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WARATAH DAM

Downstream hydrology and hydraulic modelling

5 December 2018

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Executive summary

A study on potential impacts of the decommissioning of Waratah Dam on flooding in the town of Waratah has been completed. The objectives of this study are to determine if there are flood mitigation benefits of the Waratah Dam, and whether the dam's decommissioning is likely to have a significant impact on flooding in the town. This study as part of a larger investigation into the decommissioning of this TasWater dam.

Level-discharge ratings have been developed of two hydraulic control structures in the town:

- Weir downstream of the town's upper pond
- Culvert at Smith St

A hydrological rainfall-runoff model of the Waratah Dam reservoir and catchment has been extended down to the town and used to simulate floods for a range of AEPs and design storm durations. A critical design storm duration of 24 hours has been adopted from this work. This model has been used to develop hydrographs for use in hydraulic flood modelling.

A 2D hydraulic flood model of the town has been developed for assessing the impact of removing the upstream Waratah Dam on flooding in the town.

The modelling indicates that the removal of the dam is likely to increase flood levels in Waratah town generally between 0.1 – 0.3 m, with some exceptions at around the 1:5 and 1:10 AEP floods. Modelling indicates that the removal of Waratah Dam will increase the probability of flooding of Smith St from 1:50 AEP to 1:5 AEP. The probability of flooding English St increases from 1:10 to 1:5 AEP. William St (including the William St Bridge) remains unaffected in all modelled scenarios. A floor level survey indicates that while some properties are encroached upon by flood waters for some scenarios, no floor is inundated by any of the modelled scenarios.

The major limitation of this study is the lack of at-site data, specifically hydrometric data and details of the culvert at Smith St. In particular, assumptions regarding the structure of the Smith St culvert have resulted in modelled flood risk that is conservative when compared with anecdotal information of flooding in the town. In addition, it is likely that these assumptions also result in conservative estimates of the potential impact of flooding due to the removal of Waratah Dam.

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1. Introduction

The township of Waratah is located in the north west of Tasmania. Its potable water supply has historically been provided by drawing water from the Waratah River in the town. TasWater is currently in the process of assessing the potential decommissioning of Waratah Dam for the following reasons:

- The risk of a dam crest flood (DCF) is unacceptably high: Waratah Dam has a 1:400 annual exceedance probability (AEP) of a DCF with zero freeboard (Entura 2018). This is less than the ANCOLD (2000) recommended flood capacity requirements for a Significant Consequence Category dam (Entura 2017) of between 1:1,000 and 1:10,000 AEP plus freeboard for wave action.
- A pipe failure has developed through the dam wall with a significant risk (1:2 to 1:5 AEP) of being reached with a minor flood (Entura 2018).
- The dam is in very poor condition with significant leakage even at the lowered reservoir level.
- It is not required to supply potable water to the town of Waratah.

It is noted that piping through the dam embankment at a level of 606.6 m AHD (Australian Height Datum 1983) was detected in 2017, warranting an emergency excavation of the existing spillway to protect the safety of the dam. All analysis conducted by Entura (2018) and this report have been assessed under conditions that existed prior to the emergency spillway excavation (i.e. its pre-2017 condition).

The purpose of this study is to determine if there are significant flood mitigation benefits from the existing dam in the town of Waratah. The rarity of floods is related to the level of service for town infrastructure. This benefit been assessed through hydrological modelling of the Waratah Dam reservoir and catchment and hydraulic flood modelling in the town of Waratah.

1.1 Study area description

A key feature of the town of Waratah is the Waratah River, which runs through its centre. The river flows through two distinct ponds in the town. The ponds are separated by a small weir. This weir is located approximately 50 m to the west of the William St Bridge which crosses the upper pond. The lower pond is controlled by a culvert beneath Smith St which discharges into a waterfall to the north. A smaller side pond to the south of English St is connected to the lower pond via twin 600 mm diameter culverts. These culverts are completely submerged in baseflow conditions.

A map of the town is shown in Figure 1.1. A key street not labelled is Magnet Court, accessed via Que St and located to the South-East of the English St Culvert. There are a number of properties at this location that are in close proximity to the pond.

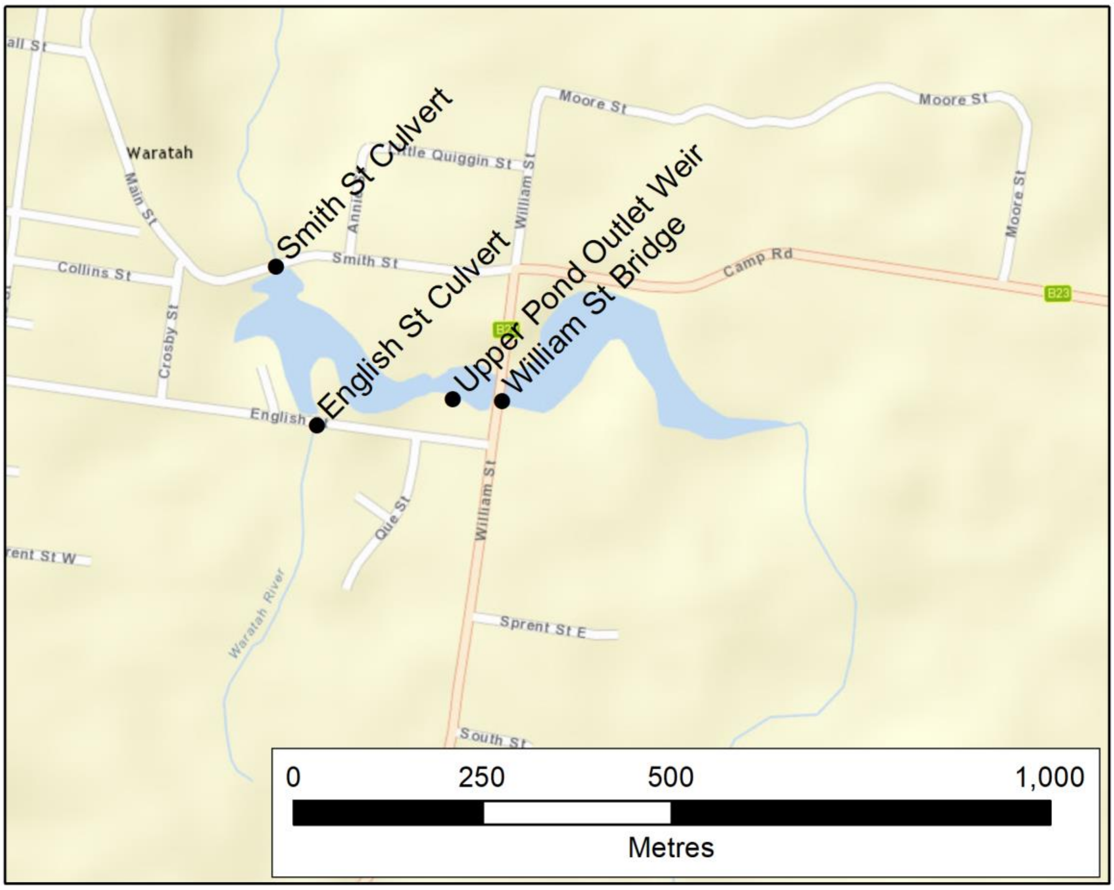


Figure 1.1: Map of Waratah town

2. Data

Aside from a rain gauge in the region managed by Hydro Tasmania (Entura 2018), no hydrometric data is available in the study region.

Entura conducted a terrestrial and bathymetric survey of the town and Waratah River on 22-23 August 2018. This survey has been critical in determining dimensions of hydraulic control structures, specifically the weir connecting the upper and lower pond and the Smith St culvert. LIDAR data provided by Forestry Tasmania has also been used to augment the ground survey. This survey included building floor levels of key properties.

Entura engineers conducted a site visit on Thursday 16th August 2018 to assess the study area and determine influential control structures. The culvert beneath Smith St was found to be the hydraulic control for the lower pond (described in Appendix A.3). No design or as-constructed information is available for this structure (pers. Comms O. Mayer 31st August 2018; N. Fagan 3rd October 2018), aside from its visible intake and outlet.

The lack of available hydrometric data and construction information of the Smith St culvert are the major limiting factors in this study. There was no access to the internal configuration of this structure, so a survey was not possible. The only information available was to the visible inlet and outlet.

An anecdotal summary of flooding at Waratah Town was provided by N. Fagan, Waratah Supervisor for Waratah-Wynyard Council (pers. Comms 3rd October 2018):

- A breach of Waratah Dam around 1975/1976 caused damage around the town. Although the Smith St culvert survived, parts of the road were washed away.
- English St was overtopped during the June 2016 storm, and has been known to overtop at other times.
- Smith St was not overtopped during the June 2016 storm, and apart from the 1975/1076 dam breach, has not overtopped.

3. Modelling

3.1 Hydrological modelling

The purpose of hydrological modelling is to estimate the critical duration of flooding at Waratah and to provide inflow hydrographs for subsequent hydraulic modelling.

This study has approximated the AEP of a dam crest flood as 1:500, in order to simplify the data processing requirements of this project. This will not alter the conclusions, even though the design DCF is approximately 1:400 AEP.

A hydrological model of Waratah Dam catchment and reservoir had been developed by Entura (2018). This model has been extended downstream to include the town of Waratah. The catchment area of the Waratah River at Waratah town is 13.7 km^2, which includes 10 km^2 upstream of Waratah Dam. Due to the absence of at-site hydrometric data, the catchment model has not been calibrated, though has been validated through use of anecdotal information at the dam site (Entura 2018).

The model includes storage routing nodes for the upper and lower ponds. The side pond south of English St has been lumped with the lower pond. Storage level-volume curves were developed from the terrain using HEC-RAS software. Outflow ratings of these ponds were developed using 1-dimensional HEC-RAS models of the structures.

Design rainfalls were obtained for the Waratah Dam catchment from the previous study (Entura 2018). As the additional catchment area for the town is very small (an additional 3.7 km^2), it has been determined that these design rainfalls would be suitable for this study. The same approach to design flood modelling as applied by Entura (2018) was used in this study, i.e. ensemble event modelling using design burst with Australian Rainfall and Runoff (Ball et al 2016) point temporal patterns (Geoscience Australia 2017), uniform spatial pattern and same design losses.

1920 design model runs were constructed and run by varying the following parameters:

- AEP (8 AEPs from 1:2 to 1:500)
- Design storm duration (12 durations between 6 hours and 168 hours)
- 10 temporal patterns per ensemble
- 2 conditions for Waratah Dam: present and not present

Results were compared and reported on at the upper and lower pond locations. The impact of removing Waratah Dam was determined to have a greater change on the lower pond water levels (Figure 3.1).

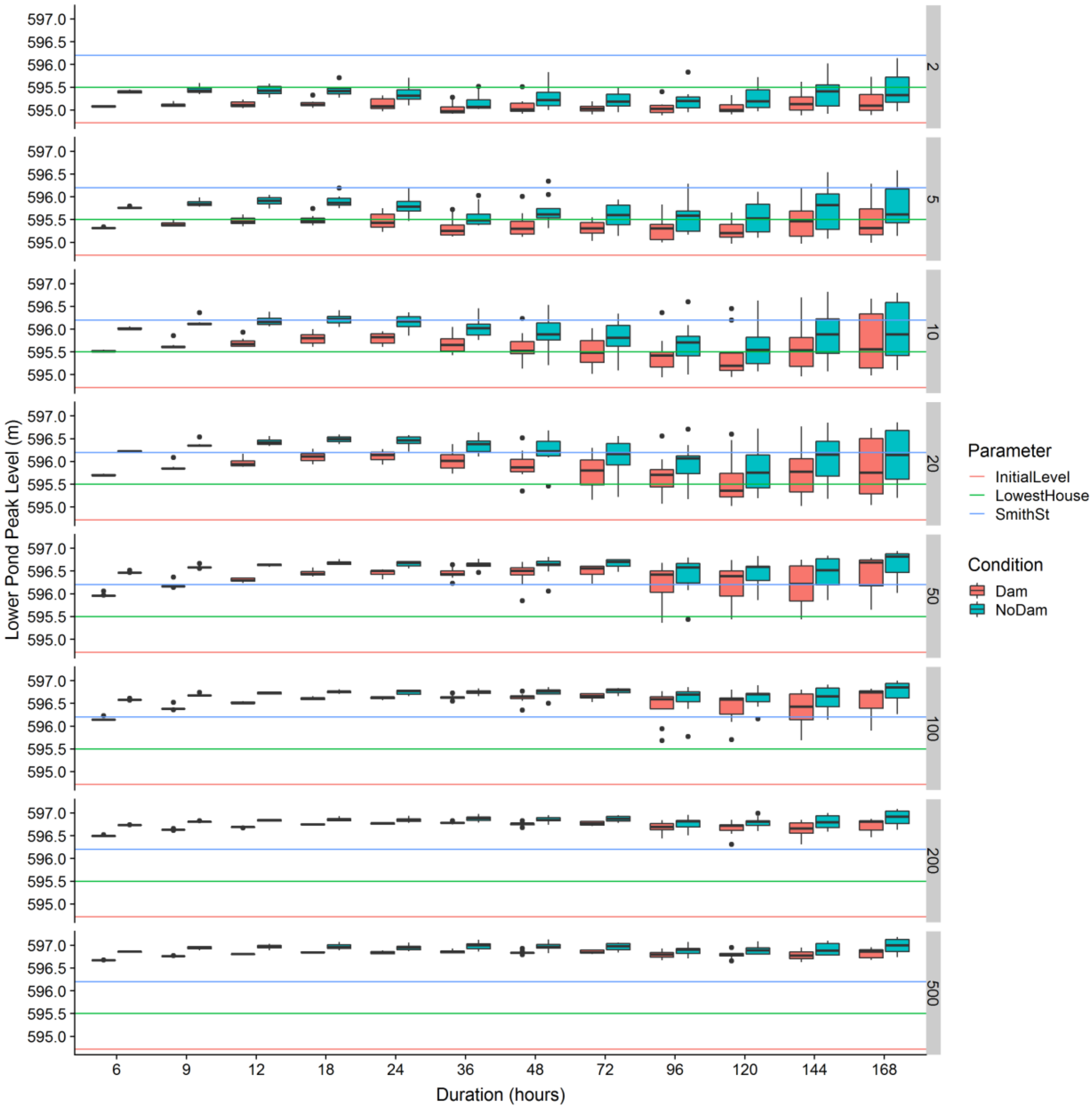


Figure 3.1: Summary of hydrological modelling results for the lower pond by duration, AEP (side column, 1:X) and dam condition given median, and 25th and 75th percentile box plots

From inspection of these results, it was decided to adopt 24 hours as a nominal critical duration for all durations. This was based on the relative insensitivity of water level change to storm duration, 24 hours producing a large response across a range of AEPs, and using a duration that reduced model run times. The degree of flood mitigation provided by the dam with the simplified hydrological appears to be approximately 0.1 – 0.5 m across durations and AEPs. The detailed hydraulic model was used to check these calculations (Section 3.2).

Mid-range events for the 24 hour duration of each AEP and dam condition, and hydrographs were extracted for use in hydraulic flood modelling (Figure 3.2). The hydraulic model requires hydrographs at three locations, referred to as A, B and C; locations are given in Figure 3.3. Hydrograph A is downstream of Waratah Dam; thus, hydrographs are provided for this location under two conditions:

- No dam
- With dam (pre-2017 condition)

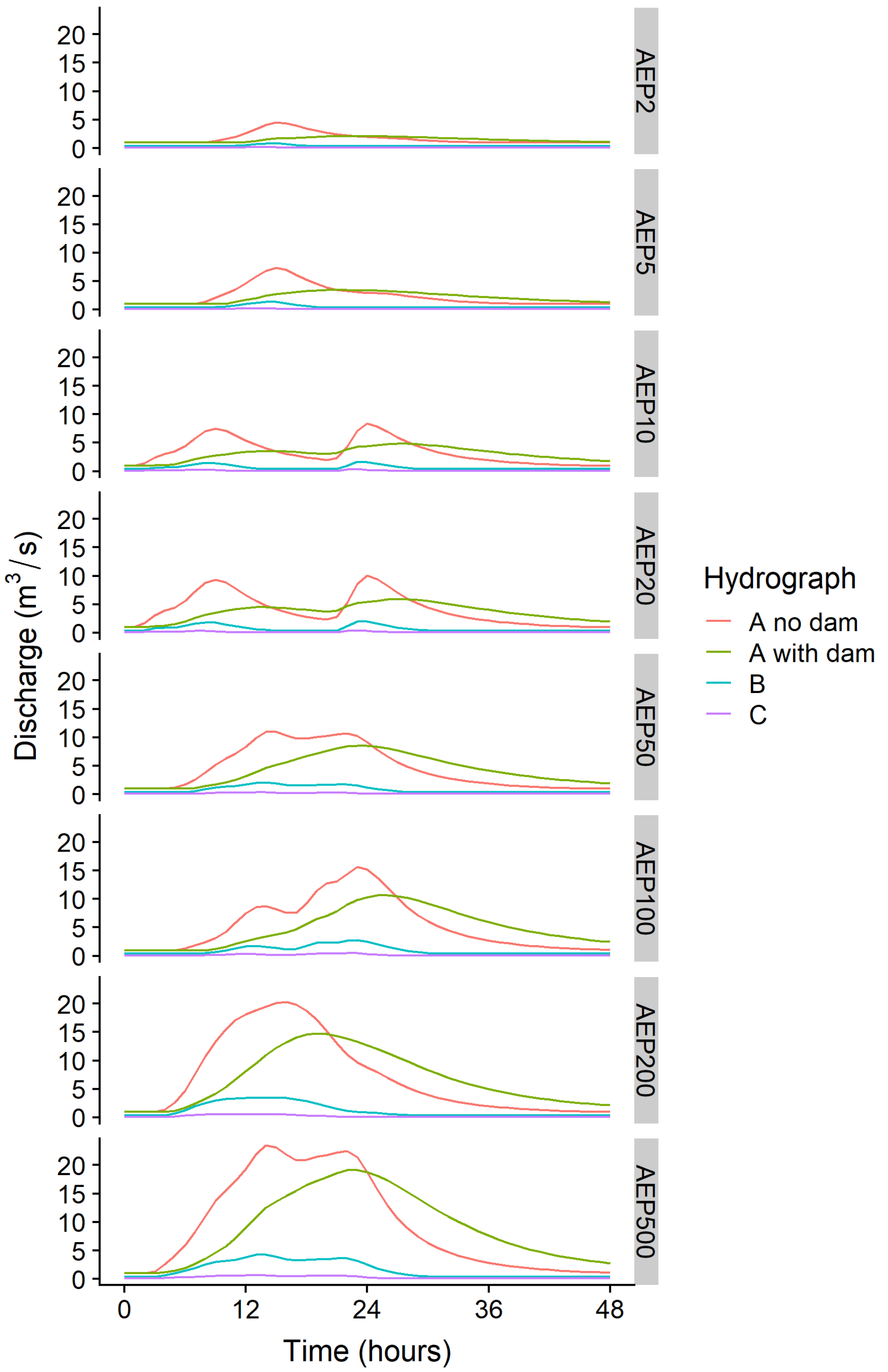


Figure 3.2: Design flood hydrographs used for hydraulic modelling (all from a 24 hour design storm). Locations are given in Figure 3.3. Location “A” is downstream of Waratah Dam, so inflow hydrographs (to the town) are provided in both scenarios

3.2 Hydraulic modelling

A 2-dimensional hydraulic model of Waratah has been developed to assess flood impact in the town using HEC-RAS software (version 5.05) as follows:

- A 1 m resolution digital terrain model was developed from LIDAR and bathymetry and augmented as follows:
    - The Upper Pond Outlet Weir was updated using survey and bathymetry data
    - The channel upstream and downstream of the English St culvert was modified to ensure the channel was lower than the culvert inverts
- Critical structures were added to the model (see Section 3.2.1)
- Break lines at critical locations were used to give better mesh alignment with flow direction
- Computation mesh were generated at a nominal 5 m resolution
- Boundary conditions were created:
    - Three inflow hydrographs (referred to as A, B, and C)
    - A normal-depth outflow boundary condition was assigned at the outlet with a friction slope of 0.5 (1 vertical: 2 horizontal)

The layout of the model is given in Figure 3.3.

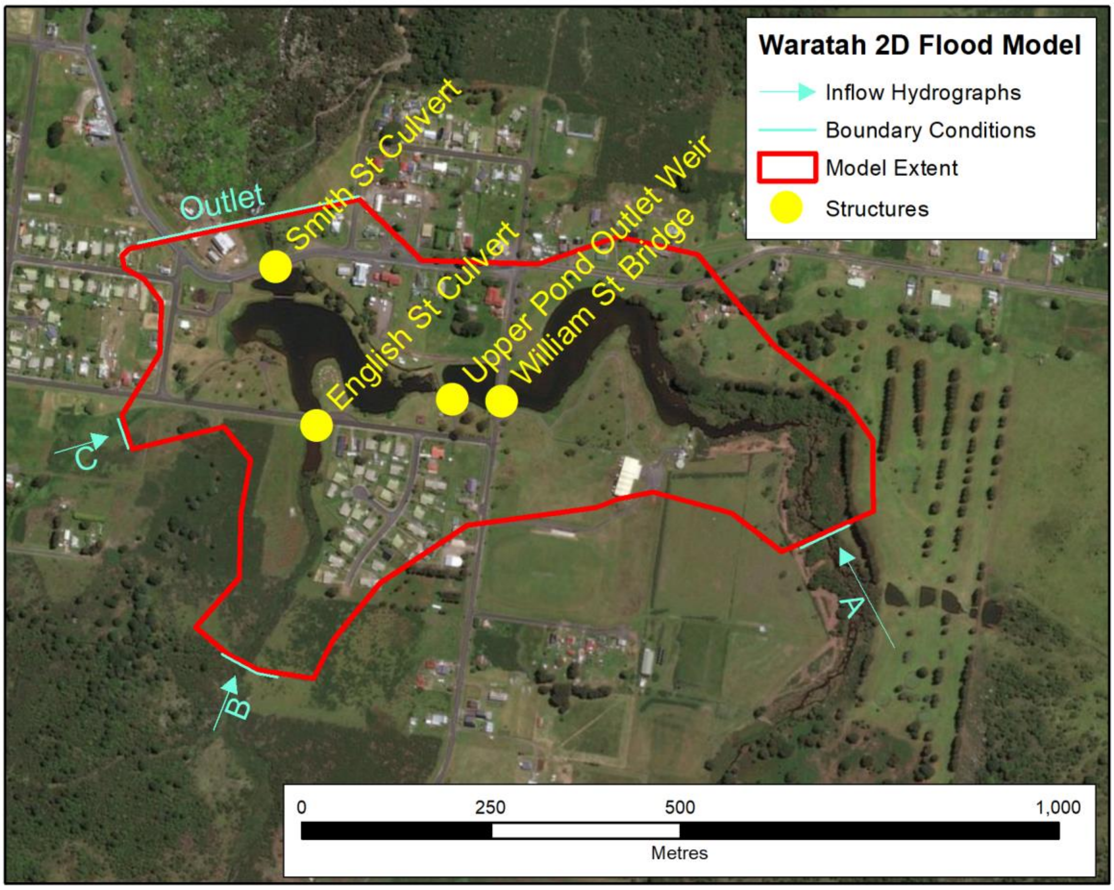


Figure 3.3: Key components of the 2D hydraulic model of Waratah

3.2.1 Structures

Four structures were represented in the model:

1. The William St Bridge

2. The upper pond outflow weir (also developed as a 1D model to develop an outflow rating for the upper pond: see Appendix B)
3. The culverts at English St
4. The Smith St Culvert (also developed as a 1D model to develop an outflow rating for the lower pond: see Appendix B). The geometry of the culvert was approximated, roughly calibrated to conditions observed at the site visit (August 2018). The lack of information on this culvert is a key limitation to this study.

Details of these structures are given in Appendix A. A rail bridge just upstream and to the south of the Smith St culvert was not explicitly modelled as it was not determined to have any significant impact on flooding as the deck soffit was above the flood water levels.

3.2.2 Initial conditions

The model was run in steady state conditions in order to establish baseflow conditions, and water levels in the ponds similar to those surveyed. The model was run for a 24 hour simulation period with the following steady state inflows:

- Location A: 1.0 m^3/s
- Location B: 0.4 m^3/s
- Location C: 0.1 m^3/s

Steady state modelled pond levels were compared with surveyed levels (Table 3.1) and were found to be suitable. The water levels at the end of this steady state simulation were used as initial conditions for the flood model simulations.

Table 3.1: Comparison of surveyed level and initial condition modelled level

Location	Surveyed level (m)	Steady state modelled level (m)	Difference (m)
Upper Pond	597.764	597.718	0.046
Lower Pond	594.717	594.782	-0.065

3.2.3 Flood modelling

The 2D hydraulic flood model was run for each of the AEPs under consideration under each of the considered dam conditions, using inflow hydrographs (Figure 3.2) and initial conditions (Section 3.2.2). The simulation period was 48 hours, with storms with rainfall that stopped at 24 hours.

4. Results and analysis

At each AEP, flood depths and flood extents were compared for the two Waratah Dam conditions (i.e. existing with the dam and with no dam). Flood maps are presented in Appendix C.1 and tabulated depths at key reporting locations are presented in Appendix C.2.

There is a discrepancy between the results and the anecdotal evidence of no overtopping of Smith St during the 2016 flood (or for any other natural flood in recent history) provided by Noel Fagan (Section 2). This discrepancy is attributed to the lack of detail of the Smith St culvert and its potential capacity to pass higher flows. It is expected that the modelled culvert results in conservative flood assessments of the lower pond. Furthermore, given that the modelled culvert is very restrictive for low flows, any difference between the dam and no dam scenarios is likely to be more pronounced, and therefore also conservative.

Waratah Dam provides some flood mitigation benefit for the town of Waratah on flow rates; the attenuation effects of storm discharge can be seen in Figure 3.2. That is, with the dam removed, the flood inflows to the town are higher for the same storm. These potential changes due to the proposed removal of the dam are on interest if they are significant and in areas that change the risk of flooding for points of interest. The main points of interest are dwellings, roadways and other areas of high population. The change in water flood levels due to the proposed dam removal are not uniform around the town. There is a significant difference of this mitigation benefit between the upper and lower ponds.

- There is very little impact of the proposed dam removal in the upper pond, with only 0.1 – 0.2 m change in flood depths at a range in AEPs, and negligible increase in flood inundation extent.
- The impact is greater in the lower pond, where there is generally a 0.1 – 0.3 m change in water level due to the proposed removal of the dam
- For frequent AEP storms (1:5 AEP, 1:10 AEP, at some locations, there is up to a 0.7 m increase at the English St culvert; this is attributed to the limitations of the modelled Smith St culvert at low flows
- Modelling indicates that the removal of Waratah Dam will increase the probability of flooding of Smith St from 1:50 AEP to 1:5 AEP

The following analysis acknowledges the limitations of available data on the results of this study.

Results indicate that in the pre-2017 condition with the dam in place, both Smith St and English St overtop with relatively high probabilities. Smith St has an overtopping risk of between 1:20 and 1:50 AEP, while English St has an overtopping risk of 1:10 AEP. With the dam removed, these risks change to 1:5 AEP for each street.

The most likely points of interest to be impacted by the removal of the dam are the houses on Magnet Court. These houses will have changes in water level of 0.5 m on the ground near them.

Flood mapping (Appendix C) indicates that some properties are affected by flooding, for scenarios with AEPs of 1:50 and rarer. For the most extreme flooding that was modelled (ie the 1:500 AEP no dam scenario), the floor level of the lowest property (3 Magnet Court at 597.5 m) was approximately 0.4 m above the maximum surface elevation of the flooding (597.1 m).

5. Conclusions and recommendations

Although Waratah Dam provides some mitigation to flooding of the town of Waratah, the most influential feature appears to be the Smith St culvert, as it is the hydraulic control for the majority of flood affected areas, including areas south of English St.

In general there is likely to be an increase in water level around the two ponds of 0.1 - 0.3 m due to the removal of the dam for storms of a rarity important to typical town infrastructure risk profiles.

The increase of flood depth around English St may be higher, up to 0.7 m for frequent events (1:5 – 1:10 AEP). Modelling indicates that the removal of Waratah Dam will increase the probability of flooding of Smith St from 1:50 AEP to 1:5 AEP. The probability of flooding English St increases from 1:10 to 1:5 AEP. William St (including the William St Bridge) remains unaffected in all modelled scenarios.

The floor level survey indicates that no floor is inundated by any of the modelled scenarios.

If more certainty around these results is required, it is recommended that a more rigorous analysis of the Smith St culvert is performed, in order to obtain a better estimate of the flooding in the lower pond. This would require more detailed information or survey within the culvert, which would require some form of flow diversion to enable access.

6. References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) 2016, Australian Rainfall and Runoff (AR&R): A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia), <http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com> 2016.

Entura 2017, Waratah, Grey Mountain No. 1 & No. 2 Dams Reservoir level reduction risk reassessment, ENTURA-CC492, 22 February 2017

Entura 2018, Waratah Dam Flood Attenuation Study, E307175/P513927 ENTURA-F1C8B, Monday 30th April 2018

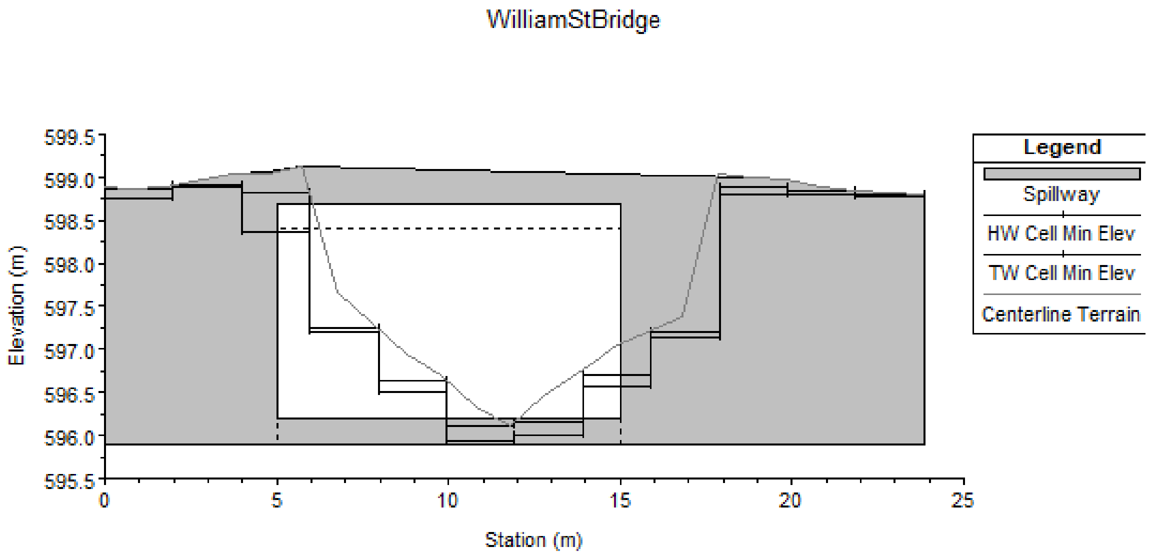
Geoscience Australia 2017, ARR Data Hub, <http://data.arr-software.org>, accessed 27th March 2018

Appendices

A Hydraulic model control structures

A.1 William St Bridge

A



b

Figure A.1: William St Bridge (a) as modelled in HEC-RAS (b) photo looking upstream

A.2 English St Culvert

The culverts under English St are twin 600 mm diameter pipes. They are fully submerged in baseflow conditions.

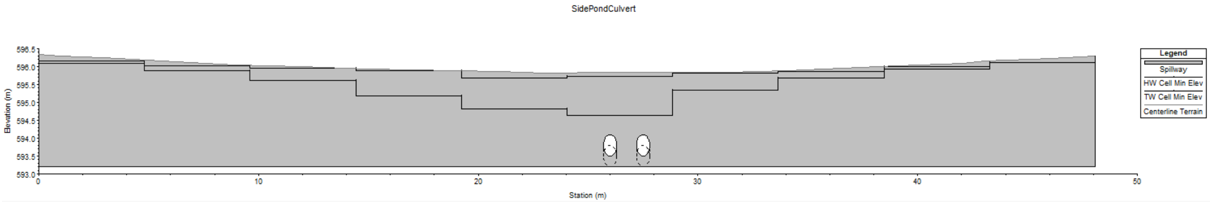


Figure A.2: English St Culverts as modelled in HEC-RAS

A.3 Smith St Culvert

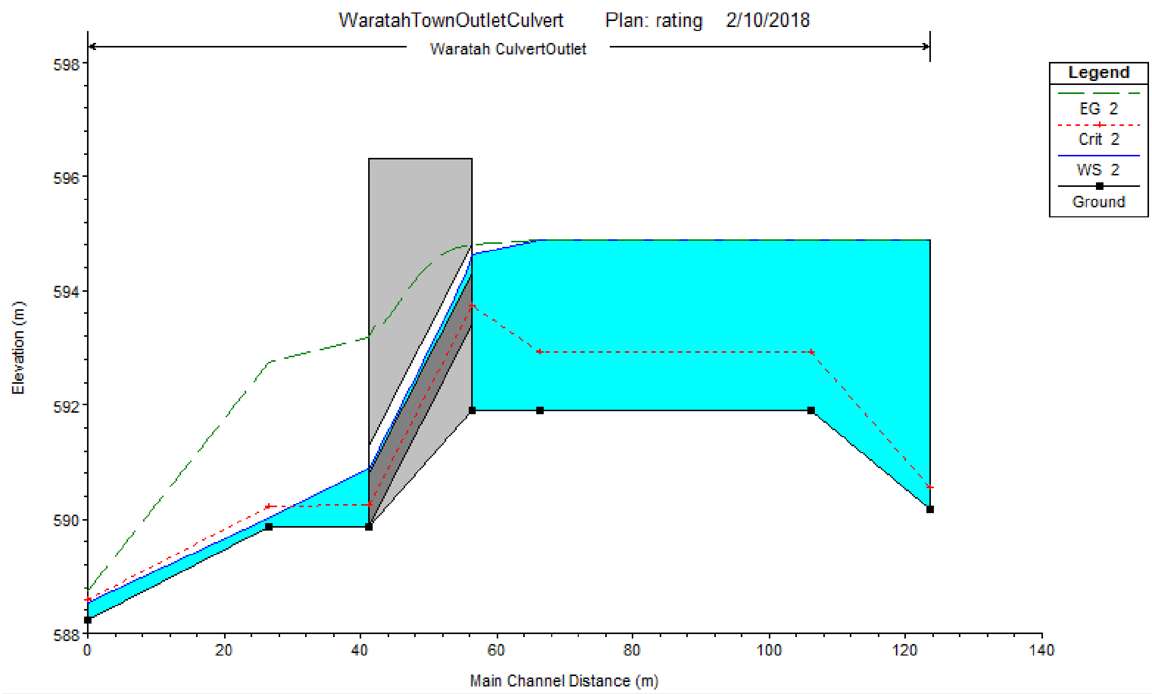
The Smith St culvert is the main hydraulic control for the lower pond. The inlet is a 3.3 m wide x 1.4 m high box, while the outlet is a 1.8 m diameter pipe. The change in level along the culvert is approximately 4 m and the structure is inlet-controlled. The internal construction is unknown. Waratah-Wynyard Council was approached to determine what plans were available, however none were.

The conditions on 6th September 2018 (the date of the site visit) had the lower pond water level approximately the same as the obvert of the intake. Although no hydrometric records were available, it was estimated that discharge through the structure could be no more than 1-2 m^3/s.

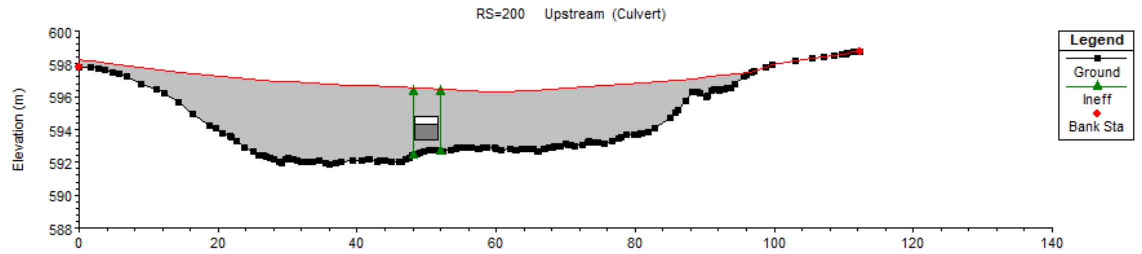
The culvert was modelled as a simple box culvert. In order to represent the observed water level with the assumed low discharge, a blockage was modelled in the structure.

Given that the flood frequency of the lower pond does not reconcile with anecdotal evidence of flooding, it is likely that this culvert model under-represents its discharge. As a result, flood modelling is likely to be conservative.

a


WaratahTownOutletCulvert Plan: rating 2/10/2018
Waratah CulvertOutlet
Legend
EG 2
Crit 2
WS 2
Ground
Elevation (m)
Main Channel Distance (m)

b


RS=200 Upstream (Culvert)
Legend
Ground
Ineff
Bank Sta
Elevation (m)

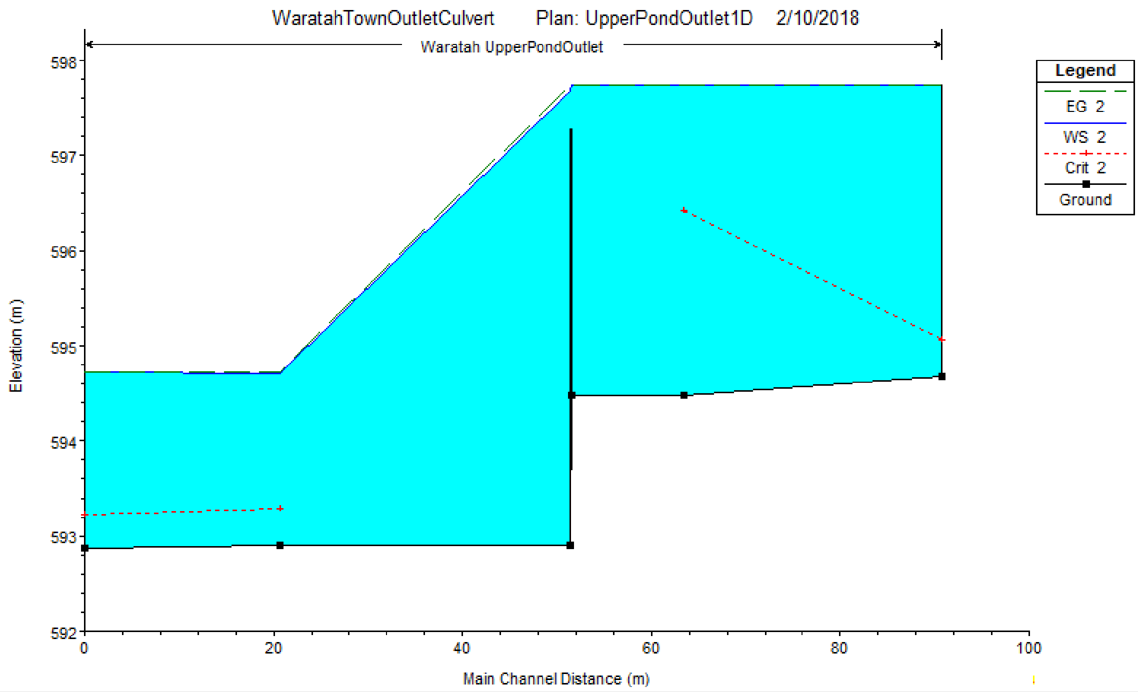
c

d

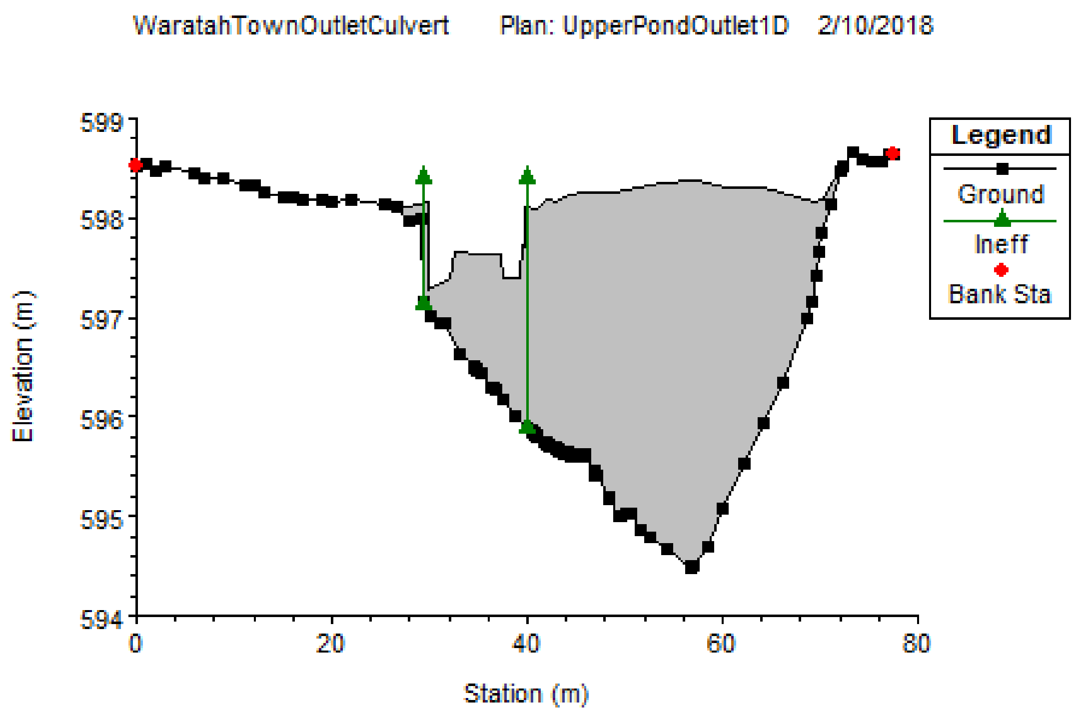
Figure A.3: Smith St Culvert (a) longitudinal profile with 2 m^2/s discharge (b) cross section (c) outlet photo (d) photo of the upstream face

A.4 Upper pond outlet weir

a



b



c

Figure A.4: Upper Pond outlet weir (a) longitudinal profile with 2 m^2/s discharge and (b) cross section (c) photo

B Discharge rating development and comparison

Discharge ratings for the upper pond outlet weir (Appendix 0) and the lower pond outlet culvert under Smith St (Appendix A.3) using 1D HEC-RAS models. These ratings are compared (with surveyed water surface elevation) in Figure B.1.

Note from Figure B.1 that the level scale (y-axis) is the same. A striking feature of the comparison of these ratings is the difference in efficiency between these two outlets: the upper pond outlet weir allows for relatively high discharge for a minor increase in level; this indicates that it can pass relatively high floods without a significant increase in level. Conversely, the lower pond will have a significant increase in level for similar flood magnitudes. Smith St will overtop when discharges exceed 6-7 m^3/s.

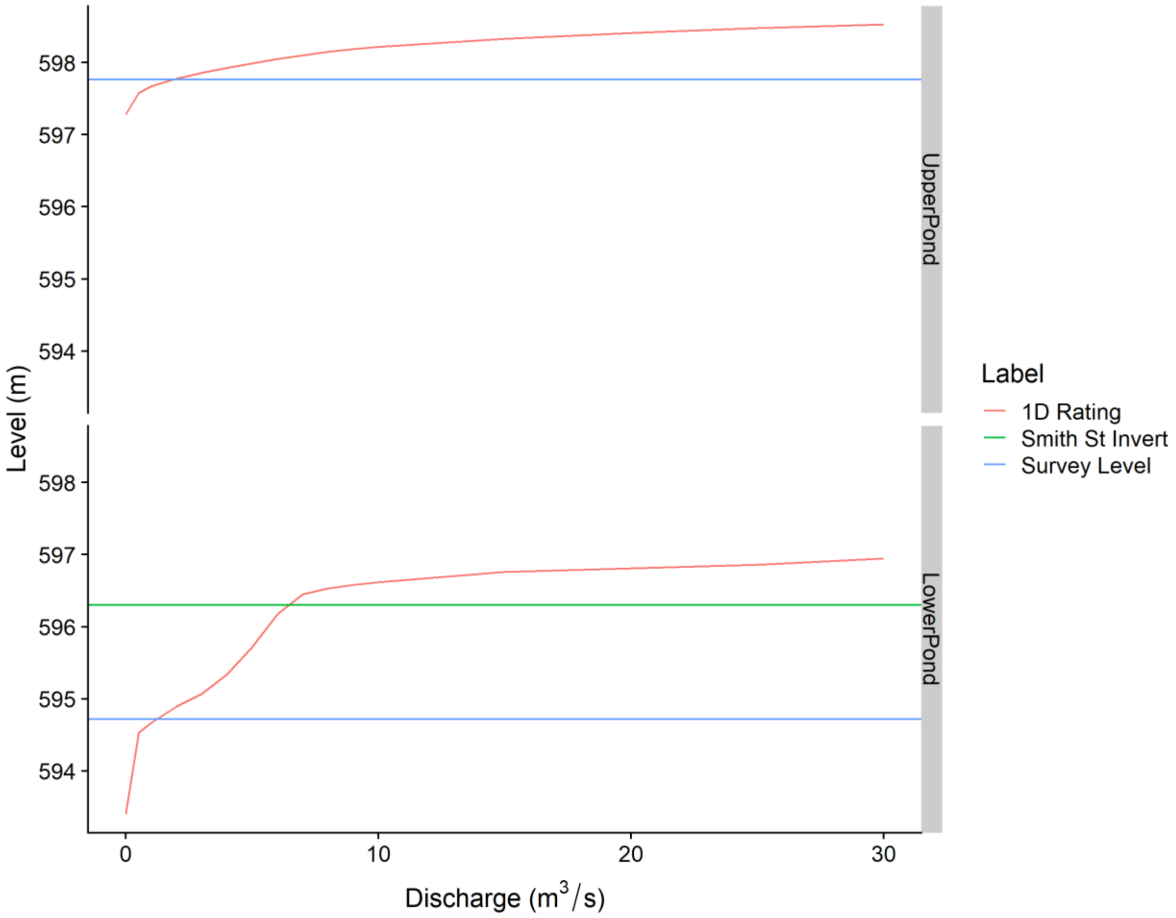


Figure B.1: Level-discharge ratings for the upper pond outlet weir (UpperPond) and the lower pond outlet culvert under Smith St (LowerPond)

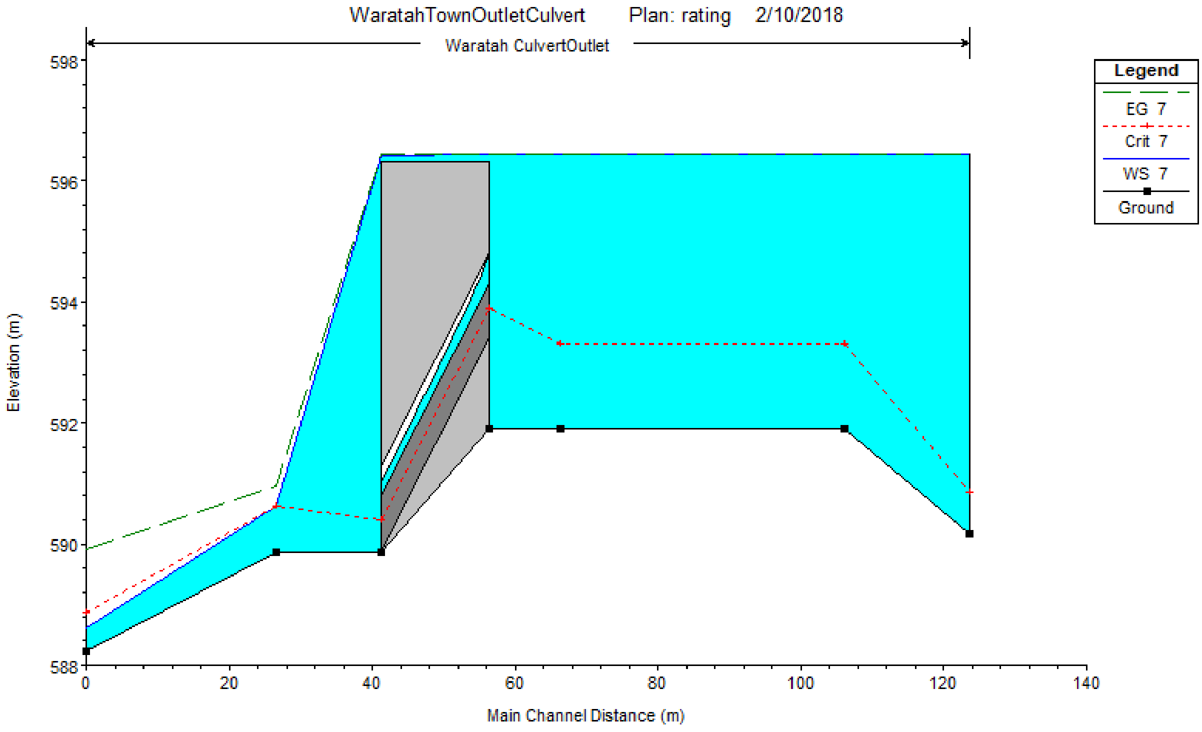
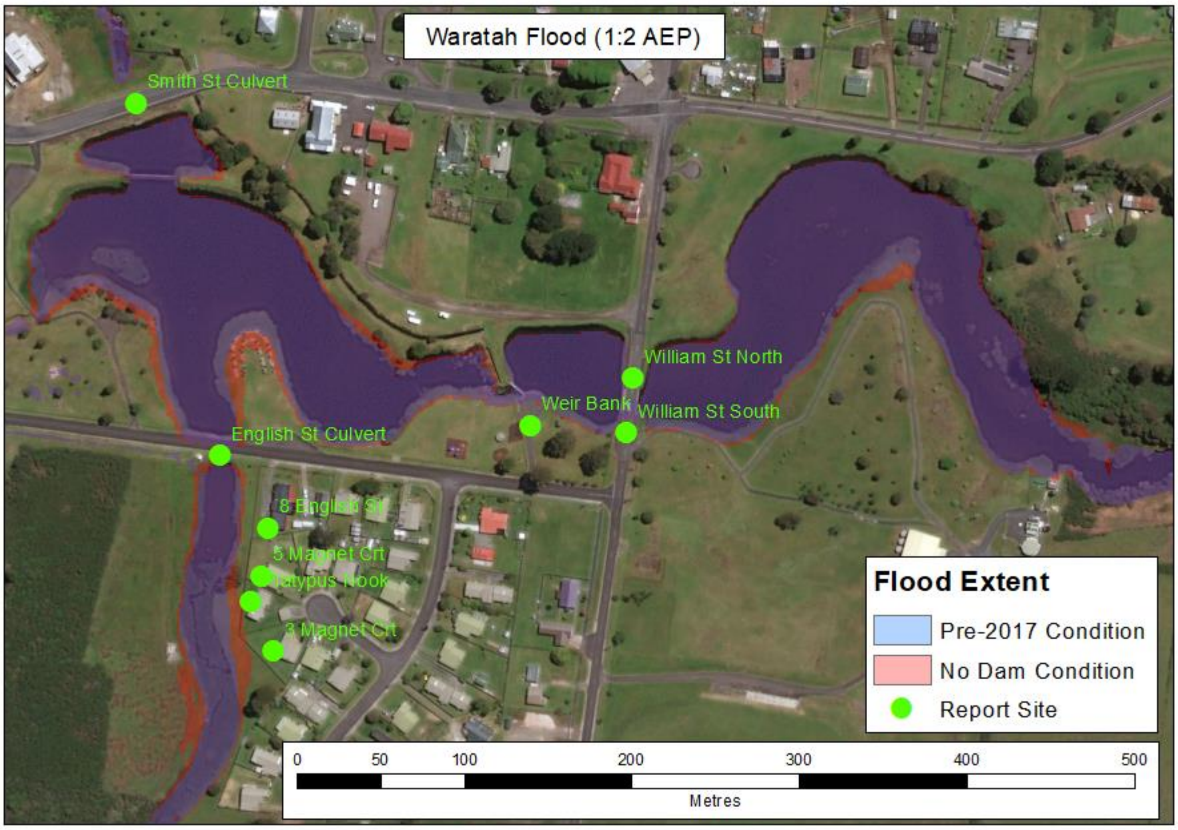
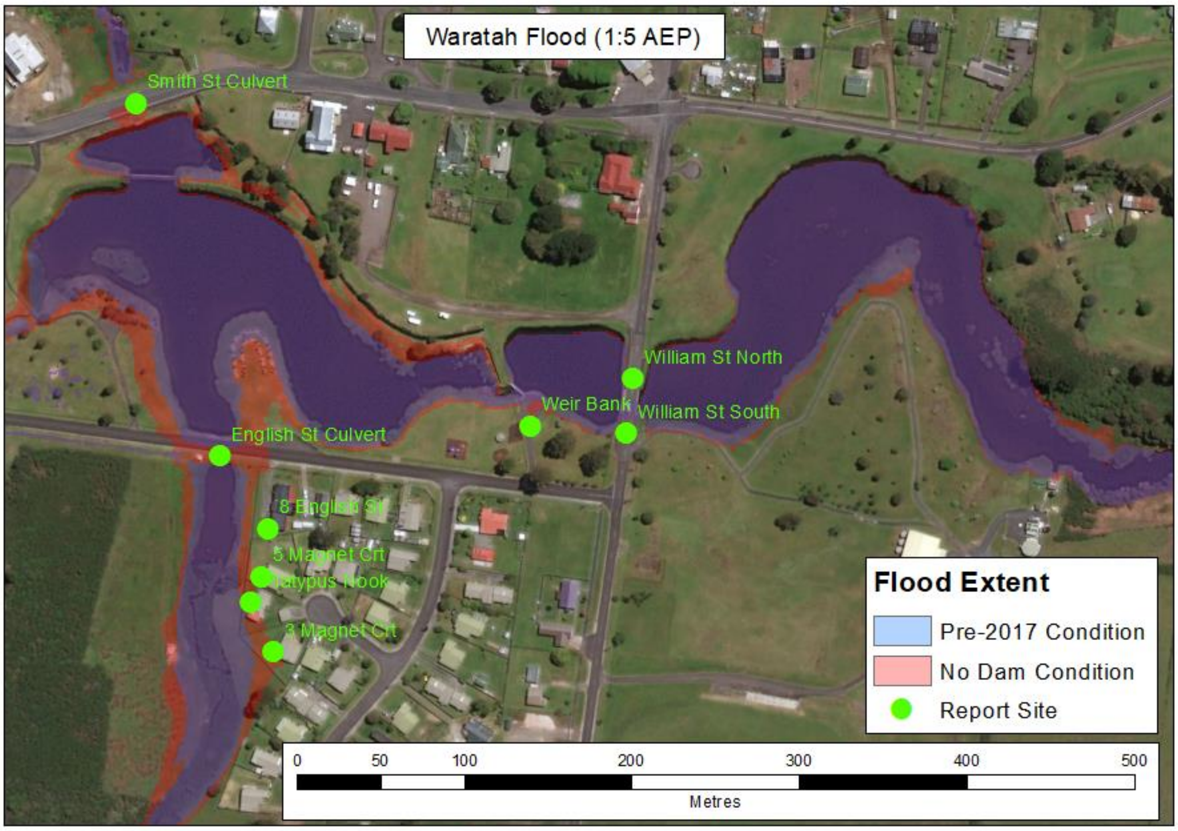


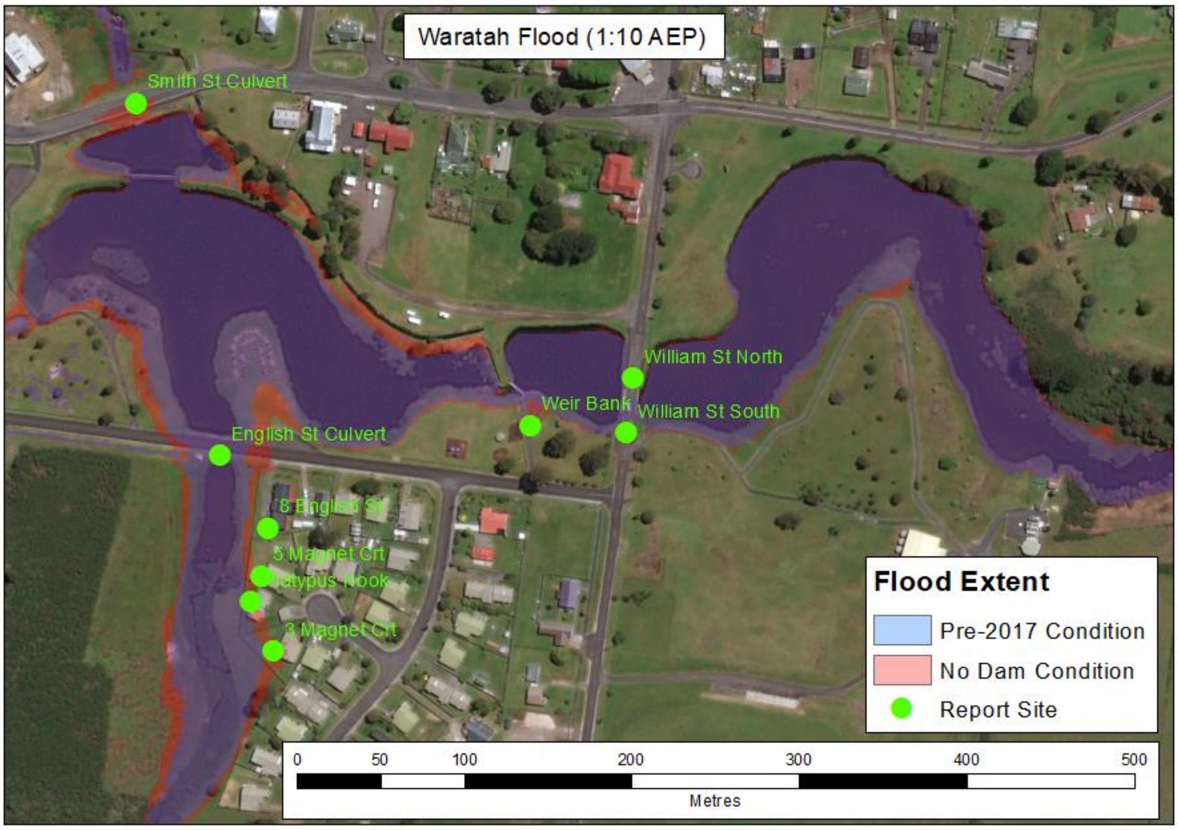
Figure B.2: 1D HEC-RAS model of Smith St culvert used for ratings development: Smith St overtops with 7 m^3/s of discharge

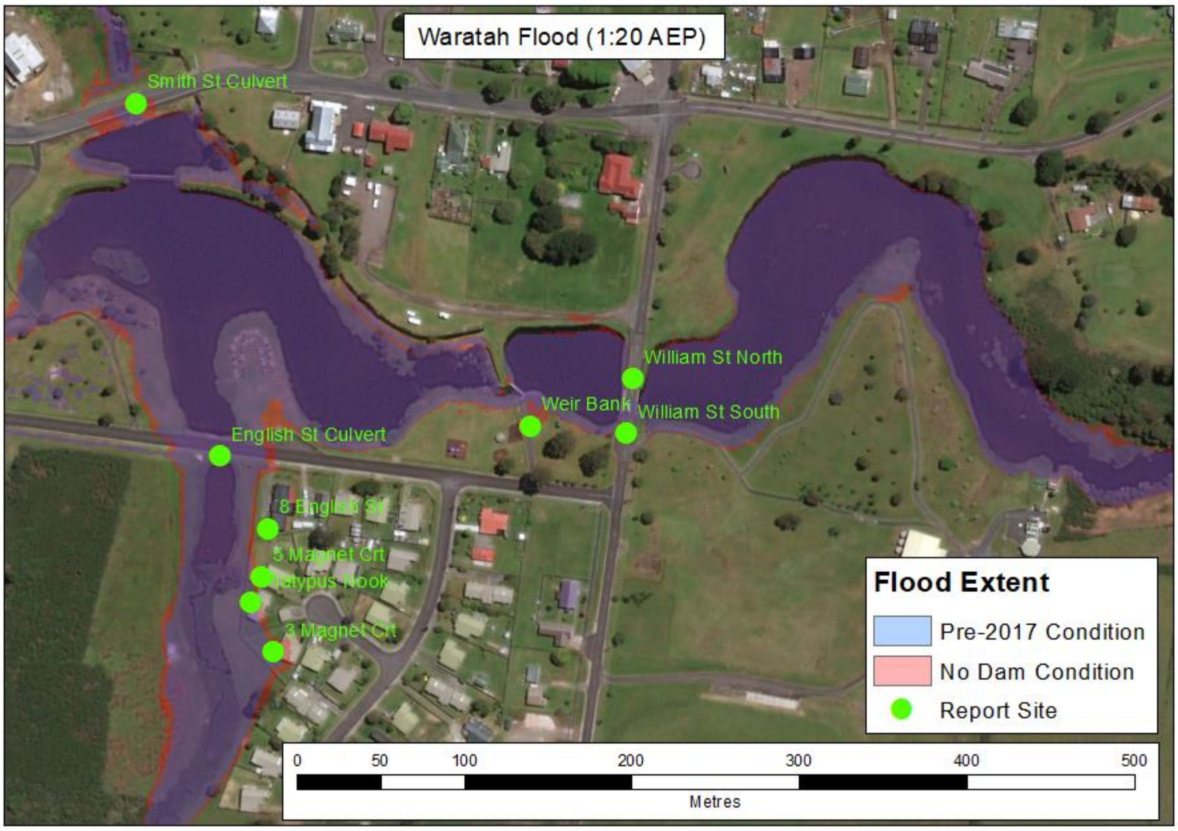
C Modelling results

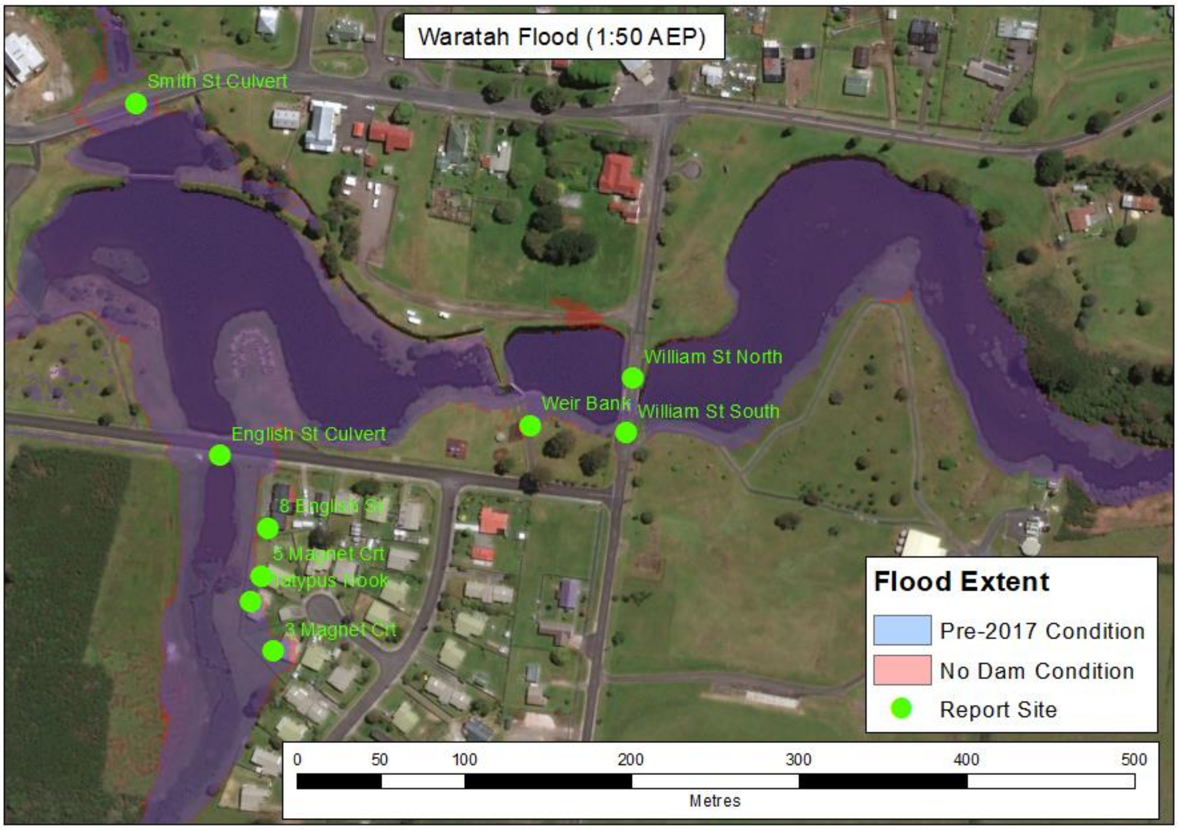
C.1 Flood maps

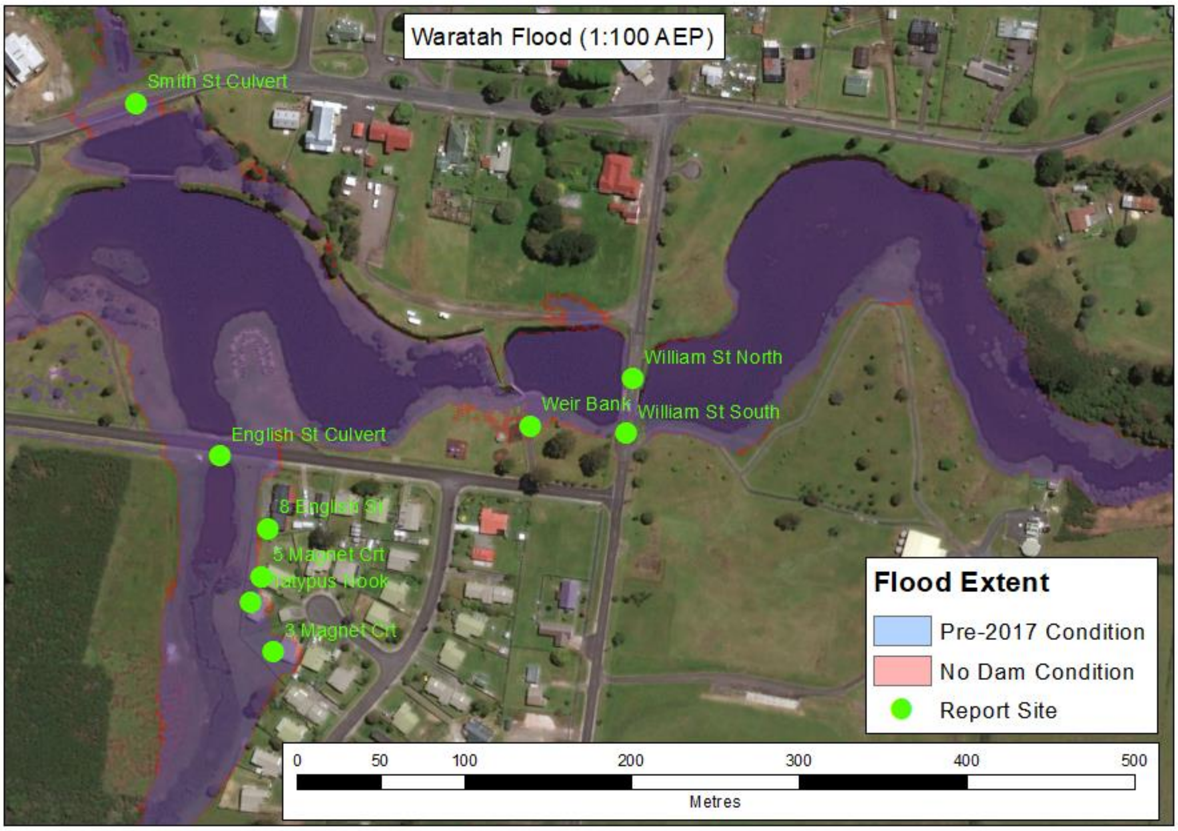


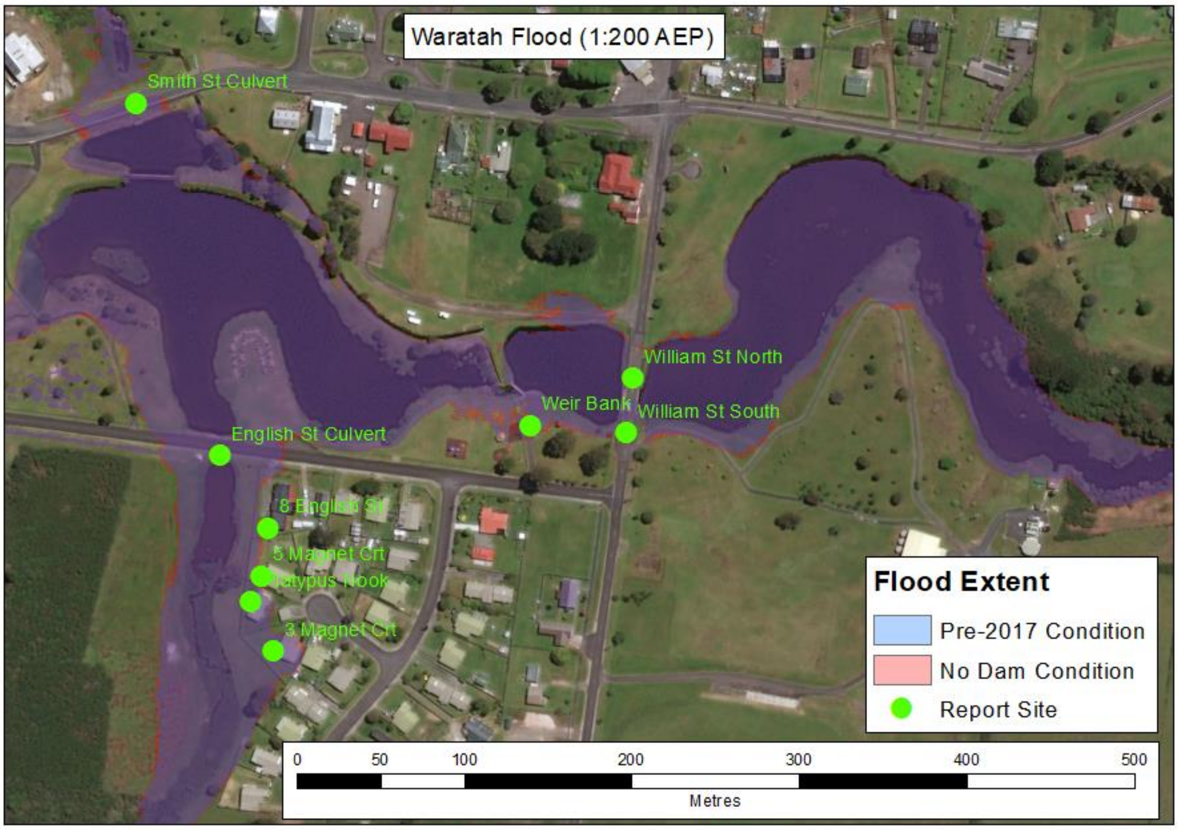

Waratah Flood (1:5 AEP)
Smith St Culvert
William St North
Weir Bank
William St South
English St Culvert
8 English St
5 Magnet Crt
Platypus Nook
3 Magnet Crt
Flood Extent
Pre-2017 Condition
No Dam Condition
Report Site
0 50 100 200 300 400 500
Metres

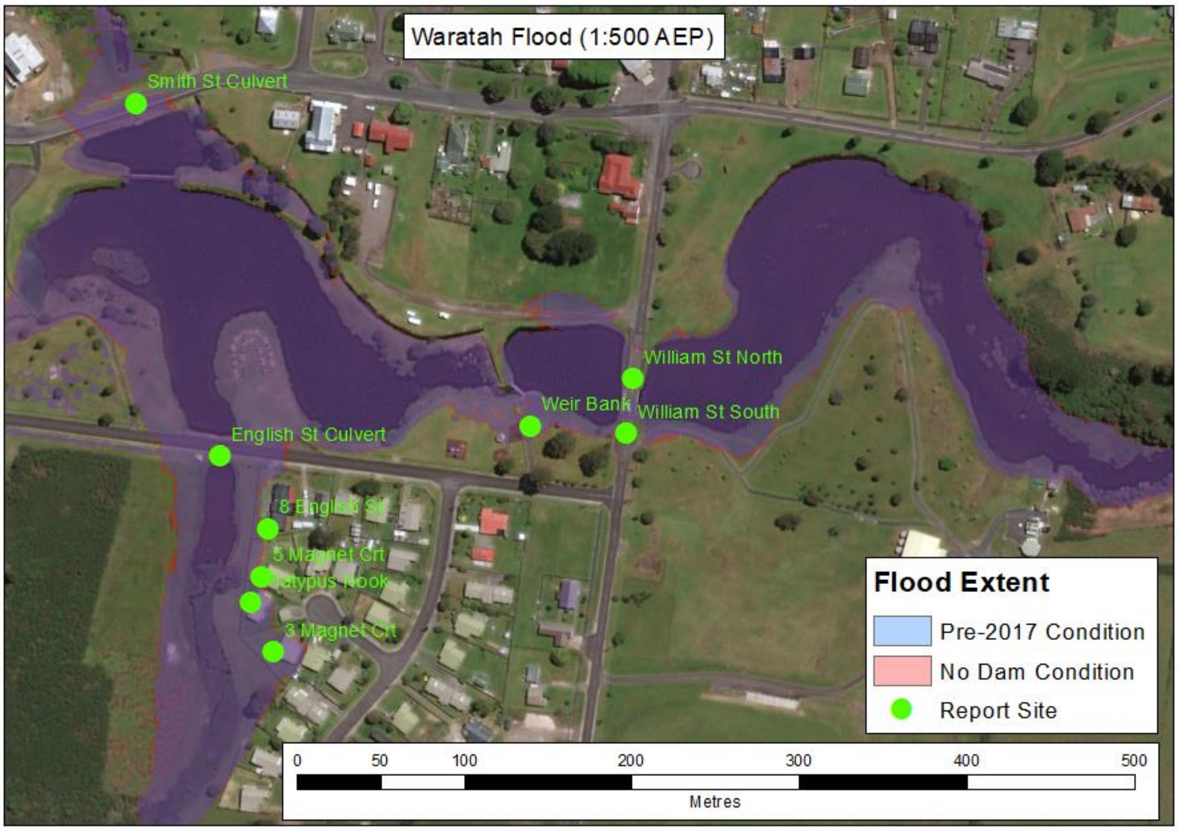

Waratah Flood (1:10 AEP)
Smith St Culvert
William St North
Weir Bank
William St South
English St Culvert
8 English St
5 Magnet Crt
Platypus Nook
3 Magnet Crt
Flood Extent
Pre-2017 Condition
No Dam Condition
Report Site
0 50 100 200 300 400 500
Metres


Waratah Flood (1:20 AEP)
Smith St Culvert
William St North
Weir Bank
William St South
English St Culvert
8 English St
5 Magnet Crt
Platypus Nook
3 Magnet Crt
Flood Extent
Pre-2017 Condition
No Dam Condition
Report Site
0 50 100 200 300 400 500
Metres


Waratah Flood (1:50 AEP)
Smith St Culvert
William St North
Weir Bank
William St South
English St Culvert
8 English St
5 Magnet Crt
Platypus Nook
3 Magnet Crt
Flood Extent
Pre-2017 Condition
No Dam Condition
Report Site
0 50 100 200 300 400 500
Metres


Waratah Flood (1:100 AEP)
Smith St Culvert
William St North
Weir Bank
William St South
English St Culvert
8 English St
5 Magnet Crt
Platypus Nook
3 Magnet Crt
Flood Extent
Pre-2017 Condition
No Dam Condition
Report Site
0
50
100
200
300
400
500
Metres


Waratah Flood (1:200 AEP)
Smith St Culvert
William St North
Weir Bank
William St South
English St Culvert
8 English St
5 Magnet Crt
Platypus Nook
3 Magnet Crt
Flood Extent
Pre-2017 Condition
No Dam Condition
Report Site
0
50
100
200
300
400
500
Metres



C.2 Tabulated peak flood depths

Flood depths at a number of reporting sites and for each AEP/dam condition are presented in Table C.1. The locations of the reporting sites are provided in the flood maps presented in Appendix C.1.

There was no flooding for any condition at any AEP for the following reporting sites:

- 5 Magnet Crt
- 8 English St
- William St North
- William St South

Table C.1: Comparison of flood depth by reporting site, AEP and condition of Waratah Dam; ground locations only (not floor level survey)

		Flood depth (m) by condition		Incremental flood depth (m)
Report Site	**AEP (1 in X)**	**Pre-2017**	**No Dam**	**Difference**
4 Magnet Crt (Platypus Nook)	2			
4 Magnet Crt (Platypus Nook)	5		0.1	0.1
4 Magnet Crt (Platypus Nook)	10		0.2	0.2
4 Magnet Crt (Platypus Nook)	20	0.0	0.3	0.3
4 Magnet Crt (Platypus Nook)	50	0.3	0.4	0.1
4 Magnet Crt (Platypus Nook)	100	0.4	0.5	0.1
4 Magnet Crt (Platypus Nook)	200	0.5	0.6	0.1
4 Magnet Crt (Platypus Nook)	500	0.6	0.7	0.1
3 Magnet Crt	2			
3 Magnet Crt	5		0.4	0.4
3 Magnet Crt	10		0.5	0.5
3 Magnet Crt	20	0.3	0.6	0.3
3 Magnet Crt	50	0.6	0.7	0.1
3 Magnet Crt	100	0.7	0.8	0.1
3 Magnet Crt	200	0.8	0.9	0.1
3 Magnet Crt	500	0.9	1.0	0.1
English St Culvert	2			
English St Culvert	5		0.7	0.7
English St Culvert	10	0.2	0.8	0.6
English St Culvert	20	0.6	0.9	0.3
English St Culvert	50	0.9	1.0	0.1
English St Culvert	100	0.9	1.1	0.1
English St Culvert	200	1.1	1.2	0.1
English St Culvert	500	1.2	1.2	0.1

		Flood depth (m) by condition		Incremental flood depth (m)
Report Site	**AEP (1 in X)**	**Pre-2017**	**No Dam**	**Difference**
Smith St Culvert	2			
Smith St Culvert	5		0.1	0.1
Smith St Culvert	10		0.2	0.2
Smith St Culvert	20		0.3	0.3
Smith St Culvert	50	0.3	0.4	0.1
Smith St Culvert	100	0.4	0.5	0.1
Smith St Culvert	200	0.5	0.6	0.1
Smith St Culvert	500	0.5	0.6	0.1
Weir Bank	2			
Weir Bank	5			
Weir Bank	10			
Weir Bank	20			
Weir Bank	50		0.0	0.0
Weir Bank	100	0.0	0.1	0.1
Weir Bank	200	0.1	0.1	0.0
Weir Bank	500	0.1	0.1	0.0