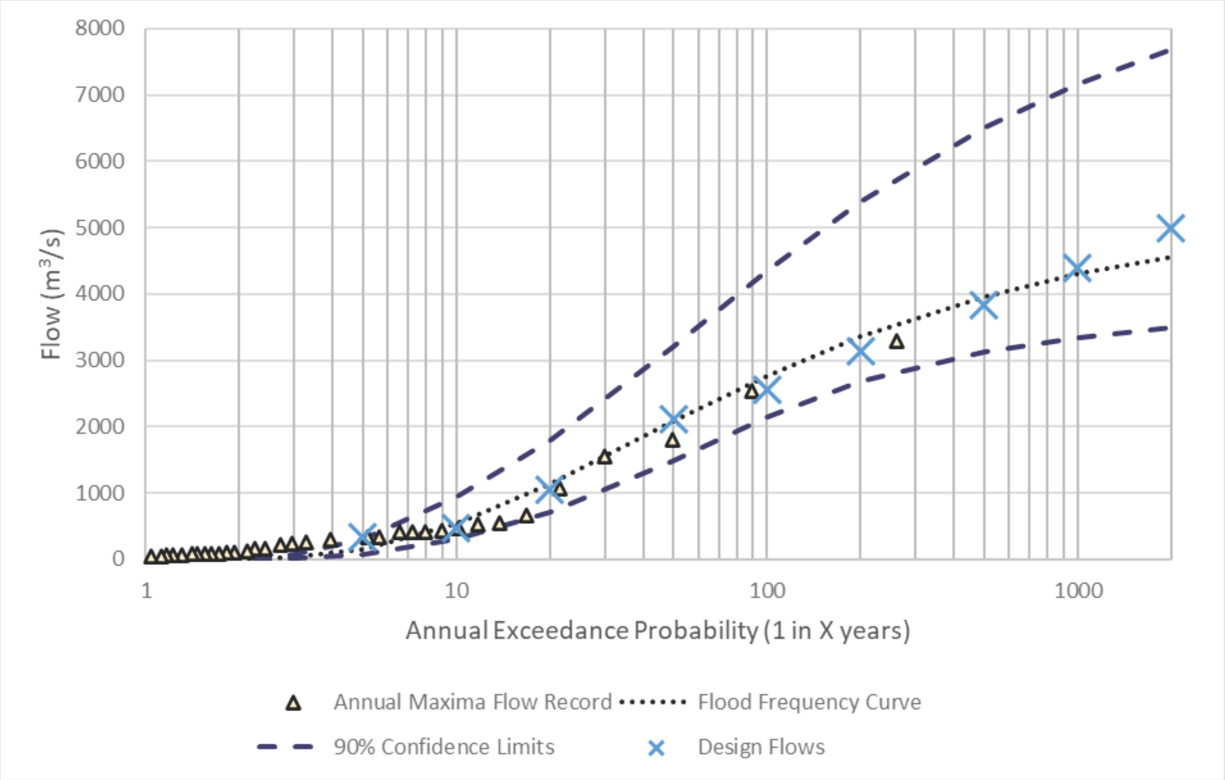


Figure 4-33 St Albans design model flow comparison with the FFA

4.4.3 Greens Creek Design Modelling

The design hydrology modelling inputs that are specific to the Greens Creek are shown in **Table 4-19**.

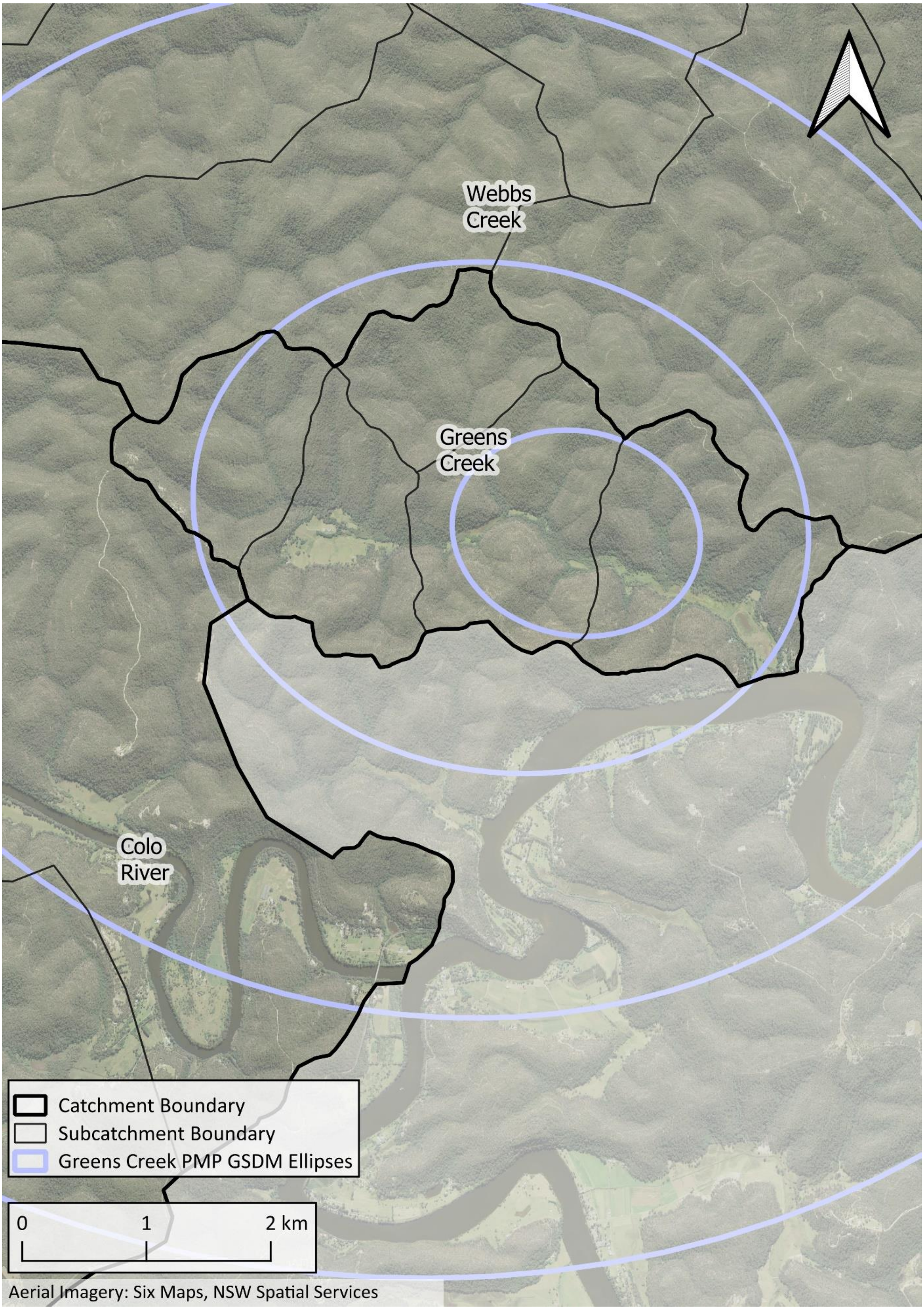
Table 4-19 Greens Creek design hydrological model input data

Parameter	Design Model Input
Temporal Pattern	The Greens Creek catchment size of 11 km^2 resulted in a series of point temporal patterns being used. A suite of ten temporal patterns were assessed per event and duration. These were sourced from ARR Data Hub. The critical temporal pattern was the one which caused a peak flow closest to the mean peak flow (with a bias factor of 2 for patterns greater than the mean) for the downstream end of the Greens Creek catchment.
Rainfall losses	The initial losses for the Greens Creek catchment used probability neutral burst losses from the ARR Data Hub. For the continuing loss, values were adopted in line with the Macdonald River catchment. See **Table 4-20** for these values.
Areal reduction factors	Areal reduction factors were implemented based on the current factors: • Region – SE Coast • Catchment Area – 11km^2 • Duration – Differed based on the model run. • AEP – Differed based on the model run

Parameter	Design Model Input
Probable Maximum Precipitation	The Generalised Short-Duration Method (GSDM) was used to determine the Probable Maximum Precipitation (PMP) for the Greens Creek catchment. The GSDM parameters used to calculate the rainfall intensities were: • Elevation Adjustment Factor – 1.0 • Moisture Adjustment Factor – 0.70 • Catchment Roughness – 100% Rough, 0% Smooth • Unfactored Rainfall Intensity – Determined using Depth-Duration-Area curves in the GSDM guidance or a table of values if a PMP ellipse was fully encompassed by the Greens Creek catchment. Rainfall intensities were calculated for each GSDM ellipse that affects the Greens Creek catchment. The placement of the GSDM ellipses over the Greens Creek catchment is shown in **Figure 4-34**. The calculated rainfall intensities were used in conjunction with GSDM storm burst temporal pattern information for a range of durations from 15 minutes to 6 hours. The PMP model also differed in the following ways: • The spatial variance of rainfall was implemented by ascribing subcatchments to a relevant GSDM ellipse using the location of the subcatchment centroid. • The rainfall losses were: Initial Loss = 0 mm and Continuing Loss = 1mm/hr. This follows guidance from Australian Rainfall and Runoff (2019). Based on this assessment, the critical duration of the PMP was determined to be 3 hours for the Greens Creek catchment.

Table 4-20 Greens Creek design rainfall losses

AEP	Initial Loss (mm)	Continuing Loss (mm/hr)
20% AEP	Probability Neutral Burst Loss	3
10% AEP	Probability Neutral Burst Loss	3
5% AEP	Probability Neutral Burst Loss	2.5
2% AEP	Probability Neutral Burst Loss	1.5
1% AEP	Probability Neutral Burst Loss	1.5
1 in 200	Probability Neutral Burst Loss	1.5
1 in 500	Probability Neutral Burst Loss	1.5
1 in 1000	Probability Neutral Burst Loss	1.5
1 in 2000	Probability Neutral Burst Loss	1.5
PMP	0	1



Aerial Imagery: Six Maps, NSW Spatial Services

Figure 4-34 Greens Creek PMF GSDM ellipses

Table 4-21 Greens Creek peak flow summary

AEP	Critical Duration (hr)	Peak Flow at Outlet (m^3/s)
20% AEP	9	13
10% AEP	9	20
5% AEP	6	27
2% AEP	12	41
1% AEP	12	49
1 in 200	12	54
1 in 500	12	63
1 in 1000	12	69
1 in 2000	12	76
PMP (GSDM)	3	556

4.4.4 Webbs Creek Design Modelling (exc. PMP)

The design hydrology modelling inputs that are specific to the Webbs Creek are shown in **Table 4-22**.

Table 4-22 Webbs Creek design hydrological model input data

Parameter	Design Model Input
Temporal Pattern	Areal temporal patterns with a reference area of 500km^2 were used for the Webbs Creek catchment. Ten temporal patterns were assessed per event and duration. These were sourced from ARR Data Hub. From the ten temporal patterns, the critical pattern based on which pattern caused a peak flow closest to the mean peak flow (with a bias factor of 2 for patterns greater than the mean) for the downstream end of the Webbs Creek catchment.
Rainfall losses	The initial losses for the Webbs Creek catchment used probability neutral burst losses from the ARR Data Hub. For the continuing loss, values were adopted in line with the Macdonald River catchment. See **Table 4-23** for these values.
Areal reduction factors	Areal reduction factors were implemented based on the following characteristics: • Region – SE Coast • Catchment Area – 360km^2 • Duration – Differed based on the model run. • AEP – Differed based on the model run.
Probable Maximum Precipitation	The Webbs Creek catchment was different to the other catchments as the GSAM and GSDM approaches were both assessed given the intermediate catchment size. Further details regarding the Webbs Creek PMP estimate are provided below.

Table 4-23 Webbs Creek design rainfall losses

AEP	Initial Loss (mm)	Continuing Loss (mm/hr)
20% AEP	Probability Neutral Burst Loss	3
10% AEP	Probability Neutral Burst Loss	3
5% AEP	Probability Neutral Burst Loss	2.5
2% AEP	Probability Neutral Burst Loss	1.5
1% AEP	Probability Neutral Burst Loss	1.5

AEP	Initial Loss (mm)	Continuing Loss (mm/hr)
1 in 200	Probability Neutral Burst Loss	1.5
1 in 500	Probability Neutral Burst Loss	1.5
1 in 1000	Probability Neutral Burst Loss	1.5
1 in 2000	Probability Neutral Burst Loss	1.5
PMP	0	1

Table 4-24 Webbs Creek peak flow summary

AEP	Critical Duration (hr)	Peak Flow at Outlet (m^3/s)
20% AEP	24	147
10% AEP	24	254
5% AEP	24	403
2% AEP	24	660
1% AEP	24	809
1 in 200	24	908
1 in 500	24	1085
1 in 1000	24	1224
1 in 2000	24	1368
PMP (GSAM and GSDM)	12	7399

Webbs Creek PMP Design Modelling

The Webbs Creek PMP Model involved both the GSAM and GSDM approaches for PMP estimation. The process used is detailed below.

GSAM

GSAM was used for durations greater than or equal to 24 hours, while GSDM was used for durations less than or equal to 6 hours.

The GSAM parameters used to calculate rainfall intensities were:

- Moisture Adjustment Factor (Annual) – 0.91
- Moisture Adjustment Factor (Autumn) – 0.85
- Catchment-Average Topographical Adjustment Factor – 1.55
- Unfactored Rainfall Intensity – Uses rainfall intensities for catchments that are 350km^2.

The calculated rainfall intensities were used in conjunction with GSAM preburst and storm burst temporal pattern information for durations from 24 hours to 96 hours.

The GSAM PMP estimate also considered:

- The spatial variance of rainfall through subcatchment-specific Topographical Adjustment Factors (TAF) which were added as a proportion of the catchment-average. The variation of the TAF across the catchment is shown in **Figure 4-30**.

- The rainfall losses were: Initial Loss = 0 mm and Continuing Loss = 1mm/hr. This follows guidance from Australian Rainfall and Runoff (Ball et al, 2019).

GSDM

The GSDM parameters used to calculate the rainfall intensities were:

- Elevation Adjustment Factor – 1.0
- Moisture Adjustment Factor – 0.70
- Catchment Roughness – 100% Rough, 0% Smooth
- Unfactored Rainfall Intensity – Determined using Depth-Duration-Area curves in the GSDM guidance or a table of values if a PMP ellipse was fully encompassed by the Webbs Creek catchment.

Rainfall intensities were calculated for each GSDM ellipse that affects the Webbs Creek catchment. The placement of the GSDM ellipses over the Webbs Creek catchment is shown in **Figure 4-35**.

The calculated rainfall intensities were used in conjunction with GSDM storm burst temporal pattern information for a range of durations from 15 minutes to 6 hours.

The rainfall losses were: Initial Loss = 0 mm and Continuing Loss = 1mm/hr. This follows guidance from Australian Rainfall and Runoff (Ball et al, 2019).

12-hour duration

It is important to note that 12-hour duration storms are not explicitly covered by either GSAM or GSDM approaches, though guidance is provided.

For Webbs Creek, the 12-hour rainfall intensity was interpolated between the 24-hour GSAM and 6 hour GSDM intensities as per the guidance from BoM (2006). The spatial variation of the 12-hour event followed the GSAM approach with the factoring of the TAF for each subcatchment.

Result

With the approach outlined above, the 12-hour PMP storm was found to be the critical duration.

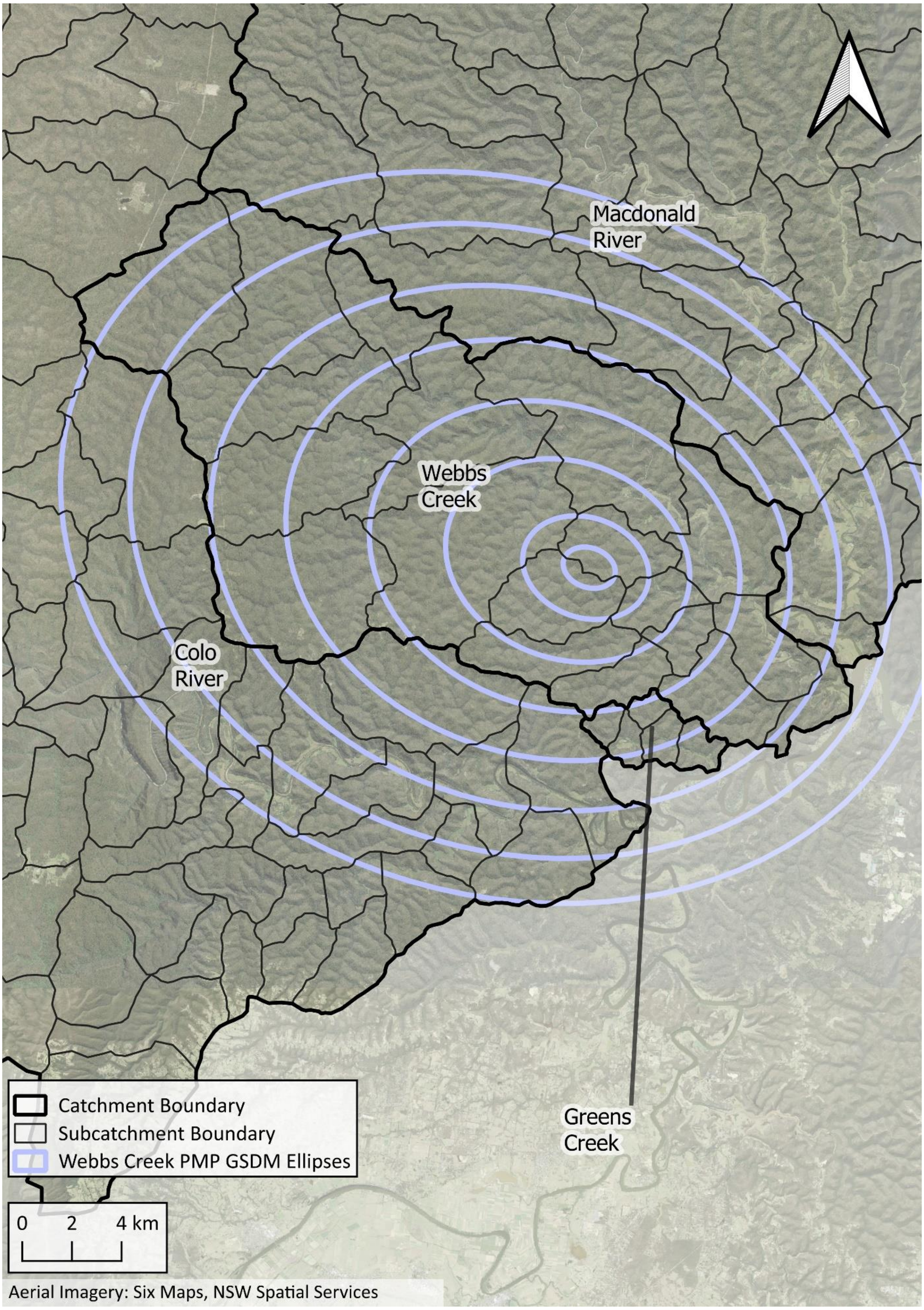


Figure 4-35 Webbs Creek PMF GSDM ellipses

4.5 Other Considerations

A review of the historic flood events used for the calibration, together with those reported in Rhelm CSS (2024), shows that rainfall is generally more intense on the eastern half of the Colo catchment, compared with the western half and in particular, the Capertee catchment. As noted in the calibration discussion (**Section 4.2.1**), often the flows in the Capertee catchment represented less than 5% of the flows at the Upper Colo gauge.

The areal reduction factors are intended to account for some of this effect, whereby in larger catchments it is unlikely to get the same intensity rainfall across the entirely of the catchment. However, in this case, there is likely a bias toward the eastern part of the catchment for events that cause larger flows at Upper Colo.

An indicative correlation analysis was undertaken for recorded events for Capertee River at Glen Davis versus the Colo River at Upper Colo, as shown in **Figure 4-36**. While the flood frequency is indicative for Glen Davis, it shows that there is relatively low correlation between large events in the Colo River versus large events in Glen Davis. This supports the historic calibration observations, showing low flow contributions in some events from Glen Davis.

On this basis, the traditional areal reduction factors may not be as capable of representing an appropriate design rainfall. A more complex Monte Carlo analysis (beyond the scope of this study) that considered various spatial patterns of rainfall may provide additional nuance.

For this study, the increasing continuing losses that have been adopted may be a result of this uneven distribution of rainfall.

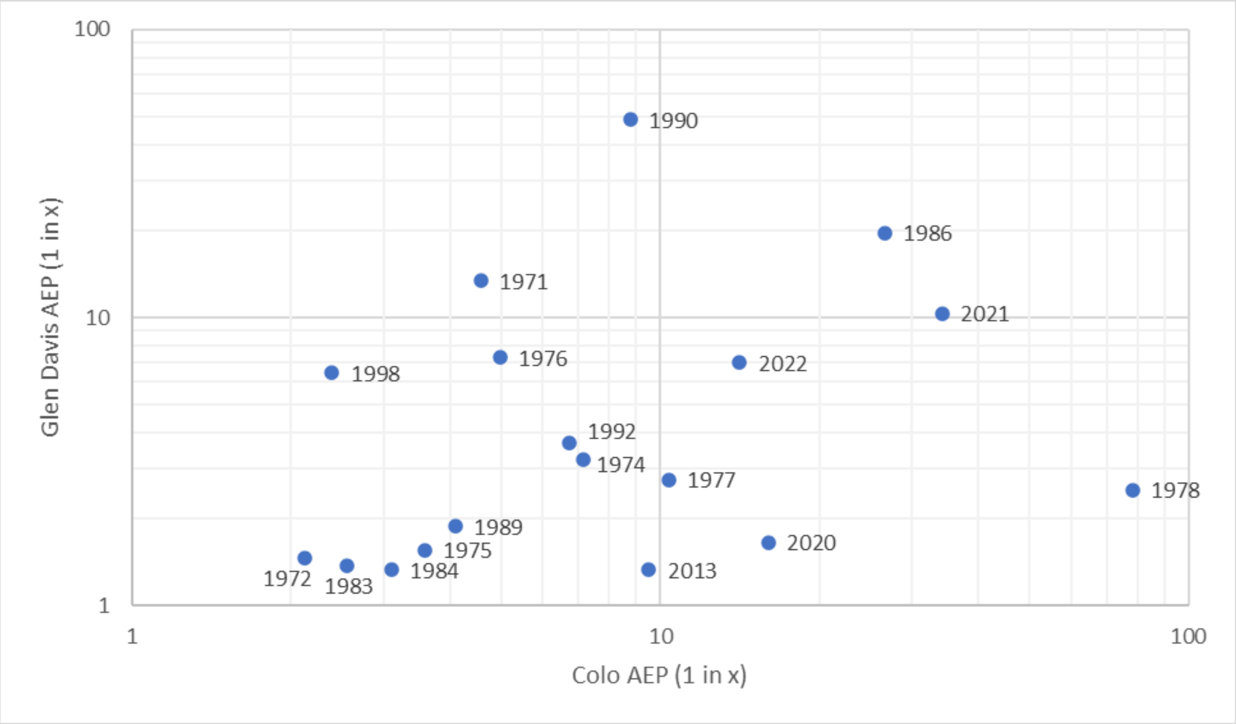


Figure 4-36 Indicative Correlation between Glen Davis and Upper Colo Gauge

5 Hydraulic Model

This section details the 2D hydraulic model build, calibration and design event modelling,

5.1 Model Setup

5.1.1 Model Extent

Each of the four watercourses (Colo River, Greens Creek, Webbs Creek and Macdonald River) were represented by an individual TUFLOW model. The extent of each model in relation to each other is shown in **Figure 5-1.** A more detailed view of each TUFLOW model layout is also provided in:

- Colo River: **Figure 5-2**
- Greens Creek: **Figure 5-3**
- Webbs Creek: **Figure 5-4**
- Macdonald River: **Figure 5-5**

As the focus of the study involves the more populated areas of each catchment, the TUFLOW model extents are focussed on the downstream end of each catchment. The exception is Greens Creek, where the TUFLOW model extent covers almost the entire catchment.

As shown in **Figure 5-2** to **Figure 5-5**, the downstream boundary of each model is placed at the Hawkesbury River junction. Although emphasis is placed on investigating mainstream flood behaviour for the main waterways within each catchment, inclusion of the model boundary at this location allows the impact of coincidental Hawkesbury River flooding to be considered.

Preliminary simulations were completed to confirm that the extent of each model was sufficient to cater for backwater storage along the various tributary catchment draining into each main watercourse.

5.1.2 Grid size and Topography

The TUFLOW software uses a grid to define the spatial variation in topography and hydraulic properties (e.g., ground elevations and hydraulic roughness) across the model area. As a result, the choice of grid size can have a significant impact on the performance of the model. In general, a smaller grid size will provide a more detailed and reliable representation of flood behaviour relative to a larger grid size. However, a smaller grid size will take longer to perform all the necessary hydraulic calculations. Therefore, it is typically necessary to select a grid size that makes an appropriate compromise between the level of detail provided by the model and the associated computational time required. A grid size of 10 metres was ultimately adopted for each model area and was considered to provide a reasonable compromise between detail and simulation time.

In addition, a TUFLOW feature called sub-grid sampling (SGS) was employed as part of the model setup. When SGS is employed, TUFLOW will calculate water level versus storage volume relationships based on a more detailed underlying terrain representation rather than relying on a single elevation at the centre of the grid cell. Similarly, TUFLOW will calculate water level versus discharge relationships across each cell side based on the more detailed terrain rather than relying on the elevation at the midpoint of each cell to control when water moves from one cell to the next. This feature allows storage and conveyance to be represented in more detail than would have otherwise been allowed. The 1 metre DEM derived from the LiDAR described in **Section 3.2.1** was used for this purpose.

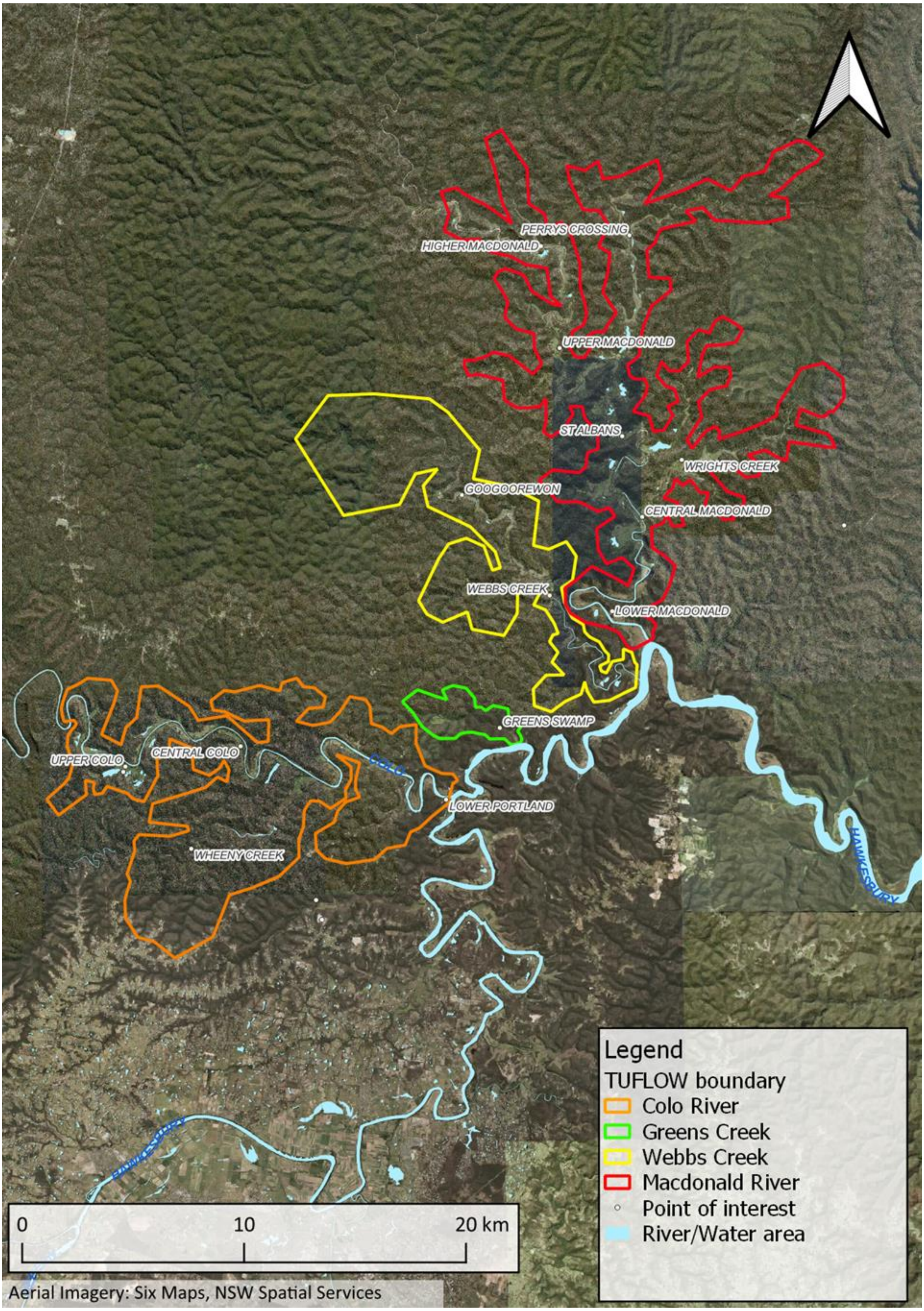
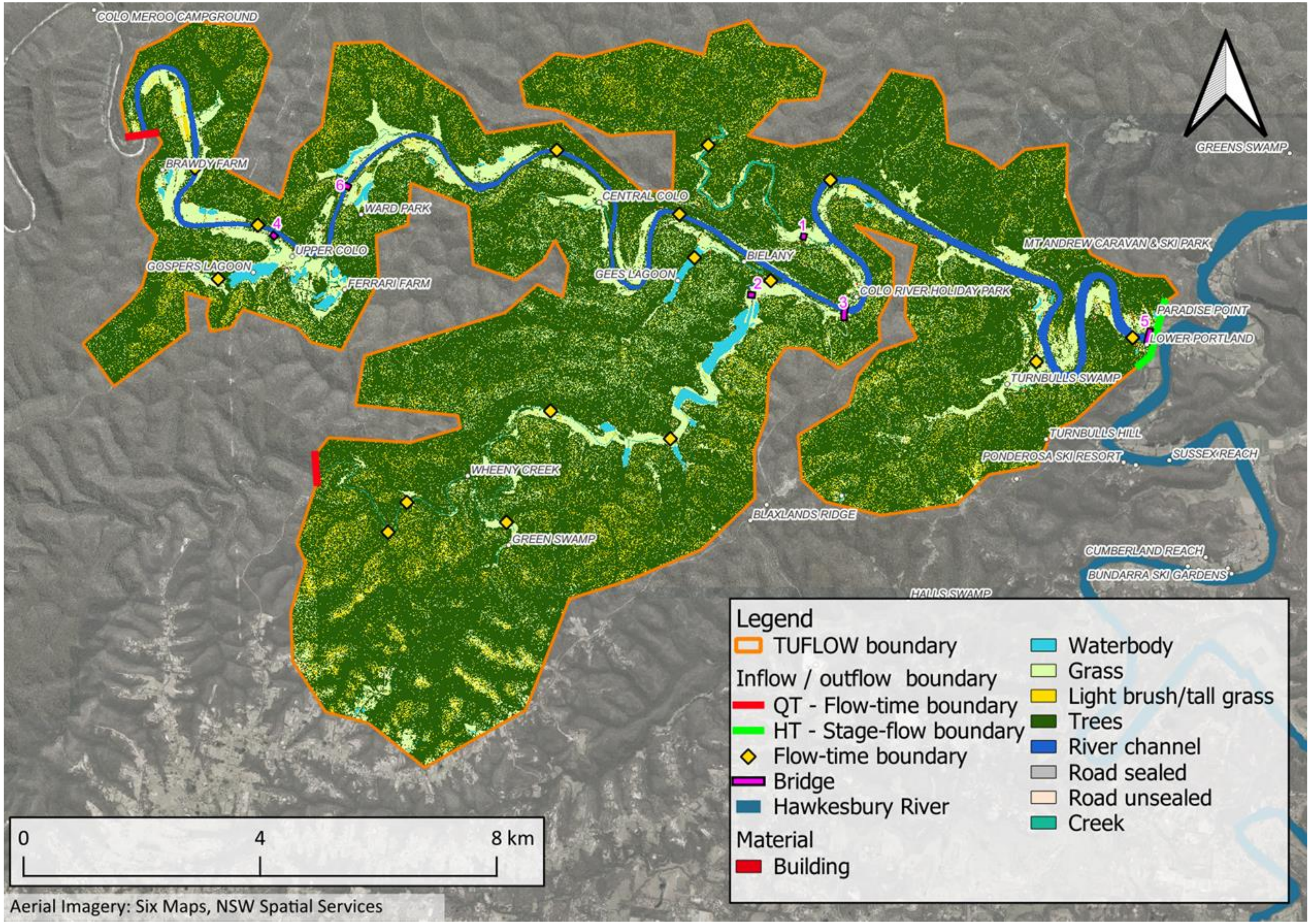
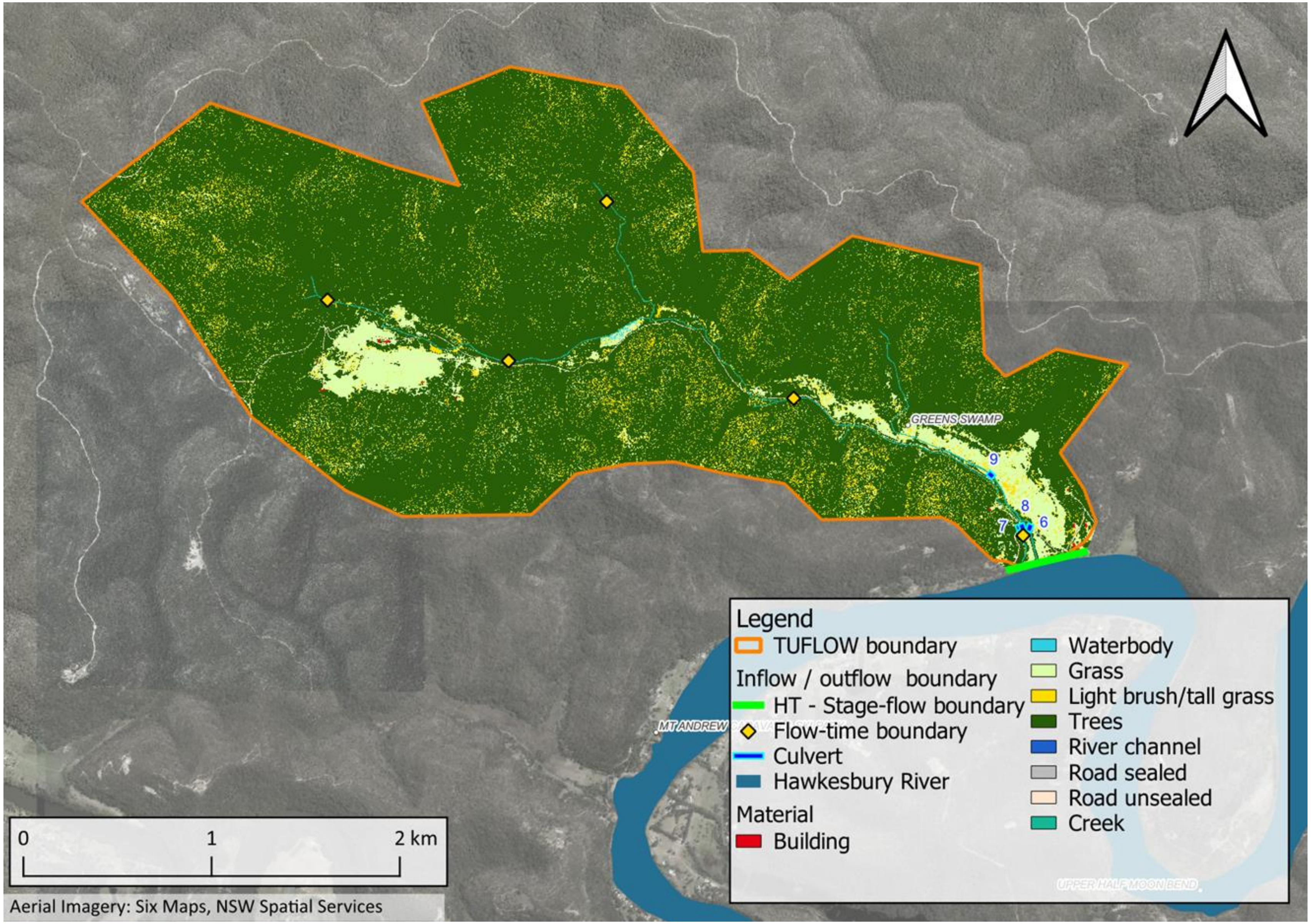


Figure 5-1 TUFLOW model extent overview



Aerial Imagery: Six Maps, NSW Spatial Services

Figure 5-2 Colo River TUFLOW model layout



Aerial Imagery: Six Maps, NSW Spatial Services

Figure 5-3 Greens Creek TUFLOW model layout

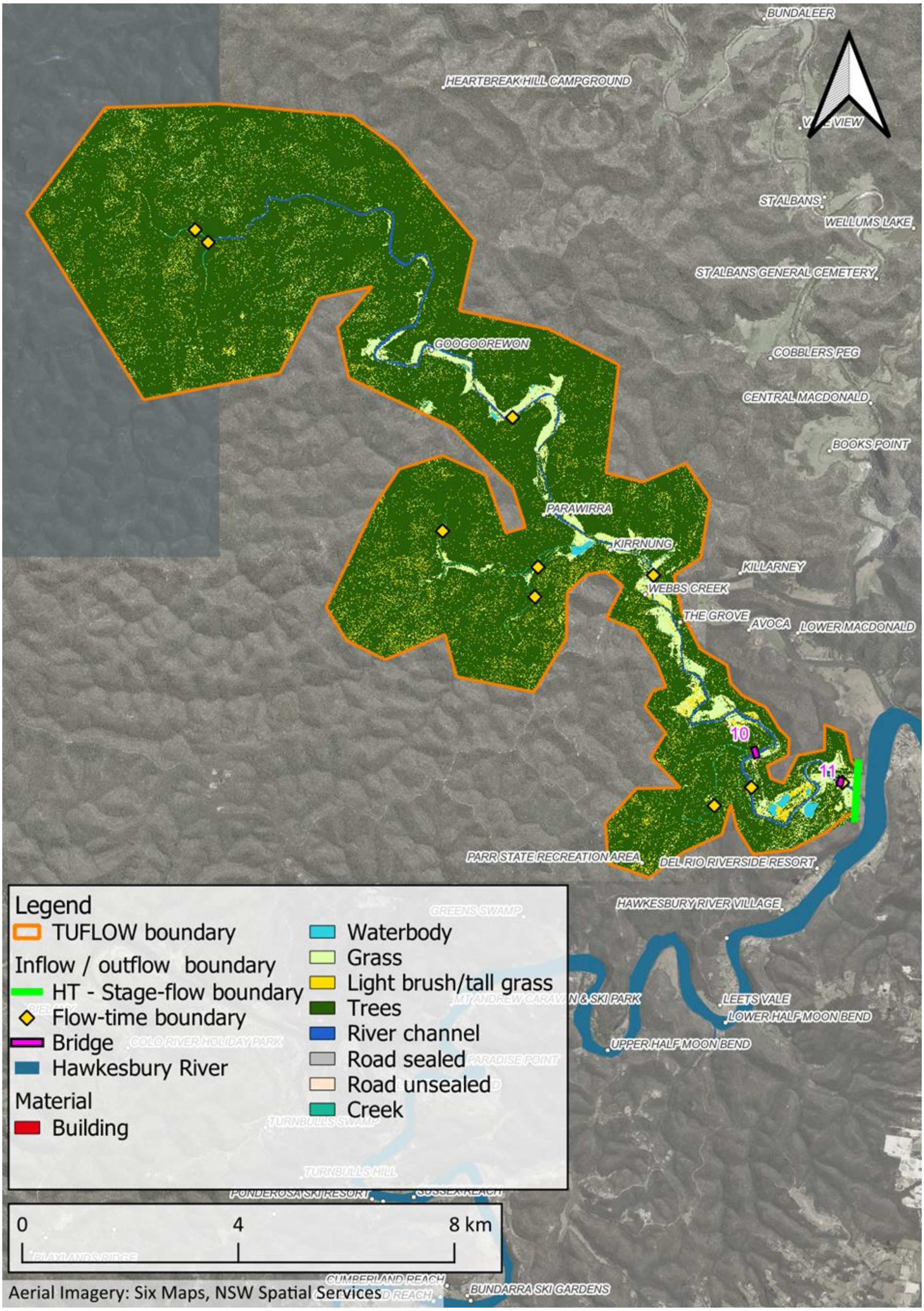


Figure 5-4 Webbs Creek TUFLOW model layout

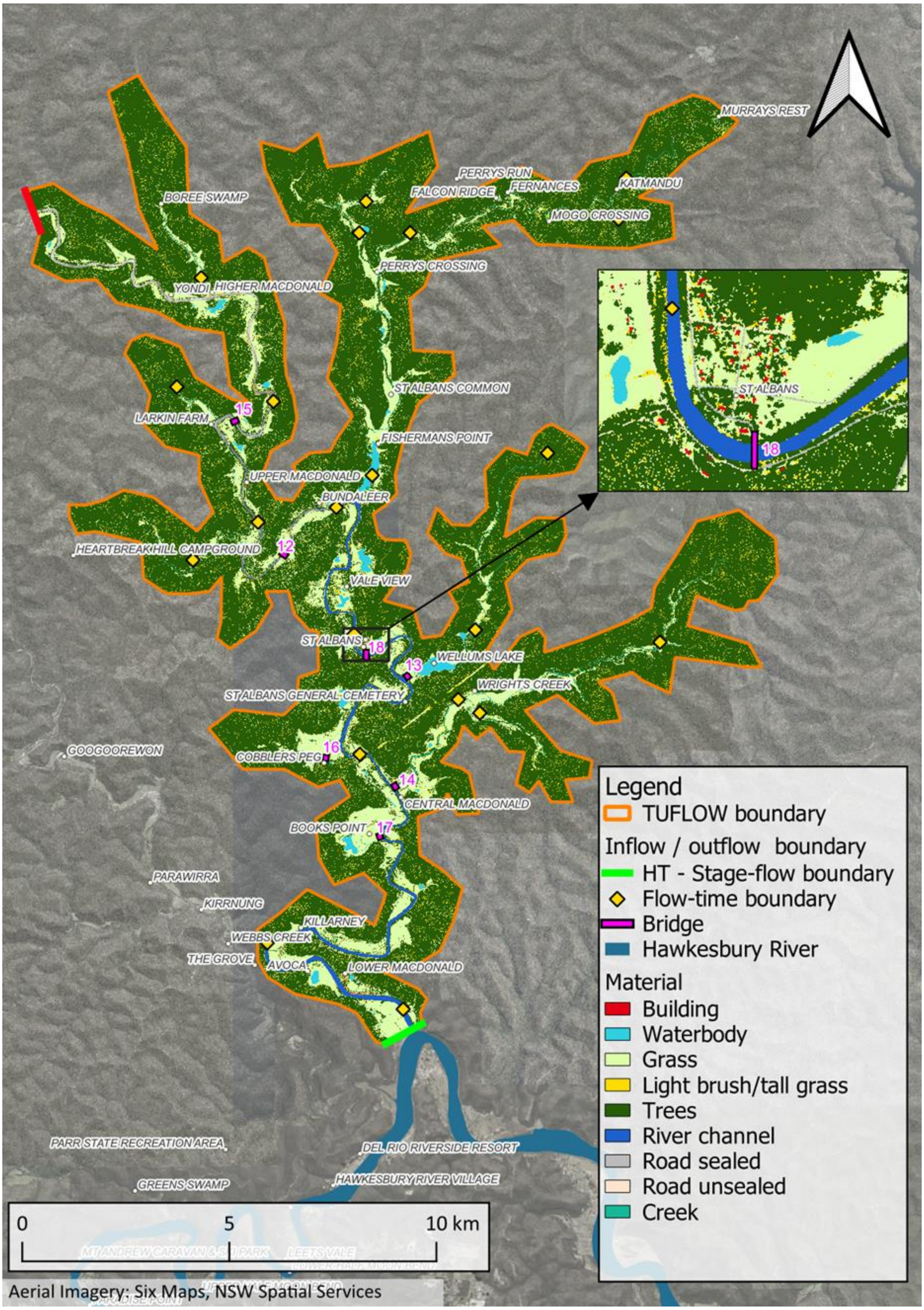


Figure 5-5 Macdonald River TUFLOW model layout

The topography below the water surface is generally not well captured by the LiDAR. Therefore, the LiDAR was supplemented with bathymetric survey information to ensure the conveyance of each watercourse was reliable represented.

5.1.3 Roughness Coefficients

The TUFLOW software uses land use information to define the hydraulic roughness assigned to each grid cell in the model. For this study, land use information derived from LiDAR was used to identify different land uses across the TUFLOW model area. This technique of land use classification was based on research titled 'Using LiDAR Survey for Land Use Classification' (Ryan, 2013). The classification algorithm divided the model areas into the following land use classifications:

- Buildings
- Water
- Trees
- Light brush/tall grass
- Grass
- Roads

Additional data sources were used to supplement remote sensing land use classifications such as the NSW Digital Cadastral Database Clip and Ship (NSW Spatial services, 2023) and building footprints produced by Bing Maps (Microsoft, 2023). The land use map for each catchment is shown in **Figure 5-2** through **Figure 5-5**.

The roughness coefficient values were initially populated from values documented in 'Australian Rainfall & Runoff' (Ball et al, 2019) and were then refined as part of the model calibration process. Further details of the TUFLOW model calibration are provided in **Section 5.3.4**. The final roughness coefficients are listed in **Table 5-1** and

Table 5-2 for each land use.

Depth varying roughness coefficients were applied to some vegetation types. This follows on from work completed as part of the 'Hawkesbury-Nepean River Flood Study – Flood Study Report' (Rhelm CSS, 2024), which confirmed that locations with significant flood height ranges can expect to see variation in hydraulic roughness with respect to water depths as water, for example, encounters tree canopy and then subsequently overtops the tree.

5.1.4 Culverts and Bridges

Culverts and bridges can have a significant influence on flood behaviour. Therefore, bridges and culverts within the TUFLOW model area were represented as 1D (1d_nwk) and 2D (2d_lfcsh) hydraulic structures. Attributes of each bridge and culvert were based on available survey data, design drawings and photos and are presented in **Table 5-3**. The location of culverts and bridges that were included within each TUFLOW model is shown in **Figure 5-2** through **Figure 5-5**.

5.2 TUFLOW Model Calibration

Computer flood models are approximations of a very complex process and are generally developed using parameters that are subject to natural variability. Accordingly, the model should be calibrated using rainfall, flow, and flood mark information from historic floods to ensure the adopted model parameters are producing reliable estimates of flood behaviour. Hydraulic model calibration is typically completed by adjusting hydraulic model parameters to match historical flood level data. The

outcomes of the hydraulic model calibrations are presented in the following sections. Table 5-1 TUFLOW roughness coefficients

Material Description	Colo River	Macdonald River	Green Creek	Webbs Creek
Grass	0.048 for all models			
Light brush / tall grass	0.055 for all models			
Roads (sealed)	0.016 for all models			
Roads (unsealed)	0.020 for all models			
Water body	0.030 for all models			
River channel	0.028	0.032	0.040	0.032
Creeks with moderate vegetation	0.040 for all models			

Table 5-2: Depth varying roughness coefficients

Material Description	Depth 1 (m)	Roughness 1	Depth 2 (m)	Roughness 2	Depth 3 (m)	Roughness 3
Buildings	0.15-3.5	1	3.51	0.016	-	-
Trees (Colo River)	0-2.5	0.060	3-12	0.085	30	0.03
Trees (Macdonald River)	0-2.5	0.090	3-12	0.130	30	0.03
Trees (Webbs Creek and Greens Creek)	0-2.5	0.075	3-12	0.100	30	0.03

Table 5-3 Culverts and Bridges included in TUFLOW models

No.	Structure	Culvert diameter / span widths (m)	Number of culverts / bridge spans	Road	River/Creek	Lat	Lon	Data Source(s)
Colo River								
1	Bridge	8.3	1	Near McDougall Drive	Whatleys Creek	-33.42	150.821	BCE Spatial Survey Site 12
2	Bridge	19.9	1	Upper Colo Road	Wheeny Creek	-33.429	150.811	BCE Spatial Survey Site 14
3	Bridge	22; 5x28; 22	7	Putty Road	Colo River	-33.432	150.828	Department of Public Works Drawings (1966)
4	Bridge	15	1	Upper Colo Road	Gospers Creek	-33.419	150.724	BCE Spatial Survey Site 17/ LiDAR/Estimated dimensions
5	Bridge	22	8	Greens Road	Colo River	-33.437	150.883	Road and Traffic Authority of NSW Schedule of Drawings (1994)
6	Bridge	12.2; 3x12; 12.2	5	Colo Heights Road	Colo River	-33.411	150.738	Bridge Design Pty Ltd (included only in design simulations)
Greens Creek								
6	Culvert	1.2	1	Greens Road	Greens Creek	-33.414	150.916	BCE Spatial Survey Site 11 - east
7	Culvert	0.6	1	Green Swamp Trail	Road Drainage	-33.414	150.916	BCE Spatial Survey Site 11 - west
8	Culvert	1.2	2	Greens Road	Greens Creek	-33.414	150.916	BCE Spatial Survey Site 11 - west
9	Culvert	0.9	1	-	Greens Creek	-33.412	150.914	LiDAR/Estimated dimensions
Webbs Creek								
10	Bridge	100	1	Barry Road	Webbs Creek	-33.383	150.956	LiDAR/Photos/Estimated dimensions
11	Bridge	14.3; 32.3; 14.3	3	Chaseling Road	Webbs Creek	-33.388	150.973	Department of Main Roads NSW Drawings (1970)
Macdonald River								
12	Bridge	10.4	6	Upper Macdonald Road	Macdonald River	-33.271	150.951	BCE Spatial Survey Site 4
13	Bridge	6.2	3	Settlers Road	Wellums Creek	-33.298	150.983	BCE Spatial Survey Site 8
14	Bridge	10.7	3	Settlers Road	Wrights Creek	-33.322	150.979	BCE Spatial Survey Site 10S
15	Bridge	14.9	3	Upper Macdonald Road	Macdonald River	-33.242	150.939	BCE Spatial Survey Site 1
16	Bridge	15.0	1	St Albans Road	Flemings Creek	-33.316	150.961	LiDAR/Google Streetview/Estimated dimensions
17	Bridge	18.0	1	St Albans Road	Bakers Gully	-33.333	150.975	LiDAR/Google Streetview/Estimated dimensions
18	Bridge	9.1; 2x10.7; 2x36; 9.1	6	Wollombi	Macdonald River	-33.293	150.972	Department of Public Works Drawings (1901)

5.3 TUFLOW Model Calibration

Computer flood models are approximations of a very complex process and are generally developed using parameters that are subject to natural variability. Accordingly, the model should be calibrated using rainfall, flow, and flood mark information from historic floods to ensure the adopted model parameters are producing reliable estimates of flood behaviour.

Hydrological model calibration is typically completed by routing recorded rainfall from historic floods through the hydrologic model and comparing simulated flows against recorded flows at stream gauge locations. Hydraulic model calibration is typically completed by adjusting hydraulic model parameters to match historical flood level data.

5.3.1 Stream gauge data

Stream gauge data are valuable as it describes the time variation in water level throughout the flood in addition to the flood peak. **Table 3-3** summarises the gauges that were active along the Colo and Macdonald Rivers during potential calibration historical floods. There are no stream gauges along Greens Creek or Webbs Creek.

5.3.2 Historical flood marks

In addition to gauged water levels, peak flood levels for historical floods have been recorded at multiple locations along the Colo and Macdonald Rivers from a range of sources (e.g., debris/high water marks and flood photographs). **Table 5-4** provides a summary of the number of flood marks per catchment for a select number of flood events. It indicates that a significant number of flood marks are available for the Colo River and Macdonald River for the March and July 2022 floods.

Table 5-4 Historical flood marks per catchment

River	Number of historical flood marks per flood event			
	Mar 1978	Feb 2020	Mar 2022	Jul 2022
Colo River	4		10	11
Greens Creek	-	-	-	-
Webbs Creek	-	-	-	-
Macdonald River	-	-	37	19

5.3.3 Selected flood events

The March 2022 and July 2022 events were selected as the primary calibration events based on the greater amount of data available for those two events. This includes stream gauge data as well as surveyed flood marks away from gauge locations. The February 2020 and March 1978 floods were selected as additional validation events.

5.3.4 Calibration process

As outlined above, the March 2022 and July 2022 floods provide the greatest abundance of stream gauge information and historical flood marks for both the Colo and Macdonald Rivers. In general, the quantity and quality of recorded data diminishes moving back in time. More recent floods also require fewer assumptions to be made to update the model to reflect topographic and development conditions at the time of the flood. Therefore, there is greater certainty about the hydraulic model representation for more recent floods.

In recognition of this, the calibration proceeded and is documented in reverse chronological order. That is, calibration commenced with the July 2022 flood simulation. Once a satisfactory agreement was achieved, the calibration moved to the March 2022 to confirm the adopted model parameters were providing a reliable description of both floods. Hydraulic roughness parameters were iteratively adjusted until a reasonable correlation was achieved for both events.

The end goal was to adopt a consistent set of model parameters for each watercourse that provided a reasonable reproduction of historical flood information for each flood simulation. However, a perfect correlation between simulated and recorded flood information cannot be expected due to hydrologic limitations (e.g., not all events provided a sufficient density of rain gauges to reliably describe the spatial and temporal variation in historical rainfall), other unknowns (e.g., the degree of blockage of major hydraulic structures during each flood), as well as factors that cannot be represented in the hydraulic model (e.g., wave action, local eddies around bridge piers, small scale topographic features). The quality of some of the documented historical flood levels was also subject to some uncertainty, particularly due to poor GPS signal strength during the survey.

5.3.5 Boundary Conditions

5.3.5.1 Upstream Boundaries

Calibrated flow hydrographs produced by the WBNM model were used to define upstream (i.e., inflow) boundary conditions to the TUFLOW models. The location where flow hydrographs were applied to each TUFLOW model is shown in **Figure 5-2** through **Figure 5-5**.

5.3.5.2 Downstream boundaries

The downstream boundaries of the Colo River and Macdonald River hydraulic models were set as HT (water level-time) boundaries at their respective junctions with the Hawkesbury River. For the Colo River model, the downstream water level time series was based on the Lower Portland (212407) gauge. For the Macdonald River model, the downstream water level time series was interpolated between the water level time series of the Webbs Creek (212408) and Wisemans Ferry Wharf (212460) gauges.

5.3.6 July 2022 Results

5.3.6.1 Colo River

Peak floodwater depths were extracted from the results of the July 2022 flood simulation and are included on **Map RG-00-001-1** for the Colo River. Also included on **Map RG-00-001-1** are peak flood level comparisons.

A longitudinal surface water profile along the Colo River for the July 2022 event is also provided in **Appendix C**. A stage hydrograph comparison for the Upper Colo gauge site is presented in **Appendix C.** This provides peak simulated water levels along the centre of the river along with surveyed peak flood marks and the recorded flood level peak at the Upper Colo gauge.

A comparison between the peak flood levels generated by the TUFLOW model and the surveyed flood marks along the Colo River for the July 2022 flood are presented in **Appendix C**.