APPENDIX

A

SITE VISIT PHOTOGRAPHS

03/02/2016 Site Visit

Figure 1-1 Various hydraulic controls looking upstream at Marsden St Bridge

Figure 1-2 Marsden St Bridge and Weir from northern bank of Parramatta River. Several hydraulic controls are in this location

Figure 1-3 Inspection of the pedestrian walkway under Lennox Bridge. There is a walkway on either side of the bridge

Figure 1-4 Looking downstream at Lennox Bridge from the banks of Parramatta River

Figure 1-5 Looking downstream to Wilde Avenue Bridge from the banks of Parramatta River near Lennox Bridge

Figure 1-6 Footbridge under Wilde Avenue Bridge. The piers of both the footbridge and the road bridge need to be considered for modelling

Figure 1-7 Looking downstream to Elizabeth St footbridge from Wilde Ave Bridge

Figure 1-10 Looking downstream Parramatta River from Charles Street Weir

Figure 1-8 Looking upstream along the formalized concrete Brickfield Creek

Figure 1-11 Charles St Weir from the banks of Parramatta River

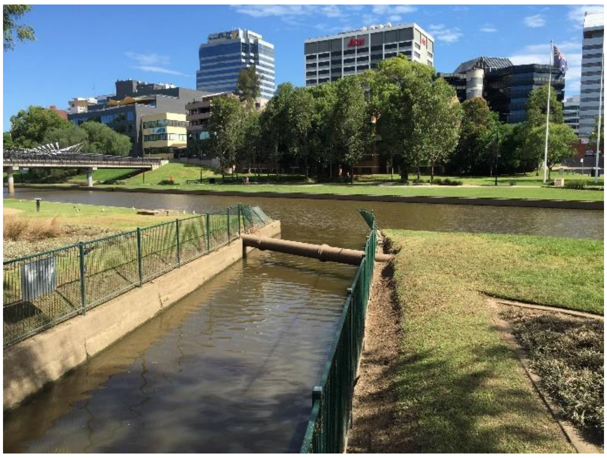


Figure 1-9 Looking downstream at the confluence of Brickfield Creek and Parramatta River. A pipeline can be seen crossing the creek.

Figure 1-12 Looking upstream along Vineyard Creek

Figure 1-13 Pit blockage in the Parramatta CBD

Figure 1-14 Large culvert and grate at Clay Cliff Creek

Figure 1-15 Culvert and grate at the intersection of Cowper and Parkes St

Figure 1-16 Clay Cliff Creek open section

Figure 1-17 Ollie Webb Reserve site inspection

Figure 1-18 Ollie Webb Reserve turns into the concrete channel for Clay Cliff Creek

19/11/2016 Site Visit

Figure 1-19 Charles St Weir from Elizabeth St footbridge (looking downstream)

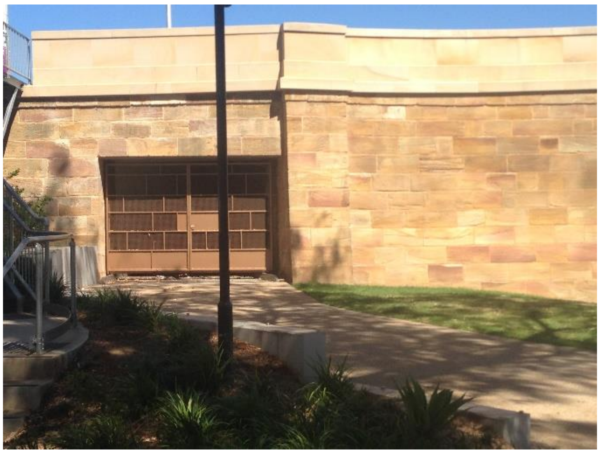


Figure 1-20 Lennox Bridge southern pedestrian portal walkway from the west showing gates locked

Figure 1-21 Lennox Bridge looking downstream from Marsden St Bridge

Figure 1-22 Looking downstream to Elizabeth St footbridge from Wilde footbridge

Figure 1-23 Macarthur St Bridge (Gasworks Bridge) central spans looking downstream from the banks of Parramatta River

Figure 1-24 Macarthur St (Gasworks Bridge) south span and abutment

Figure 1-25 Pier shape inspection for Marsden St Bridge

Figure 1-28 Detailed inspection of the footbridge, piers and pipeline at Wilde Avenue Bridge

Figure 1-26 Looking upstream to Marsden St Bridge and weir from Lennox Bridge

Figure 1-29 Pier shape inspection for Wilde Avenue Bridge

Figure 1-27 O'Connell St Bridge from Marsden St Weir

Figure 1-30 Brickfield Creek confluence from banks near Wilde Avenue

19/09/2018 Site Visit

Figure 1-31 Loyalty Road Basin formalized channel inlet looking upstream

Figure 1-32 Loyalty Road Basin channel outlet looking upstream

Figure 1-33 Water level gauge from Loyalty Road Basin

Figure 1-34 Brickfield Basin culvert grate open dimension inspection

Figure 1-35 Brickfield Basin culvert total grate openings

Figure 1-36 Finlaysons Creek concrete channel flowing into natural channel looking downstream

Figure 1-37 Circular and box culverts at Finlaysons Creek looking upstream

Figure 1-38 Inspection of the Milsons Creek and Finlaysons Creek confluence looking downstream

Figure 1-39 Milsons Creek looking upstream

Figure 1-40 Finlaysons Creek flowing into the Parramatta river through a rocky terrain

Figure 1-41 Charles Street Weir and fish ladder looking downstream

Figure 1-42 Water level gauge at Charles St Weir

APPENDIX

B

FLOOD FREQUENCY ANALYSIS

B1 Revised Rating Curve at Marsden Street Weir

Following initial calibration and Flood Frequency Analysis (FFA) it was agreed it was appropriate to review the rating curve at Marsden Street Weir using the TUFLOW model developed for the Parramatta River Flood Study. The need for the review became apparent due to challenges in determining an appropriate flow adjustment in converting historical flows to present day catchment conditions to develop a homogenous annual maxima time series for use in the FFA. The objective was to obtain defensible flow relationship by using the hydraulic model results rather than the extrapolation beyond the gauging zone applied to the available PINEENA rating curve.

The TUFLOW model was reviewed and refined in the vicinity of Marsden Street Weir and Lennox Bridge to ensure flow is modelled accurately.

The revised rating curve was derived from the TUFLOW modelling results and compared with the existing PINEENA rating curve, PINEENA field gaugings, and the UPRCT Draft 9 MIKE11 Probable Maximum Flood (PMF) modelling results. The rating curve was also validated against weir equations derived using Bentley FlowMaster software to ensure its reliability. The MIKE 11 setup was also reviewed to identify and explain differences in the hydraulic model results.

The revised rating curve was used to adjust historical flows and select historical calibration events compared with both hydrology and hydraulic modelling to further validate the revised rating curve. An updated homogenous annual maxima series was also developed using the TUFLOW revised rating curve. The updated annual maxima series is to be used as input for an updated flood frequency analysis at Marsden Street Weir.

B1.1 Review of Gaugings

The Bureau of Meteorology Water Data Online and the NSW Office of Water PINEENA database was used to extract the Marsden Street Weir rating curve and the gauging data upon which the rating is based.

A selection of gaugings including the top 15 gaugings were assessed to determine when they were collected and how they compared to the time series values.

The following observations are made:

> The gaugings were generally taken on the falling limb of a flow event – presumably the time taken to deploy field staff after recognition of a flow event. As the flows are reasonably low, there is not expected to be a difference between gaugings on the rising and falling limb for these events;

> Most data points align with the level time series, although some points appear to have a time shift when compared with the time series data, but are within the same range;

> The majority of gaugings are for flows of 10m^3/s or less;

> The maximum gauged flow is 220m^3/s;

> There are only four gauged events greater than 100m^3/s; and,

> The PINEENA rating curve plots through low flows and the top three gaugings, however, the curve plots below the majority of gaugings between 20-100m^3/s.

The observations can be seen on **Figure B1-4**.

B1.2 TUFLOW Model Setup

B1.2.1 Marsden Street Weir

Marsden Street Weir was modelled as shown in survey drawings, with a varying crest elevation which ranges from 4.16 to 4.22 mAHD. There is a lower section on the southern side of the weir and the weir also grades from upstream to downstream with an approximately 200mm drop across the weir crest. The weir has a number of low flow features including:

> 3 No. low flow pipes at approx RL 2.0m AHD
> An approx. 200mm upstand/kerb which runs along the downstream edge of the weir, which has a number of slots cut through it
> A fish ladder/environmental flow slot

The weir has been setup in the 2d TUFLOW model as accurately as possible to match lower flows and the gauging data, however, the flow behaviour through the various low flow features is complex and not able to be represented well in the model. This is not expected to affect high flow behaviour which is the focus of the Flood Study.

B1.2.2 Lennox Bridge

Lennox Bridge is a single-arch sandstone bridge located approximately 130 metres downstream of Marsden Street Weir. Flow is constricted to the archway at the bridge, and therefore has a potential to impact the flow at Marsden Street Weir.

Lennox Bridge was set up using several '2D layered flow constrictions' in the TUFLOW model with '2D Z-Shapes' to represent the abutment areas where flow cannot pass through. The '2D Z-shapes' raise terrain such that water can't flow through the bridge structure abutments. Instead, water is directed into the arch opening. Once the water level is high enough to overtop the bridge, water is also able to spill over the '2D Z-shape' in the model i.e. the roadway.

Several form loss coefficients were also tested at the edges of the bridge as these losses are complex due to the arch shape. Form losses are important to ensure a robust estimation of energy losses. The adopted form-loss coefficients are shown in **Figure B1-1**.

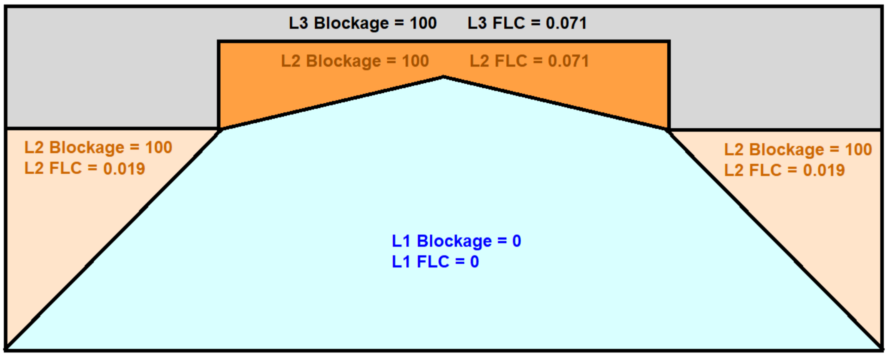


Figure B1-1Adopted Form-Loss Coefficients in the 2D Layered Flow Constriction at Lennox Bridge

Sensitivity analysis was also undertaken by removing the bridge and form losses of the arch and just modelling an opening through the abutments. This showed only small differences with the full representation of the bridge, demonstrating that the contraction of flows due to the abutments is more dominant in determining flow behaviour and loss through the structure

B1.2.3 Lennox Bridge Pedestrian Tunnels

Two large pedestrian tunnels were installed at Lennox Bridge at the end of 2014. The installation of these pedestrian tunnels allows more flow to pass under the bridge, and therefore reduce the water level upstream of the Bridge and at Marsden Street Weir. However, the invert level of the pedestrian tunnels is at approximately 5.1 mAHD and hence, flow is not conveyed through these tunnels until it reaches this level.

The installation of the tunnels affects the rating curve at Marsden St weir with a different rating curve at Marsden Street Weir for pre-portals (Dec-2014) and post portals 2015 to present. This change in hydraulic conditions post-portals has no effect on the discharge time series and maximum flows for the years 2015 and 2016, which have peak flood levels around 5.1 mAHD upstream of Lennox Bridge and the portals are only just activated. Hence there is no impact on water levels upstream of Marsden Street Weir for these flow rates.

Due to the change in the Lennox Bridge structure to introduce the pedestrian portals, it was necessary to modify the TUFLOW model to exclude the portals for simulating all events prior to 2015 to ensure that the correct hydraulic conditions were replicated.

B1.3 TUFLOW Revised Rating Curve

B1.3.1 Revised Rating Curve – Without Lennox Bridge Pedestrian Tunnels

The TUFLOW model was then used to simulate the April 1988 event, April 2015 event and the 3-hour PMF. The hysteresis curves for the three simulations were plotted as shown in Error! Reference source not found.. T he hysteresis curves for the April 1988 and April 2015 events show no difference between the flows on the rising and falling limb and plot over the rising limb of the 3-hour PMF hysteresis curve. The PMF hysteresis curve shows higher water levels for a given flow on the receding/falling limb of the hydrograph for flows greater than approximately 350m^3/s. This indicates the hysteresis of the falling limb of the PMF is cause by an elevated tailwater due to stored or delayed water volume downstream which in turn is causing a significant backwater effect at Marsden Street Weir.

Therefore, the rising limb was selected to define the revised rating curve at Marsden Street Weir, and is shown in **Figure B1-3** to **Figure B1-5** for different flow ranges. The TUFLOW revised rating curve has been plotted against the PINEENA rating curve, field gaugings and the UPRCT Draft 9 MIKE11 PMF hysteresis curve.

B1.3.2 Revised Rating Curve – Including Lennox Bridge Pedestrian Tunnels

As noted above, the installation of the Lennox Bridge Pedestrian Portals affects the rating curve at Marsden St weir with a different rating curve at Marsden Street Weir for pre-portals (Dec-2014) and post portals 2015 to present.

The TUFLOW model was used to simulate April 2015 event and the 3-hour PMF event with the setup changed to include the pedestrian portals. The post portal rating curve (2015 to present) is shown plotted against the pre-portal (pre December 2014) rating curve in **Figure B1-6** and **Figure B1-7**.

Observation of this comparison shows that the portals have the effect of increasing flow through Lennox Bridge and changes the rating curve at Marsden Street Weir for flows of approximately 460m^3/s and greater where more flow is observed for a given flood level (approximately RL6.45m AHD and above).

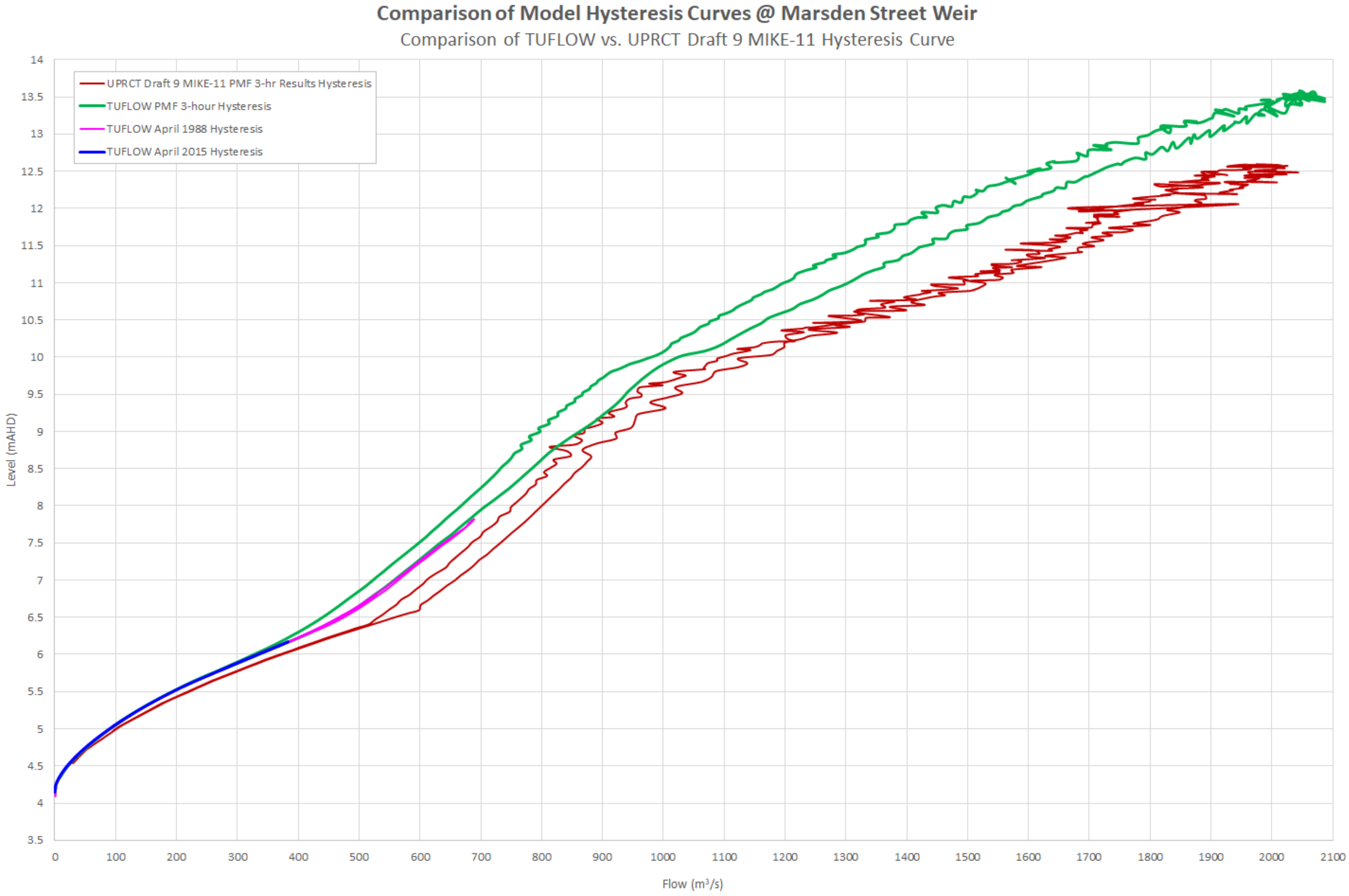


Figure B1-2 Comparison of TUFLOW and MIKE11 Hysteresis Curves

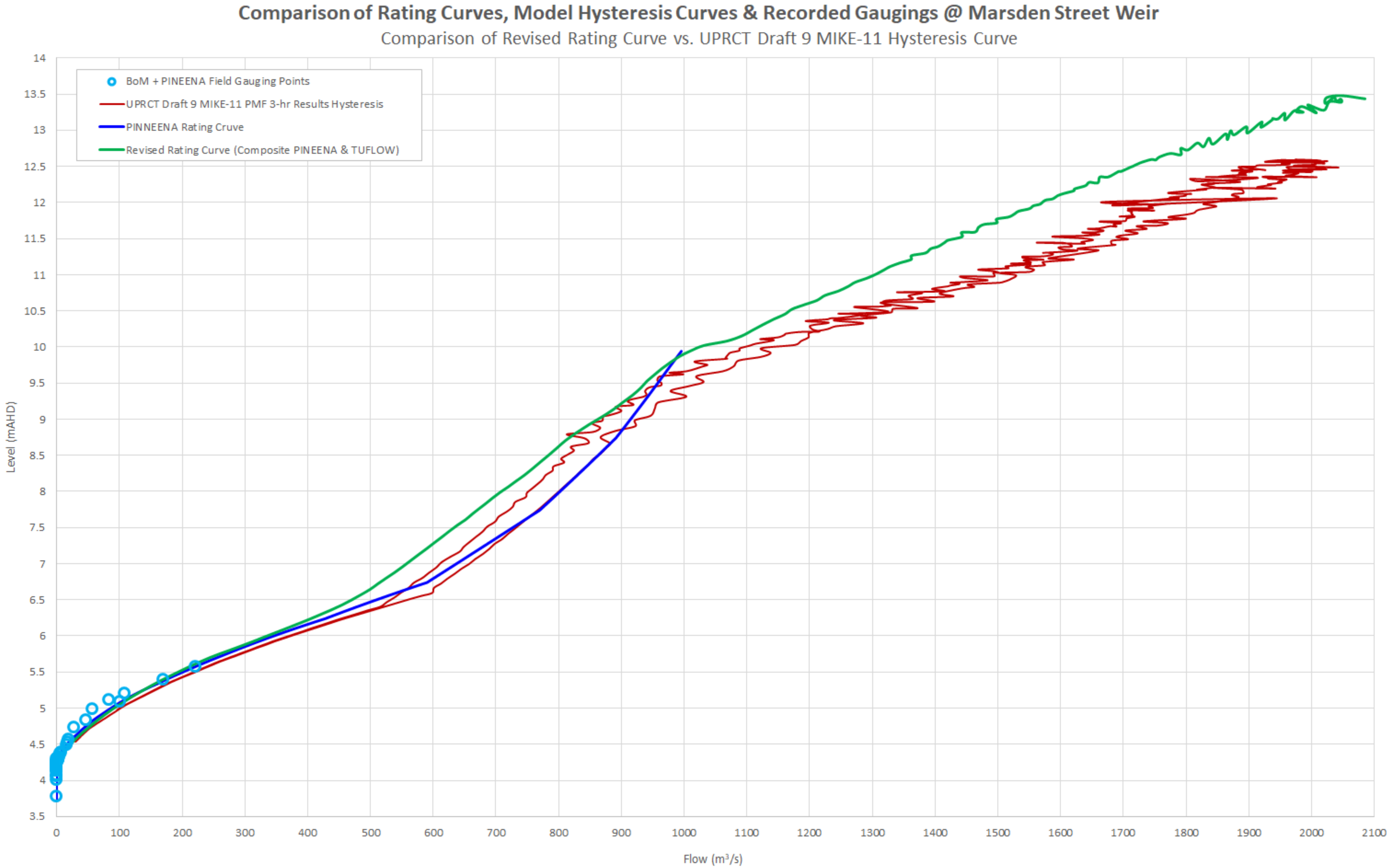


Figure B1-3TUFLOW revised rating curve at Marsden Street Weir (Full Scale)

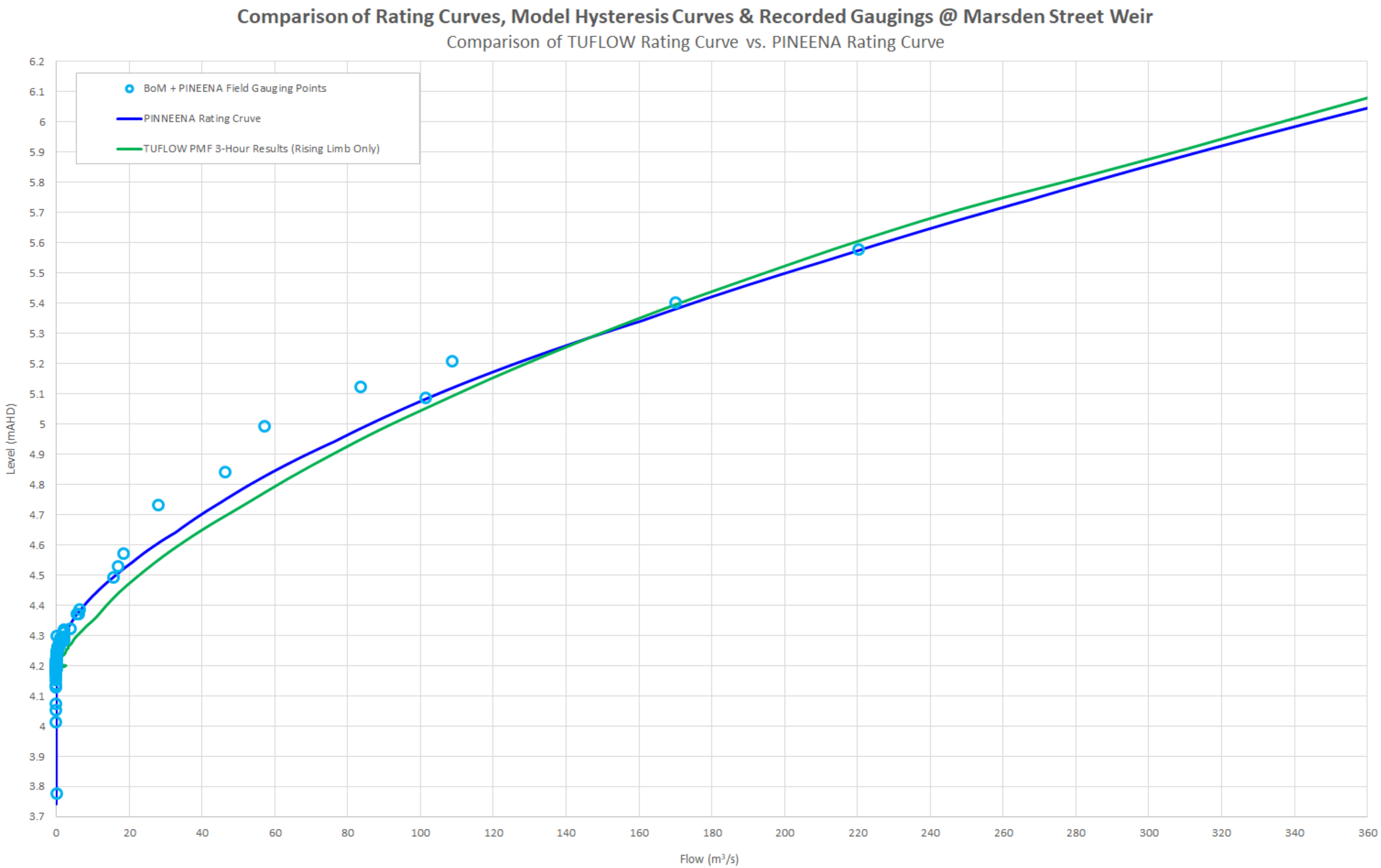


Figure B1-4TUFLOW revised rating curve at Marsden Street Weir (From 0 to 360 m^3/s)

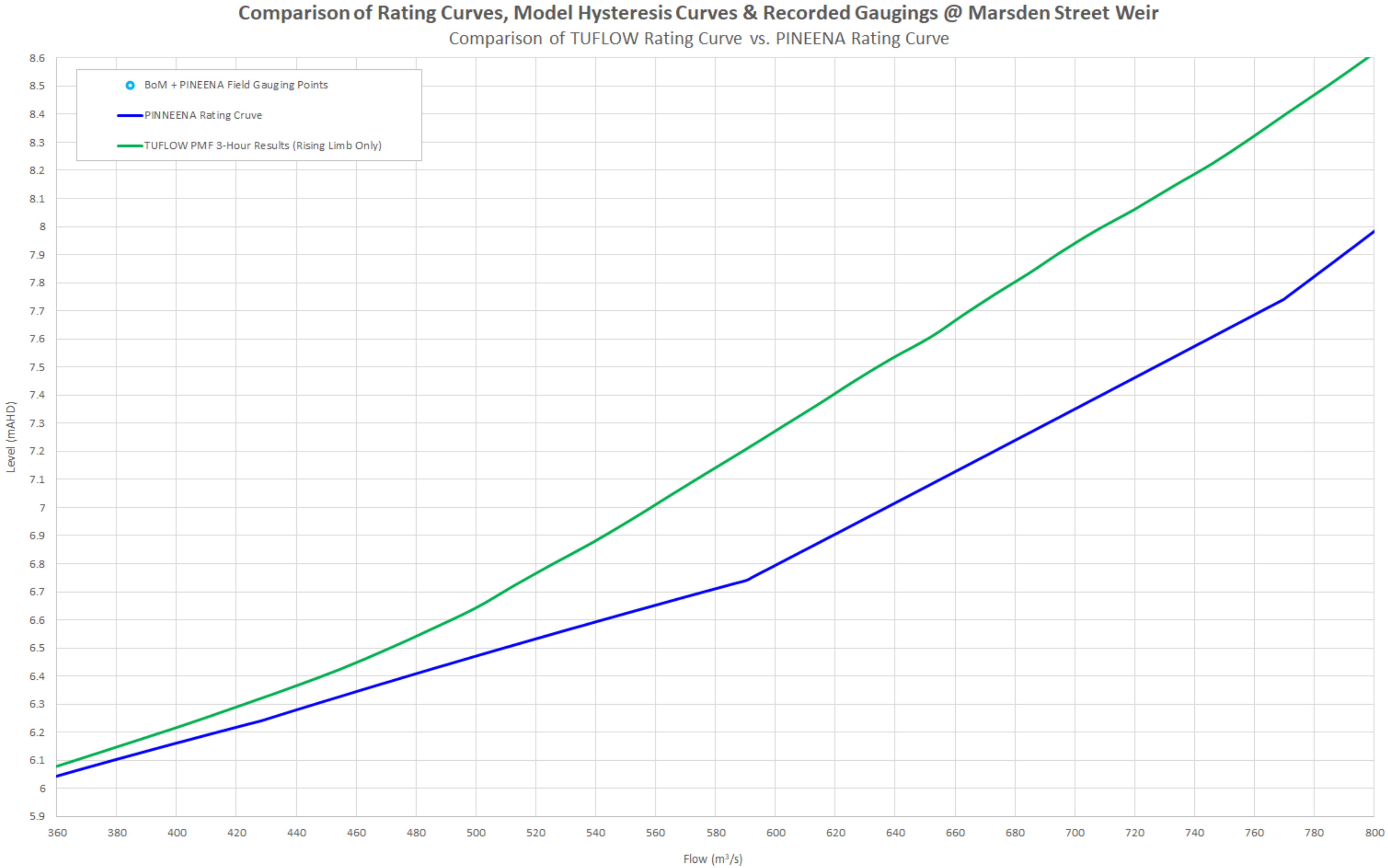


Figure B1-5TUFLOW revised rating curve at Marsden Street Weir (From 360 to 800 m^3/s)

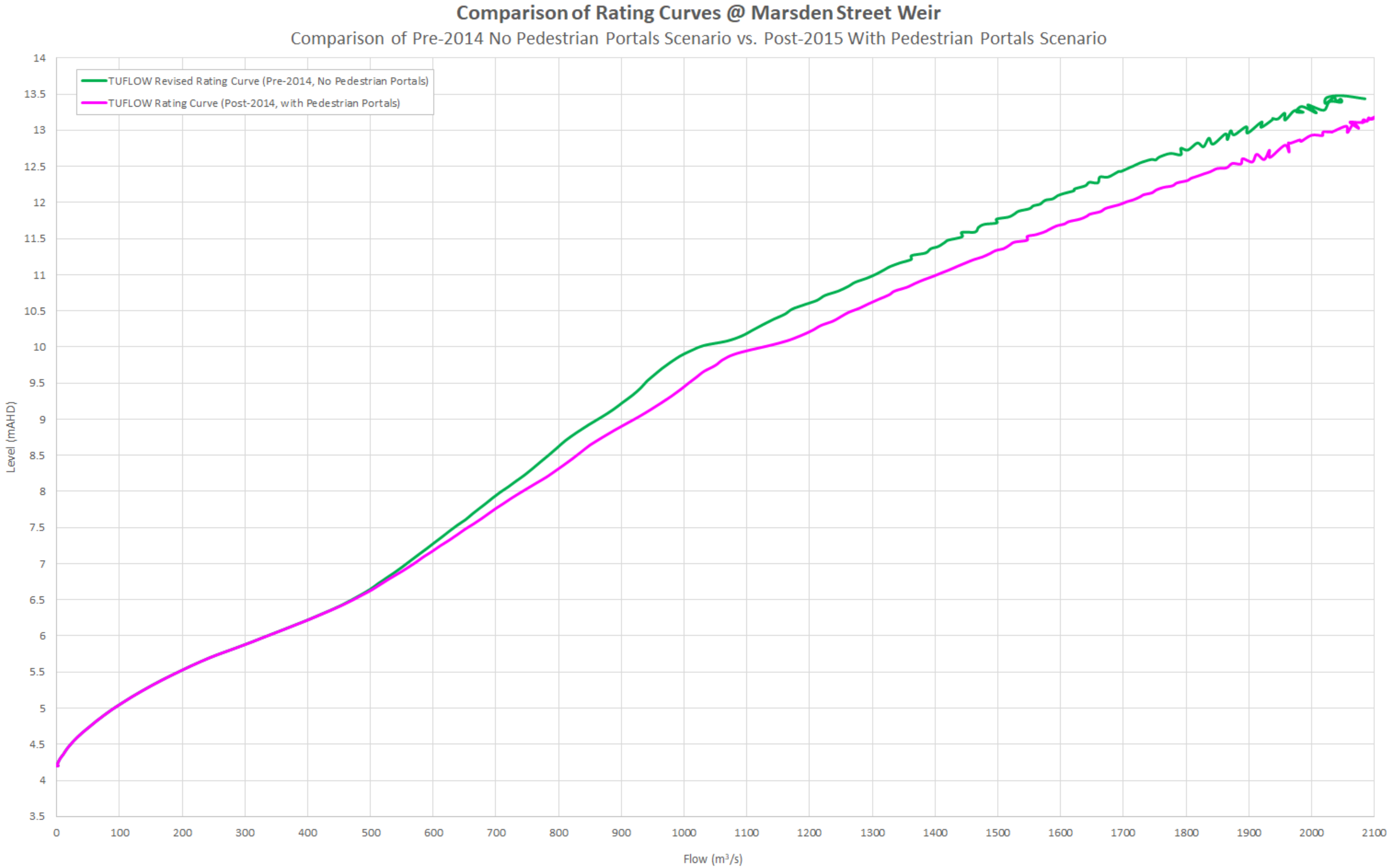


Figure B1-6 Comparison of Pre- and Post-2014 TUFLOW revised rating curve at Marsden Street Weir (Full Scale)

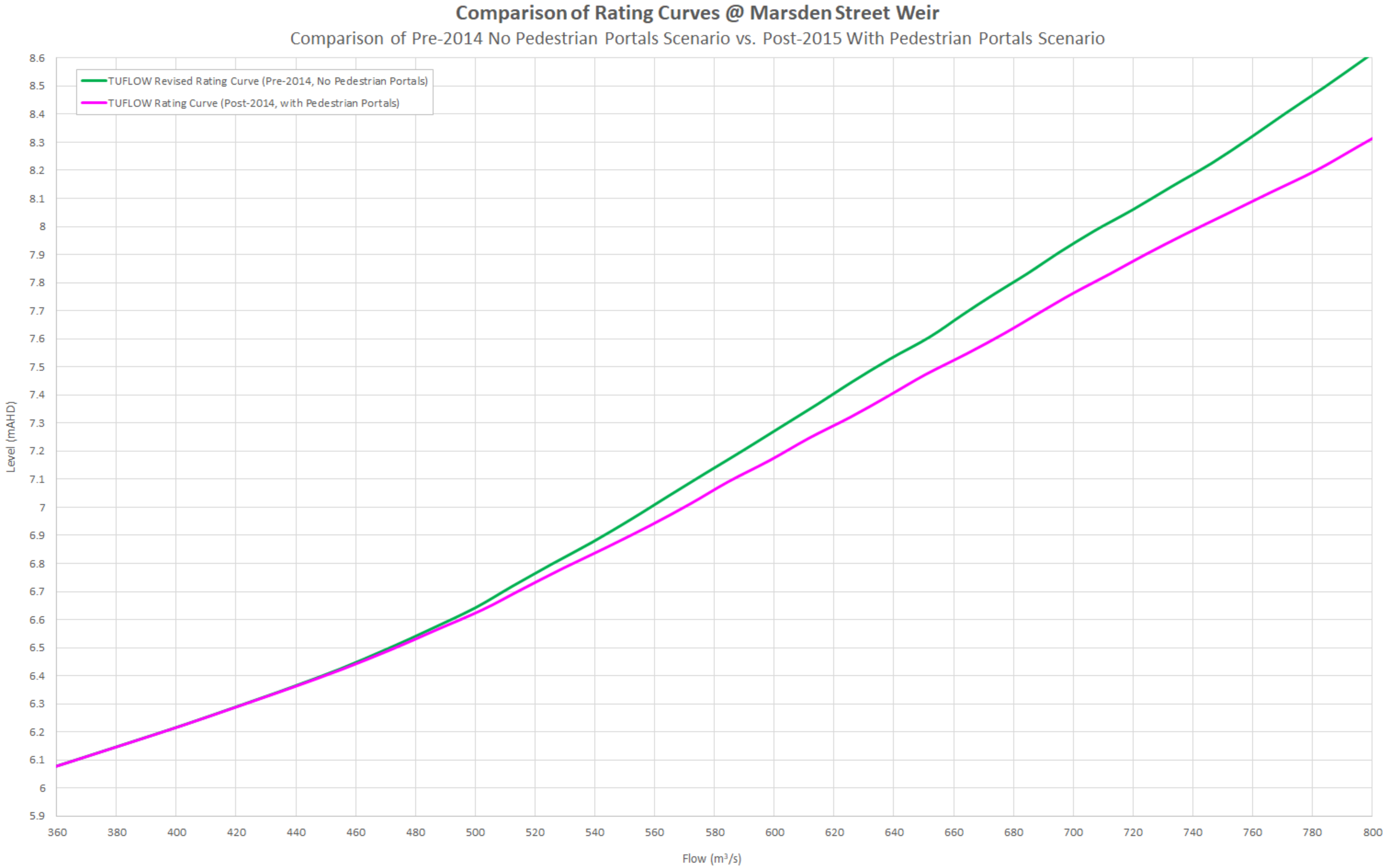


Figure B1-7 Comparison of Pre- and Post-2014 TUFLOW revised rating curve at Marsden Street Weir (From 360 to 800 m^3/s)

B1.4 Validation of TUFLOW Revised Rating Curve

B1.4.1 Comparison of RAFTS Modelling Results and Gauge Data for Historic Events

The RAFTS hydrologic model was previously used to simulate the August 1986, April 1988, February 1990, June 1991, April 2015 and June 2016 historic events. The modelled flows were compared with the gauged data (refer **Figure B1-8** to **Figure B1-11**), which was converted to flow data using the PINEENA curve (shown in grey) and using the TUFLOW rating curve (shown in green).

For the April 1986 and February 1990 historic events, the RAFTS model overestimates peak flows. However, this is likely due to a lack of rainfall data; the April 1986 event used hourly rainfall data, and data from only one rainfall gauge was used for the February 1990 event. As such, the spatial variability of rainfall is not represented in the model.

For the June 1991, April 1988, April 2015 and June 2016 events, the peak flow estimated by the RAFTS model is more consistent with the gauged flow data that was derived from the TUFLOW rating curve, when compared to the PINEENA rating curve.

B1.4.2 Comparison of TUFLOW Modelling Results and Gauge Data for Historic Events

The TUFLOW model with refined setup was used to simulate the April 1988 and April 2015 historic events. The modelled and gauged water levels are compared at Marsden Street Weir and at Riverside Theatre (immediately upstream of Lennox Bridge) and is shown in **Figure B1-10** and **Figure B1-11**.

The gauged water level graphs were converted into hydrographs using rating curves from PINEENA and the revised TUFLOW rating at Marsden Street Weir. No rating curve data was provided by MHL for the gauge at Riverside Theatre and the discharge time series data provided is plotted.

For both the April 1988 and April 2015 events, the TUFLOW model produces estimated flood levels that are consistent with the gauged water level data. However, both the RAFTS and TUFLOW models underestimate flows when compared to the flow data converted using the PINEENA rating curve (shown as the grey line). Both events show a closer correlation to the revised TUFLOW rating curve (shown as the green line).

There is a minor mismatch in the smaller sub-peak flows that occurs either side of the peak, but the hydrograph shape and timing/response is generally consistent.

For the April 1988 event, the TUFLOW model estimates a peak flow that is consistent with the rating curve derived from the TUFLOW PMF rising limb.

The RAFTS hydrologic modelling results were compared with the annual peak flows, as shown in **Table B1-1**.

Table B1-1 Peak Flows at Marsden Street Weir for Basin Sensitivity Analysis

Event	Peak Flow @ Marsden St Weir (m^3/s)		Difference	
	Annual Maximum Flow (TUFLOW Rating Derived)	RAFTS Model Results		
August 1986	508.0	570.4	62.4	12%
April 1988	689.2	708.4	19.2	3%
February 1990*	527.3	592.1	64.8	12%
June 1991*	549.6	564.4	14.8	3%
April 2015	380.8	370.1	-10.7	-3%
June 2016	366.3	354.5	-11.8	-3%

* It is noted that in the 1990 and 1991 events the water level/discharge data was only recorded approximately hourly around the peak and it appears that the data has missed the peak of the event from observation of **Figure B1-8**. As such, the gauged maximum flow in these events is likely slightly higher and would show an even closer match to the RAFTS model.

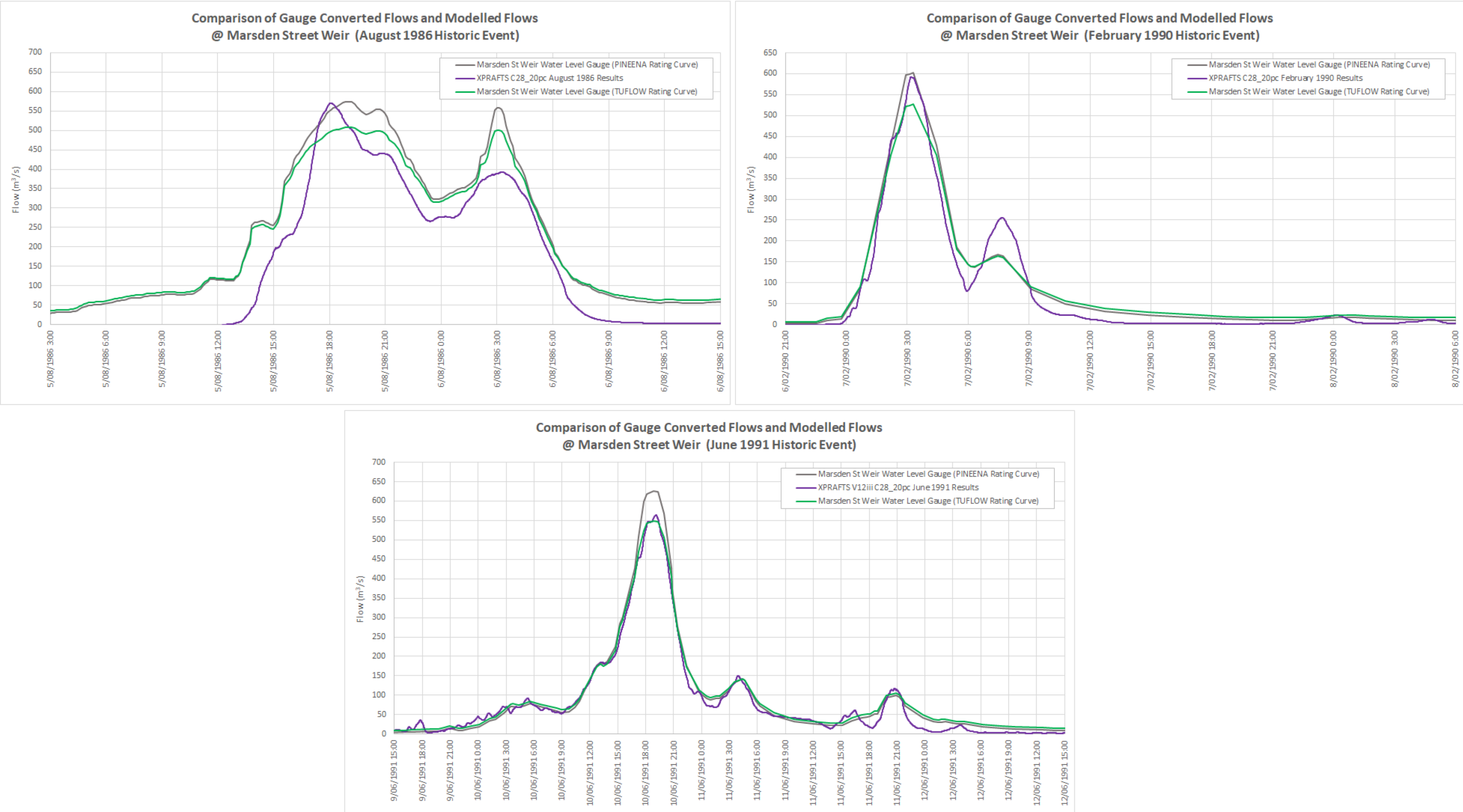
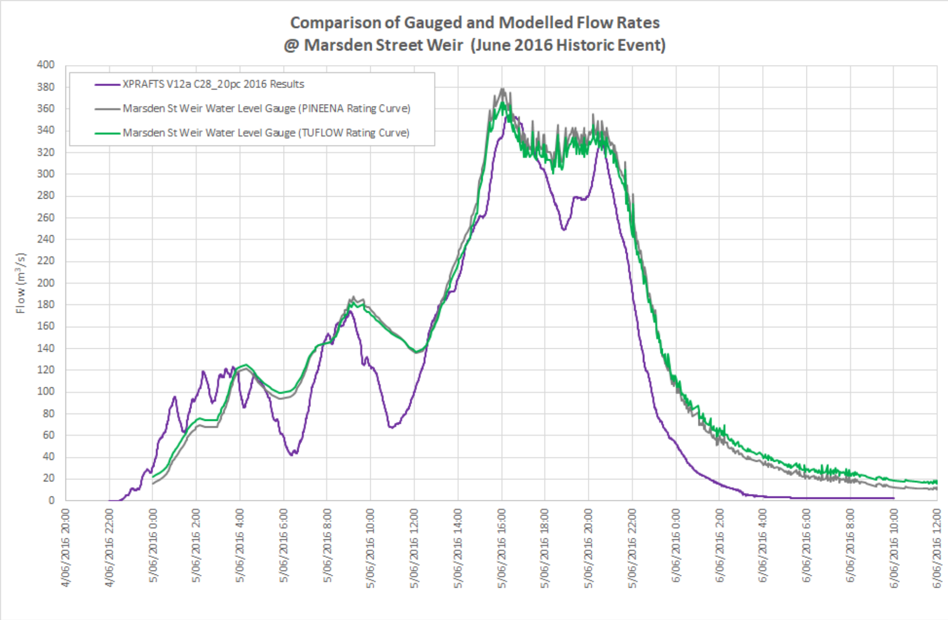


Figure B1-8 Comparison of RAFTS Modelling Results for the August 1986, February 1990 and June 1991 Events



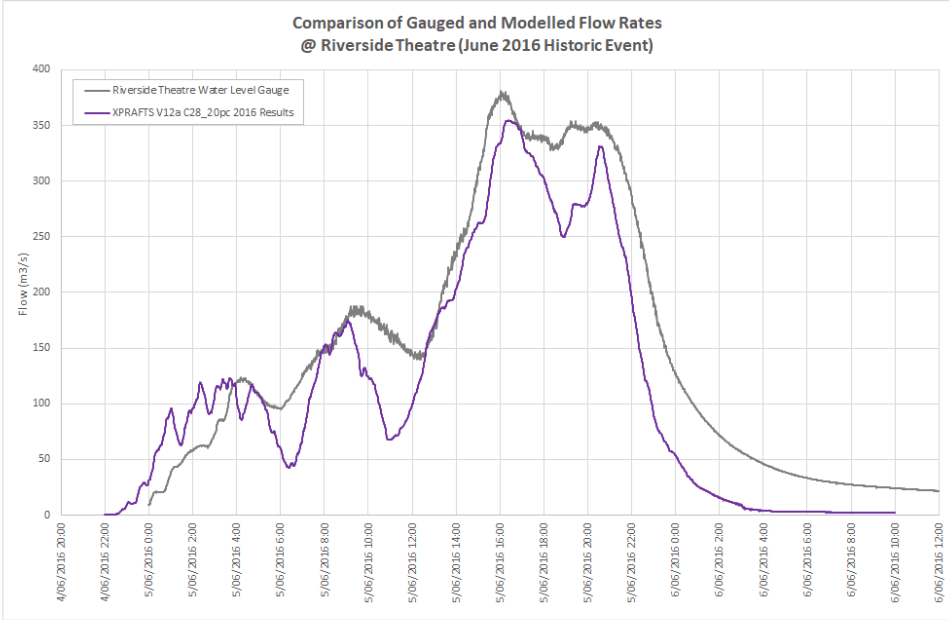
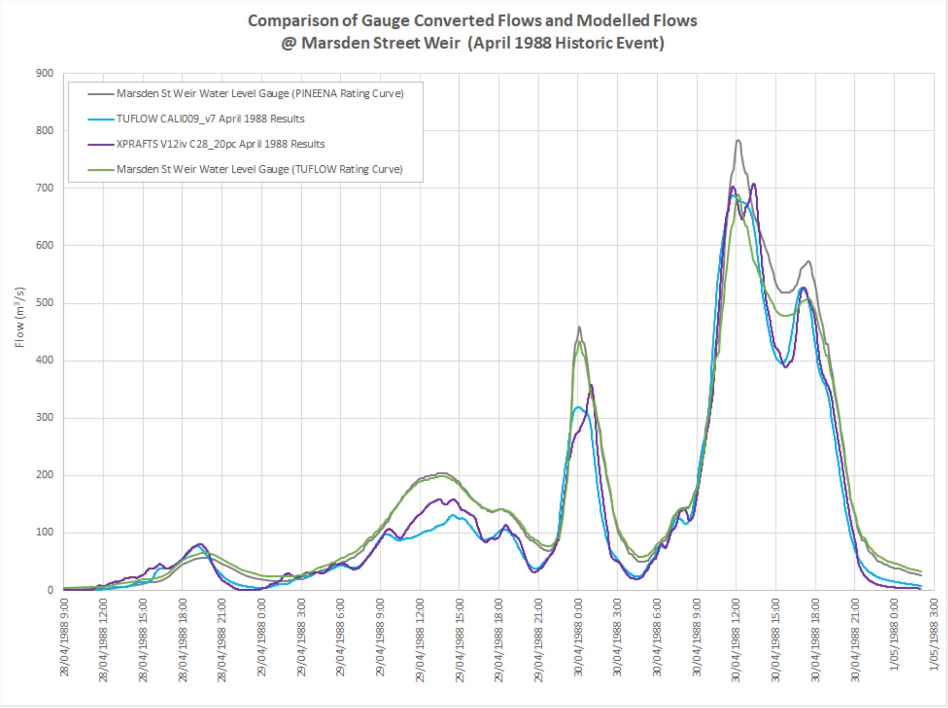


Figure B1-9 Comparison of RAFTS Modelling Results and Gauged Data for the June 2016 Event



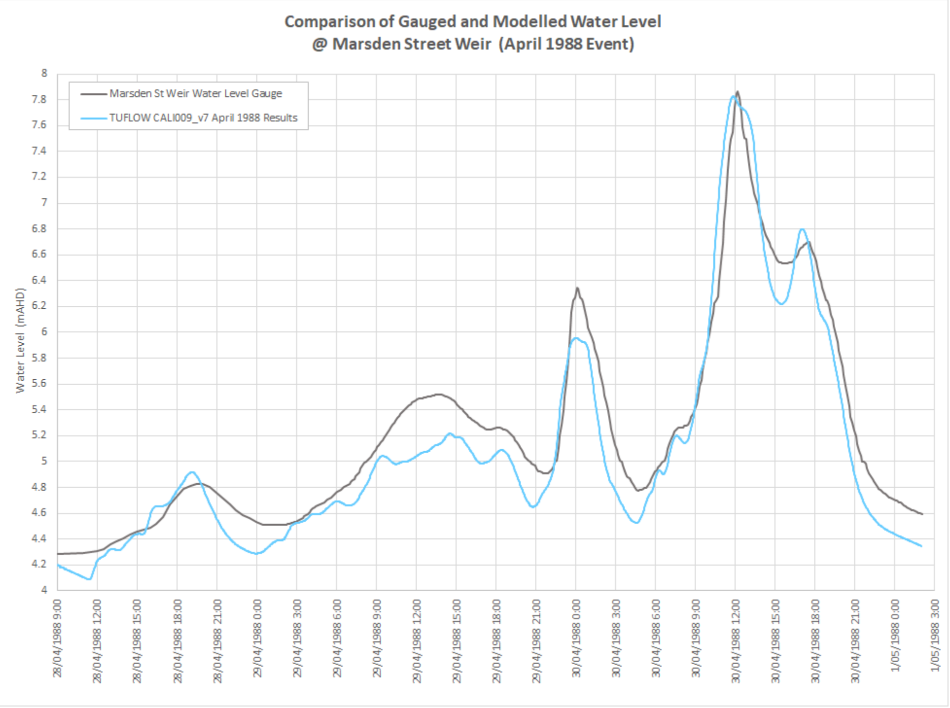


Figure B1-10 Comparison of TUFLOW and RAFTS Modelling Results and Gauged Data for the April 1988 Event

Stantec

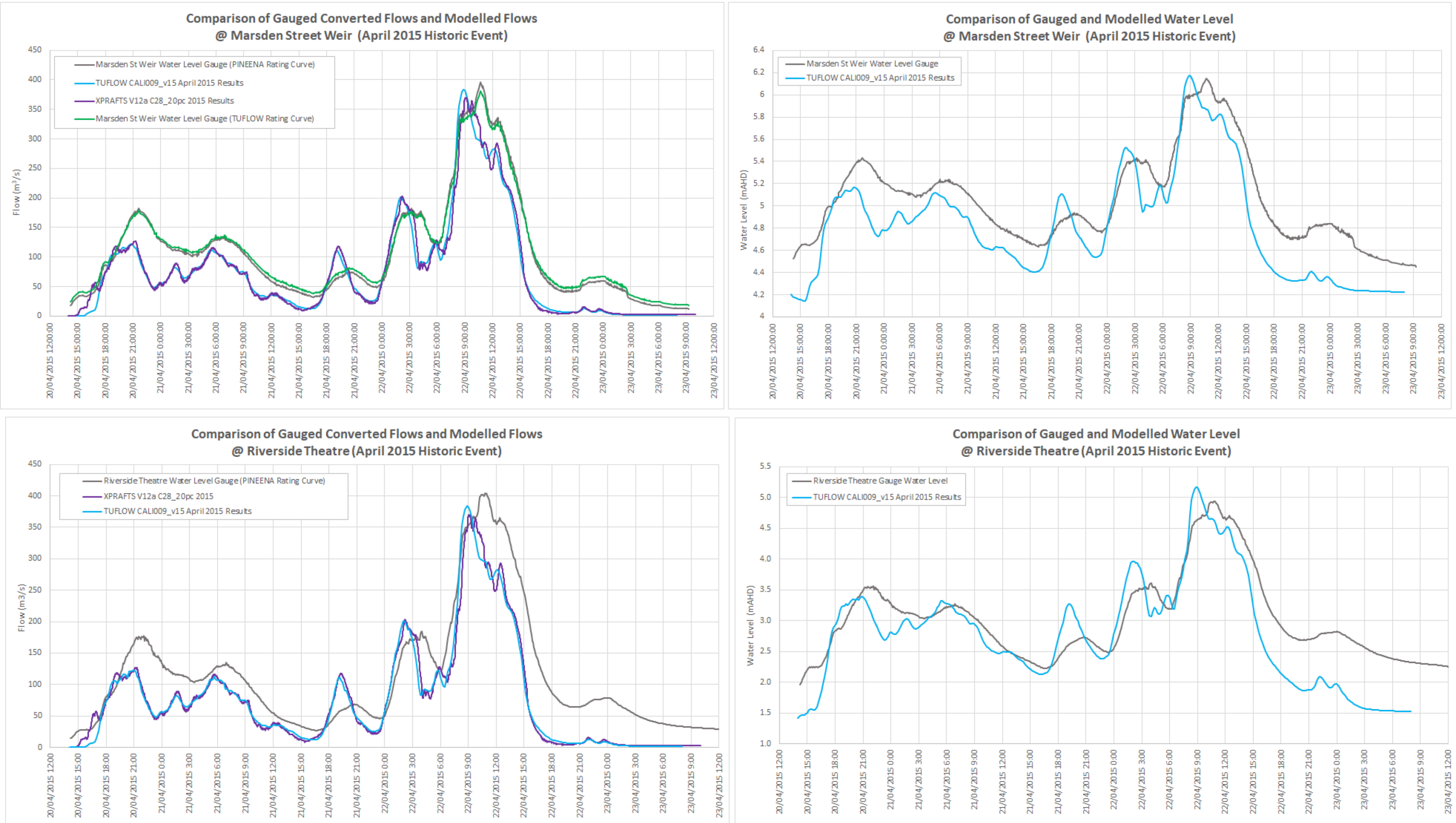


Figure B1-11 Comparison of TUFLOW and RAFTS Modelling Results and Gauged Data for the April 2015 Event

B1.4.3 Comparison to MIKE11 Hysteresis Curve

The UPRCT Draft 9 MIKE11 hysteresis curve underestimates water levels by approximately 100 mm when compared to the PINEENA rating curve, for flows up to 600 m^3/s. For flows greater than 600 m^3/s, the rising limb of the MIKE11 hysteresis curve is generally consistent with the PINEENA rating curve. It is possible that the MIKE11 curve was used to extrapolate the PINEENA rating curve for high flow values.

However, the MIKE11 hysteresis curve consistently estimates water levels that are 200 to 600 mm lower when compared to the TUFLOW revised rating curve. As such, a review of the MIKE11 model was undertaken to determine the cause of this discrepancy.

Marsden Street Weir

The Marsden St Weir cross section was reviewed and compared between the two models. As can be seen in **Figure B1-12**, the MIKE11 model has a weir section that up to RL 8.5 mAHD is approximately 10-15m wider than the surveyed weir section that is being adopted in the TUFLOW model. This additional flow width would lead to lower water levels for a given flow and this is reflected in the rating curve differences observed in **Figure B1-4**.

Lennox Bridge

In the MIKE11 model, Lennox Bridge was modelled as an irregular shaped culvert with an entry loss co-efficient of 0.5 and an exit loss of 1.0. These loss values are typical for a culvert with angled wingwalls which guide flow toward the culvert entrance. Culverts with a square edge 90º wingwall which have a more abrupt transition/contraction would typically use a higher entry loss value of 0.7 or higher.

This method of modelling the bridge as a culvert with 0.5 entry loss would have underestimated the energy losses at Lennox Bridge as MIKE11 does not model orifice flow for culverts, and the adopted entry loss co-efficient is considered low for the bridge configuration. These factors would have underestimated the water level upstream of Lennox Bridge, and therefore, would have underestimated backwater impacts at Marsden Street Weir.

A sensitivity test was undertaken to raise the entry loss coefficient in the MIKE11 model to 0.7 and 0.9 at Lennox Bridge. The rating curves for Lennox Bridge generated by MIKE11 were prepared varying the entry loss coefficient, and are shown in **Figure B1-13**.

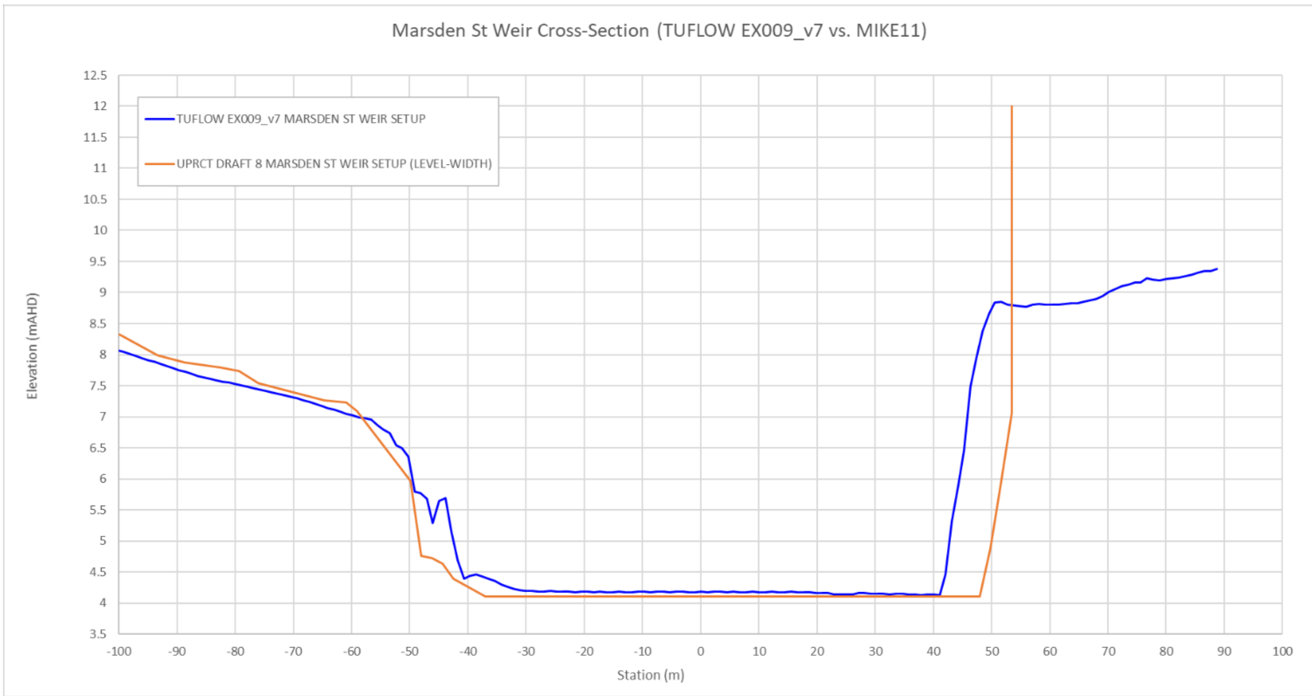


Figure B1-12 Marsden Street Weir setup in TUFLOW and MIKE11

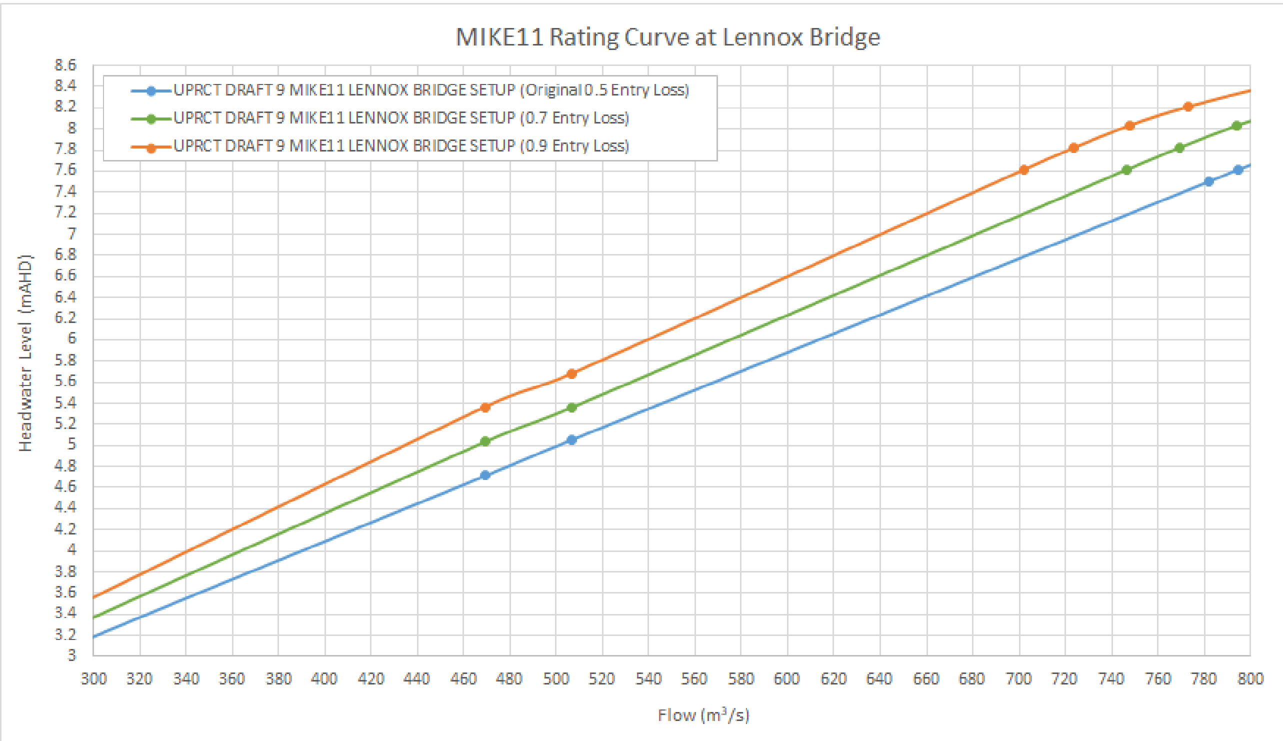


Figure B1-13 Sensitivity Test of MIKE11 Entry Loss Coefficients at Lennox Bridge

According to the sensitivity test, there may be an underestimation of the water level upstream of Lennox Bridge by approximately 300mm and up to 600 mm, when a higher entry loss co-efficient is adopted. This is consistent with the 600 mm difference with the TUFLOW revised rating curve.

Further, as a two-dimensional model calculates the transfer of momentum from one grid cell to the adjacent grid cells, the contraction of flows is more appropriately modelled in the 2d domain without the need for selection of contraction and expansion loss parameters which is necessary in a 1d representation.

B1.4.4 Comparison to Field Gaugings

Figure B1-4 shows that the field gaugings are consistently higher than the TUFLOW revised rating curve, and the MIKE11 hysteresis curve and a number of the gaugings are higher than the PINEENA rating curve, which is fitted through the gauging data.

However, given that the PINEENA rating curve which shows the best fit to the field gaugings, it may be appropriate to adopt the PINEENA rating curve for flows within the range of the gaugings, i.e. for flows less than 220m^3/s, for the purposes of validation of the rating curve at Marsden Street Weir.

B1.4.5 Bentley FlowMaster

Bentley FlowMaster software was used to generate a free-flow weir rating curve at Marsden Street Weir (refer **Figure B1-14**). This curve shows the flow conveyance at Marsden Street Weir for a given upstream water level, provided that the weir is not "drowned out", i.e. the downstream water level reamains sufficiently low for all flow rates.

The free-flow weir rating curve is compared with the TUFLOW hysteresis curve on **Figure B1-14**, which shows the two curves diverging at approximtaely 450 m^3/s.

Bentley FlowMaster was also used to determine the minimum water level downstream of Marsden St Weir that weir flow becomes affected by backwater (i.e., the weir becomes "drowned out" by the elevated downstream water levels). The required tailwater level is shown for a set of flows in **Figure B1-15**.

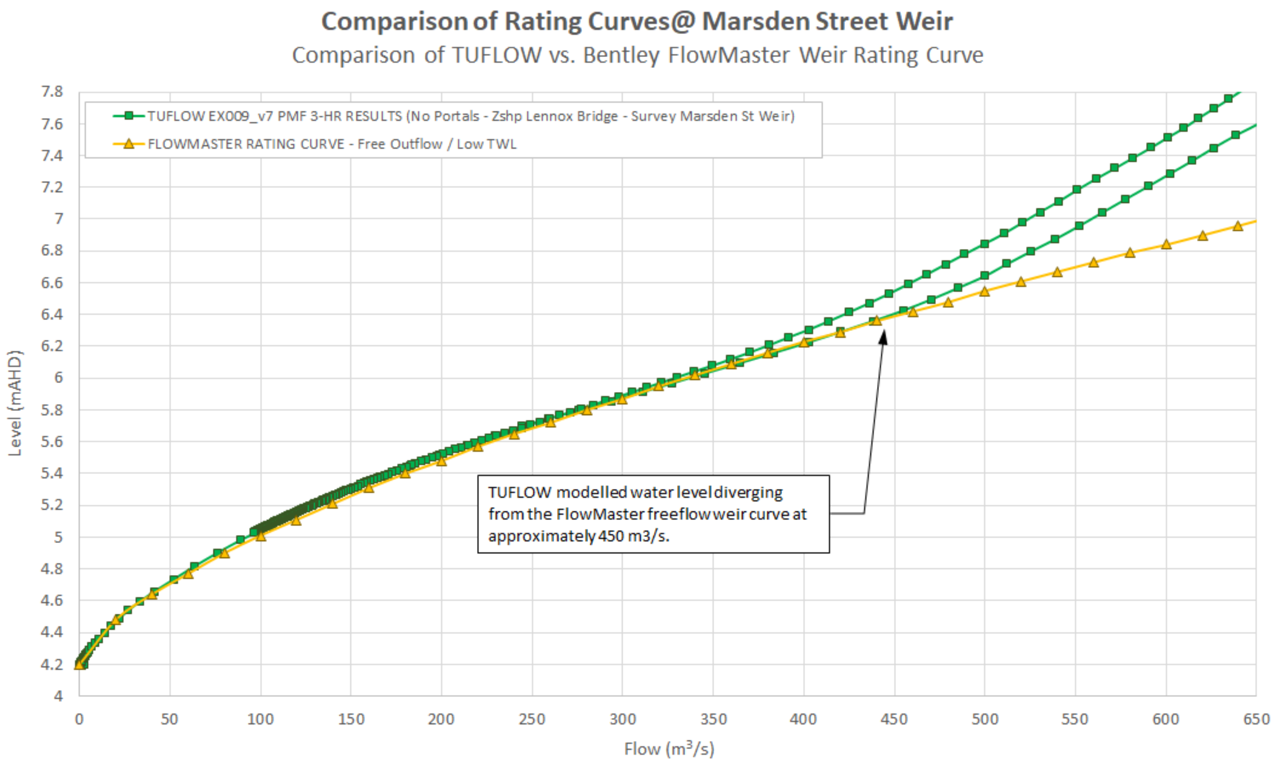


Figure B1-14 Marsden Street Weir Flow rating curve derived using Bentley FlowMaster and TUFLOW

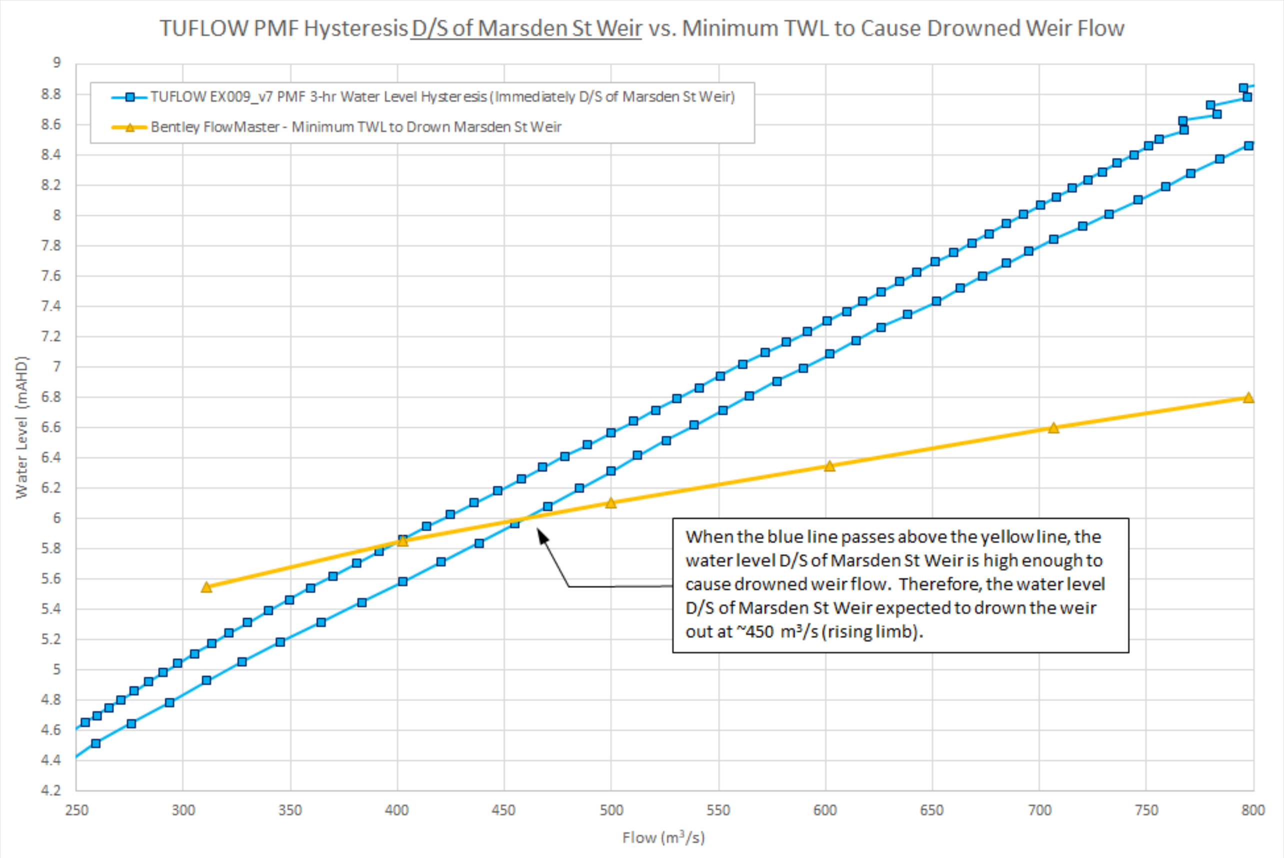


Figure B1-15 Minimum Tailwater Level Required to Caused Drowned Weir Flow

The assessment using Bentley FlowMaster is consistent with the TUFLOW model, and validates the model set up at Marsden Street Weir as well as the backwater effect from Lennox Bridge.

B2 Homogeneous Annual Maximum Flow Series

Since the 1970's, there have been a number of changes to the catchment conditions, primarily through the construction of detention basins, roads and culverts and levees and bridges. In particular, detention basins and hydraulic controls such as roads influence the way runoff is stored in parts of the catchment and the flows that arrive at lower parts of the catchment. For example, for the floods in 1988, if the same rainfall event were to happen today, the flows arriving at Marsden Street Weir would be very different due to the construction of a number of detention basins, in particular Loyalty Road Basin. This facilitates the need to adjust historic flows to expected present day catchment conditions to obtain a homogeneous annual maxima time series of flows.

B2.1 Flow Correlation Pre- and Post-Basin Analysis

Cardno undertook an assessment with the revised rating curve to determine the correlation between historic basin/catchment conditions and present day conditions in order to develop a homogenous Annual Maxima Flow Series (AMS). For the assessment, the basins included in the XPRAFTS model were adjusted to reflect the catchment conditions at the time of each historic flood event. A number of basins were unknown when they had been installed, and a sensitivity was undertaken including and excluding these basins.

At that time excluding the basins appeared to provide a better fit to the gauged discharge data, however, with the revised rating curve, it is apparent that including the unknown basins provides a more sensible correlation with the revised gauge discharge data.

As part of the pre- and post-basin flow correlation analysis, three additional historic events were also selected to provide a more detailed analysis.

The results from the flow correlation analysis were then be used to prepare a homogenous annual maxima dataset, which is used for the Flood Frequency Analysis at Marsden Street Weir.

B2.2 Calibration of Additional Historic Events

As part of the Draft Flood Study, Cardno simulated the April 1988, April 2015 and June 2016 historic flood events for calibration and validation of the hydrology and hydraulic model performance. For this assessment, three additional historic events that occurred in August 1986, February 1990, and June 1991 were selected to be modelled in the RAFTS hydrologic model. These events were selected due to their large peak flows at Marsden Street Weir, and is therefore more likely to be affected by basins in the catchment and required adjustment to current day catchment/basin conditions.

Each event was simulated using a model setup that included the basins known to have existed at the time of the event.

Construction date information for basins within the Parramatta River catchment were extracted from the *Literature Survey of Parramatta Catchment within Parramatta LGA* (Molino Stewart, 2014), and are shown in **Table B2-1**.

Table B2-1 Basins and Construction Date Information (Molino Stewart, 2014).

Retarding Basin	Year Constructed
M J Bennet Reserve	After 2013
Gollan Reserve	2000
Sydney Smith Park	1999
Loyalty Road Basin	1996
Muirfield Golf Course Basin	1993
Cumberland Brighton Street Pond	1993
Cumberland Golf Club Lower	1993
Cumberland New Pond	1993
Cumberland Main Pond	1993
Duncan Park	1992
William Lawson Reserve	1992
Belmore Park Basin	Late 1990
Sierra Place Basin	Built 1990, amplified in 2001
Gooden Drive	1990
Fox Hills Basin	1990
DoP/Boral Basin	1990
CSIRO Basin	1990
Darling Street Reserve Upper	1990
Darling Park Reserve Lower	1990
Mitchell Reserve	Early 1990
McCoy Park Basin	1984

For the basins where no construction date information was provided, but were included in the UPRCT Draft 8 RAFTS Model, they were included in all of the current models. The three catchment/basin conditions that were modelled are as follows:

- Post-1996 (or present-day) Conditions – total of 61 retarding basins activated;
- Pre-1992 Conditions – total of 42 retarding basins activated; and,
- Pre-1990 Conditions – total of 30 retarding basins activated.

Figure B2-1 to **Figure B2-4** compares the hydrographs of the modelling results (shown in orange) and the gauge data (shown in grey) at Marsden Street Weir.

The results show that the model was underestimating peak flows for some historic events. As such, a sensitivity test was undertaken to determine the impact of only including basins which had information regarding their construction date. This was to remove storage in the catchment due to basins in the model which were not known to exist at the time of the events.

In **Figure B2-1** to **Figure B2-4**, the hydrographs for these simulations are shown in blue.

It was determined that for the basin sensitivity analysis (refer report **Section 5.3**) basins with no construction date information would be excluded from the hydrologic models as these provided a better match to peak flows.

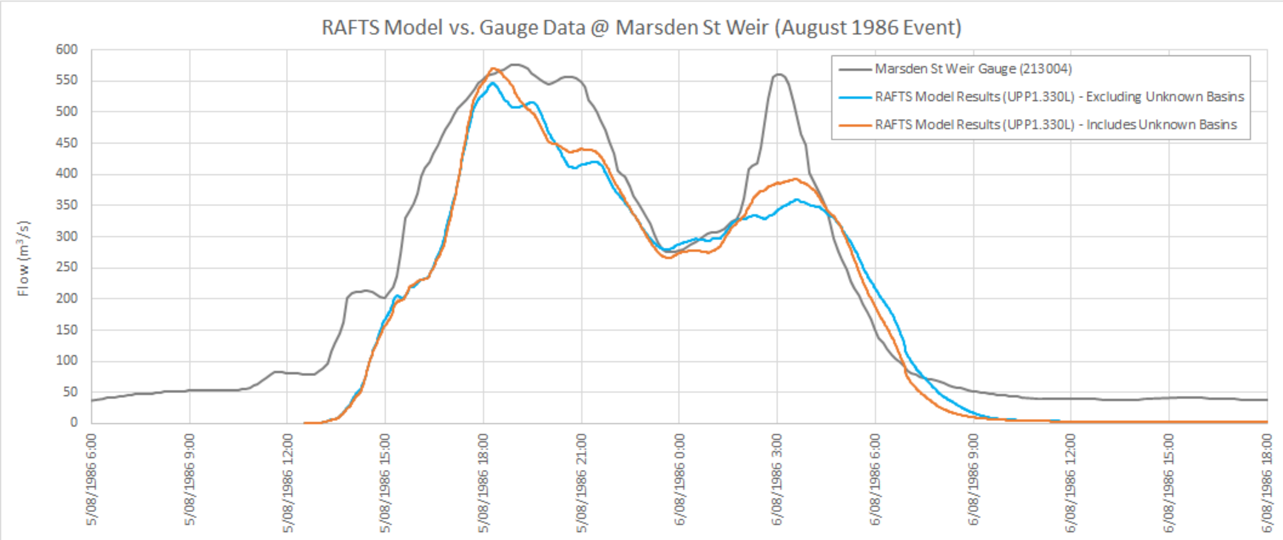


Figure B2-1 Modelled and Gauged Hydrograph at Marsden St Weir for the August 1986 event

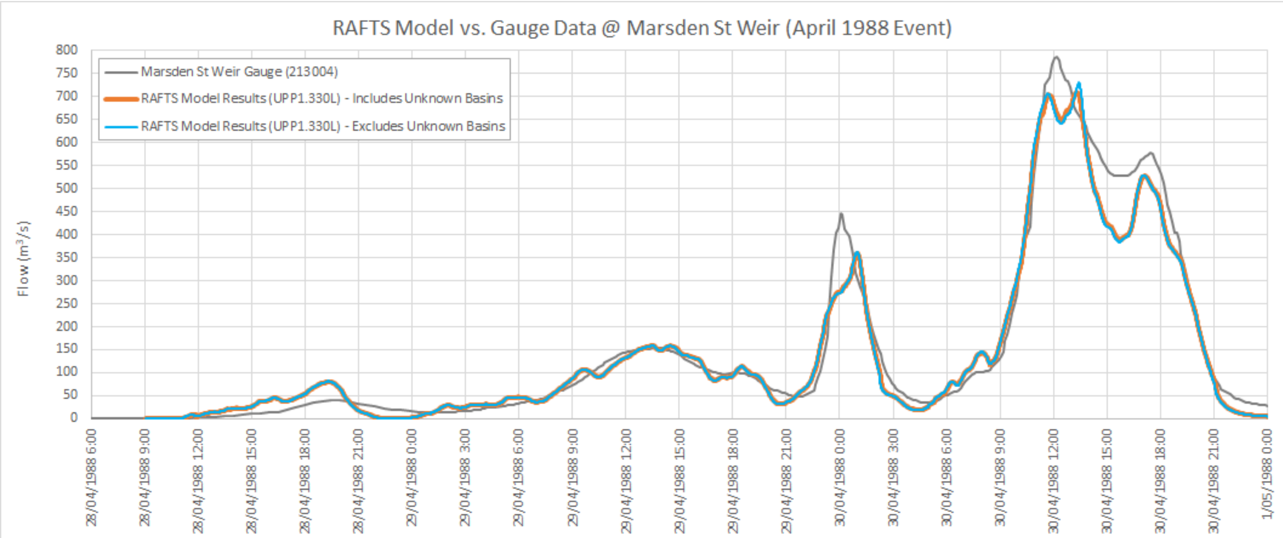


Figure B2-2 Modelled and Gauged Hydrograph at Marsden St Weir for the August 1988 event

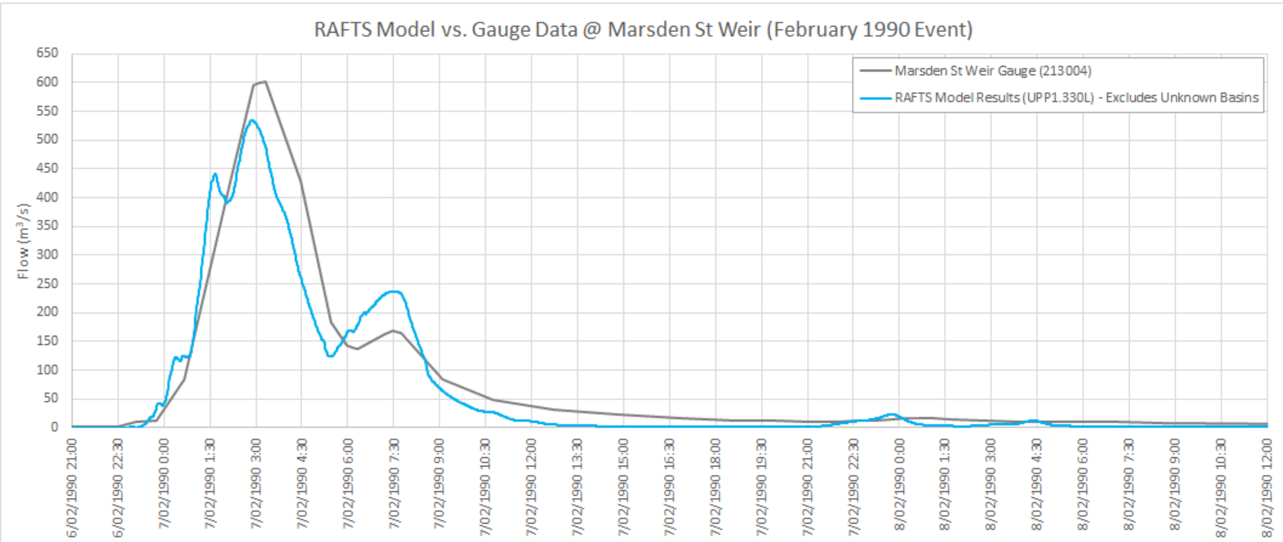


Figure B2-3 Modelled and Gauged Hydrograph at Marsden St Weir for the February 1990 event

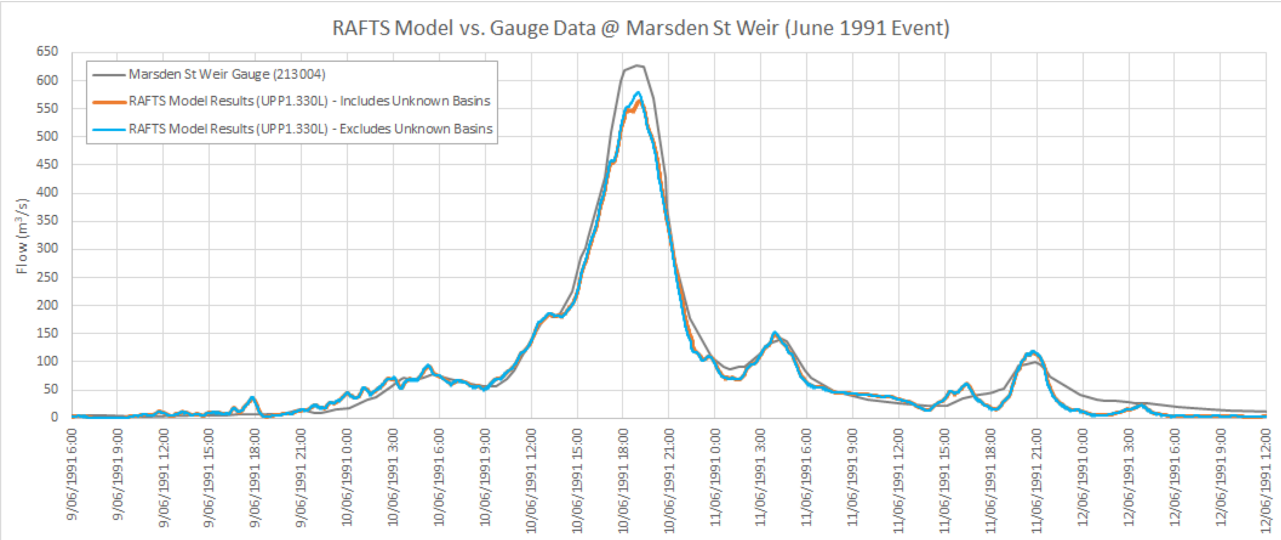


Figure B2-4 Modelled and Gauged Hydrograph at Marsden St Weir for the June 1991 event

B2.3 Modelled Storm Events

To assess the hydrologic model sensitivity to retarding basins, seven historic events were selected to be modelled under different catchment/basin conditions. These included:

- August 1986
- April 1988
- February 1990
- June 1991
- April 2015
- June 2016
- 1.5 times:
  - August 1986 Rainfall
- 2 times:
  - June 1991 Rainfall

B2.4 Catchment/Basin Condition Scenarios

The abovementioned events were then modelled under three catchment/basin conditions. These were:

- Post-1996 (or present-day) Conditions – total of 61 retarding basins activated;
- Pre-1992 Conditions – total of 42 retarding basins activated; and,
- Pre-1990 Conditions – total of 30 retarding basins activated.

It should be noted that all basins with unknown construction dates have been included in this assessment.

B2.5 Hydrologic Modelling Results

The peak flows at Marsden Street Weir for the events simulated under different development conditions are shown below in **Table B2-2**. The scatter plot in **Figure B2-5** shows the peak flows in historic development conditions, and their equivalent peak flows if the historic events were to occur in present-day development conditions. The correlation equations are also shown.

Table B2-2 Peak Flows at Marsden Street Weir for Basin Sensitivity Analysis

Event	Peak Flow @ Marsden St Weir (m^3/s)		
	Post-1996 Conditions	Pre-1992 Conditions	Pre-1990 Conditions
2x June 1991	1044.2	**1130.1**	1234.7
1.5x August 1986	917.1	964.1	**1012.2**
April 1988	634.0	691.0	**708.4**
June 1991	551.5	**579.5**	585.0
August 1986	539.7	566.7	**570.4**
February 1990	493.3	560.7	**592.1**
April 2015	**370.1**	361.3	363.4
June 2016	**354.5**	391.2	397.7

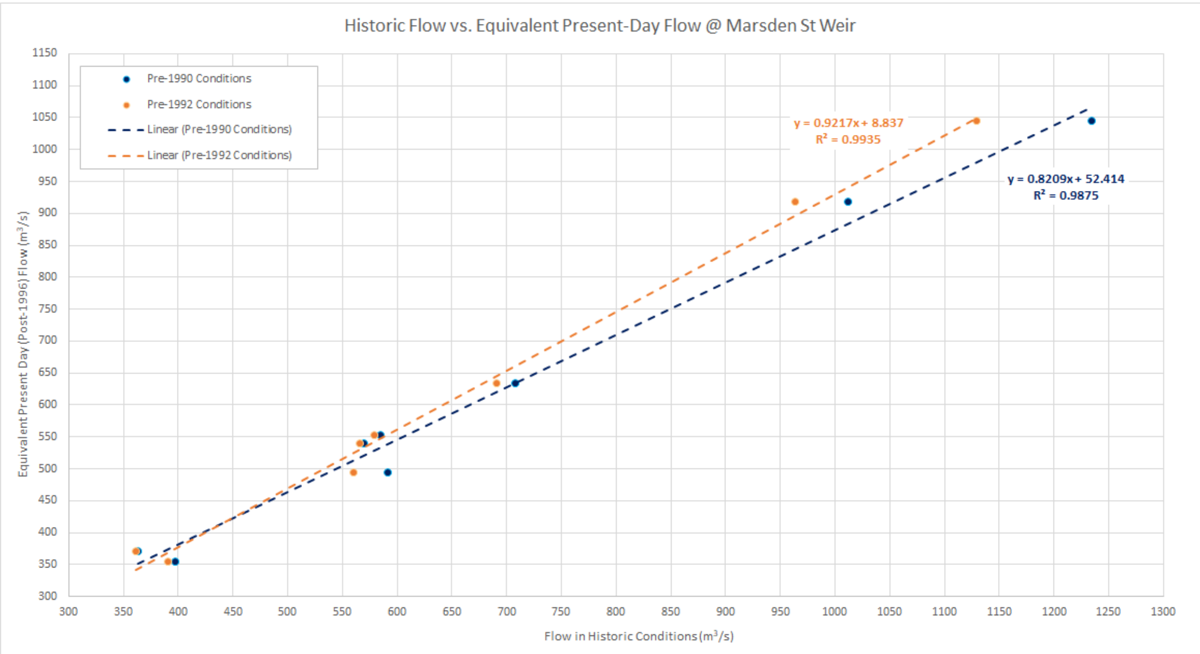


Figure B2-5 Correlation of Peak Flows in Historic and Present-Day Development Conditions

B3 Revised Annual Maxima Series

A revised annual maxima peak flow series was prepared based on the results of the basin sensitivity analysis that was provided in the *Draft Review of Flow Correlation Pre- and Post-Basin Analysis for Revised Annual Maxima Flows - RevB v3* (Cardno, April 2019). The linear correlation was re-established for Pre-1992 and Pre-1990 events, as shown in **Figure B2-5**. This linear correlation was used to adjust the larger annual maxima peak flow values to an equivalent present-day peak flow. Smaller flows remain unchanged as the impact of basins is negligible. The correlation equations derived from **Figure B2-5** used are as follows:

- For events before 1990: $(Historic\ Flow \times 0.8209) + 52.414 = Equivalent\ Present\ Day\ Flow$
- For events between 1990-1992: $(Historic\ Flow \times 0.9217) + 8.837 = Equivalent\ Present\ Day\ Flow$

The revised peak flow annual maxima series is shown in **Table B3-1**.

Table B3-1 Revised Annual Maxima Peak Flow Series

Year	Gauged Maximum Flow (m^3/s) (PINEENA Rating)	Gauged Maximum Flow (m^3/s) (TUFLOW Rating)	Adjustment	Present Day Annual Maximum Flow (m^3/s)
1889	835.0	747.1	-87.9	653.8
1914	760.6	655.5	-105.1	583.8
1956	602.7	516.5	-86.2	473.2
1961	486.7	444.9	-41.8	415.9
1967	548.9	487.4	-61.5	449.9
1979	52.5	54.1	1.6	54.1
1980	112.8	108.6	-4.2	108.5
1981	92.8	90.8	-2.0	90.8
1982	55.0	56.4	1.4	56.4
1983	120.3	114.8	-5.5	114.8
1984	124.8	118.5	-6.2	118.5
1985	151.3	140.2	-11.1	140.2
1986	573.7	505.4	-68.4	465.2
1987	203.9	185.1	-18.8	185.1
1988	785.4	688.5	-96.9	613.8
1989	238.1	215.5	-22.6	215.6
1990	602.6	526.9	-75.7	482.4
1991	626.7	549.8	-76.9	512.1
1992	246.8	223.5	-23.3	223.6
1993	140.4	131.3	-9.1	131.3
1994	67.9	68.1	0.1	68.1
1995	200.4	182.1	-18.3	182.1
1996	214.1	193.8	-20.3	193.8
1997	128.8	122.0	-6.9	122.0
1998	372.9	342.8	-30.1	343.1
1999	203.4	184.6	-18.7	184.7
2000	99.4	96.8	-2.6	96.8

Year	Gauged Maximum Flow (m^3/s) (PINEENA Rating)	Gauged Maximum Flow (m^3/s) (TUFLOW Rating)	Adjustment	Present Day Annual Maximum Flow (m^3/s)
2001	40.4	42.4	1.9	42.3
2002	79.8	78.7	-1.2	78.7
2003	88.3	86.6	-1.7	86.5
2004*#	41.8	43.8	1.9	43.7
2005#	-	-		-
2006#	-	-		-
2007#	-	-		-
2008#	-	-		-
2009*#	45.4	47.1	1.7	47.1
2010	170.4	156.1	-14.3	156.1
2011	90.1	88.3	-1.8	88.2
2012	227.7	206.1	-21.6	206.1
2013	175.3	160.3	-15.0	160.3
2014	119.9	114.5	-5.4	114.5
2015	396.2	362.7	-33.5	362.8
2016	379.0	348.1	-30.9	348.4

* Records are only for part year.

No records available and no suitable correlation possible from other gauges

B3.2 Conclusion

A revised rating curve for Marsden Street Weir has been developed using the rising limb of the TUFLOW PMF 3-Hour hysteresis curve. The revised TUFLOW rating curve has been compared to the PINEENA rating curve, UPRCT Draft 9 MIKE11 hysteresis curve and has been validated using Bentley Flow Master and other independent hydraulic calculation checks. The TUFLOW model provides a better definition of the flow rating at Marsden Street Weir, as confirmed when compared with gauged data for historic events.

The PINEENA curve has been adopted for low flows less than 50m^3/s, which better match the gauging data and the TUFLOW curve adopted for extrapolating the curve for values greater than the range of field gaugings. The TUFLOW revised rating curve and adjusted homogenous annual maxima series was adopted for the Flood Frequency Analysis to define the design flow rates for use in the Parramatta River Flood Study modelling.

B4 Flood Frequency Analysis

An initial Flood Frequency Analysis was carried out by Cardno utilising an adjusted annual maxima flow series derived from the PINEENA rating curve for height-discharge at Marsden St Weir. The design flood estimates derived from this FFA were significantly higher than the design flood estimates determined from the hydrology model through ARR2019 methods. Through discussions with Council, OEH and WMAWater (Council's peer reviewers), it was acknowledged that the rating curve review was required and Cardno undertook this work. Through the peer review process, WMAWater developed the FFA and ultimately undertook the final FFA following the rating curve review and development of a present day homogenous AMS. The description of the FFA presented below is adapted from documentation provided by WMAWater.

B4.1 Overview

The reliability of the flood frequency approach depends largely upon the length and quality of the observed record and accuracy of the rating curve. In addition, flood frequency inherently accounts for many assumptions which are required in rainfall runoff routing for determining the magnitude of flow for average recurrence intervals. These assumptions include:

> rainfall pattern and depth,

> joint probability of rainfalls of the various contributing tributaries,

> areal reduction factors, and

> loss rates.

The flood frequency approach does however have some limitations. These are:

> accuracy of high flow gaugings is in the order of ±25% as it is difficult to obtain reliable estimates for significant overbank events where the width of flooding is significant;

> changes to the local topography such as levee banks, hydraulic controls and the construction of basins can affect the homogeneity of the data set;

> short to medium term climatic changes may influence the flood record.

While some of these factors can affect the quality of the flood frequency analysis, for the purpose of assessment of flooding they are considered reasonable.

B4.2 Theory

ARR 2019 recommends that flood frequency analysis should be applied to peak flows or discharges. In frequency analysis of flows, the fitting of a particular distribution may be carried out analytically, by fitting a probability distribution. The data may consist of an annual series, where the largest peak in each year is used, or a partial series, where all floods above a selected base value are used. The relative merits of each method are discussed in detail in ARR. In general, an annual series approach is preferable as there are more methods and experience available. An annual data set was used for this study.

For this analysis a Bayesian maximum likelihood approach has been adopted in preference to L-Moments because the method readily lends itself to include limited information about events outside the continuous period of record. Although both methods are considered best practice in ARR 2019.

The FLIKE flood frequency analysis software developed by Kuczera uses the Bayesian approach and was therefore utilised in this study.

The rating curve (height- discharge relationship) adopted for the estimation of stream flows from the recorded gauge heights is critical to the success of flood frequency analysis. The flood frequency analyses were conducted using the adopted rating curves as described in **Section B1.3**.

B4.3 Analysis at Marsden Street Weir

The Marsden Street Weir gauge (GS 213004) has been operating since 1979, with a 30 year record. The gauge was not operational between March 2004 and September 2009. However no major flood events occurred during this time period, and flows are expected to be quite low.

Historical flood records at Parramatta stretch back to 1889 and show a number of large flood events prior to the start of continuous records. Significant events years include 1889, 1914, 1956, 1961 and 1967 with the

1889 event likely larger than the 1988 event. Estimations of flood levels from these events have been developed as described in Section, using information typically available at Lennox Bridge. Equivalent levels at the Marsden Street Weir were derived based on the TUFLOW model and these were combined with the gauged record, to create a 128 year record (1889-2016).

A homogenous record has been created by adjusting flows to current catchment conditions to account for detention basins built since 1960 (**Section B2**)

B4.3.1 Adopted Fit

An observed 37 flow records were used with 85 years (between 1889 and 1979) below a threshold of 6.4 mAHD and 6 events (between 2004 and 2009) censored.

The Log Pearson Type III (LPIII) was found to provide the best fit to the historical data. The updated FFA curve is plotted on **Figure B4-1**. The expected flows for design AEPs are presented in **Table B4-1**.

B4.3.2 Alternative Fit

There is a distinct jump in the AMS record with no records between 220 and 340m³/s, with the data showing a relatively smooth relationship above and below this transition. This distinct jump makes fitting the FFA difficult as these points are near or outside the 90% confidence limits. An alternative FFA was carried out with a threshold where a distribution was only fitted to the data above this transition (**Figure B4-2**). While it is accepted practice to focus on the upper part of the curve it is unusual to exclude so much of the flood record unless there is a known change in flood mechanism.

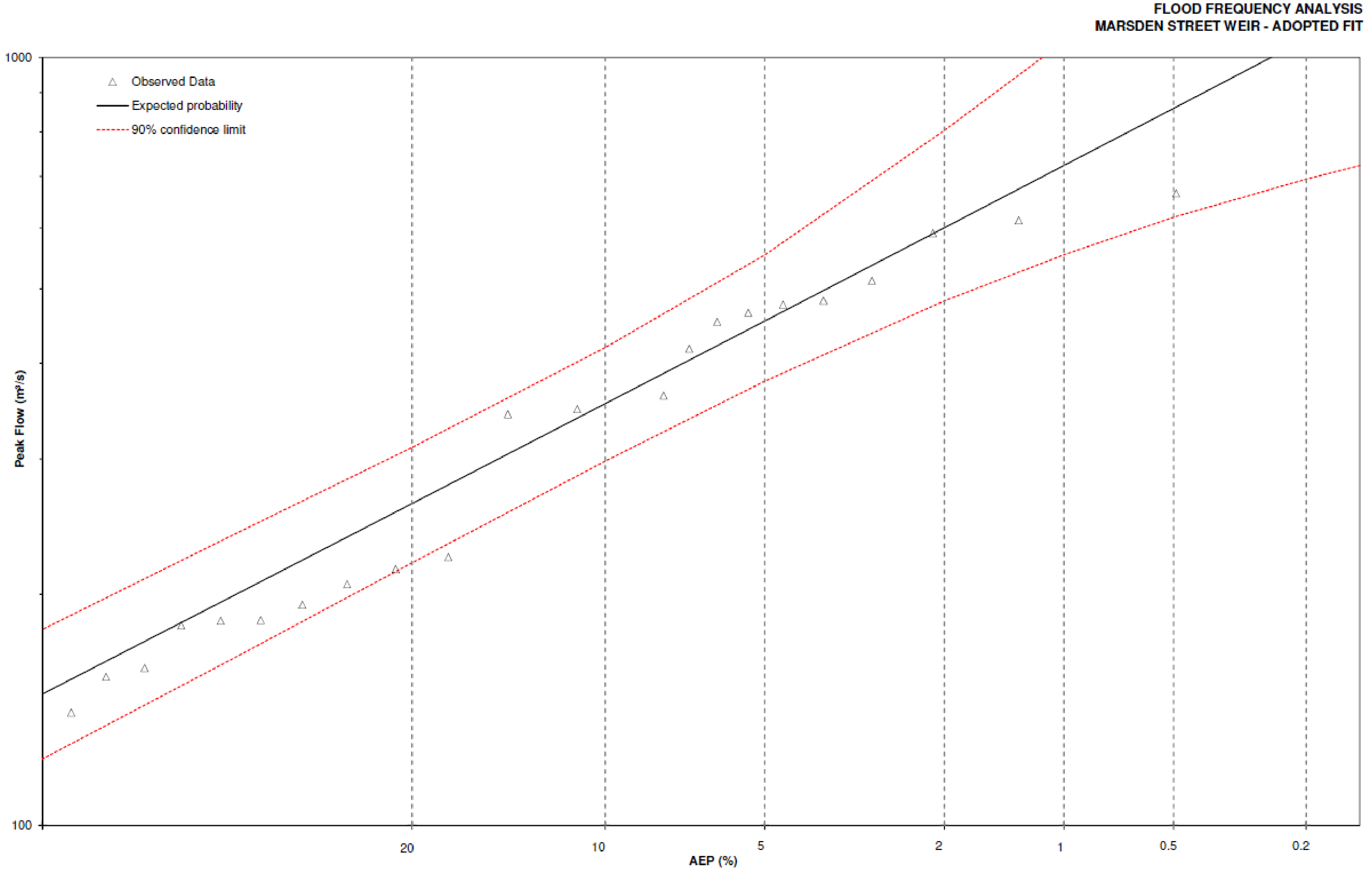
This hypothesis was tested by representing all records less than 340m³/s (a total of 31 years including the years between 2004 and 2009) as events below that threshold rather than including them as observed flows in the record. This is in addition to the 85 years between 1889 and 1979 below a threshold of 6.4m AHD as for the adopted fit.

The results are shown in **Figure B4-2**. While this is a remarkably good fit it is always easy to fit a well-behaved small sample. The results do, however, also match the adopted rainfall runoff results that were adopted prior to this test being carried out.

Table B4-1 Flood Frequency Analysis Results

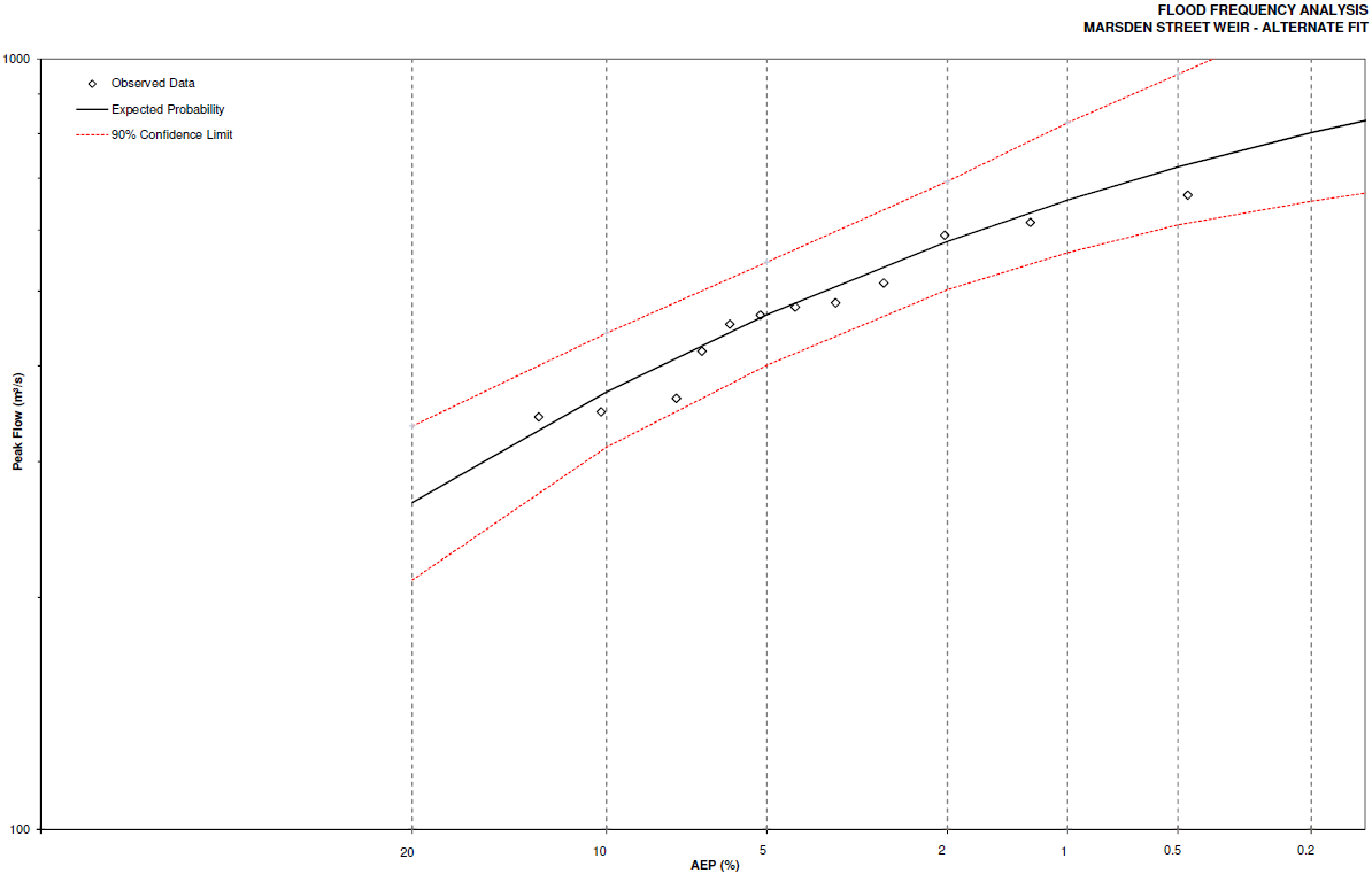
AEP (%) Flow	Adopted Fit (m³/s) Flow	Alternate fit (m³/s)
20	263	266
10	354	370
5	454	465
2	600	591
1	724	656

Figure B4-3 compares the two fits with the prior adopted design flood estimates.



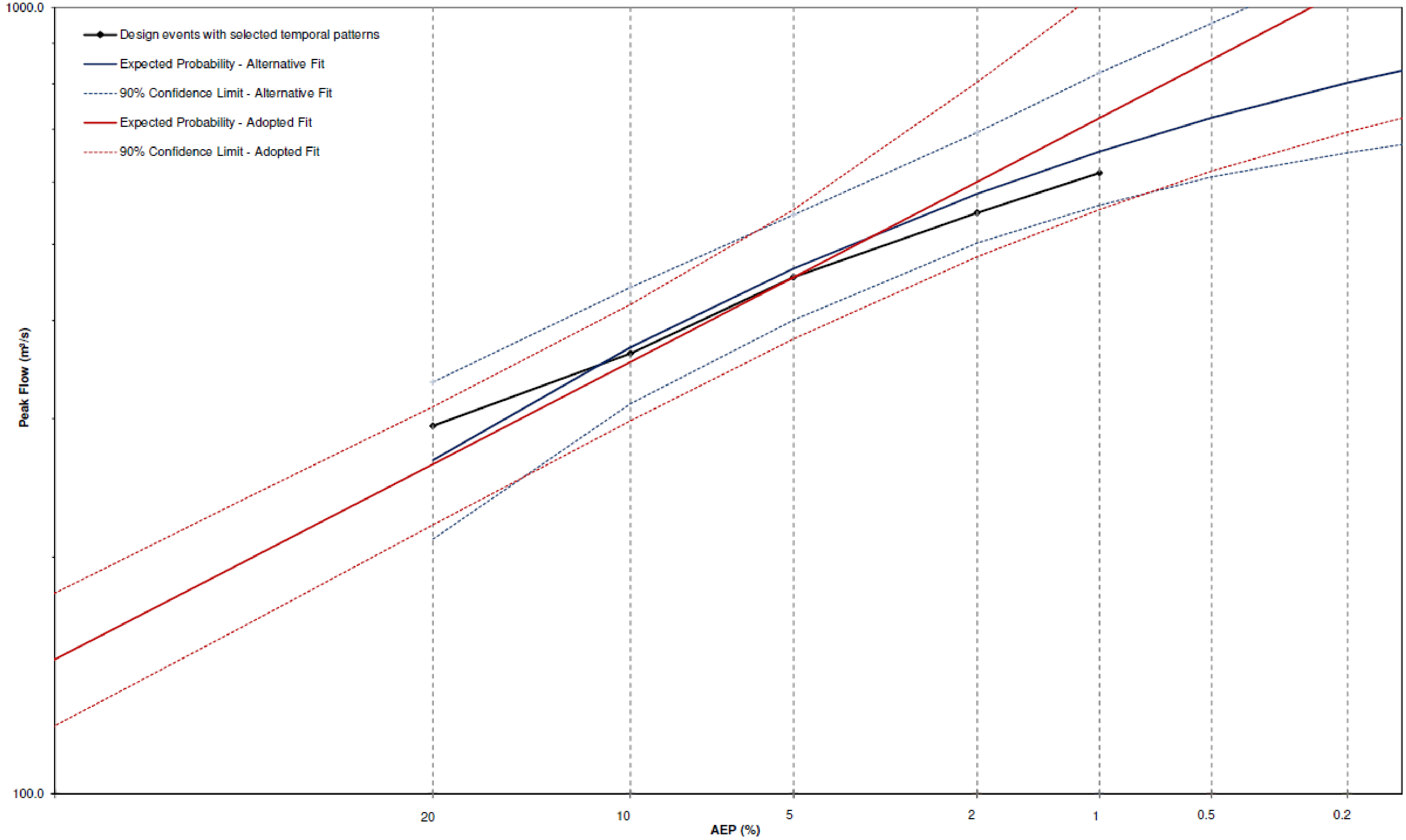
(source: WMAWater)

Figure B4-1 FFA Curve



(source: WMAWater)

Figure B4-2 Alternate FFA Curve



(source: WMAWater)

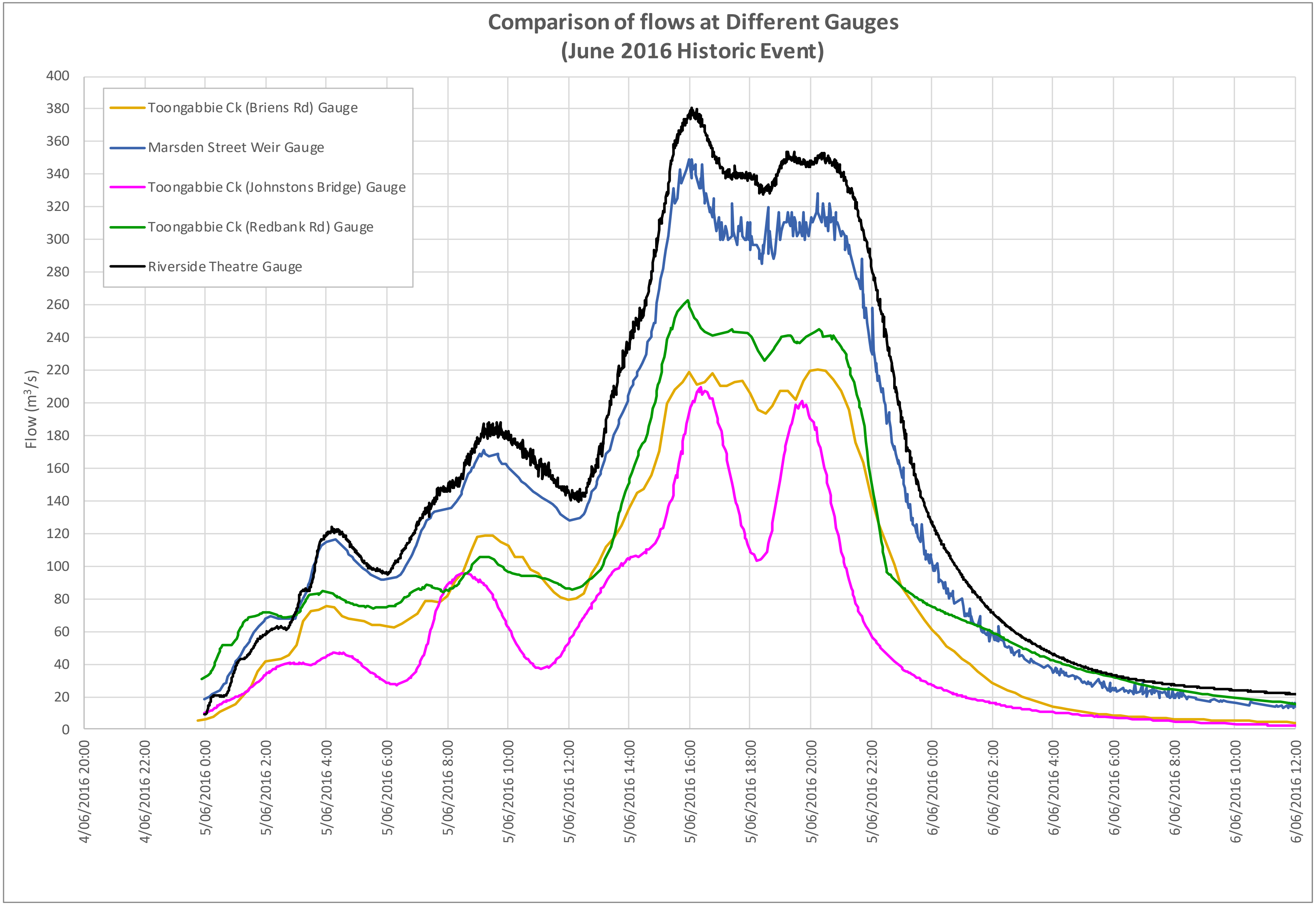
Figure B4-3 Comparison of FFA fits and Design Flood Estimates

APPENDIX

C

CALIBRATION AND VALIDATION

C1. Calibration to Historical Events


Comparison of flows at Different Gauges
(June 2016 Historic Event)
Toongabbie Ck (Briens Rd) Gauge
Marsden Street Weir Gauge
Toongabbie Ck (Johnstons Bridge) Gauge
Toongabbie Ck (Redbank Rd) Gauge
Riverside Theatre Gauge
Flow (m³/s)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
4/06/2016 20:00
4/06/2016 22:00
5/06/2016 0:00
5/06/2016 2:00
5/06/2016 4:00
5/06/2016 6:00
5/06/2016 8:00
5/06/2016 10:00
5/06/2016 12:00
5/06/2016 14:00
5/06/2016 16:00
5/06/2016 18:00
5/06/2016 20:00
5/06/2016 22:00
6/06/2016 0:00
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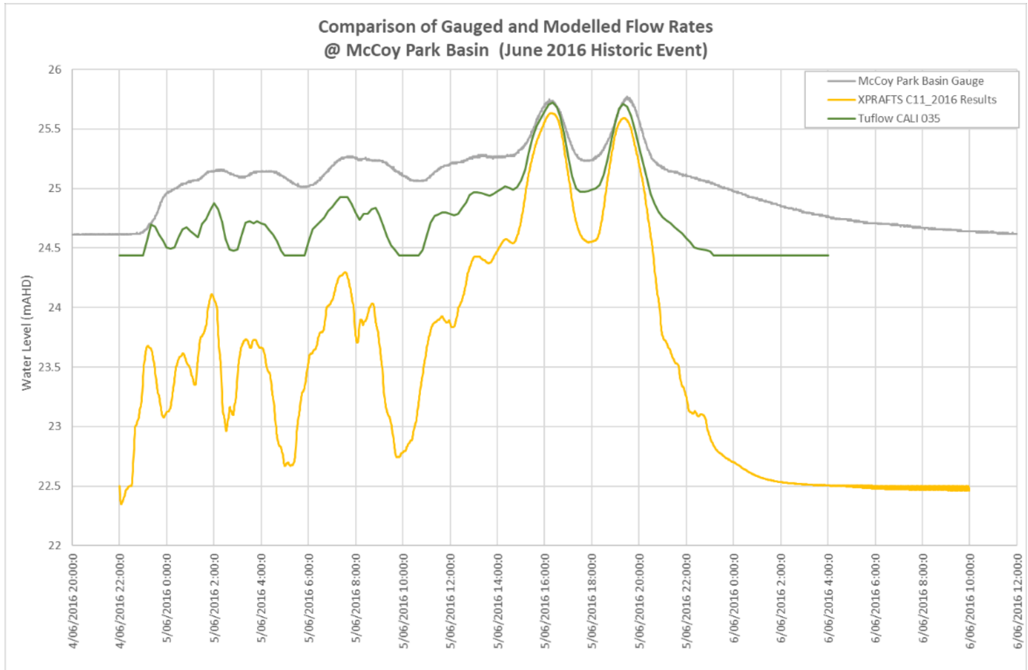
6/06/2016 12:00


Comparison of Gauged and Modelled Flow Rates
@ McCoy Park Basin (June 2016 Historic Event)
McCoy Park Basin Gauge
XPRAFTS C11_2016 Results
Tuflow CALI 035
Water Level (mAHD)
26
25.5
25
24.5
24
23.5
23
22.5
22
4/06/2016 20:00:0
4/06/2016 22:00:0
5/06/2016 0:00:0
5/06/2016 2:00:0
5/06/2016 4:00:0
5/06/2016 6:00:0
5/06/2016 8:00:0
5/06/2016 10:00:0
5/06/2016 12:00:0
5/06/2016 14:00:0
5/06/2016 16:00:0
5/06/2016 18:00:0
5/06/2016 20:00:0
5/06/2016 22:00:0
6/06/2016 0:00:0
6/06/2016 2:00:0
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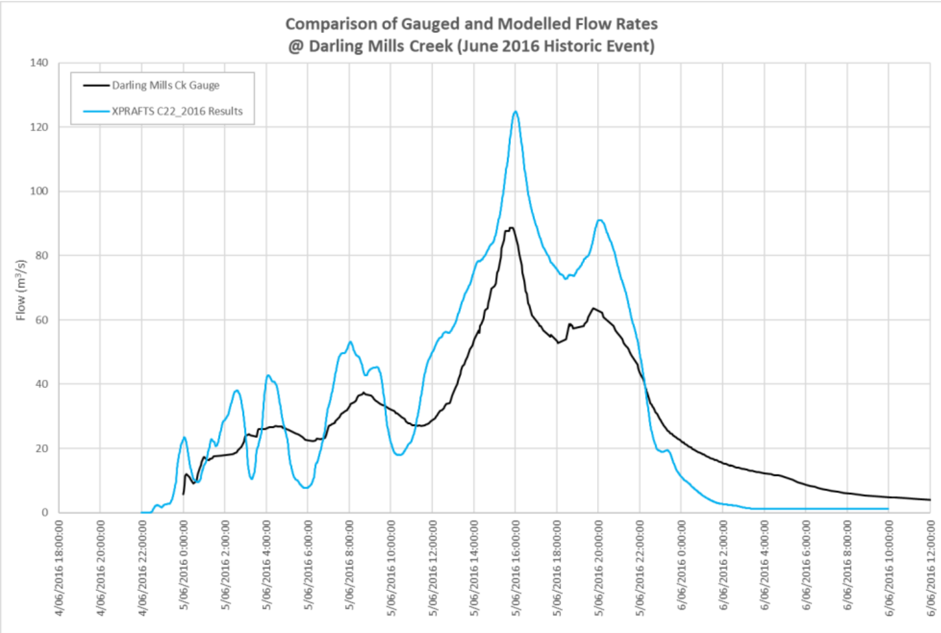
6/06/2016 12:00:0


Comparison of Gauged and Modelled Flow Rates
@ Darling Mills Creek (June 2016 Historic Event)
Darling Mills Ck Gauge
XPRAFTS C22_2016 Results
Flow (m³/s)
140
120
100
80
60
40
20
0
4/06/2016 18:00:00
4/06/2016 20:00:00
4/06/2016 22:00:00
5/06/2016 0:00:00
5/06/2016 2:00:00
5/06/2016 4:00:00
5/06/2016 6:00:00
5/06/2016 8:00:00
5/06/2016 10:00:00
5/06/2016 12:00:00
5/06/2016 14:00:00
5/06/2016 16:00:00
5/06/2016 18:00:00
5/06/2016 20:00:00
5/06/2016 22:00:00
6/06/2016 0:00:00
6/06/2016 2:00:00
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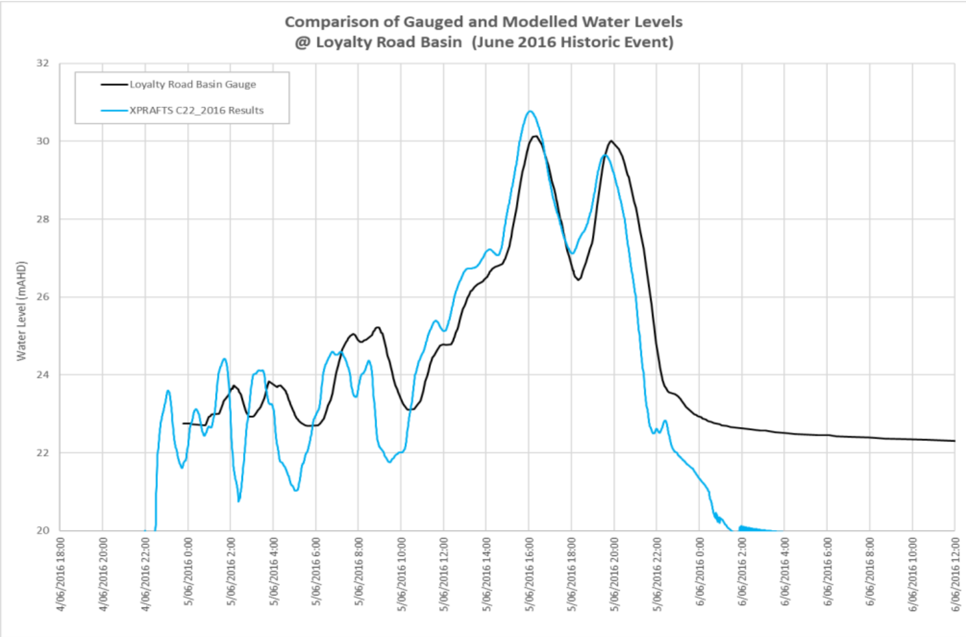
6/06/2016 12:00:00


Comparison of Gauged and Modelled Water Levels
@ Loyalty Road Basin (June 2016 Historic Event)
Loyalty Road Basin Gauge
XPRAFTS C22_2016 Results
Water Level (mAHD)
32
30
28
26
24
22
20
4/06/2016 18:00
4/06/2016 20:00
4/06/2016 22:00
5/06/2016 0:00
5/06/2016 2:00
5/06/2016 4:00
5/06/2016 6:00
5/06/2016 8:00
5/06/2016 10:00
5/06/2016 12:00
5/06/2016 14:00
5/06/2016 16:00
5/06/2016 18:00
5/06/2016 20:00
5/06/2016 22:00
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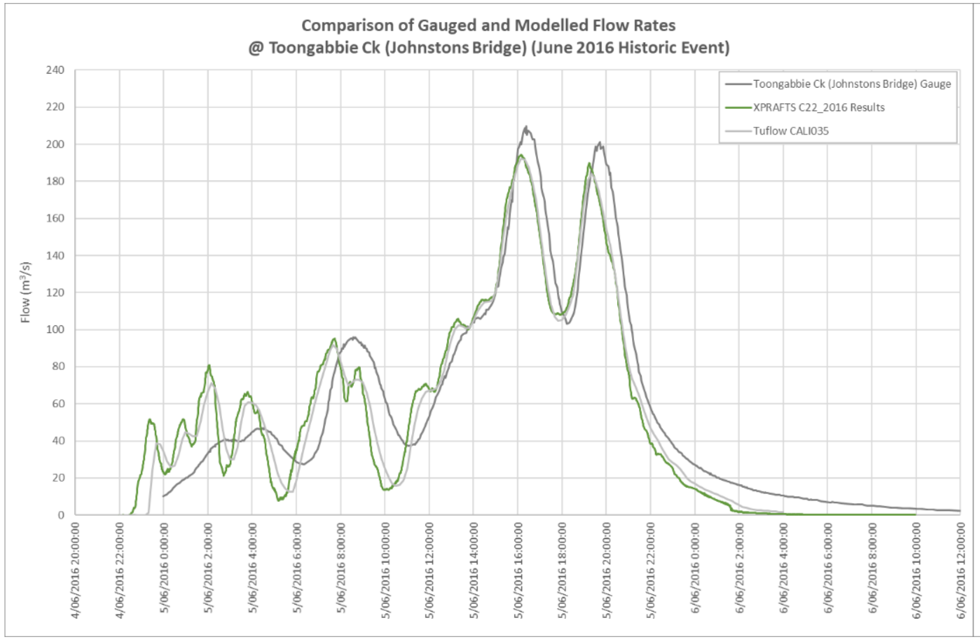
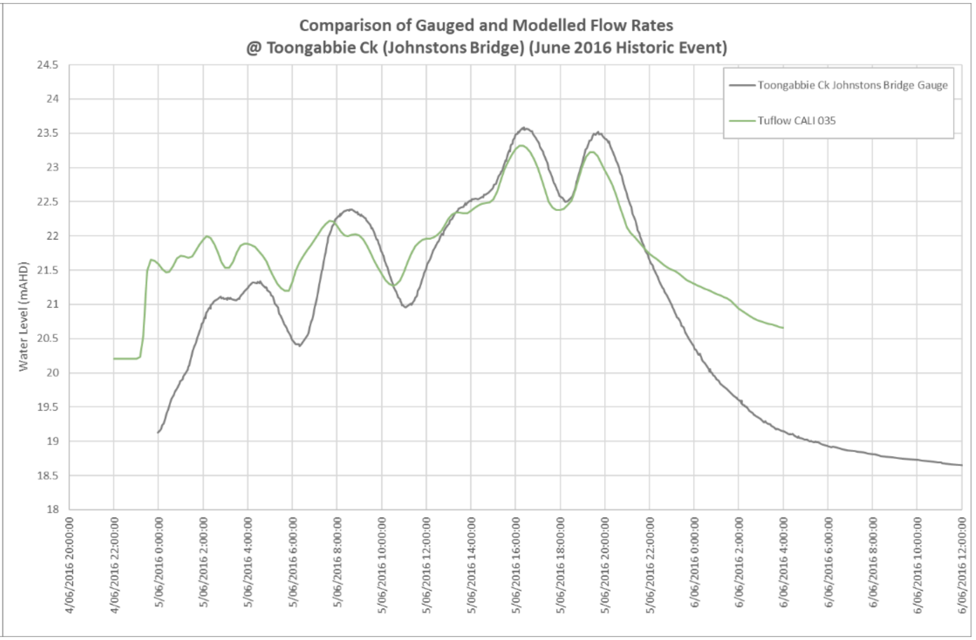
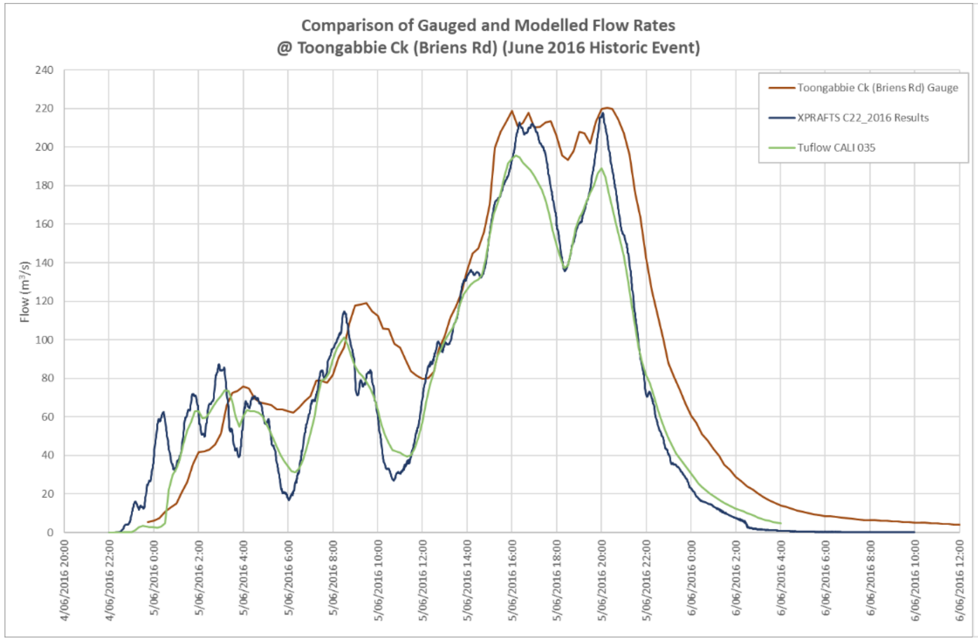
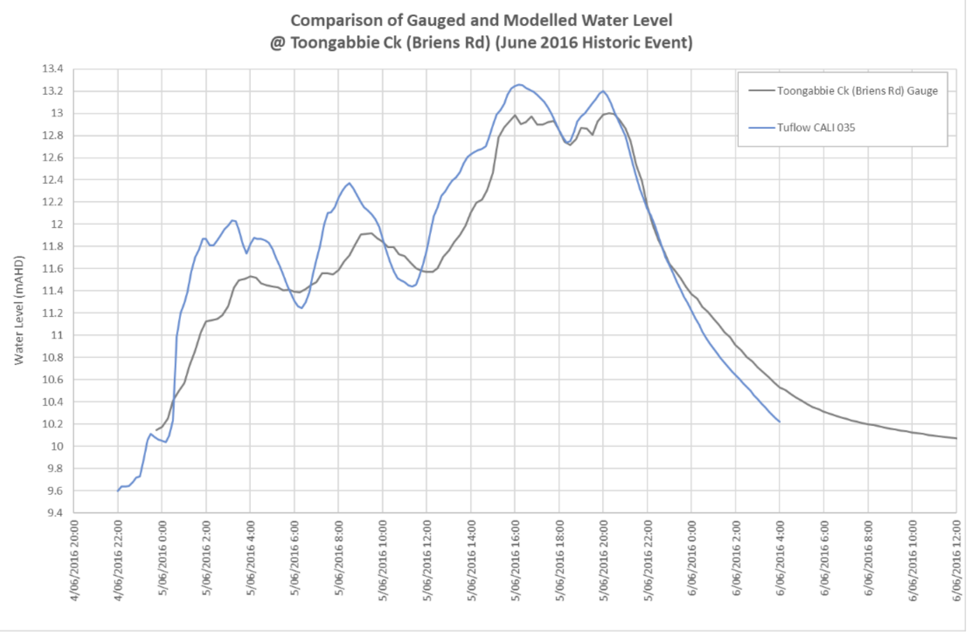
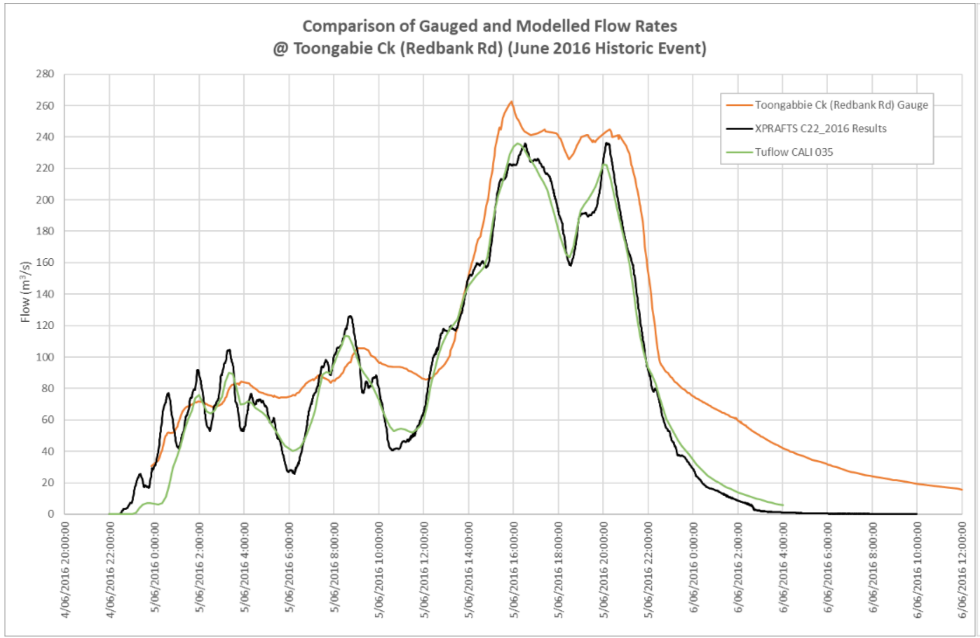
6/06/2016 12:00

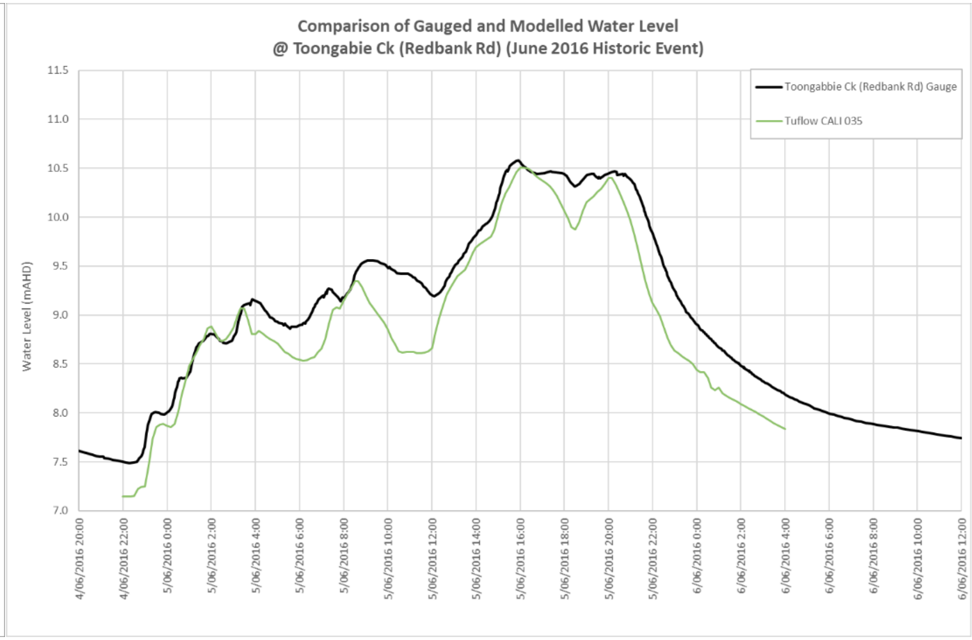

Comparison of Gauged and Modelled Flow Rates
@ Toongabbie Ck (Johnstons Bridge) (June 2016 Historic Event)
Flow (m³/s)
Toongabbie Ck (Johnstons Bridge) Gauge
XPRAFTS C22_2016 Results
Tuflow CALI035

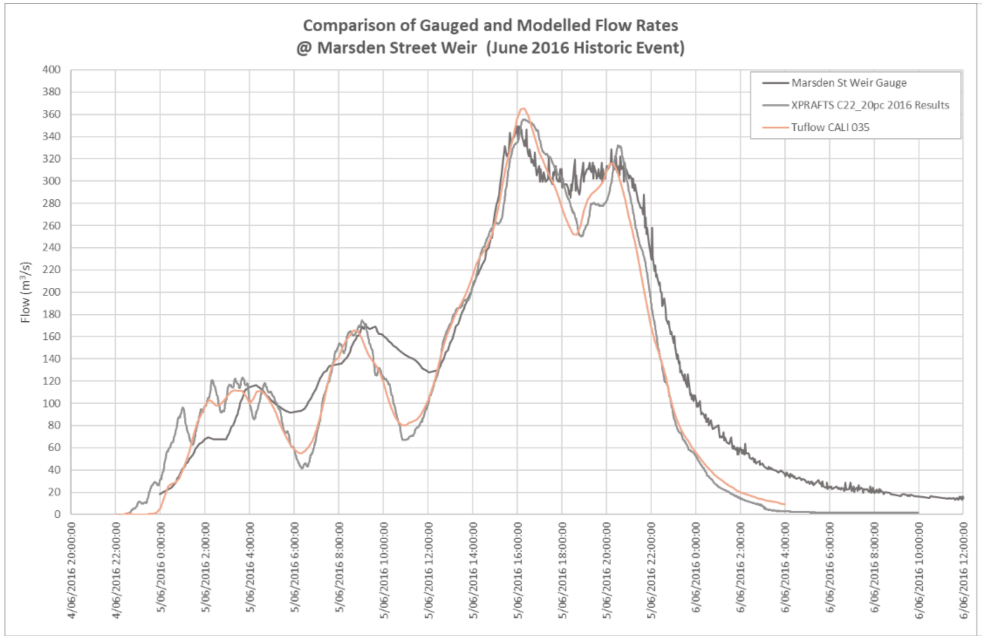

Comparison of Gauged and Modelled Flow Rates
@ Toongabbie Ck (Johnstons Bridge) (June 2016 Historic Event)
Water Level (mAHD)
Toongabbie Ck Johnstons Bridge Gauge
Tuflow CALI 035

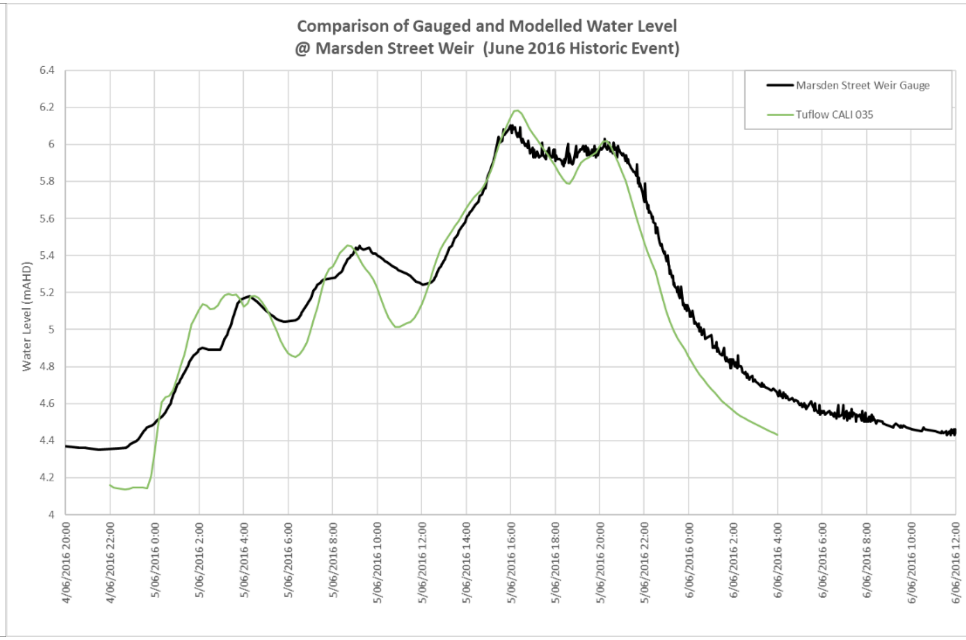

Comparison of Gauged and Modelled Flow Rates
@ Toongabbie Ck (Briens Rd) (June 2016 Historic Event)
Flow (m³/s)
Toongabbie Ck (Briens Rd) Gauge
XPRAFTS C22_2016 Results
Tuflow CALI 035

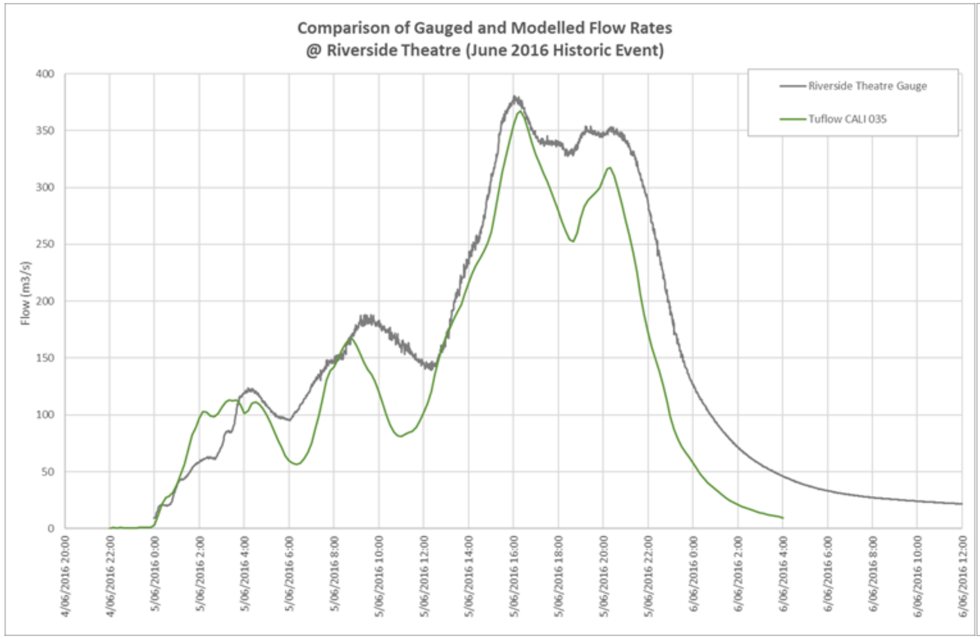

Comparison of Gauged and Modelled Water Level
@ Toongabbie Ck (Briens Rd) (June 2016 Historic Event)
Water Level (mAHD)
Toongabbie Ck (Briens Rd) Gauge
Tuflow CALI 035

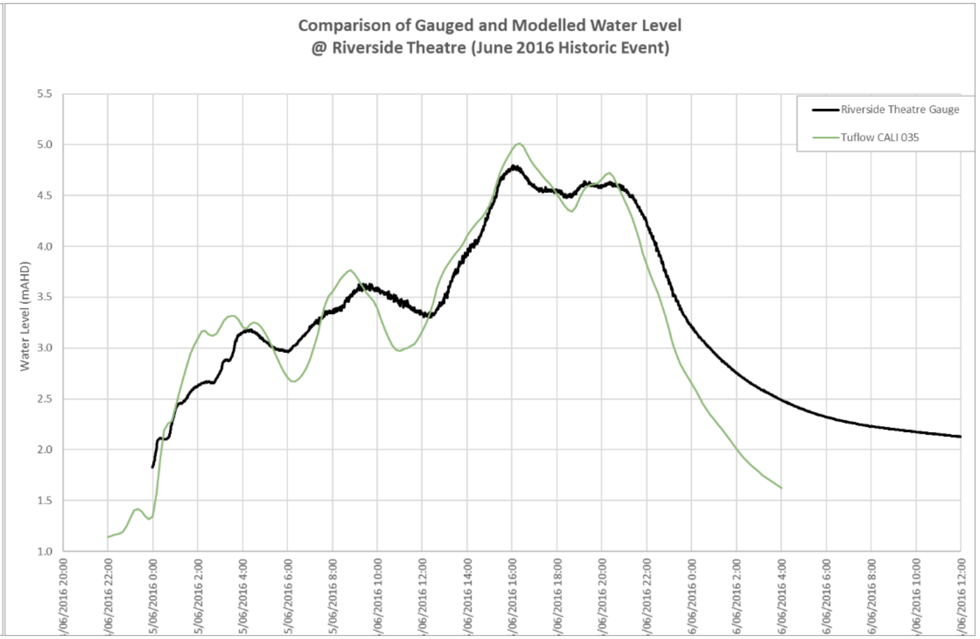

Comparison of Gauged and Modelled Flow Rates
@ Toongabie Ck (Redbank Rd) (June 2016 Historic Event)
Flow (m³/s)
Toongabbie Ck (Redbank Rd) Gauge
XPRAFTS C22_2016 Results
Tuflow CALI 035


Comparison of Gauged and Modelled Water Level
@ Toongabie Ck (Redbank Rd) (June 2016 Historic Event)
Water Level (mAHD)
Toongabbie Ck (Redbank Rd) Gauge
Tuflow CALI 035


Comparison of Gauged and Modelled Flow Rates
@ Marsden Street Weir (June 2016 Historic Event)
Flow (m³/s)
Marsden St Weir Gauge
XPRAFTS C22_20pc 2016 Results
Tuflow CALI 035


Comparison of Gauged and Modelled Water Level
@ Marsden Street Weir (June 2016 Historic Event)
Water Level (mAHD)
Marsden Street Weir Gauge
Tuflow CALI 035


Comparison of Gauged and Modelled Flow Rates
@ Riverside Theatre (June 2016 Historic Event)
Riverside Theatre Gauge
Tuflow CALI 035
Flow (m3/s)


Comparison of Gauged and Modelled Water Level
@ Riverside Theatre (June 2016 Historic Event)
Riverside Theatre Gauge
Tuflow CALI 035
Water Level (mAHD)

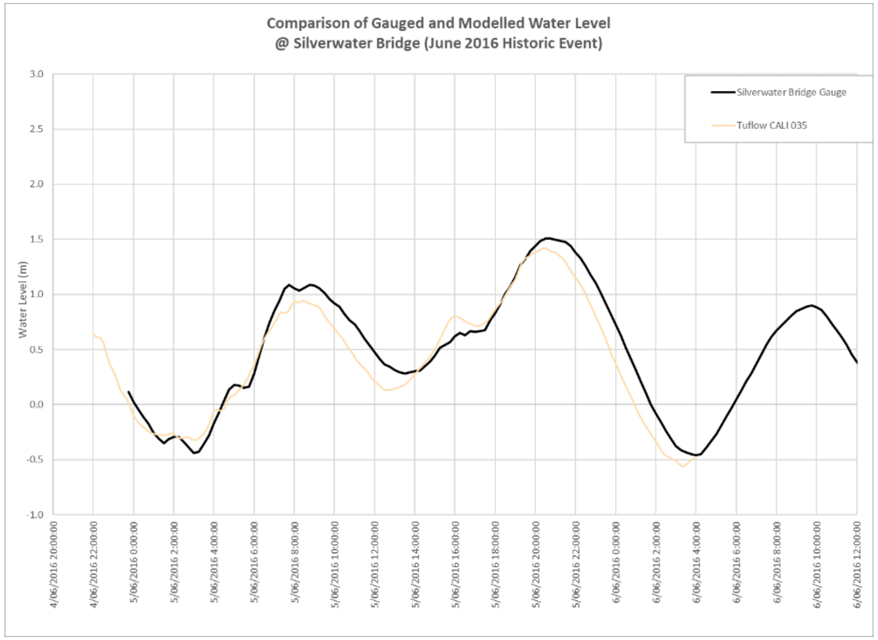
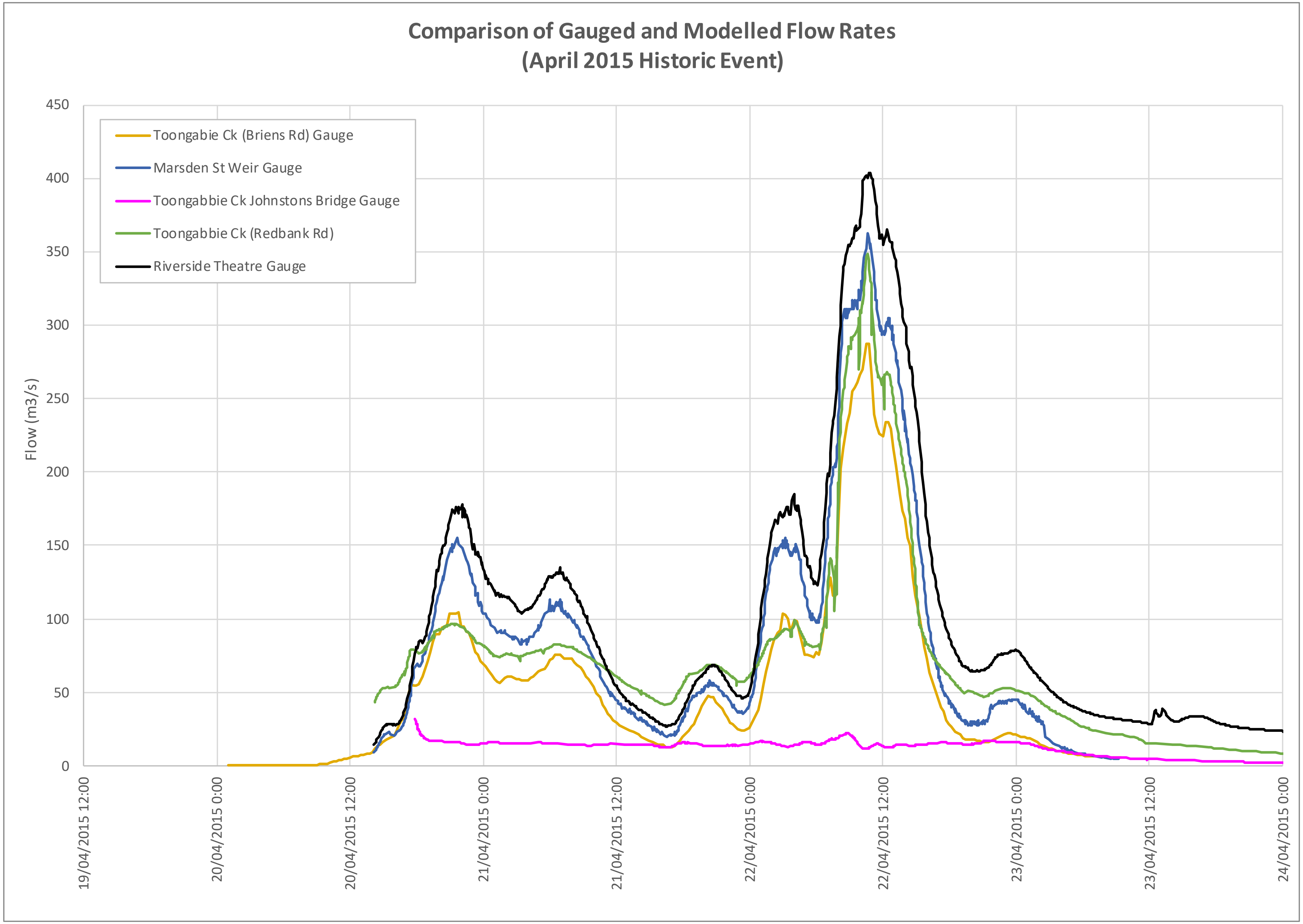
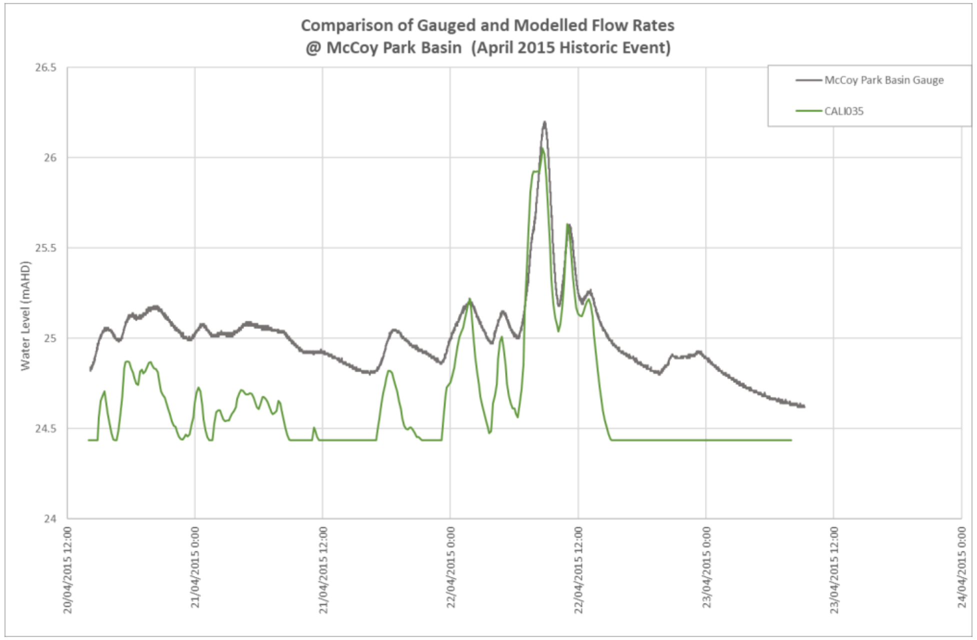
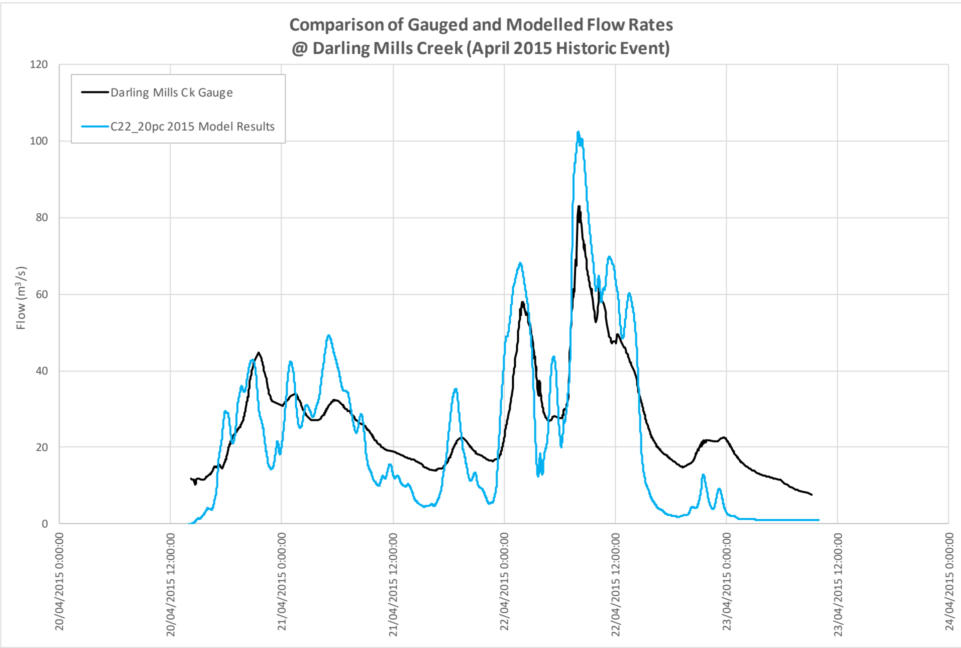

Comparison of Gauged and Modelled Water Level
@ Silverwater Bridge (June 2016 Historic Event)
Silverwater Bridge Gauge
Tuflow CALI 035
Water Level (m)

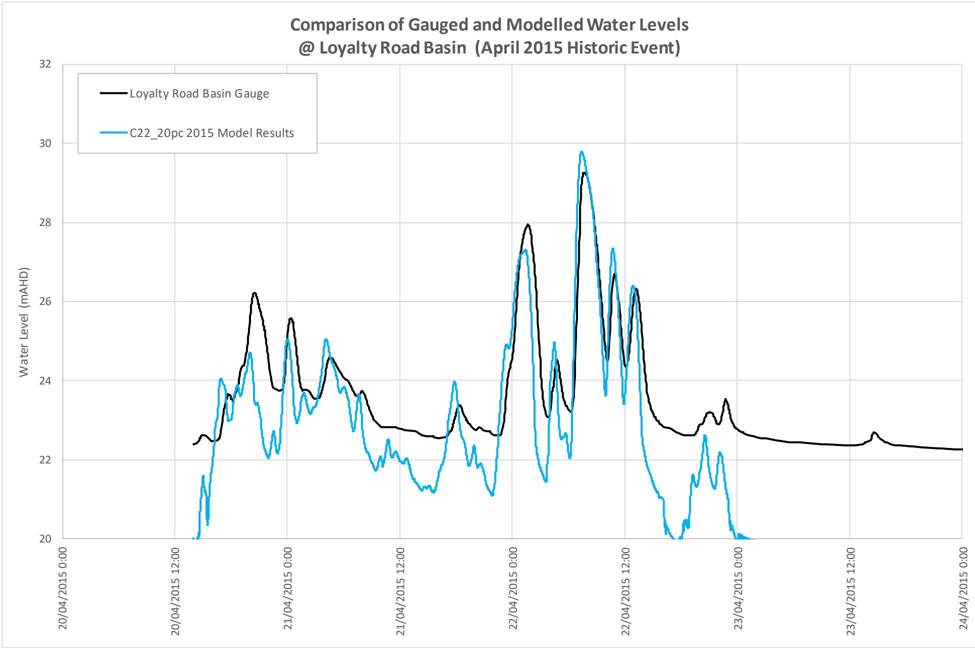
Table C.1: Comparison between historical gauge data and TUFLOW calibration model for June 2016 Storm:

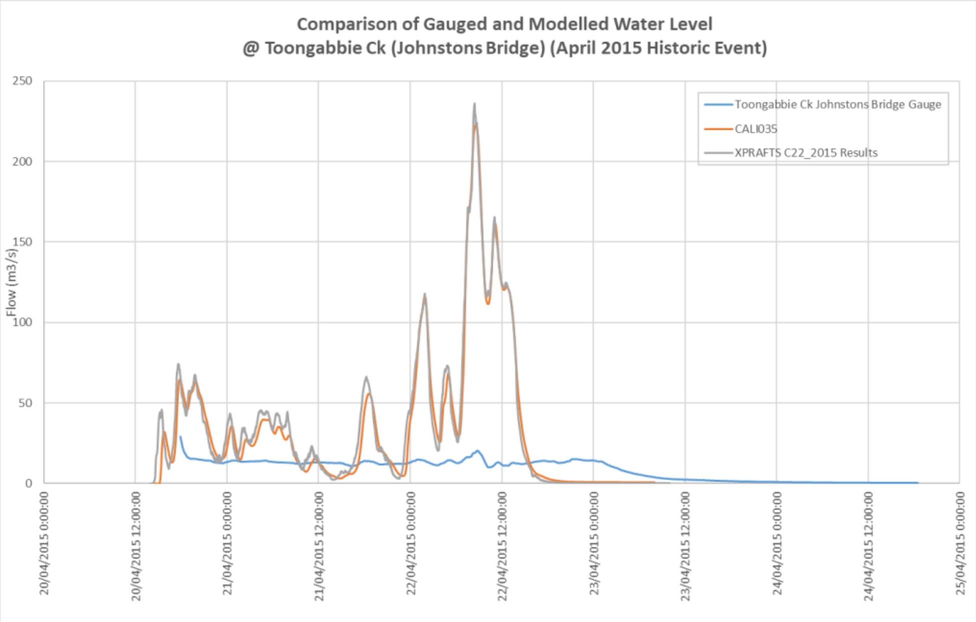
GAUGE STATION	Gauged Peak WL (mAHD)	TUFLOW Modelled Peak WL (mAHD)	WL Difference (mAHD)	Gauged Flow (m^3/s)	TUFLOW Modelled Flow (m^3/s)	Percentage (%) Flow Differences	COMMENTS
McCoy Park Basin	25.77	25.65	-0.12	N/A	139.42	N/A	Gauge flow is not available
Toongabbie Creek (JOHNSTONS BRIDGE)	23.59	23.52	-0.06	209.9	195.31	-6.97%	
Toongabbie Creek (BRIENS ROAD)	13.00	13.26	0.26	220.5	195.74	-11.2%	
Darling Mills Creek (Viaduct)	12.26	12.33	0.07	N/A	122.57	N/A	Gauge flow is not available
Lake Parramatta	29.36	N/A	N/A	N/A	N/A	N/A	Tuflow calibration model does not cover the gauge location
Toongabbie Creek (REDBANK ROAD)	10.58	10.51	-0.07	262.5	239.05	-10.14%	Gauge data may not be reliable
MARSDEN ST WEIR	6.10	6.18	0.08	363.5	365.21	0.5%	
RIVERSIDE THEATRE	4.80	5.01	0.22	380.72	367.15	-3.59%	
Silverwater Bridge	1.51	1.42	-0.09	N/A	565.62	N/A	Gauge flow is not available

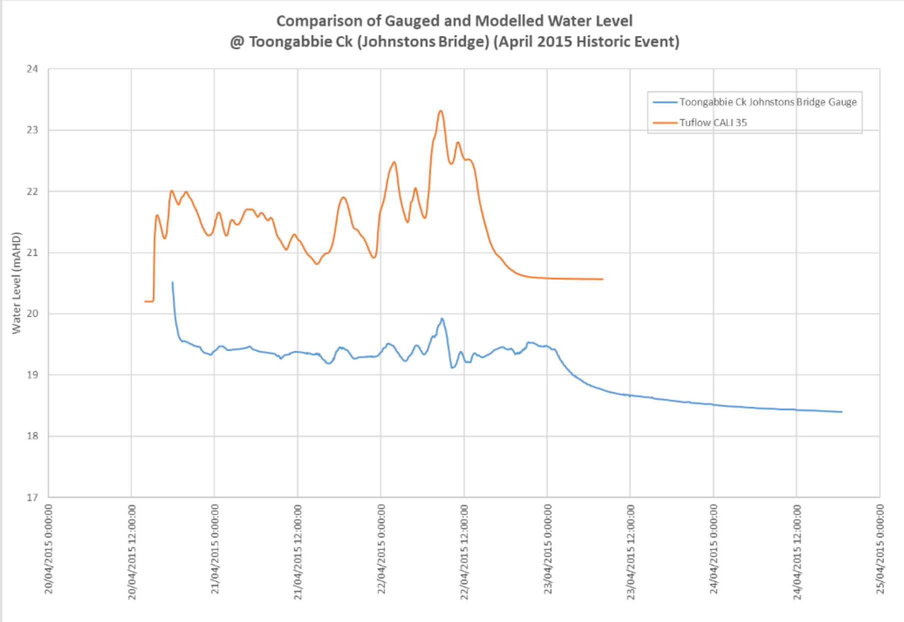

Comparison of Gauged and Modelled Flow Rates
(April 2015 Historic Event)
Toongabie Ck (Briens Rd) Gauge
Marsden St Weir Gauge
Toongabbie Ck Johnstons Bridge Gauge
Toongabbie Ck (Redbank Rd)
Riverside Theatre Gauge
Flow (m3/s)
0
50
100
150
200
250
300
350
400
450
19/04/2015 12:00
20/04/2015 0:00
20/04/2015 12:00
21/04/2015 0:00
21/04/2015 12:00
22/04/2015 0:00
22/04/2015 12:00
23/04/2015 0:00
23/04/2015 12:00
24/04/2015 0:00


Comparison of Gauged and Modelled Flow Rates
@ McCoy Park Basin (April 2015 Historic Event)
McCoy Park Basin Gauge
CALI035
Water Level (mAHD)
26.5
26
25.5
25
24.5
24
20/04/2015 12:00
21/04/2015 0:00
21/04/2015 12:00
22/04/2015 0:00
22/04/2015 12:00
23/04/2015 0:00
23/04/2015 12:00
24/04/2015 0:00


Comparison of Gauged and Modelled Flow Rates
@ Darling Mills Creek (April 2015 Historic Event)
Darling Mills Ck Gauge
C22_20pc 2015 Model Results
Flow (m³/s)
120
100
80
60
40
20
0
20/04/2015 0:00:00
20/04/2015 12:00:00
21/04/2015 0:00:00
21/04/2015 12:00:00
22/04/2015 0:00:00
22/04/2015 12:00:00
23/04/2015 0:00:00
23/04/2015 12:00:00
24/04/2015 0:00:00


Comparison of Gauged and Modelled Water Levels
@ Loyalty Road Basin (April 2015 Historic Event)
Loyalty Road Basin Gauge
C22_20pc 2015 Model Results
Water Level (mAHD)
32
30
28
26
24
22
20
20/04/2015 0:00
20/04/2015 12:00
21/04/2015 0:00
21/04/2015 12:00
22/04/2015 0:00
22/04/2015 12:00
23/04/2015 0:00
23/04/2015 12:00
24/04/2015 0:00


Comparison of Gauged and Modelled Water Level
@ Toongabbie Ck (Johnstons Bridge) (April 2015 Historic Event)
Toongabbie Ck Johnstons Bridge Gauge
CALI035
XPRAFTS C22_2015 Results
Flow (m3/s)
0
50
100
150
200
250
20/04/2015 0:00:00
20/04/2015 12:00:00
21/04/2015 0:00:00
21/04/2015 12:00:00
22/04/2015 0:00:00
22/04/2015 12:00:00
23/04/2015 0:00:00
23/04/2015 12:00:00
24/04/2015 0:00:00
24/04/2015 12:00:00
25/04/2015 0:00:00


Comparison of Gauged and Modelled Water Level
@ Toongabbie Ck (Johnstons Bridge) (April 2015 Historic Event)
Toongabbie Ck Johnstons Bridge Gauge
Tuflow CALI 35
Water Level (mAHD)
17
18
19
20
21
22
23
24
20/04/2015 0:00:00
20/04/2015 12:00:00
21/04/2015 0:00:00
21/04/2015 12:00:00
22/04/2015 0:00:00
22/04/2015 12:00:00
23/04/2015 0:00:00
23/04/2015 12:00:00
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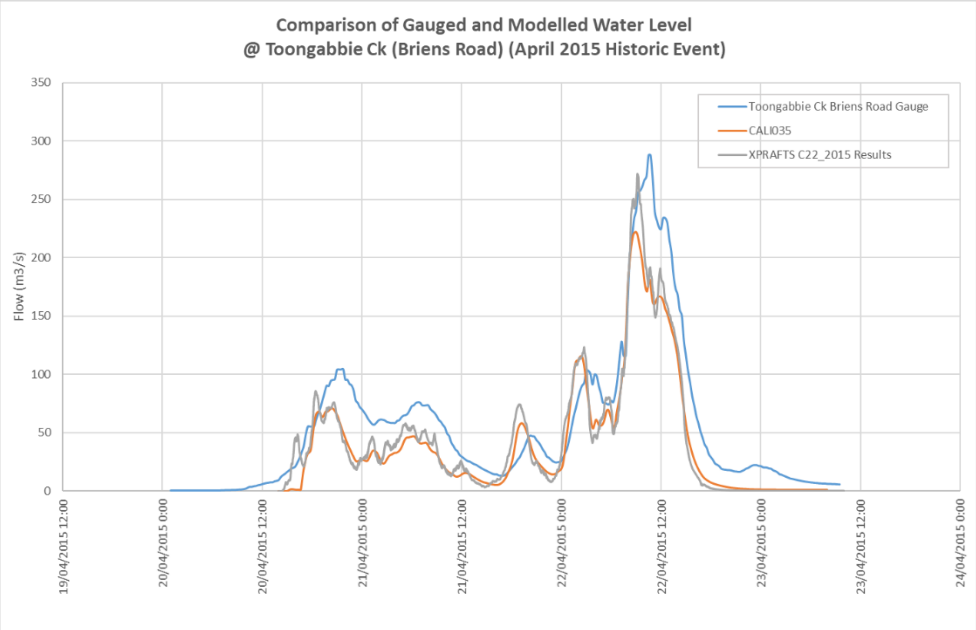
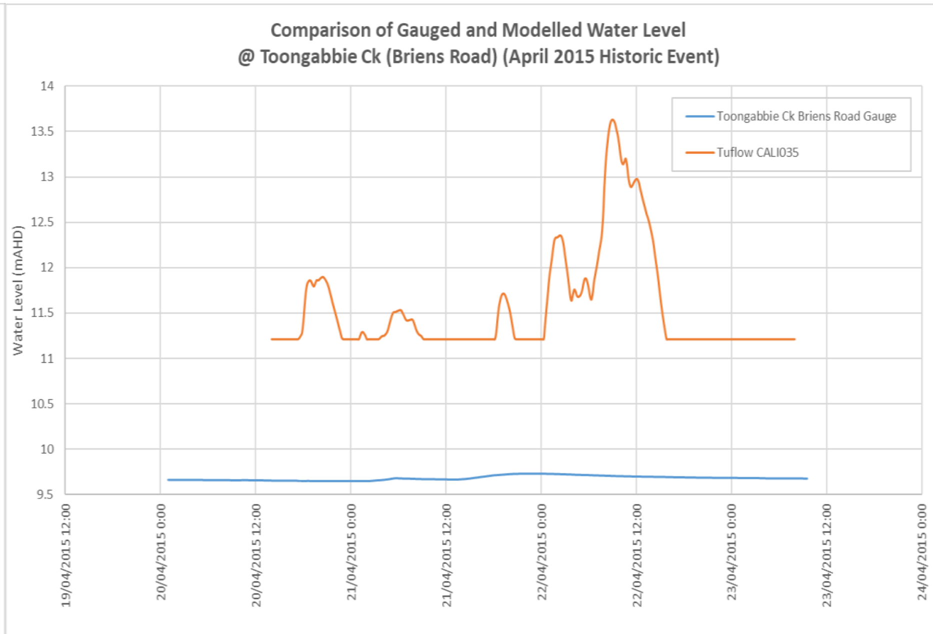
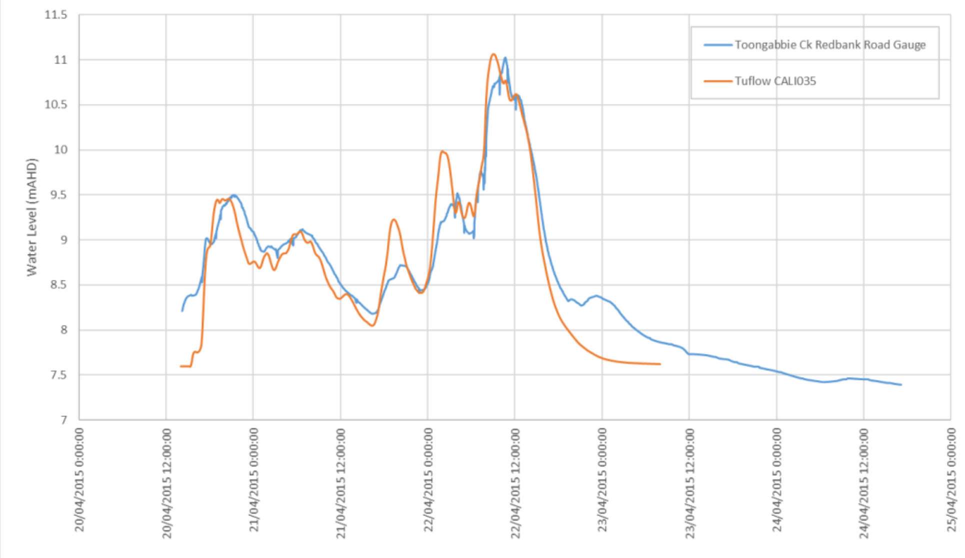
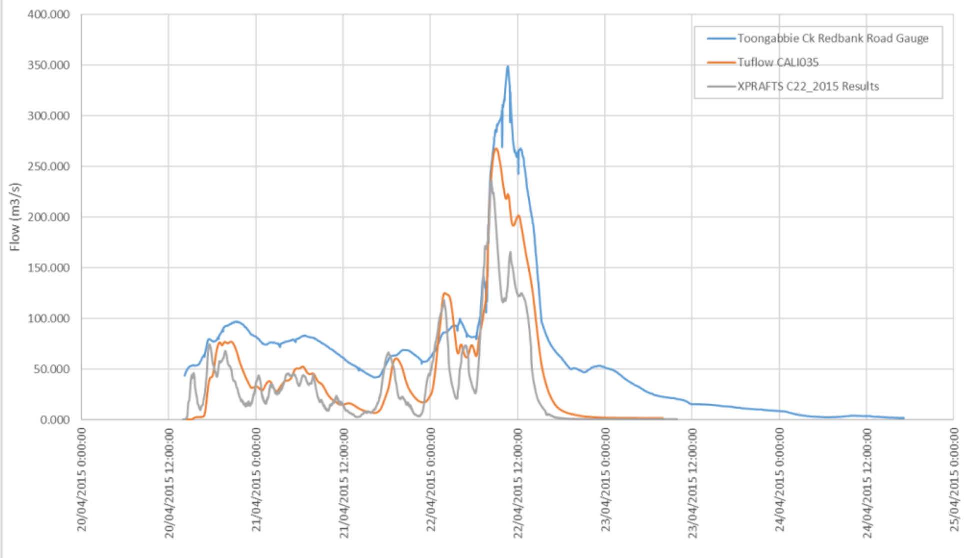
24/04/2015 12:00:00
25/04/2015 0:00:00


Comparison of Gauged and Modelled Water Level
@ Toongabbie Ck (Briens Road) (April 2015 Historic Event)
Toongabbie Ck Briens Road Gauge
CALI035
XPRAFTS C22_2015 Results
Flow (m3/s)
0
50
100
150
200
250
300
350
19/04/2015 12:00
20/04/2015 0:00
20/04/2015 12:00
21/04/2015 0:00
21/04/2015 12:00
22/04/2015 0:00
22/04/2015 12:00
23/04/2015 0:00
23/04/2015 12:00
24/04/2015 0:00

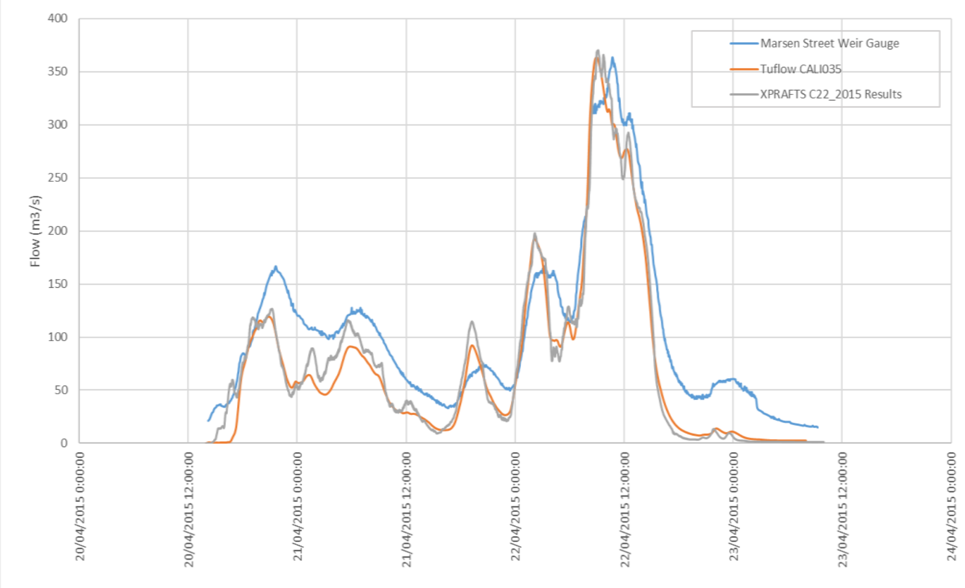

Comparison of Gauged and Modelled Water Level
@ Toongabbie Ck (Briens Road) (April 2015 Historic Event)
Toongabbie Ck Briens Road Gauge
Tuflow CALI035
Water Level (mAHD)
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
19/04/2015 12:00
20/04/2015 0:00
20/04/2015 12:00
21/04/2015 0:00
21/04/2015 12:00
22/04/2015 0:00
22/04/2015 12:00
23/04/2015 0:00
23/04/2015 12:00
24/04/2015 0:00



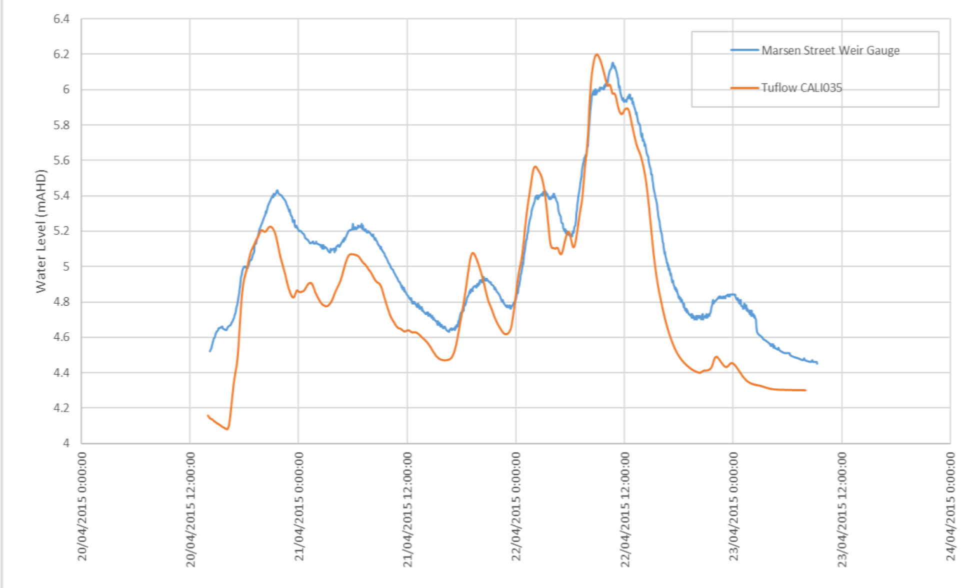
Comparison of Gauged and Modelled Water Level
@ Toongabbie Ck (Redbank Road) (April 2015 Historic Event)



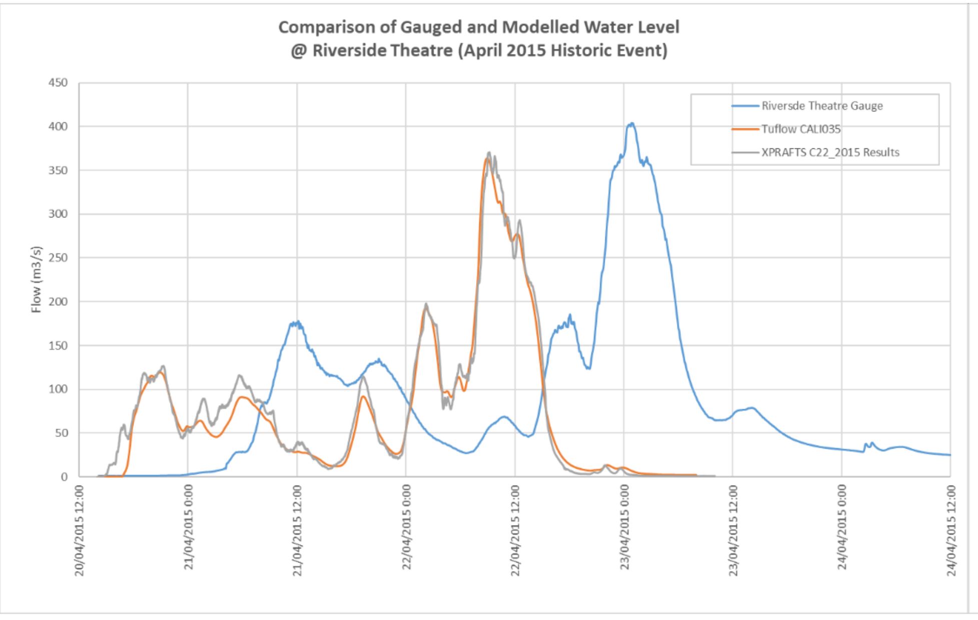
Comparison of Gauged and Modelled Water Level
@ Toongabbie Ck (Redbank Road) (April 2015 Historic Event)

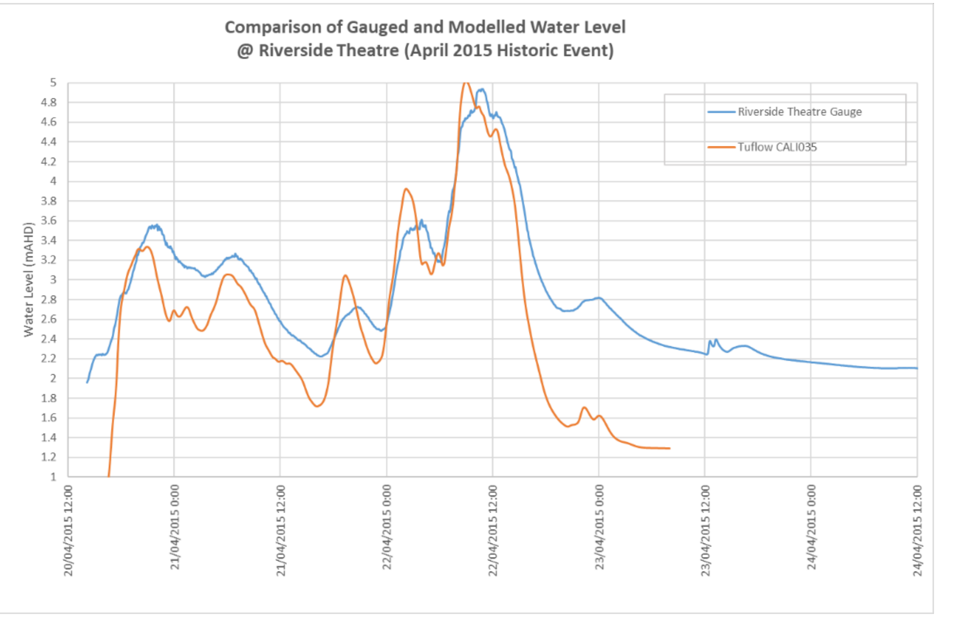


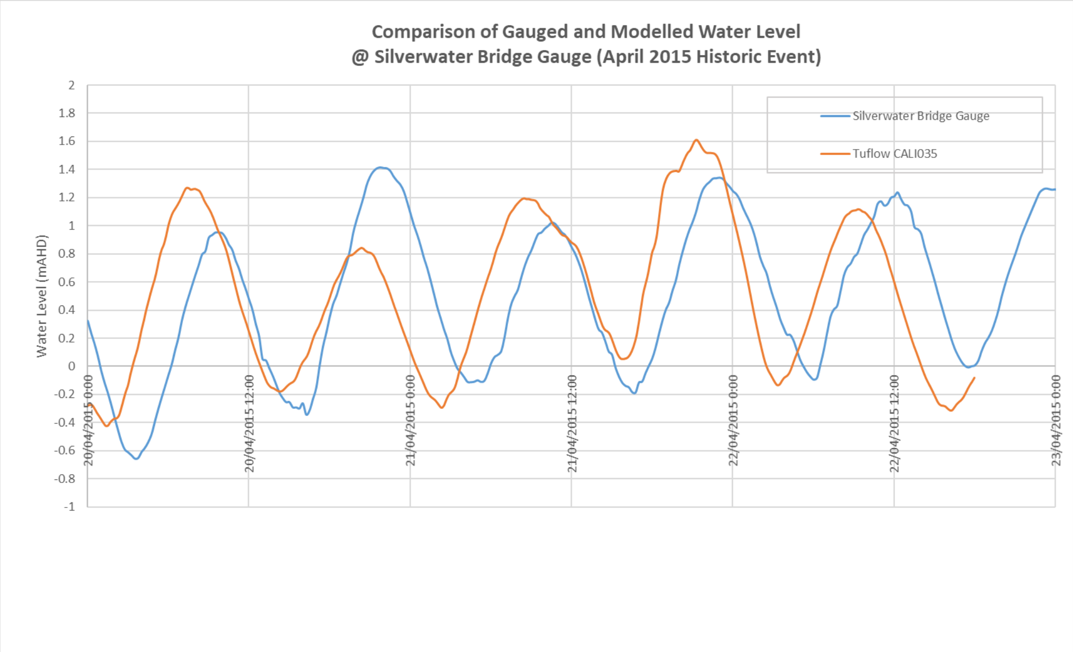
Comparison of Gauged and Modelled Water Level
@ Marsen Street Weir (April 2015 Historic Event)



Comparison of Gauged and Modelled Water Level
@ Marsen Street Weir (April 2015 Historic Event)


Comparison of Gauged and Modelled Water Level
@ Riverside Theatre (April 2015 Historic Event)
Flow (m3/s)
Riversde Theatre Gauge
Tuflow CALI035
XPRAFTS C22_2015 Results

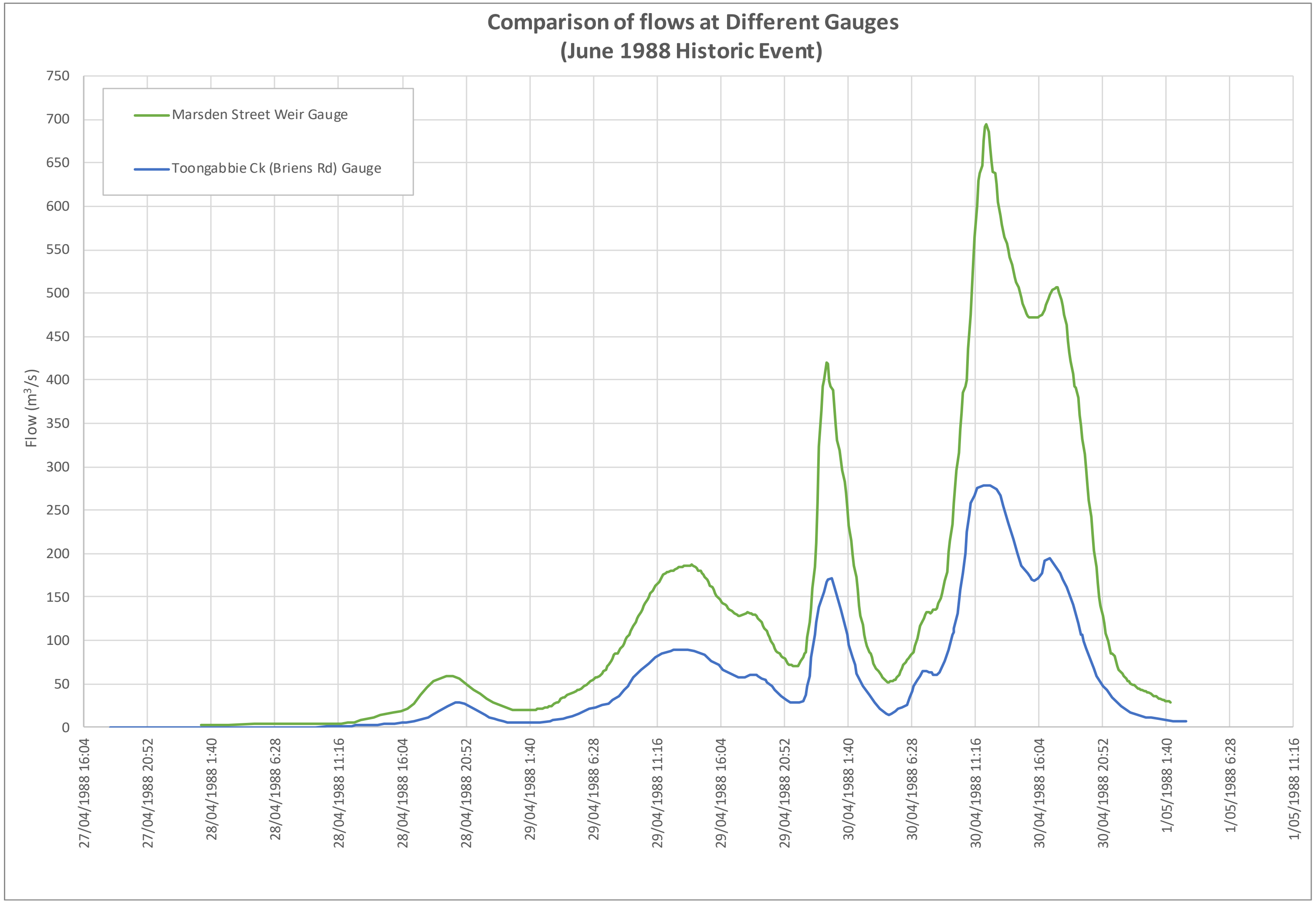

Comparison of Gauged and Modelled Water Level
@ Riverside Theatre (April 2015 Historic Event)
Water Level (mAHD)
Riverside Theatre Gauge
Tuflow CALI035

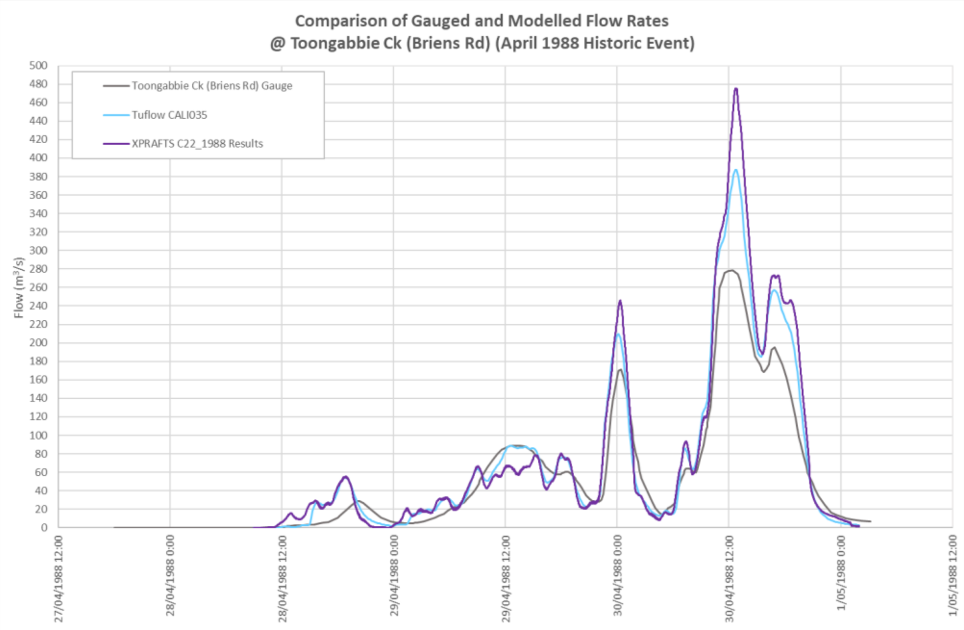


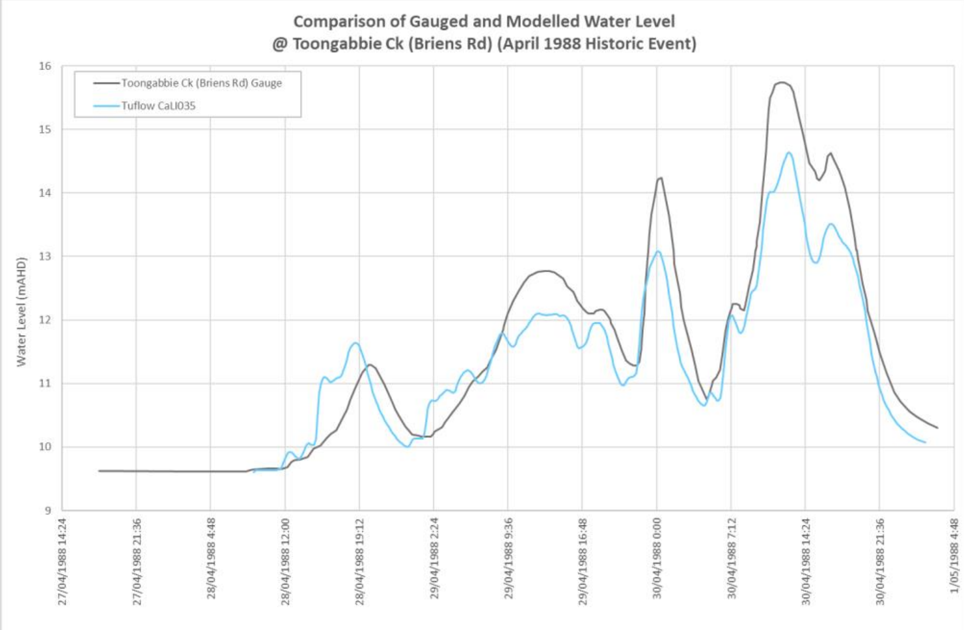
Comparison of Gauged and Modelled Water Level
@ Silverwater Bridge Gauge (April 2015 Historic Event)
Water Level (mAHD)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
20/04/2015 0:00
20/04/2015 12:00
21/04/2015 0:00
21/04/2015 12:00
22/04/2015 0:00
22/04/2015 12:00
23/04/2015 0:00
Silverwater Bridge Gauge
Tuflow CALI035

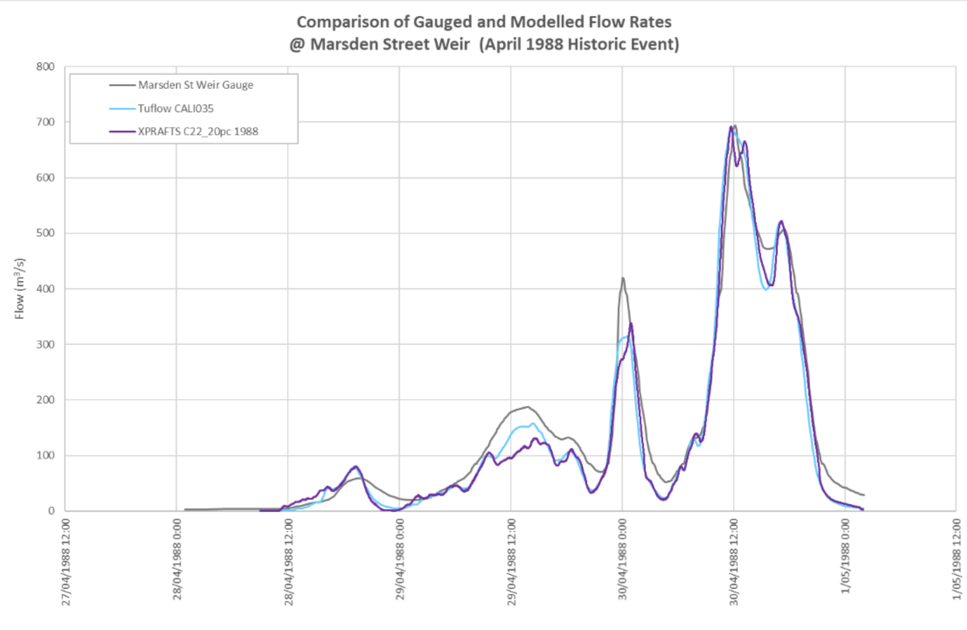
Table C.2: Comparison between the historical gauge data and TUFLOW calibrated model for April 2015:

Gauge Station	Gauged Peak WL (mAHD)	TUFLOW Modelled Peak WL (mAHD)	WL Difference (mAHD)	Gauged Flow (m^3/s)	TUFLOW Modelled Flow (m^3/s)	Percentage (%) Flow Difference	COMMENTS
McCoy Park Basin	26.20	26.10	-0.10	N/A	153.62	N/A	Gauge flow is not available
Toongabbie Creek (JOHNSTONS BRIDGE)	20.52	23.51	3.00	29.29	222.44	N/A	Gauge data not reliable
Toongabbie Creek (BRIENS ROAD)	9.73	13.63	3.90	287.62	221.94	-22.8%	Gauge data for water level not be reliable
Darling Mills Creek (Viaduct)	12.48	12.18	-0.40	83.59	102.15	22.2%	
Lake Parramatta	29.31	N/A	N/A	N/A	N/A	N/A	Tuflow calibration model does not cover the gauge location
Toongabbie Creek (REDBANK ROAD)	11.03	11.17	0.14	262.47	267.81	2.04%	Gauge data may not be reliable
MARSDEN ST WEIR	6.15	6.18	0.03	363.5	377.5	3.9%	Gauge data was adjusted
RIVERSIDE THEATRE	4.94	4.97	0.03	403.89	363.80	-9.93%	
Silverwater Bridge	1.41	1.58	0.17	N/A	497.20	N/A	Gauge flow is not available


Comparison of flows at Different Gauges
(June 1988 Historic Event)
Marsden Street Weir Gauge
Toongabbie Ck (Briens Rd) Gauge
Flow (m³/s)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
27/04/1988 16:04
27/04/1988 20:52
28/04/1988 1:40
28/04/1988 6:28
28/04/1988 11:16
28/04/1988 16:04
28/04/1988 20:52
29/04/1988 1:40
29/04/1988 6:28
29/04/1988 11:16
29/04/1988 16:04
29/04/1988 20:52
30/04/1988 1:40
30/04/1988 6:28
30/04/1988 11:16
30/04/1988 16:04
30/04/1988 20:52
1/05/1988 1:40
1/05/1988 6:28
1/05/1988 11:16


Comparison of Gauged and Modelled Flow Rates
@ Toongabbie Ck (Briens Rd) (April 1988 Historic Event)
Toongabbie Ck (Briens Rd) Gauge
Tuflow CALI035
XPRAFTS C22_1988 Results
Flow (m³/s)
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500
27/04/1988 12:00
28/04/1988 0:00
28/04/1988 12:00
29/04/1988 0:00
29/04/1988 12:00
30/04/1988 0:00
30/04/1988 12:00
1/05/1988 0:00
1/05/1988 12:00


Comparison of Gauged and Modelled Water Level
@ Toongabbie Ck (Briens Rd) (April 1988 Historic Event)
Toongabbie Ck (Briens Rd) Gauge
Tuflow CALI035
Water Level (mAHD)
9 10 11 12 13 14 15 16
27/04/1988 14:24
27/04/1988 21:36
28/04/1988 4:48
28/04/1988 12:00
28/04/1988 19:12
29/04/1988 2:24
29/04/1988 9:36
29/04/1988 16:48
30/04/1988 0:00
30/04/1988 7:12
30/04/1988 14:24
30/04/1988 21:36
1/05/1988 4:48


Comparison of Gauged and Modelled Flow Rates
@ Marsden Street Weir (April 1988 Historic Event)
Marsden St Weir Gauge
Tuflow CALI035
XPRAFTS C22_20pc 1988
Flow (m³/s)
0 100 200 300 400 500 600 700 800
27/04/1988 12:00
28/04/1988 0:00
28/04/1988 12:00
29/04/1988 0:00
29/04/1988 12:00
30/04/1988 0:00
30/04/1988 12:00
1/05/1988 0:00
1/05/1988 12:00

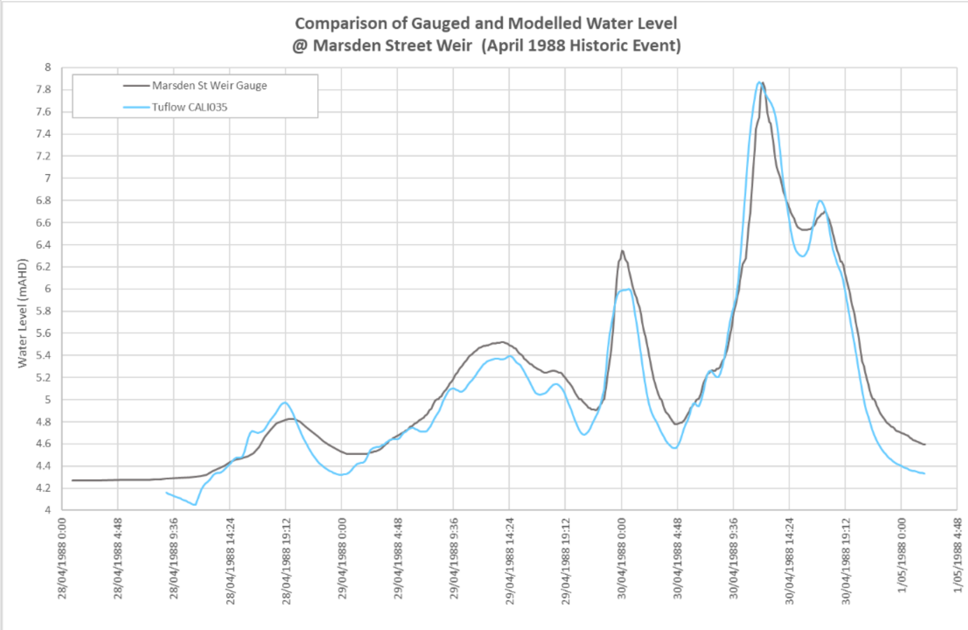
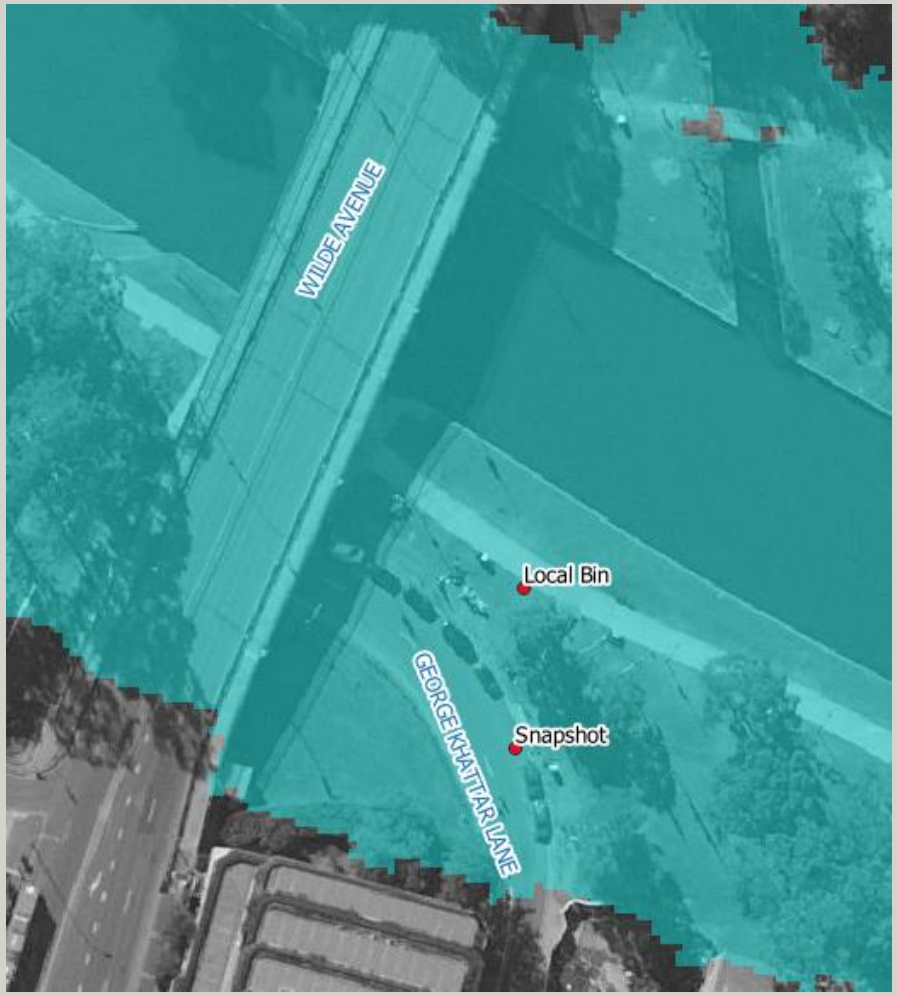

Comparison of Gauged and Modelled Water Level
@ Marsden Street Weir (April 1988 Historic Event)
Marsden St Weir Gauge
Tuflow CALI035
Water Level (mAHD)
4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6 6.2 6.4 6.6 6.8 7 7.2 7.4 7.6 7.8 8
28/04/1988 0:00
28/04/1988 4:48
28/04/1988 9:36
28/04/1988 14:24
28/04/1988 19:12
29/04/1988 0:00
29/04/1988 4:48
29/04/1988 9:36
29/04/1988 14:24
29/04/1988 19:12
30/04/1988 0:00
30/04/1988 4:48
30/04/1988 9:36
30/04/1988 14:24
30/04/1988 19:12
1/05/1988 0:00
1/05/1988 4:48

Table C.3: Comparison of April 1988 historical flood level observations from SKM with the calibration model:

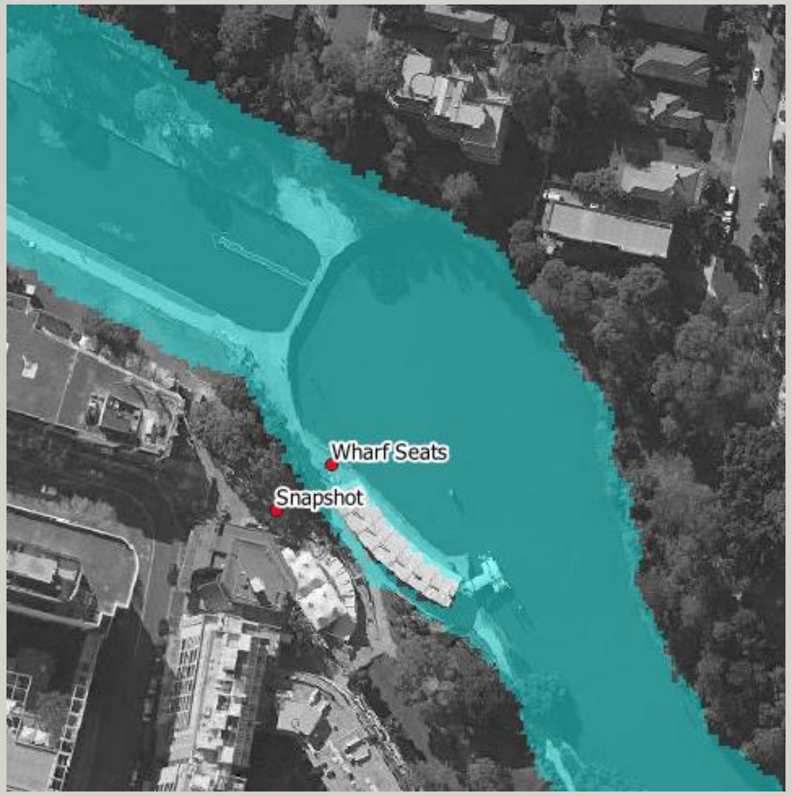
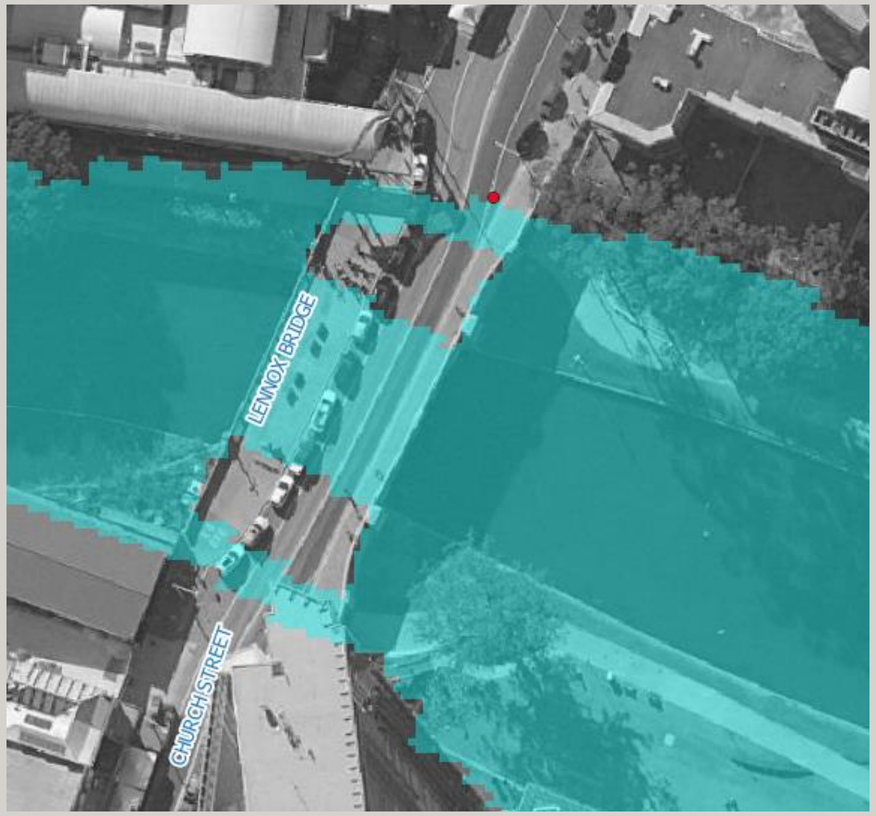
Ref No.	Storm	Location of Measurement	SKM 2005 Report 1988 Historical Water Levels (note 1) (mAHD)	Cardno 2019 1988 Calibration Model (mAHD)	Difference (m)
6	Apr-88	Parramatta River at Charles Street	5.00	5.31	0.31
7	Apr-88	Parramatta River at Morton Street	4.00	4.45	0.45
8	Apr-88	Parramatta River at Confluence with Vineyard Creek	3.50	3.73	0.23
9	Apr-88	Parramatta River at Pike Street	3.60	3.64	0.04
10	Apr-88	Parramatta River at Thackeray Street	3.00	3.29	0.29
11	Apr-88	Parramatta River at Silverwater Road	2.00	2.69	0.69
21	Apr-88	Claycliff Creek at 130 Alfred Street, across Rd cnr Oak and Alfred	4.80	4.81	0.01

Comparing Historical Photographs Observations with Calibration Models in June 2016

Table C.4: A comparison of the historical photos from June 2016 with TUFLOW calibration scenario.

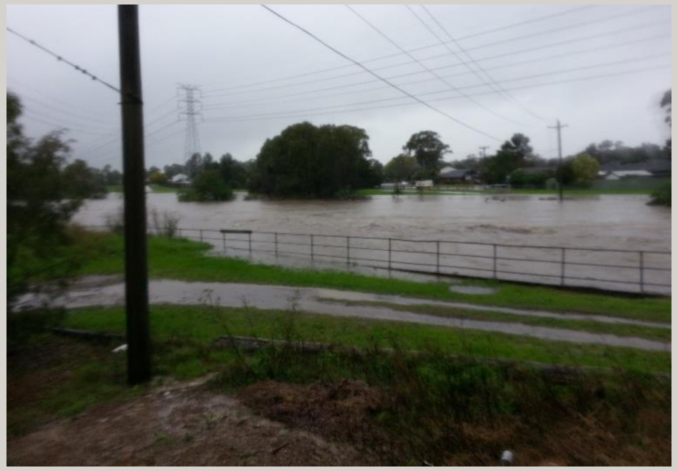
FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
Location 07: George Khattar Lane, Parramatta			The photo was taken from a car, shows the floodwaters partially inundating a local park bin. There is also local ponding on George Khattar Lane. The TUFLOW model shows an over-representation of the flood extent. This could be due to the time the photo was taken which may not have been from taken at peak times or incorrect inflow locations.

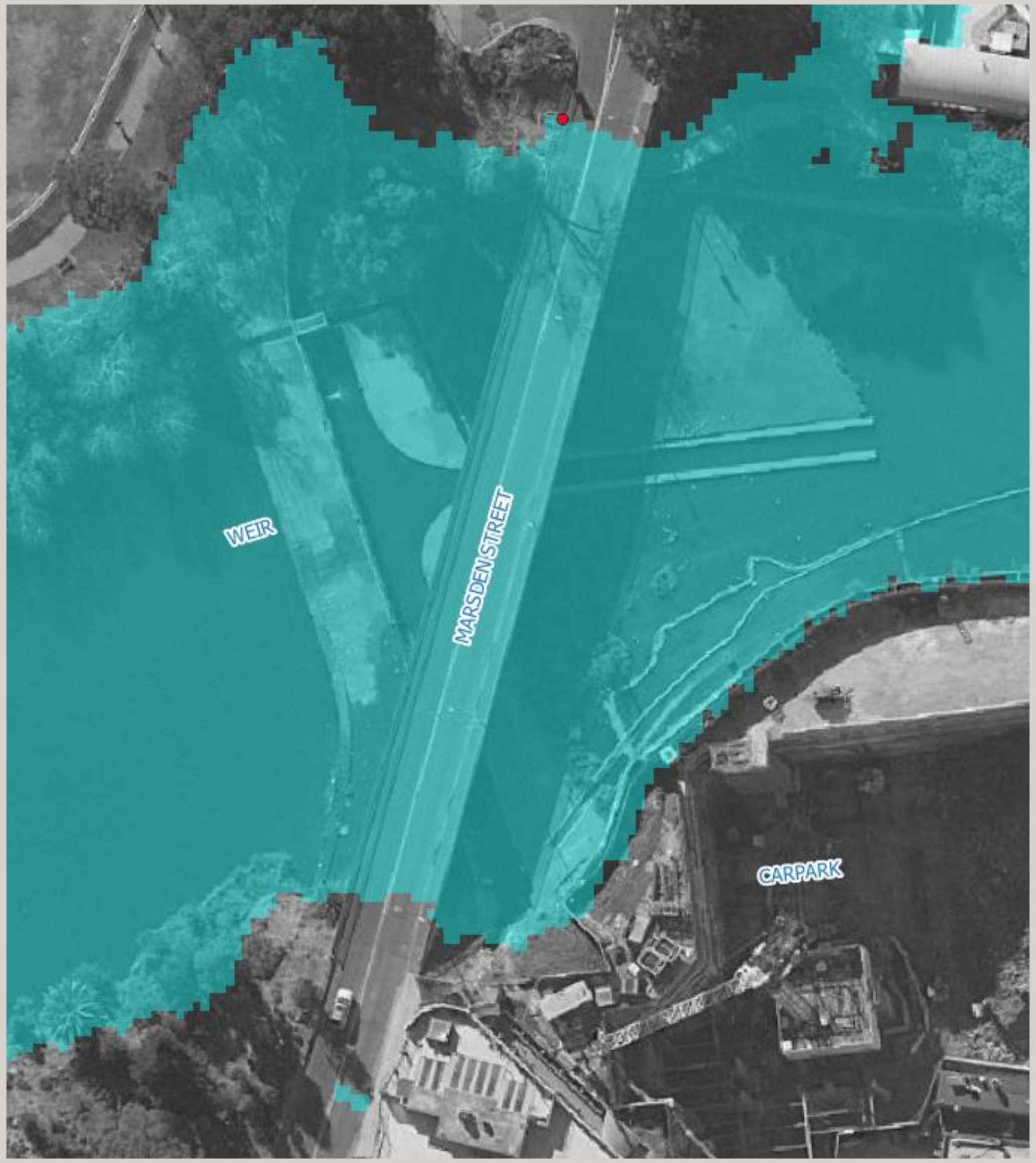
JUNE 2016 CALIBRATION AND VALIDATION COMPARISON

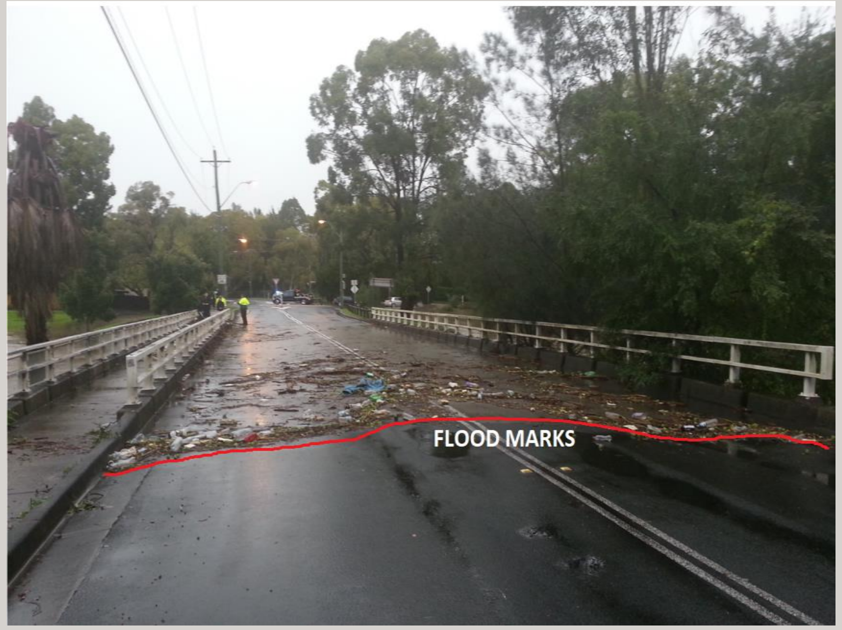
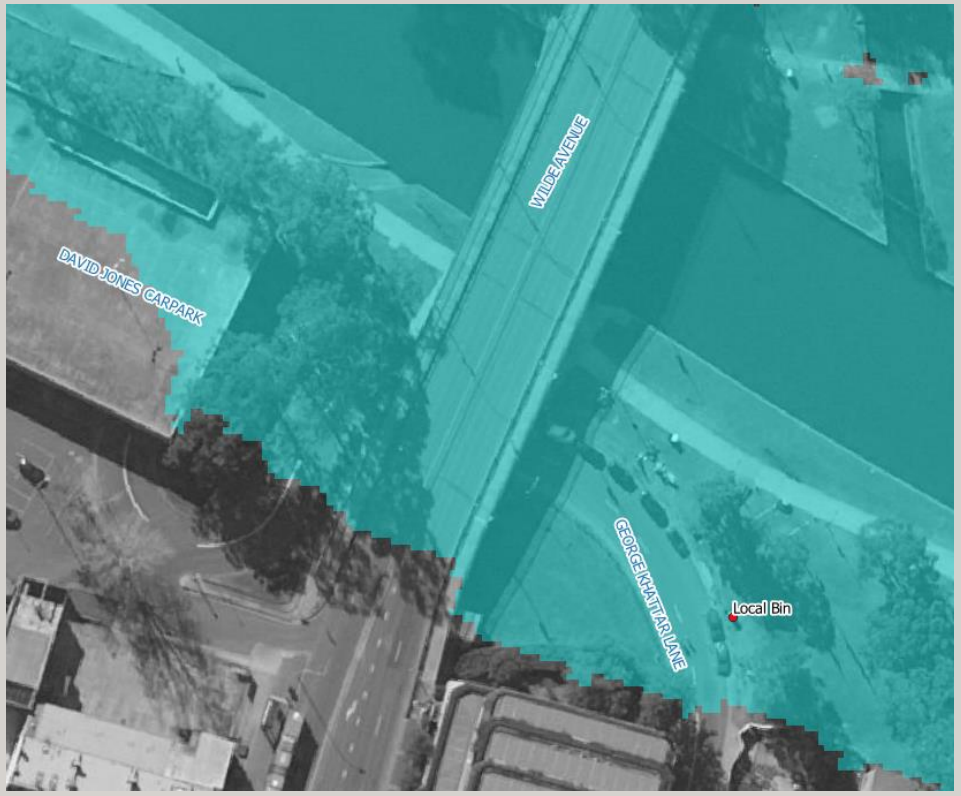
FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
Location 08: Charles Street Weir and Parramatta Wharf			The photo showed floodwater overtopping at Charles Street Weir and inundating the Parramatta Ferry Wharf. Flood waters can also be seen up flowing up the ramp behind the ferry wharf. The flood level extent is consistent with the TUFLOW model. The model showed that the flood extent reaches the pedestrian ramp behind the wharf. It also showed depths of up to 1.1m.
Location 09: Lennox Bridge, Parramatta			The photo is showing flood extent along the building perimeter. There are also flood marks from debris which also indicate that flood waters had reached to the edges of the trees. The TUFLOW model results showed that the flood extent has been overestimated and has reached the building boundaries. This could be due to the time the photo was taken which may not have been from taken at peak times or incorrect inflow locations.

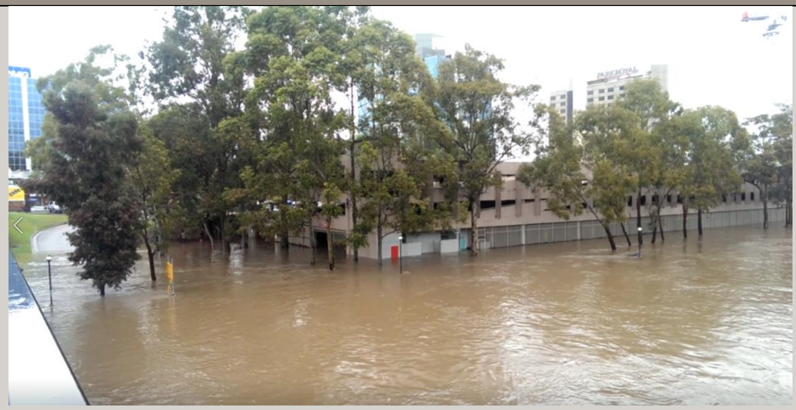
Comparing Historical Photographs Observations with Calibration Models in April 2015

Table C.5: A comparison of the historical photos from April 2015 with TUFLOW calibration scenario.

FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
Location 01: McCoy Park Basin, Toongabbie	  		The series of photos shows flooding at McCoy Park basin. The photos are consistent with the TUFLOW model showing McCoy Park behaving as a basin. Ponding is further defined by the bunds.

FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
Location 04: Marsden Street Weir, Parramatta	  		The series of snapshot was taken at Marsden Street Weir which shows floodwaters spilling over Marsden Street Weir. The snapshot also shows that the flood water extends to the abutments of the bridge on Marsden Street Weir and partially covering a low lying footpath along the open carpark. Flood mark along an access road to Marsden Street Weir indicated that flood water may have previously reached at a higher level. The TULFOW model shows Flood extent overtopping at Marsden Street Weir and flood extents reaching the Marsden Street Bridge abutments and the low lying footpath.

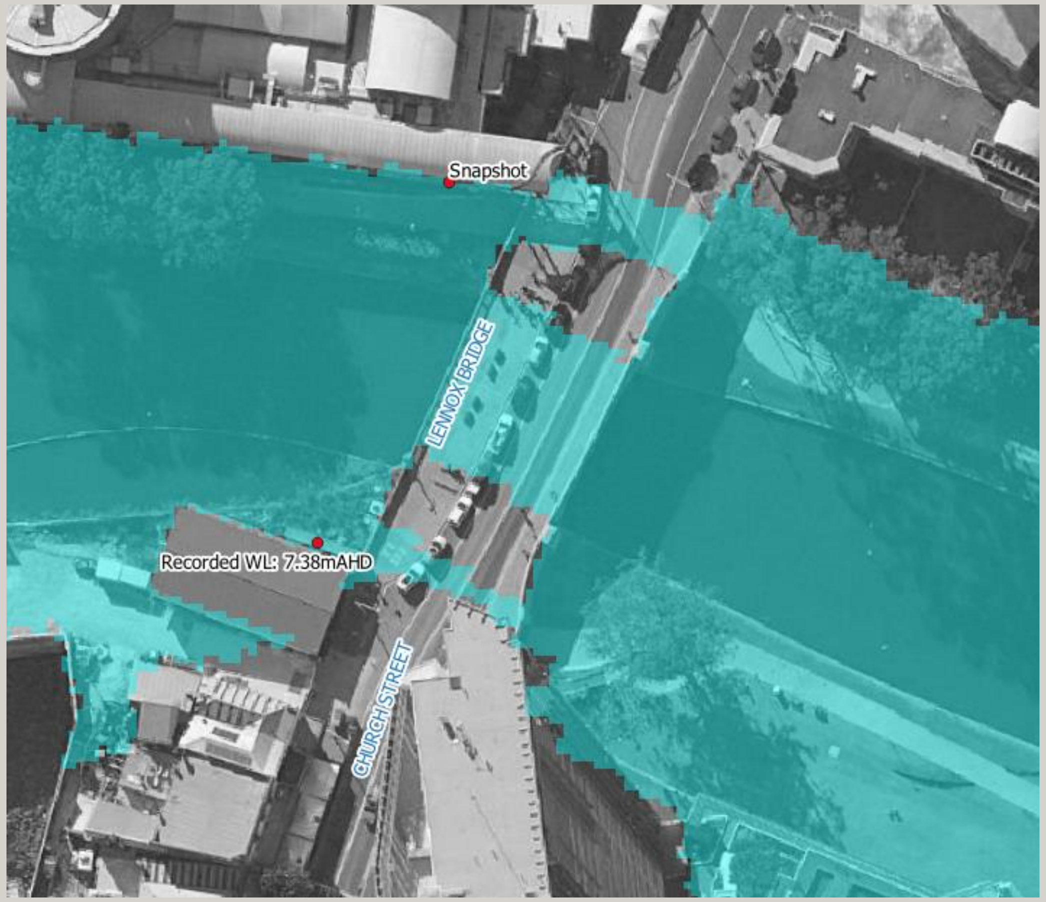
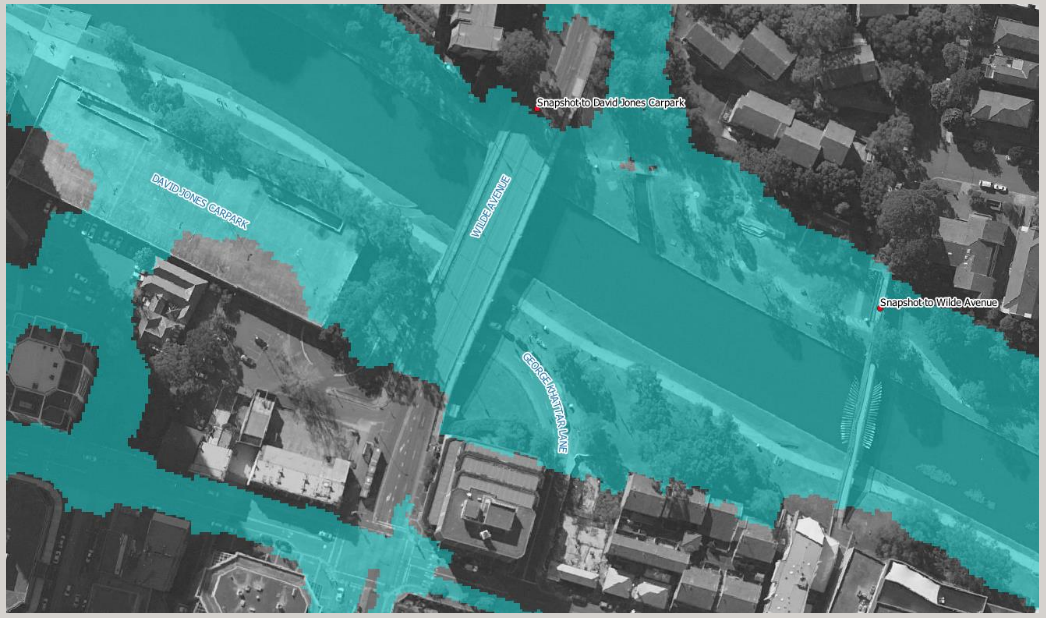
FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
Location 05: Oakes Bridge, Toongabbie			The photo showed debris on Oakes Bridge at Toongabbie Creek, which indicated that at some time during the storm, flood waters had inundated the bridge. This is consistent with the TUFLOW model flood extent as it represented floodwater inundating the bridge.
Location 06: Top of Wilde Avenue Bridge, Parramatta & Location 07: George Khattar Lane, Parramatta	 		The series of snapshots shows the flood extents at Wilde Avenue. The flood extents were observed up to the street sign and tree shrubs at George Khattar Lane and inundation of the local bin. It was also observed on Wilde Avenue bridge that flood waters had entered the ground floor carpark building. This is consistent with the TUFLOW results which also shows flood extents up to the tree shrubs at George Khattar Lane. Also, the flooding extent at the carpark building is also consistent with the TUFLOW result which shows flooding inside the carpark building.

FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
			
Location 08: Charles Street Weir and Parramatta Wharf	  		The video recorded shows an inundated Parramatta Wharf due to a major spillway at Charles Street Weir. The flood also inundated Parramatta wharf and also showed the flood extent up to the ramp. This is consistent with TUFLOW model flood extent which shows water flowing underneath the ferry wharf and submerging the ferry seats.

Comparing Historical Photographs Observations with Calibration Models in April 1988

Table C.6: A comparison of the historical photos from 1988 with TUFLOW calibration scenario.

FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
Location 01: McCoy Park Basin, Toongabbie	  		The series of photos shows flooding at McCoy Park basin. The TUFLOW flood extent showed consistencies with the photos showing McCoy Park behaving as a basin with an elevated water level nearing the top of the outlet chute walls. The model appears to predict slightly higher water levels noted by the water depth over the piece of land with the transmission tower. It is possible that the photo was not taken at the peak of the event and there does appear to be evidence of some ponding and scour on the headland which suggests the water level was higher and overtopping this headland.

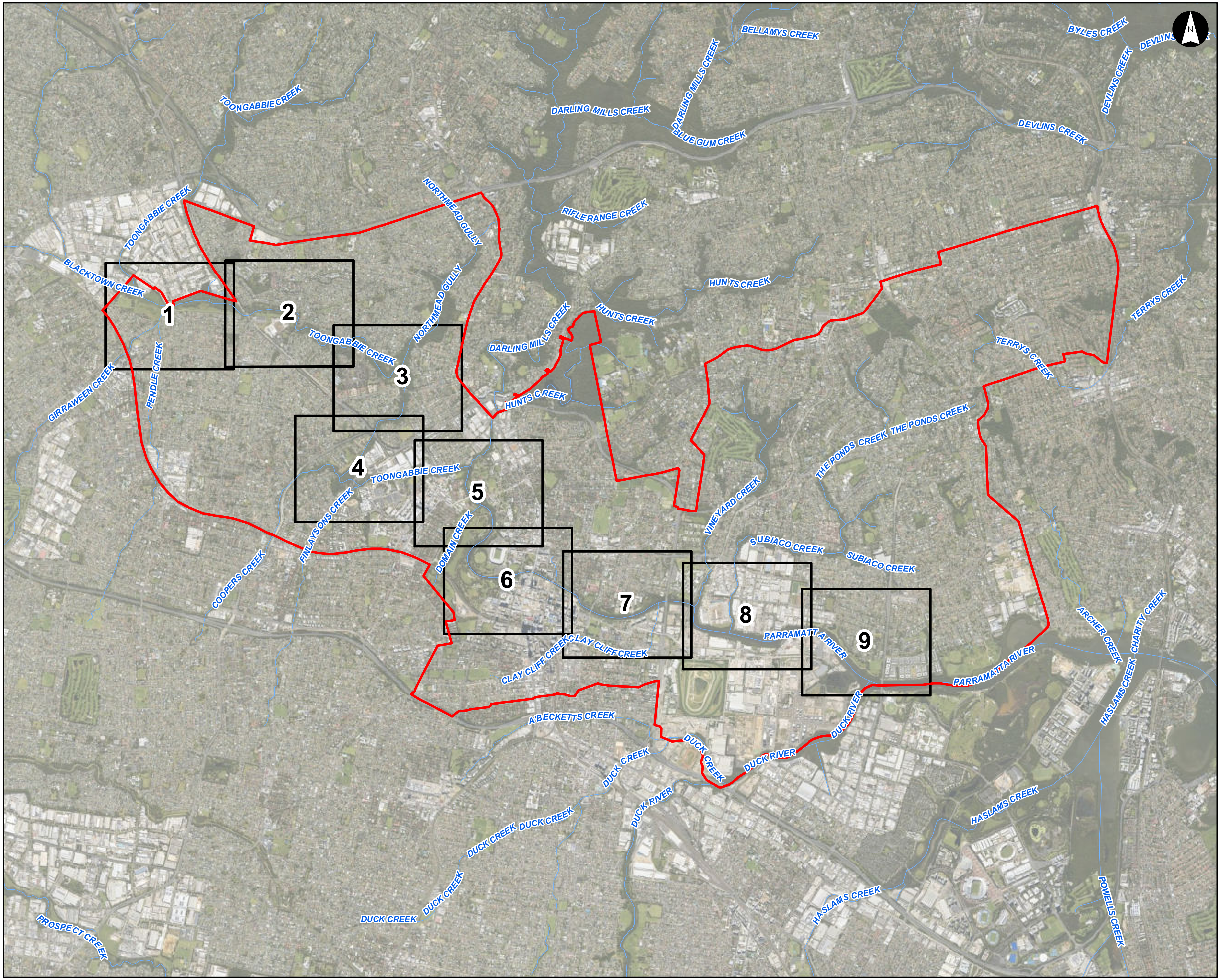
FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
Location 06: Lennox Bridge, Parramatta			The photo is showing the water level at 7.38m AHD at Lennox Bridge. The location of the photo in GIS was adjusted to reflect the location of the photo. The depth in TUFLOW is consistent with water level of 7.39m AHD. The behaviour of the flow also reflects the photo showing water flowing into the portal at Lennox Bridge.
Location 07: Barry Wilde Bridge, Parramatta			The series of photos shows flooding at Barry Wilde Bridge at different stages or durations of the flood event. It shows that at the peak depth, the water had risen up to the superstructure of the bridge. Additionally, the flood mark can also be seen at the David Jones Carpark showing debris inundating the ground floor. This is consistent with the TUFLOW result which showed that the flood extent had breached the ground flood carpark and reached a depth of 2.20m.

APRIL 1988 CALIBRATION AND VALIDATION COMPARISON

FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
			

FLOOD LOCATION ID	SITE SNAPSHOTS	TUFLOW MODEL	COMPARISON WITH MODEL BEHAVIOUR
Location 11: Footbridge over Parramatta River at Eels Place, near Parramatta Stadium (now Bankwest Stadium)	 Vol. 11, No. 17 38 George St., Parramatta. 633 3288 Tuesday, May 3, 1988 **After the rain** CRAIG Hartley, 12 from Carlingford looks at what remains of the footbridge over the Parramatta River behind the stadium. Authorities were concerned this could have the scene of a disaster as water pressure caused the collapse of the footbridge and fractured high pressure natural gas lines.		A newspaper clipping (03/05/1988) was submitted from community consultation which showed the damages from the flood event. It showed the remains of a footbridge near Parramatta Stadium (now Bankwest Stadium). This is reflected in the TUFLOW result which showed that the flood extent had overtopped the footbridge.

C2. Comparison with Previous MIKE 11 Model



Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-084-Mainstream_WL_Overview.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Map Grid

Figure C1

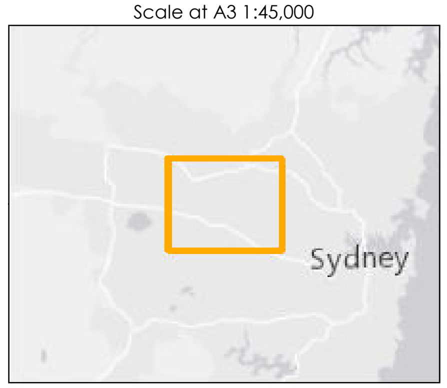
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

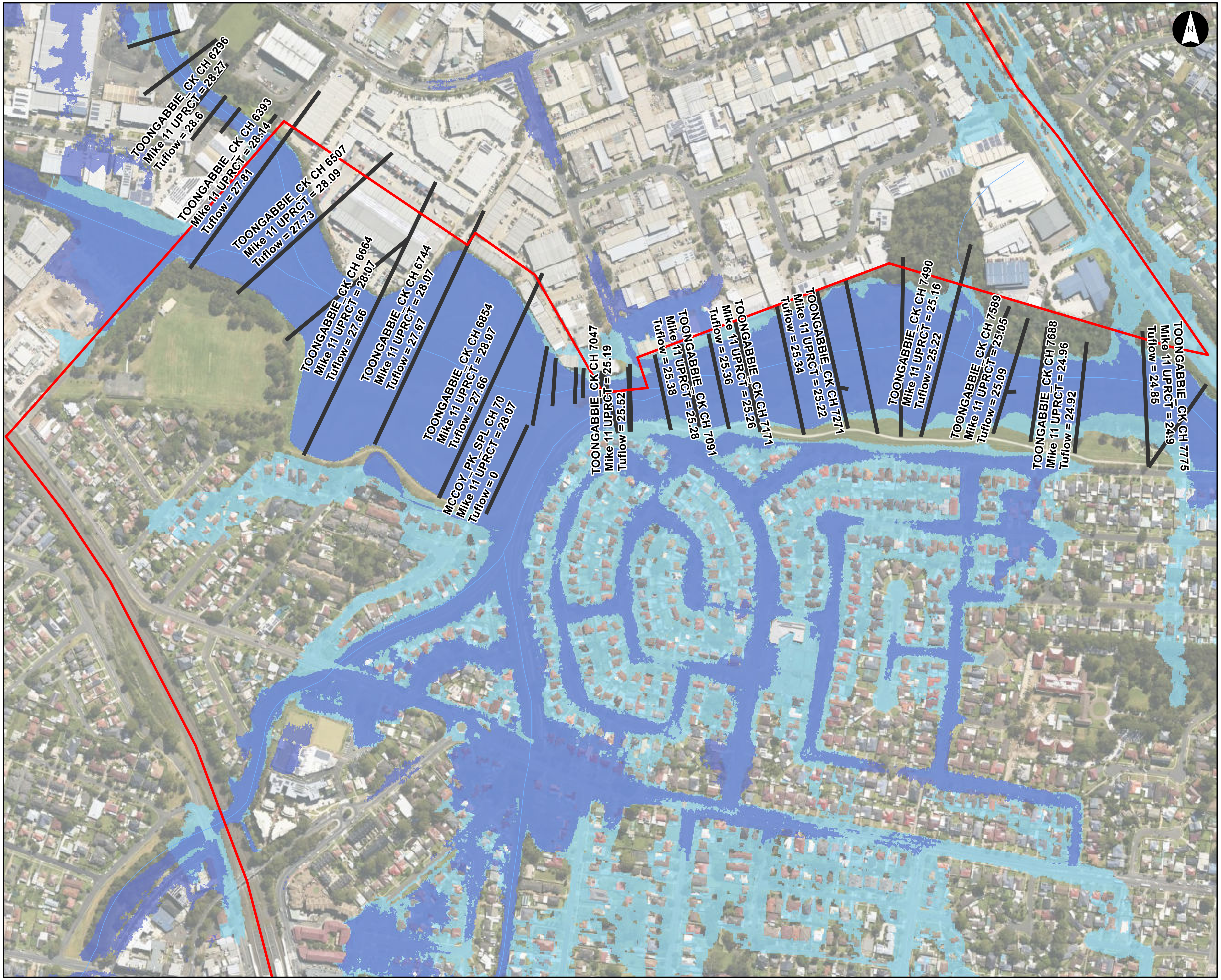
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 500 1,000 1,500 2,000 Metres

Scale at A3 1:45,000





FFA 1% AEP Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-081-Mainstream_WL_1pc.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- 1% AEP Mike 11 Flood Extent
- FFA 1% Tuflow Extent

Figure C2

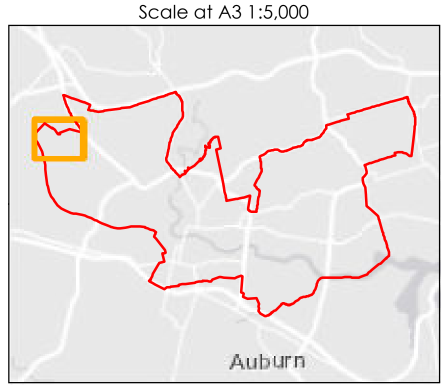
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

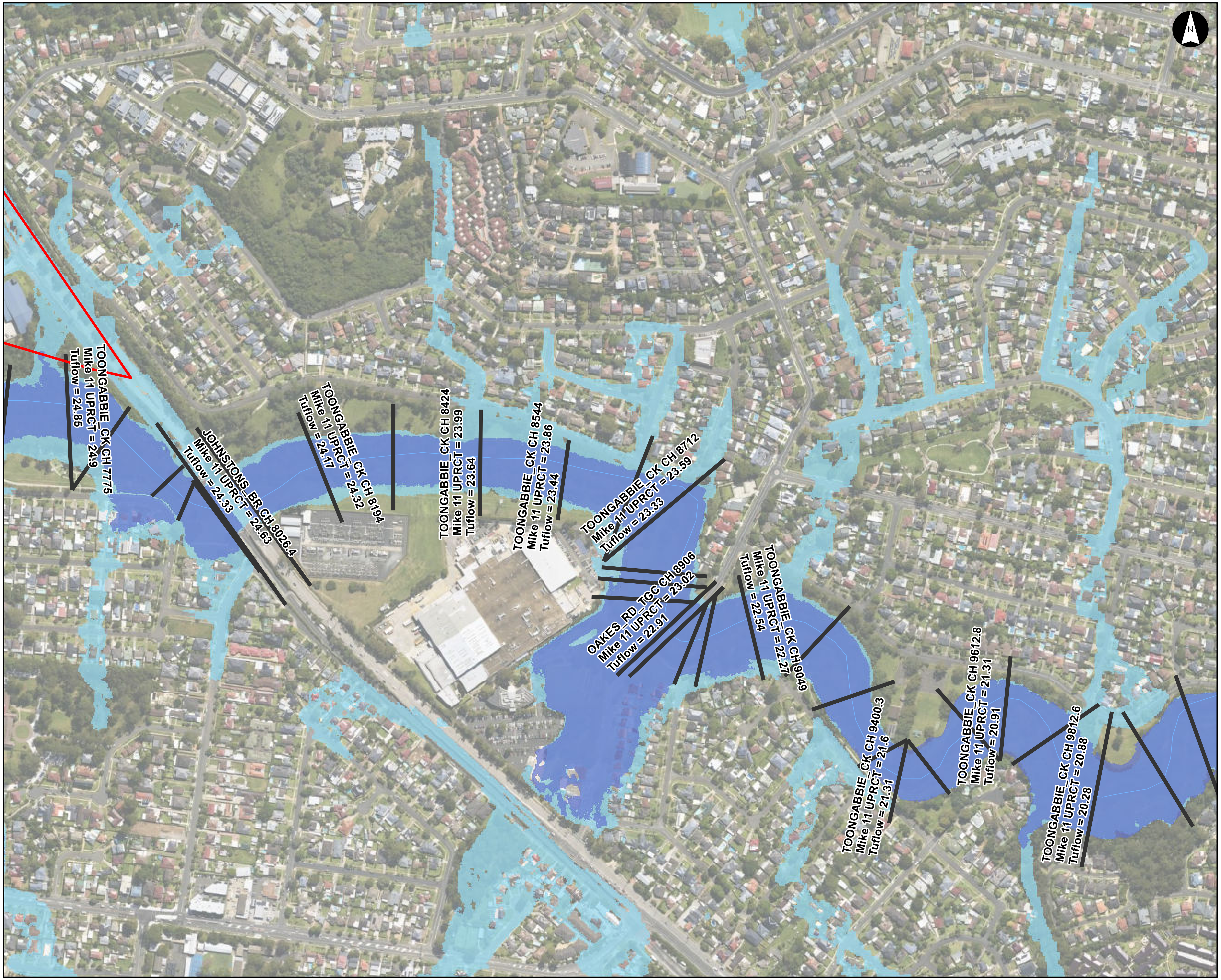
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





FFA 1% AEP Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-081-Mainstream_WL_1pc.mxd
Rev: 02
Date: 2023-05-29

Legend

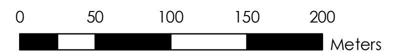
- Study Area
- Watercourse
- Mike 11 Cross Sections
- 1% AEP Mike 11 Flood Extent
- FFA 1% Tuflow Extent

Figure C3

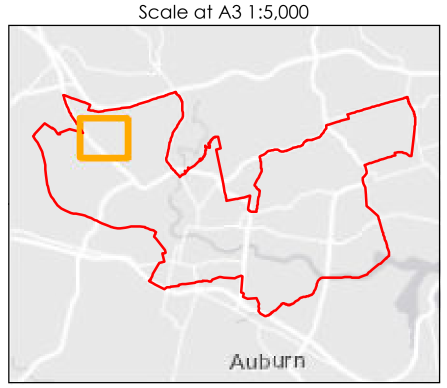
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

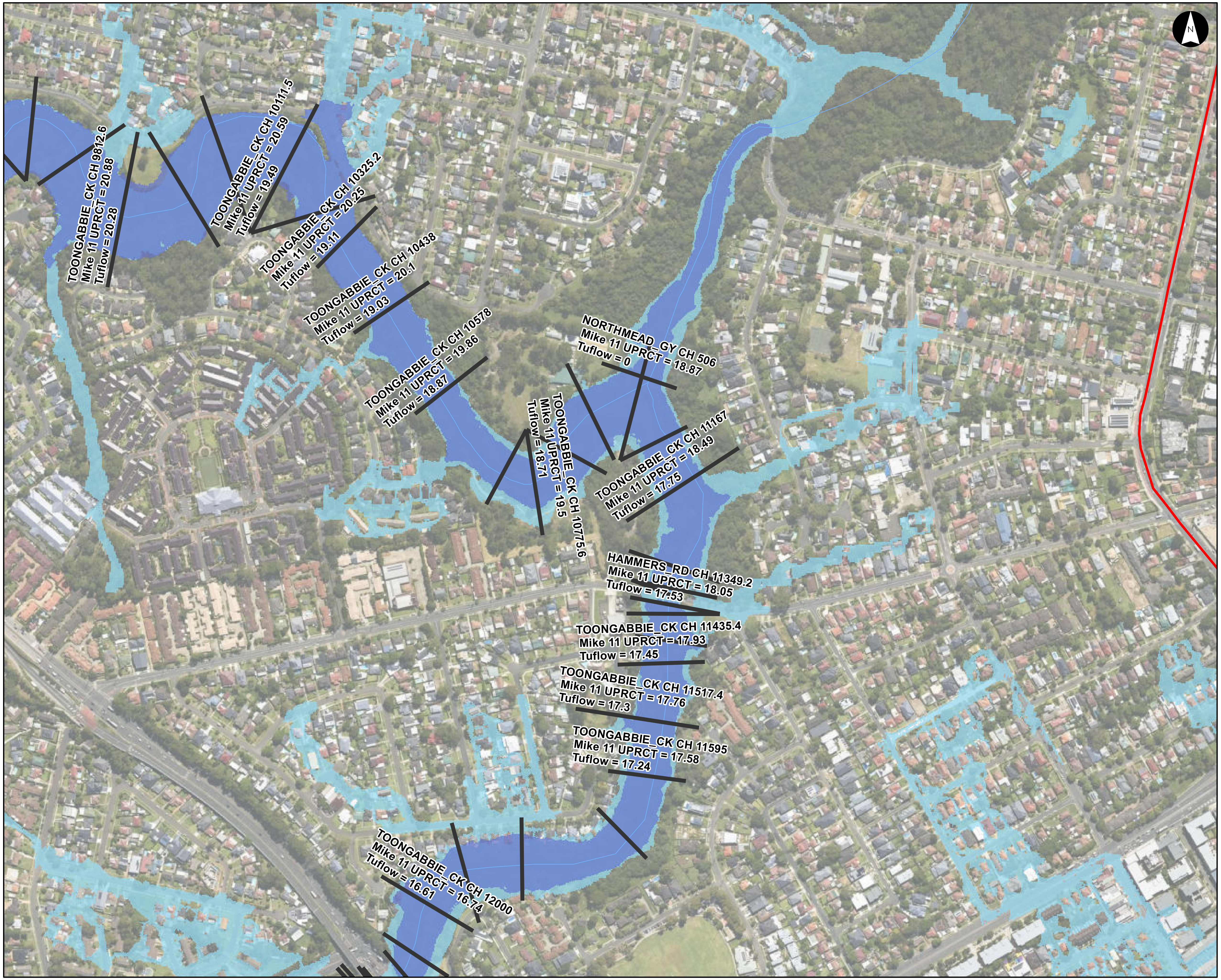
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec



Scale at A3 1:5,000





FFA 1% AEP Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-081-Mainstream_WL_1pc.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- 1% AEP Mike 11 Flood Extent
- FFA 1% Tuflow Extent

Figure C4

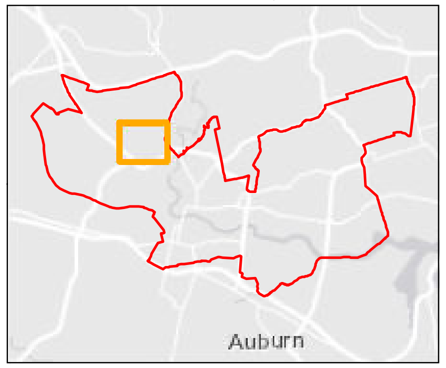
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

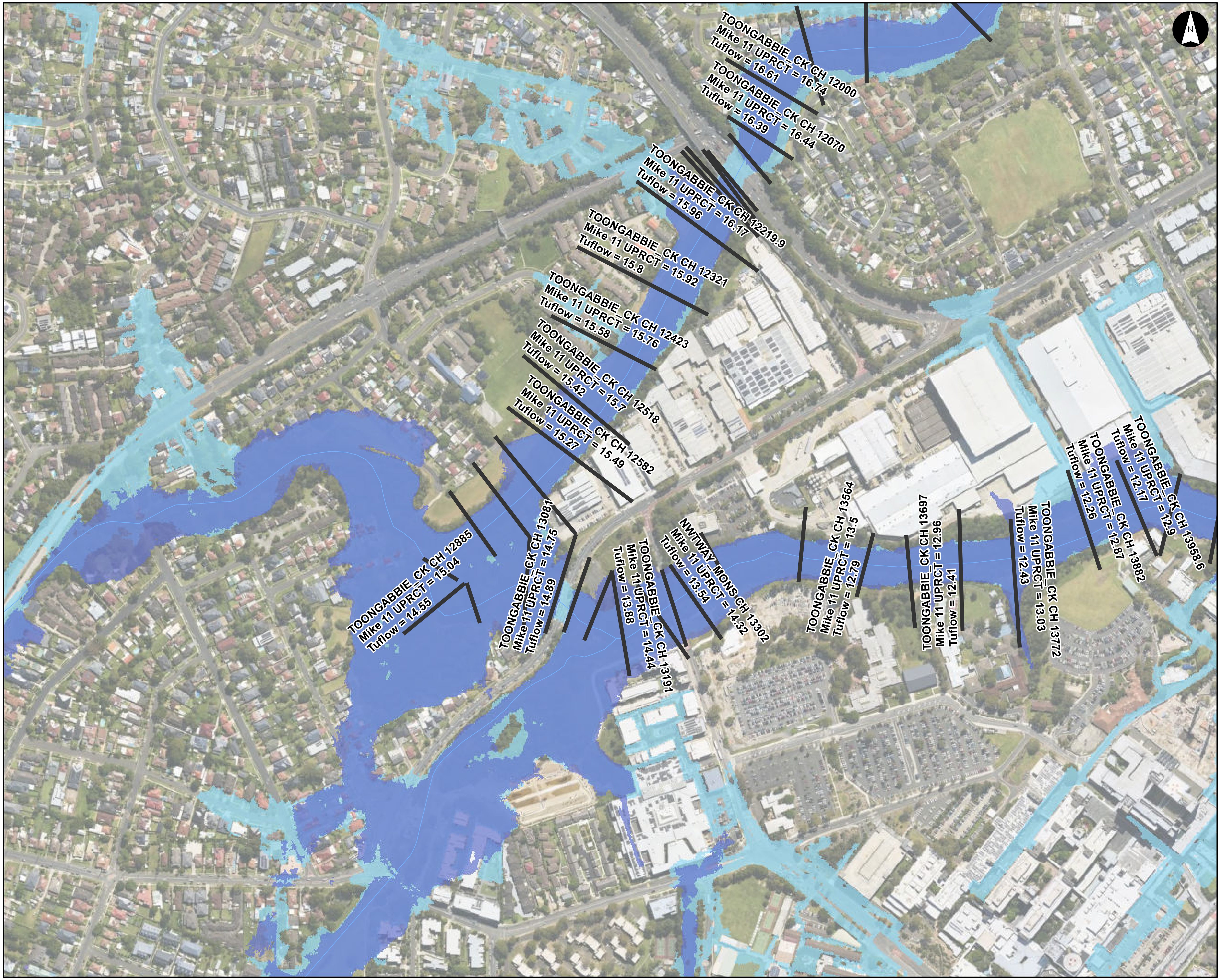
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





FFA 1% AEP Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-081-Mainstream_WL_1pc.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- 1% AEP Mike 11 Flood Extent
- FFA 1% Tuflow Extent

Figure C5

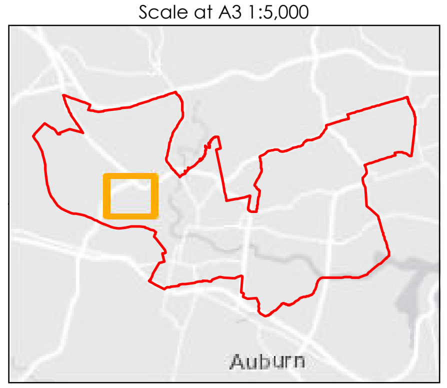
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

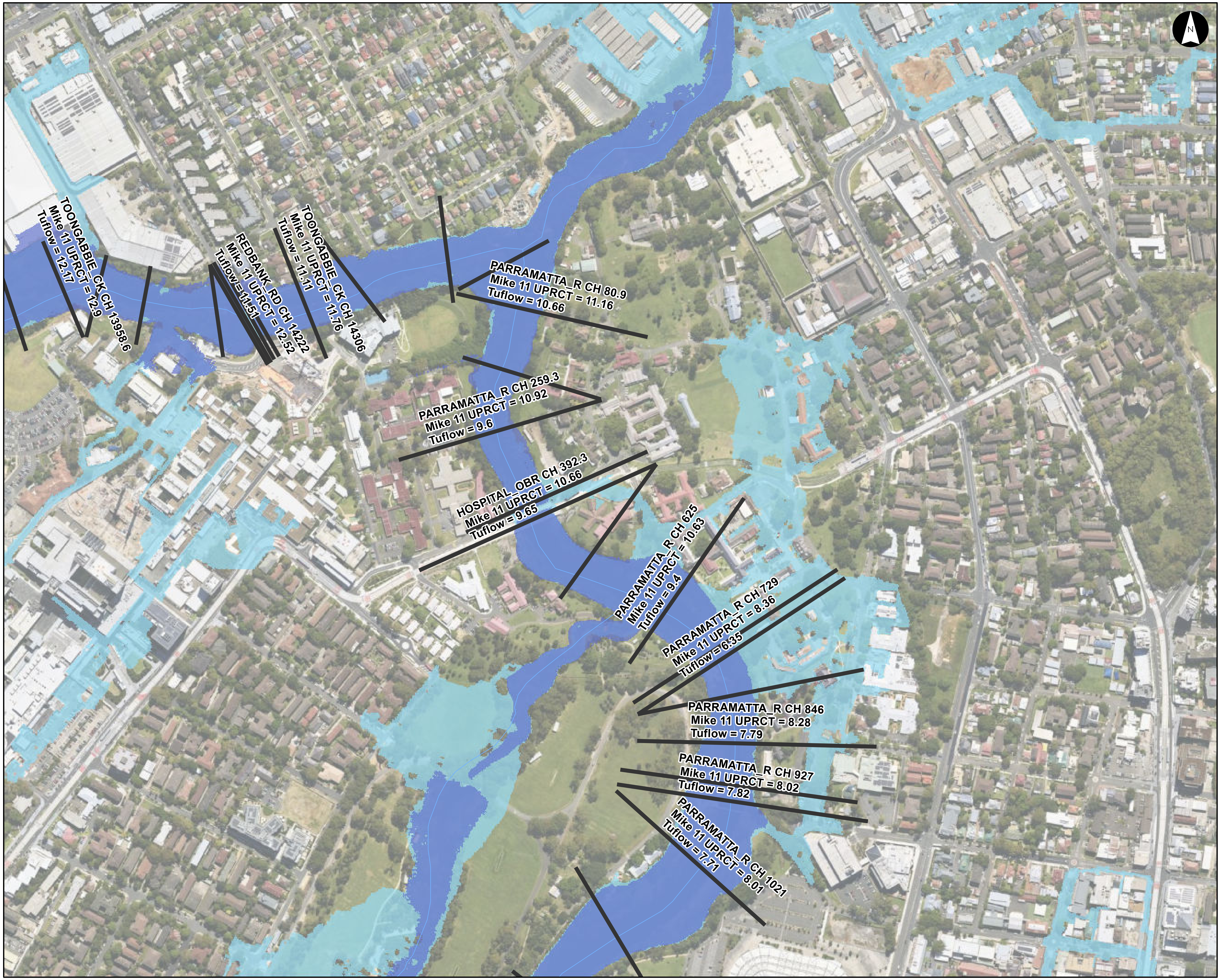
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





FFA 1% AEP Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-081-Mainstream_WL_1pc.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- 1% AEP Mike 11 Flood Extent
- FFA 1% Tuflow Extent

Figure C6

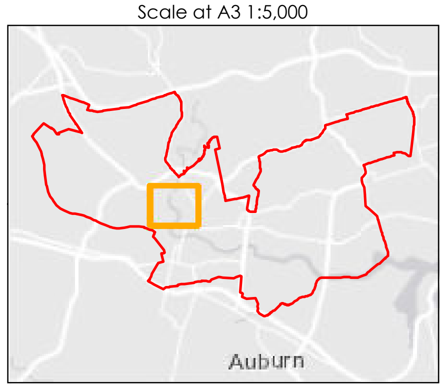
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

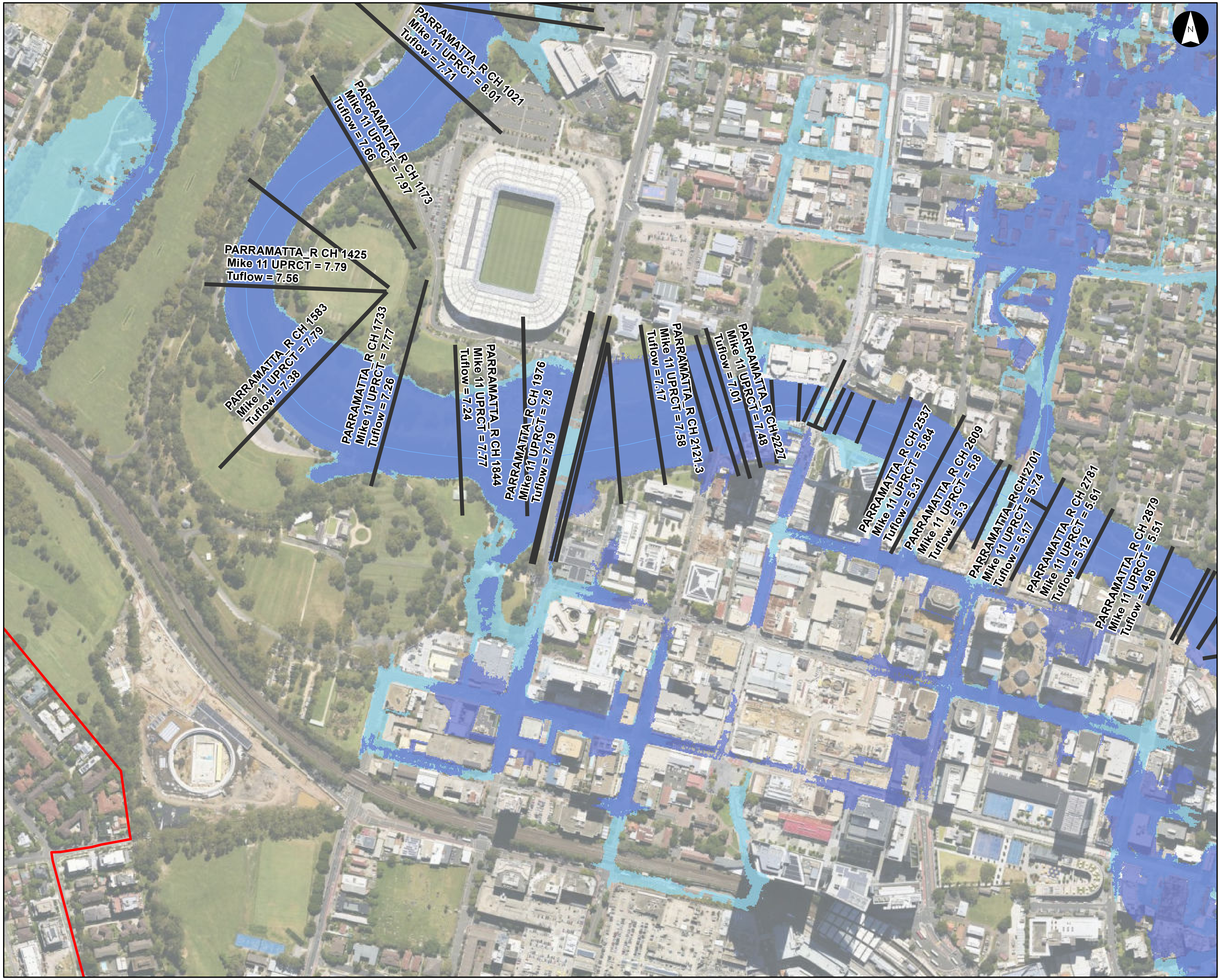
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





FFA 1% AEP Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-081-Mainstream_WL_1pc.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- 1% AEP Mike 11 Flood Extent
- FFA 1% Tuflow Extent

Figure C7

Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

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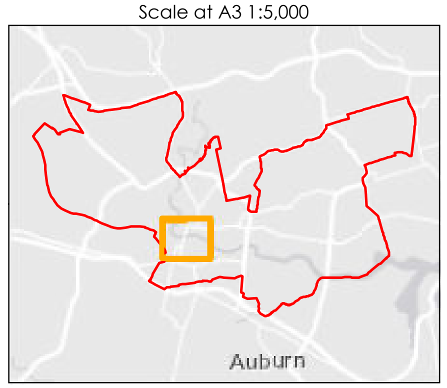
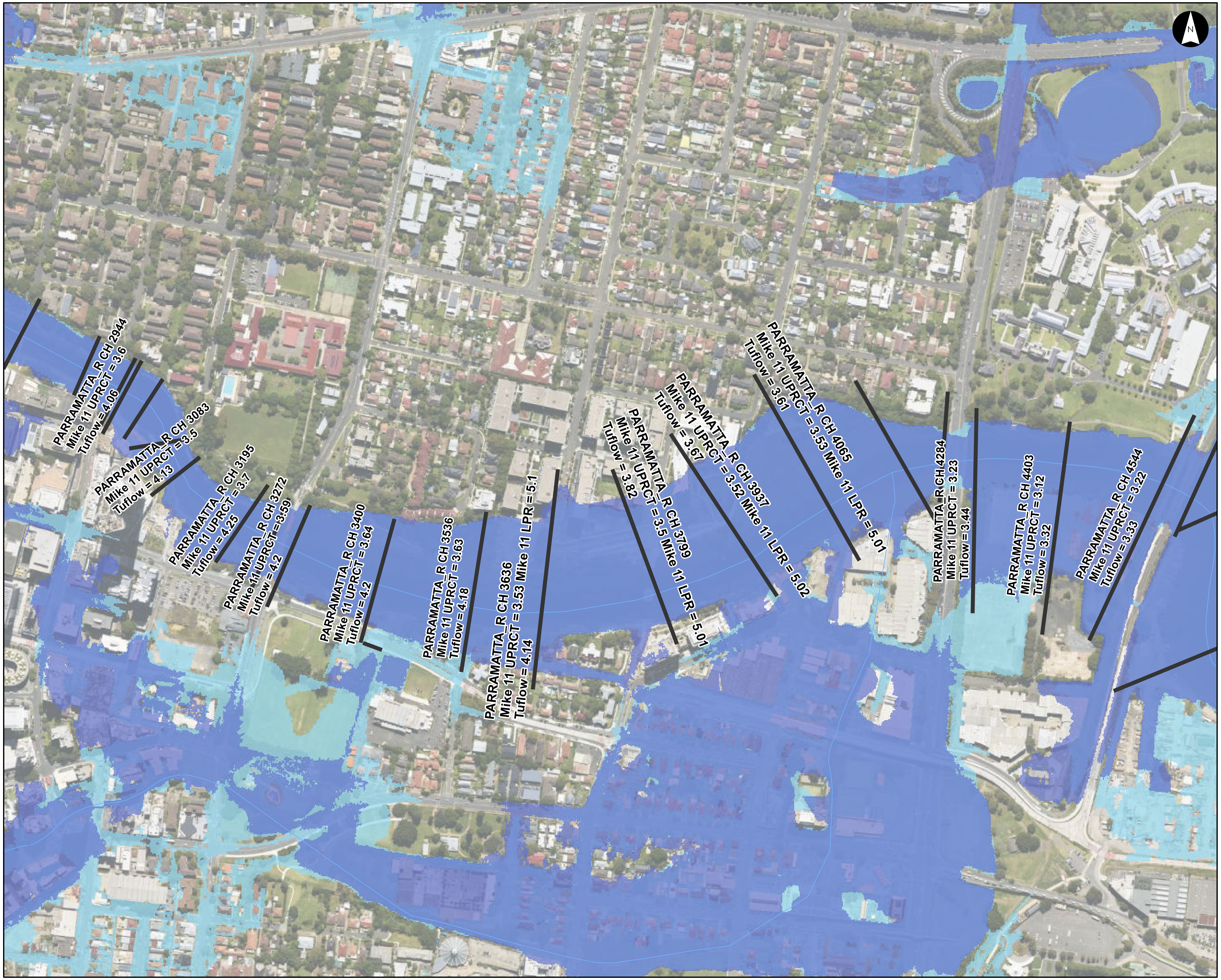
Scale at A3 1:5,000





FFA 1% AEP Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-081-Mainstream_WL_1pc.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- 1% AEP Mike 11 Flood Extent
- FFA 1% Tuflow Extent

Figure C8

Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

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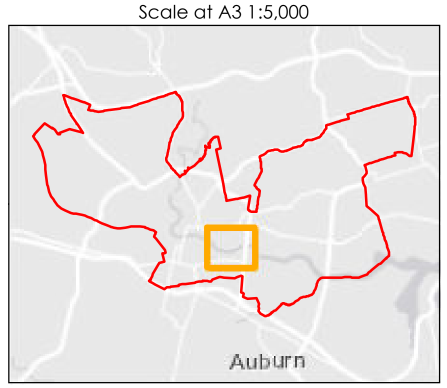
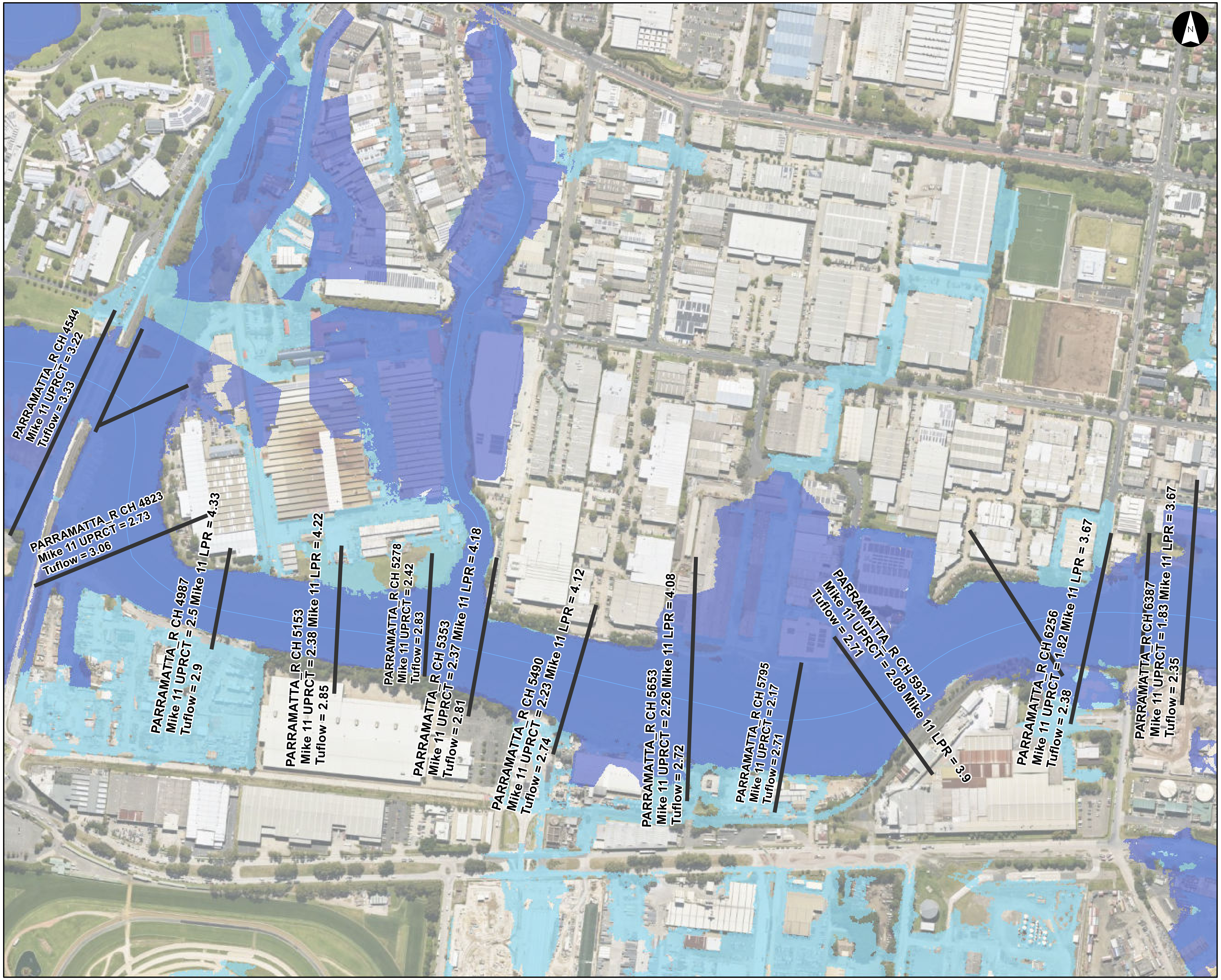
Scale at A3 1:5,000





FFA 1% AEP Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-081-Mainstream_WL_1pc.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- 1% AEP Mike 11 Flood Extent
- FFA 1% Tuflow Extent

Figure C9

Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

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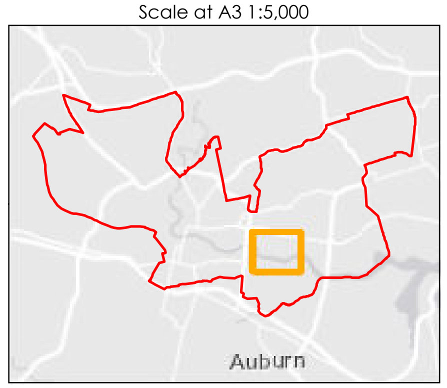
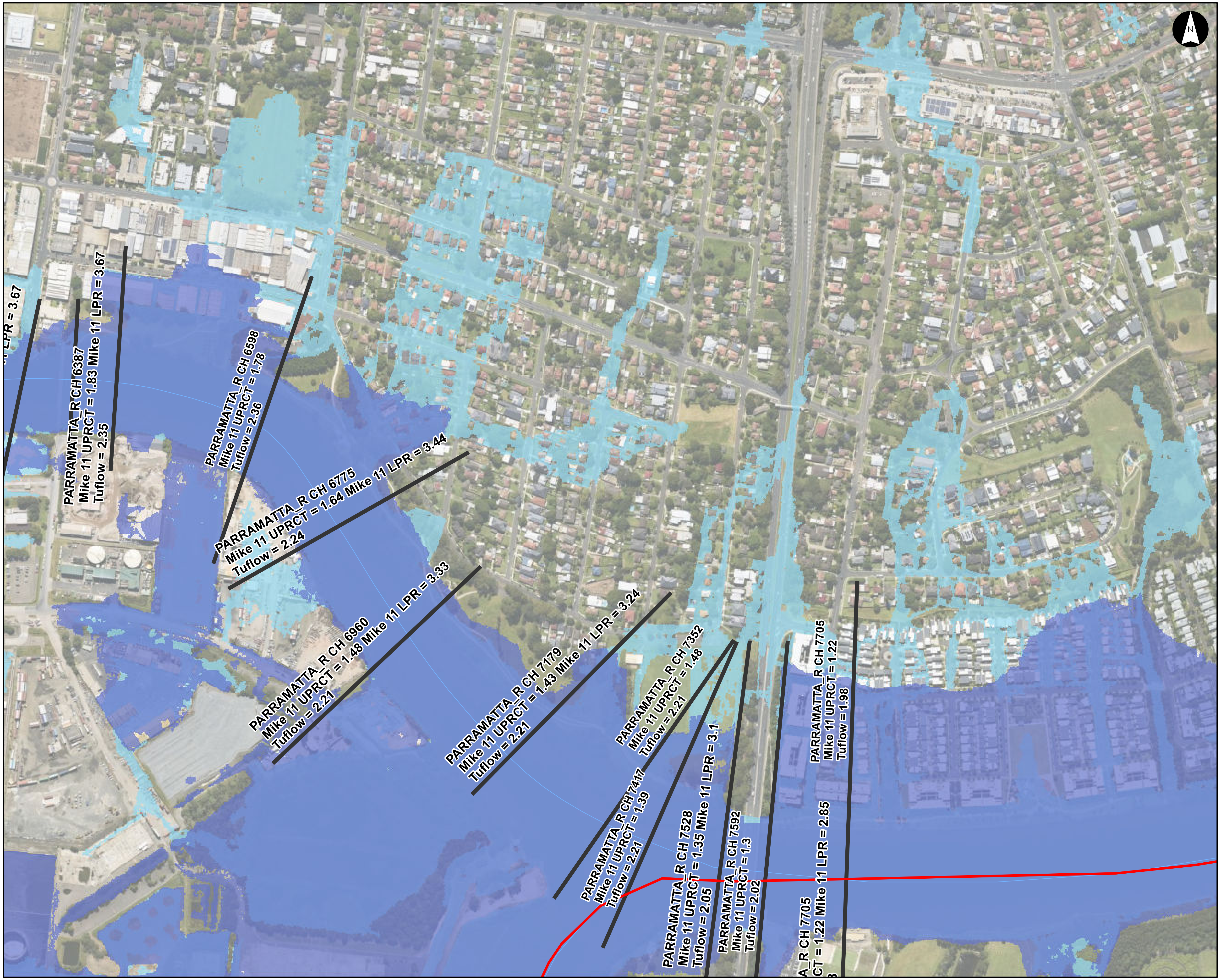
Scale at A3 1:5,000





FFA 1% AEP Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-081-Mainstream_WL_1pc.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- 1% AEP Mike 11 Flood Extent
- FFA 1% Tuflow Extent

Figure C10

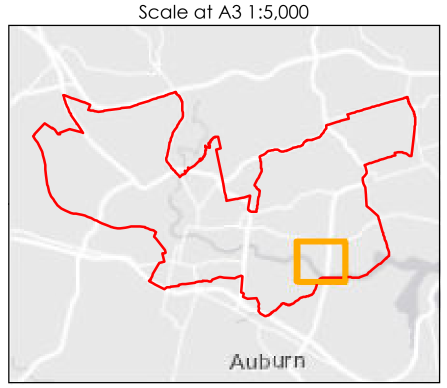
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

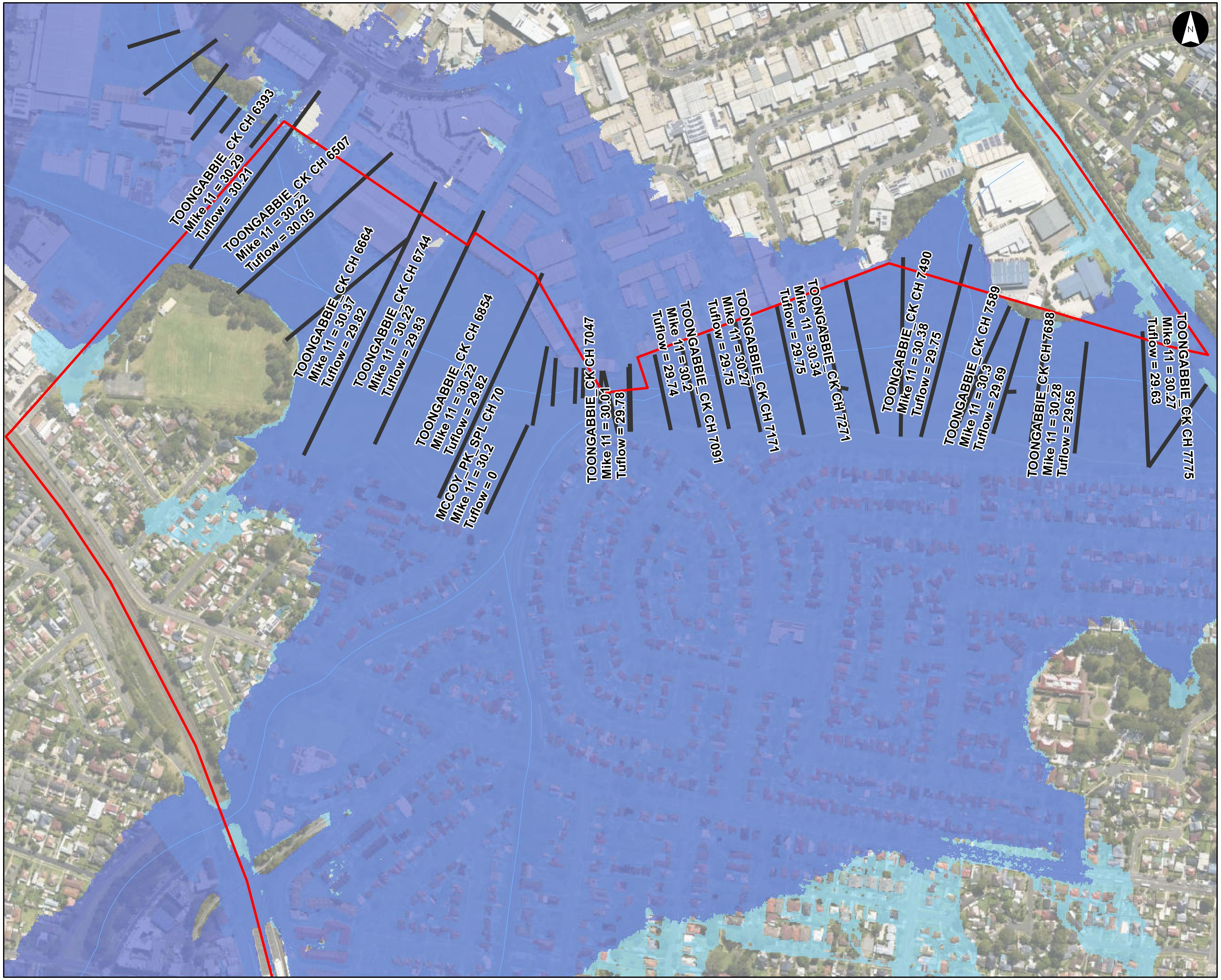
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





PMF Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-080-Mainstream_WL_PMF.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- PMF Event Mike 11 Flood Extent
- PMF Event Tuflow Extent

Figure C11

Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

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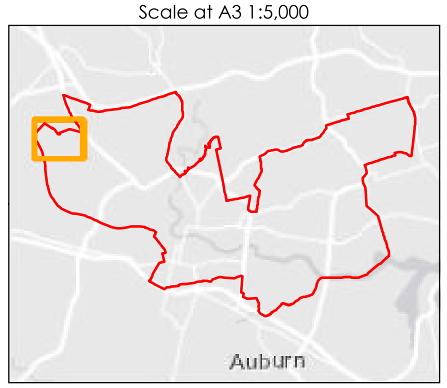
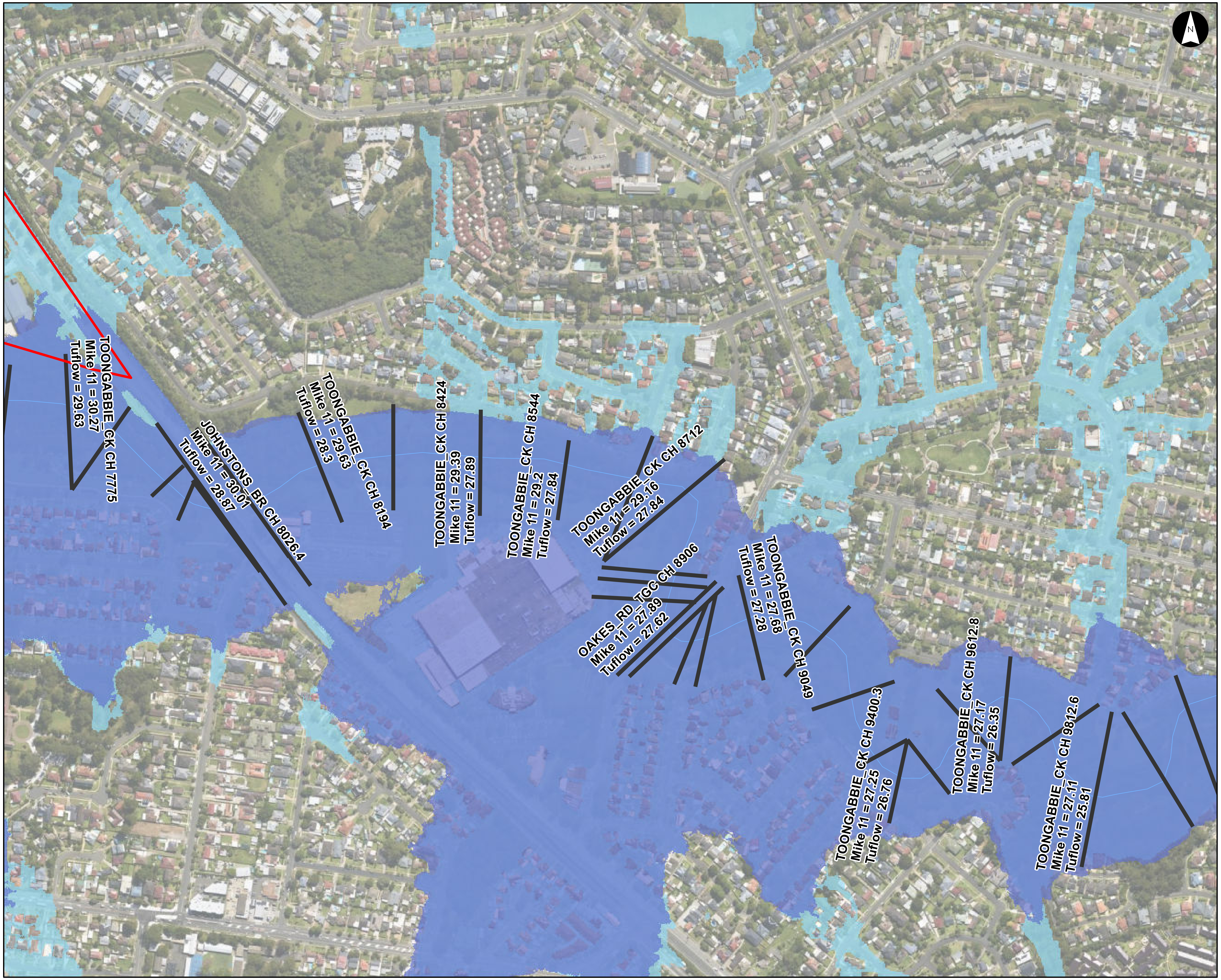
Scale at A3 1:5,000





PMF Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-080-Mainstream_WL_PMF.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- PMF Event Mike 11 Flood Extent
- PMF Event Tuflow Extent

Figure C12

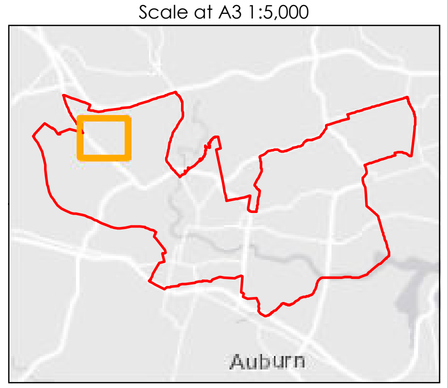
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

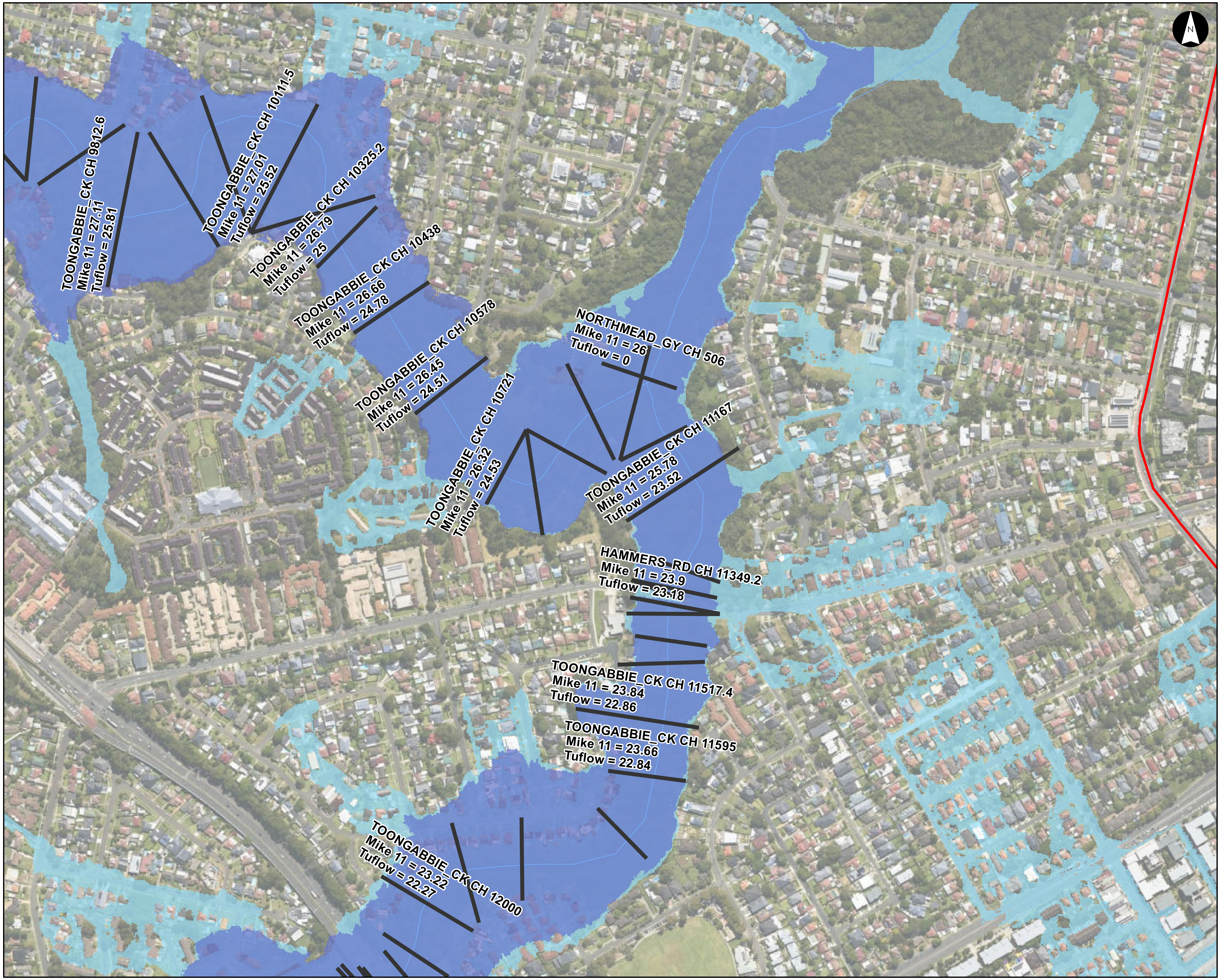
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





PMF Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-080-Mainstream_WL_PMF.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- PMF Event Mike 11 Flood Extent
- PMF Event Tuflow Extent

Figure C13

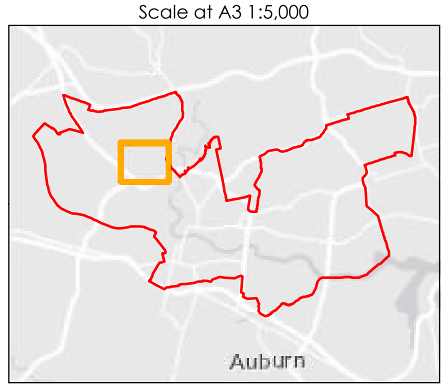
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

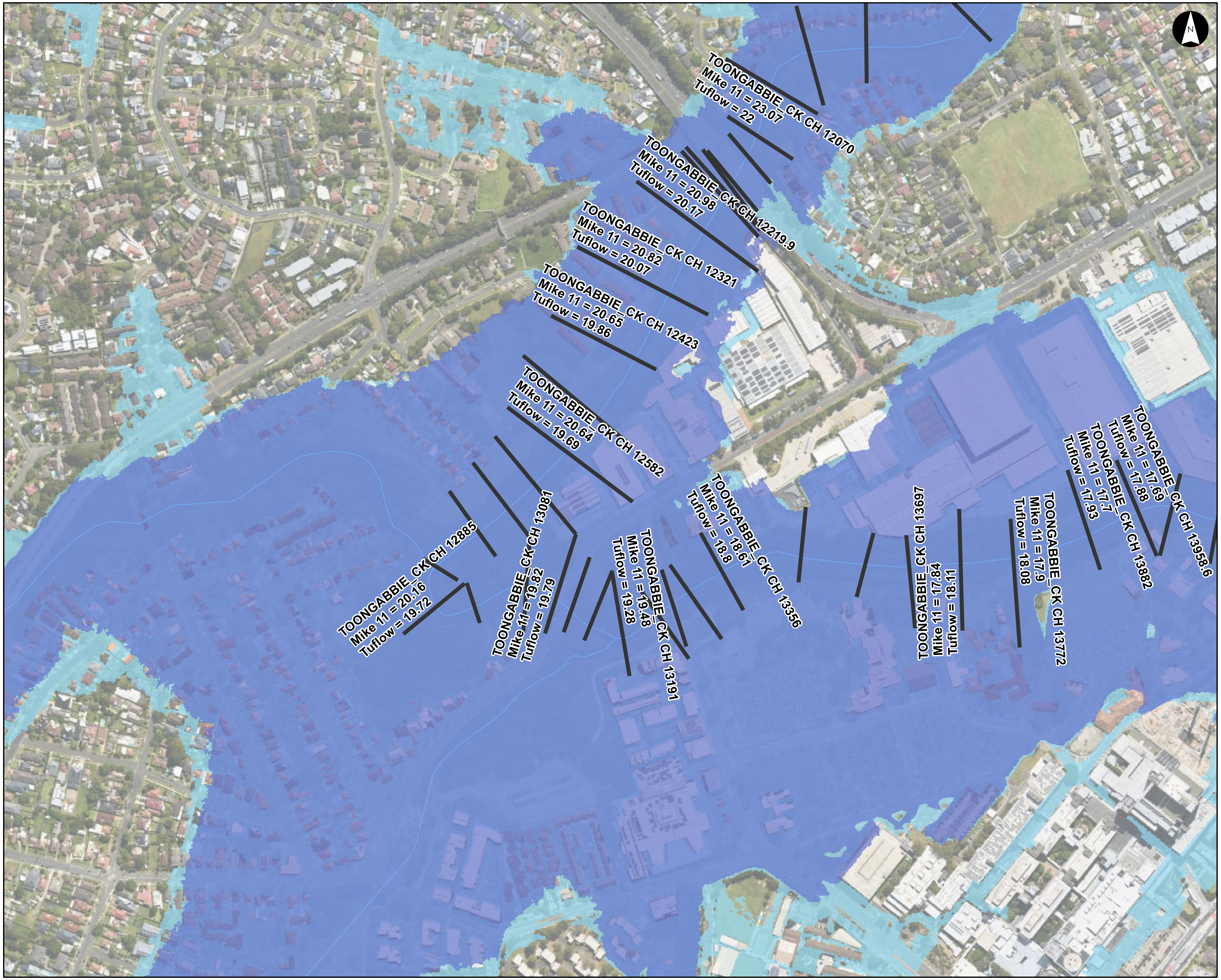
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





PMF Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-080-Mainstream_WL_PMF.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- PMF Event Mike 11 Flood Extent
- PMF Event Tuflow Extent

Figure C14

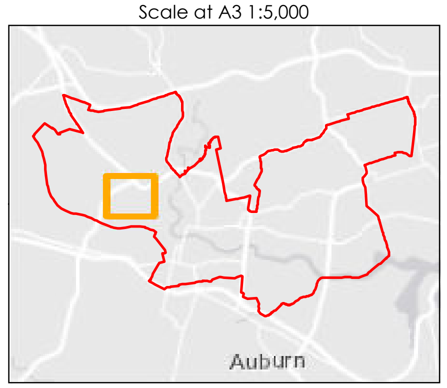
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000



PMF Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-080-Mainstream_WL_PMF.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- PMF Event Mike 11 Flood Extent
- PMF Event Tuflow Extent

Figure C15

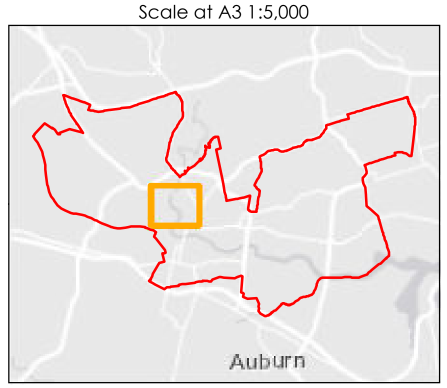
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

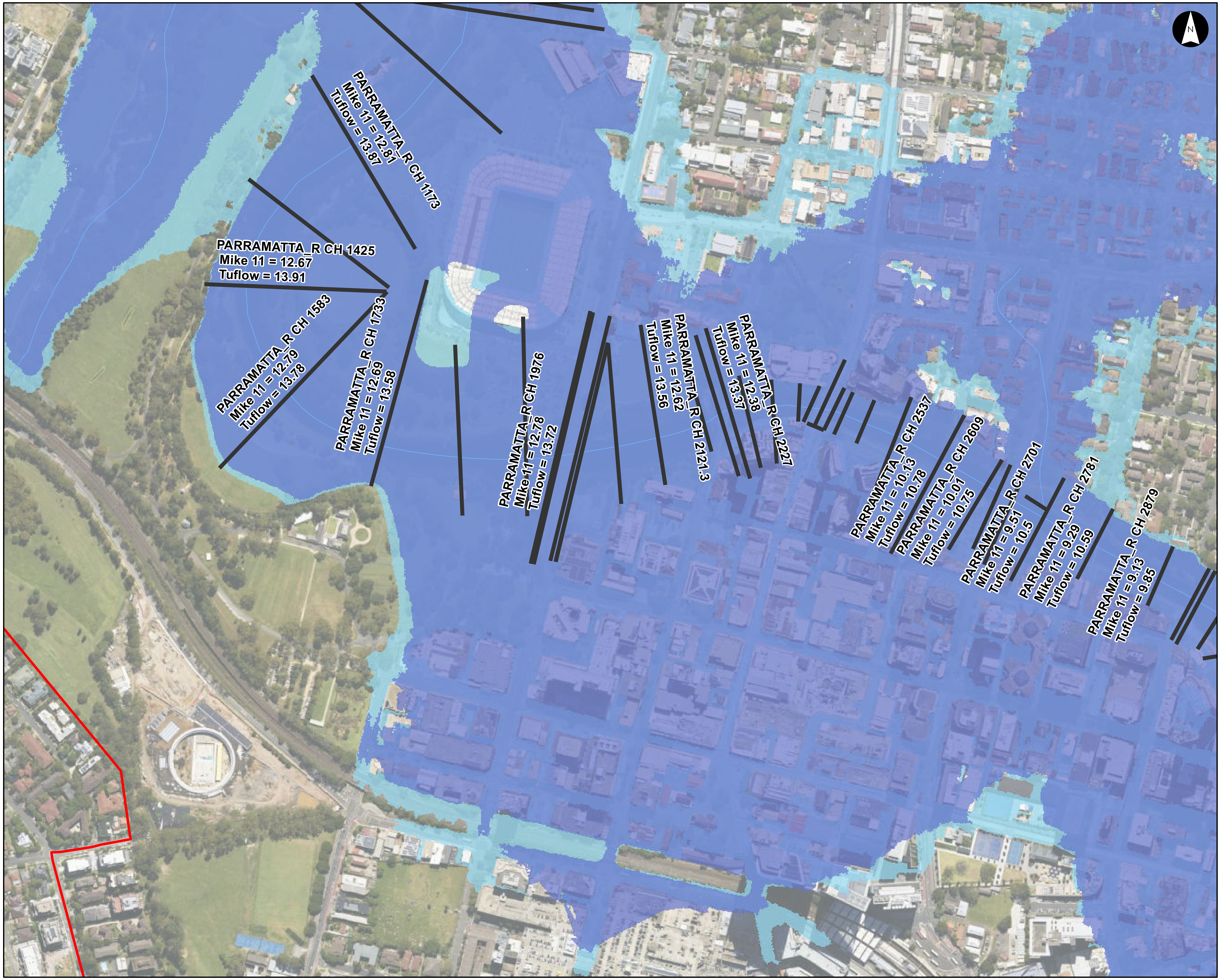
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





PMF Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-080-Mainstream_WL_PMF.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- PMF Event Mike 11 Flood Extent
- PMF Event Tuflow Extent

Figure C16

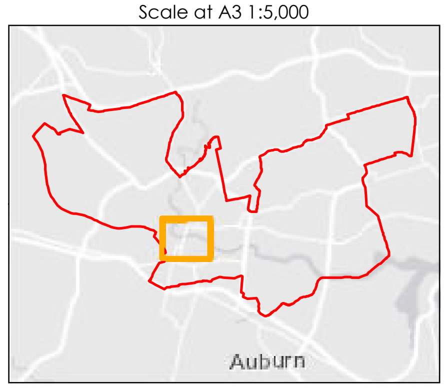
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

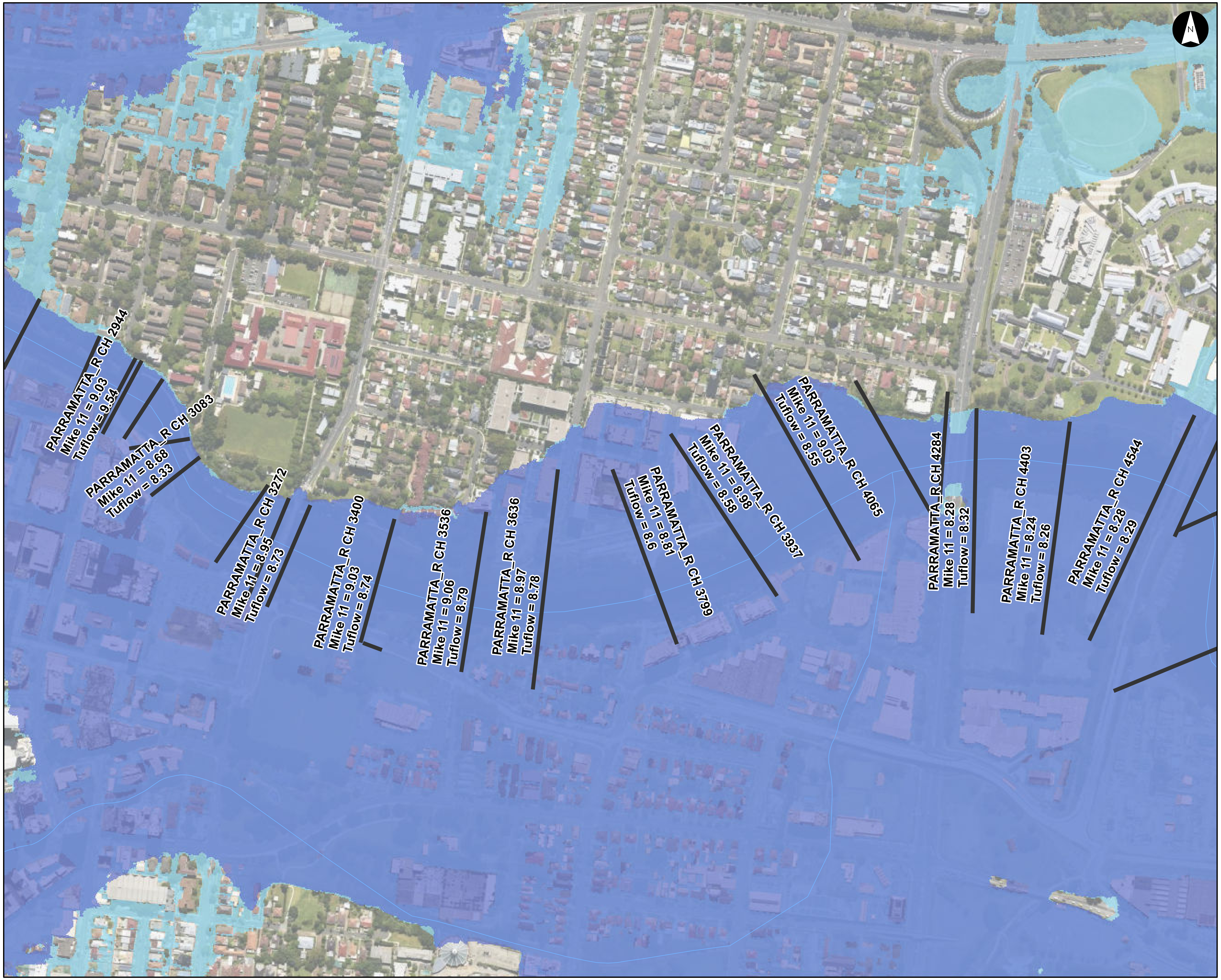
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





PMF Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

Parramatta River Flood Study

Project Code: 59916074
Drawn By: AS
Map: 59916074-GS-080-Mainstream_WL_PMF.mxd
Rev: 02
Date: 2023-05-29

Legend

- Study Area
- Watercourse
- Mike 11 Cross Sections
- PMF Event Mike 11 Flood Extent
- PMF Event Tuflow Extent

Figure C17

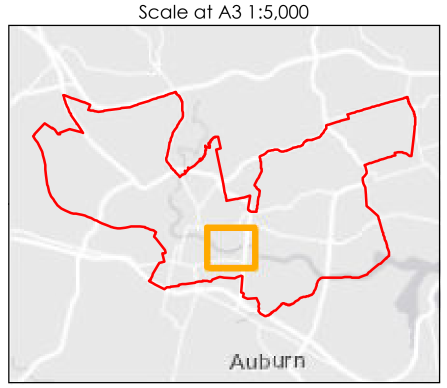
Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

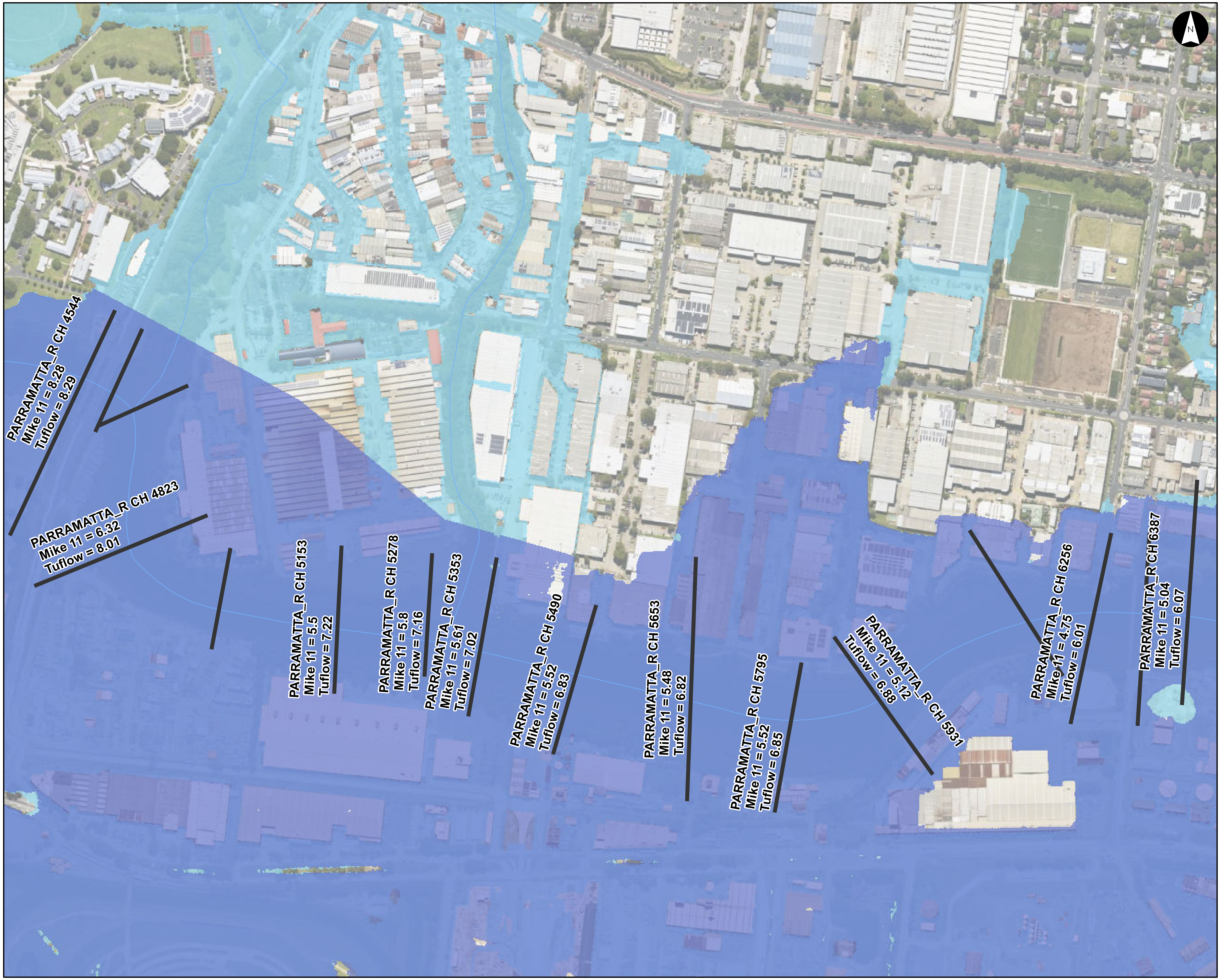
References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000





PMF Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

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Figure C18

Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

References:
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Stantec

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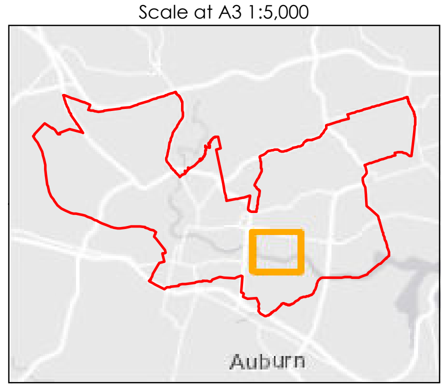
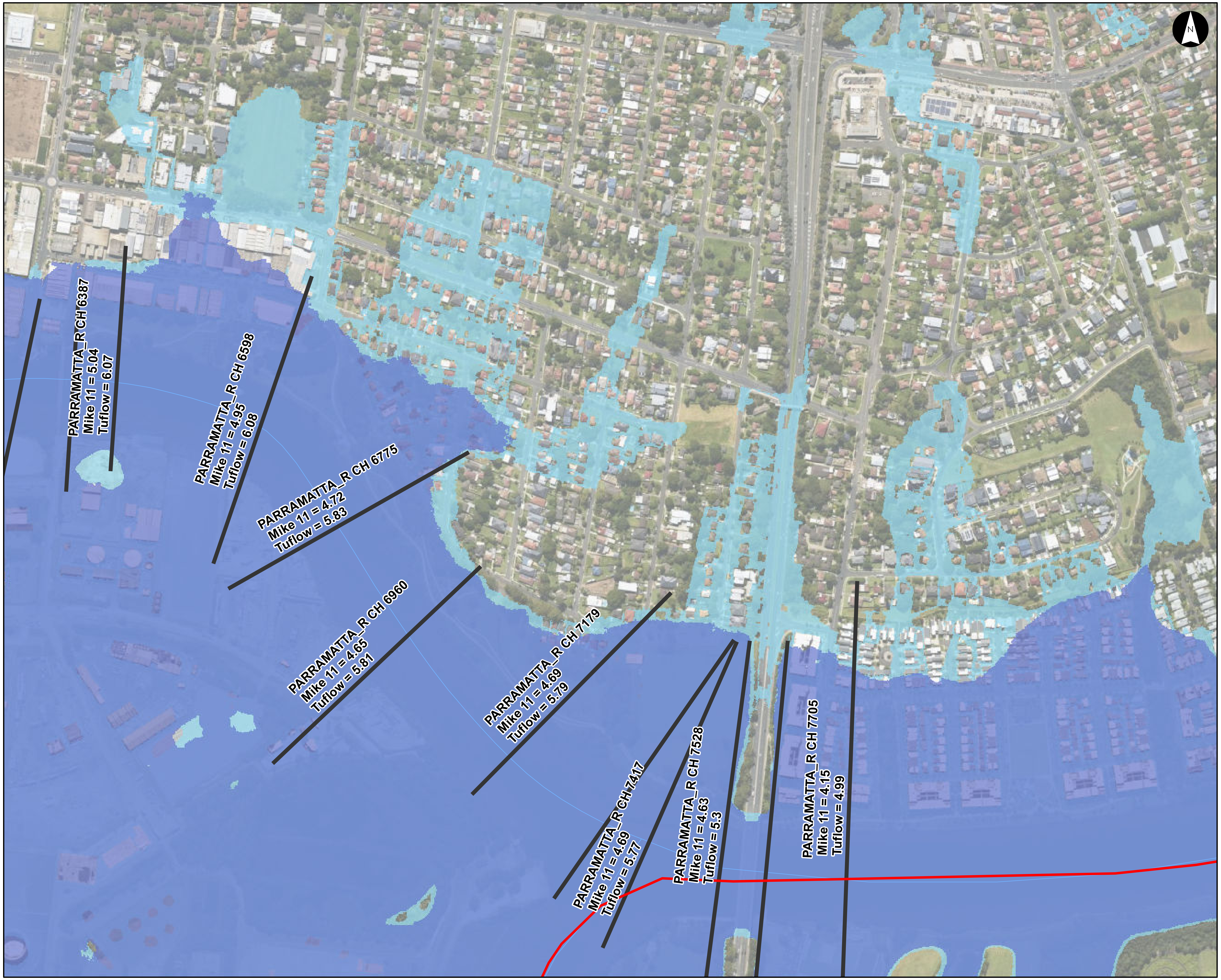
Scale at A3 1:5,000





PMF Event Peak Water Level Comparison UPRCT Draft 9 MIKE11 vs TUFLOW

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Legend

- Study Area
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Figure C19

Notes:
1. Coordinate System: GDA 1994 MGA Zone 56

References:
1. Base data supplied by NSW SS and Esri
2. Aerial imagery supplied by MetroMap

Stantec

0 50 100 150 200 Meters

Scale at A3 1:5,000

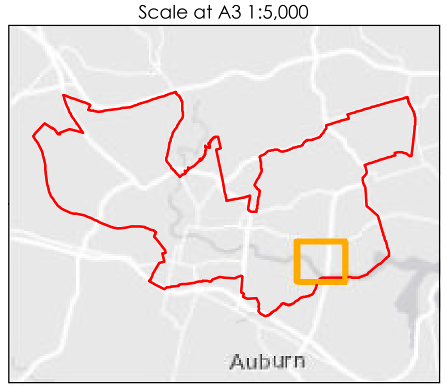

TABLE C.7

					MIKE 11 FLOW (m^3/s) and Peak Water Surface Level (m AHD)										TUFLOW PEAK WATER LEVEL (m AHD)						Peak Water Level Difference (m) (TUFLOW - MIKE11)						TUFLOW ARR87 - ARR2016
Field1	Id	Branch	Chainage	Topo_ID	WSL PMF	Q PMF	WSL 1% AEP	Q 1% AEP	WSL 2% AEP	Q 2% AEP	WSL 5% AEP	Q 5% AEP	WSL 20% AEP	Q 20% AEP	PMF	FFA 1% AEP	2% AEP	5% AEP	20% AEP	ARR87 1% AEP	PMF	1% AEP	2% AEP	5% AEP	20% AEP	ARR87 1% AEP	1% AEP
Toongabbie	3124	TOONGABBIE_CK	6171	UPRC	30.552	701.7	28.243	129.8	27.96	120.8	27.219	105.9	26.895	82.0	30.45	29.44	29.08	28.71	28.36	29.19	-0.11	1.20	1.12	1.49	1.46	0.95	-0.25
Toongabbie	3125	TOONGABBIE_CK	6221	UPRC	30.435	622.9	28.276	129.3	27.98	120.8	27.159	106.0	26.786	82.1	30.44	29.32	28.95	28.58	28.22	29.06	0.00	1.04	0.97	1.42	1.44	0.79	-0.26
Toongabbie	3126	TOONGABBIE_CK	6271	UPRC	30.323	701.9	28.218	135.2	27.92	124.5	27.015	106.1	26.617	82.1	30.42	29.11	28.75	28.39	28.05	28.86	0.10	0.90	0.83	1.38	1.43	0.64	-0.25
Toongabbie	3127	TOONGABBIE_CK	6296	UPRC	30.276	624.3	28.272	133.0	27.98	125.1	26.95	106.1	26.526	82.1	30.41	28.89	28.54	28.20	27.86	28.65	0.14	0.62	0.56	1.25	1.34	0.37	-0.25
Toongabbie	3128	TOONGABBIE_CK	6321	UPRC	30.179	625.0	28.328	139.3	28.03	127.0	26.873	106.1	26.425	82.1	30.41	28.35	28.02	27.75	27.47	28.11	0.23	0.02	-0.01	0.88	1.05	-0.22	-0.24
Toongabbie	3129	TOONGABBIE_CK	6366	UPRC	30.427	625.5	28.852	268.5	28.53	246.1	26.906	112.8	26.244	82.1	30.41	28.19	27.17	26.72	26.48	27.53	-0.02	-0.66	-1.35	-0.18	0.23	-1.32	-0.66
Toongabbie	3130	TOONGABBIE_CK	6393	UPRC	30.29	1488.2	28.145	490.2	27.84	448.7	26.875	236.2	26.268	185.5	30.41	28.34	27.49	27.08	26.76	27.78	0.12	0.20	-0.36	0.20	0.49	-0.36	-0.56
Toongabbie	3131	TOONGABBIE_CK	6507	UPRC	30.221	1492.1	28.089	314.2	27.80	285.4	26.829	232.4	26.178	183.1	30.39	28.26	27.38	26.94	26.58	27.68	0.17	0.17	-0.42	0.11	0.40	-0.41	-0.58
Toongabbie	3132	TOONGABBIE_CK	6604	UPRC	30.668	1945.9	28.052	311.2	27.76	281.6	26.769	230.4	26.082	181.6	30.24	28.19	27.26	26.70	26.15	27.61	-0.42	0.14	-0.50	-0.07	0.06	-0.45	-0.58
Toongabbie	3133	TOONGABBIE_CK	6664	UPRC	30.368	1830.3	28.073	309.5	27.78	280.0	26.787	228.7	26.09	180.2	30.22	28.18	27.25	26.67	25.82	27.60	-0.15	0.11	-0.53	-0.11	-0.27	-0.47	-0.58
Toongabbie	3134	TOONGABBIE_CK	6744	UPRC	30.22	1499.5	28.073	304.4	27.78	275.8	26.788	225.0	26.09	177.0	30.23	28.19	27.26	26.69	25.85	27.61	0.01	0.12	-0.52	-0.09	-0.24	-0.46	-0.58
Toongabbie	3135	TOONGABBIE_CK	6854	UPRC	30.219	1505.9	28.072	302.7	27.78	270.4	26.786	221.6	26.086	173.7	30.23	28.19	27.26	26.68	25.81	27.60	0.02	0.12	-0.52	-0.11	-0.27	-0.47	-0.59
Toongabbie	3136	TOONGABBIE_CK	6929	UPRC	30.353	579.6	28.052	298.1	27.76	268.4	26.76	220.6	26.055	172.7	29.84	27.63	27.40	26.84	25.94	27.94	-0.52	-0.42	-0.36	0.08	-0.11	-0.11	0.31
Toongabbie	3137	TOONGABBIE_CK	6940	UPRC	30.292	431.2	28.009	283.6	27.72	265.9	26.704	220.6	26	172.7	29.83	27.58	27.35	26.79	25.89	27.89	-0.47	-0.42	-0.37	0.09	-0.11	-0.12	0.31
Toongabbie	3138	TOONGABBIE_CK	6971	UPRC	30.322	415.1	27.907	283.6	27.60	265.9	26.567	220.6	25.884	172.7	29.80	27.37	27.14	26.67	25.70	27.67	-0.53	-0.54	-0.46	0.10	-0.18	-0.23	0.30
Toongabbie	3139	TOONGABBIE_CK	6981	UPRC	30.313	418.8	27.81	283.6	27.49	265.8	26.459	220.6	25.79	172.7	29.77	27.16	26.99	26.79	25.51	27.45	-0.55	-0.65	-0.50	0.33	-0.28	-0.36	0.29
Toongabbie	3140	TOONGABBIE_CK	7005	UPRC	30.351	428.8	27.841	283.6	27.51	265.8	26.352	220.6	25.67	172.7	30.39	25.35	27.17	27.88	24.56	25.54	0.04	-2.49	-0.34	1.53	-1.11	-2.30	0.20
Toongabbie	3141	TOONGABBIE_CK	7009	UPRC	29.984	2445.2	25.123	415.1	24.88	369.5	24.462	306.2	24.028	239.6	29.76	25.49	26.35	26.82	24.75	25.57	-0.22	0.37	1.48	2.36	0.73	0.45	0.08
Toongabbie	3142	TOONGABBIE_CK	7045	UPRC	29.989	2450.7	25.216	414.9	24.98	369.4	24.57	306.1	24.124	239.8	30.10	26.27	25.52	25.17	24.60	25.75	0.11	1.05	0.54	0.60	0.48	0.53	-0.52
Toongabbie	3143	TOONGABBIE_CK	7047	UPRC	30.01	2451.3	25.188	415.0	24.95	369.5	24.539	306.1	24.092	239.8	30.10	26.24	25.50	25.15	24.59	25.72	0.09	1.05	0.55	0.61	0.50	0.54	-0.52
Toongabbie	3144	TOONGABBIE_CK	7091	UPRC	30.196	2585.7	25.282	416.7	25.04	371.0	24.617	307.5	24.156	241.1	30.07	26.16	25.45	25.11	24.51	25.67	-0.13	0.88	0.41	0.50	0.35	0.39	-0.49
Toongabbie	3145	TOONGABBIE_CK	7131	UPRC	30.227	2688.6	25.267	416.8	25.02	371.2	24.587	307.5	24.109	241.5	30.07	26.19	25.47	25.12	24.47	25.70	-0.16	0.93	0.45	0.53	0.36	0.44	-0.49
Toongabbie	3146	TOONGABBIE_CK	7171	UPRC	30.273	2692.6	25.263	416.6	25.02	371.2	24.578	307.3	24.093	241.5	30.06	26.16	25.44	25.07	24.40	25.67	-0.21	0.90	0.42	0.49	0.31	0.41	-0.50
Toongabbie	3147	TOONGABBIE_CK	7211	UPRC	30.311	2690.5	25.245	416.4	25.00	371.2	24.558	307.0	24.07	241.5	30.06	26.16	25.43	25.06	24.38	25.67	-0.25	0.92	0.44	0.50	0.31	0.42	-0.49
Toongabbie	3148	TOONGABBIE_CK	7271	UPRC	30.338	2681.7	25.219	416.0	24.96	371.1	24.506	306.6	23.988	241.5	30.06	26.16	25.41	25.03	24.33	25.66	-0.28	0.94	0.45	0.52	0.34	0.44	-0.50
Toongabbie	3149	TOONGABBIE_CK	7331	UPRC	30.349	2673.4	25.212	416.3	24.95	372.1	24.49	307.3	23.955	242.4	30.05	26.15	25.39	25.00	24.27	25.64	-0.30	0.94	0.44	0.51	0.32	0.43	-0.51
Toongabbie	3150	TOONGABBIE_CK	7371	UPRC	30.362	1713.4	25.196	416.0	24.93	371.9	24.47	306.9	23.939	242.3	30.05	26.15	25.38	24.98	24.24	25.64	-0.31	0.95	0.45	0.51	0.30	0.44	-0.51
Toongabbie	3151	TOONGABBIE_CK	7430	UPRC	30.373	1705.6	25.175	415.6	24.91	371.8	24.445	306.5	23.9	242.2	30.05	26.13	25.36	24.95	24.20	25.61	-0.32	0.96	0.45	0.51	0.30	0.44	-0.52
Toongabbie	3152	TOONGABBIE_CK	7490	UPRC	30.378	1697.1	25.158	415.1	24.89	371.7	24.419	306.1	23.868	242.1	30.04	26.11	25.32	24.92	24.15	25.58	-0.33	0.95	0.43	0.50	0.28	0.42	-0.53
Toongabbie	3153	TOONGABBIE_CK	7550	UPRC	30.33	1690.3	25.099	418.2	24.84	375.1	24.361	308.8	23.809	244.5	30.02	26.07	25.29	24.88	24.11	25.55	-0.31	0.97	0.46	0.52	0.30	0.45	-0.52
Toongabbie	3154	TOONGABBIE_CK	7589	UPRC	30.301	1293.6	25.049	418.8	24.78	375.7	24.303	309.0	23.729	244.7	29.98	26.00	25.22	24.81	24.04	25.48	-0.32	0.95	0.43	0.50	0.31	0.43	-0.53
Toongabbie	3155	TOONGABBIE_CK	7629	UPRC	30.285	1295.6	24.982	418.8	24.72	375.8	24.23	309.0	23.682	244.7	29.95	25.93	25.14	24.73	23.97	25.40	-0.33	0.95	0.42	0.50	0.29	0.42	-0.53
Toongabbie	3156	TOONGABBIE_CK	7688	UPRC	30.279	2017.2	24.96	418.9	24.70	376.0	24.217	309.1	23.651	244.6	29.93	25.89	25.09	24.67	23.92	25.35	-0.34	0.93	0.39	0.46	0.27	0.39	-0.53
Toongabbie	3157	TOONGABBIE_CK	7775	UPRC	30.272	2016.9	24.899	419.1	24.64	376.4	24.166	309.3	23.609	244.3	29.92	25.82	25.03	24.62	23.86	25.29	-0.36	0.93	0.39	0.45	0.26	0.40	-0.53
Toongabbie	3158	TOONGABBIE_CK	7846	UPRC	30.179	2015.0	24.798	419.7	24.54	377.0	24.071	309.8	23.527	244.7	29.89	25.77	24.98	24.57	23.83	25.24	-0.29	0.97	0.44	0.50	0.30	0.44	-0.53
Toongabbie	3159	TOONGABBIE_CK	7950	UPRC	29.81	2012.2	24.663	419.8	24.42	377.2	23.964	309.9	23.432	245.3	29.75	25.64	24.85	24.45	23.73	25.11	-0.06	0.98	0.43	0.49	0.30	0.44	-0.54
Toongabbie	3160	TOONGABBIE_CK	7990.6	UPRC	29.575	2014.6	24.479	420.3	24.24	377.7	23.792	310.2	23.267	245.9	29.58	25.44	24.63	24.25	23.54	24.89	0.00	0.96	0.40	0.45	0.28	0.41	-0.55
Toongabbie	1896	JOHNSTONS_BR	8026.4	UPRC	30.009	962.3	24.633	0.7	24.38	0.6	23.912	1.2	23.36	0.9	29.30	25.42	24.62	24.22	23.48	24.88	-0.71	0.79	0.24	0.31	0.12	0.25	-0.54
Toongabbie	3161	TOONGABBIE_CK	8026.4	UPRC	30.009	2014.9	24.633	420.6	24.38	377.9	23.912	310.4	23.36	245.7	29.47	25.38	24.57	24.17	23.42	24.83	-0.54	0.74	0.19	0.26	0.06	0.20	-0.55
Toongabbie	1897	JOHNSTONS_BR	8075.8	UPRC	29.709	948.3	24.437	1.1	24.18	0.9	23.693	1.7	23.1	0.6	28.81	25.27	24.48	24.08	23.33	24.74	-0.90	0.83	0.31	0.39	0.23	0.30	-0.53
Toongabbie	3162	TOONGABBIE_CK	8075.8	UPRC	29.709	2063.8	24.437	420.5	24.18	378.0	23.693	310.4	23.1	245.6	28.81	25.27	24.48	24.08	23.33	24.74	-0.90	0.83	0.31	0.39	0.23	0.30	-0.53
Toongabbie	3163	TOONGABBIE_CK	8194	UPRC	29.634	2225.6	24.32	420.6	24.05	378.2	23.555	310.4	22.975	244.0	28.65	25.16	24.37	23.96	23.18	24.63	-0.99	0.84	0.32	0.40	0.20	0.31	-0.53
Toongabbie	3164	TOONGABBIE_CK	8304	UPRC	29.622	2234.9	24.164	420.9	23.90	378.5	23.387	310.6	22.777	244.2	28.44	24.86	24.07	23.67	22.93	24.33	-1.19	0.69	0.18	0.29	0.16	0.17	-0.53
Toongabbie	3165	TOONGABBIE_CK	8424	UPRC	29.394	2286.5	23.987	421.1	23.74	378.8	23.256	310.8	22.67	244.4	28.26	24.62	23.86	23.47	22.74	24.11	-1.13	0.64	0.12	0.21	0.07	0.13	-0.51
Toongabbie	3166	TOONGABBIE_CK	8544	UPRC	29.202	2432.0	23.855	421.4	23.61	379.1	23.122	311.0	22.537	244.5	28.22	24.47	23.66	23.24	22.44	23.93	-0.98	0.61	0.05	0.12	-0.10	0.08	-0.53
Toongabbie	3167	TOONGABBIE_CK	8638	UPRC	29.131	2461.5	23.628	421.6	23.38	379.4	22.874	311.2	22.287	244.7	28.24	24.31	23.47	23.04	22.24	23.75	-0.89	0.68	0.09	0.17	-0.05	0.12	-0.56
Toongabbie	3168	TOONGABBIE_CK	8712	UPRC	29.161	2625.4	23.592	421.9	23.34	379.7	22.845	311.5	22.237	244.9	28.24	24.36	23.53	23.09	22.25	23.81	-0.92	0.77	0.19	0.25	0.01	0.22	-0.55
Toongabbie	3169	TOONGABBIE_CK	8827	UPRC	28.698	3186.4	23.464	422.0	23.22	379.8	22.728	311.5	22.113	244.9	28.10	24.05	23.21	22.78	21.93	23.48	-0.60	0.58	-0.01	0.05	-0.18	0.01	-0.57
Toongabbie	3170	TOONGABBIE_CK	8842	UPRC	28.072	1866.2	22.966	422.3	22.74	380.0	22.261	311.7	21.649	245.1	28.09	24.07	23.24	22.80	21.96	23.51	0.02	1.10	0.50	0.54	0.31	0.54	-0.56
Toongabbie	3171	TOONGABBIE_CK	8868	UPRC	27.809	3075.0	22.961	422.3	22.74	380.1	22.277	311.7	21.677	245.1	28.06	24.04	23.21	22.78	21.92	23.48	0.25	1.07	0.47	0.50	0.25	0.52	-0.56
Toongabbie	2360	OAKES_RD_TGC	8906	UPRC	27.886	2213.0	23.015	107.0	22.78	61.9	22.306	7.2	21.692	0.3	28.02	23.91	23.02	22.55	21.62	23.32	0.14	0.90	0.24	0.24	-0.08	0.30	-0.60
Toongabbie	3172	TOONGABBIE_CK	8906	UPRC	27.886	2925.9	23.015	422.3	22.78	380.1	22.306	311.7	21.692	249.1	28.02	23.91	23.02	22.55	21.62	23.32	0.14	0.90	0.24	0.24	-0.08	0.30	-0.60
Toongabbie	2361	OAKES_RD_TGC	8918	UPRC	27.842	2260.5	22.634	107.0	22.37	61.9	21.864	7.2	21.344	0.2	28.00	23.75	22.79	22.33	21.38	23.09	0.16	1.11	0.42	0.46	0.03	0.45	-0.66
Toongabbie	3173	TOONGABBIE_CK	8918	UPRC	27.842	2174.4	22.634	428.7	22.37	386.0	21.864	316.7	21.344	249.1	28.00	23.75	22.79	22.33	21.38	23.09	0.16	1.11	0.42	0.46	0.03	0.45	-0.66
Toongabbie	3174	TOONGABBIE_CK	8953	UPRC	27.715	2265.8	22.539	428.5	22.27	386.0	21.759	316.7	21.246	249.0	28.03	23.84	22.91	22.45	21.55	23.21	0.32	1.30	0.64	0.69	0.30	0.67	-0.63
Toongabbie	3175	TOONGABBIE_CK	8979	UPRC	27.664	2243.8	22.37	428.6	22.10	386.0	21.572	316.8	21.051	249.1	28.02	23.69	22.72	22.26	21.39	23.03	0.35	1.32	0.62	0.69	0.34	0.66	-0.67
Toongabbie	3176	TOONGABBIE_CK	9049	UPRC	27.684	2309.3	22.273	428.7	21.99	386.1	21.47	316.8	20.936	249.1	27.73	23.59	22.68	22.24	21.41	22.97	0.04	1.31	0.69	0.77	0.47	0.69	-0.62
Toongabbie	3177	TOONGABBIE_CK	9151	UPRC	27.574	2330.0	22.087	429.2	21.81	386.7	21.282	317.2	20.736	249.5	27.72	23.35	22.35	21.87	21.00	22.66	0.14	1.26	0.54	0.59	0.26	0.58	-0.69
Toongabbie	3178	TOONGABBIE_CK	9255	UPRC	27.466	2281.5	21.962	429.7	21.69	387.2	21.149	317.6	20.589	249.8	27.56	23.14	22.16	21.69	20.82	22.47	0.10	1.18	0.48	0.54	0.23	0.51	-0.67
Toongabbie	3179	TOONGABBIE_CK	9350	UPRC	27.122	2211.3	21.681	429.8	21.41	387.3	20.876	317.6	20.348	249.8	27.24	22.48	21.42	20.93	20.09	21.74	0.12	0.80	0.01	0.06	-0.26	0.06	-0.73
Toongabbie	3180	TOONGABBIE_CK	9400.3	UPRC	27.255	2181.9	21.599	429.9	21.33	387.4	20.78	317.7	20.242	249.8	27.26	22.30	21.20	20.72	19.92	21.54	0.01	0.70	-0.13	-0.06	-0.32	-0.06	-0.76
Toongabbie	3181	TOONGABBIE_CK	9460	UPRC	27.134	2152.6	21.444	429.9	21.16	387.5	20.594	317.7	20.045	249.8	27.20	22.17	21.10	20.66	19.96	21.44	0.06	0.72	-0.06	0.06	-0.09	0.00	-0.73
Toongabbie	3182	TOONGABBIE_CK	9543.1	UPRC	27.143	2180.3	21.334	429.9	21.04	387.5	20.443	317.6	19.841	249.7	26.95	22.11	21.15	20.69	19.86	21.45	-0.19	0.77	0.11	0.25	0.02	0.12	-0.66
Toongabbie	3183	TOONGABBIE_CK	9612.8	UPRC	27.168	2229.3	21.31	429.8	21.01	387.5	20.406	317.5	19.796	249.6	26.88	22.16	21.19	20.73	19.86	21.49	-0.28	0.85	0.18	0.32	0.06	0.18	-0.67

					MIKE 11 FLOW (m^3/s) and Peak Water Surface Level (m AHD)										TUFLOW PEAK WATER LEVEL (m AHD)						Peak Water Level Difference (m) (TUFLOW - MIKE11)						TUFLOW ARR87 - ARR2016
Field1	Id	Branch	Chainage	Topo_ID	WSL PMF	Q PMF	WSL 1% AEP	Q 1% AEP	WSL 2% AEP	Q 2% AEP	WSL 5% AEP	Q 5% AEP	WSL 20% AEP	Q 20% AEP	PMF	FFA 1% AEP	2% AEP	5% AEP	20% AEP	ARR87 1% AEP	PMF	1% AEP	2% AEP	5% AEP	20% AEP	ARR87 1% AEP	1% AEP
Toongabbie	3184	TOONGABBIE_CK	9702.2	UPRC	27.101	2283.1	21.13	430.4	20.82	388.1	20.21	317.9	19.59	249.9	26.63	21.80	20.81	20.35	19.51	21.11	-0.47	0.67	-0.02	0.14	-0.08	-0.02	-0.68
Toongabbie	3185	TOONGABBIE_CK	9812.6	UPRC	27.108	2218.0	20.878	430.9	20.54	388.7	19.897	318.1	19.243	250.2	26.39	21.62	20.59	20.13	19.28	20.91	-0.71	0.75	0.05	0.24	0.04	0.03	-0.71
Toongabbie	3186	TOONGABBIE_CK	9920.9	UPRC	27.08	2127.0	20.817	430.7	20.48	388.6	19.834	317.9	19.178	250.1	26.42	21.52	20.46	19.97	19.04	20.79	-0.66	0.70	-0.02	0.14	-0.13	-0.03	-0.73
Toongabbie	3187	TOONGABBIE_CK	10033.7	UPRC	27.038	2077.5	20.697	430.6	20.35	388.6	19.681	317.6	18.993	249.8	26.18	21.35	20.22	19.65	18.44	20.58	-0.86	0.66	-0.13	-0.03	-0.55	-0.11	-0.77
Toongabbie	3188	TOONGABBIE_CK	10111.5	UPRC	27.007	1977.7	20.594	431.4	20.25	389.4	19.578	318.1	18.876	250.2	26.18	21.22	20.04	19.42	18.25	20.43	-0.83	0.62	-0.20	-0.16	-0.62	-0.17	-0.79
Toongabbie	3189	TOONGABBIE_CK	10273.6	UPRC	26.886	2021.4	20.353	431.6	20.01	389.6	19.327	318.0	18.601	250.1	25.77	20.81	19.71	19.15	18.12	20.06	-1.12	0.46	-0.30	-0.18	-0.48	-0.29	-0.75
Toongabbie	3190	TOONGABBIE_CK	10325.2	UPRC	26.79	2022.2	20.251	431.8	19.91	389.8	19.236	318.1	18.501	250.1	25.71	20.76	19.65	19.10	18.07	20.00	-1.08	0.50	-0.26	-0.13	-0.43	-0.25	-0.76
Toongabbie	3191	TOONGABBIE_CK	10438	UPRC	26.661	2000.0	20.104	431.9	19.77	389.9	19.086	318.0	18.345	250.1	25.50	20.61	19.55	19.03	18.02	19.89	-1.16	0.51	-0.22	-0.06	-0.33	-0.22	-0.73
Toongabbie	3192	TOONGABBIE_CK	10578	UPRC	26.452	1929.1	19.865	432.1	19.54	390.1	18.876	318.0	18.148	250.0	25.26	20.50	19.45	18.94	17.93	19.78	-1.20	0.63	-0.08	0.06	-0.21	-0.08	-0.71
Toongabbie	3193	TOONGABBIE_CK	10721	UPRC	26.315	1915.1	19.559	432.2	19.24	390.2	18.598	318.0	17.87	250.0	25.28	20.39	19.34	18.83	17.81	19.67	-1.04	0.83	0.10	0.23	-0.06	0.11	-0.72
Toongabbie	3194	TOONGABBIE_CK	10775.6	UPRC	26.32	1925.2	19.499	432.4	19.18	390.4	18.512	318.2	17.781	250.1	25.27	20.39	19.33	18.82	17.79	19.67	-1.05	0.89	0.15	0.30	0.00	0.17	-0.72
Toongabbie	3195	TOONGABBIE_CK	10870	UPRC	26.158	1936.1	19.179	432.5	18.86	390.5	18.179	318.2	17.444	250.0	25.03	20.08	19.05	18.58	17.62	19.37	-1.13	0.90	0.20	0.41	0.18	0.19	-0.71
Toongabbie	3196	TOONGABBIE_CK	10941	UPRC	26.049	1928.6	18.959	432.6	18.63	390.6	17.965	318.2	17.253	250.0	24.94	20.11	19.07	18.59	17.59	19.40	-1.10	1.15	0.44	0.62	0.34	0.44	-0.71
Toongabbie	3197	TOONGABBIE_CK	11014	UPRC	26.005	1897.6	18.866	449.4	18.54	406.3	17.872	330.4	17.152	259.6	24.94	20.10	19.05	18.57	17.57	19.37	-1.06	1.23	0.51	0.69	0.41	0.51	-0.72
Toongabbie	3198	TOONGABBIE_CK	11095	UPRC	25.848	1846.7	18.711	449.4	18.38	406.2	17.692	330.3	16.958	259.5	24.83	19.73	18.72	18.27	17.36	19.04	-1.02	1.02	0.34	0.58	0.41	0.32	-0.69
Toongabbie	3199	TOONGABBIE_CK	11167	UPRC	25.781	1843.5	18.49	449.6	18.19	406.4	17.57	330.4	16.899	259.5	24.39	19.68	18.67	18.22	17.32	18.99	-1.39	1.19	0.49	0.65	0.42	0.50	-0.70
Toongabbie	3200	TOONGABBIE_CK	11292	UPRC	25.564	1839.2	18.181	449.7	17.89	406.6	17.308	330.5	16.661	259.4	24.34	19.56	18.58	18.15	17.28	18.88	-1.22	1.38	0.69	0.84	0.62	0.70	-0.68
Toongabbie	1768	HAMMERS_RD	11326.4	UPRC	25.492	300.0	18.136	0.2	17.86	0.2	17.285	0.2	16.648	0.2	24.12	19.49	18.53	18.10	17.24	18.83	-1.37	1.36	0.67	0.81	0.59	0.69	-0.67
Toongabbie	3201	TOONGABBIE_CK	11326.4	UPRC	25.492	1838.7	18.136	450.0	17.86	406.8	17.285	330.6	16.648	259.6	24.22	19.53	18.56	18.13	17.26	18.86	-1.28	1.40	0.70	0.84	0.61	0.72	-0.67
Toongabbie	1769	HAMMERS_RD	11349.2	UPRC	23.904	300.0	18.05	0.2	17.77	0.2	17.213	0.2	16.584	0.1	24.09	19.52	18.56	18.13	17.26	18.86	0.19	1.47	0.78	0.91	0.68	0.81	-0.67
Toongabbie	3202	TOONGABBIE_CK	11349.2	UPRC	23.904	1837.6	18.05	450.0	17.77	406.8	17.213	330.6	16.584	259.5	24.09	19.52	18.56	18.13	17.26	18.86	0.19	1.47	0.78	0.91	0.68	0.81	-0.67
Toongabbie	3203	TOONGABBIE_CK	11365.1	UPRC	23.881	1837.3	17.972	450.1	17.70	406.9	17.143	330.7	16.514	259.6	23.87	19.46	18.50	18.07	17.22	18.80	-0.01	1.49	0.80	0.93	0.70	0.83	-0.66
Toongabbie	3204	TOONGABBIE_CK	11399.5	UPRC	23.971	1836.5	18.039	450.1	17.76	406.9	17.177	330.7	16.526	259.6	23.76	19.44	18.48	18.06	17.20	18.78	-0.21	1.40	0.72	0.88	0.68	0.74	-0.66
Toongabbie	3205	TOONGABBIE_CK	11435.4	UPRC	23.831	1835.8	17.931	450.2	17.65	407.0	17.088	330.7	16.46	259.6	23.75	19.45	18.49	18.06	17.21	18.79	-0.08	1.52	0.84	0.98	0.75	0.86	-0.66
Toongabbie	3206	TOONGABBIE_CK	11517.4	UPRC	23.845	1833.7	17.756	450.3	17.48	407.1	16.919	330.8	16.273	259.6	23.73	19.38	18.43	18.00	17.15	18.72	-0.11	1.63	0.94	1.08	0.88	0.97	-0.66
Toongabbie	3207	TOONGABBIE_CK	11595	UPRC	23.66	1832.2	17.579	450.5	17.31	407.3	16.772	330.9	16.144	259.7	23.73	19.34	18.39	17.97	17.13	18.68	0.07	1.76	1.07	1.19	0.98	1.10	-0.66
Toongabbie	3208	TOONGABBIE_CK	11690	UPRC	23.495	1830.7	17.374	450.7	17.12	407.5	16.577	331.0	15.958	259.8	23.69	19.27	18.33	17.91	17.08	18.62	0.19	1.90	1.21	1.33	1.12	1.25	-0.65
Toongabbie	3209	TOONGABBIE_CK	11840	UPRC	23.335	1828.9	17.072	450.9	16.80	407.7	16.24	331.1	15.6	259.9	23.28	19.08	18.18	17.79	16.99	18.46	-0.05	2.01	1.38	1.55	1.39	1.39	-0.62
Toongabbie	3210	TOONGABBIE_CK	11925.7	UPRC	23.221	1827.9	16.878	451.2	16.61	407.9	16.05	331.2	15.462	260.0	23.28	19.07	18.17	17.78	16.98	18.45	0.05	2.19	1.56	1.73	1.52	1.57	-0.62
Toongabbie	3211	TOONGABBIE_CK	12000	UPRC	23.218	1827.2	16.737	451.3	16.46	408.0	15.891	331.3	15.304	260.3	23.23	19.02	18.13	17.74	16.94	18.41	0.01	2.29	1.67	1.85	1.64	1.67	-0.62
Toongabbie	3212	TOONGABBIE_CK	12070	UPRC	23.074	1826.6	16.436	451.4	16.19	408.1	15.654	331.4	15.11	260.9	23.03	18.94	18.06	17.67	16.89	18.33	-0.04	2.50	1.87	2.01	1.78	1.89	-0.61
Toongabbie	2401	OLD_WINDSOR_RD	12101	UPRC	22.852	389.1	16.328	7.3	16.06	5.5	15.504	11.1	14.964	4.6	22.92	18.80	17.95	17.57	16.80	18.21	0.07	2.47	1.88	2.06	1.84	1.88	-0.59
Toongabbie	3213	TOONGABBIE_CK	12101	UPRC	22.852	1826.5	16.328	451.6	16.06	408.3	15.504	331.5	14.964	264.4	22.92	18.80	17.95	17.57	16.80	18.21	0.07	2.47	1.88	2.06	1.84	1.88	-0.59
Toongabbie	2402	OLD_WINDSOR_RD	12142	UPRC	21.134	389.1	16.046	6.5	15.77	10.9	15.235	10.1	14.712	10.1	21.37	16.09	14.99	14.61	13.72	15.34	0.24	0.04	-0.78	-0.63	-1.00	-0.71	-0.75
Toongabbie	3214	TOONGABBIE_CK	12142	UPRC	21.134	1825.9	16.046	451.7	15.77	408.3	15.235	331.5	14.712	290.7	21.37	16.09	14.99	14.61	13.72	15.34	0.24	0.04	-0.78	-0.63	-1.00	-0.71	-0.75
Toongabbie	3215	TOONGABBIE_CK	12149.7	UPRC	21.359	1825.8	16.145	451.7	15.85	408.3	15.302	331.5	14.784	292.4	21.07	16.00	15.15	14.84	14.13	15.41	-0.29	-0.14	-0.70	-0.46	-0.66	-0.74	-0.60
Toongabbie	2344	NWTWAY_PATHWA	12159.7	UPRC	21.455	614.6	16.225	6.1	15.93	12.6	15.348	5.4	14.85	7.7	21.30	16.48	15.61	15.27	14.48	15.89	-0.16	0.26	-0.32	-0.08	-0.37	-0.34	-0.59
Toongabbie	3216	TOONGABBIE_CK	12159.7	UPRC	21.455	1825.7	16.225	451.7	15.93	408.3	15.348	331.5	14.85	297.9	21.30	16.48	15.61	15.27	14.48	15.89	-0.16	0.26	-0.32	-0.08	-0.37	-0.34	-0.59
Toongabbie	2345	NWTWAY_PATHWA	12168.2	UPRC	20.86	609.6	16.143	3.9	15.86	5.6	15.281	5.7	14.808	4.2	20.81	16.31	15.43	15.10	14.32	15.71	-0.05	0.17	-0.43	-0.18	-0.48	-0.43	-0.60
Toongabbie	3217	TOONGABBIE_CK	12168.2	UPRC	20.86	1793.4	16.143	451.7	15.86	408.4	15.281	331.5	14.808	302.1	20.81	16.31	15.43	15.10	14.32	15.71	-0.05	0.17	-0.43	-0.18	-0.48	-0.43	-0.60
Toongabbie	3218	TOONGABBIE_CK	12219.9	UPRC	20.978	1792.4	16.17	451.9	15.86	408.6	15.221	331.6	14.627	262.0	20.77	16.20	15.47	15.19	14.47	15.70	-0.21	0.03	-0.39	-0.03	-0.16	-0.47	-0.50
Toongabbie	3219	TOONGABBIE_CK	12321	UPRC	20.815	1788.7	15.922	452.2	15.64	408.8	15.066	331.8	14.534	260.5	20.50	16.35	15.49	15.15	14.39	15.76	-0.31	0.43	-0.15	0.09	-0.15	-0.16	-0.59
Toongabbie	3220	TOONGABBIE_CK	12423	UPRC	20.649	1783.8	15.761	452.6	15.47	409.1	14.874	332.0	14.353	262.3	20.23	16.16	15.27	14.96	14.20	15.55	-0.42	0.40	-0.20	0.08	-0.15	-0.21	-0.61
Toongabbie	3221	TOONGABBIE_CK	12518	UPRC	20.685	1779.0	15.702	452.9	15.41	409.4	14.816	332.1	14.29	260.8	20.10	16.04	15.13	14.81	14.01	15.41	-0.59	0.34	-0.28	0.00	-0.28	-0.29	-0.63
Toongabbie	3222	TOONGABBIE_CK	12582	UPRC	20.638	1776.4	15.489	453.2	15.19	409.6	14.6	332.3	14.09	260.9	20.03	15.91	14.97	14.66	13.88	15.26	-0.61	0.42	-0.22	0.06	-0.21	-0.23	-0.64
Toongabbie	3223	TOONGABBIE_CK	12646	UPRC	20.559	1777.3	15.289	453.4	14.99	409.8	14.4	332.4	13.893	260.9	20.03	15.56	14.53	14.29	13.68	14.84	-0.53	0.27	-0.46	-0.11	-0.21	-0.45	-0.72
Toongabbie	3224	TOONGABBIE_CK	12696	UPRC	20.471	1778.4	15.288	453.7	14.98	410.0	14.372	332.5	13.868	261.0	20.05	15.48	14.51	14.29	13.67	14.80	-0.42	0.19	-0.47	-0.08	-0.20	-0.48	-0.67
Toongabbie	3225	TOONGABBIE_CK	12749	UPRC	20.285	1778.6	15.057	453.8	14.75	410.2	14.123	332.6	13.635	261.3	20.07	15.45	14.34	14.15	13.57	14.70	-0.22	0.39	-0.41	0.02	-0.07	-0.35	-0.75
Toongabbie	3226	TOONGABBIE_CK	12824	UPRC	20.027	1778.5	15.056	454.0	14.75	410.3	14.159	332.6	13.695	261.8	20.06	15.46	14.39	14.20	13.61	14.74	0.04	0.41	-0.36	0.04	-0.08	-0.32	-0.73
Toongabbie	3227	TOONGABBIE_CK	12885	UPRC	20.155	1526.6	15.045	425.1	14.73	393.4	14.103	326.8	13.619	260.5	20.06	15.33	14.20	14.02	13.44	14.55	-0.09	0.28	-0.53	-0.08	-0.18	-0.50	-0.78
Toongabbie	3228	TOONGABBIE_CK	12946	UPRC	19.805	1512.9	14.864	425.3	14.55	393.5	13.932	326.9	13.483	260.6	20.08	15.21	14.18	13.98	13.43	14.47	0.27	0.34	-0.37	0.04	-0.05	-0.39	-0.73
Toongabbie	3229	TOONGABBIE_CK	13028	UPRC	19.834	604.5	14.824	326.6	14.48	295.6	13.812	243.3	13.356	190.1	19.93	15.13	14.01	13.78	13.20	14.34	0.10	0.31	-0.47	-0.03	-0.15	-0.48	-0.78
Toongabbie	487	BRIENS_RD_TC	13081	UPRC	19.823	238.2	14.753	0.8	14.42	0.5	13.737	1.1	13.281	0.2	19.84	14.87	13.65	13.39	12.79	14.04	0.01	0.11	-0.77	-0.35	-0.50	-0.72	-0.83
Toongabbie	3230	TOONGABBIE_CK	13081	UPRC	19.823	595.7	14.753	326.7	14.42	295.8	13.737	243.4	13.281	190.2	19.84	14.87	13.65	13.39	12.79	14.04	0.01	0.11	-0.77	-0.35	-0.50	-0.72	-0.83
Toongabbie	488	BRIENS_RD_TC	13105	UPRC	19.467	237.4	14.433	0.4	14.09	0.3	13.393	1.1	12.697	0.1	19.81	14.73	13.44	13.15	12.41	13.87	0.35	0.29	-0.66	-0.25	-0.29	-0.56	-0.86
Toongabbie	3231	TOONGABBIE_CK	13105	UPRC	19.467	593.0	14.433	326.8	14.09	295.9	13.393	243.4	12.697	190.2	19.81	14.73	13.44	13.15	12.41	13.87	0.35	0.29	-0.66	-0.25	-0.29	-0.56	-0.86
Toongabbie	3232	TOONGABBIE_CK	13140	UPRC	19.461	591.8	14.362	327.1	14.01	296.1	13.308	243.6	12.578	190.4	19.85	14.60	13.28	12.99	12.13	13.73	0.39	0.24	-0.74	-0.32	-0.45	-0.63	-0.87
Toongabbie	3233	TOONGABBIE_CK	13191	UPRC	19.476	1541.7	14.435	512.0	14.08	464.3	13.373	371.3	12.648	291.5	19.85	14.65	13.47	13.19	12.37	13.89	0.37	0.22	-0.61	-0.18	-0.28	-0.55	-0.77
Toongabbie	2341	NWTWAY_MONS	13249	UPRC	19.412	220.5	14.346	1.2	13.99	16.6	13.254	0.4	12.524	0.2	19.75	14.26	13.10	12.84	12.10	13.51	0.34	-0.09	-0.89	-0.42	-0.43	-0.84	-0.75
Toongabbie	3234	TOONGABBIE_CK	13249	UPRC	19.412	1541.9	14.346	512.4	13.99	464.6	13.254	371.5	12.524	291.7	19.75	14.26	13.10	12.84	12.10	13.51	0.34	-0.09	-0.89	-0.42	-0.43	-0.84	-0.75
Toongabbie	2342	NWTWAY_MONS	13273.5	UPRC	18.967	220.6	0	0.0	0.00	0.0	0	0.0	0	0.0	19.55	14.24	12.99	12.71	11.96	13.42							
Toongabbie	2343	NWTWAY_MONS	13302	UPRC	18.662	152.7	14.317	1.0	13.96	19.7	13.246	0.9	12.506	0.3	19.62	14.33	13.10	12.84	12.07	13.52	0.96	0.01	-0.86	-0.41	-0.44	-0.80	-0.81
Toongabbie	3235	TOONGABBIE_CK	13302	UPRC	18.662	1474.2	14.317	512.4	13.96	464.7	13.246	371.5	12.506	291.7	19.62	14.33	13.10	12.84	12.07	13.52	0.96	0.01	-0.86	-0.41	-0.44	-0.80	-0.81
Toongabbie	3236	TOONGABBIE_CK	13356	UPRC	18.607	1474.0	14.242	512.5	13.89	464.8	13.157	371.6	12.413	291.6	19.57	14.17	13.01	12.74	11.98	13.40	0.97	-0.07	-0.88	-0.41	-0.43	-0.84	-0.77
Toongabbie	3237	TOONGABBIE_CK	13472	UPRC	18.284	1472.8	13.795	512.7	13.43	464.9	12.693	371.6	11.968	291.6	19.49	13.56	12.42	12.18	11.53	12.79	1.21	-0.23	-1.01	-0.51	-0.44	-1.00	-0.77
Toongabbie	3238	TOONGABBIE_CK	13564	UPRC	18.03	1473.5	13.499	512.9	13.13	465.0	12.412	371.7	11.678	291.7	19.31	13.41	12.45	12.24	11.63	12.78	1.28	-0.09	-0.68	-0.17	-0.05	-0.72	-0.64

Field1	Id	Branch	Chainage	Topo_ID	MIKE 11 FLOW (m^3/s) and Peak Water Surface Level (m AHD) WSL PMF	Q PMF	WSL 1% AEP	Q 1% AEP	WSL 2% AEP	Q 2% AEP	WSL 5% AEP	Q 5% AEP	WSL 20% AEP	Q 20% AEP
Toongabbie	3239	TOONGABBIE_CK	13627	UPRC	17.921	1784.8	13.188	513.1	12.85	465.2	12.178	371.8	11.483	291.7
Toongabbie	3240	TOONGABBIE_CK	13697	UPRC	17.842	1785.4	12.96	513.2	12.60	465.3	11.965	371.9	11.317	291.8
Toongabbie	3241	TOONGABBIE_CK	13772	UPRC	17.903	1788.5	13.032	514.2	12.66	466.2	11.971	372.5	11.287	292.1
Toongabbie	3242	TOONGABBIE_CK	13882	UPRC	17.701	1790.3	12.873	515.0	12.50	466.9	11.779	373.0	11.069	292.4
Toongabbie	3243	TOONGABBIE_CK	13958.6	UPRC	17.689	1790.7	12.902	515.4	12.53	467.2	11.815	373.2	11.118	292.5
Toongabbie	3244	TOONGABBIE_CK	14011	UPRC	17.562	1791.3	12.749	515.8	12.37	467.5	11.681	373.4	11.026	292.6
Toongabbie	3245	TOONGABBIE_CK	14077	UPRC	17.397	1793.4	12.591	516.3	12.21	467.9	11.531	373.6	10.907	292.8
Toongabbie	3246	TOONGABBIE_CK	14180	UPRC	17.452	1971.5	12.566	517.0	12.17	468.5	11.444	374.0	10.719	293.1
Toongabbie	2765	REDBANK_RD	14215	UPRC	17.497	1771.4	12.552	4.9	12.15	0.2	11.418	0.8	10.686	0.2
Toongabbie	3247	TOONGABBIE_CK	14215	UPRC	17.497	1989.9	12.552	517.2	12.15	468.6	11.418	374.1	10.686	293.1
Toongabbie	2766	REDBANK_RD	14222	UPRC	17.292	1783.3	12.524	4.9	12.21	0.0	12.21	0.0	12.21	0.0
Toongabbie	2767	REDBANK_RD	14229	UPRC	17.311	1792.9	12.512	4.9	12.21	0.0	12.21	0.0	12.21	0.0
Toongabbie	2768	REDBANK_RD	14238	UPRC	17.217	1782.2	11.961	4.9	11.69	0.3	11.041	1.0	10.36	0.3
Toongabbie	3248	TOONGABBIE_CK	14238	UPRC	17.217	1996.6	11.961	517.3	11.69	468.7	11.041	374.2	10.36	293.1
Toongabbie	3249	TOONGABBIE_CK	14306	UPRC	17.16	1954.5	11.761	517.6	11.48	469.0	10.789	374.3	10.149	293.2
Toongabbie	3250	TOONGABBIE_CK	14386	UPRC	17.101	1955.1	11.674	518.1	11.39	469.4	10.726	374.6	10.07	293.4
Toongabbie	3251	TOONGABBIE_CK	14516	UPRC	16.804	1955.1	11.195	518.7	10.89	469.9	10.261	374.9	9.667	293.6
Toongabbie	3252	TOONGABBIE_CK	14626	UPRC	16.911	1955.8	11.279	519.6	10.99	470.6	10.35	375.4	9.736	293.9
Parramatta	2413	PARRAMATTA_R	5.2	UPRC	16.911	2826.0	11.279	718.0	10.99	651.6	10.35	521.2	9.736	409.6
Parramatta	2414	PARRAMATTA_R	80.9	UPRC	16.888	2826.5	11.162	718.1	10.87	651.6	10.259	521.3	9.671	409.6
Parramatta	2415	PARRAMATTA_R	170.8	UPRC	16.634	2855.2	10.903	718.4	10.64	651.8	10.079	521.4	9.531	409.7
Parramatta	2416	PARRAMATTA_R	259.3	UPRC	16.595	2854.4	10.92	718.7	10.65	652.0	10.086	521.6	9.533	409.8
Parramatta	1818	HOSPITAL_OBR	370.9	UPRC	16.657	2044.9	10.802	11.6	10.54	7.1	9.97	0.6	9.426	11.6
Parramatta	2417	PARRAMATTA_R	370.9	UPRC	16.657	2852.7	10.802	719.0	10.54	652.3	9.97	521.8	9.426	409.9
Parramatta	1819	HOSPITAL_OBR	392.3	UPRC	16.087	2044.7	10.656	13.0	10.41	8.6	9.874	0.2	9.362	13.0
Parramatta	2418	PARRAMATTA_R	392.3	UPRC	16.087	2851.6	10.656	719.1	10.41	652.4	9.874	521.8	9.362	409.9
Parramatta	2419	PARRAMATTA_R	490	UPRC	15.809	2851.1	10.614	719.4	10.37	652.7	9.83	522.0	9.315	410.0
Parramatta	2420	PARRAMATTA_R	625	UPRC	15.989	2866.2	10.628	731.1	10.38	663.1	9.843	529.1	9.328	415.2
Parramatta	2421	PARRAMATTA_R	713	UPRC	15.958	2866.2	10.461	731.2	10.22	663.1	9.699	529.1	9.202	415.2
Parramatta	2422	PARRAMATTA_R	729	UPRC	13.226	2593.7	8.36	731.4	8.20	663.3	7.84	529.3	7.508	415.3
Parramatta	2423	PARRAMATTA_R	780	UPRC	13.271	2594.7	8.407	731.5	8.25	663.4	7.914	529.3	7.592	415.3
Parramatta	2424	PARRAMATTA_R	846	UPRC	13.24	2740.0	8.276	731.7	8.12	663.6	7.787	529.4	7.474	415.4
Parramatta	2425	PARRAMATTA_R	905	UPRC	13.113	3021.4	8.327	732.3	8.17	664.2	7.822	529.8	7.501	415.6
Parramatta	2426	PARRAMATTA_R	927	UPRC	12.836	2881.8	8.015	734.3	7.58	666.0	6.938	530.9	6.53	416.4
Parramatta	2427	PARRAMATTA_R	1021	UPRC	12.882	2872.4	8.008	733.5	7.57	665.6	6.922	531.0	6.509	416.4
Parramatta	2428	PARRAMATTA_R	1173	UPRC	12.808	2864.5	7.97	732.2	7.52	665.0	6.879	531.2	6.494	416.5
Parramatta	2429	PARRAMATTA_R	1303	UPRC	12.645	2863.4	7.874	731.6	7.44	664.8	6.832	531.4	6.458	416.6
Parramatta	2430	PARRAMATTA_R	1425	UPRC	12.672	2860.1	7.785	731.4	7.34	664.8	6.726	531.6	6.369	416.7
Parramatta	2431	PARRAMATTA_R	1583	UPRC	12.79	2859.3	7.792	730.2	7.30	664.4	6.59	531.8	6.251	416.8
Parramatta	2432	PARRAMATTA_R	1733	UPRC	12.692	2858.2	7.77	728.9	7.27	663.8	6.552	532.0	6.186	416.9
Parramatta	2433	PARRAMATTA_R	1844	UPRC	12.671	2856.7	7.771	728.2	7.29	663.7	6.601	532.2	6.252	417.0
Parramatta	2434	PARRAMATTA_R	1935	UPRC	12.744	2854.6	7.796	729.0	7.30	664.8	6.593	533.3	6.24	417.8
Parramatta	2362	OCONNELL_OBR	1976	UPRC	12.778	1941.2	7.8	0.1	7.30	0.2	6.606	0.1	6.252	0.1
Parramatta	2435	PARRAMATTA_R	1976	UPRC	12.778	2340.9	7.8	728.7	7.30	664.8	6.606	533.3	6.252	417.8
Parramatta	2363	OCONNELL_OBR	1980	UPRC	12.705	1942.4	0	0.0	0.00	0.0	0	0.0	0	0.0
Parramatta	2364	OCONNELL_OBR	2004	UPRC	12.706	1949.2	8.209	0.2	8.19	0.0	8.191	0.0	0	0.0
Parramatta	2365	OCONNELL_OBR	2012	UPRC	12.676	1869.6	7.628	0.1	7.19	0.1	6.516	0.1	6.194	0.1
Parramatta	2436	PARRAMATTA_R	2012	UPRC	12.676	2265.7	7.628	728.6	7.19	664.7	6.516	533.3	6.194	417.9
Parramatta	2437	PARRAMATTA_R	2060.7	UPRC	12.626	2252.3	7.631	728.8	7.19	664.9	6.513	533.5	6.191	418.0
Parramatta	2438	PARRAMATTA_R	2121.3	UPRC	12.616	2062.3	7.577	728.8	7.12	665.0	6.44	533.6	6.132	418.0
Parramatta	2439	PARRAMATTA_R	2186.3	UPRC	12.641	2062.8	7.595	728.8	7.14	665.1	6.442	533.7	6.128	418.1
Parramatta	2114	MARSDEN_O_BR	2211	UPRC	12.55	1212.6	7.572	0.3	7.09	0.3	6.156	0.0	5.365	0.1
Parramatta	2440	PARRAMATTA_R	2211	UPRC	12.55	2071.5	7.572	729.1	7.09	665.3	6.156	533.8	5.365	418.2
Parramatta	2116	MARSDEN_O_BR	2227	UPRC	12.384	580.4	7.477	0.5	6.99	0.8	6.058	0.3	5.274	0.3
Parramatta	2441	PARRAMATTA_R	2227	UPRC	12.384	968.8	7.477	730.5	6.99	666.6	6.058	534.7	5.274	418.7
Parramatta	2442	PARRAMATTA_R	2250	UPRC	12.347	1371.1	7.361	730.5	6.87	666.6	5.931	534.7	5.15	418.7
Parramatta	2443	PARRAMATTA_R	2287.9	UPRC	12.32	1367.4	7.342	730.5	6.84	666.6	5.901	534.7	5.139	418.7
Parramatta	2444	PARRAMATTA_R	2323.7	UPRC	12.191	1234.6	7.271	730.6	6.78	666.6	5.853	534.7	5.079	418.7
Parramatta	2034	LENNOX_BR_OR	2341.9	UPRC	12.184	223.7	7.245	0.2	6.75	0.2	5.817	0.2	5.036	0.1
Parramatta	2445	PARRAMATTA_R	2341.9	UPRC	12.184	1231.7	7.245	730.6	6.75	666.6	5.817	534.7	5.036	418.7
Parramatta	2035	LENNOX_BR_OR	2358.4	UPRC	12.114	642.8	8.503	0.0	8.50	0.0	8.502	0.0	8.502	0.0
Parramatta	2036	LENNOX_BR_OR	2373.3	UPRC	9.852	638.5	5.76	0.1	5.55	0.1	5.093	0.1	4.649	0.1
Parramatta	2446	PARRAMATTA_R	2373.3	UPRC	9.852	1620.6	5.76	730.9	5.55	667.0	5.093	535.0	4.649	418.8
Parramatta	2447	PARRAMATTA_R	2387.8	UPRC	9.827	1620.5	5.727	730.9	5.52	667.0	5.065	535.0	4.622	418.8
Parramatta	2448	PARRAMATTA_R	2420	UPRC	9.845	1619.9	5.746	731.0	5.54	667.0	5.082	535.0	4.64	418.8
Parramatta	2449	PARRAMATTA_R	2467	UPRC	10.095	1892.9	5.822	731.8	5.60	667.7	5.124	535.4	4.665	419.0

Id	TUFLOW PEAK WATER LEVEL (m AHD) PMF	FFA 1% AEP	2% AEP	5% AEP	20% AEP	ARR87 1% AEP
3239	19.20	12.81	11.98	11.82	11.36	12.24
3240	19.15	13.01	12.08	11.89	11.35	12.38
3241	19.14	13.02	12.11	11.92	11.38	12.41
3242	19.05	12.91	11.90	11.70	11.10	12.24
3243	19.02	12.85	11.77	11.53	10.79	12.14
3244	18.88	12.63	11.59	11.39	10.79	11.93
3245	18.74	12.43	11.46	11.28	10.76	11.76
3246	18.73	12.38	11.36	11.14	10.51	11.69
2765	18.75	12.31	11.18	10.96	10.28	11.54
3247	18.75	12.31	11.18	10.96	10.28	11.54
2766	18.60	12.12	11.11	10.89	10.19	11.46
2767	18.56	12.05	11.07	10.85	10.16	11.43
2768	18.67	12.11	11.01	10.78	10.09	11.37
3248	18.67	12.11	11.01	10.78	10.09	11.37
3249	18.61	11.87	10.62	10.37	9.64	11.04
3250	18.48	11.63	10.45	10.22	9.50	10.85
3251	18.51	11.71	10.50	10.26	9.53	10.91
3252	18.53	11.75	10.54	10.30	9.51	10.96
2413	18.53	11.75	10.54	10.30	9.51	10.96
2414	18.41	11.35	10.22	9.99	9.26	10.62
2415	17.97	10.75	9.66	9.43	8.72	10.05
2416	17.45	10.15	9.35	9.20	8.65	9.64
1818	17.51	10.13	9.39	9.24	8.69	9.66
2417	17.51	10.13	9.39	9.24	8.69	9.66
1819	16.32	10.16	9.39	9.23	8.67	9.67
2418	16.32	10.16	9.39	9.23	8.67	9.67
2419	16.34	10.01	9.26	9.11	8.58	9.54
2420	16.14	9.85	9.12	8.97	8.45	9.39
2421	15.99	9.99	9.21	9.05	8.51	9.49
2422	15.96	8.39	6.31	6.36	6.30	6.35
2423	15.80	8.58	7.18	7.09	6.71	7.57
2424	15.65	8.63	7.40	7.28	6.83	7.77
2425	15.50	8.76	7.55	7.43	6.91	7.90
2426	15.49	8.77	7.32	7.16	6.56	7.78
2427	15.37	8.62	7.24	7.06	6.46	7.68
2428	15.25	8.56	7.19	7.02	6.45	7.63
2429	15.18	8.49	7.14	6.98	6.42	7.57
2430	15.19	8.46	7.11	6.95	6.41	7.54
2431	15.02	8.38	6.90	6.74	6.25	7.35
2432	14.73	8.26	6.77	6.62	6.15	7.23
2433	14.68	8.23	6.75	6.60	6.14	7.21
2434	14.68	8.20	6.74	6.59	6.14	7.19
2362	14.79	8.10	6.67	6.52	6.08	7.11
2435	14.79	8.10	6.67	6.52	6.08	7.11
2363	14.57	7.98	6.62	6.48	6.06	7.06
2364	14.49	7.88	6.65	6.51	6.08	7.08
2365	14.63	7.96	6.67	6.53	6.09	7.10
2436	14.63	7.96	6.67	6.53	6.09	7.10
2437	14.62	7.89	6.65	6.51	6.07	7.08
2438	14.57	7.92	6.68	6.54	6.10	7.11
2439	14.65	8.04	6.81	6.66	6.18	7.24
2114	14.62	7.91	6.39	6.12	5.21	7.01
2440	14.62	7.91	6.39	6.12	5.21	7.01
2116	14.38	7.80	6.36	6.10	5.20	6.96
2441	14.38	7.80	6.36	6.10	5.20	6.96
2442	14.31	7.72	6.26	6.01	5.12	6.85
2443	14.21	7.62	6.15	5.91	5.04	6.74
2444	14.02	7.45	6.02	5.78	4.95	6.61
2034	13.89	6.86	5.61	5.41	4.72	6.12
2445	13.89	6.86	5.61	5.41	4.72	6.12
2035	12.56	5.61	5.15	5.04	4.56	5.37
2036	12.82	5.53	5.00	4.90	4.46	5.25
2446	12.82	5.53	5.00	4.90	4.46	5.25
2447	12.57	5.51	4.96	4.86	4.43	5.22
2448	12.42	5.54	4.99	4.89	4.46	5.25
2449	12.39	5.56	5.02	4.92	4.51	5.27

Id	Peak Water Level Difference (m) (TUFLOW - MIKE11) PMF	1% AEP	2% AEP	5% AEP	20% AEP	ARR87 1% AEP	TUFLOW ARR87 - ARR2016 1% AEP
3239	1.28	-0.38	-0.87	-0.36	-0.12	-0.94	-0.56
3240	1.31	0.05	-0.52	-0.07	0.03	-0.58	-0.62
3241	1.24	-0.01	-0.55	-0.05	0.09	-0.62	-0.61
3242	1.35	0.04	-0.59	-0.08	0.03	-0.64	-0.67
3243	1.33	-0.05	-0.76	-0.29	-0.32	-0.76	-0.71
3244	1.32	-0.12	-0.78	-0.29	-0.23	-0.81	-0.69
3245	1.34	-0.16	-0.75	-0.25	-0.15	-0.84	-0.67
3246	1.28	-0.18	-0.82	-0.30	-0.21	-0.88	-0.69
2765	1.25	-0.24	-0.97	-0.46	-0.41	-1.02	-0.78
3247	1.25	-0.24	-0.97	-0.46	-0.41	-1.02	-0.78
2766	1.31	-0.40	-1.10	-1.32	-2.02	-1.06	-0.66
2767	1.25	-0.46	-1.14	-1.36	-2.05	-1.09	-0.62
2768	1.45	0.14	-0.68	-0.26	-0.27	-0.59	-0.73
3248	1.45	0.14	-0.68	-0.26	-0.27	-0.59	-0.73
3249	1.45	0.11	-0.85	-0.41	-0.51	-0.72	-0.83
3250	1.38	-0.05	-0.94	-0.51	-0.57	-0.83	-0.78
3251	1.70	0.51	-0.39	0.00	-0.14	-0.28	-0.79
3252	1.62	0.47	-0.44	-0.05	-0.23	-0.32	-0.78
2413	1.62	0.47	-0.44	-0.05	-0.23	-0.32	-0.78
2414	1.53	0.19	-0.65	-0.26	-0.41	-0.54	-0.73
2415	1.33	-0.16	-0.98	-0.64	-0.81	-0.86	-0.70
2416	0.86	-0.77	-1.30	-0.89	-0.88	-1.28	-0.51
1818	0.85	-0.67	-1.15	-0.73	-0.74	-1.14	-0.47
2417	0.85	-0.67	-1.15	-0.73	-0.74	-1.14	-0.47
1819	0.24	-0.49	-1.02	-0.64	-0.69	-0.99	-0.49
2418	0.24	-0.49	-1.02	-0.64	-0.69	-0.99	-0.49
2419	0.53	-0.60	-1.10	-0.72	-0.74	-1.07	-0.47
2420	0.15	-0.78	-1.26	-0.87	-0.88	-1.24	-0.46
2421	0.03	-0.47	-1.01	-0.64	-0.69	-0.97	-0.50
2422	2.74	0.03	-1.89	-1.48	-1.20	-2.01	-2.04
2423	2.53	0.18	-1.07	-0.82	-0.88	-0.83	-1.01
2424	2.41	0.35	-0.72	-0.50	-0.64	-0.51	-0.86
2425	2.38	0.43	-0.62	-0.39	-0.59	-0.42	-0.86
2426	2.65	0.76	-0.26	0.22	0.03	-0.23	-0.99
2427	2.49	0.61	-0.33	0.14	-0.05	-0.32	-0.93
2428	2.44	0.59	-0.33	0.14	-0.04	-0.34	-0.93
2429	2.53	0.61	-0.30	0.15	-0.04	-0.30	-0.91
2430	2.52	0.67	-0.23	0.22	0.04	-0.25	-0.92
2431	2.23	0.59	-0.40	0.15	0.00	-0.44	-1.03
2432	2.04	0.49	-0.50	0.06	-0.04	-0.54	-1.02
2433	2.01	0.46	-0.53	0.00	-0.11	-0.56	-1.02
2434	1.94	0.40	-0.55	0.00	-0.10	-0.60	-1.01
2362	2.01	0.30	-0.63	-0.08	-0.17	-0.69	-0.99
2435	2.01	0.30	-0.63	-0.08	-0.17	-0.69	-0.99
2363							
2364	1.78	-0.33	-1.54	-1.68	6.08	-1.13	-0.79
2365	1.95	0.33	-0.52	0.01	-0.11	-0.52	-0.85
2436	1.95	0.33	-0.52	0.01	-0.11	-0.52	-0.85
2437	1.99	0.26	-0.54	0.00	-0.12	-0.55	-0.82
2438	1.96	0.35	-0.44	0.10	-0.03	-0.46	-0.81
2439	2.00	0.44	-0.32	0.22	0.05	-0.36	-0.80
2114	2.07	0.34	-0.70	-0.03	-0.15	-0.56	-0.90
2440	2.07	0.34	-0.70	-0.03	-0.15	-0.56	-0.90
2116	1.99	0.32	-0.63	0.04	-0.08	-0.52	-0.84
2441	1.99	0.32	-0.63	0.04	-0.08	-0.52	-0.84
2442	1.96	0.36	-0.61	0.08	-0.03	-0.51	-0.87
2443	1.89	0.28	-0.68	0.01	-0.10	-0.60	-0.88
2444	1.83	0.18	-0.76	-0.07	-0.13	-0.66	-0.84
2034	1.71	-0.38	-1.15	-0.41	-0.32	-1.13	-0.74
2445	1.71	-0.38	-1.15	-0.41	-0.32	-1.13	-0.74
2035							
2036	2.96	-0.23	-0.55	-0.19	-0.19	-0.51	-0.27
2446	2.96	-0.23	-0.55	-0.19	-0.19	-0.51	-0.27
2447	2.74	-0.22	-0.56	-0.20	-0.19	-0.50	-0.28
2448	2.58	-0.20	-0.55	-0.19	-0.18	-0.49	-0.29
2449	2.30	-0.26	-0.58	-0.20	-0.16	-0.55	-0.29

					MIKE 11 FLOW (m^3/s) and Peak Water Surface Level (m AHD)										TUFLOW PEAK WATER LEVEL (m AHD)						Peak Water Level Difference (m) (TUFLOW - MIKE11)						TUFLOW ARR87 - ARR2016
Field1	Id	Branch	Chainage	Topo_ID	WSL PMF	Q PMF	WSL 1% AEP	Q 1% AEP	WSL 2% AEP	Q 2% AEP	WSL 5% AEP	Q 5% AEP	WSL 20% AEP	Q 20% AEP	PMF	FFA 1% AEP	2% AEP	5% AEP	20% AEP	ARR87 1% AEP	PMF	1% AEP	2% AEP	5% AEP	20% AEP	ARR87 1% AEP	1% AEP
Parramatta	2450	PARRAMATTA_R	2537	UPRC	10.128	1891.8	5.845	731.9	5.62	667.8	5.132	535.5	4.654	419.0	12.45	5.76	5.21	5.09	4.59	5.48	2.32	-0.08	-0.42	-0.04	-0.06	-0.37	-0.29
Parramatta	2451	PARRAMATTA_R	2609	UPRC	10.014	1890.5	5.797	732.0	5.58	667.9	5.1	535.5	4.632	419.0	12.51	5.89	5.22	5.10	4.59	5.52	2.50	0.09	-0.36	0.00	-0.04	-0.28	-0.37
Parramatta	2452	PARRAMATTA_R	2629	UPRC	10.023	1890.4	5.809	732.1	5.59	667.9	5.105	535.5	4.635	419.1	12.54	5.43	4.94	4.85	4.39	5.19	2.52	-0.38	-0.65	-0.26	-0.25	-0.61	-0.24
Parramatta	2453	PARRAMATTA_R	2652	UPRC	9.469	1890.2	5.733	732.2	5.52	668.0	5.039	535.6	4.572	419.1	11.87	5.56	4.98	4.88	4.38	5.26	2.40	-0.18	-0.54	-0.16	-0.19	-0.48	-0.30
Parramatta	2454	PARRAMATTA_R	2701	UPRC	9.507	2057.9	5.744	746.9	5.53	680.3	5.043	543.9	4.572	424.4	12.09	5.63	5.02	4.91	4.36	5.31	2.58	-0.11	-0.50	-0.13	-0.21	-0.44	-0.33
Parramatta	2455	PARRAMATTA_R	2781	UPRC	9.29	2143.9	5.609	747.0	5.40	680.4	4.939	544.0	4.49	424.5	12.12	5.60	4.96	4.84	4.30	5.25	2.83	-0.01	-0.44	-0.10	-0.19	-0.36	-0.35
Parramatta	2456	PARRAMATTA_R	2879	UPRC	9.13	2142.2	5.57	847.3	5.41	788.0	5.159	697.2	4.859	597.4	11.37	5.40	4.80	4.69	4.19	5.06	2.24	-0.17	-0.61	-0.47	-0.67	-0.51	-0.34
Parramatta	708	CHARLES_ST_WR	2935	UPRC	9.207	2133.5	5.677	847.3	5.50	787.0	5.244	697.1	4.929	597.3	11.34	5.61	4.96	4.84	4.31	5.25	2.14	-0.07	-0.54	-0.41	-0.62	-0.43	-0.36
Parramatta	2457	PARRAMATTA_R	2935	UPRC	9.207	2146.4	5.677	27.4	5.50	27.4	5.244	27.3	4.929	27.0	11.34	5.61	4.96	4.84	4.31	5.25	2.14	-0.07	-0.54	-0.41	-0.62	-0.43	-0.36
Parramatta	709	CHARLES_ST_WR	2944	UPRC	9.032	2132.0	5.363	27.3	5.11	27.3	4.711	27.1	4.228	26.9	11.16	4.62	3.42	3.27	2.42	4.08	2.13	-0.74	-1.68	-1.44	-1.81	-1.28	-0.54
Parramatta	2458	PARRAMATTA_R	2944	UPRC	9.032	2143.4	5.363	847.2	5.11	787.1	4.711	697.1	4.228	597.3	11.16	4.62	3.42	3.27	2.42	4.08	2.13	-0.74	-1.68	-1.44	-1.81	-1.28	-0.54
Parramatta	2459	PARRAMATTA_R	2978	UPRC	9.142	2140.8	5.42	847.4	5.16	787.8	4.766	696.9	4.277	597.0	11.49	4.90	3.65	3.51	2.71	4.32	2.35	-0.52	-1.51	-1.26	-1.56	-1.10	-0.58
Parramatta	2460	PARRAMATTA_R	2979	LPRC	9.142	2463.6	5.22	847.5	4.97	788.1	4.6	696.7	4.133	596.8	11.49	4.90	3.65	3.51	2.71	4.32	2.35	-0.32	-1.32	-1.09	-1.42	-0.90	-0.58
Parramatta	2461	PARRAMATTA_R	3030	LPRC	8.953	2462.3	5.22	847.6	4.97	788.1	4.6	696.7	4.133	596.8	10.87	4.80	3.66	3.52	2.73	4.28	1.92	-0.42	-1.31	-1.08	-1.40	-0.94	-0.52
Parramatta	2462	PARRAMATTA_R	3083	LPRC	8.681	2460.4	5.346	847.8	5.09	788.6	4.696	696.3	4.208	596.4	9.79	4.53	3.49	3.36	2.61	4.07	1.11	-0.82	-1.60	-1.34	-1.60	-1.28	-0.46
Parramatta	2463	PARRAMATTA_R	3195	LPRC	9.054	2455.2	5.317	847.8	5.06	788.8	4.666	696.0	4.176	596.1	9.91	4.60	3.51	3.37	2.61	4.11	0.85	-0.72	-1.55	-1.29	-1.57	-1.21	-0.48
Parramatta	2083	MACARTHUR_BDGE	3242	LPRC	9.135	64.6	5.163	847.9	4.91	788.9	4.523	695.9	4.038	595.9	10.19	4.54	3.45	3.31	2.55	4.06	1.05	-0.62	-1.46	-1.21	-1.49	-1.11	-0.49
Parramatta	2464	PARRAMATTA_R	3242	LPRC	9.135	2649.6	5.163	848.0	4.91	788.9	4.523	695.9	4.038	595.9	10.19	4.54	3.45	3.31	2.55	4.06	1.05	-0.62	-1.46	-1.21	-1.49	-1.11	-0.49
Parramatta	2084	MACARTHUR_BDGE	3272	LPRC	8.95	64.4	5.187	848.2	4.93	788.2	4.542	695.0	4.054	594.9	9.31	4.37	3.30	3.17	2.46	3.90	0.36	-0.82	-1.63	-1.37	-1.59	-1.29	-0.47
Parramatta	2465	PARRAMATTA_R	3272	LPRC	8.95	2766.9	5.187	848.0	4.93	788.1	4.542	695.0	4.054	594.9	9.31	4.37	3.30	3.17	2.46	3.90	0.36	-0.82	-1.63	-1.37	-1.59	-1.29	-0.47
Parramatta	2466	PARRAMATTA_R	3400	LPRC	9.033	2764.8	5.156	848.5	4.90	785.1	4.508	693.7	4.016	593.6	9.38	4.34	3.28	3.16	2.46	3.88	0.34	-0.81	-1.62	-1.35	-1.55	-1.28	-0.47
Parramatta	2467	PARRAMATTA_R	3536	LPRC	9.063	2717.0	5.156	848.5	4.90	785.1	4.508	693.7	4.016	593.8	9.49	4.36	3.29	3.17	2.46	3.89	0.42	-0.80	-1.60	-1.34	-1.56	-1.27	-0.47
Parramatta	2468	PARRAMATTA_R	3636	LPRC	8.972	2615.8	5.098	849.0	4.84	785.4	4.449	693.0	3.952	593.0	9.38	4.35	3.27	3.15	2.42	3.88	0.41	-0.75	-1.57	-1.30	-1.53	-1.22	-0.47
Parramatta	2469	PARRAMATTA_R	3799	LPRC	8.815	2863.4	5.015	849.5	4.76	785.5	4.379	692.0	3.89	592.0	9.57	4.36	3.24	3.12	2.38	3.88	0.75	-0.65	-1.52	-1.26	-1.51	-1.13	-0.48
Parramatta	2470	PARRAMATTA_R	3937	LPRC	8.977	2862.3	5.017	851.5	4.76	785.3	4.372	691.3	3.874	591.4	9.55	4.32	3.16	3.03	2.29	3.82	0.57	-0.70	-1.60	-1.34	-1.58	-1.20	-0.50
Parramatta	2471	PARRAMATTA_R	4065	LPRC	9.034	2860.8	5.008	851.9	4.75	785.2	4.36	690.6	3.858	590.7	9.50	4.28	3.10	2.97	2.24	3.77	0.47	-0.73	-1.65	-1.39	-1.62	-1.24	-0.51
Parramatta	2472	PARRAMATTA_R	4185	LPRC	8.897	2771.3	4.957	855.9	4.70	786.8	4.316	690.5	3.818	590.5	9.46	4.26	3.08	2.96	2.23	3.73	0.56	-0.70	-1.62	-1.35	-1.58	-1.22	-0.52
Parramatta	2473	PARRAMATTA_R	4229	LPRC	8.705	2771.1	4.884	872.7	4.63	802.1	4.256	702.9	3.765	599.1	9.31	4.15	3.06	2.94	2.23	3.69	0.61	-0.73	-1.57	-1.31	-1.54	-1.20	-0.47
Parramatta	2474	PARRAMATTA_R	4284	LPRC	8.282	2771.5	4.753	873.0	4.51	802.4	4.144	703.1	3.663	599.2	9.22	4.05	3.00	2.88	2.18	3.62	0.94	-0.71	-1.51	-1.26	-1.48	-1.13	-0.43
Parramatta	2475	PARRAMATTA_R	4403	LPRC	8.243	2771.5	4.703	874.6	4.46	803.8	4.094	703.6	3.611	599.9	9.14	3.91	2.90	2.79	2.10	3.52	0.90	-0.79	-1.56	-1.30	-1.51	-1.18	-0.39
Parramatta	2476	PARRAMATTA_R	4544	LPRC	8.284	2771.4	4.645	884.9	4.41	813.7	4.04	711.8	3.56	606.5	9.25	4.00	2.91	2.82	2.16	3.58	0.96	-0.64	-1.50	-1.22	-1.40	-1.07	-0.42
Parramatta	2477	PARRAMATTA_R	4608	LPRC	6.53	2771.3	4.606	883.7	4.37	812.6	4.01	710.8	3.54	605.4	9.10	3.97	2.91	2.80	2.14	3.54	2.57	-0.63	-1.46	-1.21	-1.39	-1.07	-0.44
Parramatta	2478	PARRAMATTA_R	4634	LPRC	6.491	2801.7	4.644	877.9	4.40	805.8	4.04	705.4	3.56	601.2	9.10	3.91	2.88	2.77	2.11	3.50	2.61	-0.74	-1.52	-1.27	-1.44	-1.15	-0.41
Parramatta	2479	PARRAMATTA_R	4823	LPRC	6.324	2800.6	4.524	900.0	4.29	827.4	3.92	728.4	3.44	613.7	8.93	3.60	2.68	2.55	1.97	3.21	2.61	-0.93	-1.60	-1.37	-1.47	-1.32	-0.39
Parramatta	2480	PARRAMATTA_R	4987	LPRC	5.768	2799.8	4.326	900.8	4.10	828.1	3.75	728.3	3.28	613.6	8.50	3.35	2.55	2.41	1.88	3.02	2.73	-0.98	-1.55	-1.34	-1.40	-1.31	-0.33
Parramatta	2481	PARRAMATTA_R	5153	LPRC	5.495	2799.2	4.223	901.4	4.00	828.7	3.66	728.3	3.19	613.7	8.09	3.29	2.51	2.36	1.84	2.97	2.60	-0.93	-1.49	-1.30	-1.36	-1.26	-0.32
Parramatta	2482	PARRAMATTA_R	5278	LPRC	5.805	2798.5	4.229	902.0	4.00	829.2	3.65	728.3	3.18	613.8	7.97	3.26	2.49	2.33	1.81	2.94	2.17	-0.97	-1.51	-1.32	-1.37	-1.29	-0.32
Parramatta	2483	PARRAMATTA_R	5353	LPRC	5.607	2851.6	4.179	902.4	3.95	829.5	3.61	728.3	3.14	613.8	7.77	3.25	2.48	2.32	1.80	2.92	2.16	-0.93	-1.48	-1.29	-1.34	-1.25	-0.33
Parramatta	2484	PARRAMATTA_R	5490	LPRC	5.517	2850.7	4.123	975.1	3.89	901.6	3.55	792.9	3.08	659.8	7.59	3.19	2.42	2.25	1.74	2.85	2.07	-0.93	-1.47	-1.30	-1.34	-1.27	-0.34
Parramatta	2485	PARRAMATTA_R	5653	LPRC	5.477	2849.6	4.079	975.7	3.85	901.8	3.51	792.7	3.05	659.7	7.57	3.17	2.41	2.23	1.73	2.83	2.10	-0.91	-1.45	-1.28	-1.32	-1.25	-0.34
Parramatta	2486	PARRAMATTA_R	5795	LPRC	5.518	2848.6	4.029	976.3	3.80	901.8	3.46	792.7	2.99	659.7	7.62	3.18	2.40	2.22	1.72	2.83	2.10	-0.85	-1.40	-1.24	-1.27	-1.20	-0.35
Parramatta	2487	PARRAMATTA_R	5931	LPRC	5.124	2847.7	3.902	977.2	3.68	902.4	3.35	792.9	2.90	659.9	7.64	3.17	2.39	2.21	1.71	2.82	2.52	-0.73	-1.29	-1.14	-1.19	-1.08	-0.35
Parramatta	2488	PARRAMATTA_R	6167	LPRC	5.029	2846.4	3.784	978.0	3.57	902.7	3.24	793.0	2.78	660.0	6.88	2.81	2.17	1.95	1.53	2.50	1.85	-0.97	-1.40	-1.29	-1.26	-1.28	-0.31
Parramatta	2489	PARRAMATTA_R	6256	LPRC	4.747	2845.9	3.668	978.4	3.46	902.8	3.14	793.1	2.70	660.1	6.72	2.75	2.14	1.91	1.51	2.45	1.97	-0.92	-1.32	-1.23	-1.19	-1.22	-0.30
Parramatta	2490	PARRAMATTA_R	6322	LPRC	5.002	2845.5	3.701	978.6	3.48	902.9	3.16	793.1	2.71	660.1	6.72	2.72	2.12	1.89	1.50	2.43	1.72	-0.98	-1.36	-1.27	-1.21	-1.28	-0.30
Parramatta	2491	PARRAMATTA_R	6387	LPRC	5.038	2844.9	3.667	979.8	3.45	903.9	3.13	793.8	2.67	660.5	6.71	2.72	2.12	1.89	1.49	2.42	1.67	-0.95	-1.33	-1.24	-1.18	-1.24	-0.30
Parramatta	2492	PARRAMATTA_R	6598	LPRC	4.949	2842.8	3.572	981.0	3.36	904.4	3.04	793.9	2.59	660.8	6.74	2.73	2.12	1.89	1.48	2.43	1.80	-0.84	-1.24	-1.15	-1.11	-1.14	-0.30
Parramatta	2493	PARRAMATTA_R	6775	LPRC	4.725	2841.1	3.441	983.3	3.23	906.3	2.92	795.3	2.48	661.8	6.47	2.58	2.03	1.77	1.41	2.29	1.75	-0.86	-1.20	-1.15	-1.07	-1.15	-0.29
Parramatta	2494	PARRAMATTA_R	6960	LPRC	4.649	2838.9	3.326	984.4	3.12	906.9	2.81	795.7	2.37	662.3	6.44	2.55	2.01	1.76	1.40	2.27	1.79	-0.78	-1.10	-1.05	-0.97	-1.06	-0.28
Parramatta	2495	PARRAMATTA_R	7179	LPRC	4.688	2836.0	3.243	986.0	3.03	907.9	2.72	796.1	2.28	663.1	6.41	2.55	2.01	1.75	1.39	2.26	1.72	-0.70	-1.02	-0.98	-0.89	-0.98	-0.28
Parramatta	2496	PARRAMATTA_R	7352	LPRC	4.831	2829.0	3.23	991.7	3.01	910.8	2.71	797.7	2.27	665.0	6.47	2.55	2.01	1.74	1.38	2.26	1.64	-0.68	-1.00	-0.98	-0.88	-0.97	-0.28
Parramatta	2497	PARRAMATTA_R	7417	LPRC	4.691	3150.3	3.177	992.8	2.96	911.6	2.66	798.3	2.22	665.5	6.35	2.54	2.01	1.74	1.39	2.26	1.66	-0.64	-0.95	-0.92	-0.83	-0.92	-0.28
Parramatta	2498	PARRAMATTA_R	7528	LPRC	4.632	3150.1	3.099	1342.1	2.89	1222.3	2.60	1068.7	2.16	861.5	5.91	2.33	1.89	1.61	1.31	2.10	1.28	-0.77	-1.00	-0.99	-0.85	-1.00	-0.24
Parramatta	2499	PARRAMATTA_R	7592	LPRC	4.368	3150.1	2.978	1342.8	2.78	1223.0	2.49	1069.2	2.08	861.8	5.56	2.29	1.86	1.59	1.30	2.06	1.19	-0.69	-0.91	-0.90	-0.77	-0.91	-0.22
Parramatta	2500	PARRAMATTA_R	7705	LPRC	4.15	3150.1	2.854	1344.1	2.66	1224.1	2.40	1070.1	2.00	862.4	5.52	2.22	1.82	1.55	1.28	2.01	1.37	-0.63	-0.84	-0.85	-0.72	-0.84	-0.21

NB: UPRCT Draft 9 MIKE 11 Results used upstream of Charles St Weir - Cross Section PARRAMATTA_R CH2879

SKM Lower Parramatta River MIKE 11 Results used downstream of Charles St Weir - Cross Section PARRAMATTA_R CH2879

For PMF, UPRCT Draft 9 MIKE 11 Results used for full length of Parramatta River

APPENDIX

D

BRIDGE LOSS VALIDATION

D1.1 Bridge Hydraulic Loss Verification

The hydraulic losses across bridge structures have been independently verified using steady state 1D HEC-RAS hydraulic modelling.

In order to undertake a validation exercise, a HEC-RAS model has been developed at 5 locations along the Parramatta River/Toongabbie Creek.

- Briens Rd;
- Lennox Bridge;
- Hammers Road Bridge;
- Johnstons Bridge;
- Westmead Hospital access road bridge.

Each model has been established for an extent approximately 200m upstream and downstream of each bridge. HEC-RAS cross sections have been extracted from the TUFLOW DEM for the river bathymetry survey and Mannings roughness values have been selected to match the TUFLOW model materials layer.

Details of the bridges, including deck and soffit level and pier details were taken from the survey and drawings and added into HEC-RAS as Bridge/Culvert data. The bridge structures were represented in the model detailing the bridge deck levels, piers and abutments. Refer to **Figures 1-1, 1-3, 1-5, 1-7** and **1-9** for HEC-RAS model setup at each bridge.

Each model has used the tailwater level at the peak flow from TUFLOW as the downstream boundary condition. Peak flow rates upstream of the bridge were extracted from TUFLOW for each event and applied in HEC-RAS at the upstream boundary. This allows a direct comparison of the hydraulic losses achieved for the same hydraulic conditions in both models.

The method of low flow calculation was set to be based on the highest energy of the standard step, momentum, and Yarnell methods. The high flow method of backwater calculation was based on pressure/weir flow.

The HEC-RAS model and TUFLOW models were run for two events:

i) June 2016;

ii) 1% AEP (ARR1987 design event).

The flood level upstream of the proposed bridge was then compared between the models to determine the total water level difference resulting from the bridge predicted by each model.

The difference in flood level upstream of the bridge, resulting from the hydraulic loss of the bridge was then able to be compared between the HEC-RAS and TUFLOW models.

D1.1.1 Briens Rd Bridge – HEC-RAS setup

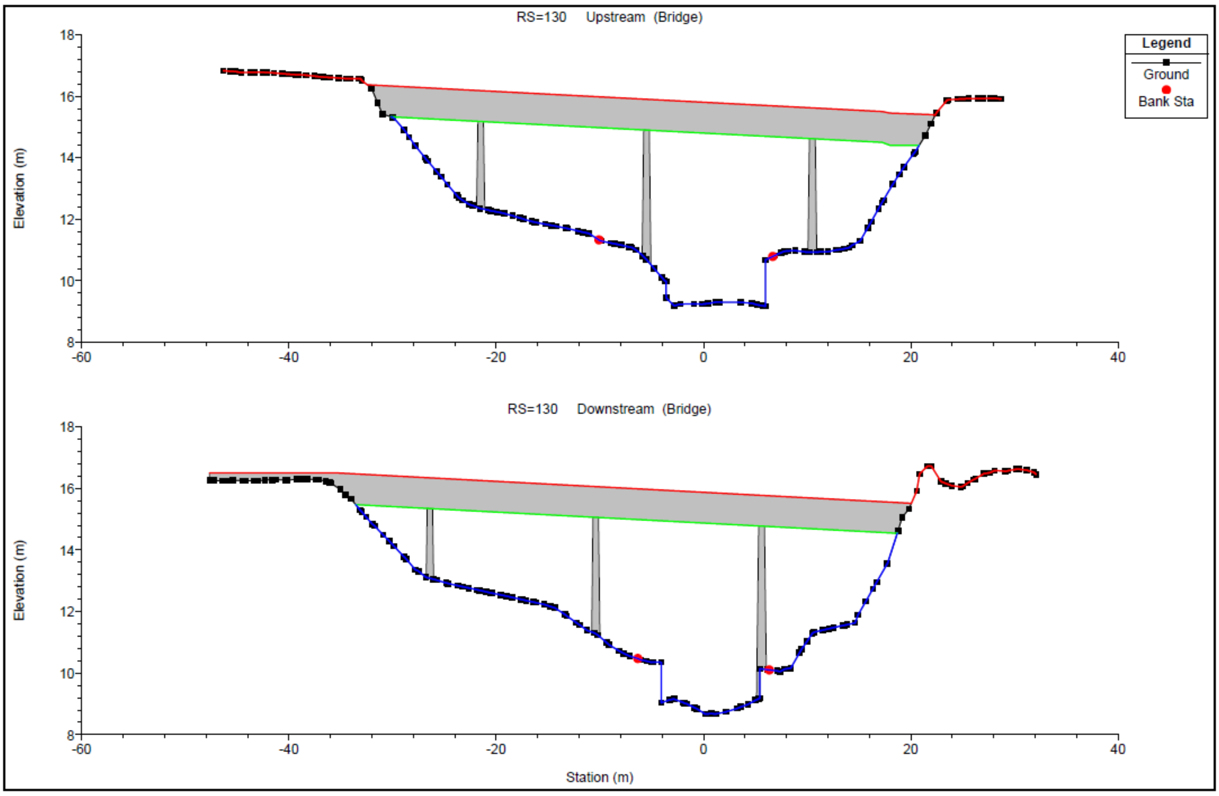

Figure D1-1 Briens Rd Bridge Section in HEC-RAS model

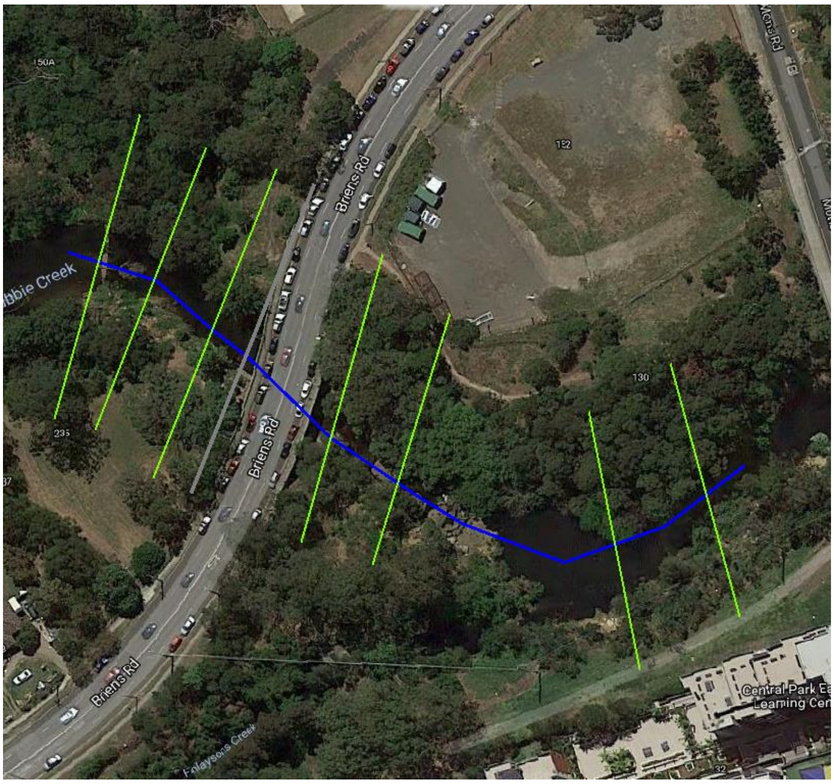

Figure D1-2 Briens Rd Bridge HEC-RAS Model Plan View

D1.1.2 Lennox Bridge – HEC-RAS setup

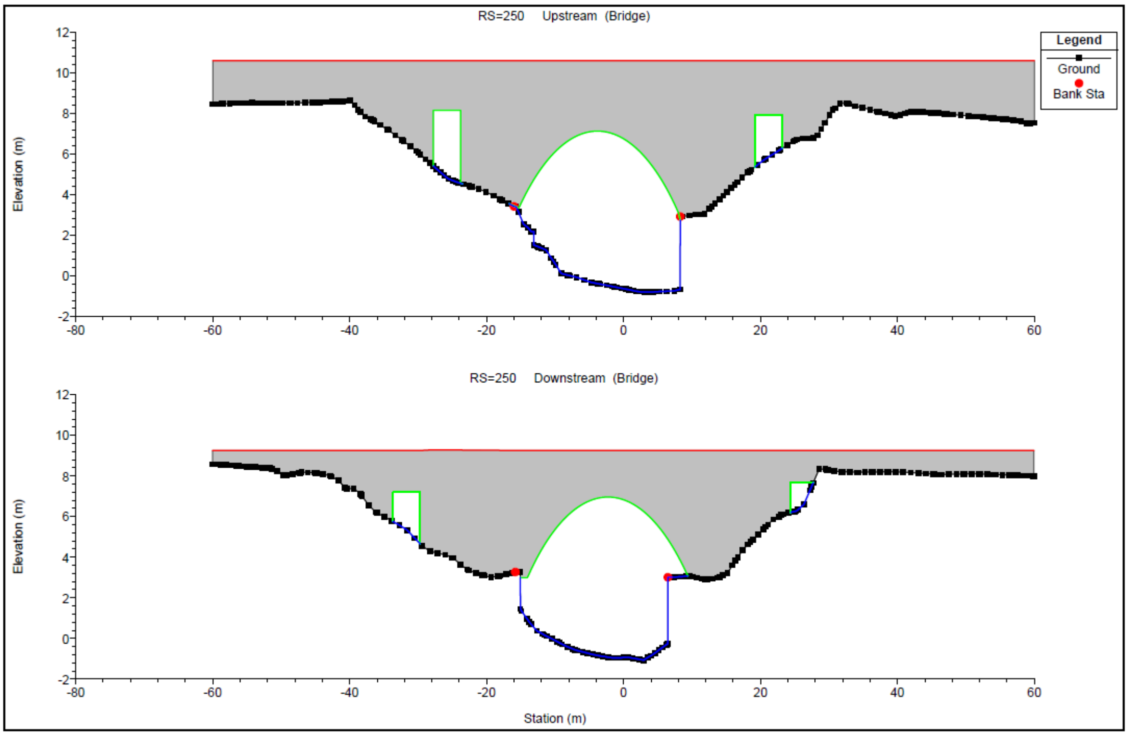

Figure D1-3 Lennox Bridge Section in HEC-RAS model

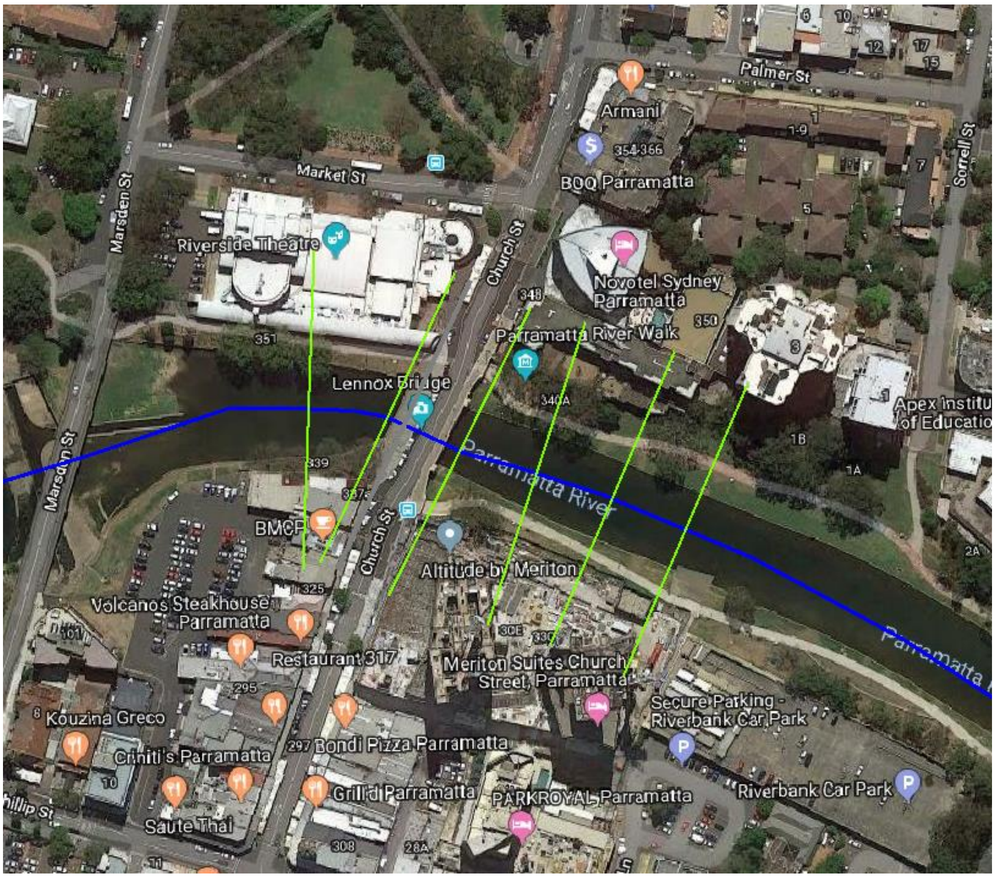

Figure D1-4 Lennox Bridge HEC-RAS Model Plan View

D1.1.3 Hammers Road Bridge – HEC-RAS setup

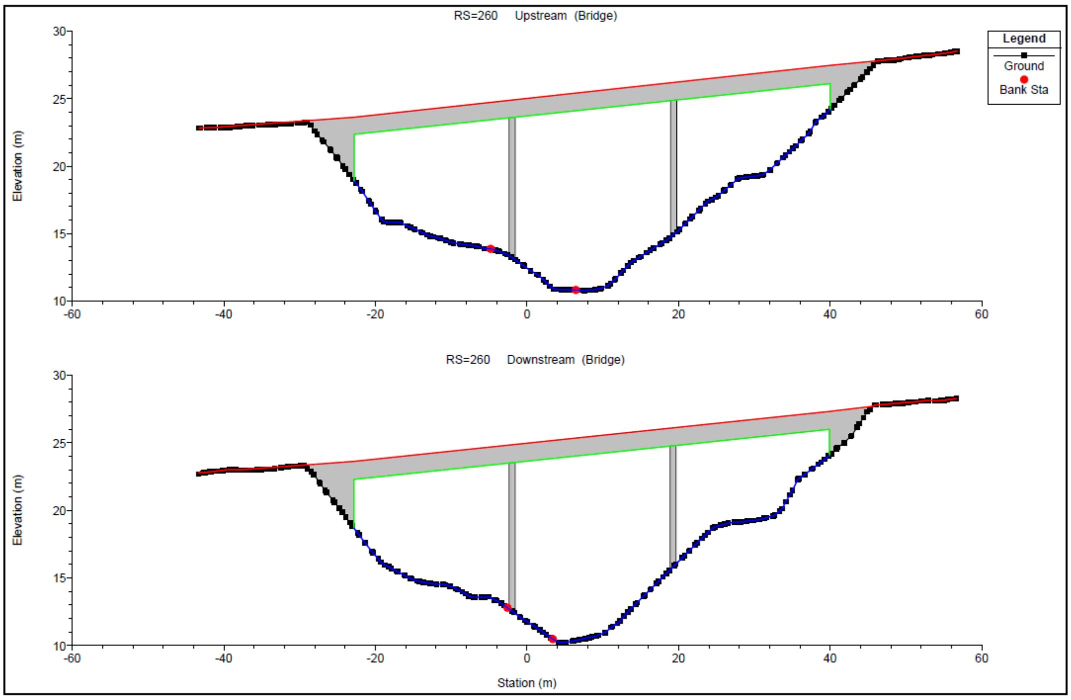

Figure D1-5 Hammers Road Bridge Section in HEC-RAS model

Figure D1-6 Hammers Road Bridge HEC-RAS Model Plan View

D1.1.4 Johnstons Bridge – HEC-RAS setup

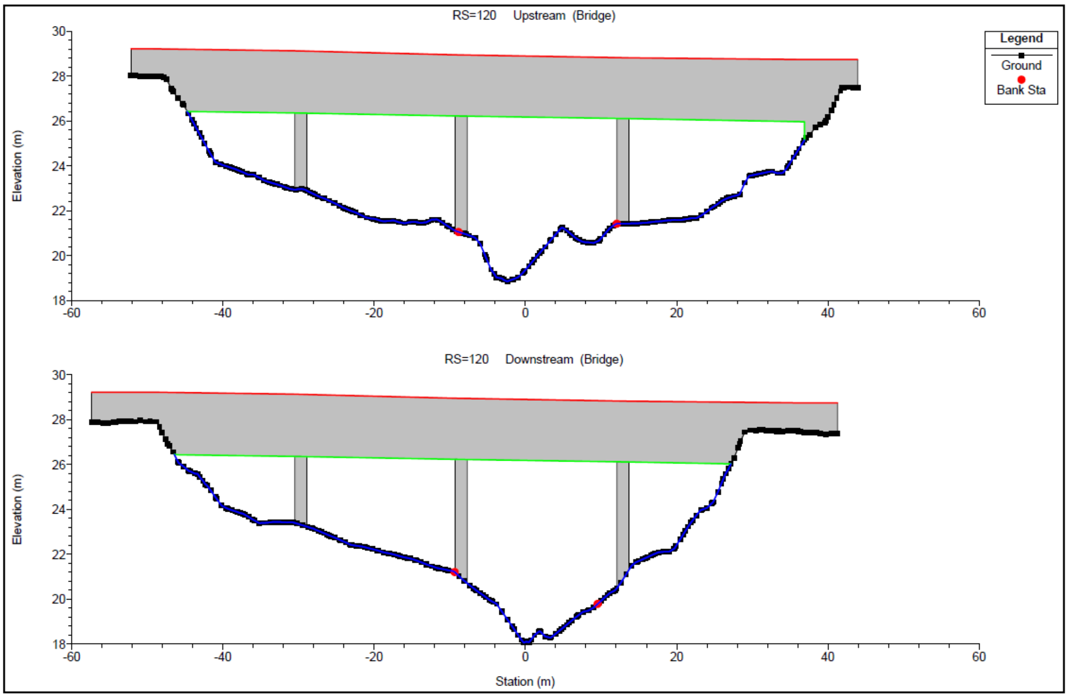

Figure D1-7 Johnstons Bridge Section in HEC-RAS model

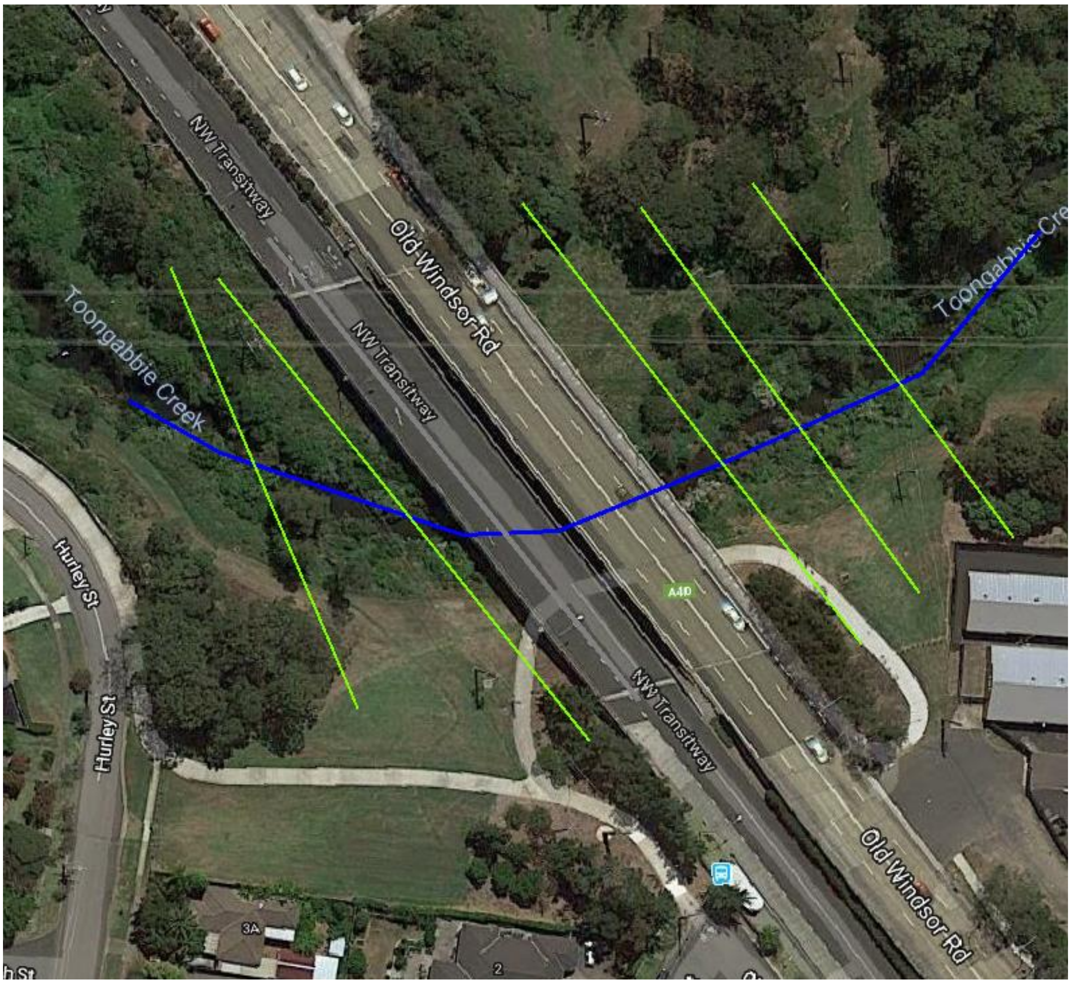

Figure D1-8 Johnstons Bridge HEC-RAS Model Plan View

D1.1.5 Westmead Hospital Access Road Bridge – HEC-RAS setup

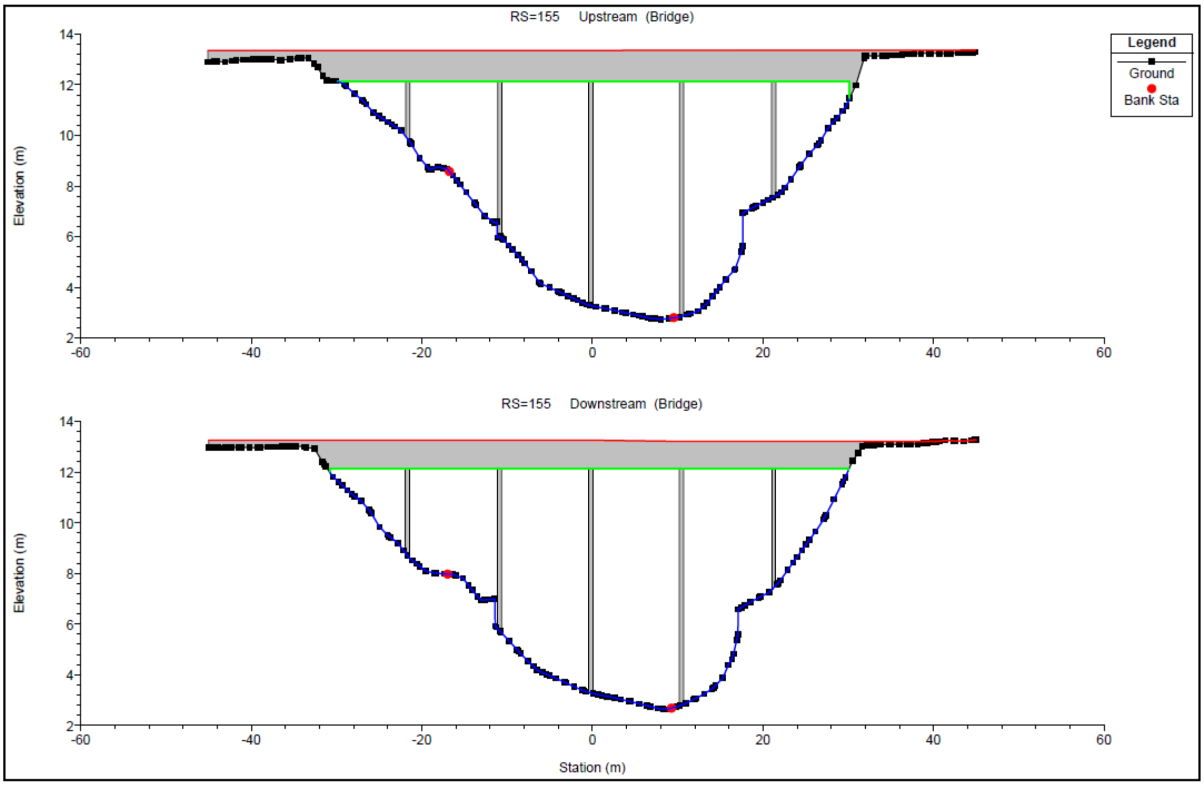

Figure D1-9 Westmead Hospital Access Road Bridge Section in HEC-RAS model

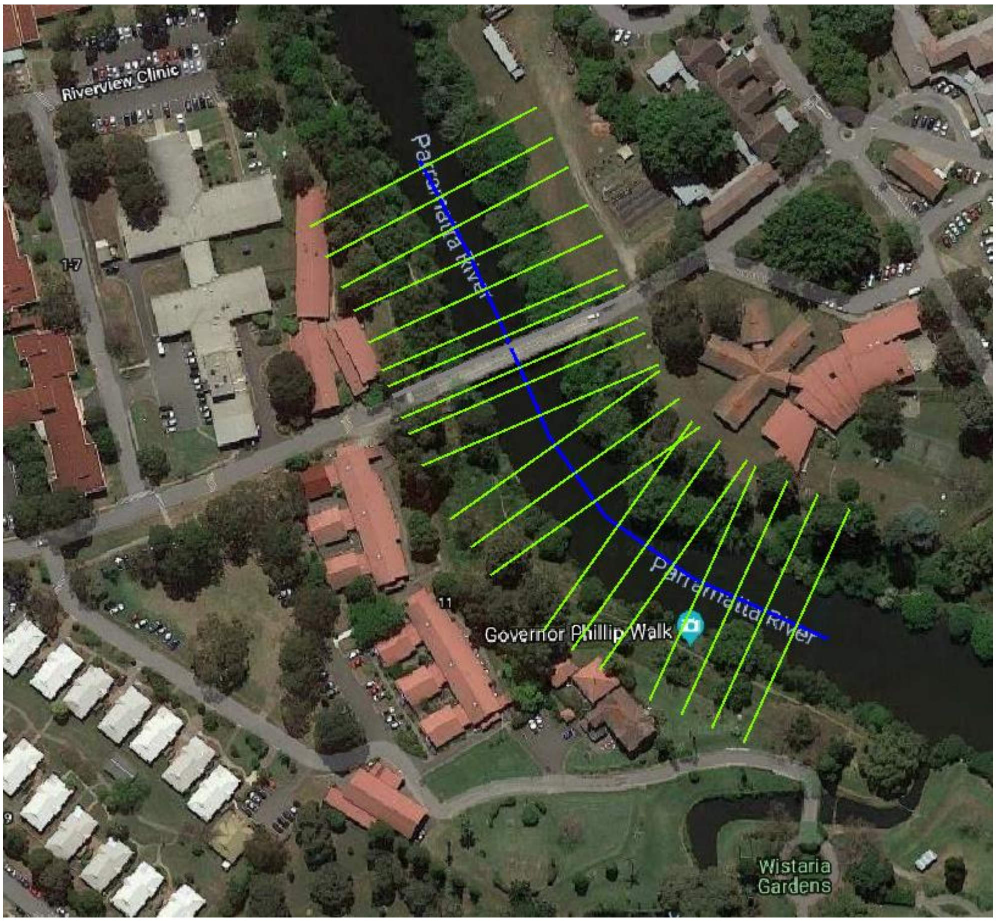

Figure D1-10 Westmead Hospital Access Road Bridge HEC-RAS Model Plan View

D1.1.6 Headloss Validation results

The results are presented in **Table 1-1** to **Table 1-5**.

It is noted that the existing 1% AEP flood levels vary across the width of the river at each bridge due to the river bends and resulting superelevation of water levels. The afflux also varies across the bridge in the TUFLOW model.

As such, the centre of the bridge in the TUFLOW model was chosen as the representative water level. The water levels at the centre of the bridge for the June 2016 event and the 1% AEP event for the bridges is shown in **Table 1-1** to **Table 1-5**.

The results show that the headloss predicted in the HEC-RAS models are generally within the range of headloss values predicted in the TUFLOW model. It is therefore considered that the loss values used in the TUFLOW model are appropriate.

Table D1-1 Head loss at Briens Road Bridges in TUFLOW and HEC-RAS

Briens Road Bridge	June 2016 Event		1% AEP Event (ARR87)	
	TUFLOW	HEC-RAS	TUFLOW	HEC-RAS
Upstream Flow (m3/s)	187.5	187.5	324.5	324.5
Flow Downstream of Finlaysons Creek (m^3/s)	238.5	238.5	506.6	506.6
Water Level Upstream of Bridge (mAHD)	**Range:** 12.71 – 13.06 **Representative:** 12.9	12.92	**Range:** 14.76 – 14.88 **Representative:** 14.8	14.85
Water Level Downstream of Bridge (mAHD)	**Range:** 12.24 – 12.46 **Representative:** 12.3	12.26	**Range:** 14.6 – 14.64 **Representative:** 14.62	14.62
Downstream Condition Water Level (mAHD)	**Range:** 12.00 – 12.16 **Representative:** 12.15	12.15	**Range:** 14.18 – 14.22 **Representative:** 14.20	14.20

Table D1-2 Head loss at Lennox Bridges in TUFLOW and HEC-RAS

Lennox Bridge	June 2016 Event		1% AEP Event (ARR87)	
	TUFLOW	HEC-RAS	TUFLOW	HEC-RAS
Upstream Flow (m^3/s)	370.8	370.8	722.3	722.3
Water Level Upstream of Bridge (mAHD)	**Range:** 4.60 – 4.80 **Representative:** 4.70	4.71	**Range:** 6.50 – 6.85 **Representative:** 6.70	6.54
Water Level Downstream of Bridge (mAHD)	**Range:** 4.32 – 4.40 **Representative:** 4.39	4.43	**Range:** 5.26 – 5.32 **Representative:** 5.29	5.26
Downstream Condition Water Level (mAHD)	**Range:** 4.50 – 4.51 **Representative:** 4.50	4.5	**Range:** 5.44 – 5.46 **Representative:** 5.45	5.45

Table D1-3 Head loss at Hammers Road Bridges in TUFLOW and HEC-RAS

Hammers Road Bridge	June 2016 Event		1% AEP Event (ARR87)	
	TUFLOW	HEC-RAS	TUFLOW	HEC-RAS
Upstream Flow (m^3/s)	205.3	205.3	437	437
Water Level Upstream of Bridge (mAHD)	**Range:** 16.90 – 16.96 **Representative:** 16.93	16.98	**Range:** 18.7 – 18.9 **Representative:** 18.80	18.98
Water Level Downstream of Bridge (mAHD)	**Range:** 16.86 – 16.95 **Representative:** 16.9	16.91	**Range:** 18.65 – 18.85 **Representative:** 18.75	18.90
Downstream Condition Water Level (mAHD)	**Range:** 16.8 – 16.82 **Representative:** 16.80	16.80	**Range:** 18.68 – 18.70 **Representative:** 18.69	18.69

Table D1-4 Head loss at Johnstons Bridges in TUFLOW and HEC-RAS

Johnstons Bridge	June 2016 Event		1% AEP Event (ARR87)	
	TUFLOW	HEC-RAS	TUFLOW	HEC-RAS
Upstream Flow (m^3/s)	192.3	192.3	406.2	406.2
Water Level Upstream of Bridge (mAHD)	**Range:** 23.34 – 23.38 **Representative:** 23.36	23.38	**Range:** 24.95 – 25.1 **Representative:** 25	25.2
Water Level Downstream of Bridge (mAHD)	**Range:** 23.23 – 23.3 **Representative:** 23.26	23.23	**Range:** 24.87 – 24.89 **Representative:** 24.88	24.85
Downstream Condition Water Level (mAHD)	**Range:** 23.19 – 23.22 **Representative:** 23.2	23.2	**Range:** 24.84 – 24.85 **Representative:** 24.84	24.84

Table D1-5 Head loss at Westmead Hospital Access Road Bridge in TUFLOW and HEC-RAS

Westmead Hospital Access Road Bridge	June 2016 Event		1% AEP Event (ARR87)	
	TUFLOW	HEC-RAS	TUFLOW	HEC-RAS
Upstream Flow (m^3/s)	362	362	706.5	706.5
Water Level Upstream of Bridge (mAHD)	**Range:** 8.86 – 8.93 **Representative:** 8.9	8.9	**Range:** 10.03 – 10.12 **Representative:** 10.1	10.05
Water Level Downstream of Bridge (mAHD)	**Range:** 8.85 – 8.9 **Representative:** 8.88	8.86	**Range:** 10.03 – 10.13 **Representative:** 10.1	10.09
Downstream Condition Water Level (mAHD)	**Range:** 8.68 – 8.80 **Representative:** 8.70	8.70	**Range:** 9.77 – 10.00 **Representative:** 9.85	9.85

APPENDIX

E

ARR2019 UPDATE AND PMF METHOD

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E1 Hydrology – ARR2019 Update

The XPRAFTS hydrologic model of the Parramatta River catchment was updated in accordance with the new Australian Rainfall and Runoff 2019 (ARR2019) Guidelines. The new ARR2019 Guidelines includes updated Intensity-Frequency-Duration (IFD) data, areal reduction factors (ARFs), and has introduced ensemble modelling methods to account for the variability in rainfall temporal patterns.

ARR Data Hub export information is provided at the end of this Appendix.

E1.1 Temporal Pattern Data

Ensemble modelling methods were introduced as part of the ARR2019 Guidelines. Ensemble modelling involves modelling a set of 10 different temporal patterns for each design event and storm duration. The temporal pattern that produces the peak flow above the mean flow of all temporal patterns is then selected to represent that particular design event and storm duration.

Design storms are sorted into three temporal pattern bins as shown in **Figure E1-1** and **Table E1-1**. A different set of 10 temporal patterns are associated with each temporal pattern bin. The 1% AEP event, for example, falls within the 'Rare' temporal pattern bin.

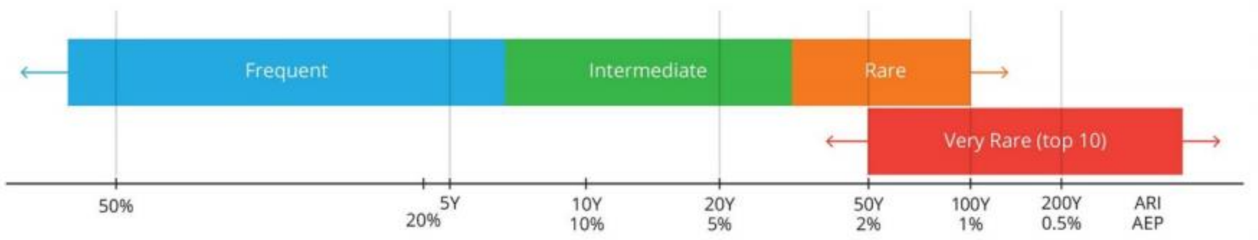

Figure E1-1 Bins for temporal patterns versus AEP (source: ARR Figure 2.5.12)

Table E1-1 Regional Temporal Pattern Bins (extracted from ARR2019 Book 2 Chapter 5)

AEP Group	AEP Range
Very Rare	Rarest 10 within region
Rare	Rarer than 3.2% AEP
Intermediate	Between 3.2% and 14.4% AEP
Frequent	More frequent than 14.4% AEP

Different sets of temporal patterns are also associated with different regions within Australia. The Parramatta River catchment falls within the 'East Coast South' region, and therefore, the temporal patterns for this region were extracted from the ARR Data Hub.

The temporal pattern data available on the ARR Data Hub includes:

- Point and areal storm burst temporal patterns. Temporal patterns are available for the 10, 15, 20, 25, 30, 45, 60, 90, 120, 180, 270, 360, 540, 720, 1080, 1440, 1800, 2160, 2880, 4320, 5760, 7200, 8640 and 10080-minute storm bursts. For each given storm burst duration, there are 10 temporal patterns for each of the Frequent, Intermediate and Rare bins; and,
- Data on the 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} percentile pre-burst rainfall observed before each storm burst category.

IFD zones were selected depending upon analysis of the rainfall depth variation across the catchment. For the consolidated model, there will be 10 temporal patterns with five different IFD zones resulting in 50 design storm events for every duration for each design event.

While ensemble modelling using the current version of XPRAFTS is possible, due to limitations of the software with a large model, it still cannot be fully automated and therefore is not efficient, requiring manual setup of design storms and processing of ensemble results external to the software.

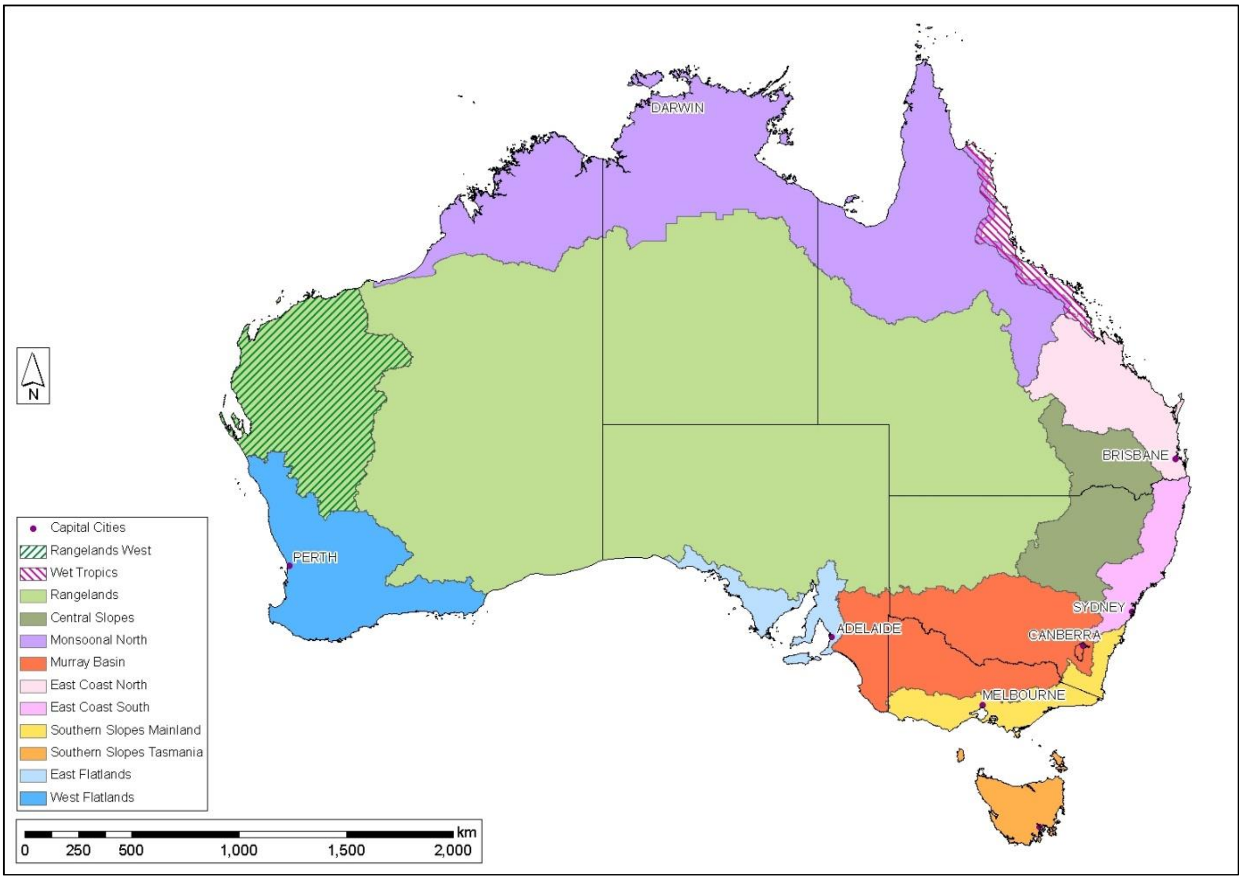

Figure E1-2 ARR2019 Temporal Pattern Regions (extracted from ARR2019 Book 2 Chapter 5)

E1.2 Intensity-Frequency-Duration Data

Design rainfall data was obtained from the Bureau of Meteorology (BoM) website. The ARR2019 IFD data replaces the ARR1987 IFDs. The BoM states that the 2016 IFDs are:

- Based on a more extensive data base, with more than 30 years of additional rainfall data and data from extra rainfall stations;
- More accurate estimates, combining contemporary statistical analysis and techniques with an expanded rainfall database; and
- By combining contemporary statistical analyses and techniques with an expanded database, the new 2016 IFDs provide more accurate design rainfall estimates for Australia.

Due to its large size, several different IFD values apply to different regions within the Parramatta River catchment. A single IFD therefore would not represent the variation across the entire catchment. As such, the Parramatta River catchment was delineated into five IFD zones, as detailed in the following sections.

E1.2.1 Determination of IFD Zones

The main purpose of defining the IFD zones are reflecting the rainfall variation over the catchment area. The variation in rainfall depth for the 1% AEP event is approximately 25% within the Parramatta River catchment.

For the purposes of reflecting this rainfall variation, a grid showing the rainfall depths was extracted from BoM and was used to access the background rainfall depth and clearly define and demonstrate the variability across the catchment. The IFD zones are based on this rainfall variation and the flood extents defined by tributaries. As part of preliminary modelling, a direct-rainfall TUFLOW model was set up and

Figure E1-3 shows the PMF modelling results for the Parramatta River catchment. The total catchment area is 218.33 km^2.

A grid showing rainfall depths for a 120-minute duration 1% AEP storm was obtained from BoM and is shown in **Figure E1-4**. The colour coding starts from blue and transforms to red through the catchment travelling to north which indicates the intensities are increasing from the south to the north parts of the catchment. Variability across the catchment is in the order of 25% difference in rainfall values for a given event and duration. The data was contoured and IFD zones selected to represent areas which had similar rainfalls with +/- 5% variability across the chosen zone.

The centroid location of each IFD Zone is calculated and the rainfall intensity is downloaded from the BOM website which gives a clear indication of the rainfall variation across the catchment is provided in **Table E1-2**.

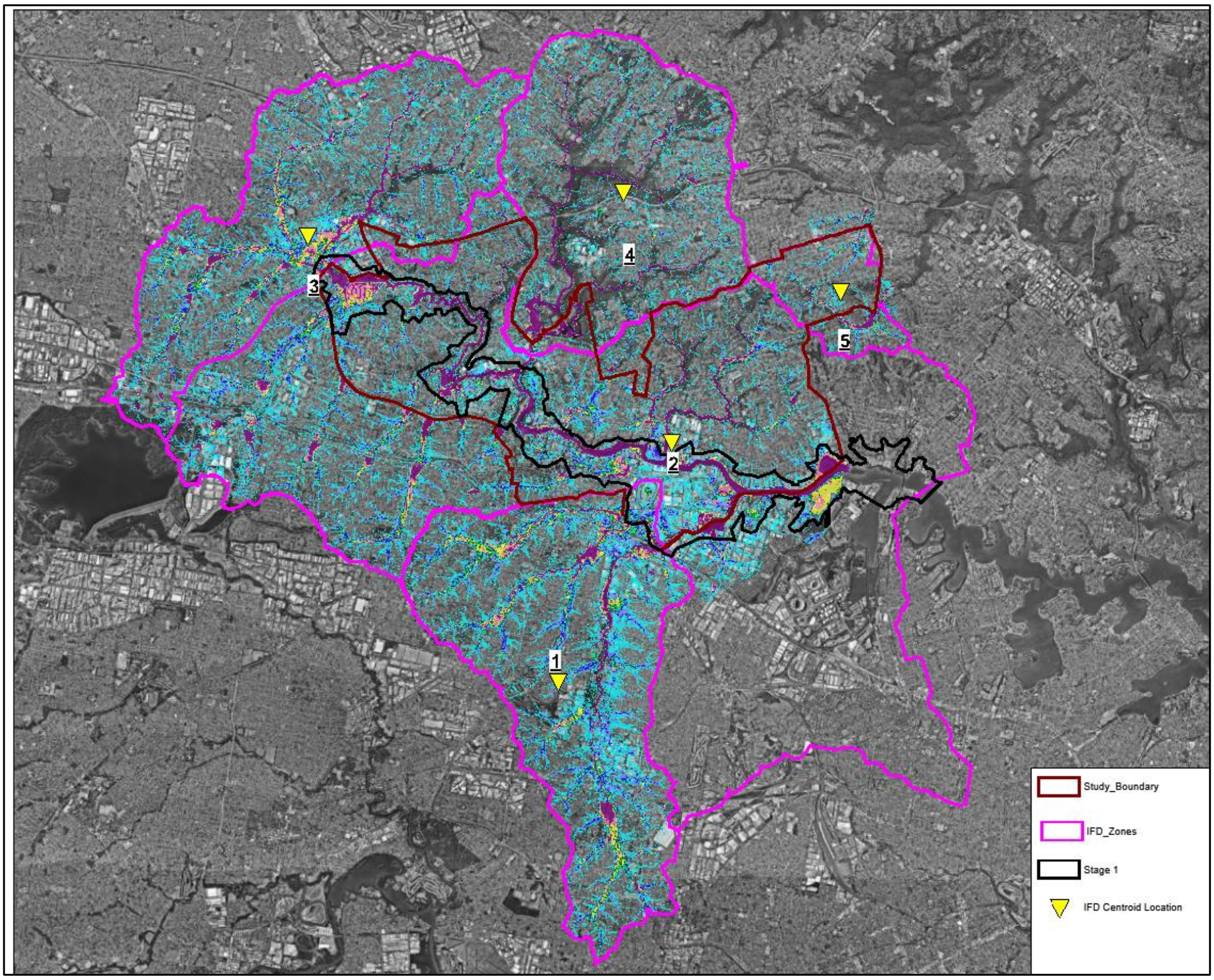

Figure E1-3 PMF Event Rain on Grid Model Results and IFD Zones

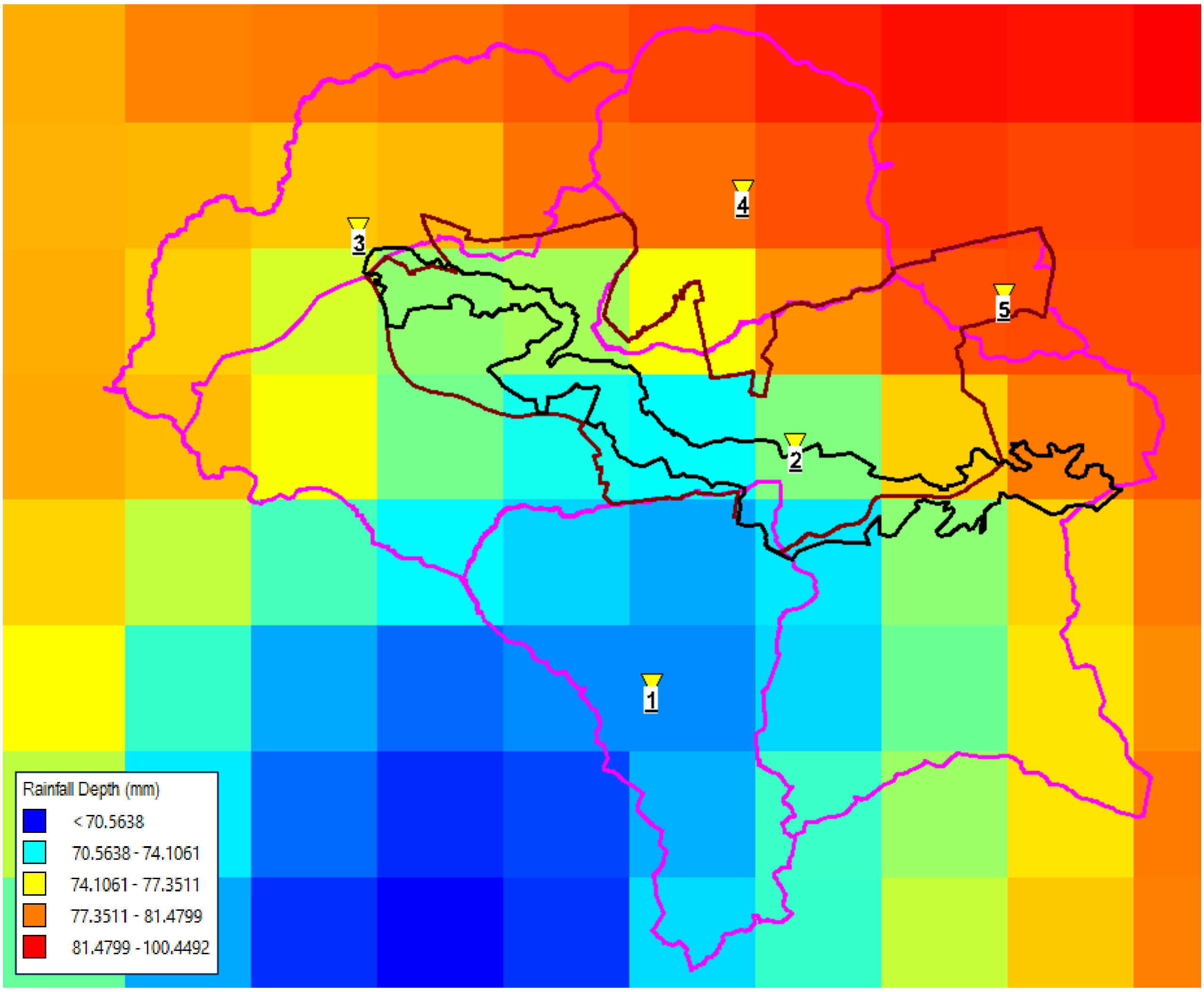

Figure E1-4 ARR2019 Rainfall Depths (1% AEP 120-minute Duration) Extracted from the BoM

Table E1-2 IFD Zones for Parramatta River Catchment

IFD Zone	Lat.	Long.	Area(ha)	Area(km2)
1	-33.861624	151.004460	3643	36.43
2	-33.821000	151.021000	11327	113.27
3	-33.766000	150.948000	3311	33.11
4	-33.763354	151.022497	2980	29.80
5	-33.861624	151.004460	576.9	5.77

E1.2.2 Sensitivity Analysis for Determination of IFD Zones

The Parramatta River catchment area covered a substantial land area as discussed, the rainfall variation is reflected based on IFD zones. There has to be selection of certain zones to be able to reflect the variability across the catchment, however, this needs to be a reasonable number to reduce complexity.

It is clear that zones with less variation in rainfall will be represented by the centroid IFD location intensity for each event which corresponds to the representative average of rainfall across the zone. Although zones such as Zone 4 (Darling Mills Creek) still shows around 10-20% variation in rainfall intensity across the zone. For determining the accuracy of IFD zones a sensitivity analysis is performed to determine if it would still be accurate in terms of using the centroid average rainfall depth. The zone is subdivided into 4 sub-zones provided in **Figure E1-5.**

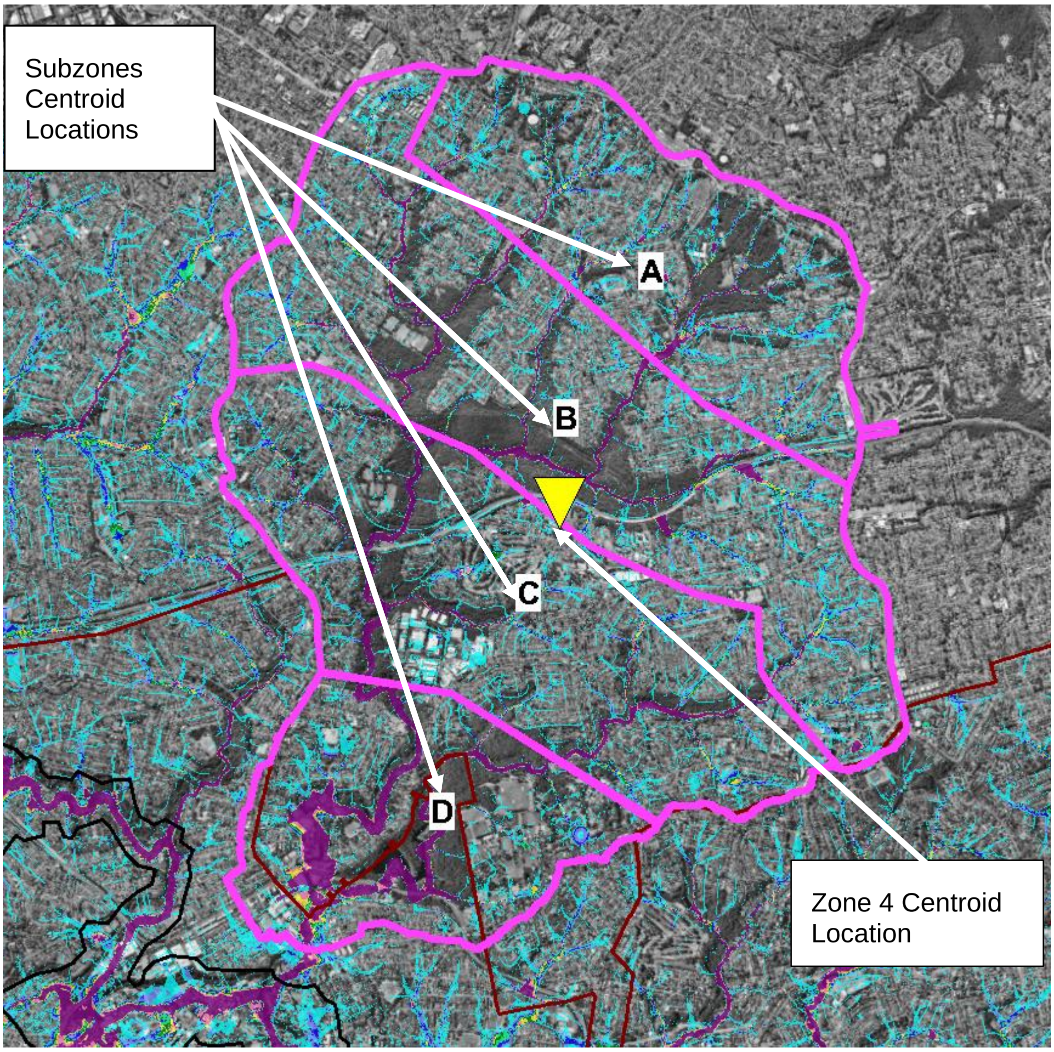

Figure E1-5 IFD Zone 4 and Sub-Zones

The centroid location of each IFD Sub-Zone is calculated and the rainfall intensity is downloaded from the BOM website is provided in **Table E1-3**. Zone B and C have the same intensity based on the data from BOM website because the centroid locations fall on the same rainfall depth grid cell. Areal reduction factor is calculated as 0.862 is applied throughout Zone 4.

Table E1-3 IFD Zone 4 Sub Zones- Rainfall Intensity and Areal Reduction Factor

IFD Zone 4 – 2-hour Duration 1% AEP Event					
IFD Sub-Zones	Latitude	Longitude	Intensity (mm/hr)	ARF	Intensity ARF (mm/hr)
A	-33.74656	151.03859	47.80	0.862	41.20
B	-33.75720	151.02323	41.90		36.12
C	-33.76996	151.01961	41.90		36.12
D	-33.78586	151.01166	38.70		33.36
Average					36.70

E1.2.2.2 *Sensitivity Assessment*

The XPRAFTS model is isolated for Zone 4 and setup is based on the 1% AEP and 2-hour duration rainfall. The temporal patterns under the 'Rare' bin was used for 1% AEP event 120-minute duration.

The methods were applied in different sections by assigning;

1. Zone A intensity (41.2 mm/hr) to every node in Zone 4 (Figure Sub_A)
2. Zone B-C intensity (36.12 mm/hr) to every node in Zone 4 (Figure Sub_BC_Avg). Sub-zones B and C have the same intensity due to the being on the same rainfall grid in BOM rainfall data.
3. Zone D intensity (33.36 mm/hr) to every node in Zone 4 (Figure Sub_D)
4. Individual intensities at each zone (Figure TP6_Local_Storm)

The total flow graphs are extracted at the outlet location of Zone 4 provided at **Figure E1-6, Figure E1-7** and **Figure E1-8** .

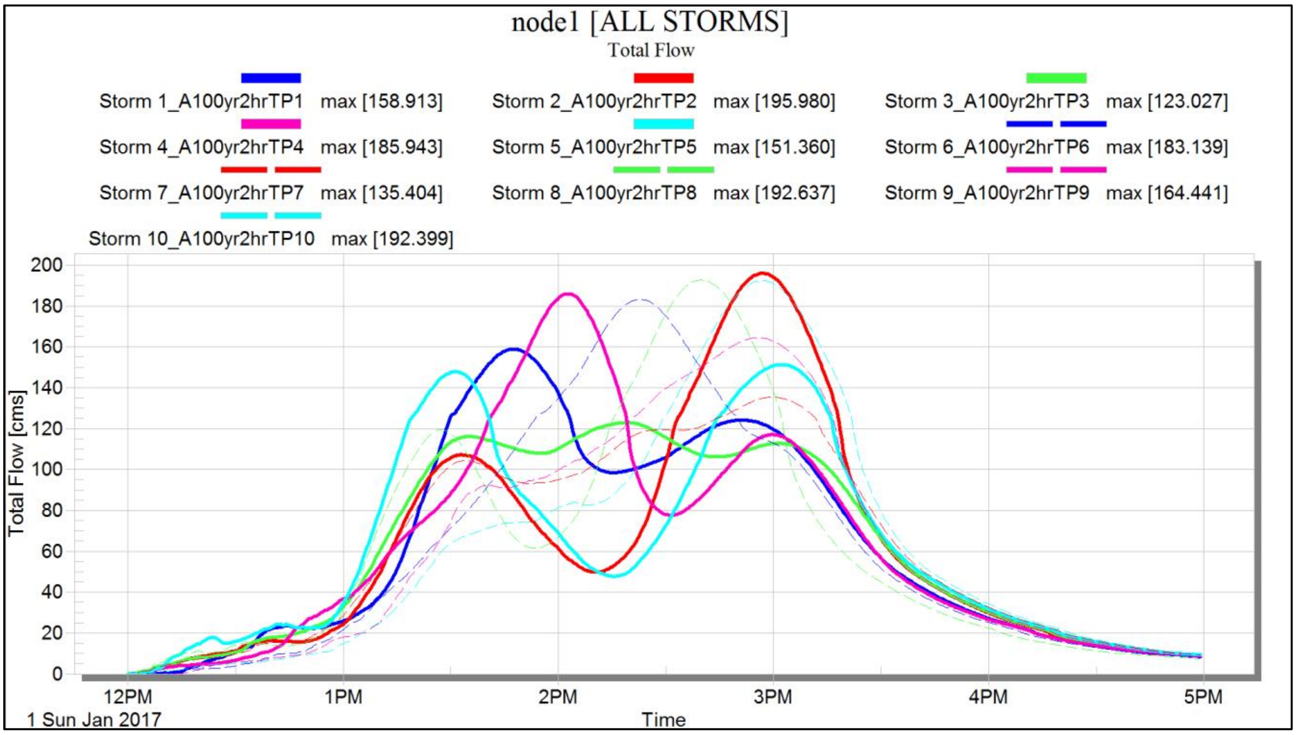

Figure E1-6 Zone 4 Outlet Location Total Flow Hydrographs – Sub-zone A intensity applied

According to these results temporal pattern 6 (TP6) is the upper median flow hydrograph with a peak flow of 183.1 m^3/s at the outlet location.

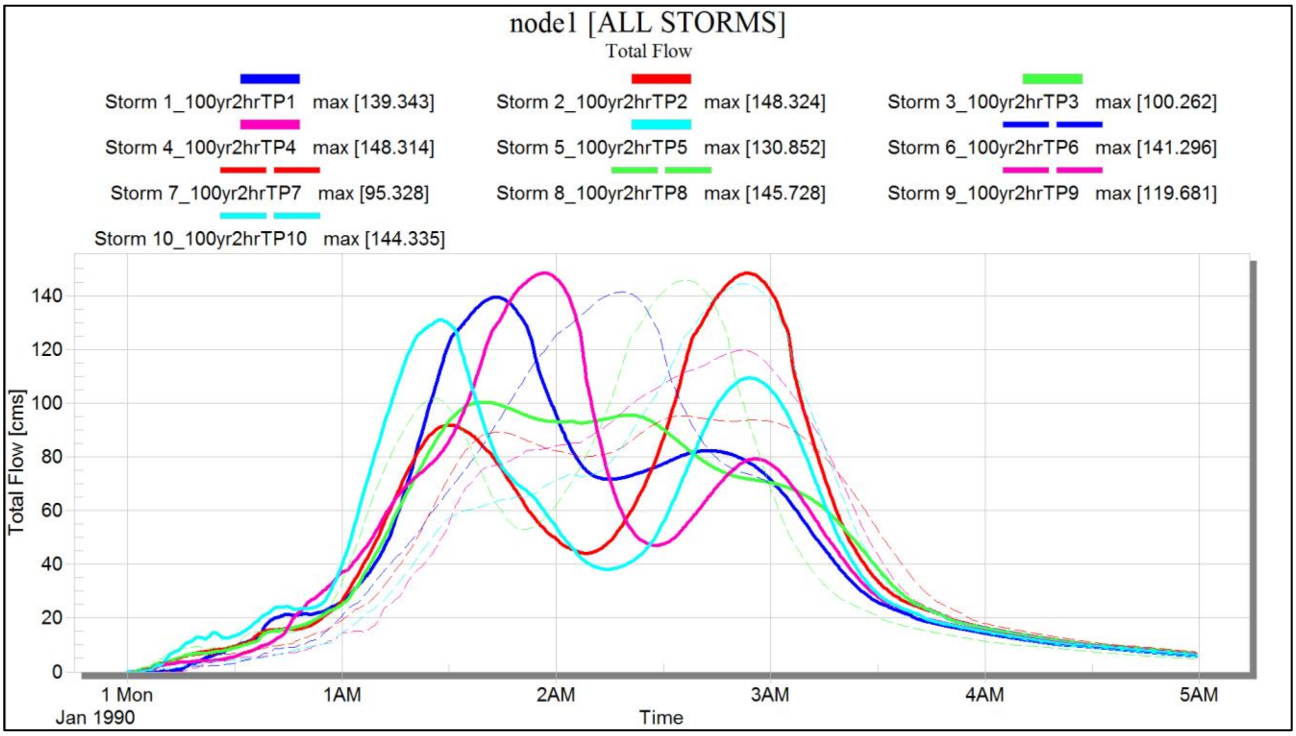

Figure E1-7 Zone 4 Outlet Location Total Flow Hydrographs – Sub-zone B-C intensity applied

According to these results temporal pattern 6 (TP6) is the median flow hydrograph with a peak flow of 141.3 m^3/s at the outlet location.

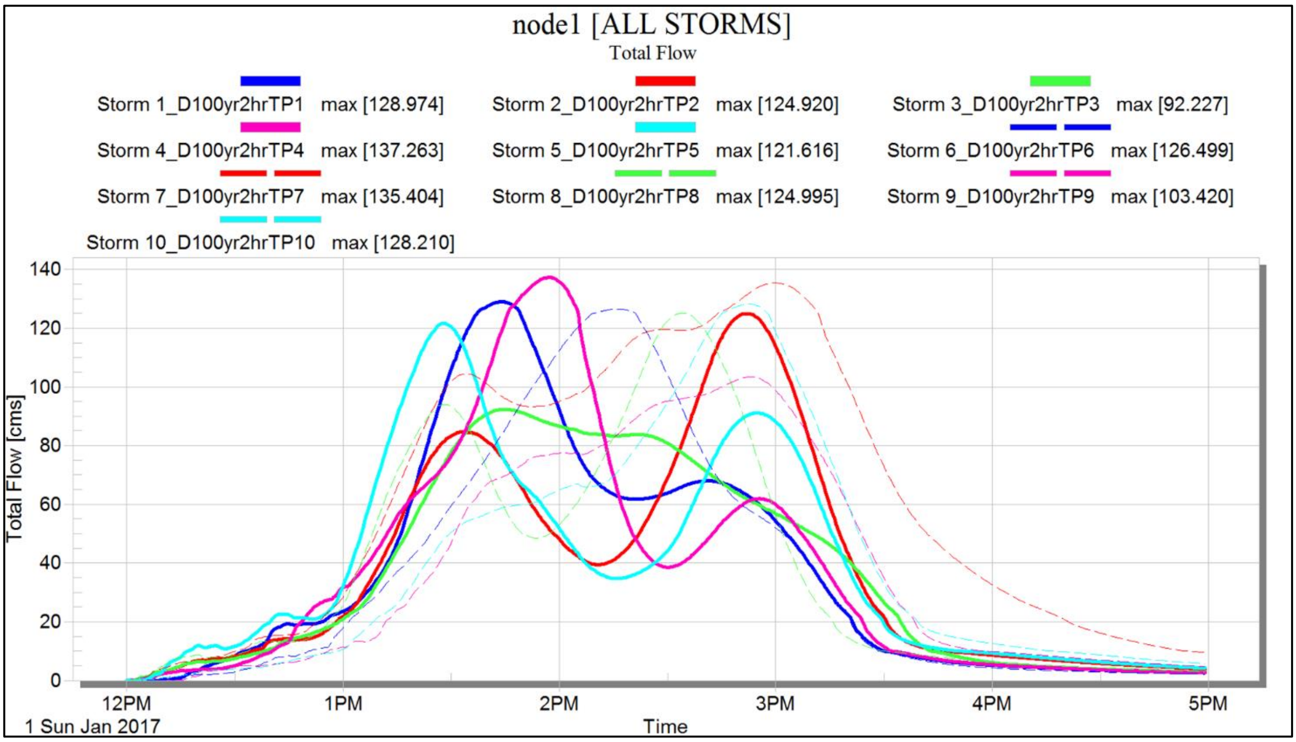

Figure E1-8 Zone 4 Outlet Location Total Flow Hydrographs – Sub-zone D intensity applied

According to these results temporal pattern 6 (TP6) is the upper median flow hydrograph with a peak flow of 126.5 m^3/s at the outlet location.

After these results it has been observed that the upper median temporal pattern is TP6 which is independent from the intensity.

E1.2.2.3 *Applying individual intensities for each zone*

The XPRAFTS model was isolated for Zone 4 and setup was based on the 1% AEP and 2-hour duration rainfall intensities applying 41.2mm/hr intensity to Zone A, 36.12 mm/hr to Zone B and C and 33.36 mm/hr to Zone D using Temporal pattern 6 (TP6) by defining local storms at each node.

The same areal reduction factor of 0.862 is still applied as in other cases.

The total flow hydrograph is extracted at the outlet location of Zone 4 and shown in **Figure E1-9**.

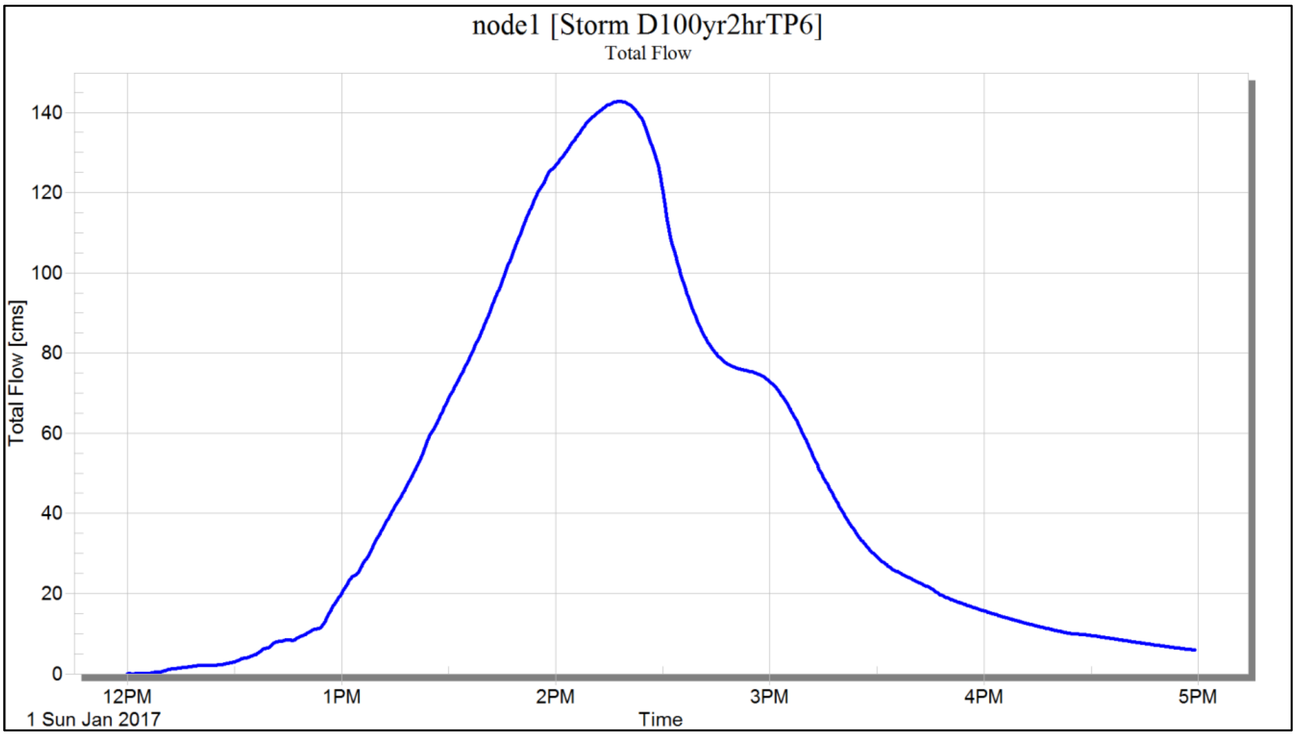

Figure E1-9 Zone 4 Outlet Location Total Flow Hydrographs - Different intensities at each zone

According to these results temporal pattern 6 (TP6) has a peak flow of 142.7 m^3/s at the outlet location.

E1.2.2.4 *Comparison of results*

A comparison of the total flow hydrographs at the outlet to Zone 4 for each of the methods is shown in **Figure E1-10**. The results indicate that applying individual intensities or average intensity through the entire catchment does not have a major impact in terms of total flows calculated in the hydrology model. The Zone B-C setup intensity is also equal to the average intensity applied at the centroid of Zone 4 without sub-zones.

Applying Method 4 *(Individual intensities at each zone)* results in a peak flow of 142.8 m^3/s while Method 2 *(Zone B-C intensity (36.12 mm/hr) to every node in Zone 4)* results in 141.3 m^3/s peak flow. There is only 1% difference between the two methods. Sub-zone A intensity is not representative of the catchment and would over-estimate flows. Similarly, Sub-zone D intensity is not representative of the catchment and would under-estimate flows.

Zone 4 is a small representation of the overall Parramatta RAFTS model which has a high variable rainfall depth although there was a minor difference in flow estimates, the representative average IFD application is more practicable to use in terms of model setup and investigating results as the new ARR2019 methods involves simulating 10 different temporal patterns for each event and duration.

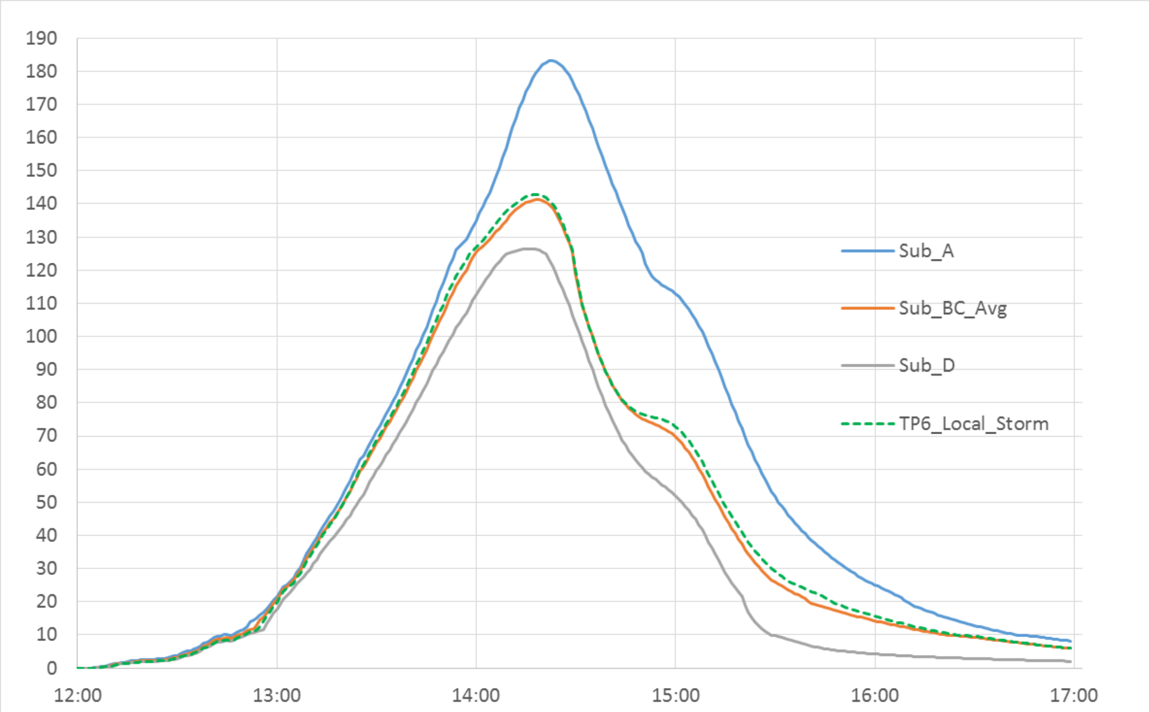

Figure E1-10 Zone 4 Outlet Location Total Flow Hydrographs Comparison

E1.3 Areal Reduction Factors (ARFs)

ARR2019 states that flood estimates are required for catchments that are sufficiently large such that design rainfall intensities at a point are not representative of the areal average rainfall intensity across the catchment. The ratio between the design values of areal average rainfall and point rainfall, computed for the same duration and Annual Exceedance Probability (AEP), is called the Areal Reduction Factor (ARF). This allows for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area.

It should be noted that the ARF provides a correction factor between the catchment rainfall depth (for a given combination of AEP and duration) and the mean of the point rainfall depths across a catchment (for the same AEP and duration combination). Applying an ARF is a necessary input to computation of design flood estimates from a catchment model that preserves a probability neutral transition between the design rainfall and the design flood characteristics. The ARF merely influences the average depth of rainfall across the catchment, it does not account for variability in the spatial and/or space-time patterns of its occurrence over the catchment.

E1.3.1 Mainstream model

Based on complexity and size of the catchments in Parramatta, areal reduction factors are required to provide an accurate representation of rainfall intensity across the catchments and the resulting flows for the mainstream watercourses.

Areal reduction factor calculations for the Parramatta River catchment to Marsden Street Weir were automated using XPRAFTS software. This location was chosen as it is central to the study area and is appropriate for the calibration at Marsden Street weir. Checks indicate there is less than 3% difference in ARF between using the whole catchment area to the downstream boundary and using the catchment area upstream of Marsden Street Weir.

Areal reduction factor calculations in Australian Rainfall and Runoff *Table 2.4.1. ARF Procedure for Catchments Less than 30 000 km^2 and Durations up to and Including 7 Days* were used in order to calculate the areal reduction factors and applied in XPRAFTS.

E1.3.2 Tributary & Overland Flow models

The average catchment size was assessed to determine the local rainfall and flood peak. As shown in **Table E1-4** the majority of the tributary catchments are between 2 – 6 km^2, with the exception of Hunts Creek and the entire Darling Mills Creek catchment. Their sub-catchments related to overland flow are smaller again. Guidance in ARR recommends that the point rainfalls are valid for catchments up to 4km^2. As such, given most catchments are around 4 km^2 or less, it was deemed appropriate that no ARF be applied to the rainfall in determining the 1% AEP flows for the Tributary and Overland Flow models.

Table E1-4 Catchment Size for Tributary Catchments

Creek Catchment Name	Area (km^2)
Brickfield Creek	3.18
Clay Cliff Creek	1.96
Coopers Creek	4.26
Darling Mills Creek	22.53
Domain Creek	1.49
Devlins Creek	1.81
Finlaysons Creek	6.13
Greystanes (Girraween) Creek	0.24
Hunts Creek	7.83
Milsons Creek	0.92
Quarry Branch Creek (Northmead Gully)	3.22
Pendle Hill Creek	5.50
The Ponds Creek	4.71
Subiaco Creek	3.73
Terrys Creek	2.34

E1.4 Pre-Burst Rainfall

E1.4.1 Pre-Burst Depth

Currently, there is no guidance provided in ARR2019 as to which pre-burst depths to adopt for design event modelling. In order to determine an appropriate pre-burst depth to adopt, an analysis of the three historic storms that occurred during April 1988, April 2015 and June 2016 was undertaken. Examination of the historical events indicates the that these floods were produced by East Coast Low (ECL) events.

The analysis calculated the storm bursts of different durations (2 hours, 9 hours and 12 hours) within each event and then calculated the pre-burst depth which preceded each storm burst. The AEP of each storm burst was estimated and the calculated pre-burst compared with the pre-burst tables from the ARR Data Hub.

The analysis showed that the pre-burst depths during these events is significant and often greater than the burst depth, and tended to exceed the 90^{th} percentile design pre-burst depths. As such, it was deemed appropriate that 90^{th} percentile pre-burst should be adopted for design event modelling for the mainstream model.

For overland flow, it is acknowledged that the flood producing storms are more likely to be thunder storm cells with a shorter pre-burst and it was agreed with Council and OEH to adopt a 75^{th} percentile pre-burst for the overland flow modelling.

E1.4.2 Pre-Burst Duration

There is also no guidance provided in ARR2019 as to the duration that the pre-burst rainfall is to be applied over. As such, sensitivity testing was undertaken to determine an appropriate duration to apply pre-burst rainfall.

With reference to the historic events, it was found applying the pre-burst rainfall over a duration of 30 hours across all events and durations would be appropriate. This allows for a consistent method of pre-burst rainfall application across all events and durations, as well as achieving a pre-burst rainfall intensity that is similar to that of the historic events.

E1.4.3 Sensitivity Analysis

Sensitivity analysis was undertaken to examine the impact of applying different pre-burst depths and different durations for the pre-burst rainfall.

Sensitivity analysis found that peak flows in shorter duration storms and more frequent events are more sensitive to the duration that the pre-burst rainfall is applied over. This is due to the higher intensity created by applying the pre-burst depth to a shorter pre-burst duration. Sensitivity analysis of pre-burst duration also showed that applying pre-burst rainfall over a period longer than 30 hours showed little effect on peak flows for a range of events and durations.

Sensitivity analysis also showed that due to the long periods over which pre-burst occurred during the historical events, that using the actual pre-burst depths from historical events had little impact on peak flows when compared with using the 90th percentile pre-burst depths.

E1.5 Design Event Modelling

E1.5.1 Ensemble Modelling Results

The hydrologic model was initially used to simulate the 1%, 5% and 20% AEP design events a range of durations. The following parameters were used in the simulation of design events for the Mainstream Hydraulic Model:

- Pre-burst Depth: 90th percentile;
- Areal reduction factor: calculated using the catchment area upstream of Marsden St Weir.

The results of the hydrologic ensemble modelling for the 1%, 5% and 20% AEP design events are shown in **Table E1-5** to **Table E1-7** for the peak flow at Marsden Street Weir. These flows were then applied to the Mainstream Hydraulic Models.

The full set of hydrologic ensemble modelling results at key locations along the mainstream and within each tributary are shown as box plots in **Figure 1** to **59**. These include a combined set of results that are applied to both Mainstream and Tributary & Overland Flow Hydraulic Models, and for all design events and durations.

Table E1-5 Hydrologic Modelling Results for the 1% AEP Event for Mainstream Hydraulic Model

Temporal Pattern	1% AEP 2-Hour	1% AEP 3-Hour	1% AEP 4.5-Hour	1% AEP 6-Hour	1% AEP 9-Hour	1% AEP 12-Hour	1% AEP 18-Hour
1	567.5	539.5	546.9	494.0	542.3	558.2	698.4
2	547.1	590.0	564.5	553.5	548.6	612.4	442.8
3	551.6	563.0	555.1	549.0	452.8	700.4	518.9
4	589.8	509.1	509.7	528.5	581.7	460.6	359.3
5	545.9	549.1	496.1	606.5	559.5	719.5	524.2
6	563.0	543.8	573.6	678.2	432.7	609.5	512.8
7	550.8	591.1	515.2	539.4	512.3	506.2	476.8
8	548.0	593.1	476.2	472.1	464.1	612.3	342.1
9	551.1	587.7	513.3	557.4	701.3	753.0	524.6
10	530.1	550.9	578.7	611.2	472.3	565.3	392.2
“Upper Mean” Peak Flow	**563.0**	**563.0**	**546.9**	**557.4**	**542.3**	**612.3**	**512.8**

Table E1-6 Hydrologic Modelling Results for the 5% AEP Event for Mainstream Hydraulic Model

Temporal Pattern	5% AEP 2-Hour	5% AEP 3-Hour	5% AEP 4.5-Hour	5% AEP 6-Hour	5% AEP 9-Hour	5% AEP 12-Hour	5% AEP 18-Hour
1	432.5	443.3	469.0	475.5	415.4	330.5	390.4
2	472.2	459.0	470.7	493.7	468.8	371.5	275.5
3	458.6	462.5	457.1	497.7	534.2	386.7	365.9
4	467.4	466.6	364.2	493.9	292.1	291.0	514.2
5	451.8	469.1	338.9	468.9	423.3	459.7	353.8
6	444.8	443.9	454.0	489.4	311.7	376.7	329.7
7	444.8	420.3	385.5	348.0	325.9	377.5	282.1
8	441.9	460.7	367.8	332.4	377.5	524.0	310.3
9	447.6	393.0	390.4	419.9	452.8	451.7	328.6
10	440.5	419.2	476.7	440.2	478.9	367.0	548.6
“Upper Mean” Peak Flow	**451.8**	**443.9**	**454.0**	**468.9**	**415.4**	**451.7**	**390.4**

Table E1-7 Hydrologic Modelling Results for the 20% AEP Event for Mainstream Hydraulic Model

Temporal Pattern	20% AEP 2-Hour	20% AEP 3-Hour	20% AEP 4.5-Hour	20% AEP 6-Hour	20% AEP 9-Hour	20% AEP 12-Hour	20% AEP 18-Hour
1	344.6	320.0	294.3	332.1	436.9	353.0	239.2
2	343.5	380.6	345.5	292.7	277.9	363.8	259.9
3	334.0	297.8	348.9	289.2	229.5	233.5	297.6
4	349.2	268.2	337.7	321.1	250.6	220.1	193.3
5	301.4	319.5	259.9	267.8	254.5	238.5	204.5
6	361.5	287.3	302.0	260.2	345.8	215.7	232.1
7	334.8	292.0	377.4	301.9	245.6	234.8	279.3
8	308.6	292.9	258.3	317.6	324.6	290.7	257.0
9	303.7	300.0	307.6	300.0	262.5	298.2	278.9
10	316.7	313.8	371.2	304.5	249.0	303.8	267.5
“Upper Mean” Peak Flow	**334.0**	**313.8**	**337.7**	**300.0**	**324.6**	**290.7**	**257.0**

E1.5.2 Comparison with Flood Frequency Analysis

A flood frequency analysis was undertaken for the gauge at Marsden Street Weir, and is detailed in a report enclosed in **Appendix B**. The "Adopted Fit" and Alternative Fit" were produced and following review the "Adopted Fit" was selected to define the 1% Design FFA matched flow at Marsden Weir. In general the ARR2019 design event flow estimates from XPRAFTS and Flood Modelling generally correlate well with the FFA expected flows although for the 1% AEP design event there was a need to upscale the flows to match the FFA defined flood.

The 1% AEP "upper mean" peak flow at Marsden Street Weir of 612 m^3/s (using 90^{th} percentile pre-burst depths) is lower than the estimated 1% AEP peak flow from the flood frequency analysis.

For the 1% AEP design storm event the modelled flows were scaled in order to match expected FFA flows at Marsden Weir in the detailed hydraulic model and the scaling was expanded to the mainstream and all tributary flows for the purposes of defining the Flood Planning Layer. No scaling has been applied to the other design events. It estimates that the peak flow for the FFA 1% AEP matched at Marsden Street Weir should be approximately 721 m^3/s under current catchment conditions.

The ARR2019 design flood estimates are considered to be a reasonable correlation to the FFA and observed data and suitable for use in simulating the design flood events in the hydraulic model.

E1.6 Sensitivity Analysis and Comparison with ARR87

Due to the ARR2019 1% AEP estimates being lower than the FFA estimated 1% AEP flow, further investigation was undertaken to test the sensitivity of the hydrology model to different rainfall IFD and temporal patterns.

As agreed with Council and OEH, the following scenarios were assessed:

Table E1-8 Design Flood Estimates Sensitivity Assessment Scenarios – ARR2019 vs ARR87

Scenario	Method	IFD	Temporal Patterns	ARF	Pre-Burst	Design Events (AEP)	Storm durations
1	ARR87	ARR87	ARR87	N	-	1%, 5%, 10%	2hr, 9hr, 12hr
2	ARR2019	ARR87	ARR2019	N	-	1%, 5%, 10%	2hr, 9hr, 12hr
3	ARR2019	ARR2019	ARR2019	Y	Median	1%	2hr
4	ARR2019	ARR2019	ARR2019	Y	90th %ile	1%, 5%, 10%	2hr, 9hr, 12hr

Stantec undertook sensitivity testing for the above scenarios to assess the impact on peak flow estimates at Marsden St Weir. It is noted that initially, no Areal Reduction Factors were used for ARR87 IFD scenarios. Results of the sensitivity testing are shown in **Table E1-9**. Further assessment was undertaken for testing ARR87 methods and varying the loss model and the use of ARFs to determine if a closer fit could be found for the 1% AEP. The results are presented in **Table E1-10** below.

The following comments are made on the outcomes:

1. Estimated peak flows for ARR87 IFD with ARR87 temporal patterns had a 9-hour critical duration. Peak estimates with no ARF appear to be too high when correlated with the FFA for all events.
2. Using ARR87 IFD with ARR2019 temporal patterns reduces flow rates such that the 1% AEP is closer to FFA, but the 5% and 10% AEP are close to the FFA estimates but a little high.
3. Using full ARR2019 methods, IFD and temporal patterns, the 1% AEP is underestimated when compared with the FFA, while the 5% AEP shows a good match and the 10% AEP is overestimated.

A comparison of the ARR87 IFD and the ARR2019 IFD data adopted for hydrologic modelling are shown in **Table E1-11** to **Table E1-15**. When comparing the ARR87 and ARR2019 IFD tables, there is a reduction of up to 20% in average rainfall intensities for 1-hour to 12-hour storm durations. The critical durations across the Mainstream and Tributary & Overland Flow hydraulic models mostly fall within these durations.

Storm durations less than 1-hour generally have similar average rainfall intensities, and storm durations greater than 12 hours generally have increased rainfall intensities of up to 20% when adopting ARR2019.

Table E1-9 ARR2019 vs ARR87 Sensitivity Assessment Results

Scenario	IFD	Temporal Pattern/s	ARF	Rainfall Loss Type	Pre-burst	Storm Duration	1% AEP	5% AEP	10% AEP
							Peak Flow* @ Marsden Street Weir (m^3/s)		
Revised Flood Frequency Analysis							656	465	370
1	ARR87	ARR87	N	IL=28 CL=0	-	2 hour	740	558	478
						9 hour	841	671	587
						12 hour	753	580	507
2	ARR87	ARR2019	N	IL=28 CL=0	-	2 hour	707	542	456
						9 hour	675	531	471
						12 hour	701	502	438
3	ARR2019	ARR2019	Y	Calibrated ARBM	Median	2 hour	301	-	-
4	ARR2019	ARR2019	Y	Calibrated ARBM	90th %ile	2 hour	540	460	424
						9 hour	534	416	359
						12 hour	612	375	320

Table E1-10 ARR2019 vs ARR87 Sensitivity Assessment Results – 1% AEP

Scenario	Event	Duration	IFD	Temporal Pattern	ARF	Rainfall Loss	Pre-burst	Median Peak Flow @ Marsden St Weir (m^3/s)	Max Peak Flow @ Marsden St Weir (m^3/s)
1	1% AEP	9 hour	ARR87	ARR87	N	IL=28, CL=0	Nil	840.5	N/A
2	1% AEP	9 hour	ARR87	ARR87	N	ARBM (20% initial stores)	Nil	746.3	N/A
3	1% AEP	9 hour	ARR87	ARR87	Y	ARBM (20% initial stores)	Nil	614.5	N/A
4	1% AEP	9 hour	ARR87	ARR87	Y	ARBM (90% initial stores)	Nil	726.3	N/A
5	1% AEP	9 hour	ARR87	ARR87	Y	IL=0 CL=0	Nil	728.4	N/A
6	1% AEP	9 hour	ARR87	ARR2019	N	ARBM (20% initial stores)	Nil	586.2	862.7
7	1% AEP	9 hour	ARR87	ARR2019	N	ARBM (90% initial stores)	Nil	674.3	877.9
8	1% AEP	9 hour	ARR87	ARR2019	N	IL=28, CL=0	Nil	671.3	877.5
9	1% AEP	9 hour	ARR2019	ARR2019	Y	ARBM (20% initial stores)	90th %ile	518.6	693.3
10	**1% AEP**	**12 hour**	**ARR2019**	**ARR2019**	**Y**	**ARBM (20% initial stores)**	**90th %ile**	**612.0**	**741.9**
11	1% AEP	12 hour	ARR2019	ARR2019	N	ARBM (20% initial stores)	90th %ile	669.0	775.7

Table E1-11 Comparison of ARR87 and ARR2019 Intensity-Frequency-Duration Table for IFD Zone 1

Duration	ARR87 Total Rainfall Intensity (mm/hr) – Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	85.4	109	138	155	177	206	227
10 min	65.5	83.9	106	119	136	158	175
20 min	47.9	61.3	77.7	87.1	99.6	116	128
30 min	39	49.9	63.3	71	81.2	94.5	105
1 hour	26.4	33.8	43.1	48.4	55.4	64.6	71.5
2 hour	17.1	22	28.2	31.8	36.6	42.8	47.5
3 hour	13.1	16.9	21.8	24.7	28.4	33.3	37.1
6 hour	8.33	10.8	14	15.9	18.4	21.7	24.2
12 hour	5.36	6.95	9.13	10.4	12.1	14.3	16
24 hour	3.52	4.58	6.06	6.94	8.09	9.6	10.8
48 hour	2.3	3	3.99	4.59	5.37	6.39	7.18
72 hour	1.73	2.26	3.03	3.49	4.09	4.88	5.49

Duration	ARR2019 Total Rainfall Intensity (mm/hr) – Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	88.7	97.2	123.6	142.8	160.8	184.8	202.8
10 min	70.2	78.0	100.8	116.4	132.0	151.8	166.2
20 min	50.1	55.5	72.0	83.1	93.9	107.7	118.2
30 min	39.8	43.8	56.4	64.8	73.0	83.8	92.0
1 hour	25.6	27.9	35.3	40.4	45.4	52.2	57.4
2 hour	16.2	17.6	22.0	25.2	28.4	32.8	36.3
3 hour	12.4	13.5	17.0	19.5	22.1	25.6	28.5
6 hour	10.7	12.0	16.0	19.0	22.0	26.2	29.5
12 hour	7.1	8.1	11.3	13.7	16.1	19.3	21.9
24 hour	4.5	5.3	7.6	9.3	11.1	13.3	15.0
48 hour	2.6	3.0	4.3	5.3	6.3	7.5	8.5
72 hour	1.7	2.0	2.9	3.5	4.2	5.0	5.7

Table E1-12 Comparison of ARR87 and ARR2019 Intensity-Frequency-Duration Table for IFD Zone 2

Duration	ARR87 Total Rainfall Intensity (mm/hr) – Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	85	109	138	154	177	205	227
10 min	65.1	83.4	106	119	136	158	175
20 min	47.5	60.9	77.3	86.7	99.2	115	128
30 min	38.7	49.6	62.9	70.6	80.8	94	104
1 hour	26.2	33.7	42.9	48.3	55.3	64.5	71.5
2 hour	17.2	22.1	28.5	32.1	37	43.3	48.1
3 hour	13.2	17.1	22.2	25.2	29.1	34.2	38.1
6 hour	8.48	11	14.5	16.5	19.2	22.7	25.5
12 hour	5.5	7.17	9.52	10.9	12.8	15.2	17
24 hour	3.65	4.75	6.32	7.26	8.48	10.1	11.3
48 hour	2.4	3.12	4.13	4.74	5.52	6.56	7.36
72 hour	1.81	2.36	3.13	3.59	4.18	4.97	5.58

Duration	ARR2019 Total Rainfall Intensity (mm/hr) – Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	89.0	97.8	126.0	144.0	163.2	188.4	208.8
10 min	70.2	78.0	102.6	118.8	134.4	155.4	171.6
20 min	50.4	56.1	72.9	84.6	95.7	110.4	121.5
30 min	40.0	44.0	57.0	65.8	74.4	85.6	94.4
1 hour	25.7	28.1	35.6	40.9	46.1	53.2	58.8
2 hour	16.2	17.6	22.2	25.5	28.8	33.4	37.1
3 hour	12.4	13.5	17.1	19.7	22.3	26.1	29.1
6 hour	8.0	8.8	11.4	13.3	15.3	18.2	20.3
12 hour	5.3	5.9	8.0	9.5	11.1	13.3	15.0
24 hour	3.5	4.0	5.6	6.8	8.1	9.8	11.0
48 hour	2.2	2.6	3.7	4.6	5.5	6.6	7.5
72 hour	1.7	1.9	2.8	3.5	4.2	5.0	5.6

Table E1-13 Comparison of ARR87 and ARR2019 Intensity-Frequency-Duration Table for IFD Zone 3

Duration	ARR87 Total Rainfall Intensity (mm/hr) – Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	80.6	103	132	148	170	198	220
10 min	61.8	79.3	101	114	130	152	169
20 min	45	57.7	73.5	82.5	94.5	110	122
30 min	36.6	46.9	59.6	66.9	76.7	89.3	98.8
1 hour	24.8	31.9	40.6	45.6	52.3	61	67.5
2 hour	16.4	21.1	27.1	30.5	35	40.9	45.4
3 hour	12.8	16.5	21.2	24	27.6	32.3	35.9
6 hour	8.38	10.8	14	15.9	18.4	21.6	24.1
12 hour	5.47	7.09	9.27	10.6	12.2	14.4	16.1
24 hour	3.54	4.59	6.07	6.95	8.09	9.61	10.8
48 hour	2.22	2.89	3.87	4.46	5.22	6.23	7.01
72 hour	1.64	2.15	2.9	3.35	3.94	4.72	5.32

Duration	ARR2019 Total Rainfall Intensity (mm/hr) – Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	86.3	96.2	128.4	150.0	171.6	201.6	225.6
10 min	68.4	76.8	104.4	123.0	141.6	166.2	185.4
20 min	48.9	54.9	74.4	87.6	100.8	118.2	131.7
30 min	38.6	43.2	58.0	68.2	78.4	91.8	102.2
1 hour	24.7	27.4	36.2	42.3	48.5	56.8	63.4
2 hour	15.6	17.2	22.4	26.1	30.0	35.3	39.6
3 hour	11.9	13.1	17.1	20.1	23.1	27.3	30.7
6 hour	7.7	8.6	11.3	13.4	15.6	18.5	21.0
12 hour	5.1	5.7	7.8	9.4	11.1	13.3	15.3
24 hour	3.4	3.8	5.5	6.7	8.0	9.7	11.0
48 hour	2.1	2.5	3.6	4.5	5.5	6.6	7.5
72 hour	1.6	1.8	2.7	3.4	4.2	5.0	5.6

Table E1-14 Comparison of ARR87 and ARR2019 Intensity-Frequency-Duration Table for IFD Zone 4

Duration	ARR87 Total Rainfall Intensity (mm/hr) – Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	83.9	108	137	154	176	205	227
10 min	64.4	82.6	105	118	136	158	175
20 min	46.9	60.1	76.7	86.3	99	115	128
30 min	38.1	48.9	62.4	70.2	80.6	94	104
1 hour	26	33.4	42.8	48.2	55.3	64.7	71.8
2 hour	17.3	22.2	28.7	32.5	37.4	43.9	48.8
3 hour	13.5	17.5	22.7	25.7	29.7	34.9	38.9
6 hour	8.88	11.5	15.1	17.2	20	23.6	26.4
12 hour	5.87	7.62	10.1	11.5	13.4	15.9	17.9
24 hour	3.88	5.04	6.68	7.65	8.92	10.6	11.9
48 hour	2.51	3.26	4.31	4.94	5.74	6.82	7.64
72 hour	1.89	2.46	3.25	3.73	4.35	5.16	5.78

Duration	ARR2019 Total Rainfall Intensity (mm/hr) – Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	89.3	99.4	130.8	153.6	176.4	206.4	231.6
10 min	70.8	79.8	106.8	125.4	143.4	168.0	187.2
20 min	50.7	57.0	76.2	89.4	102.6	119.7	133.2
30 min	40.0	44.8	59.6	69.8	80.0	93.6	104.0
1 hour	25.6	28.5	37.5	43.8	50.2	58.9	65.9
2 hour	16.2	17.9	23.5	27.5	31.5	37.3	42.0
3 hour	12.4	13.8	18.1	21.2	24.5	29.1	32.9
6 hour	8.1	9.0	12.1	14.4	16.7	20.0	22.7
12 hour	5.4	6.1	8.4	10.2	12.0	14.4	16.4
24 hour	3.6	4.2	5.9	7.3	8.7	10.5	11.9
48 hour	2.4	2.7	4.0	4.9	5.9	7.1	8.0
72 hour	1.8	2.0	3.0	3.7	4.5	5.4	6.1

Table E1-15 Comparison of ARR87 and ARR2019 Intensity-Frequency-Duration Table for IFD Zone 5

ARR87 Total Rainfall Intensity (mm/hr)							
Duration	Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	87.9	113	143	160	183	213	236
10 min	67.4	86.5	110	124	142	165	183
20 min	49.1	63.1	80.7	90.8	104	122	135
30 min	39.9	51.4	65.8	74.1	85.2	99.6	110
1 hour	27.2	35.1	45.2	51.1	58.8	69	76.6
2 hour	18.1	23.4	30.4	34.5	39.8	46.9	52.2
3 hour	14.2	18.4	24	27.3	31.6	37.2	41.6
6 hour	9.34	12.1	16	18.3	21.2	25.1	28.1
12 hour	6.15	8.01	10.6	12.2	14.3	17	19
24 hour	4.02	5.26	7.04	8.12	9.51	11.4	12.8
48 hour	2.56	3.36	4.54	5.26	6.18	7.41	8.36
72 hour	1.92	2.52	3.42	3.97	4.68	5.63	6.38

ARR2019 Total Rainfall Intensity (mm/hr)							
Duration	Average Exceedance Probability						
	63.20%	50%	20%	10%	5%	2%	1%
5 min	92.2	102.6	135.6	159.6	182.4	214.8	240.0
10 min	73.2	82.2	109.8	129.0	147.6	172.8	192.6
20 min	52.5	58.8	78.6	92.1	105.6	123.3	137.1
30 min	41.4	46.2	61.6	72.2	82.8	96.8	107.8
1 hour	26.6	29.5	39.1	45.7	52.5	61.7	69.0
2 hour	16.9	18.7	24.7	28.9	33.3	39.4	44.4
3 hour	13.0	14.4	19.1	22.5	26.0	30.9	35.0
6 hour	8.6	9.6	12.9	15.3	17.8	21.3	24.2
12 hour	5.8	6.6	9.0	10.8	12.8	15.3	17.4
24 hour	4.0	4.5	6.4	7.8	9.2	11.0	12.5
48 hour	2.6	3.0	4.3	5.3	6.3	7.5	8.5
72 hour	2.0	2.3	3.3	4.0	4.8	5.7	6.4

E1.7 Conclusion

Following an initial FFA on the Marsden Street Weir gauge data and further consultation with Council, it was determined that the rating curve at Marsden Street Weir needed to be updated, and subsequently, the annual maxima series used to revise the FFA. A detailed description of the Marsden Street Weir rating curve update, annual maxima series revision and updated FFA is provided in **Appendix B**.

Design event flows using ARR2019 have been derived and flow estimates show consistent results with the peak flows predicted by the updated FFA at Marsden Street Weir. It was identified that there had previously been a good match between hydrological and hydraulic outcomes for design events, but this trend did not continue with 1% AEP flow. The 1% AEP flow estimate (612 m^3/s) is lower than the "Adopted Fit" FFA estimate that the peak flow for the 1% AEP at Marsden Street Weir should be approximately 719 m^3/s under current conditions using the standard Log-Pearson III fit to the entire data set.

Sensitivity testing to determine the impacts of changes between ARR87 and ARR2019 show that with ARR2019, there are reductions in IFD rainfall intensities for most durations and different temporal patterns lead to lower design flood estimates when compared with ARR87. Sensitivity testing included examining the impacts of applying ARF and low initial and continuing loss parameters.

Sensitivity analyses was also undertaken using different pre-burst depths and durations to check whether model input data could increase flow estimates to achieve a closer match with the FFA. No significant increase in flow estimates could be achieved, using methods or parameters that could be justified. The main source of the lower flow estimates is the rainfall which comes from the IFD data and temporal patterns obtained from the ARR Data Hub.

However, the model has been well calibrated to the June 2016 historical event and design event flow estimates correlate with the observed annual maxima flood flows. As such, it was deemed appropriate to proceed with adopting ARR2019 and hydrologic parameters that were used in design event modelling.

The project requires inflows and flood levels throughout the study area for both mainstream and overland flows. There are inherent difficulties in adopting a global approach to other events, durations and locations within the catchment where there is no FFA for comparison. As a result, adopting the ARR2019 method of selecting the temporal pattern with peak flow at Marsden Street Weir and key locations in the tributary catchments is appropriate.

For the 1% AEP design storm event the modelled flows were scaled in order to match defined FFA flows at Marsden Weir in the detailed hydraulic model and the scaling was expanded to the main river and all tributary flows for the purposes of defining the Flood Planning Layer. No scaling has been applied to the other design events not associated or required for Flood Planning purposes. An upscaled hydrology model that aimed to replicate the FFA defined flow, set up described in report **Section 7.**

E2 PMF Hydrology Approach

The PMF hydrology approach is based on the Estimation of Probable Maximum Precipitation (PMP) in Australia: Generalised Short-Duration Method (GSDM) (June 2003).

As part of this method, the estimates of PMP rainfall depths are calculated based on catchment parameters related to catchment characteristics. Then a spatial distribution may be applied across a catchment through the placement of scaled ellipses over the centroid of the catchment. The mean rainfall depth is varied in areas that fall within different rings of the ellipses A to J. As shown in **Figure E2-1**, placing the PMP spatial distribution ellipses over the centroid of the Parramatta River Flood Study Catchment area, the catchments lie within Ring A to Ring F.

E2.1 Previous Studies

The "*Probable Maximum Flood Study – Upper Parramatta River Catchment* for Upper Parramatta River Catchment Trust (SKM 2001)" report adopted the GSDM for estimation of PMP depth, spatial and temporal distribution. Ellipses representing the GSDM spatial distribution were overlaid on the catchment and the grouping was done on the basis of variability of rainfall depth for the sub-catchments. A weighted PMP depth was adopted for each group for the selected duration.

The "*Lower Parramatta River Floodplain Risk Management Study – Flood Study Review*" for Parramatta City Council (SKM 2005)" report adopted a hybrid method. The method involved using the inflow hydrograph for the 4 hour PMP event for the Upper Parramatta River catchment and applying a suitable multiplier to the 4.5 hour 1% Annual Exceedance Probability (AEP) inflow hydrographs from sub-catchments located between Charles Street Weir and Ryde Bridge to maximise outflow at Ryde Bridge. For the downstream catchments, the PMF was based on three times the 1% AEP flows.

It is noted that the above approach for the Lower Parramatta River is considered conservative as it applies the GSDM method to the Upper Parramatta River catchment rather than over the whole catchment. This would concentrate the rainfall depths within the inner rings of the spatial ellipses. This flow is added as an inflow as the top of the hydraulic model and then an arbitrary multiplier is used to determine flows for the Lower Parramatta River catchment as a surrogate for re-calculating the PMF. Applying the GSDM depths and spatial ellipses over the entire catchment, would likely result in lower flow estimates as the rainfall would be spatially scaled for areas within the outer rings for a storm over the entire catchment.

In previous studies for individual tributary catchments e.g. Clay Cliff Creek or Vineyard Creek, the PMF would have been determined by placing the ellipses over the centroid of the study area for those catchments.

E2.2 Adopted PMF Methodology

As the current study is concerned with assessing the PMF for all areas within the catchment, different approaches were required to be adopted for the Mainstream model and Overland Flow areas. The different approaches are outlined below.

E2.2.1 Mainstream PMF Approach

Estimate PMP rainfall depths using GSDM method for the entire study area (219 km^2) catchment boundary and apply spatial ellipses centred over the catchment (**Figure E2-1**). In this process the area within Ring A will have highest rainfall intensity and gradually decreases from Ring A to Ring F;

Table E2-1 summarises the PMF intensities for each ellipse for a duration of 15 min (0.25hr).

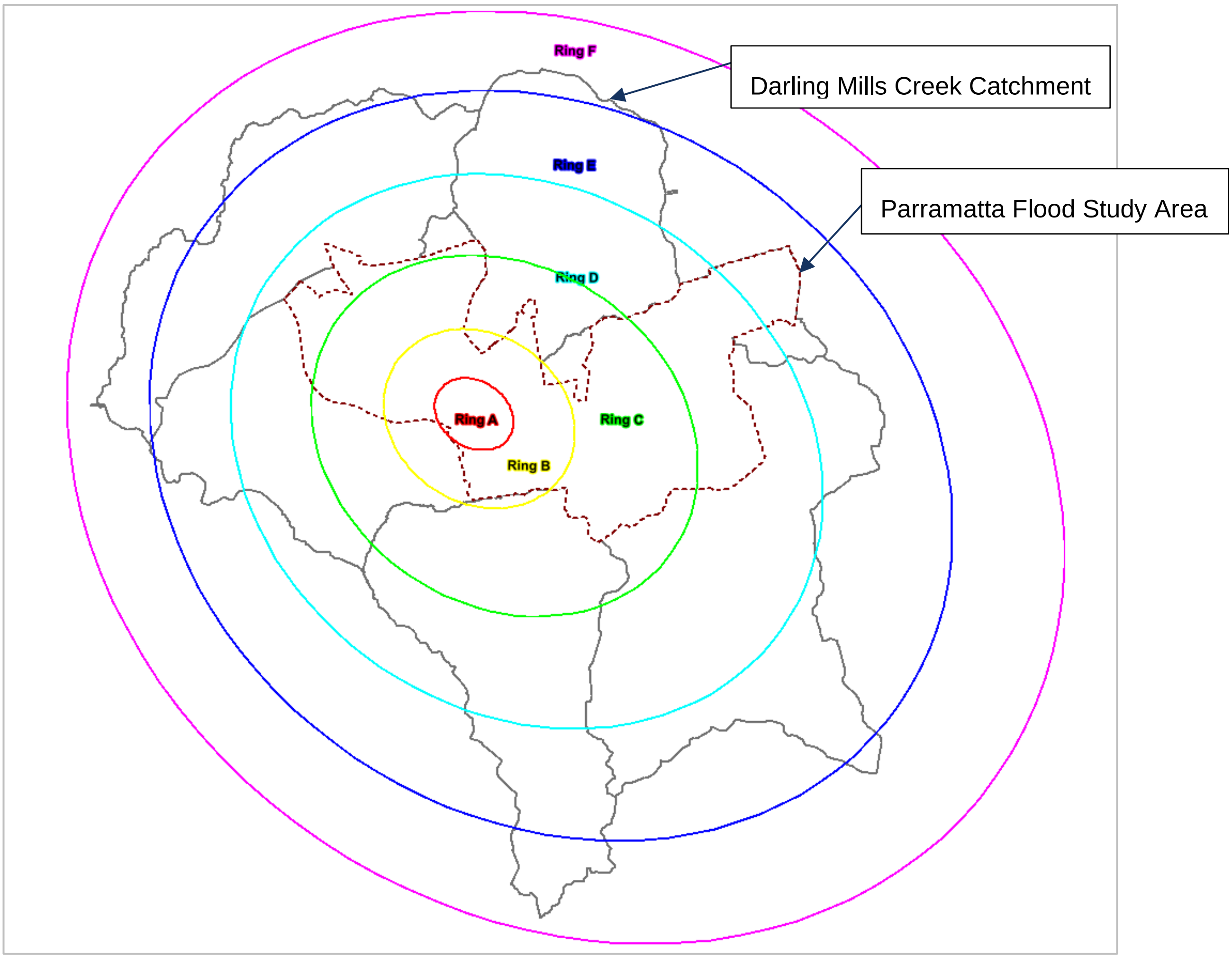

Figure E2-1 GSDM PMP spatial distribution ellipses centred over entire Parramatta Flood Study area

Table E2-1 PMP Rainfall Depth and Intensity for Mainstream catchment

PMP Ellipse (Figure E2-1)	Rainfall Depth (mm)	Intensity (mm/hr)
A	162.4	650
B	135.6	542
C	116.8	467
D	103.5	414
E	76.8	307
F	63.8	255

E2.2.2 Tributary and Overland Flow PMF Approach

Estimating the PMP rainfall depth using GSDM method and applying the spatial ellipses for each tributary catchment will provide the best PMF estimate at the downstream end of each tributary. However, this study is interested in the likely PMF flows and flood extents for all areas within the catchment. Due to the varying scales and point of interest of flood results, an alternate method is required.

It is appropriate to adopt a weighted average intensity and apply to the model. The rainfall intensity for the GSDM B-ellipse was applied for all Tributary & Overland Flow models. This provides a representative estimate of PMF rainfall intensity for each Tributary & Overland Flow model without the complexity of applying GSDM ellipses for every catchment.

While using the A-Ellipse may be more appropriate for the small overland flow catchments to obtain peak flows, due to the size of the models, this would tend to overestimate volumes and produce spurious results in the low parts of the catchments/tributaries.

For example, if we choose Darling Mills Creek Catchment (22 km^2), as shown in **Figure E2-2**, the catchment lies within between Ring A to Ring C.

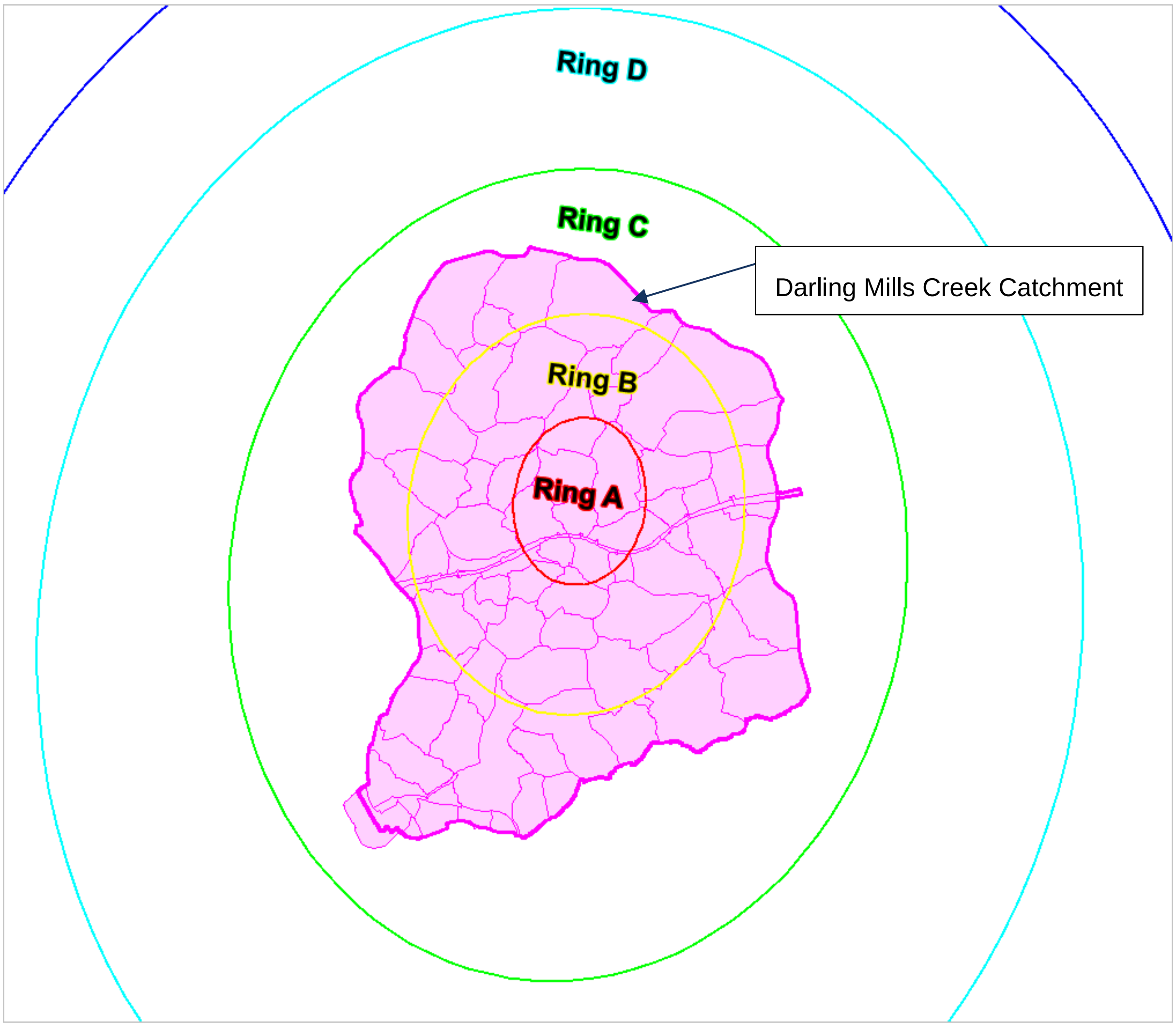

Figure E2-2 GSDM PMP spatial distribution ellipses centred over Darling Mills Creek Catchment

If we calculate a weighted average depth and intensity for the catchment, we find that this correlates with the B Ellipse depth and intensity.

Table E2-2 summarises the PMF intensities for each of the above approaches for a duration of 15 min (0.25hr).

Table E2-2 PMP Average Rainfall Depth and Average Intensity for Tributary and Overland Flow Catchments

PMP Rings (Darling Mills Creek) Figure 2	Depth (mm)	Intensity (mm/hr)	Weighted Average Depth (mm)	Weighted Average Intensity (mm/hr)
A	162.4	650	133	532
B	135.6	542		
C	124.9	500		