WINGECARRIBEE SHIRE COUNCIL

Review of Whites Creek

Floodplain Risk Management Study & Plan

Final Report

Volume 1 of 2: Report Text & Appendices





Revision 3
February 2020

Catchment Simulation Solutions

Review of Whites Creek

Floodplain Risk Management Study & Plan

Final Report

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EXECUTIVE SUMMARY

Overview

The Whites Creek catchment is located in the Southern Highlands of New South Wales. It drains a 7 square kilometre catchment in a north westerly direction through Moss Vale before draining into the Medway Rivulet and into the Wingecarribee River. The extent of the Whites Creek catchment draining through Moss Vale is shown in **Figure ES1** on the following page.

During periods of heavy rainfall across the catchment, there is potential for flooding to occur as a result of major watercourses overtopping their banks and "overland" flooding when the capacity of the local stormwater system is exceeded. Flooding has been experienced on a number of occasions, particularly across Lackey Road, Railway Street and the Illawarra Highway/Argyle Street.

The *'Whites Creek Floodplain Risk Management Study'* (URS) was prepared in 2012, outlining a range of measures that could be potentially implemented to better manage the existing and potential future flood risk across the Whites Creek catchment at that time. Since this study was completed, technological updates, as well as changes to development in the catchment that may impact flood behaviour, necessitate a review and update the floodplain risk management study and plan for the Whites Creek catchment. Catchment Simulation Solutions have been commissioned by Wingecarribee Shire Council to undertake this work.

The Flooding Problem

The extent of the existing flooding problem was quantified using new computer flood models of the Whites Creek catchment that were developed specifically for the study. The computer models were validated against historic flood information to ensure they were providing a reliable description of flood behaviour across the catchment.

The validated model was then used to simulate a range of hypothetical "design" floods. Peak floodwater depths were extracted from the results of the design flood simulations for the 1% AEP (Annual Exceedance Probability) flood and probable maximum flood (PMF) and are presented in **Figures ES2** and **ES3**. The floodwater depth and velocity results were also used to prepare flood hazard mapping for the 1% AEP flood, which is provided in **Figure ES4**.

The outcomes of the modelling determined that the most significant floodwater depths are predicted to occur within roadways, with Argyle Street and Lackey Road the most vulnerable roadways in the study area. In large floods, more roads would become inundated and would not be trafficable. In general, commercial properties adjoining Argyle Street are subject to a higher flood exposure during more frequent floods than residential properties. Overall, it is expected that 140 properties (101 residential and 39 commercial) would be subject to above floor flooding during the PMF event.

A flood damage assessment was completed as part of the study to quantify the financial impact of flooding across the catchment. The damages assessment determined that if a 1% AEP flood was to occur today, over $500,000 worth of damage could be expected across the Whites Creek catchment.

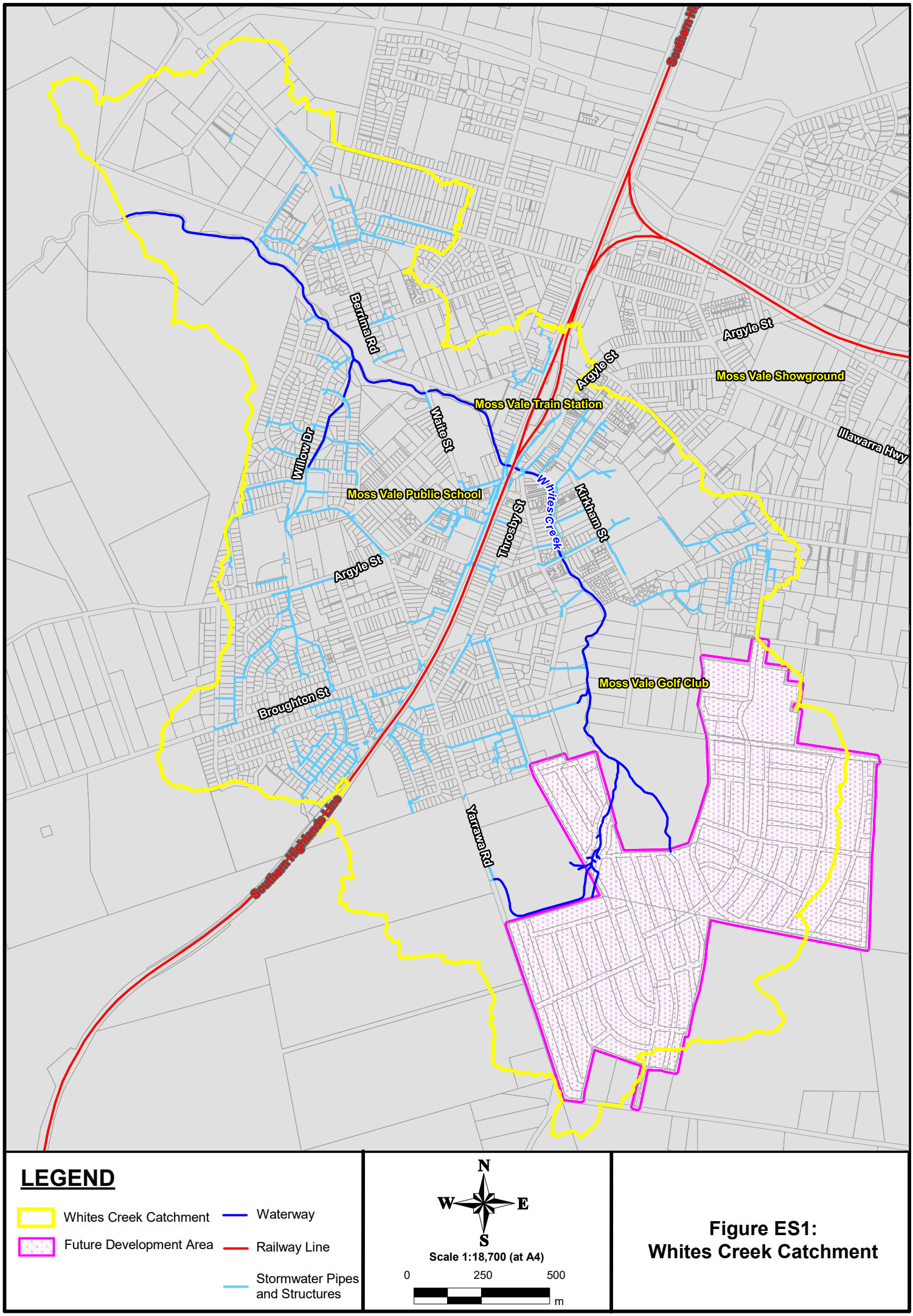
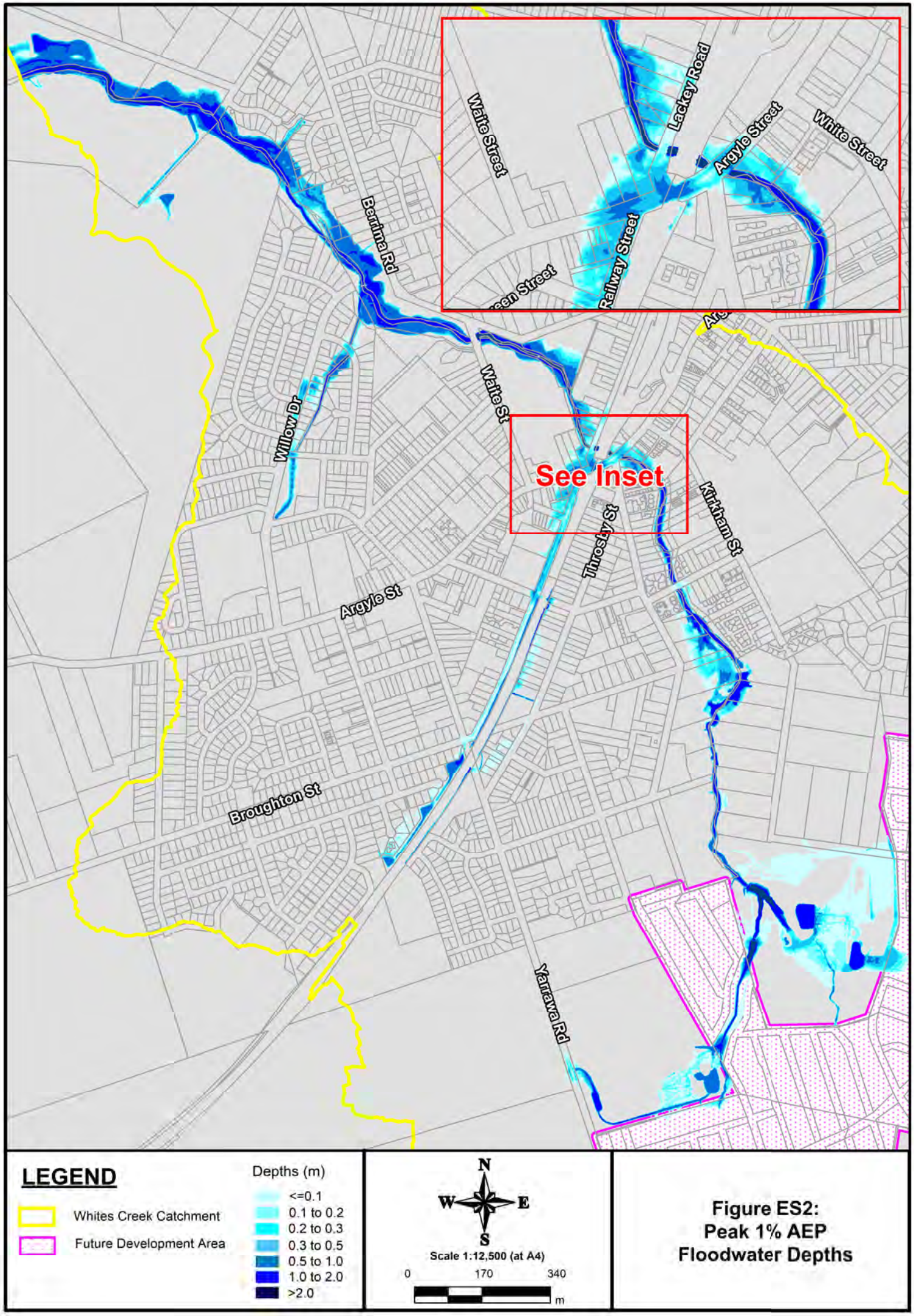
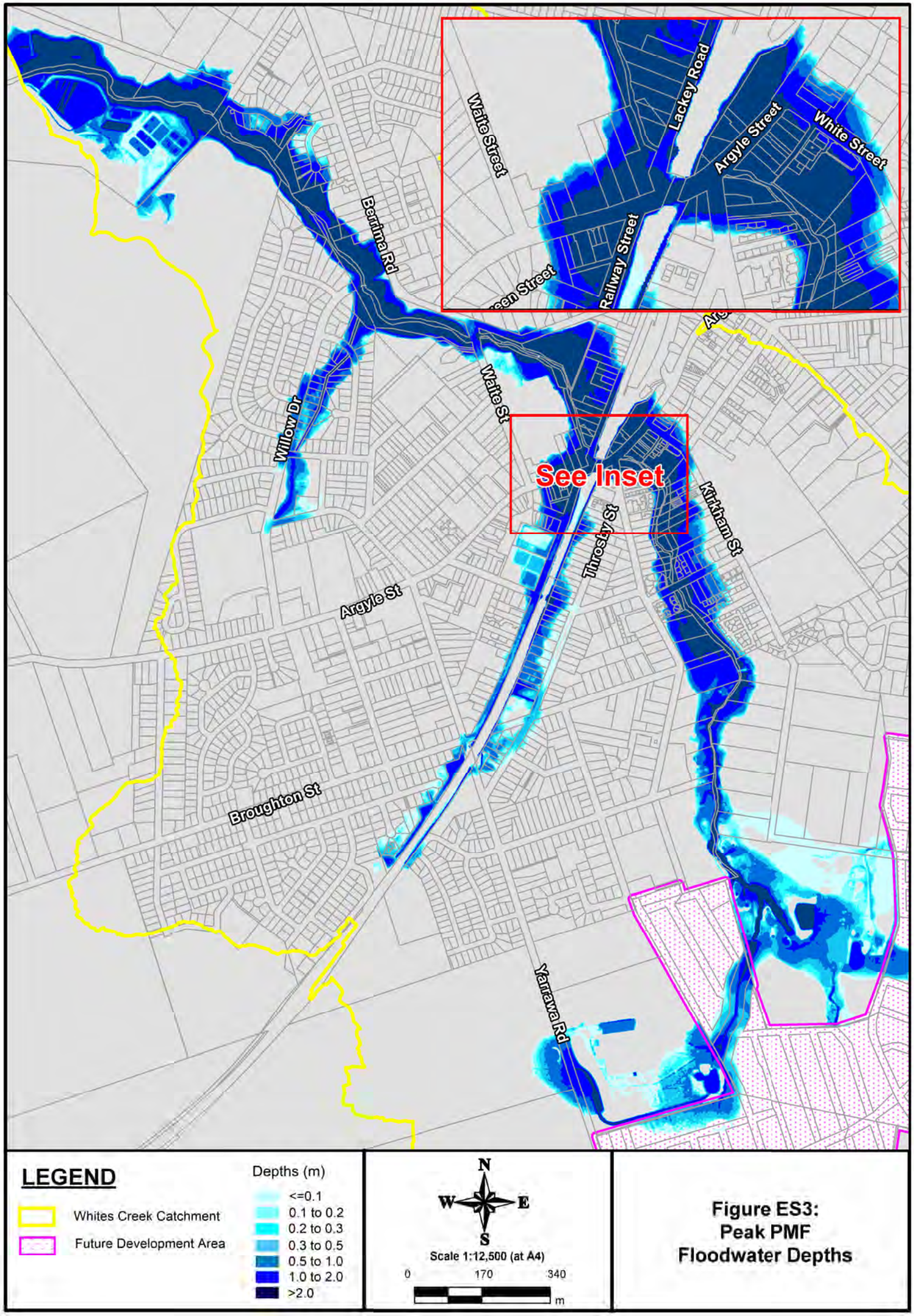
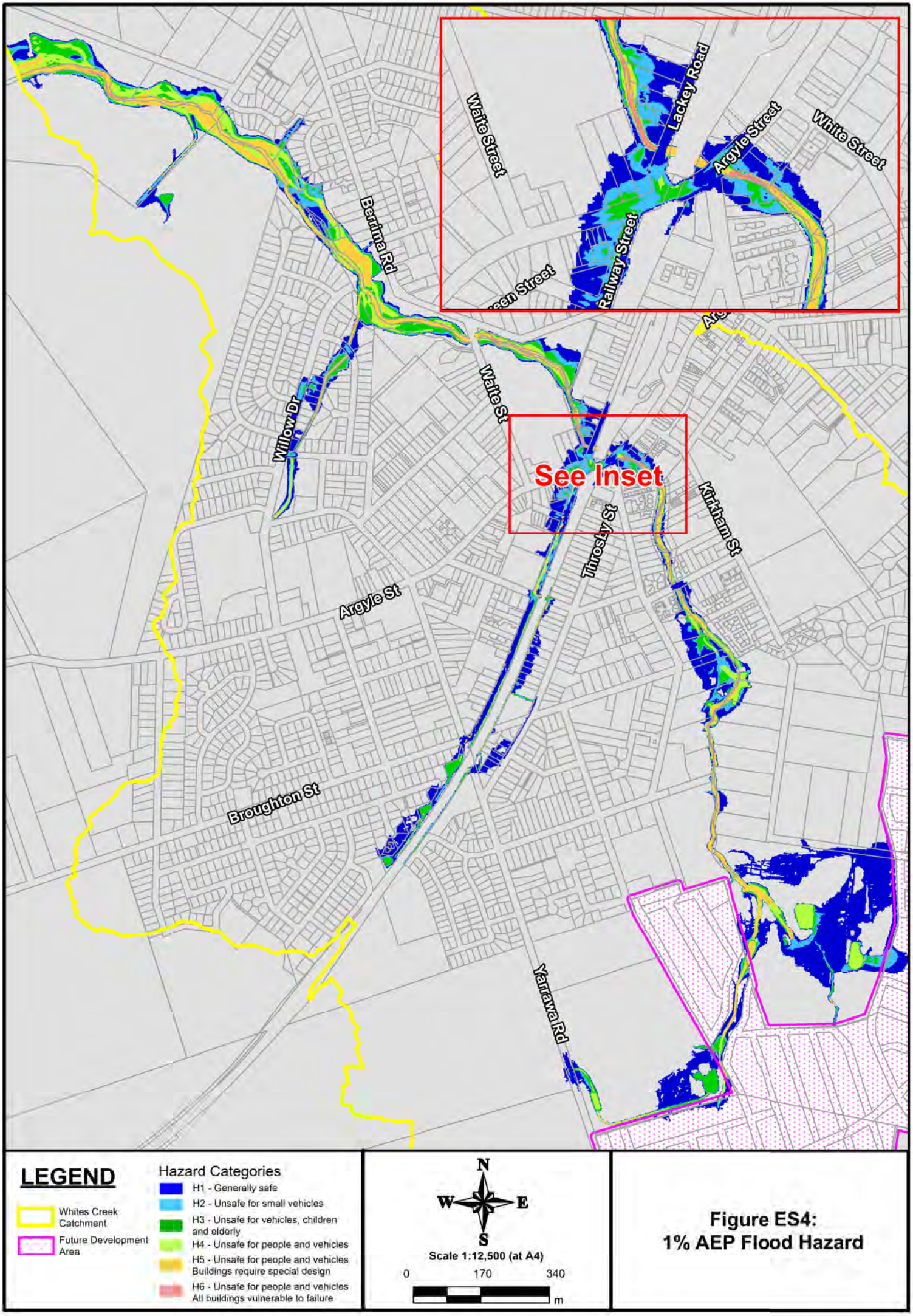


Figure ES1:
Whites Creek Catchment


Waite Street
Lackey Road
Argyle Street
White Street
Railway Street
Berrima Rd
Willow Dr
Waite St
See Inset
Tilbrook St
Kirkham St
Argyle St
Broughton St
Yarrawa Rd
LEGEND
Whites Creek Catchment
Future Development Area
Depths (m)
<=0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.5
0.5 to 1.0
1.0 to 2.0
>2.0
N
W
E
S
Scale 1:12,500 (at A4)
0
170
340
m
Figure ES2:
Peak 1% AEP
Floodwater Depths


Waite Street
Lackey Road
Argyle Street
White Street
Railway Street
Berrima Rd
Willow Dr
Waite St
See Inset
Throsby St
Kirkham St
Argyle St
Broughton St
Yarrawa Rd
LEGEND
Whites Creek Catchment
Future Development Area
Depths (m)
<=0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.5
0.5 to 1.0
1.0 to 2.0
>2.0
N
W
E
S
Scale 1:12,500 (at A4)
0
170
340
m
Figure ES3:
Peak PMF
Floodwater Depths


Waite Street
Lackey Road
Argyle Street
White Street
Railway Street
Berrima Rd
Willow Dr
Waite St
See Inset
Throsby St
Kirkham St
Argyle St
Broughton St
Yarrawa Rd
LEGEND
Whites Creek Catchment
Future Development Area
Hazard Categories
H1 - Generally safe
H2 - Unsafe for small vehicles
H3 - Unsafe for vehicles, children and elderly
H4 - Unsafe for people and vehicles
H5 - Unsafe for people and vehicles Buildings require special design
H6 - Unsafe for people and vehicles All buildings vulnerable to failure
N
W
E
S
Scale 1:12,500 (at A4)
0
170
340
m
Figure ES4:
1% AEP Flood Hazard

The study also considered the potential future flood risk in the catchment by assessing the impacts climate change and future development may have on flood behaviour. These assessments indicated that future catchment development and climate change increases as a result of increasing rainfall intensities would likely increase existing flood levels along most of Whites Creek. Future development has the potential to result in increased flood damage across 17 buildings/properties.

Options for Reducing the Existing and Potential Future Flooding Problem

A range of flood modification, property modification and response modification measures were considered to help manage the existing and potential future flood risk. Over 40 preliminary options were assessed qualitatively. The outcomes of the quantitative assessment yielded a shortlist of 24 options that were assessed in detail. The detailed assessment of each option involved evaluation against a range of specific criteria to provide an appraisal of the potential feasibility of each option. This included the impact that each option is predicted to have on existing flood behaviour, the environment, economics and emergency response as well as the technical feasibility of each option. All options that were assessed in detail are shown in **Figure ES5**.

Creek modification options including vegetation management and channel reshaping were considered, however, were found to have negligible impacts during large floods. As a result, they are not recommended for implementation as a flood risk management option. However, options such as vegetation management can have aesthetic and environmental benefits so can still be considered for implementation (although this needs to be balanced against increased potential for bed and bank erosion).

Floodplain Risk Management Plan

Based upon the outcomes of the detailed evaluation, the options highlighted in yellow on **Figure ES5** are recommended for implementation/further detailed investigation as part of the draft Floodplain Risk Management Plan for the Whites Creek catchment. Those options that were evaluated in detail but were not found to be viable are shown in grey.

It is expected that implementation of the plan will have a capital cost of approximately $720,000. In addition to the capital costs, some options will require an investment in time from various agencies including Wingecarribee Shire Council and the State Emergency Service in addition to monetary contributions. Ongoing costs will generally be the responsibility of Council. Two options will require significant discussions with third parties to gain their support for the option, before the detail design, refined cost estimate and true benefit cost ratio can be determined.

It should be noted that the costs indicated on **Figure ES5** are estimates only. The cost for each recommended option will need to be refined through further detailed investigations and preparation of detailed design plans which is beyond the scope of the current study.

It is important that the Floodplain Risk Management Plan is continually monitored, reviewed and updated over time to ensure that it evolves with the catchment and new flood knowledge. It is recommended that Council review the Whites Creek Floodplain Risk Management Study and Plan in 5 years' time.

PM1 - Changes to Wingecarribee Shire Council LEP
Recommendations:
A) Amend Wingecarribee Shire Council LEP to remove the flood planning area map from the LEP and make publicly available elsewhere and/or on council's website.
B) Include an additional "Floodplain Risk Management" clause in the LEP for areas between the flood planning area and the edge of the low flood risk precinct.

PM2 - Changes to Moss Vale Town Plan DCP
Recommendation: Amend Moss Vale Town Plan DCP considering the detailed review presented in Section 4.3.2 of this report

PM3 - Update Section 10.7 Certificate Information
Recommendation: Updated Section 10.7 certificate to reference updated design flood information generated as part of the current study.

PM4 - Voluntary House Raising
Recommendation: Not recommended for implementation.

RM1 - Community Education Strategy
Recommendation: Develop local Floodsafe documents, develop educational messages targeting dangerous behaviours during a flood and undertake localised and tailored education campaigns for high hazard areas.

RM2 - Make Property Level Flood Information Available
Recommendation: Make additional flood information available at a property scale for all properties impacted by flooding up to and including the PMF, including flood depths, hazards and emergency response classifications, with suitable explanations and guidance as to how this information can be used to inform flood emergency plans.

RM3 - Home Flood Plan Preparation
Recommendation: Host community or locality meetings to promote the preparation of Home Emergency Plans. These plans should highlight the vulnerability of and disruption to the road network during flood times in Moss Vale and provide advice on potential alternate evacuation routes.

RM4 - Business Flood Plan Preparation
Recommendation: Host a Business FloodSafe Breakfast to promote the preparation of Business FloodSafe Plans

RM5 - Local Flood Plan Updates
Recommendation: Update Wingecarribee Shire Local Flood Plan based upon Table 19 in Section 5.1 of this report

RM6 - Develop a Safe On-site Refuge Policy
Recommendation: Develop an on-site refuge strategy with appropriate guidance from the NSW SES and the community and update the DCP to ensure structural adequacy of such refuges during the PMF.

RM9 - Flood Insurance
Recommendation: Recommend those properties located within the floodplain consider reviewing the flood insurance component of their house or business insurance with regard to the updated flood information provided in this report. Consider taking out flood insurance if the property does not currently have it.

Fut1 - Do not increase runoff characteristics for developments
Recommendation: Recommended to include updates to the current Moss Vale DCP to specify what design storm events are to be considered in a Stormwater Management Plan.

Fut2 - Do not increase development densities in flood constrained lands
Recommendation: Ensure development densities do not increase in flood constrained land.

FM8 - Channel and Floodplain Modifications between 6-12 Berrima Road
Recommendation: Not recommended for implementation.

RM8 - Creation of an emergency railway level crossing between Vale Road and Lytton/Lackey Road
Recommendation: Recommended for further investigation and true feasibility evaluation in conjunction with planning for the Moss Vale bypass.

RM7 - Regrading of Argyle Street
Recommendation: Not recommended for implementation.

FM13 - Regrading of Lackey Road from Argyle Street to Whites Creek
Recommendation: Not recommended for implementation.

FM6 - Upgrade Stormwater System on Willow Drive and Dangar Street
Recommendation: Not recommended for implementation.

FM2a - New Detention Basin within Broulee Park
Recommendation: Recommended for further detailed investigation.

FM2b - New Detention Basin in Strode Park
Recommendation: Not recommended for implementation.

FM3 - Upgrade Stormwater System along Railway Street (near Argyle Street)
Recommendation: Not recommended for implementation.

FM9 - Elevate Pedestrian Walkway between Railway and Throsby Street to Direct Flows into Downstream Channel
Recommendation: Not recommended for implementation.

FM10 - Construct Levee on Eastern Bank of Whites Creek near Lackey Road
Recommendation: Not recommended for implementation.

FM5 - Upgrade Culverts along Whites Creek at Argyle Street and the Railway
Recommendation: Feasibility assessment recommended.

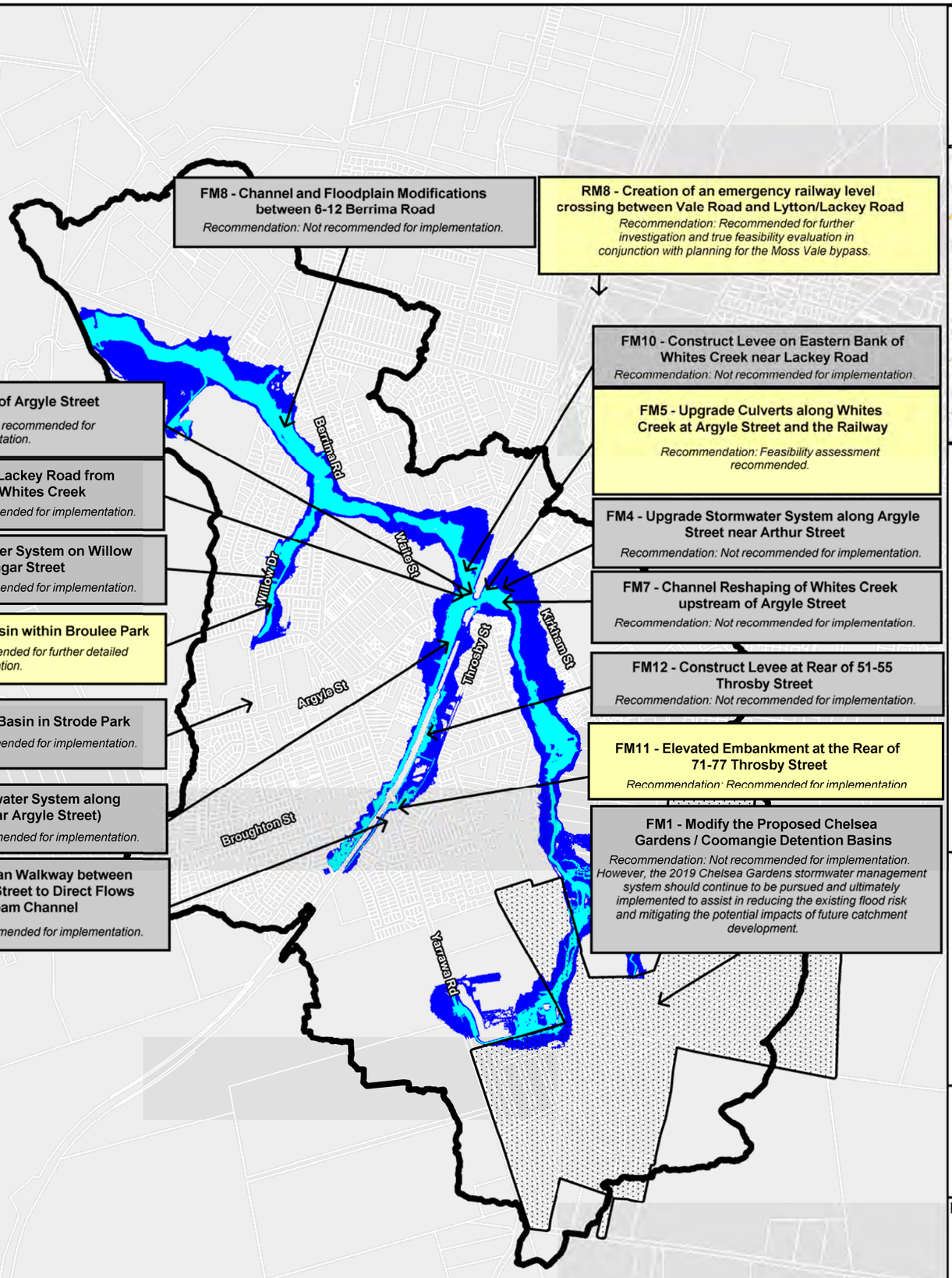
FM4 - Upgrade Stormwater System along Argyle Street near Arthur Street
Recommendation: Not recommended for implementation.

FM7 - Channel Reshaping of Whites Creek upstream of Argyle Street
Recommendation: Not recommended for implementation.

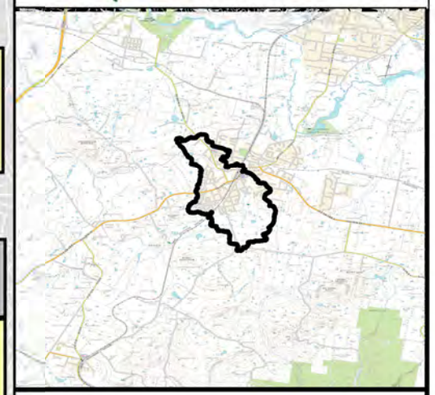
FM12 - Construct Levee at Rear of 51-55 Throsby Street
Recommendation: Not recommended for implementation.

FM11 - Elevated Embankment at the Rear of 71-77 Throsby Street
Recommendation: Recommended for implementation

FM1 - Modify the Proposed Chelsea Gardens / Coomangie Detention Basins
Recommendation: Not recommended for implementation. However, the 2019 Chelsea Gardens stormwater management system should continue to be pursued and ultimately implemented to assist in reducing the existing flood risk and mitigating the potential impacts of future catchment development.



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Recommended Option
- Not Recommended Option
- FM — Flood Modification Option
- PM — Property Modification Option
- RM — Response Modification Option
- Fut — Option for Managing the Potential Future Flood Risk
- Whites Creek Catchment Area
- Future Development Area
- 1% AEP Extent
- PMF Extent

N
W E
S

Scale 1:19,380 (at A3)

0 0.50 1.00 Km

Figure ES5: Draft Floodplain Risk Management Plan

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File Name: Fig - Draft FPRMP.wor

Table 1 Draft Whites Creek Floodplain Risk Management Plan

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing
FM2	Further detail investigation of new detention basin in Broulee Park	7.2.2	Council	$60,000	0.7	High	2 years
FM5	Feasibility assessment for upgrading the existing railway culverts near Argyle Street	7.3.3	Council & ARTC	$650,000	0.2	Medium	<2 year
FM11	Elevated Embankment at the Rear of 71-77 Throsby Street	7.5.3	Council	$10,000	3.0	High	1 year
PM1	LEP Amendments	8.2.1	Council	Council Time	n/a	High	3 years
PM2	DCP Amendments	8.2.2	Council	Council Time	n/a	High	2 years
PM3	Update Section 10.7 certificate information	8.2.3	Council	Council Time	n/a	High	<1 year
RM1	Community Education	9.2.1	Council & SES	Council & SES Time	n/a	High	1-2 years
RM2	Make property level flood information available	9.2.2	Council	Council	n/a	Medium	1 year
RM3	Encourage the community to develop household Flood Plans	9.2.3	SES / Individual Residents	Council & SES Time	n/a	Medium	2 years
RM4	Encourage the community to develop business Flood Plans	9.2.3	SES / Individual Business Owners	Council & SES Time	n/a	Medium	2 years
RM5	Local Flood Plan Updates	9.2.4	SES	SES Time	n/a	High	2 years
RM6	Develop a safe on-site refuge policy	9.2.5	Council	Council & SES Time	n/a	Medium	2 years

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing
RM8	Creation of an emergency railway level crossing between Vale Road and Lytton/Lackey Road	9.3.2	Council	Council time	n/a	High	<1 year
RM9	Flood Insurance	9.4	Property owner	variable	n/a	Low	1-3 years
Fut1	Update Stormwater Management Plan requirements in DCP	10.1.1	Council	Council Time	n/a	High	1 year
Fut2	Do not increase future development densities in flood constrained land	10.1.2	Council	Council Time	n/a	High	1 year

1 INTRODUCTION

1.1 Background

The Whites Creek catchment is located in the Southern Highlands of New South Wales and drains a 7 km^2 catchment through Moss Vale. The extent of the catchment is shown in **Figure 1**.

The main watercourse in the catchment is Whites Creek, which originates south of the Moss Vale Golf Club and drains in a north-westerly direction through the Moss Vale urban area. Whites Creek continues to drain in a north-westerly direction before turning west and draining into the Medway Rivulet which ultimately drains into the Wingecarribee River.

During periods of heavy rainfall across the catchment, there is potential for flooding to occur as a result of major watercourses overtopping their banks. There is also potential for "overland" flooding when the capacity of the local stormwater system is exceeded. Flooding has been experienced on a number of occasions, particularly across properties fronting Lackey Road, Railway Street and the Illawarra Highway.

In recognition of the potential for flooding to occur, Wingecarribee Shire Council prepared the *'Whites Creek Flood Study'* (URS) in 2009. The flood study defined the nature and extent of flood behaviour across the study area based upon the best topographic information and modelling tools that were available at that time. The flood study was followed by the *'Whites Creek Floodplain Risk Study and Plan'* (URS), which was completed in 2012. The floodplain risk management study and plan outlined a range of measures that could be implemented to better manage the existing and potential future flood risk across the Whites Creek catchment.

Since the flood study and floodplain risk mangement study were prepared there have been advances in modelling technology, access to updated and more detailed topographic information (e.g., LiDAR) and significant updates to the national guideline for flood estimation (i.e., Australian Rainfall and Runoff). Additional development has also occurred since the flood study was prepared, which has likely altered flood behaviour. Therefore, Council resolved to review and update the Whites Creek Floodplain Risk Management Study and Plan to ensure they are based upon the latest available knowledge, data and modelling tools.

Accordingly, Wingecarribee Shire Council engaged Catchment Simulation Solutions to complete a review of the *'Whites Creek Floodplain Risk Management Study'* (URS, 2012). The following document summarises the outcome of the review.

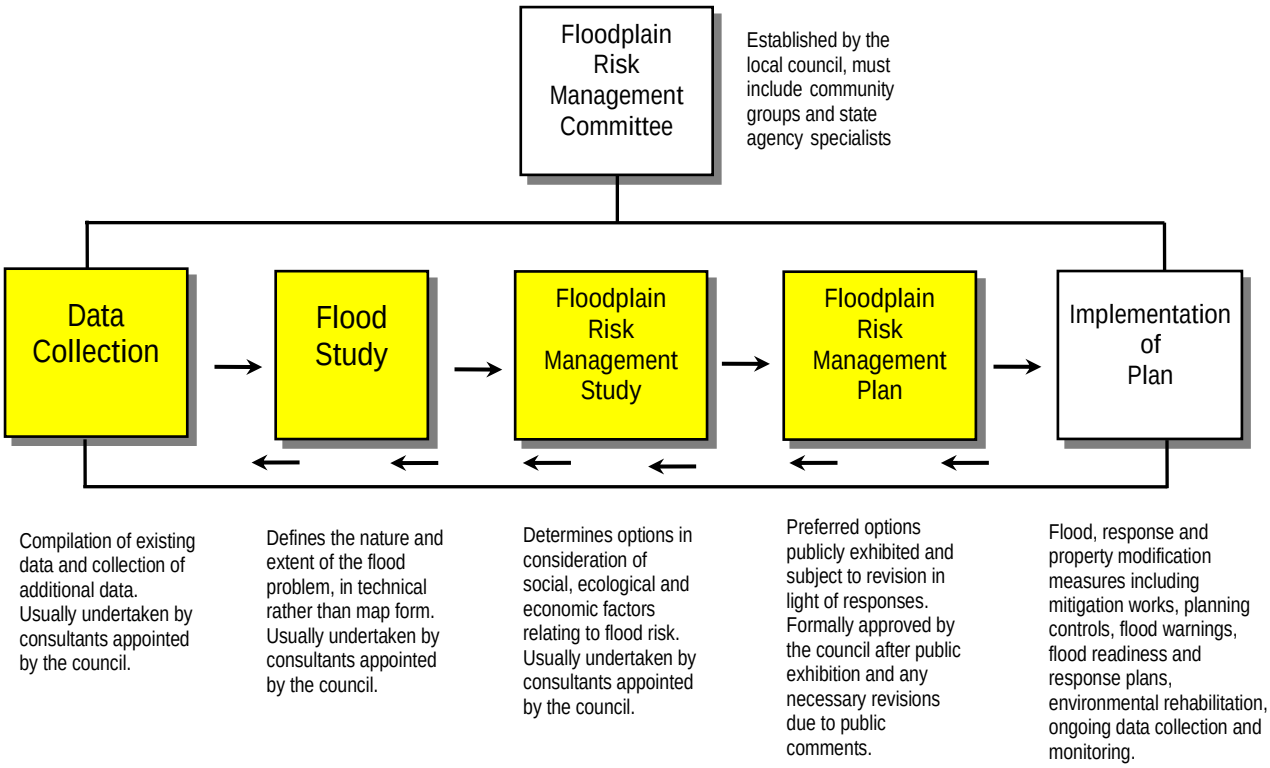
1.2 The Floodplain Risk Management Process

The '*Review of Whites Creek Floodplain Risk Management Study and Draft Plan'* has been prepared in accordance with the requirements of the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005).* The '*Floodplain Development Manual'* guides the implementation of the State Government's *Flood Policy*. The *Flood Policy* is

directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. The Policy is defined in the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005)*.

Under the Policy, the management of flood liable land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Local Government in its floodplain management responsibilities.

The Policy provides for technical and financial support by the State Government through the following stages of the floodplain risk management process:



Stages 1 through 4 of this process were previously completed as part of the 2009 flood study and 2012 floodplain risk management study and plan. The current study will build upon this previously completed work and will serve to review and update this previously completed work culminating in the preparation of a revised draft Floodplain Risk Management Plan. The revised Plan will outline a preferred set of measures that will guide the future management of flood prone land across the catchment.

This current study includes the collection of the latest available data for the catchment and the development of new flood models that will update the nature and extent of the existing flooding problem. It will also identify, assesses and compares various options for managing the flood risk across the catchment. The Floodplain Risk Management Plan draws on the

outcomes of the Study and provides a set of recommended options that will outline how to best manage the existing, future and continuing flood risk across the Whites Creek catchment.

1.3 Report Structure

The following report forms the revised Floodplain Risk Management Study and Draft Plan for the Whites Creek catchment. It has been divided into the following sections:

- Section 2 - Catchment Information: Provides general information regarding the catchment and a summary of available information and past reports.
- Section 3 – The Existing Flood Risk: Describes the current impact of flooding on the community for a range of different floods. This includes an assessment of the impact of flooding on key facilities, the potential cost of flooding as well as the potential for floodwater to damage buildings and/or pose a danger to personal safety.
- Section 4 – Existing Planning Information: summarises, with an emphasis on flooding, existing planning legislation, policy and guidelines that affect the development of land within the catchment
- Section 5 – Existing Emergency Response Protocols: provides an overview of emergency management measures that are currently implemented across the catchment to assist in managing the flood risk. Opportunities to improve these existing protocols are also discussed.
- Sections 6 to 10: discusses the merits of a range of flood, property and response modification measures that could be potentially employed to manage the existing, future and continuing flood risk across the catchment.
- Section 11 – Floodplain Risk Management Plan: provides a preferred list of options that are considered appropriate for implementation by Council to manage the flood risk across the Whites Creek catchment.

The report comprises two volumes:

- Volume 1 (this document): contains the report text and appendices
- Volume 2: contains all figures and maps

2 CATCHMENT INFORMATION

2.1 Catchment Description

The Whites Creek catchment is located in the Southern Highlands of New South Wales and occupies a total area of 7.05 km^2. The extent of the catchment is shown in **Figure 1**.

The catchment originates south of the Moss Vale Golf Club and drains in a north-westerly direction through the Moss Vale urban area, before draining into the floodplain downstream of the Moss Vale Sewerage Treatment Plant. The downstream section of the catchment comprises a mix of residential, commercial and industrial land uses. The upstream catchment is largely undeveloped. However, there is significant subdivision adjoining the Moss Vale Golf Club referred to as "Chelsea Gardens" that is partly contained within the catchment and has been approved for development.

The catchment is drained primarily by natural watercourses, with Whites Creek being the main watercourse within the catchment. The location of all open channel/watercourses is shown by the blue lines in **Figure 1**. There are two unnamed tributaries downstream of the railway line, the most significant being a well-defined waterway running in a northerly direction towards Whites Creek, generally parallel to Willow Drive. The other tributary joins Whites Creek near the Sewage Treatment Works.

The urbanised sections of the catchment are also drained by a stormwater system which carries local catchment runoff into the watercourses via a network of stormwater pipes, pits, open channels and culverts (refer aqua lines in **Figure 1**).

A Digital Elevation Model (DEM) was developed based upon 2014 LiDAR information. The DEM shows ground surface elevations across the catchment and is provided in **Figure 2**. **Figure 2** shows that ground surface elevations vary between 750 mAHD by the water supply reservoir near Hill Road down to 650 mAHD adjacent to the Moss Vale Sewage Treatment Plant. Part sections of the catchment are steep, with grades approaching 20%. However, the grades along and immediately adjacent to each watercourse are subtler, generally being around 0.5%.

2.2 Past Studies

2.2.1 Whites Creek Flood Study (2009)

The *'Whites Creek Flood Study'* was prepared by URS for Wingecarribee Shire Council in 2009. The study was commissioned to define flood behaviour across the Whites Creek catchment for topographic and development conditions at that time.

The study sourced newspaper articles from *'The Scrutineer'* and *'The Southern Highlands News'* that indicated major rainfall/flooding events in the Whites Creek catchment occurred on the following dates:

- 13 December 1889;
- 8 March 1893;
- 30 January 1895;
- 16 February 1898;
- 12 February 1903;
- 6 December 1907;
- 4 March 1955; and
- 22 March 1978.

Photographs relating to the March 1955 flood were extracted from these newspaper articles and are reproduced in **Plate 1** to **Plate 3**.

The flood study also amassed a significant amount of survey data. This included the following datasets:

- Aerial Laser Survey (ALS);
- Detailed ground survey; and
- Culvert and bridge structure details.



Plate 1 Railway Street – March 1955



Plate 2 Argyle Street downstream of Railway – March 1955



Plate 3 Railway Street - March 1955

The culvert structure details extracted from the flood study are listed in **Table 2**.

Table 2 Structures surveyed for the *'Whites Creek Flood Study' (2009)*

Structure Location	Shape	Branch	Dimension	Length (m)	Invert Upstream (mAHD)	Invert Downstream (mAHD)	Top of Road RL (mAHD)
Mack Street	Box	Whites Creek	8.1m (wide) x 1.5m (high)	15.8	667.64	667.53	669.74
Argyle Street	Box	Whites Creek	3.4m (wide) x 2.05m (high)	17.2	664.63	664.43	667.15
Railway	Circular	Whites Creek	2 x 2.4m (diameter)	28.9	664.23	664.08	672.00
Lackey Road	Box	Whites Creek	7.6m (wide) x 2.6m (high)	12.1	663.97	663.92	666.93
Berrima Road	Box	Whites Creek	9.15m (wide) x 2.1m (high)	17.2	662.07	661.98	665.01
Campbell Crescent	Box	Willow Creek	2.4m (wide) x 1.5m (high)	34.8	662.68	662.33	664.45

The study noted that there were no streamflow records or sub-daily pluviometer rainfall records available for the historic flood events in the catchment.

The flood study included the development of an XP-RAFTS hydrologic model to define rainfall-runoff processes. A total of twenty-four (24) subcatchments were delineated and used to represent the hydrologic characteristics of the Whites Creek catchment. The model was used to generate design discharge hydrographs for the design 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the Probable Maximum Flood (PMF). The XP-RAFTS modelling determined that the critical storm duration for the catchment was 9-hours for most of the design storms, with a critical duration of 2-hours for the PMF.

A one-dimensional MIKE-11 model of the Whites Creek catchment was also prepared as part of the study to define flood hydraulics. The model was developed to include a representation of the three major waterway branches within the catchment (i.e., Whites Creek, and the unnamed tributaries in the catchment referred to in the flood study as "Willow Creek" and "Railway Creek"). The model extends 4 kilometres along the main creek channel, from the Moss Vale Golf Club to a point downstream of the Sewage Treatment Plant. It included the six (6) culverts listed in **Table 2** as well as six (6) weir structures. Cross-sections for the 1D model were extracted from the detailed survey and a Digital Elevation Model (DTM) created from the ALS. Flood discharges derived from the XP-RAFTS modelling were input into the model and the MIKE-11 model was used to simulate the design 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the Probable Maximum Flood (PMF).

As discussed, no recorded stream flow or sub-daily rainfall records were available for the Whites Creek catchment. Therefore, calibration of the XP-RAFTS and MIKE-11 models was not possible. However, the model was verified by comparing the total flow hydrographs produced

by both the XP-RAFTS and Mike-11 models at common locations. The shape of the hydrograph, time to peak flow and magnitude of the peak flow were found to provide a reasonable correlation.

The outputs from the design flood simulation were used to prepare design flood surface profiles, as well as flood extent and flood hazard mapping.

The modelling results yielded the following findings:

- The flood profiles clearly illustrate that the various bridges and culverts along Whites Creek generate significant backwater effects. This is most noticeable in the Argyle Street/Railway/Lackey Street area. When the capacity of the culvert in this area is exceeded the excess water joins flows running down Railway Street resulting in access along Argyle Street being cut for up to 4 hours.
- Property in Moss Vale is affected by floodwaters overtopping the banks of Whites Creek as well as from overland flow that is making its way to the creek. The major overland flow path is along Railway Street to the south west of Whites Creek. In the upper catchment, flooding mainly affects properties located in close proximity to Whites Creek.
- Floodwaters are predicted to also affect properties along Mack Street as well as properties fronting Arthur Street. Floodwater depths in this area for the 1% AEP design event vary from 0.05 metres at Mack Street to 0.9 metres at the northern end of Arthur Street (near Argyle Street).
- The greatest flood impact is experienced in the vicinity of the Argyle Street culvert where it passes under the Main Southern Railway. This is in line with anecdotal evidence and historic flood information.

Flooding was predicted to impact on a number of roadways. This included Argyle Street which would be inundated by 0.2 metres in the 20% AEP flood and over 5 metres in the PMF. Lackey Road was not predicted to be inundated in events up to and including the 0.5% AEP flood, although during the PMF it would be inundated by 0.8 metres of water.

The results of this flood study indicated six major directions for further investigation in the subsequent Floodplain Risk Management Study and Plan, including:

- Development controls to be applied to new or infill development in the catchment;
- The potential impact of culvert blockage on flood levels and flood risk should be fully understood;
- Upgrading the capacity of the Argyle Street culvert, including realignment of the upstream reach, reconstruction of the culvert and realignment with the railway culvert;
- Addressing the drainage system along Railway Street;
- Investigating options to manage cross-catchment flows through the Spring Street underpass; and
- Maintaining the capacity of the creek below Berrima Road through vegetation control and other environmental measures.

2.2.2 Whites Creek Floodplain Risk Management Study and Plan (2012)

The *'Whites Creek Floodplain Risk Management Study and Plan'* (2012) was prepared by URS for Wingecarribee Shire Council. The study was commissioned to investigate a range of options that could be potentially implemented to reduce flood damages within the Whites Creek catchment.

These options investigated as part of the study included a range of flood modification measures, property modification measures and response modification measures. The flood modification measures investigated included:

- Flood detention basin in Moss Vale Golf Club;
- Argyle Street culvert upgrade;
- Argyle Street culvert upgrade with Moss Vale Golf Club basin;
- Sandbag alternatives; and
- Control runoff from new development (OSD and WSUD policies).

The property modification measures investigated included:

- Building and development controls;
- Flood planning levels; and
- Flood proofing buildings.

The response modification measures investigated included:

- Community awareness and preparedness; and
- Flood emergency plans.

The modelling of the flood modification measures was undertaken using the XP-RAFTS and MIKE-11 models developed as part of the *'Whites Creek Flood Study'* (URS, 2009). Several modifications were made to the XP-RAFTS model to facilitate the modelling of the various floodplain management options. In particular, the Whites Creek model was merged with a Chelsea Gardens XP-RAFTS model developed by Patterson Britton and Partners (2006) in order to incorporate the Chelsea Gardens development into the hydrologic modelling. This modification involved several sub-catchments at the upstream reach of the model being replaced by the Chelsea Gardens model or modifying the sub-catchment areas. The sub-catchment details and model parameters of the Chelsea Gardens model sub-catchments were maintained for both the existing and developed scenarios. However, during the floodplain management study, Wingecarribee Shire Council stated that this development had been delayed and may not proceed at all. As a result, the flood mitigation options did not take into account modified catchment flows associated with Chelsea Gardens subdivision. However, it was assumed that, should the development proceed, suitable measures would be in place to reduce post-development flows leaving the site to existing levels.

The MIKE-11 hydraulic model developed as part of the *'Whites Creek Flood Study'* (URS, 2009) was also used as part of this floodplain risk management study. However, a HEC-RAS 1D hydraulic model was also developed to verify the performance of structures in the model and to model one of the structural flood mitigation options.

Two enhancements of the original MIKE-11 model were carried out as part of the study. The first was to combine the Main Southern Railway and Lackey Road culverts into 1 structure using the Main Southern Railway culvert geometry information to better replicate the existing conditions (as the Main Southern Railway culvert is the upstream control of the Lackey Road culvert). The second enhancement was to remove the Railway Street branch which formed part of the original MIKE-11 model as it was felt that the model was not providing a reliable representation of flood behaviour along this steep overland flow path.

In recognition of the modelling limitations of the Railway Street branch, a separate DRAINS model was developed to represent the subsurface drainage and overland flow system along this branch. The stormwater drainage network data, including pit surface levels, inverts and pipe lengths, was based on the detailed survey of the Illawarra Highway, Railway Street and Lackey Road area undertaken on the 13 August 2010. Roadway gutters were represented as overland flow paths and use standard road/gutter cross sections in DRAINS. Culverts beneath roadways were represented using pipes and headwalls. The DRAINS model was used to simulate the 20%, 5% and 1% AEP events. The results of the DRAINS stormwater drainage investigation were then used as inputs into the modified MIKE-11 and HEC-RAS models.

The updated models were used to model a range of design flood events, including the impacts of climate change. Revised flood profiles from the updated XP-RAFTS and MIKE-11 modelling are presented in the report. Hydraulic and hazard mapping was also produced for this study for the 1% AEP flood event.

The study included the collection of floor level survey data. This floor level data was used in conjunction with property and land use information as the basis of the calculation of flood damages for the catchment. The study determined the Average Annual Damage (AAD) for the Whites Creek catchment to be approximately $750,000.

Recommendations determined by the study included:

- A detailed scoping study to further investigate the feasibility of constructing a detention basin in Moss Vale Golf Club. It is understood that although the scoping study determined the construction of the basin to be feasible, negotiations with the Golf Club have not allowed the basin to be constructed at this point in time;
- A detailed scoping study to further investigate the feasibility of upgrading the Main Southern Railway and Argyle Street culverts;
- A detailed scoping study on upgrading of the Railway / Argyle Street local drainage system specifically pit sizes along Railway Street to alleviate local overland flooding. Increasing pit capacity will allow more stormwater to enter the system thus decreasing overland flows along Railway Street;
- Consideration be given to providing temporary flood protection measures, such as the “Floodgate” line of products, to permanent commercial structures along Argyle Street in conjunction with flood proofing measures;
- The Flood Planning Level (FPL) be adopted as equal to the 1% AEP flood level plus 0.5m freeboard;

- Continuation of Council's on-site detention (OSD) policy, and promotion of Water Sensitive Urban Design (WSUD);
- Preparation of flood-proofing guidelines, to encourage flood protection measures among proprietors and residents;
- Council and SES to develop a community flood awareness and education program on the need to address flood risk across the full range of floods, covering issues such as non-compatible development and what measures are needed for floodplain risk management;
- Improve public awareness of flood risks, by producing a Whites Creek FloodSafe brochure and website, installing flood markers in a central location, revising and regularly issuing flood certificates, and holding hazard awareness days.

2.3 Local Environment

2.3.1 Flora/Vegetation

The catchment includes two vegetation species that are registered under the Environmental Protection and Biodiversity Conservation 1999 (EPBC) Act. The location of each species is shown on **Figure 3** and occupies less than 1% of the total catchment area. The species include:

- Southern Highland Shale Forest and Woodland of the Sydney Basin Bioregion (Critically Endangered Ecological Community);
- Temperate Highland Peat Swamps on Sandstone (Endangered Ecological Community).

The potential for implementation of structural mitigation measures in these areas will be limited as there is potential for adverse impacts.

2.3.2 Aboriginal Heritage Site

There are nine (9) aboriginal heritage sites located within the catchment. The location of the heritage sites is shown in **Figure 3**. A detailed summary of these sites is listed below in **Table 3.**

Table 3 Summary of Aboriginal Heritage Sites

ID	Site Name	Site Features
1	MVSW AO2	Artefact: -
2	MVSW AO3	Artefact: -
3	MVSW AO4	Artefact: -
4	BSMV PAD2	Artefact: -
5	MVSW A01	Artefact: -
6	MVSW1	Artefact: -
7	MVSW A18	Artefact: -
8	Chelsea Gardens Locale 2	Artefact: 11
9	Chelsea Gardens Locale 1	Artefact: 8

2.3.3 Heritage Conservation Areas

The Wingecarribee LGA incorporates 16 Heritage Conservation Areas (HCAs). There are four HCA contained within the Whites Creek catchment, which are shown on **Figure 3** in red.

An HCA is an area that displays unifying attributes or elements of heritage significance. Accordingly, restrictions will be placed on any works that may damage the heritage attributes within these areas.

Under the Wingecarribee Shire Council Local Environmental Plan 2010, there are a number of heritage conservation areas within the Whites Creek catchment. Council's heritage mapping is shown on **Figure 3**. As shown in **Figure 3**, these conservation areas are concentrated in the urban area of Moss Vale and a number of these areas are adjacent to the main Whites Creek channel.

There are also a number of Heritage Items listed in the historic areas of Moss Vale village under the Wingecarribee Shire Council Local Environmental Plan 2010.

The potential for implementation of structural mitigation measures in those areas with heritage listing will need to consider the effect of the proposed measure on the heritage significance of the item or area and comply with Council's development consent conditions for heritage areas.

2.3.4 NSW State Heritage Sites

Two sites within the Whites Creek catchment are listed under the NSW Heritage Act. The location of the heritage sites is shown by the yellow diamonds in **Figure 3** and are summarised in **Table 4.**

Table 4 Summary of NSW Heritage Sites

ID	Description
1	Moss Vale Railway Station and Yard Group
2	Moss Vale Underbridge Over Argyle Street

2.3.5 Other Heritage Sites

There are also a number of locations that are registered as heritage sites by other state agencies as well as local government as having local significance. Each of these sites is shown on **Figure 3** as aqua triangles and are described in **Table 5**. As shown in **Figure 3**, many of the heritage sites are contained within the HCAs.

Table 5 Summary of Heritage Sites listed by Local Government and State Agencies

ID	Description
1	Willow Grange House and Grounds
2	St Andrew's Presbyterian Church
3	St John's Anglican Church
4	St Paul's International College (Former Dominican Convent)
5	Moss Vale Rail Station
6	Moss Vale Station Master's Residence (Former)
7	Moss Vale Post Office (Former) and associated items
8	Semi-detached Houses
9	Moss Vale Court House
10	Leighton Gardens and Pavilion
11	Kalaurgan House
12	Moss Vale Public School
13	Jemmy Moss Inn
14	Argyle House
15	Moss Vale School of Arts (Former)
16	Hereford House
17	National Australia Bank (Former)
18	Whytes Shop
19	Throsby Manor, (Former Council Chambers)
20	Victorian Worker's Cottage
21	Cherry Hinton House
22	Redbraes House and Garden
23	Cottesbrooke House
24	Lynton
25	Glendalough
26	Coach House Antiques
27	Victorian Shop, Painted Wall Signs and House
28	Interwar Bungalow
29	Interwar Transitional Bungalow
30	Federation Cottage
31	Cottage
32	Federation House
33	Dormie House Guest House

2.4 Demographics

Understanding the characteristics of the population living and working within the catchment is an important component of developing and assessing potential flood risk management measures. For example, the availability of internet, the primary language spoken at home and the availability of a motor vehicle can have a strong bearing on the feasibility of different education, flood warning and evacuation strategies.

In this regard, the Australian Bureau of Statistics (ABS) provides a range of information for the village of Moss Vale that was collected as part the 2016 census. A summary of pertinent information extracted from the ABS website (http://www.abs.gov.au/) is provided in **Table 6**.

Table 6 Summary of Catchment Demographics

Statistic			
Population Statistics	Total population		8,579
	Age	Median	43
		<15 years of age	1,586
		>=65 years of age	1,898
	Education	Year 12 or equivalent	2,893
		Year 10 or equivalent	2,059
		Did not Complete Year 10	954
Dwelling Statistics	Motor Vehicl	Dwellings with no vehicles	185
		Dwellings with ≥ 1 vehicle	2,889
		Average persons per dwelling	2.4
		Proportion of unpaid volunteers	27%
	Languag e spoke	Speaks English only	7,467
		Speaks other language:	633
	Dwelling Type	Separate house	2,716
		Semi-detached, row or terrace house, townhouse	302
		Flat, unit or apartment:	83
		Other dwelling (cabin, caravan):	51
Internet Statistics (no. of dwellings)	Type of Internet Connection	No Internet connection	519
		Internet connection	2,584
		Internet connection not stated	86

The information presented in **Table 6** shows that:

- Approximately 8,600 people reside in the Moss Vale area. Noting that the Whites Creek catchment covers approximately 50% of the village of Moss Vale, it is estimated that the population contained within the catchment is about 4,300. However, this population is likely to increase in the future as a result of developments such as the "Chelsea Gardens" subdivision.
- Approximately 40% of the population would be considered more vulnerable to the impacts of flooding (i.e., people under the age of 15 or over the age of 65). The median age of residents within the area is 43.
- The majority of households only speak English at home. However, there are a limited number of households that also speak Mandarin, Cantonese, Nepali, Italian and Vietnamese.
- 81% of households have an internet connection.
- The average household within the catchment typically has 2 or more people, and at least one motor vehicle.

2.5 Community Consultation

2.5.1 Overview

Wingecarribee Shire recognises that the community is an important part in the development of the floodplain risk management study and plan for the Whites Creek catchment.

Community consultation was completed as part of the *'Whites Creek Flood Study'* (URS, 2009) as well as the *'Whites Creek Floodplain Risk Management Study and Plan'* (2012). A summary of the key outcomes of this consultation is provided below.

Consultation with the community was also completed as part of the current study to obtain additional information that may not have been reported during these previous studies or may have come to light since these studies were prepared. A summary of the outcomes of the consultation that was completed as part of the current study is also provided below.

2.5.2 Whites Creek Flood Study (2008)

Two notices were published in the "Wingecarribee Today" Newspaper by Council during the *'Whites Creek Flood Study'* (URS, 2009). The first notice was posted in June 2006 and requested any information, photographs or descriptions for large historical flood events in the Whites Creek catchment. The second notice was posted in July 2007 and requested any photographs of flooding in the Wingecarribee Shire.

Six responses were initially received to the notices and telephone discussions were subsequently conducted with each one. A further six residents were nominated during the telephone discussions as being able to provide additional historic flood information.

The majority of the residents did not hold specific historical flood information; however, they were concerned about the possibility of flooding. For example, a resident who previously lived on the intersection of Arthur and Mack Streets described the creek system "narrowing"

downstream of Argyle Street as a possible issue and was concerned about increasing development within the catchment.

One respondent was reported to have provided a significant series of historical records of flooding in Whites Creek, although the exact nature of these records was unclear from the Flood Study report.

2.5.3 Whites Creek Floodplain Risk Management Study and Plan (2012)

Community consultation was undertaken in October 2009 as part of the *'Whites Creek Floodplain Risk Management Study and Plan'* (2012). It consisted of a questionnaire and covering letter posted to 195 property owners, as well as an advertisement in Council's information page in two weekly local papers. The purpose of the questionnaire was to collect information on the demographics of the study area, information on previous floods experienced, and awareness of flood risks and actions.

A total of 24 responses were received. Of these, the key findings included:

- 42% of respondents were aware of flooding in the area;
- 38% of respondents were unaware of flooding in the area;
- 33% of respondents had their property flooded; and
- 21% of respondents had been inconvenienced by flooding.

2.5.4 Current Study

Community Questionnaire

A questionnaire was distributed to 251 households and businesses during the initial stage of the project in an effort to understand the types of flooding impacts that the community has experienced, how people would respond during future floods and what key objectives potential flood risk management measures should focus on. A copy of the questionnaire is included in **Appendix A**.

A total of 35 questionnaire responses were received and a summary of all questionnaire responses is provided in **Appendix A** in **Tables A1** to **A3**.

Most of the responses included addresses enabling spatial interpretation of the questionnaire responses. **Figure A1** in **Appendix A** shows the spatial distribution of reported flood impacts. **Figure A2** in **Appendix A** shows the spatial distribution of how people will likely respond during future floods.

The responses to the questionnaire indicate that:

- 18 of the 35 respondents (51%) have experienced some form of inundation or disruption as a result of flooding. The location and types of flood impacts that were reported are shown in **Figure A1**. The most common type of flood impact that was reported was access being lost due to inundation of roadways. A number of respondents also reported inundation of garages/sheds as well as above flood inundation of their house.

- During future floods, 40% of respondents indicated they would remain at home while only 26% indicated they would evacuate (refer **Figure A2**). 23% of respondents were unsure of how they would respond during a future flood.
- For those intending to evacuate, safety of their family was the overriding concern.
- The primary reason for not evacuating (i.e., staying home) was the discomfort/inconvenience of evacuation as well as concerns for the security of their property if they were to evacuate.

In terms of options for better managing/mitigating the flood risk, most of the suggested options were supported by the community. However, the following options were ranked highest by the community:

- Stormwater upgrades
- Regular maintenance and clearing of creeks
- Debris control structures to prevent blockage of culverts/bridges
- Flood forecasting/warning system
- SES local flood plan updates
- Community education

As discussed, most of the suggested options were supported by the community. However, the following options were the least favoured by the community:

- Voluntary house raising
- Voluntary house purchase
- Channel realignment

Public Exhibition

The draft 'Review of Whites Creek Floodplain Risk Management Study & Plan' was placed on public exhibition at Moss Vale, Bowral and Mittagong libraries, as well as the Wingecarribee Shire Council Civic Centre from 3 October 2019 to 7 January 2020. A digital version of the draft report was also available on the Wingecarribee Shire Council's website during the exhibition period. The public exhibition provided the opportunity for the community and key stakeholders to review the final draft report and provide feedback on the report content.

Three submissions were received during the exhibition period. A summary of the submissions that were received is provided in **Appendix O**. Also included in **Appendix O** are responses to each submission.

The actions that were taken to address the submissions did not alter the overall outcomes documented in the final draft report. However, an additional detention basin option was explored, and the outcomes of this assessment is provided in Section 7.2.3.

3 DEFINING THE FLOOD RISK

3.1 Overview

In order to identify and evaluate potential options for managing the flood risk, it is first important to have an understanding of the nature and extent of the existing flood risk as well as the potential future flood risk. This is typically achieved through the preparation of a flood study, which provides information on key flood characteristics (e.g., flood depths, levels and velocities) for a range of floods up to and including the Probable Maximum Flood.

As discussed, the '*Whites Creek Flood Study*' (URS, 2009) defined the nature and extent of flood behaviour across the study area based upon the best topographic information and modelling tools that were available at that time. The flood study was followed by the *'Whites Creek Floodplain Risk Management Study and Plan'* (URS, 2012). The floodplain risk management study and plan outlined a range of measures that could be implemented to better manage the existing and potential future flood risk across the Whites Creek catchment.

However, since the flood study and floodplain risk mangement study were prepared there have been advances in modelling technology, access to updated and more detailed topographic information (e.g., LiDAR) and significant updates to the national guideline for flood estimation (i.e., Australian Rainfall and Runoff). Additional development has also occurred since the flood study was prepared, which has likely altered flood behaviour. Therefore, as part of the current study, a new hydrologic model and a new hydraulic model were developed to ensure the definition of the existing flood behaviour is based upon the latest available knowledge, data and modelling tools.

The hydrologic model was developed using the XP-RAFTS software and the hydraulic model was developed using the TUFLOW software. The XP-RAFTS and TUFLOW models were validated against the June 2016 event to ensure that the models were providing realistic reproductions of past flood behaviour. The model development process and the outcomes of the validation for the hydrologic and hydraulic models are described in detail in **Appendix B** and **Appendix C**, respectively. A sensitivity analysis was also undertaken to establish the sensitivity of the results generated by the computer models to changes in model input parameter values. The outcomes of the sensitivity analysis are presented in **Appendix H**.

The following sections describe the outputs from the revised hydrologic and hydraulic modelling and how those outputs were used to establish the extent of the existing flood risk. It also describes the nature and extent of the potential future flood risk by quantifying the potential impacts that climate change as well as future catchment development may have on flood behaviour.

3.2 Existing Flood Behaviour

3.2.1 Hydrology

Model Updates

At the time this study was prepared, plans were underway to commence development across the Chelsea Gardens Subdivision. As this study will serve as the baseline document for defining flood behaviour the catchment for a number of years, it was considered to be important to include a full representation of these new development areas in the hydrologic and hydraulic model as part of the design flood simulations. Accordingly, the XP-RAFTS model that was developed to reflect existing catchment conditions was updated to reflect full development across this future development area.

The XP-RAFTS model was updated to reflect the increase in impervious surfaces across the proposed subdivision. An impervious proportion of 80% was adopted for proposed roadway and residential development areas which was extracted from the *'Stormwater Management Strategy Chelsea Gardens and Coomungie Lands'* (Calibre Consulting, 2015).

The Chelsea Gardens subdivision will include a series of detention basins that will serve to capture and temporarily store runoff from the subdivision to ensure downstream discharges do not increase as a result of the development. A representation of the detention basins was also included in the XP-RAFTS model using information contained in the *'Stormwater Management Strategy Chelsea Gardens and Coomungie Lands'* (Calibre Consulting, 2015). The locations of these basins are shown in **Figure B1.4**.

The XP-RAFTS input parameters that were adopted as part of the design flood simulations are included in **Appendix B**.

Australian Rainfall & Runoff 2016

For the past three decades flood behaviour across the Wingecarribee Shire Council LGA has been defined based upon guidance contained in the 1987 version of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia) (referred to herein as ARR1987). This included the *'Whites Creek Flood Study'* (URS, 2009) and the *'Whites Creek Floodplain Risk Management Study and Plan'* (URS, 2012).

In December 2016, a revised version of Australian Rainfall and Runoff was released (Geoscience Australia, 2016) (referred to herein as ARR2016). Therefore, investigations were completed to determine the impact that the revised hydrologic procedures may have on design flood estimates across the catchment.

The outcomes of the assessment are presented in **Appendix F**. The assessment determined that application of ARR2016 hydrologic procedures to the Whites Creek catchment is predicted to generate lower peak discharges across all design floods up to and including the 1% AEP event relative to ARR1987. This is predicted to also result in a reduction in design flood levels across the catchment relative to ARR1987. The differences are primarily a result of the lower ARR2016 design rainfall depths and, to a lesser extent, higher "burst" rainfall losses.

Although there are concerns that adopting lower design discharges and flood levels could underestimate the flood risk across the catchment, available information for the area indicates that the more regionalised ARR2016 input information is more reliable than the generalised ARR1987 inputs. Accordingly, it was considered that application of ARR2016 procedures as part of this FPRMS will provide an improved representation of design flood behaviour relative to the ARR1987 procedures.

Accordingly, the results that are presented in the following sections reflect the updated ARR2016 outputs.

Design Flood Discharges

The XP-RAFTS model was used to simulate design flood behaviour across the Whites Creek catchment based upon ARR2016 hydrology for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the PMF. Peak discharges for each subcatchment are included in **Appendix G**. Peak discharges were also extracted at a selection of key locations and are summarised in **Table 7**. The location where the peak discharges were extracted is shown in **Plate 4**.

Table 7 Design Discharges at Key Locations within the Whites Creek Catchment

ID#	Location Description	Peak Discharge (m^3/s)							
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	Moss Vale Sewage Treatment Plant	27.3	34.3	39.3	48.5	54.8	63.6	76.2	472
2	Northern end of Cosgrove Park	21.5	30.2	33.7	42.1	47.1	54.6	66.3	434
3	Corner of Willow Dr and Danger St	4.23	5.31	6.57	8.43	10.1	12.7	16.0	73.8
4	Culvert under the railway between Argyle St and Lackey Rd	13.2	18.0	21.1	26.0	34.4	32.5	42.5	301
5	Northern end of Roy Baker Walkway	12.5	17.3	19.7	25.3	33.4	32.2	42.1	291
6	Mack Street Bridge	11.3	15.5	17.6	22.9	23.7	31.5	41.3	268
7	Northern end of Moss Vale Golf Club	10.7	14.9	16.5	21.9	22.7	31.1	40.7	256
8	Moss Vale Golf Club near Dormie House	10.1	13.3	15.0	19.7	22.6	29.4	38.7	226
9	Southern end of Moss Vale Golf Club	9.13	12.0	13.2	18.0	20.8	27.2	36.1	209

refer to Plate 4 for Location ID

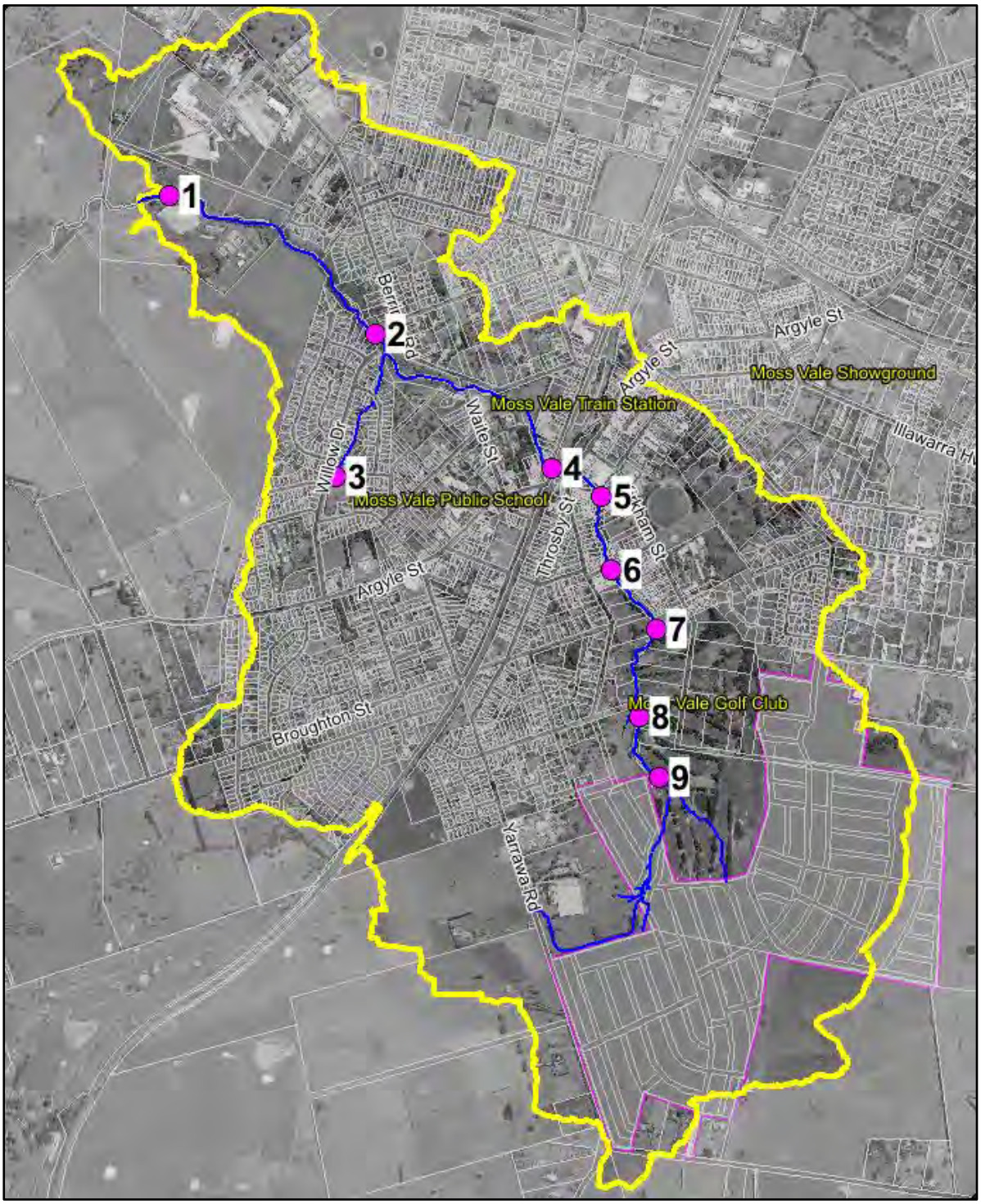


Plate 4 Locations where peak discharges were extracted

Appendix G also lists the critical duration and temporal patterns for each design flood and each subcatchment. A review of this information indicates critical durations are predicted to vary from 15 minutes up to 12 hours.

3.2.2 Hydraulics

Model Updates

As discussed, development across the Chelsea Gardens subdivision is likely to commence in the near future. Therefore, it was considered important to include a representation of the proposed subdivision in the TUFLOW model as part of the design flood simulations.

Proposed topographic modifications across this area were extracted from the *'Stormwater Management Strategy Chelsea Gardens and Coomungie Lands'* (Calibre Consulting, 2015) and included into the TUFLOW hydraulic model. This included a proposed rock-lined channel along a part section of the Whites Creek channel as well as elevating all roads to the levels of the 1% AEP flood and all residential areas 0.5 metres above the 1% AEP flood level. Material types and corresponding Manning's "n" values were also updated to reflect the modified hydraulic roughness across the subdivision.

As construction across the subdivision is yet to commence a detailed delineation of features across the subdivision, such as buildings, could not occur. As a result, the Manning's "n'" values were assigned to reflect a "weighted average" value (refer **Table C1** in **Appendix C**).

Design Blockage

As discussed in **Appendix C**, blockage factors were applied to each hydraulic structure for each design flood based on guidelines contained in 'Blockage of Hydraulic Structures' (Engineers Australia, 2015). However, it was noted that application of partial blockage to each hydraulic structure effectively creates a number of small storages across the catchment that serve to attenuate flows and reduce water levels downstream of each structure.

In recognition of the potential attenuation effects provided by the blockage factors and the understanding that structure blockage can be highly variable, each design flood was also simulated with no structure blockage. This was completed to ensure the flood risk downstream of each hydraulic structure was not underrepresented.

Design Flood Envelope

As discussed, a range of different storm durations and temporal patterns were simulated for each design flood. In addition, simulations were completed with partial blockage as well as no blockage of hydraulic structures. As a result, a range of results were generated as part of the design flood modelling.

Therefore, the results from each of the individual simulations (i.e., different storm durations/temporal patterns and blockage scenarios) were subsequently merged to form a "flood envelope" for each design flood. This involved extracting and comparing peak flood levels, depths and velocities at each TUFLOW grid cell and adopting the highest depth, level and velocity at each grid cell. It is this design flood envelope, comprising the critical depths, velocities and levels at each grid cell that forms the basis for the results documented in the following sections.

Floodwater Levels, Depths and Velocities

Peak floodwater depths, levels and velocity vectors were extracted from the results of the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF simulations and are presented in **Figures 4.1** to **11.3** inclusive.

Peak flood levels were also extracted from the results of the modelling at key locations throughout the Whites Creek catchment and are presented in **Table 8**. The location identification (ID) numbers are shown in **Plate 5**.

The results presented in **Figures 4.1** to **11.3** shows that:

- Flood behaviour across the Whites Creek catchment is typically characterised by relatively shallow depths of inundation (i.e., < 0.5 metres). However, more significant depths are predicted along and immediately adjacent to designated waterways where flood depths are predicted to reach up to 2 metres.
- The most significant flooding impacts are predicted across low lying land adjoining Whites and Willow Creeks, including properties located in the following areas:
  - Argyle Street
  - Lackey Road
  - Campbell Crescent
  - Lapwing Place
- Flooding is also predicted along the drainage channels that adjoin the Main Southern Railway corridor and impacts on properties along Railway Street and Throsby Street
- Several roadways within the catchment are predicted to be inundated in events as frequent as the 20% AEP flood. This includes Argyle Street, Lackey Road, Railway Street, Throsby Street, Campbell Crescent and Dangar Street.
- During major flooding (i.e. events greater than or equal to the 1% AEP flood) Mack Street, Waite Street, Arthur Street, Morrice Court and Lapwing Place are also predicted to be inundated.
- Flooding in this area occurs as a result of floodwaters overtopping the Argyle Street culvert and combining with flows that drain along either side of the railway embankment.

Flood Hazard Categories

Flood hazard defines the potential impact that flooding will have on development and people across different sections of the floodplain. More specifically, it describes the potential for floodwaters to cause damage to property or loss of life / injury (AIDR, 2014).

Provisional hazard categories were prepared based on criteria contained in Appendix L of the *'Floodplain Development Manual'* (2005) (FDM) as Council currently uses this information to assist in defining flood risk precincts (refer Section 3.3). The resulting hazard maps for the 10% AEP, 0.5% AEP and 1% AEP floods as well as the PMF are shown in **Figures 12.1** to **15.3** inclusive.

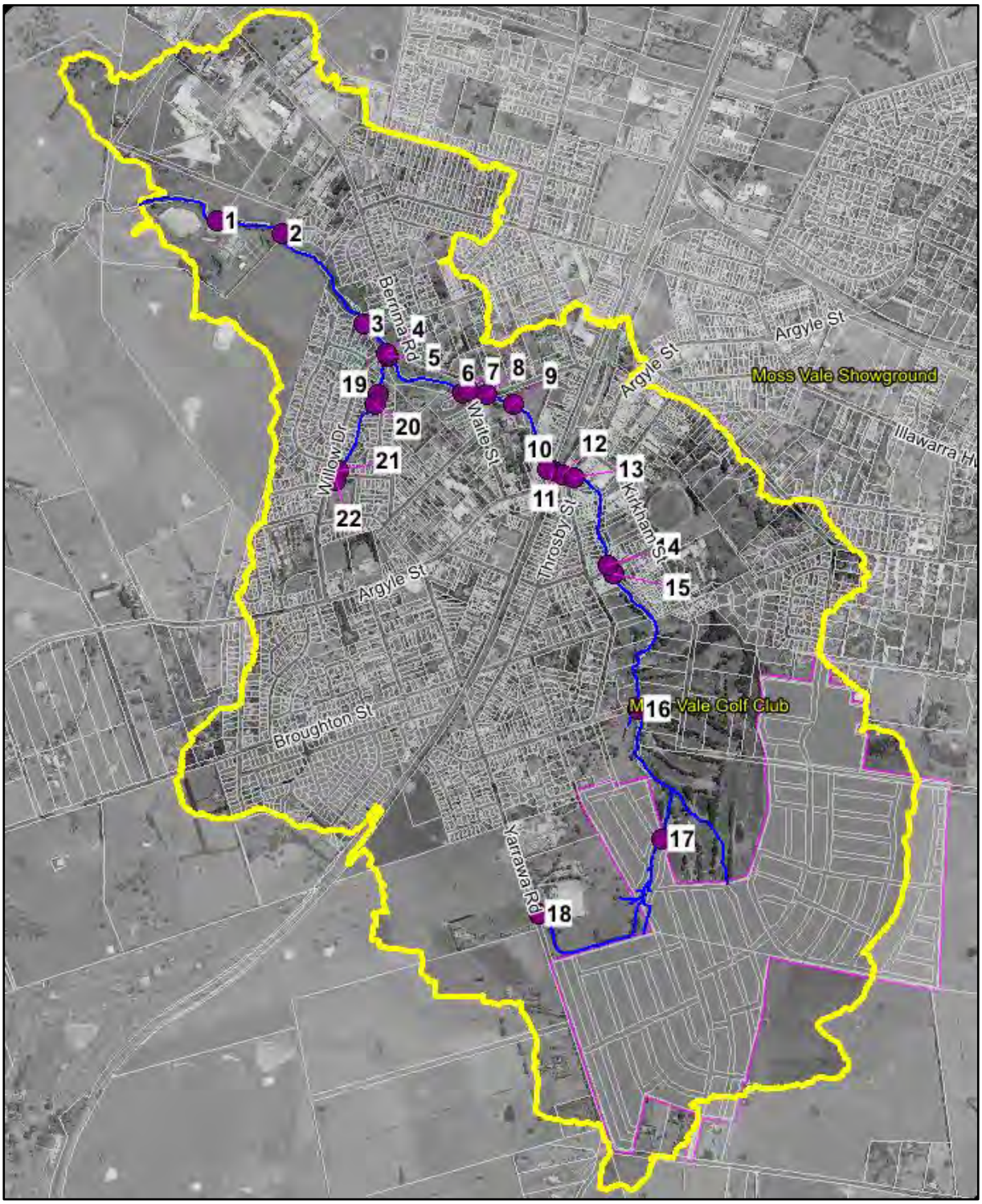


Plate 5 Locations where peak flood levels were extracted

Table 8 Peak Design Floodwater Level

ID	Location	Peak Floodwater Level *(mAHD)*							
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Whites Creek									
	Moss Vale Sewage Treatment Plant	655.43	655.65	655.68	655.85	655.98	656.04	656.20	657.97
2	End of Gibbons Road	657.42	657.55	657.57	657.68	657.78	657.83	657.97	659.86
3	Northern Boundary of Cosgrove Park	660.57	660.68	660.70	660.79	660.87	660.90	661.00	662.66
4	Cosgrove Park Footbridge - Upstream	662.02	662.17	662.19	662.32	662.44	662.48	662.62	664.45
5	Confluence with Willow Creek	662.05	662.20	662.22	662.35	662.47	662.51	662.65	664.51
6	Waite Street - Downstream	663.28	663.47	663.51	663.66	663.78	663.84	663.99	666.18
7	Waite Street - Upstream	663.62	663.98	664.04	664.40	664.78	665.24	665.33	666.46
8	St Paul's International College - Upstream of Footbridge 1	663.90	664.20	664.25	664.54	664.87	665.29	665.39	667.23
9	St Paul's International College - Upstream of Footbridge 2	664.60	664.78	664.80	664.98	665.17	665.43	665.56	667.61
10	Lackey Road - Downstream	665.76	666.04	666.05	666.19	666.33	666.37	666.51	668.55
11	Lackey Road - Upstream	665.79	666.09	666.11	666.24	666.39	666.44	666.59	668.57
12	Railway Line - Upstream	666.22	666.68	666.68	666.94	667.19	667.72	667.95	671.16
13	Argyle Street - Upstream	667.15	667.69	667.70	667.75	667.77	667.90	668.08	671.20
14	Mack Street - Downstream	668.62	668.81	668.82	668.98	669.11	669.17	669.37	671.81
15	Mack Street - Upstream	668.90	669.13	669.14	669.37	669.64	669.83	670.07	671.94
16	Moss Vale Golf Club near Dormie House	672.55	672.72	672.73	672.94	673.11	673.14	673.40	674.97
Whites Creek Tributary									
17	Eastern Boundary of Moss Vale Golf Club	680.47	680.55	680.61	680.70	680.77	680.83	680.92	681.69
18	Yarrawa Road - Downstream	687.76	687.85	687.89	687.99	688.09	688.15	688.30	689.54
Willow Creek									
19	Campbell Crescent - Downstream	663.01	663.06	663.12	663.22	663.30	663.35	663.49	664.80
20	Campbell Crescent - Upstream	664.67	664.69	664.94	665.03	665.11	665.25	665.35	666.05

ID	Location	Peak Floodwater Level *(mAHD)*							
		20% AEP	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
21	Dangar Street - Downstream	665.79	665.90	666.00	666.12	666.22	666.27	666.41	667.39
22	Dangar Street - Upstream	667.48	667.54	667.59	667.65	667.71	667.75	667.84	668.44

refer to Plate 5 for Location ID

The FDM hazard category mapping indicates that the high hazard areas typically coincide with defined waterways. Very few habitable areas are predicted to be exposed to a high flood hazard during events up to and including the 1% AEP event. Nevertheless, several roadways within the study area are predicted to be high hazard areas at the peak of the 1% AEP flood, including Argyle Street, Railway Street and Lackey Road. Waite Street, Lackey Road and Mack Street are predicted to be high hazard areas at the peak of the PMF.

It was noted that more contemporary flood hazard vulnerability curves have been published in the Australian Institute for Disaster Resilience's (AIDR) *'Technical Flood Risk Management Guideline: Flood Hazard'* (2014). The hazard curves are reproduced in **Plate 6** and are also described in **Table 9**. As shown in **Plate 6**, the hazard curves assess the potential vulnerability of people (for differing physical abilities), cars and structures based upon the depth and velocity of floodwaters at a particular location. Accordingly, this guideline is considered to provide a more detailed understanding of the potential flood hazard and it was considered valuable to also prepare flood hazard mapping in accordance with this guideline.

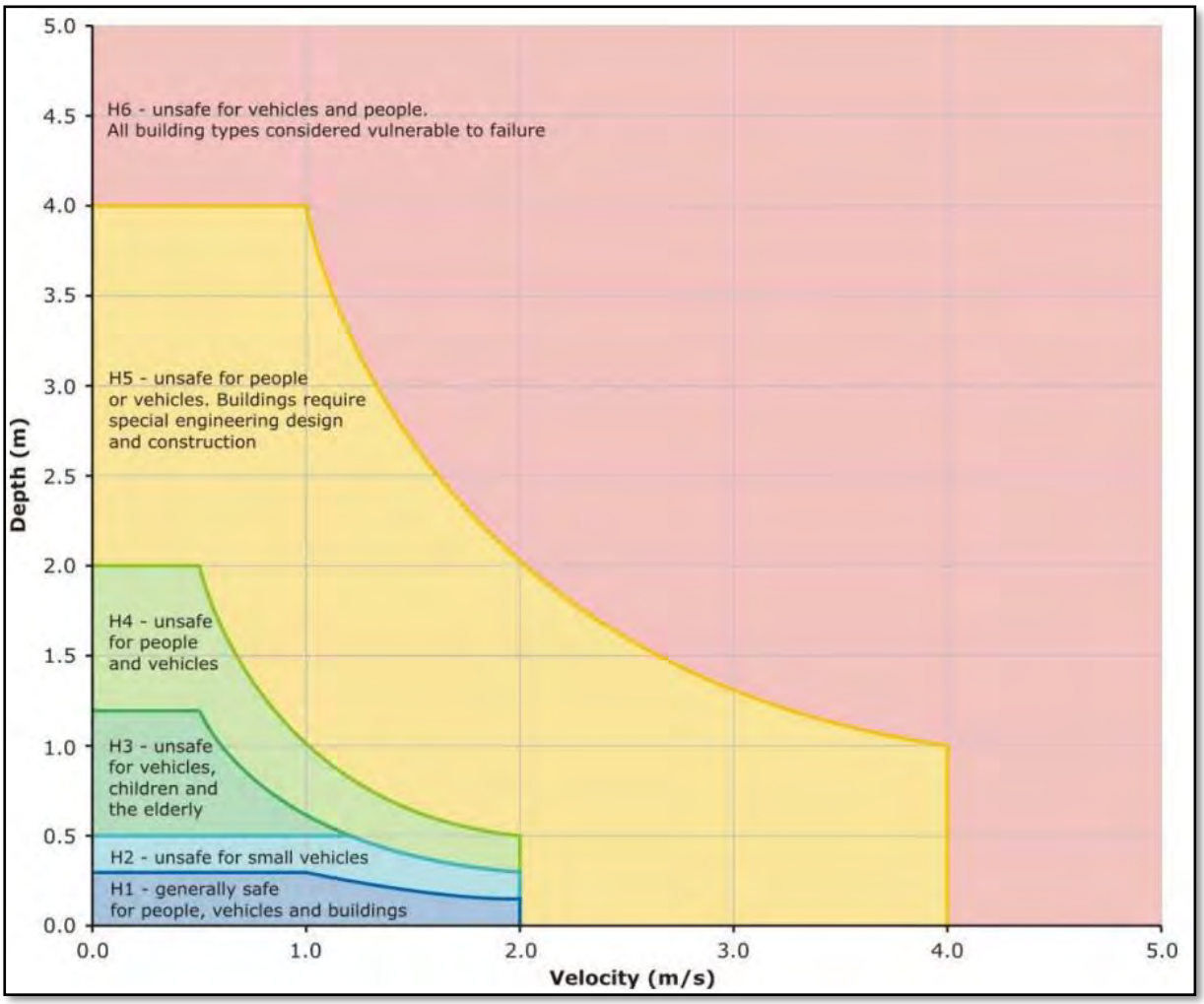


Plate 6 Flood hazard vulnerability curves (AIDR, 2014)

Table 9 Description of Adopted Flood Hazard Categories (Australian Government, 2014)

Hazard Category	Description
H1	Generally safe for vehicles, people and buildings. Relatively benign flood conditions. No vulnerability constraints
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

The resulting "national" hazard category maps are included in **Appendix I** as **Figures I1.1** to **I4.3** inclusive.

Figures I2.1 to **I2.3** indicate that during the 1% AEP flood, most areas would be exposed to a H1 hazard, which indicates that the water would not present a significant hazard to people or vehicles. Nevertheless, there are some localised areas (most notably the Argyle Street/Railway Street/Lackey Road area) where the hazard is predicted to exceed H3. This may be hazardous for people and vehicles. In general, H5 and H6 areas are restricted to the main watercourses.

Figures I3.1 to **I3.3** shows that during the PMF, more extensive areas of H5 and H6 are predicted. This includes some residential and commercial areas fronting Lapwing Place, Morrice Court, Argyle Street, Lackey Road, Railway Street, Campbell Crescent and Willow Drive. This hazard category indicates that there is potential for structural failure of buildings in these areas should a flood of PMF magnitude occur. Many of these roadways would also experience hazards of H4 or above and would not be safe for vehicles or people.

Hydraulic Categories

Hydraulic categories provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour and highlights areas that should be retained for the conveyance and storage of floodwaters (failure to do so will likely have an adverse impact on existing flood behaviour).

The *'Floodplain Development Manual'* (2005) subdivides flood prone land into one of three hydraulic categories, which are summarised in **Table 10**. The hydraulic categories define areas that are important for the conveyance and storage of floodwaters and, at the same time, highlight areas where development (e.g., filling) has the potential to adversely impact on flood behaviour.

Table 10 Qualitative and Quantitative Criteria for Hydraulic Categories

Hydraulic Category	Qualitative Description	Adopted Criteria*
Floodway	• those areas where a significant volume of water flows during floods • often aligned with obvious natural channels and drainage depressions • they are areas that, even if only partially blocked, would have a significant impact on upstream water levels and/or would divert water from existing flowpaths resulting in the development of new flowpaths. • they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	• V x D > 0.4 m^2/s; or • V > 1 m/s
Flood Storage	• those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood • if the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. • substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.	• Not floodway and depth ≥ 0.2 m
Flood Fringe	• the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. • development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.	• Not floodway and depth < 0.2 m

NOTES: V = Velocity, D = Depth
**The adopted criteria were developed specifically for the Whites Creek catchment only and may not be appropriate for any other areas.*

The FDM does not provide explicit quantitative criteria for defining hydraulic categories. This is because the extent of floodway, flood storage and flood fringe areas are typically specific to a particular catchment. However, quantitative criteria were developed as part of this study and are reproduced in **Table 10**. The resulting hydraulic category maps for the 10 % and 1% AEP floods as well as the PMF are shown in **Figures 16.1** to **18.3** inclusive.

To confirm the suitability of the hydraulic categorisation, verification simulations were completed based upon the 1% AEP flood. The verification was completed by:

- Floodway Verification: obstructions were included across part sections of floodways to confirm that the partial obstructions *"…would have a significant impact on upstream water levels and/or would divert water from existing flowpaths"*
- Flood Storage Verification: All flood storage areas were completely filled to confirm that removal of the storage areas would cause flood levels in nearby areas to increase.

- Flood Fringe Verification: Flood fringe areas were completely filled to confirm that removal of the fringe areas would *"…not have any significant effect on the pattern of flood flows and/or flood levels"*.

The outcomes of the verification are summarised in **Appendix M** and show that the adopted criteria meet the requirements/definitions set out in the *'Floodplain Development Manual'* (2005).

The hydraulic category maps show that floodways are typically contained in close proximity to the main watercourses during events up to and including the 1% AEP. However, some roadways would likely function as floodways at the peak of the 1% AEP event, including Argyle Street, Lackey Road, Railway Street, Dangar Street and Campbell Crescent. At the peak of the PMF, Throsby Street, Arthur Street, Waite Street and Mack Street are also predicted to be floodways. In addition, the open drains alongside the Main Southern Railway Line are also predicted to function as floodways.

A significant floodway area extends from the upstream boundary of St Paul's International College to the Moss Vale Sewage Treatment Plant during the 1% AEP flood. During the PMF, this significant floodway area also extends upstream to the Railway Line and encompasses several existing residential and commercial properties, most notably along Argyle Street, Lackey Road, Morrice Court and Lapwing Place.

As outlined in **Table 10**, flood storage areas are important for the temporary storage of floodwaters and filling these areas has the potential to adversely impact on existing flood behaviour. This was confirmed as part of the hydraulic category verification presented in **Appendix M**, which showed filling all flood storage areas would result in existing 1% AEP flood levels commonly increasing by between 0.1 and 0.2 metres. It should be noted that hydraulic assessments of filling of storage areas on individual properties may not always indicate a significant impact. However, when similar filling is considered across all existing and potential lots, the cumulative impact does become significant. This must be kept in mind when assessing individual development proposals. In general, filling across the flood storage areas defined as part of this project should be discouraged. In the event filling is proposed, compensatory storage should be provided, and the suitability of the compensatory storage should be confirmed via appropriate hydraulic analysis.

Emergency Response Precinct Classifications

In an effort to understand the potential emergency response requirements across different sections of the Whites Creek catchment, flood emergency response precinct (ERP) classifications were prepared in accordance with the flow chart shown in **Plate 7** (Australian Emergency Management Institute, 2014). The ERP classifications can be used to provide an indication of areas which may be inundated or may be isolated during floods. This information, in turn, can be used to quantify the type of emergency response that may be required across different sections of the floodplain during future floods. This information can be useful in emergency response planning.

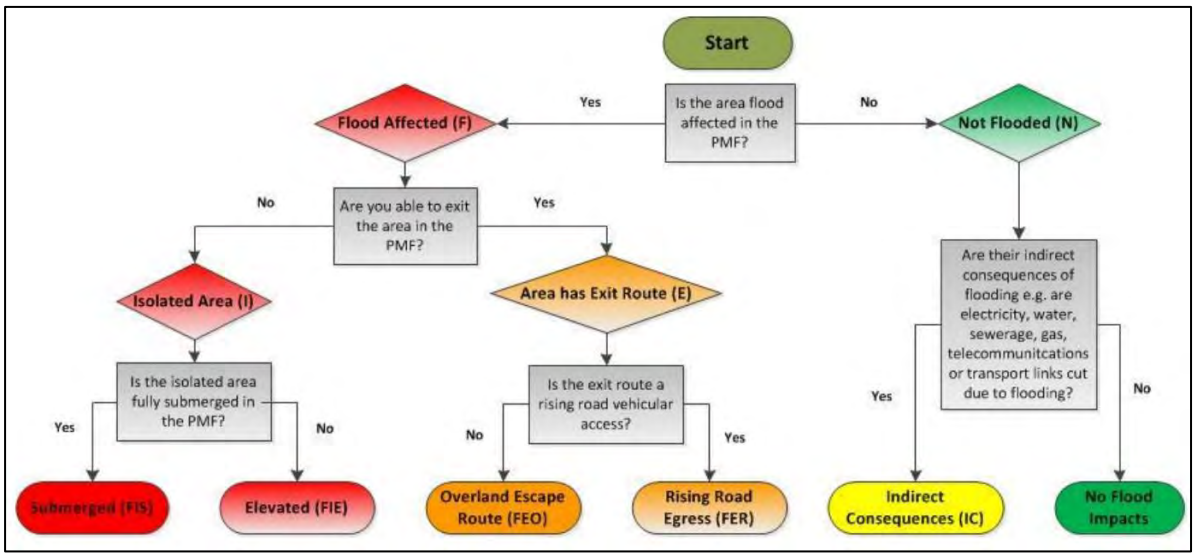


Plate 7 Flow Chart for Determining Emergency Response Planning Classifications (AEMI, 2014).

Each allotment within the catchment was classified based upon the ERP flow chart shown above for the 5% AEP, 2% AEP and 1% AEP floods as well as the PMF. This was completed using the TUFLOW model results, digital elevation model and a road network GIS layer in conjunction with proprietary software that considered the following factors:

- Whether evacuation routes/roadways get "cut off" by the depth of inundation (a 0.2 m depth threshold was used to define a "cut" road).
- Whether evacuation routes continuously rise out of the floodplain.
- Whether properties become inundated.

The resulting ERP classifications are provided in **Figures 19** to **Figure 22**. A range of other datasets were also generated as part of the classification process to assist Council and the SES. This includes the locations where roadways are first cut by floodwaters, which are discussed in more detail in Section 3.4.2.

Figures 21.1 to **21.3** show that during the 1% AEP flood, the most common ERP classification is "Rising Road Egress", which indicates that evacuation routes grade up and out of the floodwaters. However, there are some "flooded isolated submerged" areas (i.e., low flood islands) and "flooded isolated elevated" areas, which indicates that evacuation routes are likely to be cut prior to inundation of the properties themselves. This includes a number of properties fronting Argyle Street, as well as some properties adjoining Railway Street and Campbell Crescent.

Figures 22.1 to **22.3** show that during the PMF, the number of "flooded isolated submerged" and "flooded isolated elevated" areas increase significantly. Accordingly, if a particularly large flood was to occur, there is potential for a very large number of lots to become isolated. The sheer number of these "flooded isolated submerged" lots during the PMF (118 lots) and the limited warning times (as indicated by the "time road first cut") means that it is unlikely emergency services will be able to offer assistance.

3.3 Flood Risk Precincts

Wingecarribee Shire Council have a suite of Development Control Plans (DCPs) that outline Council's requirements for development on all floodplains within the Local Government Area. This includes the Whites Creek catchment. Further discussion on the DCPs applicable to the Whites Creek catchment are included in Section 4.3.2.

Section A5.3.2 of the DCPs introduces the concept of "Flood Risk Precincts", which subdivides the floodplain accordingly to the potential flood hazard/risk. This flood risk precinct classification, in turn, determines what flood-related development controls are applicable for a particular parcel of land. The four flood risk precincts that are documented in the DCPs are summarised in **Table 11**.

To aid Council in defining the spatial extent of each flood risk precinct across the Whites Creek catchment, a Flood Risk Precinct map was prepared based on the outcomes of the design flood simulations and hazard mapping. The flood risk precinct maps are shown in **Figures 30.1** to **30.3** inclusive.

Table 11 Flood Risk Precinct Definitions

Flood Risk Precinct	Description
High	This Precinct contains that land below the 1% AEP flood that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties. The high flood risk precinct is where high flood damages, potential risk to life, and evacuation problems would be anticipated, or development would significantly and adversely affect flood behaviour. Most development should be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood related building and planning controls.
Medium	This Precinct contains that land below the 1% AEP flood that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties. In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.
Fringe-Low	This Precinct contains that land between the extents of the 1% AEP flood and the 1% AEP flood plus 0.5m in elevation (being a freeboard). In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.
Low	This Precinct contains that land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within any of the above Flood Risk Precincts. The Low Flood Risk Precinct is where risk of damages is low for most land uses and most land uses would be unrestricted within this precinct.

3.4 Impacts of Flooding on the Community

3.4.1 Impact of Flooding on Key Facilities

The Whites Creek catchment is home to a range of property types and infrastructure. This includes facilities where the occupants may be particularly vulnerable during floods, such as schools. In addition, some facilities may play important roles for emergency response and

evacuation purposes during future floods (e.g., hospitals & evacuation centres). Therefore, it is important to have an understanding of the potential vulnerability of these facilities during a range of floods.

Critical and vulnerable facilities located within the Whites Creek catchment are summarised below. A discussion on the impacts of flooding on each facility is provided below and is also summarised in **Table 12**.

- **Police Stations:**
  - ***Southern Highlands Police Station*** (67 Elizabeth Street, Moss Vale): The police building is not predicted to be inundated during 1% AEP flood. The south west corner of the lot is affected by up to H3 hazard during the PMF. However, above floor inundation is not anticipated. Access along Clarence Street would be cut at the peak of the PMF. However, access along Elizabeth Street would still be available.
- **Fire Stations:**
  - ***Fire and Rescue NSW Moss Vale*** (64 Elizabeth Street, Moss Vale): The Fire Station is not predicted to be inundated during any design flood up to and including the PMF. Access along Elizabeth Street would be available during the 1% AEP flood, however the intersection of White Street and Elizabeth Street is predicted to be inundated during PMF.
- **Medical Centres:**
  - ***Southern Medical*** (61 Elizabeth Street, Moss Vale): Southern Medical is not predicted to be inundated during any design flood up to and including the PMF. Access along Clarence Street and Elizabeth Street would be available during all floods.
  - ***Moss Vale Early Childhood Health Centre*** (62 Elizabeth Street, Moss Vale): The facility is located next to Fire and Rescue NSW. Above floor inundation is not anticipated during any flood. Access along Elizabeth Street would be available during the 1% AEP flood. However, access along White Street is unlikely to be available during the PMF.
- **Schools:**
  - ***KU Donkin Preschool*** (Donkin Ave, Moss Vale): It is not predicted to be impacted during any of the design floods up to and including the PMF.
  - ***St Pauls Primary School*** (18 Garrett Street, Moss Vale): St Pauls is not predicted to be inundated during any design flood up to and including the PMF. Access would be available along Garrett Street and Innes Road during floods.
  - ***Moss Vale Public School*** (Browley Street, Moss Vale): Moss Vale Public School is not predicted to be inundated during any design flood up to and including the PMF. Access would be available along Browley Street.
  - ***St Pauls International College*** (Argyle Street, Moss Vale): White Creeks flows along the eastern side of St Pauls International College Precinct. The eastern sections of the site are predicted to be exposed to H5 hazard during the 1% AEP flood and up to H6 hazard during the PMF. However, this is concentrated away from buildings and above floor inundation is not predicted. Access along Waite Street would be available during the 1% AEP flood. During the PMF, Waite Street would be cut at the northern

end but evacuation along the Illawarra Highway / Argyle Street would likely still be available.

Table 12 Impact of Flooding on Key Facilities

Facility		1% AEP Flood			PMF		
		Max Hazard	Flooded Above Floor?	Vehicular Access Cut?	Max Hazard	Flooded Above Floor?	Vehicular Access Cut?
Fire Stations	Fire and Rescue NSW Moss Vale (64 Elizabeth Street, Moss Vale):						
Police Stations	Southern Highlands Police Station (67 Elizabeth Street, Moss Vale):				H3		
Medical Centre	Southern Medical (61 Elizabeth Street, Moss Vale):						
	Moss Vale Early Childhood Health Centre (62 Elizabeth Street, Moss Vale):						
Schools	KU Donkin Preschool (Donkin Ave, Moss Vale):						
	St Pauls Primary School (18 Garrett Street, Moss Vale):						
	Moss Vale Public School (Browley Street, Moss Vale):						
	St Pauls International College (Argyle Street, Moss Vale):	H5			H6		
Aged Care Facilities	RFBI Moss Vale Masonic Village (50-52 Elizabeth Street, Moss Vale):						
	Harbison (36 Yarrawa Road, Moss Vale):						☑
	Anglicare Community Care (5/274 Argyle St, Moss Vale NSW 2577)				H4	☑	☑
Child Care Facilities	KU Moss Vale (Cnr Mann Crescent and Ralfe Street, Moss Vale):				H5		
	Rainbow Kindy Moss Vale (35 Spring Street, Moss Vale)			☑			☑

Caravan Park	Moss Vale Village Caravan Park (Willow Dr, Moss Vale)						

- **Caravan Park:**
  - ***Moss Vale Village Caravan Park*** (Willow Dr, Moss Vale): Moss Vale Village Caravan Park is not predicted to be inundated during any design flood up to and including the PMF. Access along the Willow Drive towards Argyle Street would be available.
- **Aged Care Facilities:**
  - ***RFBI Moss Vale Masonic Village*** (50-52 Elizabeth Street, Moss Vale): RFBI Moss Vale is not predicted to be inundated during any design flood up to and including the PMF. Access along Elizabeth Street would be available during all design floods.
  - ***Harbison*** (36 Yarrawa Road, Moss Vale): Harbison is not directly affected by flooding during events up to and including the PMF. Access along Yarrawa Road would typically be available. However, during the PMF multiple roads in the area would likely be cut resulting in this facility being isolated for 1-2 hours.
  - ***Anglicare Community Care*** (5/274 Argyle Street, Moss Vale): The Anglicare Community Care is not predicted to be inundated during 1% AEP flood. The building is affected up to H4 hazard during the PMF. No above floor inundation is predicted during the 1% AEP flood. However, during the PMF, more than 1.5 m of water is expected through the building. Evacuation along White Street and Argyle Street would likely be possible during 1% AEP. However, the access along both roads would be cut during the PMF (although Argyle Street would only be cut for about 30 mins).
- **Child Care Facilities:**
  - ***KU Moss Vale*** (Corner Mann Crescent and Ralfe Street, Moss Vale): KU Moss Vale is not predicted to be inundated during 1% AEP flood. However, the western part of the lot is exposed to H5 hazard during the PMF (although in the immediate vicinity of the building H1 hazard is most common). Above floor inundation is not predicted during any of the design floods. Evacuation would be possible along Mann Crescent during 1% AEP. The low point in Mann Crescent as well as the driveway into the facility is like to be cut during the PMF. However, evacuation on foot from the front of the property to Mann Crescent would still be possible (only H1 hazard in this area during the PMF).
  - ***Rainbow Kindy Moss Vale*** (35 Spring Street, Moss Vale): The Rainbow Kindy Moss Vale is not predicted to be inundated during any design flood up to and including the PMF. Railway Street and Mack Street would likely be cut by floodwaters during the 1% AEP flood and PMF resulting in the site being temporarily isolated (access would typically be cut for less than 2 hours).

3.4.2 Transportation Impacts

There are several major roadways within the Whites Creek catchment which may be required for evacuation or emergency services access during floods. It is important to understand the impacts of flooding on these roads so that appropriate emergency response planning can occur.

An assessment of the location where roadways are first predicted to be overtopped was completed as part of the Flood Emergency Response Precinct classifications discussed in Section 3.2.2. The roadway overtopping locations are shown as yellow dots in **Figures 19.1** to **22.3**. Also included are labels describing the amount of time it takes for the roads to be inundated relative to the onset of rainfall (green label) and the total duration of roadway inundation (red label). Accordingly, this provides information describing the amount of warning time that would typically be available and how long the roadway would be cut by floodwaters after inundation first occurs.

With regard to the impact of floods on major roadways in the catchment, the roadway inundation information indicates that (also refer **Table 13**):

- ***Mack Street:*** Mack Street is predicted to experience inundation during all of the design floods greater than and including the 1% AEP flood. This ranges from 0.1 metre during the 1% AEP flood to more than 1 metre during the PMF. Accordingly, the road would likely remain trafficable during smaller floods, but access would be cut during events greater than the 1% AEP flood.
- ***Argyle Street:*** Argyle Street is predicted to be inundated during all of the simulated design floods. Depths of inundation are predicted to range from about 0.5m during the 20% AEP event to over 1 metre during the PMF. Accordingly, it is unlikely that vehicular access along Argyle Street would be possible during the 20% AEP event and for all events up to and including the PMF. This would result in a number of businesses becoming isolated.
- ***Lackey Road:*** Lackey Road is predicted to be inundated during all of the simulated design floods. Depths of inundation are the highest near the intersection with Argyle Street and are predicted to range from about 0.5m during the 20% AEP event to over 1 metre during the PMF. Accordingly, it is unlikely that vehicular along Lackey Road would be possible during the 20% AEP event and for all events up to and including the PMF. This would result in a number of properties becoming isolated.
- ***Railway Street:*** Railway Street is predicted to be inundated during all of the simulated design floods. Depths of inundation are highest at the northern end of the road near the intersection with Argyle Street and are predicted to range from about 0.2m during the 20% AEP event at the northern end of the road at the intersection with Argyle Street, to 0.3 metres during the 10% AEP flood, up to 0.5 metre during the 1% AEP flood and over 1 metre during the PMF. Accordingly, it is unlikely that vehicular along Railway Street would be possible during the 10% AEP event and for all events up to the PMF event. This would result in a number of properties at the northern end of the street becoming isolated.
- ***Arthur Street:*** Inundation of Arthur Street is limited to the intersection with Argyle Street for all design events up to and including the 0.2% AEP flood. However, during the PMF Arthur Street is predicted to experience inundation of greater than 1 metre. Accordingly, the road would likely remain trafficable during most flood events, but access would be cut during extreme flooding such as the PMF.
- ***Throsby Street:*** Shallow depths of inundation (i.e. less than 0.15 metres) are predicted on Throsby Street north of Chapman Street during events up to and including the 1% AEP flood. During the 0.5%, 0.2% AEP floods and the PMF, inundation depths increase

up to 0.5 metres. Accordingly, the roadway would likely remain trafficable during smaller floods, but access would be cut during events greater than the 1% AEP flood.

Table 13 Impact of Flooding on Key Transportation Links

Roadway	Access Cut During 20% AEP Flood?	Access Cut During 1% AEP Flood?	Access Cut During PMF?
Mack Street		☑	☑
Argyle Street	☑	☑	☑
Lackey Road	☑	☑	☑
Railway Street	☑	☑	☑
Arthur Street			☑
Throsby Street			☑
White Street			☑
Kirkham Street			☑
Waite Street			☑
Berrima Road			☑
Innes Road			☑
Dangar Street	☑	☑	☑
Willow Drive		☑	☑
Campbell Crescent		☑	☑

- ***White Street:*** White Street is predicted to remain "flood free" during all events except the PMF. Depths across the street during the PMF are predicted to exceed 1 metre. Accordingly, White Street is only predicted to be cut during very large floods.
- ***Kirkham Street:*** Kirkham Street is predicted to remain "flood free" during all events except the PMF. Depths across the roadway during the PMF are predicted to exceed 0.5 metre. Accordingly, Kirkham Street is only predicted to be cut during very large floods.
- ***Waite Street:*** Waite Street is predicted to remain "flood free" during all events except the PMF. Depths across the roadway during the PMF are predicted to exceed 0.5 metre. Accordingly, Waite Street is only predicted to be cut during extreme floods.
- ***Berrima Road:*** Berrima Road is predicted to remain "flood free" during all events except the PMF. Depths across the roadway during the PMF are predicted to exceed 1 metre. Accordingly, Berrima Road is only predicted to be cut during extreme floods.
- ***Innes Road:*** Innes Road is predicted to remain "flood free" during all events up to and including the 1% AEP flood. During the 0.5% and 0.2% it is predicted to be subjected to shallow depths of inundation up to 0.3 metres. Depths across the roadway during the PMF are predicted to exceed 1 metre. Accordingly, Innes Road is predicted to remain

trafficable during all events up to and including the 0.2% AEP flood, however it will be cut during the PMF.

- ***Dangar Street:*** Dangar Street is predicted to be inundated during all of the simulated design floods. Shallow depths of inundation (i.e. less than 0.15 metres) are predicted during the 20% AEP flood. However, floodwater depths in excess of 0.3 metres are predicted during events greater than and including the 10% AEP flood and would exceed 0.5 metre during the PMF. Accordingly, it is unlikely that vehicular along Railway Street would be possible during the 10% AEP event and for all events up to the PMF event.
- ***Willow Drive:*** Willow Drive is predicted to be cut during events including and greater than the 5% AEP flood. However, depths of inundation less than 0.3 metres are predicted during the 5% AEP flood. Therefore, the road would remain trafficable in events up to and including the 5% AEP event. During larger events, the road is predicted to be inundated by floodwater depths up to 1 metre. This would result in a number of residential properties fronting Willow Drive becoming isolated.
- ***Campbell Crescent:*** Shallow depths of inundation (i.e. less than 0.15 metres) are predicted on Campbell Crescent during the 10% AEP flood. During the 5% AEP flood and greater magnitude flood events, depths of flooding on Campbell Crescent are predicted to range between 0.2 metres and about 1 metre. Accordingly, the roadway would likely remain trafficable during smaller floods, but access would be cut during events greater than the 5% AEP flood.

It should be noted that under no circumstances should vehicles attempt to drive through floodwaters regardless of the floodwater depth of the type of vehicle they are driving.

It should be noted that the roadway inundation information is based on "design" flood information. No two floods are the same and future floods will likely exhibit different characteristics. Nevertheless, the information provides a good indication of the relative susceptibility of roadways in different parts of the study area to inundation and can assist emergency services in evacuation planning.

3.4.3 Above Floor Flooding

In an effort to quantify the impact that flooding has across the Whites Creek Catchment, the number of residential, commercial and industrial buildings expected to be subject to above floor flooding during each design flood was calculated. This was completed by comparing peak design flood level information with surveyed floor levels that were collected as part of the *'Whites Creek Floodplain Risk Management Study'* (URS, 2012).

The number of properties expected to be subject to above floor flooding during each design flood across the Whites Creek Catchment was extracted and is summarised in **Table 14**. The design flood at which above floor flooding first occurs was extracted from the results of the analysis and is presented in **Figure 29**.

Table 14 shows that only a relatively small number of residential properties are predicted to be exposed to above floor flooding during events up to and including the PMF. In general, industrial/commercial properties are subject to a higher flood exposure during more frequent floods, most notably the commercial properties fronting Argyle Street. However, the number

of residential properties subject to above floor inundation is predicted to increase significantly during the PMF. Overall it is expected that 140 properties would be subject to above floor flooding during the PMF.

Table 14 Number of Properties Subject to Above Floor Inundation

Flood	Number of buildings with above floor flooding		
	Residential	Commercial/ Industrial	Total Number
20% AEP	0	1	1
5% AEP	2	3	5
1% AEP	2	6	8
PMF	101	39	140

3.4.4 The Cost of Flooding

To assist in quantifying the financial impacts of flooding on the community, a flood damage assessment was also completed. The flood damage assessment aimed to quantify the potential flood damage costs incurred during a range of design floods across the Whites Creek catchment. A detailed description of the approach used to establish the flood damage cost estimates is provided in **Appendix J**.

As outlined in **Appendix J**, flood damage estimates were prepared using flood damage curves in conjunction with design flood level estimates and building floor levels for each of the following property/asset types.

- Residential properties below floor flooding
- Residential properties above floor flooding
- Commercial properties above floor flooding
- Industrial properties above floor flooding
- Infrastructure

Residential property damage has been divided into below floor and above floor flooding as damages can be expected to occur within a property before flooding inundates the residential floor level. For example, garages are normally at ground level and are used for storage of goods as well as vehicles, therefore damage could be expected once water inundates the garage floor level. Yards may become damaged once floodwaters submerge the landscape and plants.

The flood damage estimates for each design flood are summarised in **Table 15**. It indicates that if a 1% AEP flood was to occur, over $500,000 worth of damage could be expected across the Whites Creek catchment. **Table 15** shows that residential properties are the primary contributor the total damage costs across the catchment due to the damage expected throughout the property below floor level.

Table 15 Summary of Flood Damage Costs for Existing Conditions

Flood	Flood Damages ($)				
	Residential	Commercial	Industrial	Infrastructure	Total Damages
20% AEP	$44,500	$3,500	$0	$7,200	$55,200
5% AEP	$218,700	$76,200	$0	$44,200	$339,100
1% AEP	$356,400	$162,700	$0	$77,900	$597,000
PMF	$10,446,400	$4,839,600	$0	$2,292,900	$17,578,900

The damage estimates were also used to prepare an Average Annual Damage (AAD) estimate for each property. The AAD takes into consideration the frequency of a particular event occurring and the damage incurred during that event to estimate the average damage that is likely to occur each year, on average.

The AAD for the Whites Creek catchment was determined to be **$124,000**. Accordingly, if the "status quo" was maintained, residents and business owners within the study area as well as infrastructure providers, such as Council, would likely be subject to flood damage costs of approximately $124,000 per annum (on average).

3.5 Impacts of Future Catchment Development

Although the Whites Creek catchment comprises a significant urban proportion, there are some sections of the catchment that are currently undeveloped. Some of these areas do have the potential to be developed in the future based upon current land use zonings defined in the Wingecarribee LEP 2010. A representation of some of this development that will occur in the immediate future (e.g., Chelsea Gardens) was included as part of the 'base' flood results.

Nevertheless, there are sections of the catchment where there is potential for further, new development to occur and this was not included in the 'base" simulations. This future development has the potential to alter existing flood behaviour which may impact on the existing flood risk across the catchment. Accordingly, additional simulations were completed to quantify the potential impacts that future development may have on the results of the modelling.

Those areas that are currently undeveloped but are likely to be developed in the future (based upon current LEP zoning) were identified. This was completed by reviewing land use zoning information relative to contemporary aerial imagery. In addition, Wingecarribee Shire Council strategic planners were consulted to identify areas that have the potential to be rezoned in the future to promote further urban development. The extent of the land that was identified as having the potential for future urban development is shown on **Figure 23**.

As the future "make up" of these areas is not known, assumptions were made regarding the likely land use composition. This information, in turn, was used to calculate weighted average impervious and pervious "n" values for each land use that were used as the basis for updating the XP-RAFTS hydrologic model (refer **Table 16**).

The updated impervious and pervious "n" values were applied to an updated "ultimate catchment development" version of the XP-RAFTS model. The updated model was used to re-simulate the 20% AEP, 1% AEP and 0.5% AEP storms under potential future catchment development conditions. Peak discharges extracted from the results of the revised hydrologic assessment are presented in **Appendix K**. Peak 20% AEP, 1% AEP and 0.5% AEP discharges for current catchment development conditions are also included in **Appendix K** for comparison.

The discharge comparison indicates that future catchment development is predicted to generate localised increases in peak design discharges. At the 15 focus locations within the catchment, the following average changes in peak design discharges are predicted:

- 20% AEP Event: Discharges are predicted to increase by 21%;
- 1% AEP Event: Discharges are predicted to increase by 18%;
- 0.5% AEP Event: Discharges are predicted to increase by 16%.

Table 16 Adopted land use information for future development assessment

Future Land Use Zone	Zone Description	Composition	Impervious	Pervious "n"
R2	Low Density Residential	50% building, 25% grass, 20% concrete, 5% trees	70%	0.026
R3	Medium Density Residential	60% building, 10% grass, 25% concrete, 5% trees	85%	0.022
IN1	General Industrial	70% building, 15% concrete, 10% car park, 5% grass	95%	0.018
IN2	Light Industrial	70% building, 15% concrete, 10% car park, 5% grass	95%	0.018
B2	Local Centre	70% building, 15% concrete, 10% car park, 5% grass	95%	0.018
B4	Mixed Use	70% building, 15% concrete, 10% car park, 5% grass	95%	0.018
B5	Business Development	70% building, 15% concrete, 10% car park, 5% grass	95%	0.018

More significant increases (>160%) are predicted immediately downstream of some of the future development areas. Accordingly, future development does have the potential to produce notable increases in current peak design discharges across the catchment.

To quantify the impact that the increases in design discharges are predicted to have on future flood behaviour, the hydrographs generated by the future catchment conditions XP-RAFTS model were subsequently applied to the TUFLOW model. It should be noted that only flood hydrology was modified and that no updates were completed to the terrain representation to reflect the potential future development (as the future landforms cannot be precisely defined at this point).

Peak floodwater depths, levels and velocity vectors for the 20%, 1% and 0.5% AEP events were extracted from the results of the future catchment development modelling and are presented in **Figures 24.1** to **26.3** inclusive.

Updated flood hazard mapping was also prepared for the 1%AEP event based on the future catchment development simulation. The hazard map is presented in **Figure 27**.

It was also considered important to identify areas that should be retained in the future for the conveyance of flood flows and the temporary storage of floodwaters. In this regard, updated hydraulic category mapping was also prepared and is presented in **Figure 28**.

Flood level difference mapping was also prepared to quantify the impact that future catchment development is predicted to have on "existing" design flood levels across the catchment. The difference mapping is presented in **Plate 8**, **Plate 9** and **Plate 10** for the 20%, 1% and 0.5% AEP events respectively.

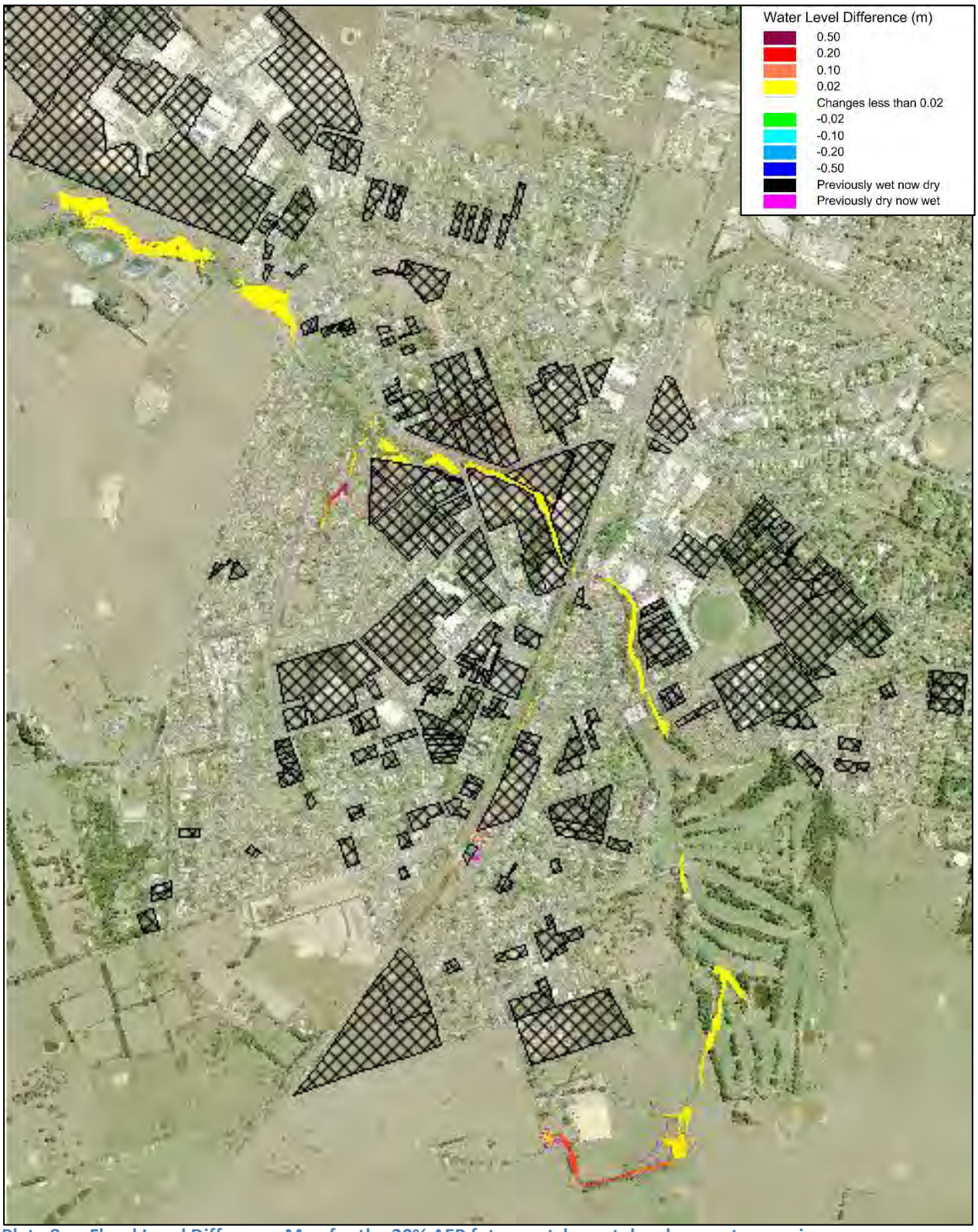


Plate 8 Flood Level Difference Map for the 20% AEP future catchment development scenario

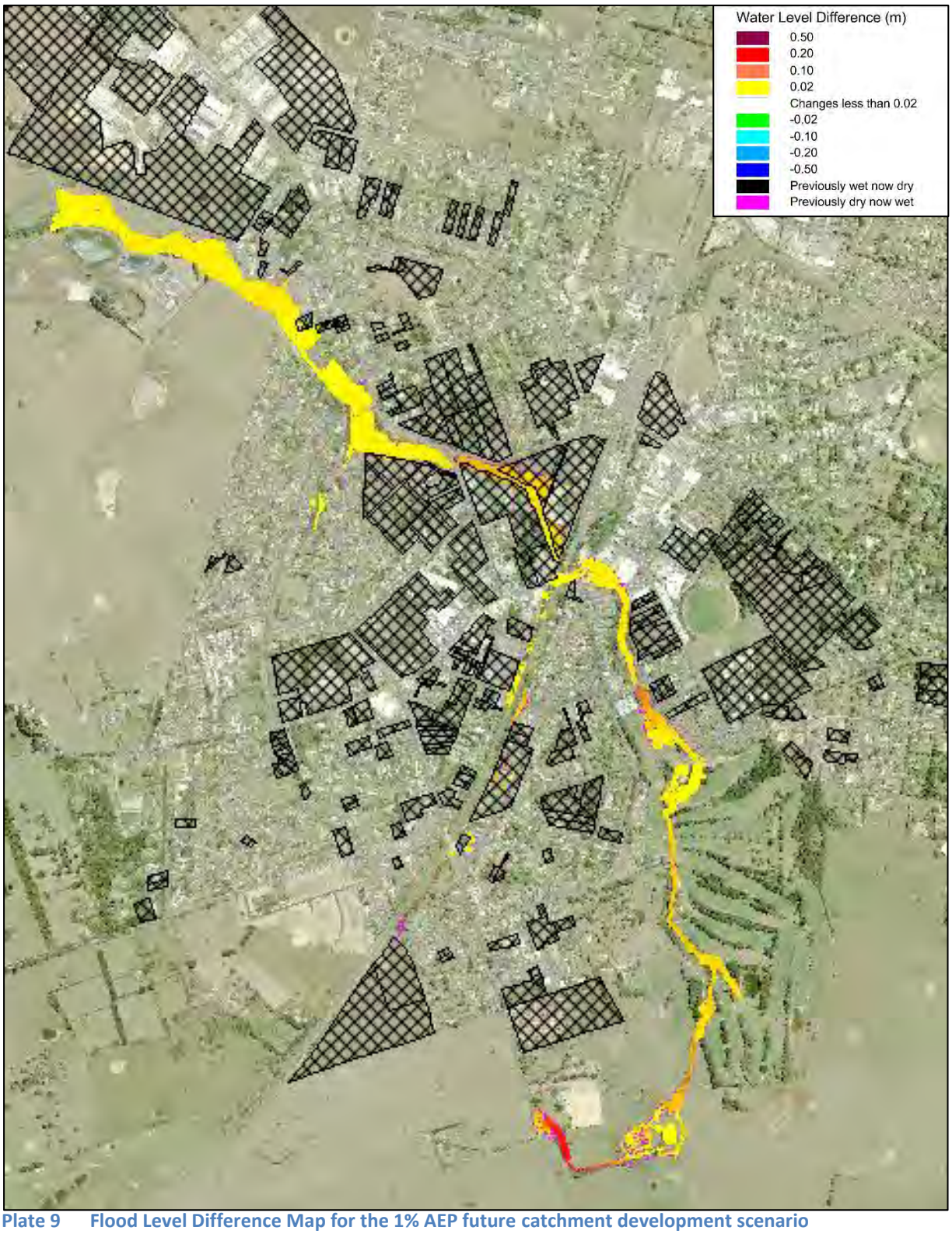


Plate 9 Flood Level Difference Map for the 1% AEP future catchment development scenario

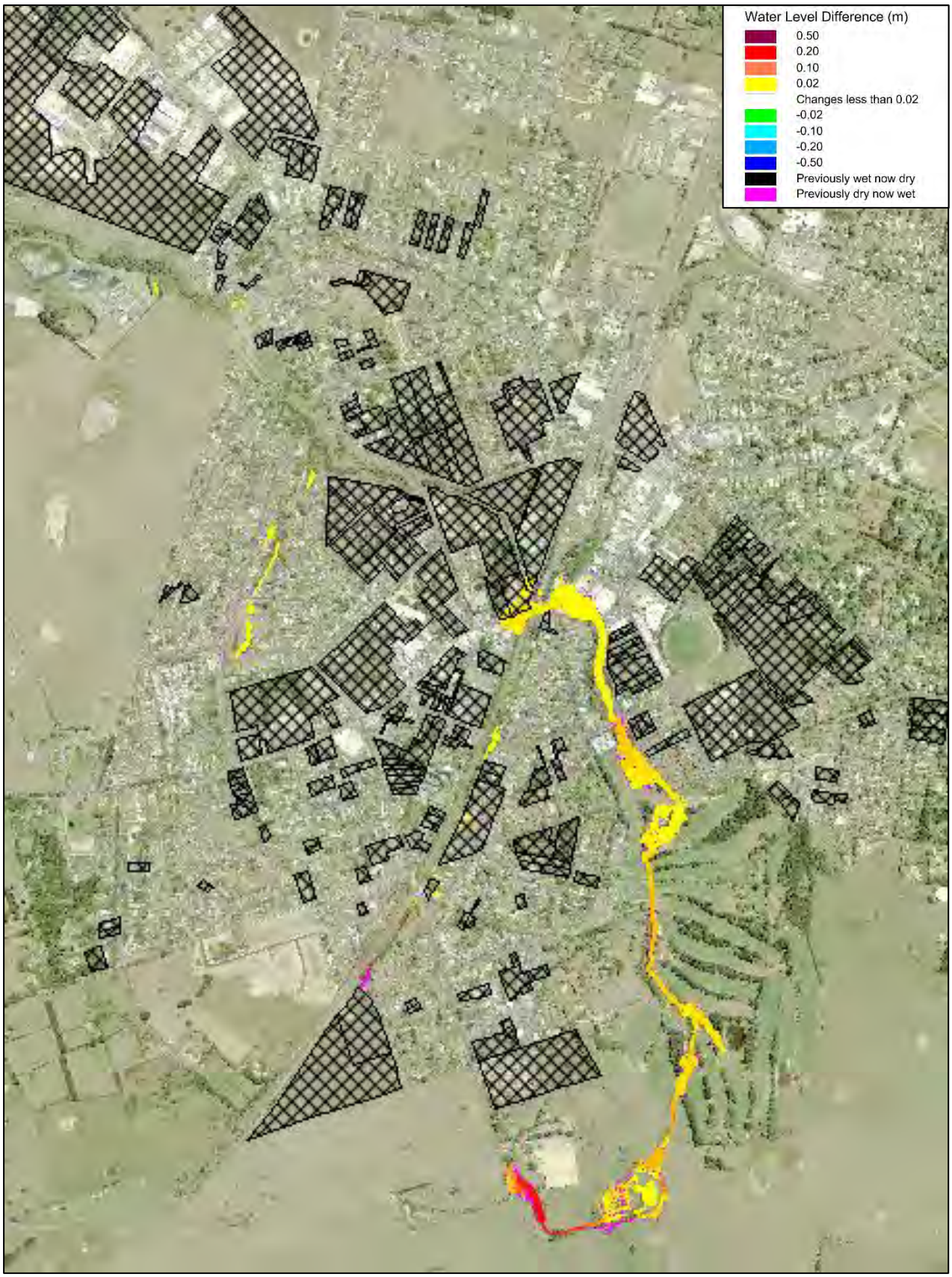


Plate 10 Flood Level Difference Map for the 0.5% AEP future catchment development scenario

Plate 8 indicates that during the 20% AEP flood, future development is generally predicted to generate increases in mainstream flood levels. In general, the flood level increases are predicted to be less than 0.05 metres. However, a localised increase of more than 0.3 metres is predicted immediately upstream of Campbell Crescent.

The flood level differences shown in **Plate 9** indicate that during the 1% AEP event flood level increases are typically in the order of 0.05 to 0.1 metres. The most significant increase is predicted immediately upstream of the railway culvert (0.13 metre).

Plate 10 shows that in the 0.5% AEP event, future development is predicted to generate localised increases that are typically less than 0.05 metres. The most significant increases are predicted across the Moss Vale Golf Club and upstream of Mack Street.

Overall, the difference mapping tends to indicate that future development is likely to have a more significant impact during more frequent floods, rather than rarer floods

A revised damage assessment was also completed to determine the impacts that potential future development may have on existing flood damage estimates. The future average annual damage (AAD) estimates were compare to the "existing" AAD estimates (refer Section 3.4.4) and this determined that future catchment development has the potential to increase AAD by about $4,800.

A review of the revised flood damage estimates shows that a total of 17 buildings are predicted to be exposed to an increase in flood damage as a result of future catchment development. These properties are shown in **Plate 11**.

As shown in **Plate 11**, the increase in AAD across commercial properties near the intersection of Argyle Street and Lackey Road is predicted to be relatively small (i.e., <$250 per property for most properties). However, more significant increases are anticipated for a residential property on Lackey Road and three commercial properties on Argyle Street. Two residential properties further south on Throsby Street are also predicted to experience increases in AAD of up to $500.

Accordingly, future catchment development does have the potential to cause localised increases in flood discharges and levels. This has the potential to increase the flood exposure and flood damage potential across some existing properties. Most of the adverse impacts are predicted along Argyle Street, Lackey Road and Throsby Street.

3.6 Impacts of Climate Change

3.6.1 General

Climate change refers to a significant and lasting change in weather patterns arising from both natural and human induced processes. The Office of Environment and Heritage's (formerly Department of Environment, Climate Change and Water) *'Practical Consideration of Climate Change'* states that climate change is expected to have adverse impacts on sea levels and rainfall intensities in the future.



Plate 11 Change in Average Annual Damages (AAD) associated with future development

Although increases in sea level are not predicted to have an impact on flood behaviour across the Whites Creek catchment, increases in rainfall intensities would produce increases in runoff volumes across the catchment. This, in turn, would likely produce an increase in the depth, extent and velocity of floodwaters.

This Floodplain Risk Management Study will form the basis for defining flood behaviour and also evaluates a range of flood risk mitigation measures to mitigate the impacts of flooding in the future. Therefore, it is important that potential climate change impacts are quantified so that development decisions and the robustness of flood risk mitigation measures can be assessed in an informed manner.

The following sections describe the process that was employed to quantify climate change impacts on flooding across the Whites Creek catchment.

3.6.2 Hydrology

Although there is considerable uncertainty associated with the impact that climate change may have on rainfall, it was considered important to provide an assessment of the potential impact that climate change may have on the current flood risk across the study area. The climate change factors published in Australian Rainfall and Runoff (Geoscience Australia, 2016) indicates that a 9.1% increase in rainfall is the best estimate of likely rainfall intensities increases by 2090 under Representative Concentration Pathway scenario 4.5 (RCP4.5) (i.e., greenhouse gas emissions are reduced in the future). Under RCP 8.5 conditions (i.e., current greenhouse gas emissions increase in the future), rainfall intensities would likely increase by 18.6% by 2090 (refer **Plate 12**).

Interim Climate Change Factors

Values are of the format temperature increase in degrees Celcius (% increase in rainfall)

	RCP 4.5	RCP6	RCP 8.5
2030	0.892 (4.5%)	0.775 (3.9%)	0.979 (4.9%)
2040	1.121 (5.6%)	1.002 (5.0%)	1.351 (6.8%)
2050	1.334 (6.7%)	1.28 (6.4%)	1.765 (8.8%)
2060	1.522 (7.6%)	1.527 (7.6%)	2.23 (11.2%)
2070	1.659 (8.3%)	1.745 (8.7%)	2.741 (13.7%)
2080	1.78 (8.9%)	1.999 (10.0%)	3.249 (16.2%)
2090	1.825 (9.1%)	2.271 (11.4%)	3.727 (18.6%)

Plate 12 Adopted rainfall intensity increase for climate change simulation (Geoscience Australia, 2016)

The rainfall intensity increases were applied to the current 1% AEP rainfall depths and the revised rainfall was routed through the XP-RAFTS model. The revised 1% AEP discharges were extracted from the results of the modelling and are included in **Appendix L**. Peak 1% AEP discharges for the "base" conditions are also included in **Appendix L** for comparison.

The peak discharge comparison indicates that increases in rainfall will increase peak discharges throughout the catchment. The peak 1% AEP discharges are predicted to increase by 13%, on average, at key locations if rainfall intensities were to increase by 9.1%. If rainfall intensities were to increase by 18.6%, peak 1% AEP discharge could be expected to increase by 27%, on average, at key locations.

3.6.3 Hydraulics

The revised 1% AEP flows were also applied to the TUFLOW model to determine the impact that the rainfall intensity increases may have on peak 1% AEP flood levels. Peak water levels were extracted from the results of the modelling and were compared against peak water flood levels for "base" design conditions. This allowed water level difference mapping to be prepared showing the magnitude of any change in water levels associated with climate change.

The difference mapping is presented in **Plate 13** and **Plate 14**.

Plate 13 and **Plate 14** show that rainfall increases associated with climate change will increase current 1% AEP flood level estimates across the catchment. The 9.1% increase in rainfall scenario is predicted to result in typical increases of up to 0.1 metres along Whites and Willow Creeks, however localised increases approaching 0.2 metres are predicted along the Whites Creek channel upstream of the Waite Street and Mack Street culverts.

The 18.6% increase in rainfall scenario is predicted to increase existing 1% AEP flood levels by more than 0.2 metres along most of Whites Creek. However, increases in peak 1% flood level along Willow Creek and across other areas of the floodplain are typically in the order of 0.1 metres or lower.

Accordingly, the outcomes of the climate change simulations show that increases in rainfall associated with climate change have the potential to increase the severity of flooding across the catchment.



Plate 13 1% AEP Flood level difference map with 9.1% Increase in rainfall



Plate 14 1% AEP Flood level difference map with 18.6% Increase in rainfall

4 EXISTING PLANNING INFORMATION

Appropriate land use planning is one of the most effective measures available to floodplain managers, especially to control future risk but also to reduce existing flood risks as redevelopment occurs. The following sections discuss existing planning legislation and policies that affect the development of land within the Wingecarribee Shire Council Local Government Area. Where appropriate, recommendations for ways in which Council's planning documents could be modified to better manage the existing and future flood risk are provided.

4.1 National Provisions

4.1.1 Building Code of Australia

The 2016 edition of the Building Code of Australia (BCA) introduced new requirements related to building in flood hazard areas (FHAs), which provide a minimum construction standard across Australia for specified building classifications in FHAs up to the Defined Flood Event (DFE). This 2016 version has been updated to version 3 which came into force on 1 May 2019.

The DFE is analogous to the "planning flood" (described in more detail in Section 4.3.1) and is most commonly the 1% AEP flood for residential development. FHAs are defined in the BCA as encompassing land lower than the flood hazard level (FHL), which in turn is defined as 'the flood level used to determine the height of floors in a building and represents the DFE plus the freeboard'. Therefore, FHAs would typically be defined as those areas falling within the flood planning area described in Section 4.3.1.

Volume One, BP1.4 and Volume Two, P2.1.2 specify the Performance Requirements for the construction of buildings in FHA. They only apply to buildings or parts of Class 1, 2, 3, 4, (residential) and 9a health-care buildings and 9c aged-care buildings. These Performance Requirements necessitate a building in an FHA to be designed and constructed to resist flotation, collapse and significant permanent movement resulting from floodwater actions during the DFE. The actions and requirements to be considered to satisfy this performance requirement include but are not limited to:

- Flood actions;
- Elevation requirements;
- Foundation and footing requirements;
- Requirements for enclosures below the flood hazard level;
- Requirements for structural connections;
- Material requirements;
- Requirements for utilities; and
- Requirements for occupant egress.

The Deemed To Satisfy provisions of Volume One, B1.6 and Volume 2, 3.10.3.0 require buildings in the classes described above and located in FHAs to comply with the ABCB *Standard for Construction of Buildings in Flood Hazard Areas 201*2.3 (the ABCB Standard).

The ABCB Standard specifies detailed requirements for the construction of buildings to which the BCA requirements apply, including:

- Resistance in the DFE to flood actions including hydrostatic actions, hydrodynamic actions, debris actions, wave actions and erosion and scour;
- Floor height requirements, for example that the finished floor level of habitable rooms must be above the flood hazard level (FHL);
- Maximum of 1 metre depth of water above the lowest non-habitable floor level;
- The design of footing systems to prevent flotation, collapse or significant permanent movement;
- The provision in any enclosures of openings to allow for automatic entry and exit of floodwater for all floods up to the FHL;
- Ensuring that any attachments to the building are structurally adequate and do not reduce the structural capacity of the building during the DFE;
- The use of flood-compatible structural materials below the FHL;
- The siting of electrical switches above the FHL, and flood proofing of electrical conduits and cables installed below the FHL; and
- The design of balconies etc. to allow a person in the building to be rescued by emergency services personnel, if rescue during a flood event up to the DFE is required.

Building Circular BS13-004 (NSW Department of Planning and Infrastructure, 2013) summarises the scope of the BCA and how it relates to NSW planning arrangements. The scope of the ABCB Standard does not include parts of FHA that are subject to flow velocities exceeding 1.5 m/s or are subject to mudslide or landslide during periods of rainfall and runoff. It is particularly noted that the Standard applies only up to the defined flood event (DFE), which typically will correspond to the level of the 1% AEP flood plus 0.5m freeboard. The Building Circular emphasises that because of the possibility of rarer floods, the BCA provisions do not fully mitigate the risk to life from flooding.

The ABCB has also prepared an *Information Handbook for the Construction of Buildings in Flood Hazard Areas*. This Handbook provides additional information relating to the construction of buildings in FHA but is not mandatory or regulatory in nature.

In the NSW planning system, the BCA takes on importance for complying development under the *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (see Section 4.2.1). Currently, certain development on the floodplain is also required to satisfy the requirements of the BCA under the Moss Vale Town Plan Development Control Plan (DCP) 2017. The Building Circular also indicates that following development approval, an application for a construction certificate (CC) will require assessment of compliance with the BCA.

All development in the Moss Vale area is required to satisfy the BCA at some point throughout the approval process. This may be via a formal development application and certification

process through Council, or via complying development under the *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (see Section 4.2.1). Moss Vale Town Plan Development Control Plan (DCP) 2017 also has requirements for development on the floodplain. Following development approval, all applications for a construction certificate (CC) will require assessment of compliance with the BCA. As such, it could be considered that the BCA is the most consistent and strongest mechanism in the current planning framework with flood related development controls.

4.2 State Provisions

4.2.1 State Environmental Planning Policies

State Environmental Planning Policies or SEPPs are the highest level of planning instrument in NSW and generally prevail over Local Environmental Plans (discussed in Section 4.3.1).

SEPP (Exempt and Complying Development Codes) 2008

State Environmental Planning Policy (Exempt and Complying Development Codes) 2008 (the *Codes SEPP*) defines development which is exempt from obtaining development consent and other development which does not require development consent if it complies with certain criteria. The Codes SEPP is aimed at simplifying the development application process for relatively small, low risk developments.

Clause 1.5 of this Codes SEPP defines a 'flood control lot' as 'a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing)'. These development controls may apply through a Local Environmental Plan (LEP) or Development Control Plans (DCP). Exempt development is not permitted on flood control lots, but some complying development is permitted.

Clause 3.5 of the Codes SEPP states that complying development is permitted on flood control lots where a Council or professional engineer can certify that the part of the lot proposed for development is not a flood storage area, floodway area, flow path, high hazard area or high risk area. The Codes SEPP specifies various controls in relation to floor levels, flood compatible materials, structural stability (up to the PMF if on-site refuge is proposed)[1], flood affectation, access, and car parking (see **Plate 15**).

In addition, Clause 1.18(1)(c) of the Codes SEPP indicates that complying development must meet the relevant provisions of the Building Code of Australia.

In order to facilitate the process of applying for complying development, the following maps have been prepared as part of the study:

[1] Clause 3.5(2)(c) implies that an on-site refuge can function as a refuge under clause 3.5(2)(e) for the purposes of the SEPP.

- land where Council is confident a Complying Development Certificate (CDC) could be issued, that is, where the land in a flood control lot is not a flood storage area, floodway area, flow path, high hazard area or high-risk area. A map was prepared to identify these areas (refer to **Figure 31**) based upon the following assumptions:
  - floodway or flood storage during the 1% AEP flood (based upon **Figure 17.1** to **Figure 17.3**).
  - exposed to a high flood hazard during the 1% AEP flood (based upon **Figure 13.1** to **Figure 13.3**).
- function as a major flow path in what 1% AEP (a velocity depth product of > 0.4 m^2/s was used for this purpose).
- A high-risk area was defined as an area that becomes isolated early in a flood and then becomes inundated (flooded, isolated, submerged emergency response classification).

(2) If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards:
- (a) if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,
- (b) any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,
- (c) any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),
- (d) the development must not result in increased flooding elsewhere in the floodplain,
- (e) the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,
- (f) vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,
- (g) the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.

Plate 15 Extract from 'Codes' SEPP 2008 Clause 3.5(2)
Note: version dated 22 December 2017

SEPP (Housing for Seniors or People with a Disability) 2004

State Environmental Planning Policy (Housing for Seniors or People with a Disability) 2004 aims to encourage the provision of housing (including residential care facilities) that will increase the supply of residences that meet the needs of seniors or people with a disability. This is achieved by setting aside local planning controls that would prevent such development.

Clause 4(6) and Schedule 1 indicate that the policy does not apply to land identified in another environmental planning instrument (such as Wingecarribee LEP 2010) as being a floodway or high flooding hazard.

As outlined previously, floodway and/or high flood hazard areas in the Whites Creek catchment are typically contained in close proximity to each of the main watercourses during events up to and including the 1% AEP. Accordingly, this policy could apply to a little more land beyond the top of bank of the existing main watercourses through Moss Vale.

4.2.2 Environmental Planning and Assessment Act 1979

The NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) creates the mechanism for development assessment and determination by providing a legislative framework for development and protection of the environment from adverse impacts arising from development. The EP&A Act outlines the level of assessment required under State, regional and local planning legislation and identifies the responsible assessing authority.

Section 9.1 Directions – Direction No. 4.3 (Flood Prone Land)

NSW flood related planning requirements for local councils are set out in Ministerial Direction No. 4.3 Flood Prone Land, issued in 2007 under Section 9.1 (formally Section 117) of the EP&A Act. It requires councils to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy as set out in the 'NSW Floodplain Development Manual' (NSW Government, 2005). It requires provisions in a Local Environmental Plan on flood prone land to be commensurate with the flood hazard of that land. In particular, a planning proposal must not contain provisions that:

- Permit development in floodway areas;
- Permit development that will result in significant flood impacts to other properties;
- Permit a significant increase in the development of that land;
- Are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services; or
- Permit development to be carried out without development consent except for the purposes of agriculture, roads or exempt development.

The Direction also requires that councils must not impose flood related development controls above the residential flood planning level (typically the 1% AEP flood plus 0.5m freeboard) for residential development on land, unless a relevant planning authority provides 'adequate justification' for those controls to the satisfaction of the Director-General.

The question as to whether flood behaviour across the Whites Creek catchment warrants the imposition of flood related development controls above the residential flood planning level is considered in Section 4.3.1.

Section 10.7 Planning Certificates

Planning certificates are a means of disclosing information about the development potential of a parcel of land including the planning restrictions that apply to the land on the date the certificate is issued. Two types of information are provided in planning certificates: information under Section 10.7(2) and information under Section 10.7(5) of the EP&A Act. (Note that previously this clause was Section 149 of the EP&A Act).

Information to be disclosed on a Section 10.7 (2) Planning Certificate is specified under the Environmental Planning and Assessment Regulation 2000. A planning certificate under Section 10.7(2) discloses matters relating to the land, including whether or not the land is affected by a policy that restricts the development of land. Those policies can be based on identified hazard risks (*Environmental Planning and Assessment Regulation 2000*, Clause 279 and Schedule 4 Clause 7), and whether development on the land is subject to flood-related development controls (EP&A Regulation, Schedule 4 Clause 7A and 7B). If no flood-related

development controls apply to the land (such as for residential development in "low risk" areas above the flood planning level, unless exceptional circumstances have been granted), information describing the flood affectation of the land would not be indicated under Section 10.7(2). A lot that is a flood control lot is a prescribed matter for the purpose of a certificate under section 10.7(2).

A planning certificate may also include information under Section 10.7(5). This allows a council to provide advice on other relevant matters affecting land. This can include past, current or future issues such as draft environmental planning instruments or anecdotal information.

Inclusion of a planning certificate containing information prescribed under Section 10.7(2) is a mandatory part of the property conveyancing process in NSW. The conveyancing process does not mandate the inclusion of information under Section 10.7(5), but any purchaser may request such information be provided, generally pending payment of a fee to the issuing council.

4.2.3 NSW Flood Related Manuals

Flood Prone Land Policy and Floodplain Development Manual, 2005

The overarching policy context for floodplain management in NSW is provided by the NSW *Flood Prone Land Policy*, contained within the '*Floodplain Development Manual*' (NSW Government, 2005) (The Manual). The Policy aims to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods, using ecologically positive methods wherever possible. The Manual advocates a merit approach for development decisions in the floodplain, taking into account social, economic, ecological and flooding considerations. The primary responsibility for management of flood prone land in NSW rests with local councils through the development of local environment plans. The Manual assists councils in their management of the use and development of flood prone land by providing guidance in the development and implementation of local floodplain risk management plans.

Guideline on Development Controls on Low Flood Risk Areas, 2007

The *Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual* (the Guideline) was issued on 31 January 2007 as part of Planning Circular PS 07-003 at the same time as the Section 9.1 Direction described previously. The Guideline is intended to be read as part of the *Floodplain Development Manual*.

It stipulates that 'unless there are exceptional circumstances, councils should adopt the 100 year flood as the flood planning level (FPL) for residential development' and that "*unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land … that is above the residential FPL*".

Flood related development controls are not defined but would include any development standards relating to flooding applying to land, that are a matter for consideration under Section 4.15 (previously Section 79C) of the EP&A Act.

The Guideline states that councils should not include a notation for residential development on Section 10.7 certificates for land above the residential FPL if no flood related development controls apply to the land. However, the Guideline does include the reminder that councils can include 'such other relevant factors affecting the land that the council may be aware [of]' under Section 10.7(5) of the EP&A Act.

In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. Justification for exceptional circumstances would need to be agreed by relevant State Government departments prior to exhibition of a draft local environmental plan or a draft development control plan that proposes to introduce flood related development controls on residential development above the default FPL.

Further discussion on whether an application for exceptional circumstances may be required for the Whites Creek catchment is provided in Section 4.3.1.

4.3 Local Provisions

4.3.1 Wingecarribee Local Environmental Plan 2010

Wingecarribee Local Environmental Plan 2010 (Wingecarribee LEP 2010) outlines the zoning of land, what development is allowed in each land use zone and any special provisions applying to land. Wingecarribee LEP is made up of a written instrument with maps. Sheets FLD_007C and FLD_007F of the Flood Planning Area Maps that accompany the written instrument (as provided on the http://www.legislation.nsw.gov.au website) include flood mapping for the Whites Creek catchment. This flood mapping relates to mainstream flooding only in this location.

Flood planning and floodplain risk management are addressed in Clause 7.9 of Wingecarribee LEP 2010. This is reproduced in **Plate 16**. Clause 7.9 relates to land within the Flood Planning Area (FPA) (i.e., land at or below the flood planning level (FPL)), and other land at or below the FPL. The FPL is defined in Wingecarribee LEP 2010 as 'the level of a 1:100 ARI (Average Recurrent Interval) flood event plus 0.5 metre freeboard'.

The appropriateness of the Wingecarribee LEP 2010 for managing flood risk in the Whites Creek catchment is considered under the following headings:

- Suitability of Current Zoning;
- Flood planning area;
- Flood Risk Precincts and Flood Planning Area; and
- Need for 'Exceptional Circumstances'.

Compatibility of Current LEP 2010 Zones with Flood Hazard

The current land zoning within the Whites Creek catchment is presented in **Figure 32**. It shows that the northern portion of the catchment primarily comprises a mix of "IN2" (Light Industrial), "R2" (Low Density Residential), "R3" (Medium density Residential), "SP1" (Special

Activities), “SP2” (Infrastructure), “RE1” (Public Recreation), “RU2” Rural Landscape” and “E3” (Environmental Management).

7.9 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land’s flood hazard, taking into account projected climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

(a) land that is shown as “Flood Planning Area” on the Flood Planning Area Map, and

(b) other land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affection of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, situation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses, and

(e) will not be likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the *NSW Government’s Floodplain Development Manual* published in 2005, unless it is otherwise defined in this clause.

(5) In this clause:

Flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 meters freeboard.

Plate 16 Extract from Wingecarribee LEP 2010 Clause 7.9

Note: version dated 10 December 2018

The central area of the catchment, in and around the Moss Vale town centre, is dominated by “B2” (Local Centre Business), “B4” (Mixed Use Business), “B5” (Business Development), “R3” (Medium Density Residential), with a small area of “R2” (Low Density Residential) to the west of the town centre. There is also a lot zoned “B1” (Neighbourhood Centre) near the western boundary of the catchment at Southlands Care Op Shop and Community Centre.

The southern portion of the catchment predominantly comprises “R2” (Low Density Residential), “RE2” (Private Recreation), “E3” (Environmental Management) and “RU2” Rural Landscape, with scattered areas of “R5” (Large Lot Residential) and “RE1” (Public Recreation).

The Hume Highway and railway line are zoned “SP2” (Infrastructure), and the Whites Creek corridor and its surrounds are zoned “RE1” (Public Recreation).

An assessment of the compatibility of the existing land use zoning (under *Wingecarribee LEP 2010*) with the national flood hazard categories was undertaken. The results of this assessment for the 1% AEP and PMF are presented in **Table 17.** Those LEP zones where habitable development is possible are highlighted in blue.

Table 17 Compatibility of Current Land Use Zones with National Flood Hazard Categories During the 1% AEP and PMF

Land Zone	Hazard Category													
	PMF							1%AEP						
	No Hazard	H1	H2	H3	H4	H5	H6	No Hazard	H1	H2	H3	H4	H5	H6
B1 (Neighbourhood Centre)	100%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
B2 (Local Centre)	69%	1%	1%	4%	6%	17%	2%	88%	6%	4%	1%	0%	0%	0%
B4 (Mixed Use)	70%	1%	1%	3%	5%	17%	3%	93%	5%	2%	0%	0%	0%	0%
B5 (Business Development)	100%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
E3 (Environmental Management)	97%	1%	0%	1%	0%	0%	0%	99%	1%	0%	0%	0%	0%	0%
IN1 (General Industrial)	100%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
IN2 (Light Industrial)	99%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
R2 (Low Density Residential)	96%	1%	1%	1%	1%	1%	0%	99%	1%	0%	0%	0%	0%	0%
R3 (Medium Density Residential)	84%	3%	2%	3%	3%	5%	1%	96%	3%	1%	0%	0%	0%	0%
R5 (Large Lot Residential)	100%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
RE1 (Public Recreation)	69%	3%	1%	1%	2%	8%	16%	80%	3%	2%	3%	4%	7%	0%
RE2 (Private Recreation)	54%	17%	6%	4%	5%	11%	3%	76%	17%	2%	1%	2%	2%	0%
RU2 (Rural Landscape)	95%	0%	0%	0%	0%	1%	3%	96%	1%	0%	1%	1%	1%	0%
SP1 (Special Activities)	100%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
SP2 (Infrastructure)	75%	5%	2%	3%	3%	9%	3%	95%	1%	1%	1%	1%	1%	0%
SP3 (Tourist)	100%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%

Of most interest in reviewing the information presented in **Table 17** is land zoned for urban development within flood hazard H6 as the depth and velocity of floodwater in these areas is likely to be sufficient to cause structural failure of buildings. The results indicate that the current zoning is broadly compatible with the flood hazard, with no residential "R2", "R3" and R5", commercial "B1", B2", "B4" and "B5" and industrial "IN1 and "IN2" being exposed to a H4 or H5 or H6 hazard during the 1% AEP flood.

Some areas are predicted to be exposed to a H5 and H6 hazard during the PMF. This includes about 20% of the commercial zoned areas (centred around Argyle Street) and about 7% of residential zoned land. In both cases, H6 hazard is only predicted across relatively small areas (i.e., 1% of residential zoned areas and 5% of commercial zoned areas).

Apart from the locations noted above, the LEP zoning appears to be broadly appropriate to the flood hazard for this study area. That is, there is no obvious need for modification to the current LEP zones with regard to the existing flood hazards.

Flood Planning Area

Flood Planning Levels (FPLs) are an important tool in the management of flood risk. FPLs are typically derived by adding a freeboard to a specific design flood level. This specific design flood is frequently referred to as the "planning" flood. The FPLs can be combined with topographic information to establish the Flood Planning Area (FPA). The FPL / FPA can then be used to assist in managing the existing and future flood risk by:

- Setting design levels for mitigation works (e.g., levees); and,
- Identifying land where flood-related development controls apply to ensure that new development is undertaken in such a way as to minimise the potential for flood impacts on people and property.

As noted previously, the FPL is defined in Wingecarribee LEP 2010 as 'the level of a 1:100 ARI (Average Recurrent Interval) flood event plus 0.5 metre freeboard'. This is consistent with the 'Floodplain Development Manual' (NSW Government, 2005), which suggests that a flood planning level consisting of the 1% AEP flood plus a 0.5 metre freeboard will generally be appropriate for new residential development unless exceptional circumstance exist. This "standard" is also echoed by the 'Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual' (Department of Planning, 2007) which states that "*…unless there are exceptional circumstances, councils should adopt the 100 year flood as the FPL for residential development"*.

The freeboard can be considered as a "factor of safety" that is used to cater for uncertainties in the estimation of the planning flood. An assessment of the suitability of Council's 0.5 metre freeboard requirement was completed as part of the sensitivity analysis and is documented in **Appendix H**. This assessment drew on the results of various sensitivity simulations and determined that an allowance of 0.3 metre would suitably account for modelling uncertainty along mainstream flooding areas within this study area. Accordingly, the adoption of a 0.5 metre freeboard would make an allowance for modelling uncertainty of up to 0.3 metres and at least a 0.2 metre allowance for areas of "other" uncertainty that cannot be explicitly represented in the modelling (e.g., wind and wave action). Therefore, it is considered that the 0.5 metre freeboard is suitable for application across areas subject to mainstream flooding.

The 0.5 metre freeboard was added to the peak 1% AEP flood levels to develop a flood planning level layer. The flood planning level layer was extended laterally until the flood planning level encountered higher terrain. This formed the flood planning area for the catchment. The flood planning area is shown in **Figure 33**. Flood planning level contours are also included on **Figure 33**.

Extent of Flood Risk Precincts versus extent of Flood Planning Area

As noted previously, the FPL is defined in Wingecarribee LEP 2010 as 'the level of a 1:100 ARI (Average Recurrent Interval) flood event plus 0.5 metre freeboard'. The FPL, in turn, is used to establish the flood planning area which is mapped in the LEP.

The Moss Vale Town Plan DCP (discussed in Section 4.3.2) defines the 'low flood risk precinct' as land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within the high, medium or fringe-low flood risk precincts. The fringe-low flood risk precinct is defined as the land between the extents of the 100-year flood and the 100 year flood plus 0.5m freeboard (i.e., flood planning area).

Accordingly, the flood prone land between the edge of the low flood risk precinct and the probable maximum flood extent is not covered by the current definition of flood planning as per Clause 7.9 of the Wingecarribee LEP 2010. It is not clear if the land to which controls are currently applied to in low flood risk precincts are correctly identified on Section 10.7 certificates as having flood related development controls applying to them, with this discrepancy noted as to what is actually identified as flood prone in the Wingecarribee LEP 2010. As such, it is recommended that Council introduce an additional LEP clause related to "floodplain risk management" that would relate to the areas between the current flood planning area and the edge of the low flood risk precinct, ensuring all known flood prone land within the LGA are identified. The flood planning area mapping would also then need to be updated to ensure that all flood prone areas up to and including those at the edge of the probable maximum flood extent are included on the LEP/DCP mapping and definitions.

These recommended updates are discussed further in Section 8.2.1.

Need for 'Exceptional Circumstances'

An assessment was completed to determine if and where 'exceptional circumstances' may be appropriate for flood related development controls on residential development on land outside of the FPA. Exceptional circumstance may be triggered when there is an unacceptably high flood risk above and beyond the FPL/FPA. This was completed by determining if there were any H6 hazard areas during the PMF in areas located beyond the FPA.

Plate 17 shows locations outside of FPA where the hazard is predicted to reach H6 during the PMF (refer yellow areas). As shown in **Plate 17**, there are some areas where the PMF hazard is predicted to reach H6 outside of the FPA. However, these areas are relatively small and include:

- Small areas within the Moss Vale STP (within "SP2" zoning);
- A very small area on the northern floodplain of Whites Creek opposite the Moss Vale STP (within "RU2" zoning);



Plate 17 Locations Outside of FPA Where H6 Hazard Is Predicted During PMF (Yellow)

- An area on Waite Street near the culvert crossing of Whites Creek (within "RE1" zoning");
- An area within the railway corridor adjacent to the railway crossing of Argyle Street (within "SP2" zoning);
- A small area within a lot at the intersection of Lackey Road and Argyle Street (with "B2" zoning);
- A very small area on Mack Street near the culvert crossing of Whites Creek (within "RE1" zoning");
- Small areas along the eastern side of the railway line south of Spring Street (within "R2" zoning);
- Small areas within the Moss Vale Golf Club (within "RE2" zoning);
- A small area along the internal access road of 37 Yarrawa Rd, Moss Vale (within "R2" zoning").

The areas listed above are very small and the majority of these areas are not predicted to extend across land currently zoned for habitable development. As a result, it is considered that application of appropriate development controls within the FPA should be sufficient to manage the flood risk and an application for exceptional circumstances for flood related development controls is not necessary for residential development.

There is a small area of concern for the commercial area where the H6 is expected and there are evacuation difficulties during a 1% AEP and PMF event. These properties identified as "flood isolated elevated" or "flood isolated submerged" on the Emergency Response Classification mapping of Figures 21 and 22. These are primarily the commercial properties immediately adjacent to Whites Creek crossing of the railway line. Redevelopment of these properties is expected in the near future, and the application of appropriate development controls to manage these flood risks up to and including the PMF is recommended to help mitigate these flood risk. As these areas are located within the proposed flood planning area, exceptional circumstances would not be required.

4.3.2 Moss Vale Town Plan Development Control Plan 2017

The *Moss Vale Town Plan Development Control Plan 2017* (Moss Vale Town Plan DCP 2017) applies to all land zoned for residential and business uses within the locality of Moss Vale (and within the Whites Creek catchment). Land under an Industrial zoning in or around Moss Vale is covered under the *Industrial Land Development Control Plan 2017* (refer to Section 4.2.3), with the exception of the Moss Vale Enterprise Corridor in the north of the catchment that is covered by the *'Moss Vale Enterprise Corridor Development Control Plan' (as at 14 November 2012)*. Other land zonings within the catchment (e.g., "RU2" (Rural Landscape) and "E3" (Environmental Management)) are covered under the *Rural Lands Development Control Plan 2017*.

"Section 5" (Flood Liable Land) of the Moss Vale Town Plan DCP 2017 outlines the general development controls relating to the management of flood risk. This section discusses the appropriateness of the controls for development on flood liable land to manage overland flow inundation and mainstream flood risks in the Whites Creek catchment. "Section 5" (Flood Liable Land) of the Moss Vale Town Plan DCP 2017 is reviewed below.

It should be noted that the Moss Vale Enterprise Corridor lies outside the predicted extent of Whites Creek flooding in all events up to the 0.2% AEP. However, a very small area at the southern extent of the site (adjacent to Gibbons Road) is predicted to be inundated at the peak of the PMF. As the controls for development on flood liable land (outlined in Part 4 Appendix 3 of the *'Moss Vale Enterprise Corridor Development Control Plan'*) are largely an identical reproduction of those controls in "Section 5" (Flood Liable Land) of the Moss Vale Town Plan DCP 2017 and considering that such a very small area of the Whites Creek floodplain lies within the Enterprise Corridor, they have not been discussed separately.

Flood Risk Precincts

The flood risk management controls defined within the Moss Vale Town Plan DCP apply to all land within the Moss Vale township that is affected by flooding, that is all land that lies within a flood risk precinct.

"Flood Risk Precincts" are used to grade the severity of the flood risk and determine what development types are permissible across different sections of the floodplain. As noted in Section 3.3 of this report, the DCP includes four flood risk precinct classifications (refer **Figure 30**):

- High Flood Risk Precinct
- Medium Flood Risk Precinct
- Low-Fringe Flood Risk Precinct
- Low Flood Risk Precinct

The adopted flood risk precinct categories are convenient for aligning with the Floodplain Development Manual 2005 and the Codes SEPP 2008. For this reason, no changes to this classification system are considered necessary.

Land Use Categories

The land use categories discussed in relation to the flood risk management controls within the DCP are grouped together to include:

- Critical Uses and Facilities;
- Sensitive Uses and Facilities;
- Residential;
- Commercial or Industrial;
- Recreation and non-urban; and,
- Concessional development (i.e., additions or alterations).

These development types are suitably defined in Section A5.3.3 of the DCP, however they do not relate specifically to the land use zoning specified in the Wingecarribee LEP 2010.

Risk Compatibility Categories

The Moss Vale Town Plan DCP 2017 provides a list of compatible development and flood related development controls for properties in each Flood Risk Precinct (FRP) via a "flood plain

matrix" of prescriptive controls. The matrix includes three categories, one of which is applied to each land use/FRP combination:

- Development is permitted with no flood related development controls;
- Development is permitted with flood related development controls (refer to numbered prescriptive criteria below);
- Development is not permitted.

A summary of the permitted development types within each FRP are illustrated in **Table 18**.

Table 18 Permissible Development Types within each Flood Risk Precinct.

Flood Risk Precincts	Development Type					
	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development
Low Flood Risk						
Low-Fringe Flood Risk						
Medium Flood Risk						
High Flood Risk						

Permitted without Controls | Permitted with Controls | Not Permitted

No flood-related development controls apply for all land uses in the Low FRP except for 'Critical Uses' (where no development is permitted) and 'Sensitive Uses'. Flood-related development controls do apply for many land uses in the Low Fringe and Medium Flood Risk Precincts. Development within the High FRP is only permissible for non-urban development types and concessional development. The land uses in Table 18 are considered to be compatible with the Flood Risk Precincts and no modifications are considered necessary.

It was noted that the quality of the text in Figure A4.2 of the DCP available on Councils website was poor, making some text difficult to read. Therefore, provision of a higher resolution version would be beneficial and is highly recommended.

Prescriptive Controls for General Development (A5.4)

The prescriptive controls for general development include compliance with the requirements of the flood plain matrix (Figure A4.2) of the DCP. The controls include:

- **Minimum Floor Level:** Habitable floor levels for residential, commercial and industrial development are to be no lower than 1% AEP flood level plus freeboard. As noted in Section 4.3.1 of this report, a 0.5 metre freeboard is considered appropriate for the Whites Creek catchment. Non-habitable floor levels should also be greater than the 1% AEP flood level plus freeboard where possible or otherwise no lower than the 20% AEP flood level plus freeboard. The minimum floor level for sensitive uses and facilities must be no lower than the PMF level. These controls are considered appropriate given the potential vulnerability of occupants of these facilities and/or the important role that they may play in emergency response during floods.

- **Building Component:** The DCP requires all structures to have flood compatible building components below the 1% AEP flood level plus 0.5m freeboard and a list of flood compatible materials is provided in Figure A4.4 of the DCP. This is consistent with the requirement in the Codes SEPP. Sensitive land uses require flood compatible building materials to be provided up to the level of the PMF. No modifications are considered necessary.
- **Structural Soundness:** The DCP requires all structures to be built to withstand forces of floodwater, debris and buoyancy up to and including the 1% AEP flood plus freeboard or the PMF (sensitive land uses only). As noted in Section 4.3.1, there are some areas of concern where the flood hazard reaches H6 in a PMF event and there are evacuation difficulties from that site (most notably the commercial areas around Argyle Street). As such, the need to extend the structural soundness requirements to include the PMF for other development types should be considered where refuge-in-place is the preferred evacuation strategy (discussed in more detail under 'evacuation' below).
- **Flood Effects:** The DCP outlines that any proposed development shall not increase flood effects elsewhere, having regard to loss of flood storage, changes in flood levels and velocities and the cumulative impact of multiple potential developments. This control is fairly standard across many council development control plans. However, it is not clear if this requirement applies to all potential floods (i.e., up to and including the PMF) or is applicable to a specific flood (e.g., 1% AEP flood). It is considered that the 1% AEP flood is suitable for assessing the potential impacts of most development types. However, consideration of the impacts during the PMF would be beneficial for sensitive facilities. Therefore, Council could give consideration to modifying this section of Figure A4.2 to provide specific advice on what floods need to be considered as part of the flood impact assessment.
- **Car Parking and Driveway Access:** Car parking controls are important given the ease with which vehicles can become buoyant and float and then become floating debris with potential to block culverts and pose environmental hazards during a flood. The DCP requires carports and garages with less than 3 cars to be no lower than the 20% AEP flood level plus freeboard. In areas of overland flow where inundation depths are typically shallow, an option to provide carports or garages 300mm above the ground level could be provided.
- **Evacuation:** The potential for evacuation across some sections of the catchment may be limited owing to the short warning times (i.e., less than 1 hour before some roads are cut). The DCP does include a requirement for most development types to provide a refuge area above the PMF level or a minimum of 20% of the gross floor levels to be above the PMF level, which may allow for safe refuge in place if evacuation cannot be achieved. However, as noted above, in order to ensure the safety of occupants, it is considered that the 'structural soundness' requirements will need to be modified so that the structures are designed to withstand the forces of floodwater during all events up to and including the PMF for these sites.

Controls for Fencing (A5.5)

Fencing can have a significant impact on flood flows. Ideally, fencing should not impede the flow of floodwaters so as to result in additional flood impacts on surrounding land and should

be able to withstand flooding or to collapse in a controlled manner to prevent a ‘wave’ causing additional problems downstream.

The DCP largely address these requirements by requiring permeable/opening fencing in High Flood Risk Precinct areas. Brick or masonry (i.e., impervious) type fence is generally not be permitted. These controls are considered to be appropriate, although it is recognised that maintaining and enforcing fencing controls can be difficult for Council.

5 EXISTING EMERGENCY MANAGEMENT PROTOCOLS

It is generally not economical to provide "structural" flood risk management options that address the flood risk for all events up to and including the PMF. Therefore, emergency management measures such as evacuation planning and community education are typically employed to manage the residual flood risk during both frequent as well as very rare floods.

The following chapter outlines current emergency management strategies for the Whites Creek catchment. Where appropriate, it also makes suggestions on ways in which the current emergency management strategies could be potentially improved.

5.1 Wingecarribee Shire Local Flood Plan

The *Wingecarribee Shire Local Flood Plan* (NSW SES, 2013) (LFP) sets out procedures to follow before, during and after a flood including who is responsible for each of these activities within the Wingecarribee Shire area. A summary of pertinent components of the LFP for the Whites Creek catchment are provided in **Table 19.**

Volume 1 of the LFP was last updated in November 2013. It details organisational responsibilities for managing flooding hazards, and sets out tasks related to the preparedness, response and recovery phases of disaster management. There is scope for minor refinement, for example, to add one site for active reconnaissance during floods, but noting the challenges for active reconnaissance during a flood event given the likelihood of fast rising and falling floodwaters.

Volume 2 of the LFP was last updated in May 2007. This volume is in need of an update, both to align the structure and contents with the new NSW SES LFP template, and to incorporate flood intelligence from more recent flood studies, floodplain risk management studies, and actual floods. In particular, it currently says very little about flooding risks from local overland flow, including overlooking this form of flooding in the Whites Creek catchment.

Volume 3 of the LFP was last updated in May 2007 and describes response arrangements. The section is relatively vague with respect to when warnings and evacuation orders should be issued. Therefore, this section should be updated using information from this report. The volume should also include a list of gauges to be monitored prior to and during flooding (although it is noted that there are no gauges within the Whites Creek catchment and very limited warning time). The list of media outlets should be reviewed (Annex C). Additionally, Annex F and G provides no information targeting Moss Vale so should be updated using information contained in Section 3.4 of this report. The maps should also be updated to include the Whites Creek catchment. Finally, considerable effort is needed to provide the detail consistent with the new SES LFP template.

Table 19 Comments on Current Wingecarribee Shire Local Flood Plan

Section	Description	Comment
Volume 1		
1.5.21	Responsibilities of Roads and Maritime Services	The list of roads for which RMS exercises responsibility should be included
3.18.42	List of evacuation centres	While there is an evacuation centre at Bowral (Chevalier College), it is likely that access from the western side of the catchment towards Bowral will be cut by floodwaters near the Argyle Street railway underpass. Therefore, opportunities to provide an evacuation centre for the western parts of the catchment could be explored. The Moss Vale Services Club (located on the corner of Illawarra Highway and Yarrawa Street) could be potentially utilised in this regard.
Volume 2 Hazard and Risk in Wingecarribee		
Annex A Section 3 & 4	Flood History	Should be updated to include reference to more recent floods (e.g., February 2007, June 2016)
Annex A Section 5	Extreme Flooding	Information in this FRMS should be used to describe what happens in floods rarer than the 1% AEP event in the Whites Creek catchment.
Annex B	Effects of Flooding on the Community	Currently there is no description of Flooding in the Community for the Whites Creek catchment. Suggested text is included below. In addition, maps of potential flooding should be included in the Local Flood Plan. **Whites Creek** The Whites Creek catchment drains much of the western sections of Moss Vale. Inundation from the various watercourses can cut many local roads as well as major roads including Argyle Street / Illawarra Highway, which would isolate parts of Moss Vale. Flooding within Whites Creek catchment can occur relatively quickly from the onset of rainfall. Flooding typically will have a high rate of rise and subside relatively quickly once rainfall has ceased. Therefore, the warning time available for evacuation will be minimal, and the duration of isolation is likely to be only a few hours. Available information indicates the following locations are prone to relatively frequency flooding: 1) Argyle Street/Illawarra Highway (near the railway underpass) 2) Lackey Road 3) Railway Street 4) Dangar Street

<table>
<tr><th>Section</th><th>Description</th><th>Comment</th></tr>
<tr><td></td><td></td><td>A series of design floods have been modelled as part of the Whites Creek Floodplain Risk Management Study and Plan. The table below indicates the number of buildings with over-floor flooding at the various design flood levels.
<table>
<tr><td>Annual Exceedance Probability (Annual Return Interval)</td><td>Number of houses with over-floor flooding</td><td>Total number of buildings with over-flood flooding</td></tr>
<tr><td>20% (1 in 5-year flood)</td><td>1</td><td>3</td></tr>
<tr><td>10% (1 in 10-year flood)</td><td>2</td><td>5</td></tr>
<tr><td>2% (1 in 50-year flood)</td><td>4</td><td>10</td></tr>
<tr><td>1% (1 in 100-year flood)</td><td>4</td><td>14</td></tr>
<tr><td>Probable Maximum Flood</td><td>101</td><td>140</td></tr>
</table>
The Whites Creek Floodplain Risk Management Study noted the following flood impacts to critical facilities:
• Moss Vale Police Station would be impacted during the PMF. However, it would not be inundated above floor level and access would be available along Elizabeth Street
• Anglicare Community Care would be flooded above floor level during the PMF
• Access to Rainbow Kindy Moss Vale would likely be cut during a 1% AEP flood</td></tr>
<tr><td colspan="3">Volume 3 SES Response Arrangements</td></tr>
<tr><td>Annex C</td><td>Dissemination of SES Flood Bulletins</td><td>The list of media outlets for warning dissemination needs to be reviewed.</td></tr>
<tr><td>Annex D</td><td>Template Evacuation Warning Message</td><td>The template message should be updated to fit with areas that do not have a quantified flood warning and therefore rely on other warning products such as severe weather warnings or flood watches.

Similarly, additional template warnings should also be prepared for short form communications such as the emergency alert system.</td></tr>
<tr><td>Annex F</td><td>Vulnerable Facilities</td><td>Should be updated based upon the information contained in Section 3.4.1 of this report.</td></tr>
<tr><td>Annex G</td><td>Roads Subject to Flooding</td><td>The list of roads should be updated based on information contained in Section 3.4.2 of this report. Also, other regional roads on the way to or from Moss Vale that have potential to be cut by floodwaters should also be included.</td></tr>
</table>

Section	Description	Comment
Maps	Maps	The maps should be updated to include a map dedicated to Moss Vale.
Missing Information		Volume 3 is also missing a number of key components, particularly: • A list of gauges that should be monitored during flood operations • A breakdown of the local SES response arrangements (e.g. sectors) and response strategies

5.2 Emergency Services' Capability

As of 2018, the Wingecarribee SES unit had a volunteer membership of 100 with the local headquarters based in Etheridge Street, Mittagong (approximately 12km north-east of the Whites Creek catchment). There is also potential to call in out-of-area units to supplement local resources. Discussion with the SES Deputy Local Controller throughout the course of this study indicates that these resources are sufficient to manage the flood risk across the LGA.

However, given the size of the at-risk communities in the LGA, and the speed with which flash flooding can occur, adverse consequences are likely to occur across the Whites Creek catchment before emergency services personnel can be deployed. As a result, it will be critical that the at-risk communities are able to cope with flooding without reliance on the emergency services.

5.3 Response Strategy

5.3.1 Theory

A major point of contention in contemporary flood emergency management planning relates to the advantages and disadvantages of evacuation compared to seeking on-site refuge.

The Australian Fire and Emergency Services Authorities Council (AFAC) (2013) '*Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events*' is considered to represent best practice on this issue. It recognises that the safest place to be in a flood is well away from the affected area. Provided that evacuation can be safely implemented, this is the most effective strategy. Properly planned and executed evacuation is the most effective strategy in terms of a reliable public safety outcome.

However, AFAC recognises that evacuating too late may be worse than not evacuating at all because of the dangers inherent in moving through floodwaters. If evacuation has not occurred prior to the arrival of floodwater, taking refuge inside a building may generally be safer than trying to escape by entering the floodwater.

Nevertheless, AFAC argues that remaining in buildings likely to be affected by flooding is not low risk and should never be a default strategy for pre-incident planning: 'where the available warning time and resources permit, evacuation should be the primary response strategy' (p.4). The risks of a 'on-site refuge' strategy include:

- Floodwater reaching the place of shelter (unless the shelter is above the PMF level);
- Structural collapse of the building that is providing the place of shelter (unless the building is designed to withstand the forces of floodwater, buoyancy and debris in a PMF);
- Isolation, with no known basis for determining a tolerable duration of isolation;
- People's behaviour (drowning if they change their mind and attempt to leave after entrapment);
- People's immobility (not being able to reach the highest part of the building);
- The difficulty of servicing medical emergencies (pre-existing condition or sudden onset e.g. heart attack) during a flood;
- The difficulty of servicing other hazards (e.g. fire) during a flood.

For evacuation to be a defensible strategy, the risk associated with the evacuation must be lower than the risk people may be exposed to if they were left to take refuge within a building which could either be directly exposed to or isolated by floodwater (Opper et al., 2011). Pre-incident planning therefore needs to include a realistic assessment of evacuation timelines (both time available and time required for evacuation), including assessment of resources available. Successful evacuation strategies require a warning system that delivers enough lead time to accommodate the operational decisions, the mobilisation of the necessary resources, the warning and the movement of people at risk.

5.3.2 Whites Creek Practice

The current Wingecarribee Local Flood Plan proposes evacuation as the primary strategy. As discussed, it is likely that flooding will be occurring and large parts of the catchment isolated prior to the effective mobilisation of the emergency services, therefore the delivery of timely evacuation warnings and orders is unlikely to be achievable in the Whites Creek catchment. While evacuation is the primary and preferred strategy, the Local Flood Plan contains no details on how this may be enacted and currently lists no specific evacuation centres for the Whites Creek catchment.

On-site refuge may be a pragmatic approach for the majority of the catchment, given:

- The worst flooding occurs as a result of short storms with the critical storm duration in most locations varying between 2 and 6 hours. There may be no specific prior indication of flooding, and early evacuation in response to only general warnings such as a (generalised) Flood Watch, Severe Weather Warning or Severe Thunderstorm Warning is likely to be socially unsustainable. Attempting to evacuate as flooding manifests itself may expose evacuees to adverse conditions such as heavy rainfall, hail, lightning, strong winds and the risk from flying debris, falling trees or power lines;
- Roads may be cut less than 30 minutes after the commencement of a storm, leaving very little opportunity for evacuation triggered by environmental cues;
- Roadways may be impassable for approximately 2 – 4 hours, which means a relatively short period of isolation;
- The national hazard mapping (refer **Appendix I**) indicates the maximum hazard during the 1% AEP flood is most often H1–H3, which is not unsafe for adults or buildings. However, more extensive areas would be exposed to a hazard classification of at least

H5 hazard during the PMF event which would be unsafe for people and buildings may be susceptible to failure if they are not specifically designed to withstand the forces of the floodwaters (refer discussion on structural soundness included in Section 4.3.2). Those properties where more than 50%) of the lot area would be exposed to H5 or H6 hazard during the PMF are shown in **Plate 18**;

- Estimated depths of above-floor inundation in the PMF event are less than 1.2 metres for 71 buildings. However, 69 buildings would be exposed to above floor flooding depths greater than 1.2 metres which is considered unsafe for adults (refer **Plate 19**).

Nonetheless, evacuation is still recommended in some situations including the following:

- People whose prior medical condition means any isolation from medical help cannot be tolerated should evacuate prior to flooding.
- Sites where the national hazard rating exceeds H4 during the PMF which would likely be unsafe for buildings and their occupants. These properties are shown in shown in **Plate 18**.
- Locations where the depth of above floor flooding is predicted to exceed 1.2 metres during the PMF. These properties are shown in **Plate 19**.

An on-site refuge strategy requires that occupants of the building know their flood risk exposure and plan how to respond. There is a risk that as floodwater first penetrates a house, people may panic and enter deeper, faster floodwater outside a building while attempting to evacuate. Information and education are required to help residents plan how to respond appropriately.

If the NSW SES wishes to maintain an evacuation strategy, then significant work needs to be undertaken to ensure that evacuation can be successfully achieved. This includes at a minimum:

- The identification of appropriate evacuation centres. With different areas of the catchment potentially isolated from each other, several evacuation centres are required to prevent evacuees from entering floodwaters in an attempt to reach the evacuation centre. As discussed, it is suggested that the Moss Vale Services Club may be a suitable evacuation centre for the western sections of the catchment. The Moss Vale TAFE could be potentially used as an evacuation centre for the eastern section of the catchment (although access along Kirkman Street may be cut during the PMF).
- Given the relatively small population at risk and the short duration of flooding, there would be minimal requirements for space and supplies at evacuation centres. It is also likely that a significant proportion of the population at risk will evacuate to private residences such as family and friends, further reducing the potential requirements of local evacuation centres.
- The positioning of emergency services in each isolated section. If an evacuation is enacted, it is likely that in each of the isolated sections of the catchments there will be occupants that require assistance from emergency services to evacuate. Therefore, it is important that there are emergency service personnel located within each of the isolated sections prior to the access becoming cut.



Plate 18 Properties exposed to H5 or H6 hazard during the PMF (evacuation considered essential).

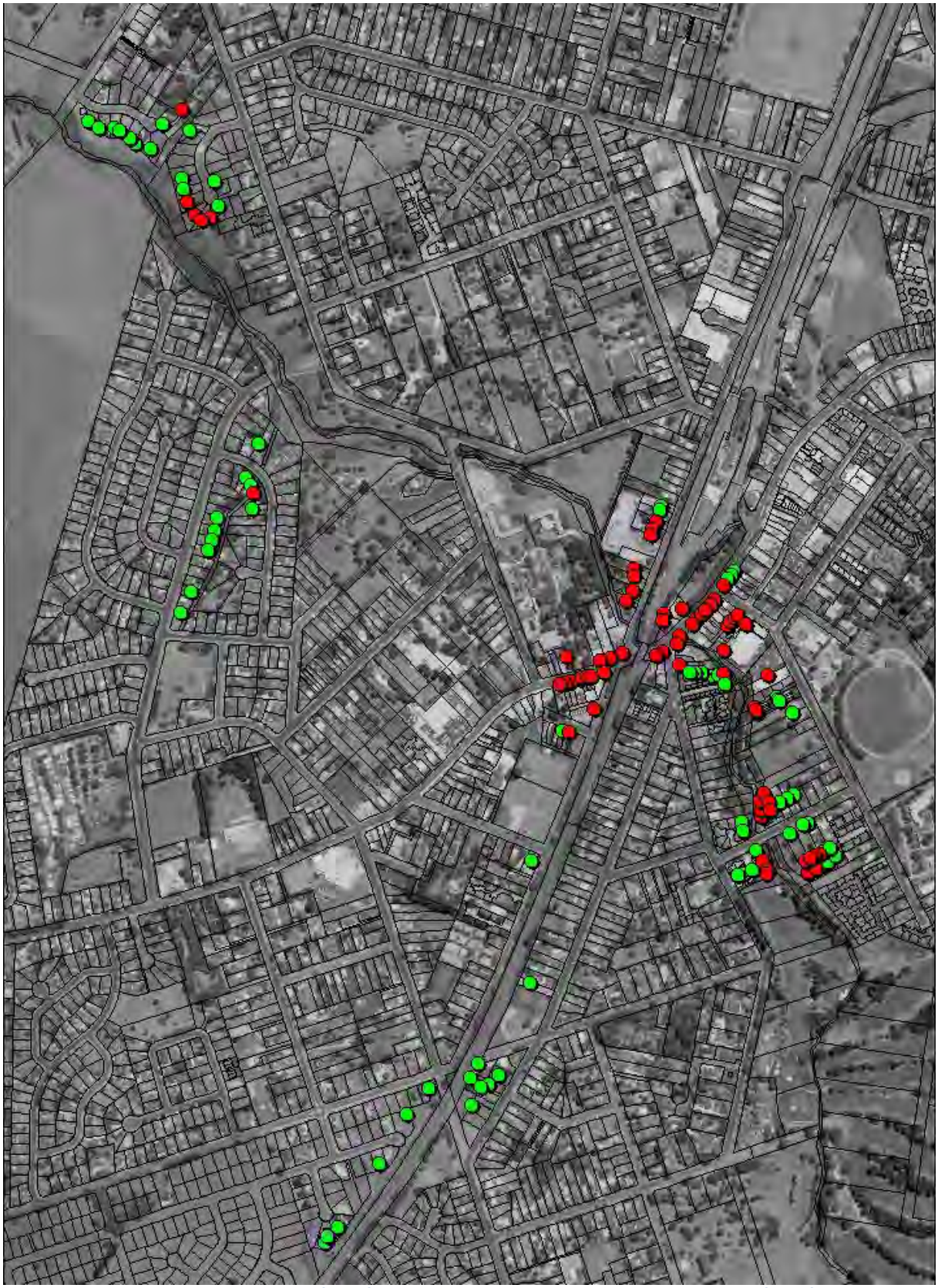


Plate 19 **Buildings subject to above floor flooding during the PMF. Red indicates above floor flooding depths of more than 1.2 metres (evacuation essential) and green indicates above floor flooding depths of less than 1.2m (refuge on-site may be feasible).**

6 Options for Managing the Flood Risk

6.1 General

As outlined in Section 3, a number of properties across the Whites Creek catchment are predicted to be exposed to a significant flood risk and/or significant financial impacts during floods within the catchment. Accordingly, the following chapters outline options that could be implemented to better manage the flood risk.

6.2 Potential Options for Managing the Flooding Risk

6.2.1 Types of Options

Options for managing the flood risk can be broadly grouped into one of the following categories:

- **Flood Modification Options**: are measures that aim to modify existing flood behaviour, thereby reducing the extent, depth or velocity of floodwater across flood liable areas. Flood modification measures will generally benefit a number of properties and are primarily aimed at reducing the existing flood risk. However, they can also be designed to mitigate potential increases in flood risk associated with future catchment development.
- **Property Modification Options**: refers to modifications to planning controls and/or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. Modifications to individual properties is typically used to manage existing flood risk while planning measures (e.g., land use/development controls) are employed to manage future flood risk.
- **Response Modification Options**: are measures that can be implemented to change the way in which emergency services as well as the public responds before, during and after a flood. Response modification measures are the key measures employed to manage the continuing flood risk.

6.2.2 Options Considered as Part of Current Study

An initial list of potential flood risk management options was prepared for consideration by Council. The risk management measures were developed based upon consideration of the following factors:

- Location of high flood risk/high flood damage properties
- Recommendations in previous reports
- Council recommendations; and
- Community recommendations

A list of options was initially identified and these options are summarised in **Table 20** (flood modification options), **Table 21** (property modification options) and **Table 22** (response modification options).

Table 20 Preliminary List of Flood Modification Options Considered for Managing the Flood Risk

Potential Flood Modification Options	Description of Option
Detention Basins	
Modification to the proposed Chelsea Gardens/Coomangie Detention Basins	Modification to the design of the proposed detention basins as part of the Chelsea Gardens/Coomangie developments to increase the volume of water to be temporarily stored from the developments as well as the upstream catchment and reduce downstream flows/water levels.
New detention basin within the Moss Vale Golf Club	Create a detention basin/storage area within the Moss Vale Golf Club grounds to store water from the upstream catchment and reduce downstream flows/water levels
New detention basin within Broulee Park	Create a detention basin/storage area within Broulee Park to store water from the upstream catchment and reduce downstream flows/water levels
New detention basin within the Moss Vale Community Oval	Create a detention basin/storage area within the Moss Vale Community Oval to store water from the upstream catchment and reduce downstream flows/water levels
New detention basin upstream of Yarrawa Road	Create a detention basin/storage area upstream of Yarrawa Rd near Harper Collins Publishers to store water from the upstream catchment and reduce downstream flows/water levels
Drainage Upgrades	
Upgrade stormwater system along Railway Street (near Argyle Street)	Upgrade of existing, and addition of infrastructure to convey a larger proportion of flow below ground to Whites Creek.
Upgrade stormwater system along Argyle Street near Railway Street and Arthur Street	Upgrade of existing, and addition of stormwater infrastructure to convey a larger proportion of flow below ground to Whites Creek.
Upgrade culverts along Whites Creek at Argyle Street and the railway	Upgrade culverts along Whites Creek at the Argyle Street and railway crossings to reduce overtopping and inundation of Argyle Street from Whites Creek.
Upgrade stormwater system on Willow Drive and Dangar Street	Upgrade stormwater system on Willow Drive near Roe St and Kennedy Close and on Dangar Street to convey a larger proportion of flow below ground and reduce inundation of the roadway and properties in the vicinity of the crossing.
New stormwater pipe from Spring Street to Whites Creek along eastern side of railway	Additional stormwater pipeline along the railway to divert flow along the Eastern side of the railway and prevent it moving along Spring St to the Western side of the railway.
Channel Modification	
Creek maintenance/removal of dense vegetation in swale adjacent Railway Street	Creek maintenance including removal of dense vegetation to provide additional flow carrying capacity within swale adjacent to Railway Street between Yarrawa Street and Spring Street
Channel and floodplain modifications near 2-10 Berrima Road	Creek maintenance including removal of dense vegetation to provide additional flow carrying capacity within the creek channel and floodplain near 2-10 Berrima Road
Channel reshaping between Dangar Street and Campbell Crescent	Channel reshaping between Dangar Street and Campbell Crescent to increase channel conveyance and storage capacity and reduce inundation of adjacent properties and Campbell Crescent
Channel reshaping of Whites Creek upstream of Argyle Street	Channel reshaping and stabilisation, and /or embankment raising to increase conveyance and storage capacity of Whites Creek and reduce

Potential Flood Modification Options	Description of Option
	the existing constriction to flow prior to entering the culvert under Argyle Street.
Enlarge swale along Railway St between Yarrawa St and Spring St and create new swale between Spring Street and Argyle Street	Enlargement and clearing of the swale adjacent Railway Street between Yarrawa Street and Spring Street and construct new swale between Spring Street and Argyle Street to minimise floodwater inundation of Railway Street
Lower northern floodplain elevations of Whites Creek between 6-12 Berrima Road	Channel and floodplain earthworks to increase the conveyance capacity of Whites Creek between 6-12 Berrima Road
Topographic Modifications	
Elevate pedestrian walkway in Walton Park between railway and Throsby Street to direct flows into downstream channel	Elevate pedestrian walkway in Walton Park between railway and Throsby Street to direct flows into downstream channel to reduce diversion of flow and inundation of properties in the vicinity of the pathway
Construct bund wall/levee on eastern bank of Whites Creek near 201-207 Lackey Road	Construct levee on eastern bank of Whites Creek at rear of properties near 201-207 Lackey Road to reduce potential for water to spill from Whites Creek and inundate properties
Modify existing overland flowpath and/or existing levee at rear of 71-77 Throsby Street	Modify existing overland flowpath and/or existing levee at rear of 71-77 Throsby Street to intercept flow diverted from railway swale and direct back to downstream swale adjacent to the railway
Construct bund wall/levee on bank of railway swale at rear of 51-55 Throsby Street	Construct bund wall/levee on eastern bank of railway swale at rear of properties at 51-55 Throsby Street to reduce potential for water to spill from swale and inundate properties
Regrading Lackey Road from Argyle Street to Whites Creek	Regrading of Lackey Road and adjacent land to promote movement of water off the roadway and into the Whites Creek channel to minimise floodwater inundation on roadway
Modification to edge of channel on downstream side of Argyle Street	Modification to the solid boundary fence of Whites Creek channel (revert to open type) on the downstream side of Argyle Street to reduce ponding depths on Argyle Street

Table 21 Preliminary List of Property Modification Options Considered for Managing the Flood Risk

Potential Property Modification Options	Description of Option
Planning Modifications	
Updates to LEP	Update Council LEP to reflect the detailed review completed as part of the current study
Updates to DCP	Update Council DCP to reflect the detailed review completed as part of the current study
Updates to Section 10.7 certificates	Update Council Section 10.7 certificates to reflect the detailed review completed as part of the current study
Residential Property Modifications	
Voluntary purchase of select properties	Voluntary purchase of select properties in high hazard / floodway areas
Voluntary flood proofing of select properties	Flood proofing of select residential properties
Voluntary raising of select residential properties	Voluntary raising of select houses subject to frequent above floor inundation

Table 22 Preliminary List of Response Modification Options Considered for Managing the Flood Risk

Potential Response Modification Options	Description of Option
Education	
Community education activities	Various community education activities to increase flood awareness and allow residents to be more self-sufficient during future floods
Make property level flood information available	Increase the availability and access to the most contemporary property level flood information for all residents and businesses within the LGA to increase flood awareness
Flood Plans	
Preparation of residential flood plans	Preparation of flood plans by residential property occupiers to identify actions to be taken before, during and after a flood
Preparation of business flood plans	Preparation of flood plans by business owners to identify actions to be taken before, during and after a flood
Local flood plan updates	Update NSW SES local flood plan to take advantage of updated flood information generated as part of the current study
Evacuation Route Upgrades	
Regrading/raising of Argyle Street between Arthur Street and Railway Street	Raising of Argyle Street to minimise floodwater inundation and increase evacuation potential and decrease risk to life
Miscellaneous	
Flood warning system	Development of a flood warning system for the catchment to provide additional evacuation time
Refuge in place strategy	Develop a strategy to allow for safe refuge in place at suitable locations within the catchment

It was not considered feasible to undertake a detailed assessment of all options in **Table 20, Table 21** and **Table 22**. Therefore, a relative assessment of each potential option was completed to provide an initial assessment of the potential feasibility of each option and to determine which measures showed merit for further detailed assessment. The evaluation criteria/scoring system that was employed to complete this assessment is summarised in **Table 23** and the outcomes of the assessment are provided in **Table 24**, **Table 25** and **Table 26**.

Where possible, this qualitative assessment utilised outputs or outcomes from detail assessments undertaken in other floodplain risk management studies for the same or similar options, to help inform the evaluation criteria, particularly the change in flood levels, technical and economic feasibility. This includes the creek modification options of vegetation management and channel reshaping, which can appear to have aesthetic benefits but in effect have minimal hydraulic benefits and can have adverse environmental impacts, such as bank and bed erosion.

Table 23 Adopted Evaluation Criteria and Scoring System for Qualitative Assessment of Flood Risk Management Options

Score:	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance
-2	Significant increases in levels/extents	Significant disbenefit to emergency services	Significant technical challenges	Significant impacts	Costs significantly outweigh benefits	Majority of community opposed
-1	Minor increases in levels/extents	Slight disbenefit to emergency services	Some technical challenges	Minor impacts	Costs outweigh benefits	Some opposed
0	Negligible changes in levels/extents	No impact on emergency services	Minor technical challenges	No impacts	Benefits and costs approximately equal	Neutral
1	Minor decreases in levels/extents	Slight benefit to emergency services	Negligible technical challenges	Some benefits	Benefits outweigh costs	Some support
2	Significant decreases in levels/extents	Significant benefit to emergency services	No technical challenges	Significant benefits	Benefits significantly outweigh costs	Majority of community support

Table 24 Qualitative Assessment of Preliminary List of Flood Modification Options

Potential Flood Modification Options#	Evaluation Criteria/Score						
	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Detention Basins							
Modification to the proposed Chelsea Gardens/Coomangie Detention Basins	0	0	1	0	1	2	**4**
New detention basin within the Moss Vale Golf Club	1	0	-2	0	-2	1	**-2**
New detention basin within Broulee Park	1	2	0	0	-1	-1	**1**
New detention basin within the Moss Vale Community Oval	1	0	0	0	-2	-1	**-2**
New detention basin upstream of Yarrawa Road	1	1	0	0	-1	-1	**0**
Drainage Upgrades							
Upgrade stormwater system along Railway Street (near Argyle Street)	2	2	-2	0	-2	1	**1**
Upgrade stormwater system along Argyle Street near Railway Street and Arthur Street	1	2	-2	0	-1	1	**1**
Upgrade culverts along Whites Creek at Argyle Street and the railway	2	2	-2	0	-2	1	**1**
Upgrade stormwater system on Willow Drive and Dangar Street	1	1	-1	0	-1	1	**1**
New stormwater pipe from Spring Street to Whites Creek along eastern side of railway	1	1	-1	-1	-2	-1	**-3**
Channel Modifications							
Creek maintenance/removal of dense vegetation in swale adjacent Railway Street	1	0	0	-2	-1	-1	**-3**
Channel and floodplain modifications near 2-10 Berrima Road	0	0	1	-2	-2	-1	**-4**

Potential Flood Modification Options#	Evaluation Criteria/Score						
	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Channel reshaping between Dangar Street and Campbell Crescent	1	1	-1	-1	0	-1	**-1**
Channel reshaping of Whites Creek upstream of Argyle Street	1	1	-1	0	0	1	**2**
Enlarge swale along Railway St between Yarrawa St and Spring St and create new swale between Spring Street and Argyle Street	1	1	1	-2	-2	1	**0**
Lower northern floodplain elevations of Whites Creek between 6-12 Berrima Road	1	0	2	-2	-1	1	**1**
Topographic Modifications							
Elevate pedestrian walkway in Walton Park between railway and Throsby Street to direct flows into downstream channel	1	0	1	0	0	1	**3**
Construct bund wall/levee on eastern bank of Whites Creek near 201-207 Lackey Road	1	0	1	-1	1	1	**3**
Modify existing overland flowpath and/or existing levee at rear of 71-77 Throsby Street	1	0	0	-1	1	1	**2**
Construct bund wall/levee on bank of railway swale at rear of 51-55 Throsby Street	1	0	1	0	0	-1	**1**
Regrading Lackey Road from Argyle Street to Whites Creek	1	1	-1	0	-1	1	**1**
Modification to edge of channel on downstream side of Argyle Street	0	0	0	0	-1	0	**-1**

Note: # refer to **Table 20** for a detailed description of each option

Table 25 Qualitative Assessment of Preliminary List of Property Modification Options

Potential Property Modification Options[#]	Evaluation Criteria/Score						
	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Planning Modifications`							
Updates to LEP	0	0	2	0	1	1	**4**
Updates to DCP	0	0	2	0	2	1	**5**
Updates to Section 10.7 certificates	0	0	2	0	2	1	**5**
Residential Property Modifications							
Voluntary purchase of select properties	0	1	1	1	-2	-1	**0**
Voluntary flood proofing of select properties	0	0	1	0	-1	-1	**-1**
Voluntary raising of select residential properties	0	0	1	0	1	-1	**1**

Note: [#] refer to **Table 21** for a detailed description of each option

Table 26 Qualitative Assessment of Preliminary List of Response Modification Options

Potential Response Modification Options[#]	Evaluation Criteria/Score						
	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Education							
Community education activities	0	2	1	0	1	1	**5**
Make property level flood information available	0	1	1	0	1	1	**4**
Flood Plans							
Preparation of residential flood plans	0	2	1	0	1	1	**5**
Preparation of business flood plans	0	2	1	0	1	0	**4**
Local flood plan updates	0	2	0	0	1	2	**5**
Evacuation Route Upgrades							
Regrading/raising of Argyle Street between Arthur Street and Railway Street	1	1	-2	0	-1	2	**1**
Miscellaneous							
Flood warning system	0	2	-2	0	-2	2	**0**
Refuge in place strategy	0	1	0	0	1	1	**3**

Note: [#] refer to **Table 22** for a detailed description of each option

As shown in **Table 24**, **Table 25** and **Table 26,** each measure was evaluated against six criteria. The expected performance of each measure against each criterion was scored between 2 (significant positive impact) and -2 (significant negative impact).

The relative scores were subsequently summed to provide an overall score for each option and enable a means of comparing the different options as well as provide an initial assessment of whether specific options would provide a net positive outcome. Those options where the assessment yielded an overall score of greater than 0 are highlighted in green and were carried forward into the detailed assessment.

It should be reinforced that this assessment was relative in nature only and was only used to prepare a shortlist of options for further detailed investigation.

6.3 Flood Risk Management Options Assessed in Detail

Based upon the qualitative assessment presented in **Table 24**, **Table 25** and **Table 26**, the options listed in **Table 27** were selected for detailed assessment.

6.3.1 Detailed Options Assessment Approach

Each flood risk management option will generally be a compromise as it is unlikely that an option will provide only benefits (e.g., there may be an adverse environmental impact or significant costs associated with the implementation of the option). In general, if the advantages associated with implementing the option outweigh the disadvantages, it will afford a net positive outcome and may be considered viable for future implementation. Therefore, each option was evaluated against a range of criteria to provide an appraisal of the potential feasibility of each option.

As outlined in the previous section, a qualitative assessment of each potential option was completed to provide an initial appraisal of the likely feasibility of each option (refer **Table 24**, **Table 25** and **Table 26**). However, as part of the detailed option assessment, it was considered important to provide a quantitative assessment of the advantages and disadvantages of each option. In this regard, each flood and property modification option was evaluated against the following criteria, where sufficient information was available:

- Change in flood levels/extents
- Economic feasibility
- Environmental impacts
- Emergency responses impacts
- Technical feasibility

Further details on each of these evaluation criteria is presented below.

Table 27 Options Selected for Detailed Investigations

	Option ID	Flood Modification Options	Option ID	Property Modification Options	Option ID	Response Modification Options
Above Ground Storages	FM1	Modification to the proposed Chelsea Gardens/Coomangie Detention Basins	PM1	Updates to LEP	RM1	Community education strategy
	FM2	New detention basin within Broulee Park	PM2	Updates to DCP	RM2	Make property level flood information available
Drainage Upgrades	FM3	Upgrade stormwater system along Railway Street (near Argyle Street)	PM3	Updates to Section 10.7 certificates	RM3	Preparation of residential flood plans
	FM4	Upgrade stormwater system along Argyle Street near Railway Street and Arthur Street	PM4	Voluntary raising of select residential properties	RM4	Preparation of business flood plans
	FM5	Upgrade culverts along Whites Creek at Argyle Street and the railway			RM5	Local flood plan updates
	FM6	Upgrade stormwater system on Willow Drive and Dangar Street			RM6	Regrading/raising of Argyle Street between Arthur Street and Railway Street
Channel Modifications	FM7	Channel reshaping of Whites Creek upstream of Argyle Street			RM7	Shelter-in-place strategy
	FM8	Lower northern floodplain elevations of Whites Creek between 6-12 Berrima Road				
Topographic Modifications	FM9	Elevate pedestrian walkway in Walton Park between railway and Throsby Street to direct flows into downstream channel				
	FM10	Construct bund wall/levee on eastern bank of Whites Creek near 201-207 Lackey Road				

	Option ID	Flood Modification Options	Option ID	Property Modification Options	Option ID	Response Modification Options
	FM11	Modify existing overland flowpath and/or existing levee at rear of 71-77 Throsby Street				
	FM12	Construct bund wall/levee on bank of railway swale at rear of 51-55 Throsby Street				
	FM13	Regrading Lackey Road from Argyle Street to Whites Creek				

The response modification options were generally not evaluated against these criteria as they will generally have negligible hydraulic and environmental impacts, are difficult to quantify in monetary benefits (i.e., response modification options will generally not reduce flood damages) and will generally improve emergency response.

Change in Flood Levels/Extents

Flood modification options will alter the distribution of floodwaters. Although this aims to reduce the extent and depth of inundation across populated areas, it may divert floodwaters elsewhere, thereby increasing the flood risk across other areas. Therefore, it is important that the potential flood impacts associated with implementing each option is understood.

To assess the hydraulic impact that each flood modification option is likely to have on existing flood behaviour, the TUFLOW hydraulic model was updated to include each flood modification option. The updated TUFLOW models were then used to re-simulate each of the design floods with the option in place. The flood level and extent results from the revised simulations were compared against the flood level and inundation extent results from the existing conditions/do nothing scenario to prepare “difference mapping”. The difference mapping shows the magnitude and location of changes in flood levels and inundation extents associated with implementation of the option.

A focus was placed on the flood level differences during the 20% AEP and 1% AEP floods to provide an indication of the how the option would perform during relatively regular (i.e., 20% AEP) as well as rarer (i.e., 1% AEP) floods.

Economic Feasibility

A preliminary economic assessment of select flood modification and property modification options was completed to assist in determining the financial viability of each option. The assessment was completed by estimating the ‘costs’ and ‘benefits’ that could be expected if the option was implemented. This enabled a benefit-cost ratio (BCR) to be prepared for each option.

The BCR provides the following economic insights:

- BCR > 1: The economic benefits (i.e., reduction in flood damage costs) are predicted to be greater than the cost to implement the option.
- 0 < BCR < 1: There is still an economic benefit (i.e., reduction in flood damage costs). However, the cost of implementing the option is greater than the economic benefit.
- BCR = 0: There is no economic benefit (i.e., no reduction in flood damage costs) associated with implementing the option.
- BCR < 0 (i.e., negative): Implementing the option is predicted to generate a negative economic impact (i.e., increase flood damage costs).

From a flooding perspective, economic 'benefits' were quantified as the reduction in flood damage costs if the option is implemented. The benefits of each option were estimated by preparing damage estimates for each design flood event with the option in place and using this information to prepare a revised average annual damage (AAD) estimate. In order for a BCR to be estimated, it is necessary to modify the 'base' AAD estimates (which reflect the average damage that is likely to be incurred in a single year) to a total damage that could be expected to occur over the life of each flood risk management option. Accordingly, the AAD estimates were accumulated over a 50-year period and then discounted to a present-day value by applying a discount rate of 7%.

Cost estimates have also been prepared for each option that showed a positive hydraulic benefit. The cost estimate includes capital costs as well as ongoing costs (e.g., maintenance) to provide a total life cycle cost for each option. It was assumed that each option has a design life of 50 years for the purposes of establishing the life cycle cost.

The cost estimates were prepared using the best available information. However, precise cost estimates can only be prepared following detailed investigations and once detailed design plans have been prepared. Therefore, the cost estimates presented in this report should be considered approximate only. Nevertheless, they are considered suitable for providing an initial appraisal of the financial viability of each option.

Environmental Impacts

Any flood risk management option that involves structural works on the floodplain has the potential to impact on local flora and/or fauna. At the same time, some options may provide an opportunity to improve the local environment (e.g., some options may reduce gross pollutants reaching downstream waterways). Therefore, the potential environmental impact was considered as part of the evaluation of each structural option.

Emergency Response Impacts

Emergency response is arguably one of the most important measures for managing the continuing flood risk across any catchment, particularly during very large floods where flood modification options may not be effective. Therefore, the potential for each option to impact on current emergency response processes was considered as part of the assessment of each option.

Technical Feasibility

If a structural option is proposed, it needs to be physically possible to construct and maintain the option, giving consideration to the option itself as well as any local constraints. Therefore, an assessment of any technical impediments was completed for each option to determine if there would be any “showstoppers” that may render the option impractical.

7 FLOOD MODIFICATION OPTIONS

7.1 Introduction

Flood modification options are measures that aim to modify existing flood behaviour, thereby, reducing the extent, depth and velocity of floodwater across developed areas. Flood modification measures will generally benefit a number of properties and are primarily aimed at reducing the existing flood risk.

Flood modification options considered as part of the study included:

- Above-ground storages (Section 7.2);
- Drainage upgrades (Section 7.3);
- Channel modifications (Section 7.4); and,
- Topographic modifications (Section 7.5).

As discussed in Section 6.3.1, the hydraulic benefits of each flood modification option were assessed by including the option in the hydraulic model and using the updated model to re-simulate each design flood. The hydraulic benefits were then quantified by preparing flood level difference mapping for each option.

All hydraulic simulations were completed based upon "design" catchment conditions, which assumes existing catchment conditions along with development of the Chelsea Gardens subdivision. In instances where there was a potential for the option to mitigate potential increases in flood risk associated with future catchment conditions, additional simulations were also completed based upon future catchment conditions. This assumes full development to the extent possible under the current LEP zoning in addition to development across other areas that have the potential to be rezoned and developed in the future (refer Section 3.5).

The change in the number of properties subject to above floor inundation during each design flood was also quantified for each option and is included in **Table 28**. Negative numbers indicate a reduction in the number of properties exposed to above floor inundation while positive numbers indicate an increase in the number of properties subject to above floor inundation.

Cost estimates for each option were also prepared and are included in **Table 29**. **Table 29** also summarises the predicted reduction in flood damage costs if the option was implemented along with the associated benefit-cost ratio.

Further detailed discussion on each flood modification option investigated to assist in managing the existing flood risk is presented in the following sections.

Table 28 Change in Number of Properties Subject to Above Floor Flooding for Each Flood Modification Option for Design Catchment Conditions

Flood Event	Change in Number of Properties with Above Floor Inundation*					
	Above-ground Storages		Drainage Upgrades			
	Modifications to the proposed Chelsea Gardens/ Coomangie Detention Basins (FM1)	New detention basin within Broulee Park (FM2)	Upgrade stormwater system along Railway Street (near Argyle Street) (FM3)	Upgrade stormwater system along Argyle Street near Railway Street and Arthur Street (FM4)	Upgrade culverts along Whites Creek at Argyle Street and the railway (FM5)	Upgrade stormwater system on Willow Drive and Dangar Street (FM6)
20% AEP	0	0	-1	0	0	0
5% AEP	-2	0	-2	-2	-2	0
1% AEP	0	0	-2	0	-1	0
PMF	-5	0	-1	0	-2	0

Flood Event	Channel Modifications		Topographic Modifications				
	Channel reshaping of Whites Creek upstream of Argyle Street (FM7)	Lower northern floodplain elevations of Whites Creek between 6-12 Berrima Road (FM8)	Elevate pedestrian walkway in Walton Park between railway and Throsby Street to direct flows into downstream channel (FM9)	Construct bund wall/levee on eastern bank of Whites Creek near 201-207 Lackey Road (FM10)	Modify existing overland flowpath and/or existing levee at rear of 71-77 Throsby Street (FM11)	Construct bund wall/levee on bank of railway swale at rear of 51-55 Throsby Street (FM12)	Regrading Lackey Road from Argyle Street to Whites Creek (FM13)
20% AEP	+2	0	0	0	0	0	0
5% AEP	0	0	0	0	0	0	0
1% AEP	0	0	0	0	0	0	0
PMF	-2	0	0	0	0	-1	-1

NOTE: * A negative value indicates the option is predicted to reduce the number of properties subject to above floor flooding and a positive value indicates the option is predicted to increase the number of properties subject to above floor flooding.

Table 29 Economic Assessment for Flood Modification Options for Design Catchment Conditions

Option		Cost Estimate (millions of dollars)	Total Damage for Existing Conditions	Total Damage with Option in Place	Reduction in Damage with Option in Place	Benefit-Cost Ratio
Above-ground Storages	**FM1 - Modifications to the proposed Chelsea Gardens/ Coomangie Detention Basins**	>$1	$1.71	$1.56	$0.15	<0.1
	FM2 - New detention basin within Broulee Park	$0.06		$1.67	$0.04	0.7
Drainage Upgrades	**FM3 - Upgrade stormwater system along Railway Street (near Argyle Street)**	$1.23		$1.57	$0.14	0.1
	FM4 - Upgrade stormwater system along Argyle Street near Railway Street and Arthur Street	$0.34		$1.62	$0.09	0.3
	FM5 - Upgrade culverts along Whites Creek at Argyle Street and the railway	$0.65		$1.59	$0.12	0.2
	FM6 - Upgrade stormwater system on Willow Drive and Dangar Street	$0.39		$1.67	$0.04	0.1
Channel Modifications	**FM7 - Channel reshaping of Whites Creek upstream of Argyle Street**	-		Not Calculated		
	FM8 - Lower northern floodplain elevations of Whites Creek between 6-12 Berrima Road	-		Not Calculated		
Topographic Modifications	**FM9 - Elevate pedestrian walkway in Walton Park between railway and Throsby Street to direct flows into downstream channel**	$0.10		$1.68	$0.03	0.3
	FM10 - Construct bund wall/levee on eastern bank of Whites Creek near 201-207 Lackey Road	$0.27		$1.70	$0.01	<0.1
	FM11 - Modify existing overland flowpath and/or existing levee at rear of 71-77 Throsby Street	$0.01		$1.68	$0.03	3.0
	FM12 - Construct bund wall/levee on bank of railway swale at rear of 51-55 Throsby Street	$0.03		$1.70	$0.01	0.3
	FM13 - Regrading Lackey Road from Argyle Street to Whites Creek	$0.45		$1.69	$0.02	<0.1

7.2 Above-Ground Storages

7.2.1 Modifications to the Proposed Chelsea Gardens / Coomangie Detention Basins (FM1)

Recommendation: Not recommended for implementation. However, the 2019 Chelsea Gardens stormwater management system should continue to be pursued and ultimately implemented to assist in reducing the existing flood risk and mitigating the potential impacts of future catchment development.

Design Catchment Conditions

As discussed, at the time this study was prepared, plans were underway to commence development across the Chelsea Gardens Subdivision which occupies a significant proportion of the upper Whites Creek catchment. As part of the water cycle management plan for the subdivision, six detention areas were proposed to ensure that the proposed subdivision does not adversely impact on flood behaviour across downstream areas.

As development of the Chelsea Gardens subdivision is yet to commence, opportunities to expand the proposed detention basins were explored as a way of not only mitigating the impact of the Chelsea Gardens subdivision but also to improve the current flooding situation downstream of the subdivision. To provide an initial understanding of the potential benefits of this option, the following modifications were completed to the original detention basin design proposed as part of the subdivision:

- Basin storage capacities were doubled for Basins A, B/C, E, F and G.
- Design outflows were halved for the same Basin subset.

The extent of the original and potentially modified basins is shown in **Figure 34**.

The XP-RAFTS hydrologic model was updated to include a representation of the modified basin arrangement and the model was re-run for each design flood. The modified hydrographs from the XP-RAFTS model were then applied to the TUFLOW hydraulic model and the TUFLOW model was used to re-simulate each design flood. Peak floodwater level difference maps were prepared the for the 5% AEP, 1% AEP and PMF are provided in Plate 20, Plate 21 and Plate 22.

Plate 20 shows that at the peak of the 5% AEP event, flood level reductions are predicted along the entire length of Whites Creek. Typically, these reductions are restricted to areas in close proximity to the creek. However, flood level reductions are also predicted to extend across Moss Vale Golf Club, Argyle Street, and some properties north of Cosgrove Park on Berrima Road and Lapwing Place. In general, the flood level reductions are predicted to be less than 0.05 metres, however, reductions of more than 0.1 metres are predicted across Argyle Street.

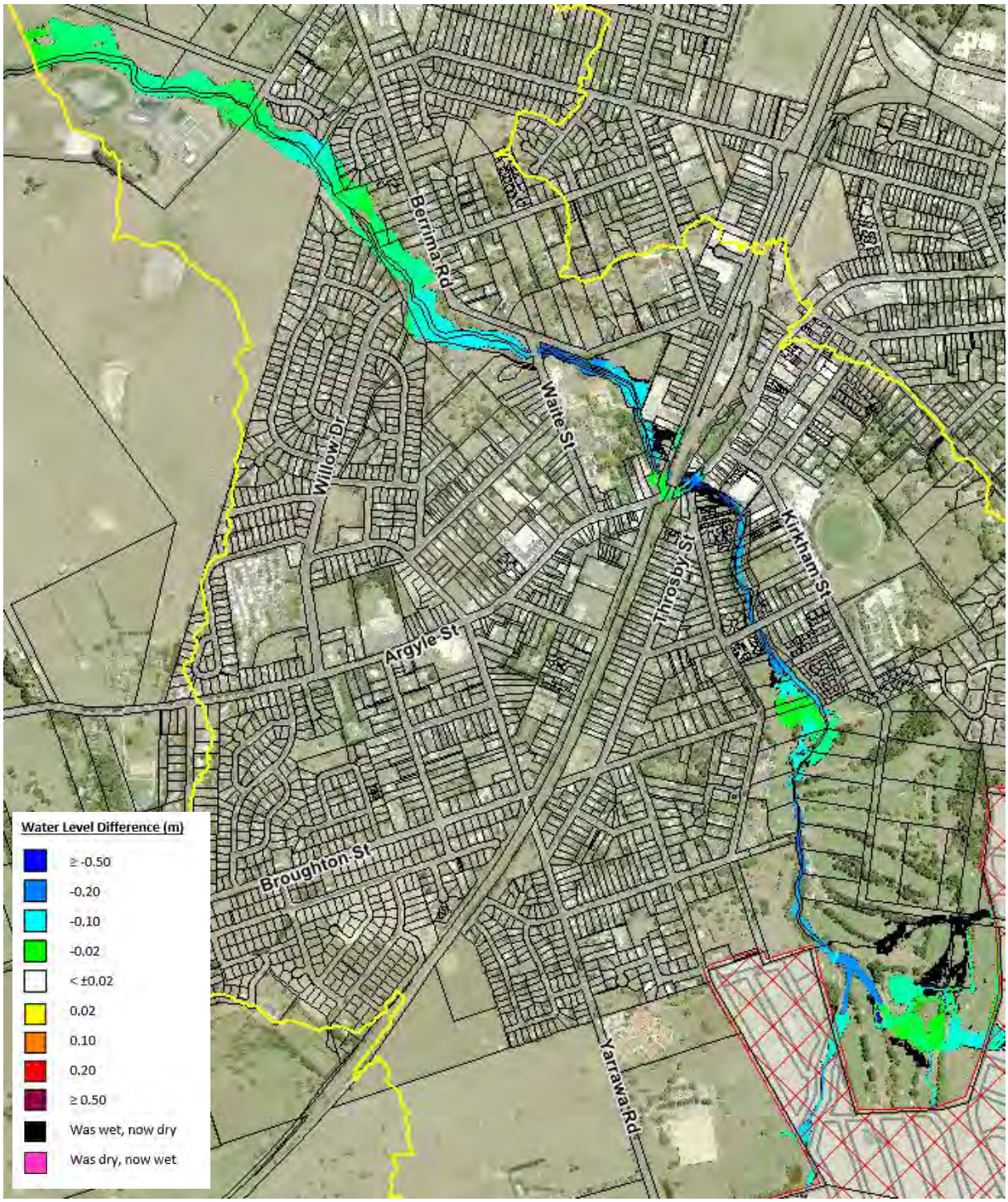


Plate 20 5% AEP Flood Level Difference Map for the Modifications to the Proposed Chelsea Gardens / Coomangie Detention Basins (FM1)

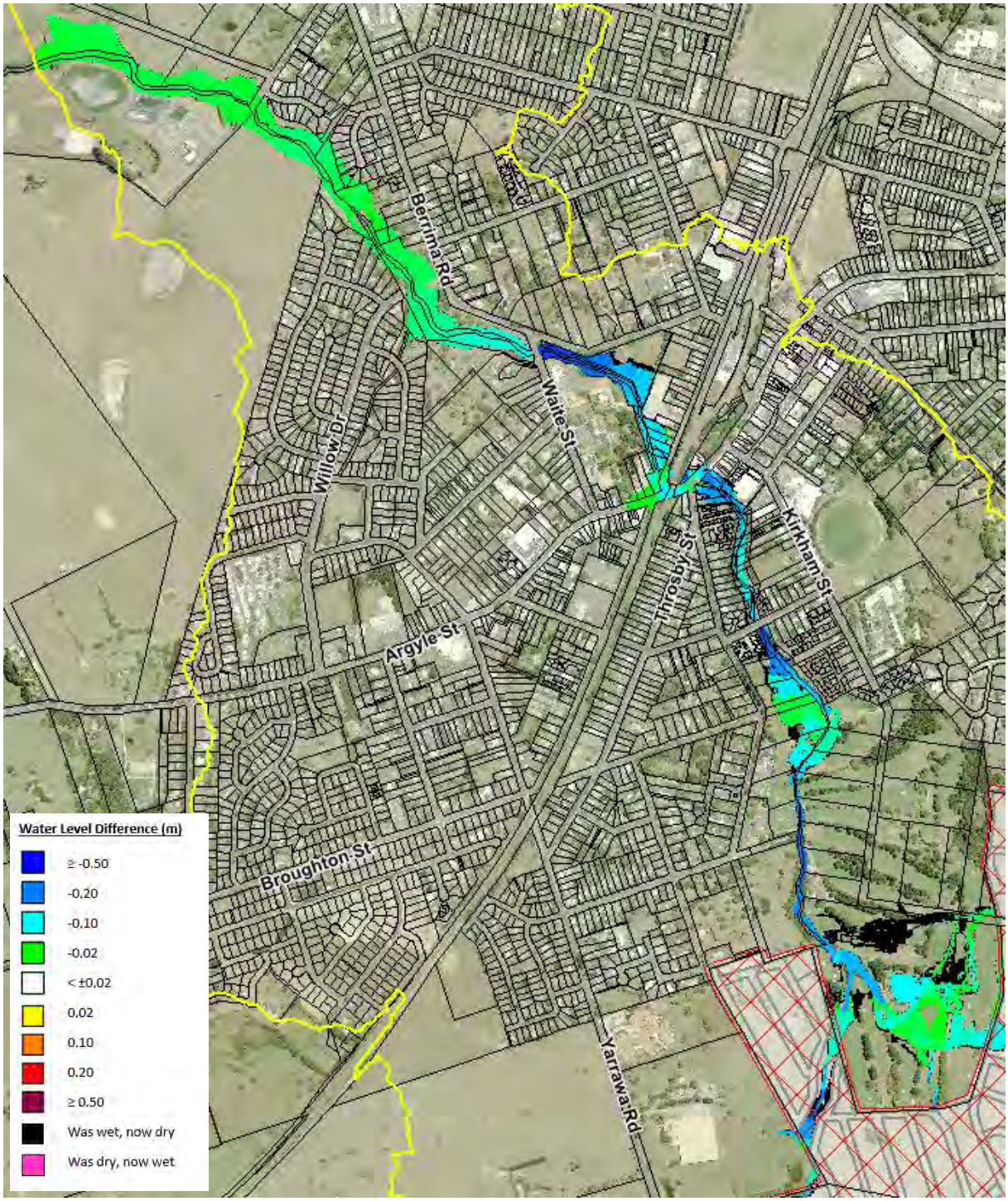


Plate 21 1% AEP Flood Level Difference Map for the Modifications to the Proposed Chelsea Gardens / Coomangie Detention Basins (FM1)

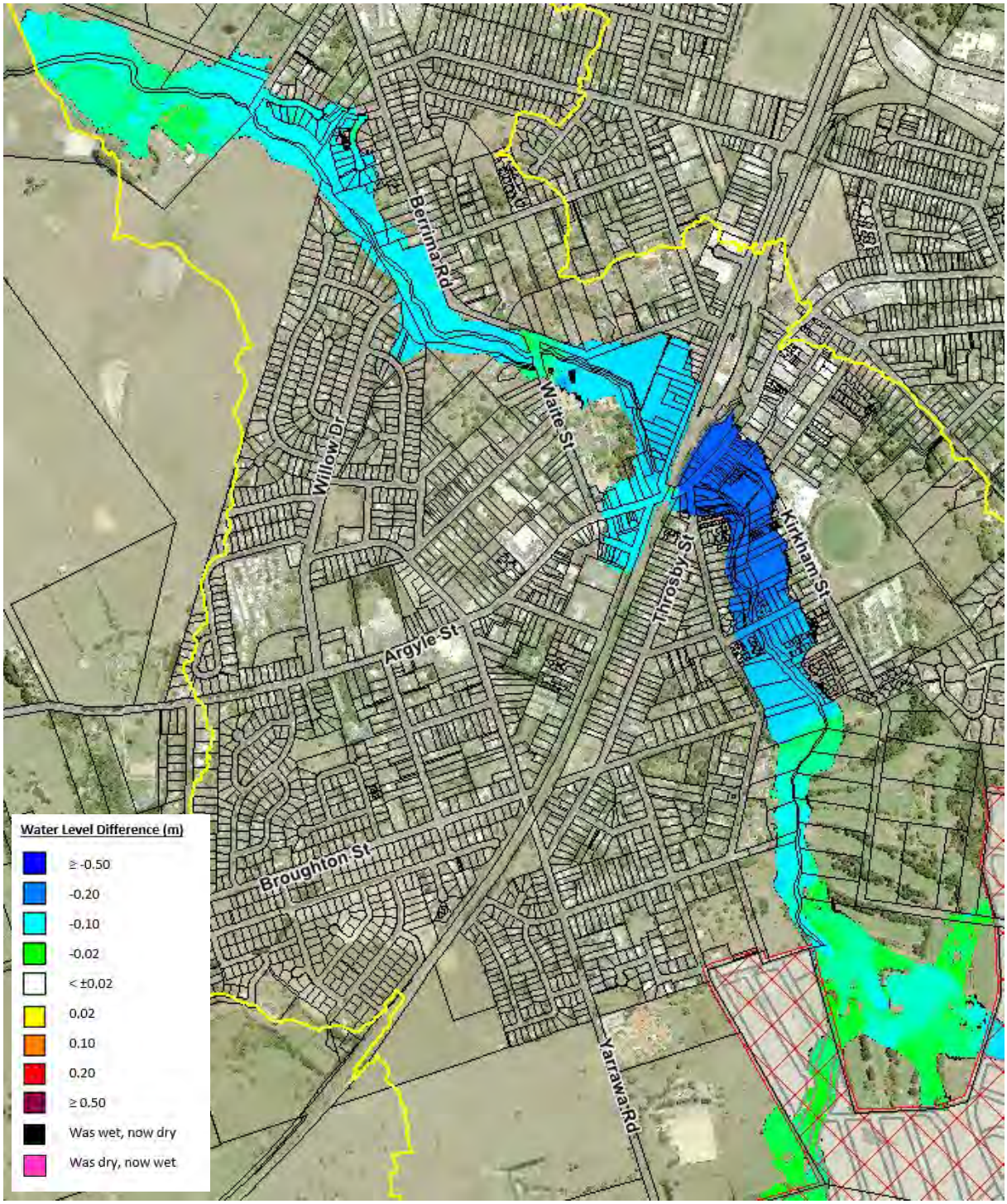


Plate 22 PMF Flood Level Difference Map for the Modifications to the Proposed Chelsea Gardens / Coomangie Detention Basins (FM1)

Plate 21 shows that during the 1% AEP flood, similar flood level reductions are predicted along Whites Creek. However, the flood level reductions are predicted to extend across a larger area. The most significant reductions are predicted across the Moss Vale Golf Club and in the vicinity of major culverts/bridges (e.g., upstream of Waite Street, upstream of Mack Street and near Argyle Street). Reductions of up to 0.3 metres are predicted at each of these locations.

Plate 22 also shows some notable reductions in flood levels during the PMF. The most significant reductions are predicted across and upstream of Argyle Street (typical reductions are just under 0.3 metres).

In addition to the costs associated with constructing the larger basins there will also likely be compensatory costs that will need to be accounted for (i.e., Council will likely need to purchase the additional land required for the basins from the developers). The acquisition costs are difficult to quantify at this point in time. Therefore, the current cost estimate is based on consideration of the construction costs only. Based upon this assumption, the cost of this option is likely to be in excess of $1 million. A detailed breakdown of the costs is provided in **Appendix N**.

A revised damage assessment was also completed based on the results of the revised flood simulations. This determined that implementation of the modified Chelsea Gardens basins would generate a reduction in annual flood damages of $150,000. This yields a preliminary BCR of less than 0.1 and indicates that there is unlikely to be a significant financial benefit in pursuing this option.

Updated basin designs for Chelsea Gardens Development

The evaluation of FM1 presented above explored the opportunity of upgrading/enlarging six detention basins that were proposed as part of the original water cycle management plan for the Chelsea Gardens subdivision. However, after this option was initially evaluated, a revised water cycle management study was submitted to Council (Cardno, 2019).

Although the revised water cycle management study was delivered too late to allow a full evaluation of potential augmentation/enlargement opportunities, it was still considered important to provide an initial hydrologic evaluation to quantify the performance of the revised stormwater management system and to confirm if there was any evidence to support further, detailed exploration of this option in the future.

This involved updating the XP-RAFTS model to include the revised stormwater management system and re-running this updated model for the 1% AEP flood. The results of these simulations showed that:

- Under current catchment conditions (i.e., without Chelsea Gardens), the peak 1% AEP discharge at Argyle Street is predicted to be about 55 m^3/s.
- The 1% AEP discharge at Argyle Street with the original detention basin arrangement was predicted to be 48 m^3/s.
- The 1% AEP discharge at Argyle Street with the revised stormwater system (as detailed in the Cardno 2019 report) is predicted to drop to 42m^3/s. That is, the revised basin arrangement is predicted to offer some notable improvements relative to the original detention basin concept that formed the basis for the modelling for this study.

The opportunity to increase the size of the revised basins was then investigated to determine if it would afford any significant hydrologic benefits. This review determined that there was only one basin (Basin B) with an obvious potential to be expanded due to the proximity of proposed “open space” to this proposed basin and the lack of open space near the other basins. This adjoining “open space” could be potentially utilised as an expanded detention

basin without impacting on the yield for the subdivision. An examination of the preliminary subdivision layout indicated that there was potential to triple the overall capacity of Basin B. Plate 23 shows this expanded basin arrangement in red.

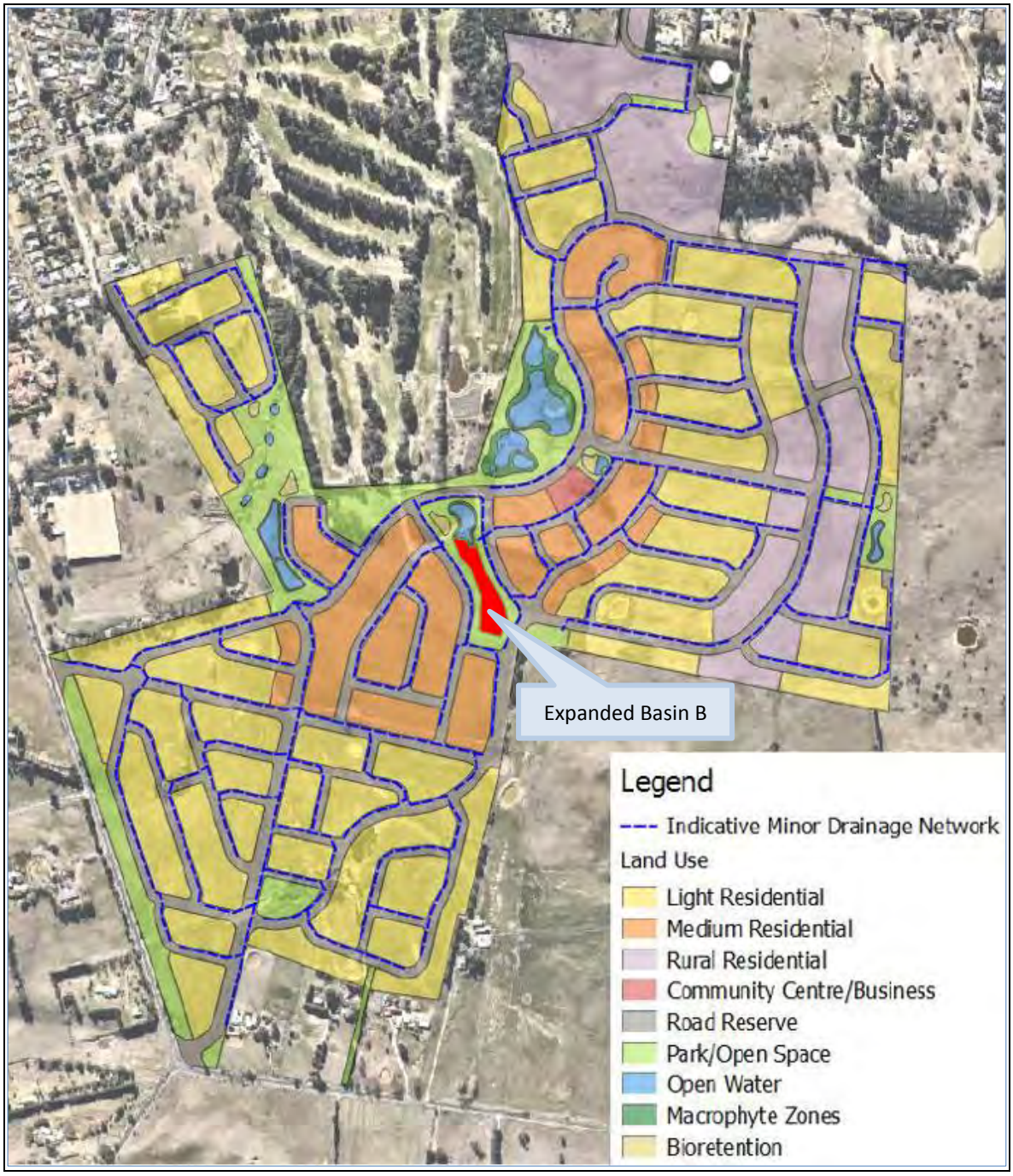


Plate 23 Updated design plans for the Chelsea Gardens subdivision including expanded Basin B (shown in red).

The expanded Basin B arrangement was included in a revised version of the XP-RAFTS model and was then used to re-simulate the 1% AEP flood. The results of the revised simulation with the larger Basin B showed that peak 1% AEP discharges at Argyle would be reduced by less than 1.5 m^3/s. Therefore, the expanded basin arrangement is unlikely to afford a significant reduction in existing flood levels and/or reduction in existing flood damage costs. As a result, this option is not considered worth pursuing as a means of reducing the existing flood risk.

Future Catchment Conditions

As described in Section 3.5, future development does have the potential to further increase the existing flood risk across the catchment. This includes the Whites Creek channel downstream of the Chelsea Gardens subdivision. Therefore, the modified Chelsea Gardens basin arrangement has the potential to mitigate some of the adverse impacts that are predicted under future development conditions.

The potential hydraulic benefits afforded by the modified basins was quantified by updating and undertaking additional XP-RAFTS and TUFLOW model simulations under future catchment conditions with the modified basins in place.

The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 5% AEP flood, 1% AEP flood and PMF are provided in Plate 24 Plate 25 and Plate 26. The difference maps were prepared by subtracting peak flood levels for existing catchment conditions from peak future catchment flood levels with the modified basins in place (to verify if the works would mitigate the adverse flood impacts that are predicted with future catchment development).

Plate 24 and Plate 25 shows that the modified basins are predicted to largely mitigate the predicted flood impacts along Whites Creek associated with future catchment conditions. However, they are unable to offset the predicted impacts along Willow Creek or Railway Street. Plate 26 also shows that the modified basins are unable to offset predicted flood level increases during the PMF across Moss Vale Golf Club.

Therefore, this option does not appear to be suitable for completely offsetting the impacts of future catchment development if implemented in isolation. If future catchment development impacts are to be fully mitigated, it will be necessary to supplement this option to ensure no adverse impacts on other properties.

It should be noted that future catchment development is predicted to increase design discharges along Whites Creek by less than 20% (typically <6 m3/s at Argyle Street) (refer Section 3.5). However, as noted above, the revised water management system for the Chelsea Gardens subdivision (as detailed in the Cardno 2019 report) is predicted to afford improved performance relative to the original detention basin arrangement that formed the basis for this assessment. More specifically, the revised basin arrangement is predicted to reduce peak 1% AEP discharges by a further 6 m^3/s relative to what was adopted in this study. This will largely offset the predicted increase in flows associated with future catchment development without any additional enlargement or augmentation.

Overall, there does not appear to be sufficient evidence to support modifications of the proposed Chelsea Gardens subdivision detention basins / stormwater management to increase their storage capacity for flood risk management purposes. The proposed detention basins detailed in the Cardno 2019 report appear to afford some notable reductions in discharges and flood levels along Whites Creek relative to existing catchment conditions. Furthermore, the stormwater management system appears to be sufficiently sized/designed to significantly reduce the potential flood impacts associated with future catchment development including those areas located outside of the Chelsea Gardens subdivision. If this stormwater management system is implemented in conjunction with an appropriate onsite

detention policy across other future development areas (refer Section 10.1.1), it should be sufficient to reduce the potential for increases in future flood risk. As a result, it is recommended that the 2019 Chelsea Gardens stormwater management system should continue to be pursued and ultimately implemented to assist in reducing the existing flood risk and reducing the potential impacts of future catchment development along Whites Creek.

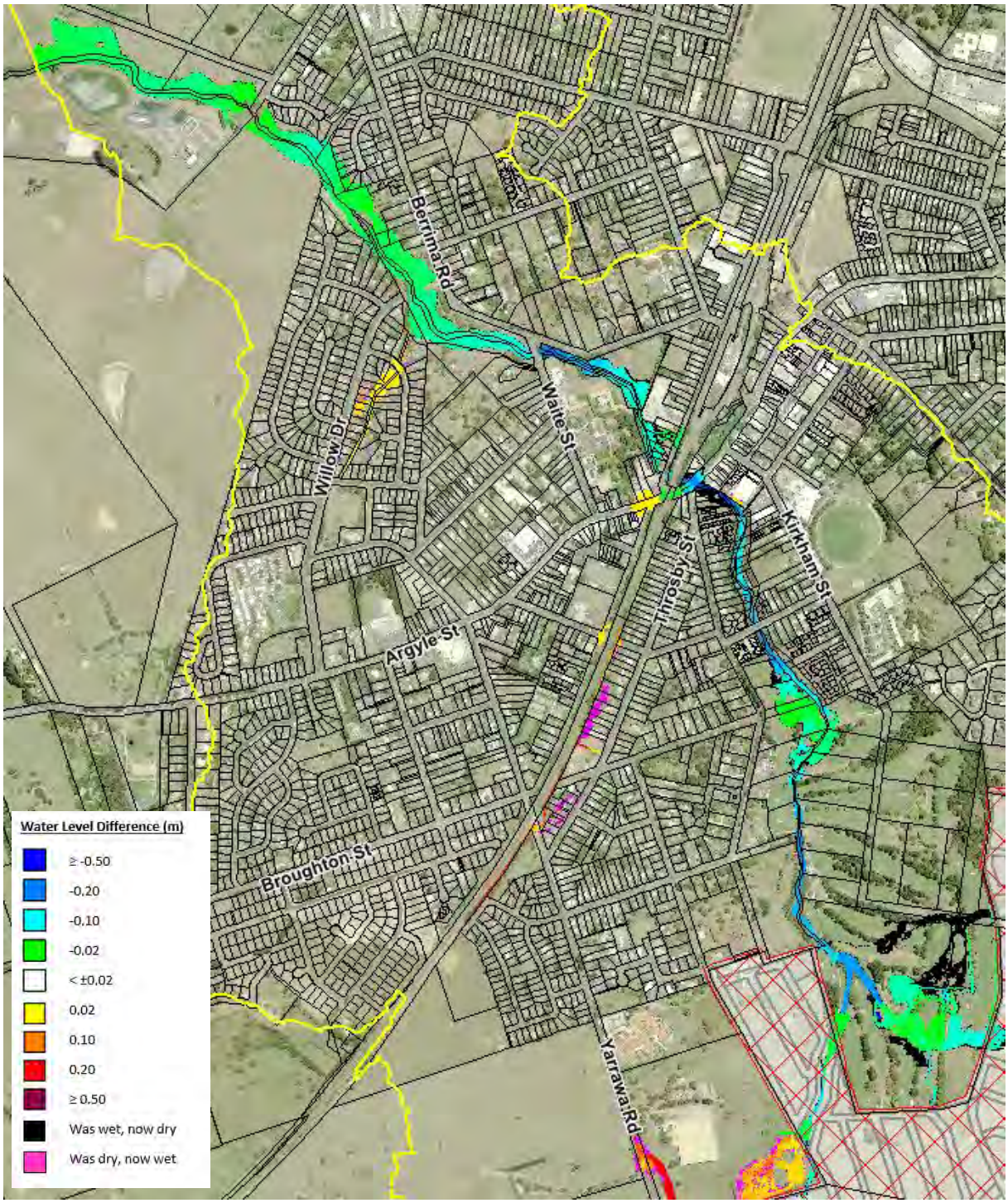


Plate 24 5% AEP Flood Level Difference Map for the Modifications to the Proposed Chelsea Gardens / Coomangie Detention Basins (FM1) with Future Catchment Conditions

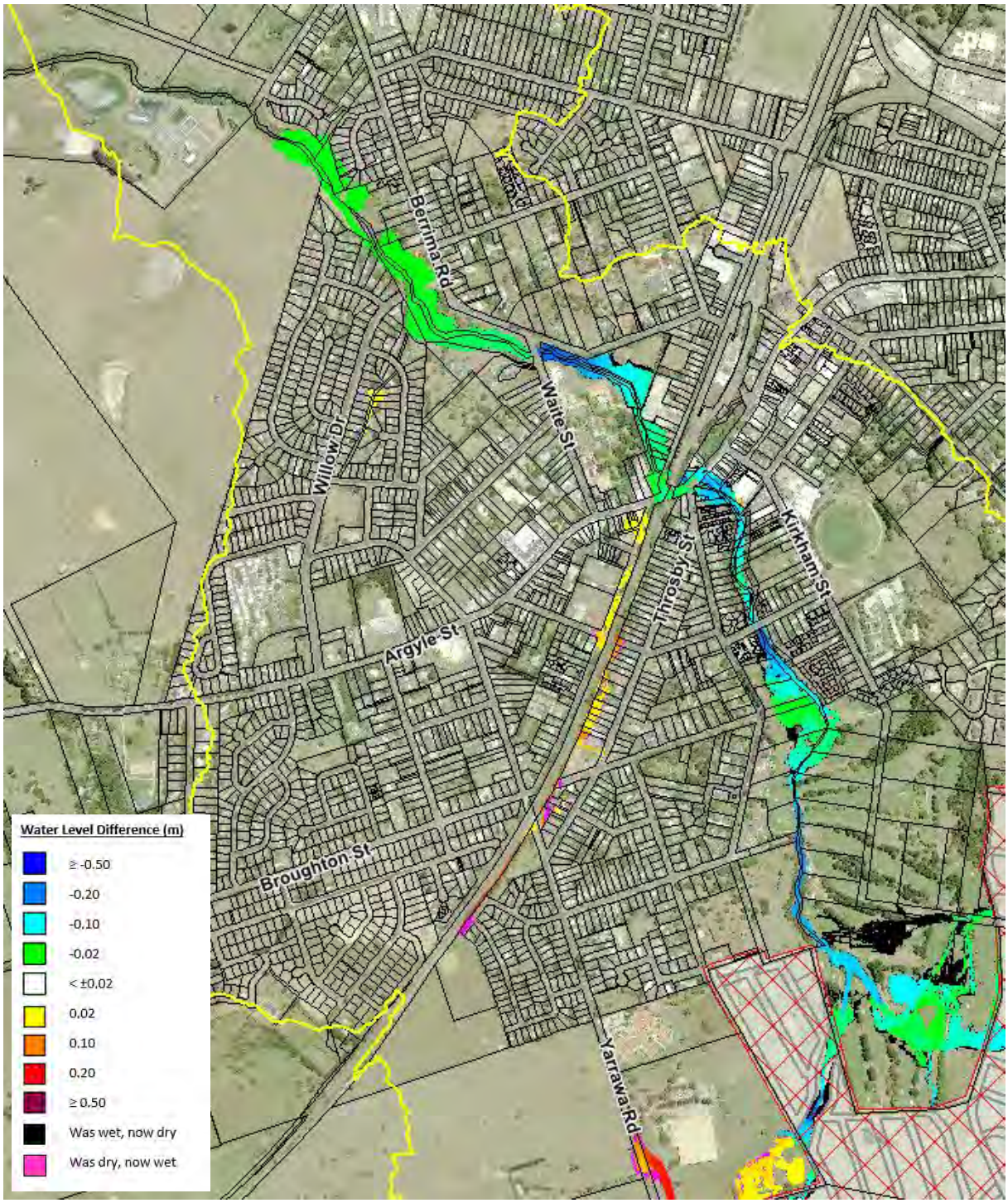


Plate 25 1% AEP Flood Level Difference Map for the Modifications to the Proposed Chelsea Gardens / Coomangie Detention Basins (FM1) with Future Catchment Conditions

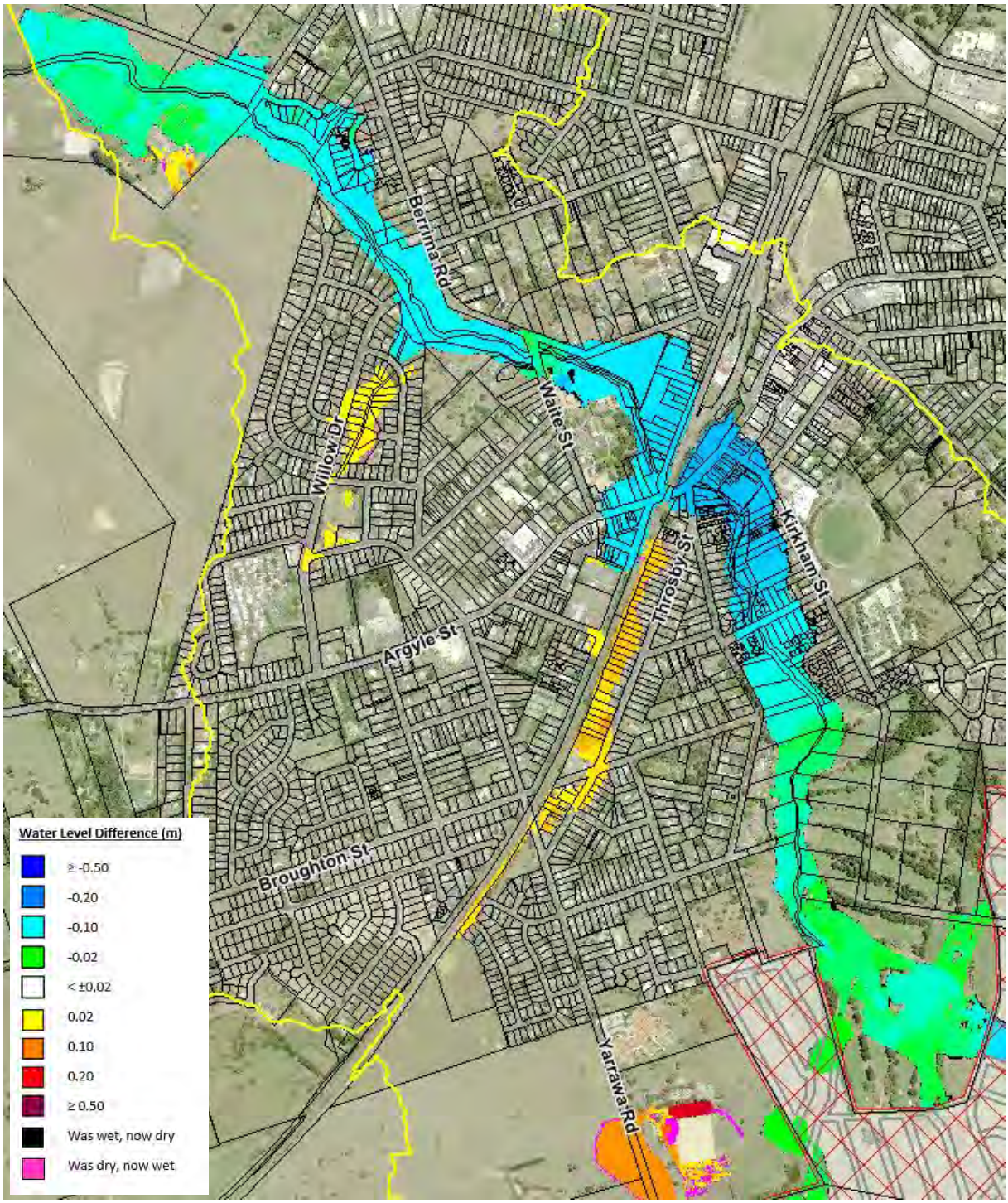


Plate 26 PMF Flood Level Difference Map for the Modifications to the Proposed Chelsea Gardens / Coomangie Detention Basins (FM1) with Future Catchment Conditions

7.2.2 New Detention Basin within Broulee Park (FM2a)

Recommendation: Recommended for further detailed investigation

The outcomes of the existing design flood simulation show that floodwaters are predicted to spill out of Broulee Park, and spill through a number of properties adjoining Willow Drive and Danger Street. Therefore, this option looked at the potential benefits associated with constructing an earthen embankment along the corner of Willow Drive and Dangar Street to increase the flood storage afforded by Broulee Park. The embankment would typically be elevated about 1 metre above the current ground level.

It was assumed that the existing culvert that drains water from Broulee Park beneath Danger Street would remain unchanged and would serve as the main outlet for the detention area. A spillway would be provided and would direct flows in excess of the capacity of the detention area into the Willow Creek channel located north of Danger Street.

Key features of this option are shown in **Figure 35**.

It is expected that implementation of this option would comprise a total cost of $60,000. A detailed breakdown of the cost estimate is provided in **Appendix N**.

To gain an understanding of the potential hydraulic benefits of this option, the TUFLOW computer model was updated to include the feature shown in **Figure 35**. The updated TUFLOW model was then used to re simulate a range of design floods. Peak floodwater difference maps were prepared and are shown in Plate 27, Plate 28 and Plate 29 for the 5% AEP, 1% AEP and PMF design flood events.

Plate 27 shows that during the 5% AEP event, flood levels are fully contained within the proposed basin preventing inundation of Dangar Street and Willow Drive. Flood level increases are predicted to be contained within Broulee Park and the Willow Creek channel located downstream of Dangar Street.

Plate 28 shows that during the larger 1% AEP flood event, floodwaters are predicted to overtop the proposed basin. However, the detention area is predicted to reduce the severity of flooding across a number of Willow Street properties. Flood level reductions of more than 0.2 metres are predicted across some properties, although the reductions are more commonly around 0.1 metres.

Plate 29 shows that the storage is largely ineffective in providing significant reductions in flood level during the PMF. Although small reductions are predicted across two properties this is offset by flood level increases across two properties.

The results of the revised flood simulations indicate that implementation of this option would not alter the number of properties subject to above floor flooding for any of the design events.

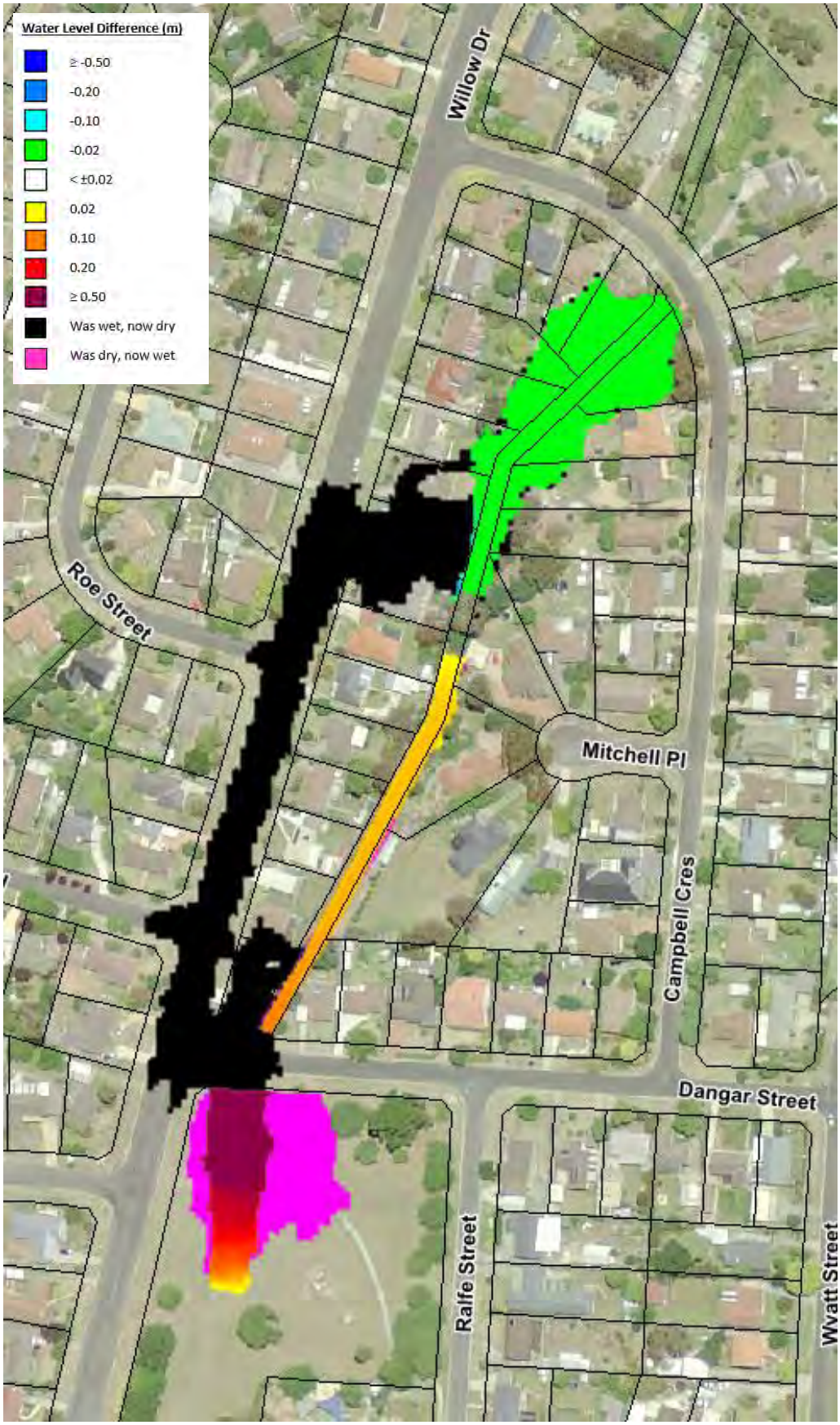


Plate 27 5% AEP Flood Level Difference Map for FM2a

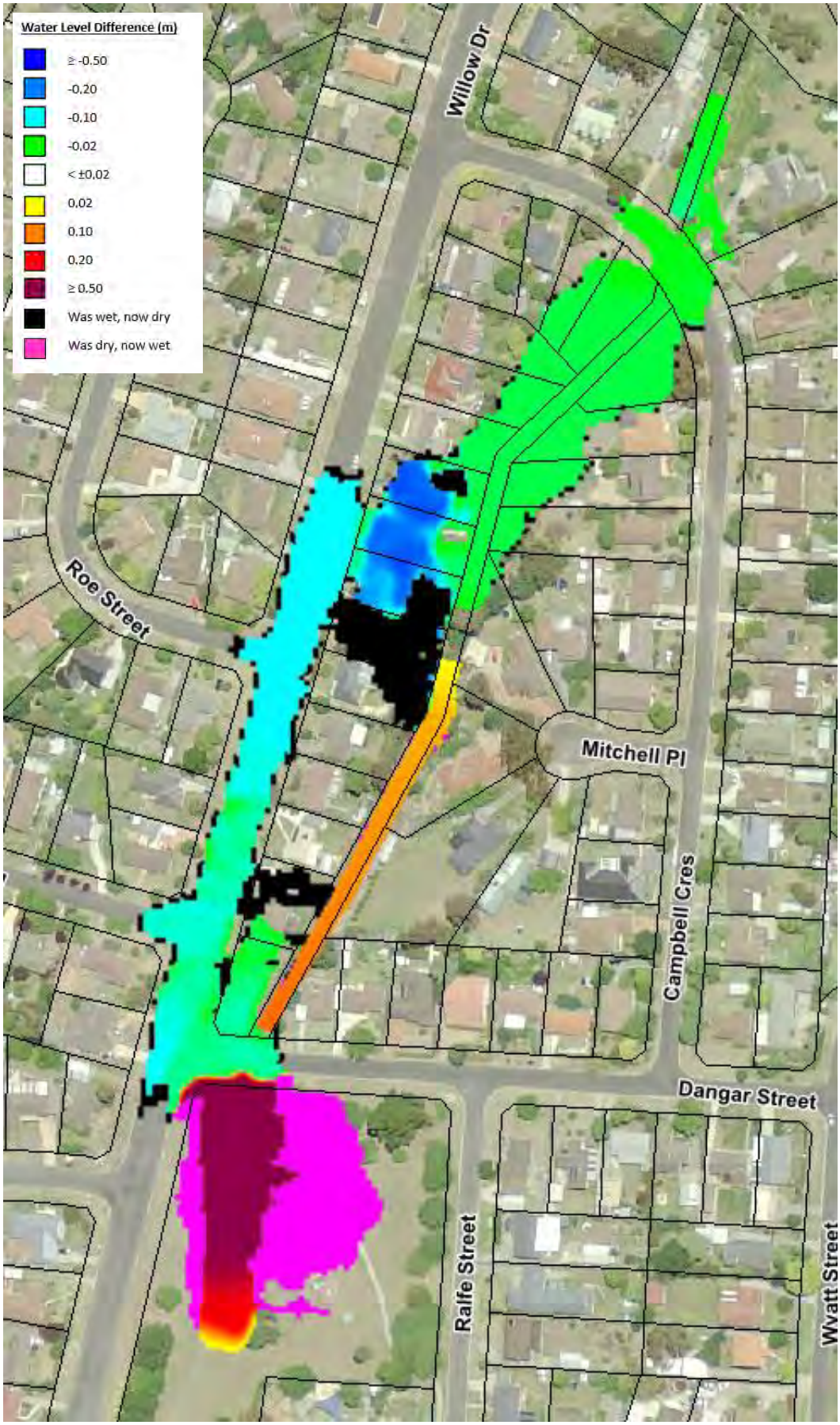


Plate 28 1% AEP Flood Level Difference Map for FM2a

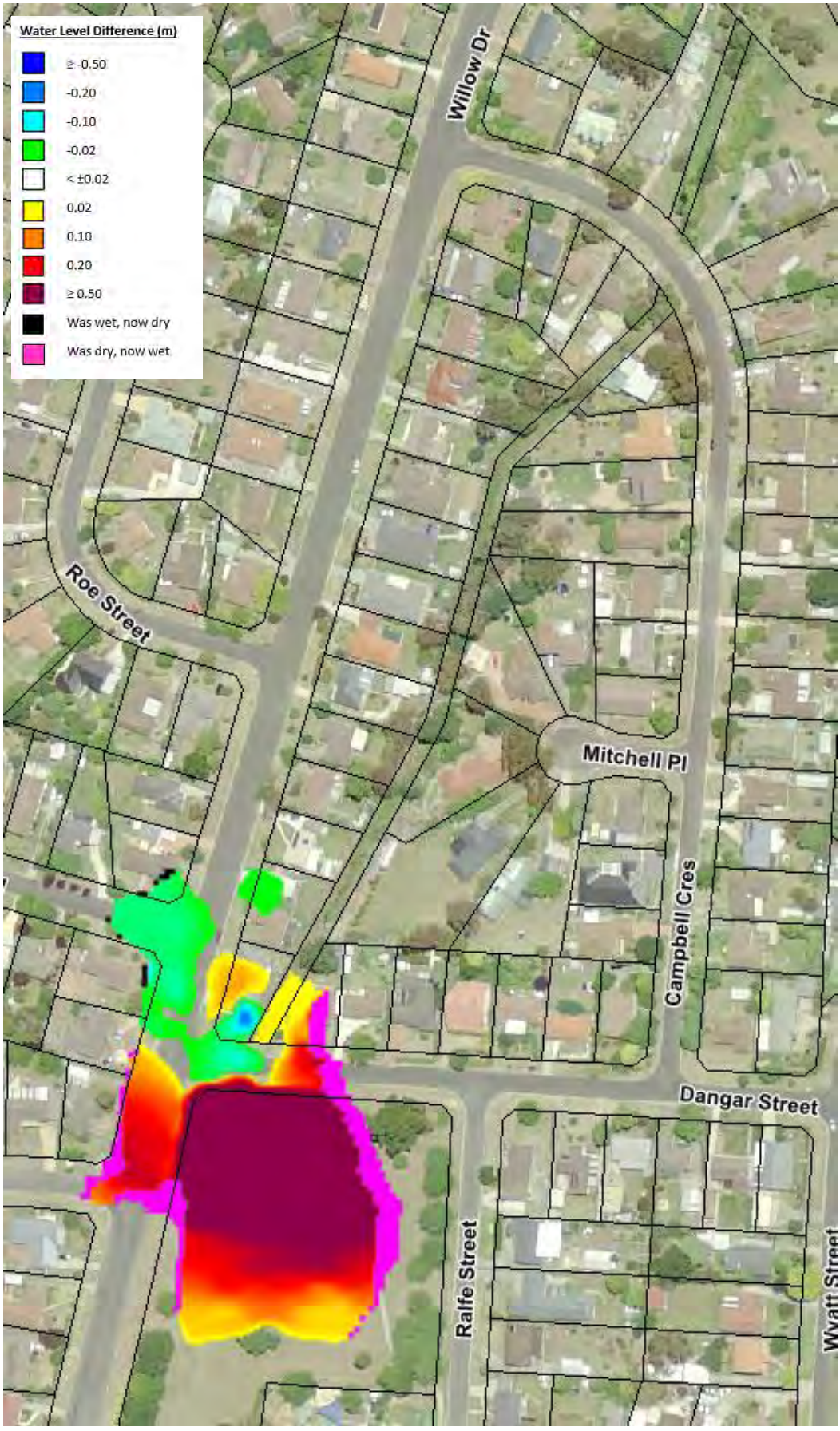


Plate 29 PMF Flood Level Difference Map for FM2a

A revised flood damage estimate was prepared based upon the results of the TUFLOW simulations. This determined that the implementation of the works would reduce flood damage costs by approximately $40,000 over the design life of the basin (i.e., 50 years). This yields a preliminary BCR of 0.7. Therefore, the costs of implementing the option are predicted to outweigh the reductions in flood damage costs. However, this option still affords one of the highest BCR of all options considered as part of the current study.

This option is predicted to afford some evacuation/emergency response benefits. During the 20% AEP and 5% AEP, inundation of Willow Drive properties is prevented. Therefore, there is a reduced flood risk to occupants of these properties during more frequent events in additional to a reduced requirement for potential rescue/evacuation. Although the proposed storage does not eliminate inundation during larger floods, it does "hold back" water for longer which will likely afford additional evacuation time (>1 hour).

Feedback from the community consultation suggested that in general people were in support of flood detention basin options with 40% in support, 3% against and the remainder neutral or unsure.

Some trees may be impacted by the suggested works. Therefore, there is a potential for some adverse environmental impacts. Furthermore, the inclusion of a ~1m high embankment may reduce accessibility (i.e., an existing pathway would likely need to be relocated and people may need to travel further to access the realigned path).

It is also noted that this option would afford benefits to properties that were typically constructed after 1986. As a result, this option would not be eligible for full funding under NSW Government's floodplain management grants program. This may impact on the financial feasibility of the option. However, as it is not a particularly "expensive" option, this is not considered to be a major limitation.

This option is likely to yield several benefits to properties located downstream of the Broulee Park including reduced frequency of inundation and additional evacuation time. Despite the BCR being less than 1, this option affords one of the higher BCR of all of the options considered as part of the study. As the implementation cost is approximate only, more detailed investigations may yield a slightly lower cost estimate which would improve the economic viability of this option. As council already owns the land, there would not be any land acquisitions costs. Therefore, this option is recommended for further detailed investigation including consultation with downstream property owners.

7.2.3 New Detention Basin within Strode Park (FM2b)

Recommendation: Not recommended for implementation

As an alternative to the Broulee Park detention basin, the potential to create a detention basin within Strode Park (located on the corner of Argyle Street and Willow Drive) was explored. The design features of this options are shown in Plate 30 and includes lowering the existing ground levels by approximately 1 metres and creating a 0.5 metre high embankment at the northern end of the park. A 900 mm diameter outlet pipe was also included to allow for the controlled release of water into the downstream channel.

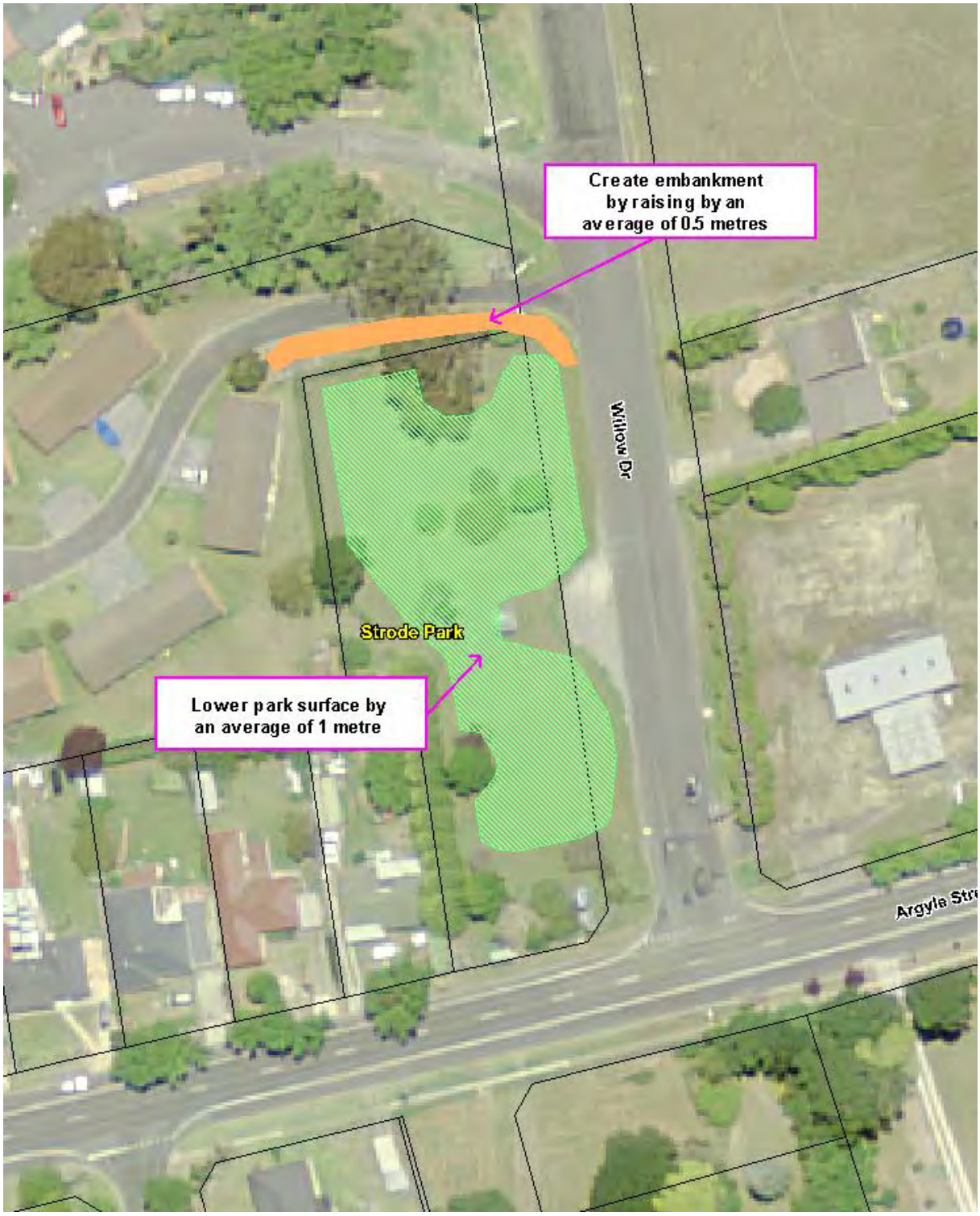


Plate 30 Concept Design of Strode Park detention basin

The Strode Park detention basin was included in a revised version of the XP-RAFTS model and the XP-RAFTS model was used to re-simulate each design flood. The revised flow hydrographs were then applied to the TUFLOW model and the TUFLOW model was used to simulate flood behaviour with the detention basin in place.

Flood level difference mapping was prepared to demonstrate how the basin is predicted to alter existing flood levels and extents. The difference mapping for the 5% AEP flood is provided in Plate 31 and the difference mapping for the 1% AEP flood is provided in Plate 32.

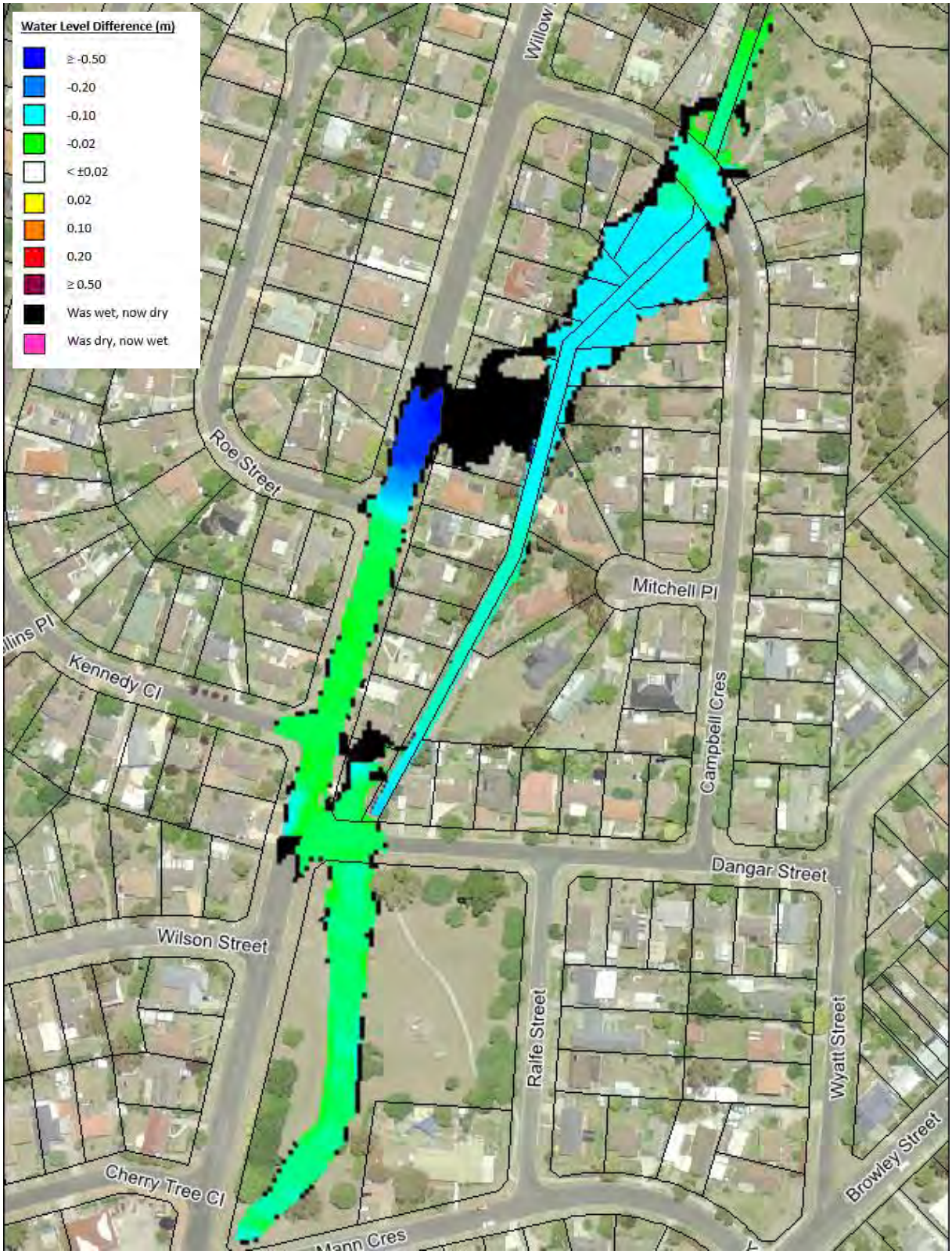


Plate 31 5% AEP Flood Level Difference Map for FM2b

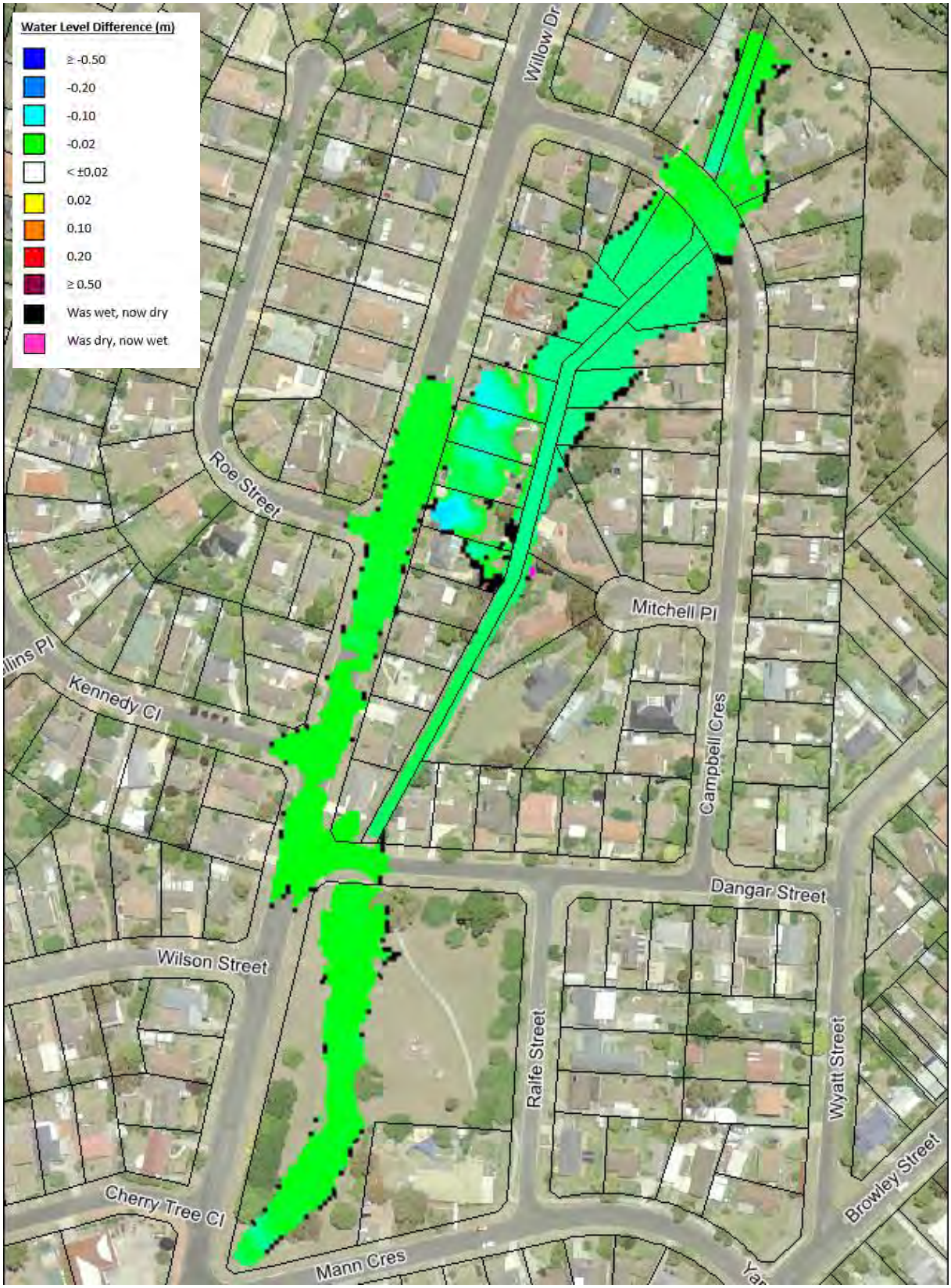


Plate 32 1% AEP Flood Level Difference Map for FM2b

Plate 31 shows that the basin is predicted to produce flood level reductions along Willow Drive during the 5% AEP flood. Flood level reductions of up to 0.22 metres are predicted at the low point of Willow Drive. Properties adjoining the low point in Willow Drive are also predicted

to become "flood free" during the 5% AEP flood. Although this is a notable improvement, this option does not perform as well as option FM2a (Broulee Park Basin) which is predicted to completely remove flooding from Willow Drive during the 5% AEP flood.

Plate 32 shows that the Strode Park basin is also predicted to reduce existing flood levels along Willow Drive, Willow Creek and adjoining properties during the 1% AEP flood. However, the flood level reductions generally do not exceed 0.03 metres and are predicted to generate negligible reductions in flood extents. Again, this option does not perform as well as Option FM2a during the 1% AEP flood where reductions of more than 0.1 metres are common. The reduced hydraulic performance of the Strode Park basin is primarily attributed to fact that a smaller proportion of the overall catchment drains to this basin and the available basin "footprint"/storage volume is less than what is available at Broulee Park.

As the Strode Park basin is not predicted to perform as well as the Broulee Park basin during both frequent and rarer floods, it is recommended that the Broulee Park basin is investigated in preference to the Strode Park basin. In the event that the Broulee Park basin is determined to be unfeasible, the Strode Park basin could be revisited.

7.3 Drainage Upgrades

7.3.1 Upgrade Stormwater System along Railway Street (near Argyle Street) (FM3)

Recommendation: Not recommended

Design Catchment Conditions

As noted in Section 3.2.2, significant inundation is predicted along Railway Street as well as Argyle Street during each design flood. This option looks to increase the capacity of the stormwater system along Railway Street between Spring Street and Whites Creek, thereby reducing flood depths and extents along Railway Street itself as well as reducing the amount of flow traveling overland and "ponding" at the low point in Argyle Street. The key features that were considered as part of this stormwater upgrade option are shown in **Figure 36**.

As shown in **Figure 36**, this option incorporates upgrades to the stormwater pipes and culverts (to increase the amount of flow conveyed below ground) as well as upgrades to the stormwater pits (to increase the ability to capture overland flows and distribute the flows to the subsurface stormwater system).

It is expected that the proposed upgrades would have a capital cost of over $1 million. A breakdown of the cost estimate is provided in **Appendix N**.

The TUFLOW computer model that was used to define design conditions was updated to include a representation of the proposed stormwater network. The updated TUFLOW model was then used to re simulate a range of design floods. Peak floodwater maps for the 5% AEP and 1% AEP are provided in Plate 33 and Plate 34. Difference mapping was also prepared for the PMF, but this showed no changes in existing flood levels, so it is not included.

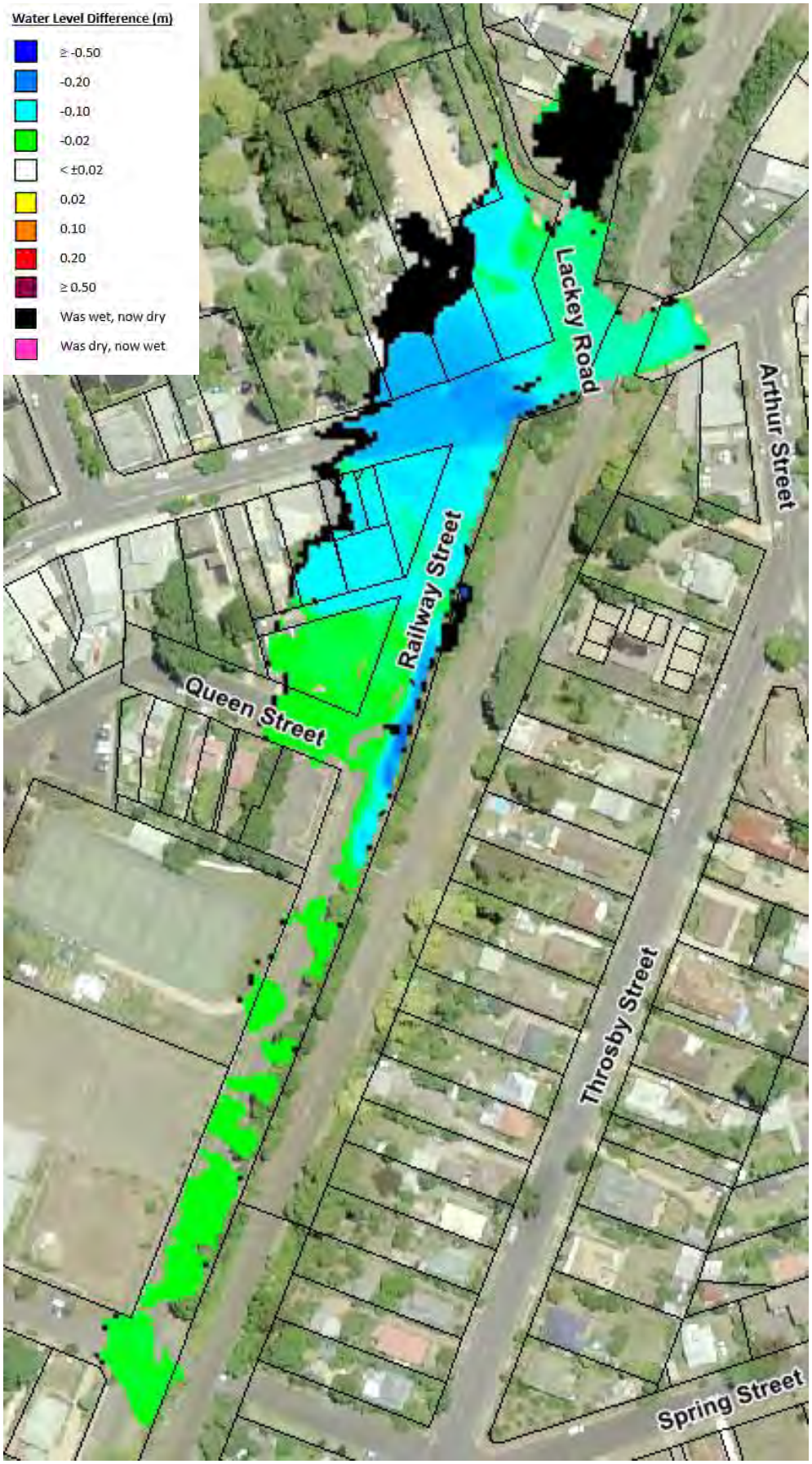


Plate 33 5% AEP Flood Level Difference Map for FM3

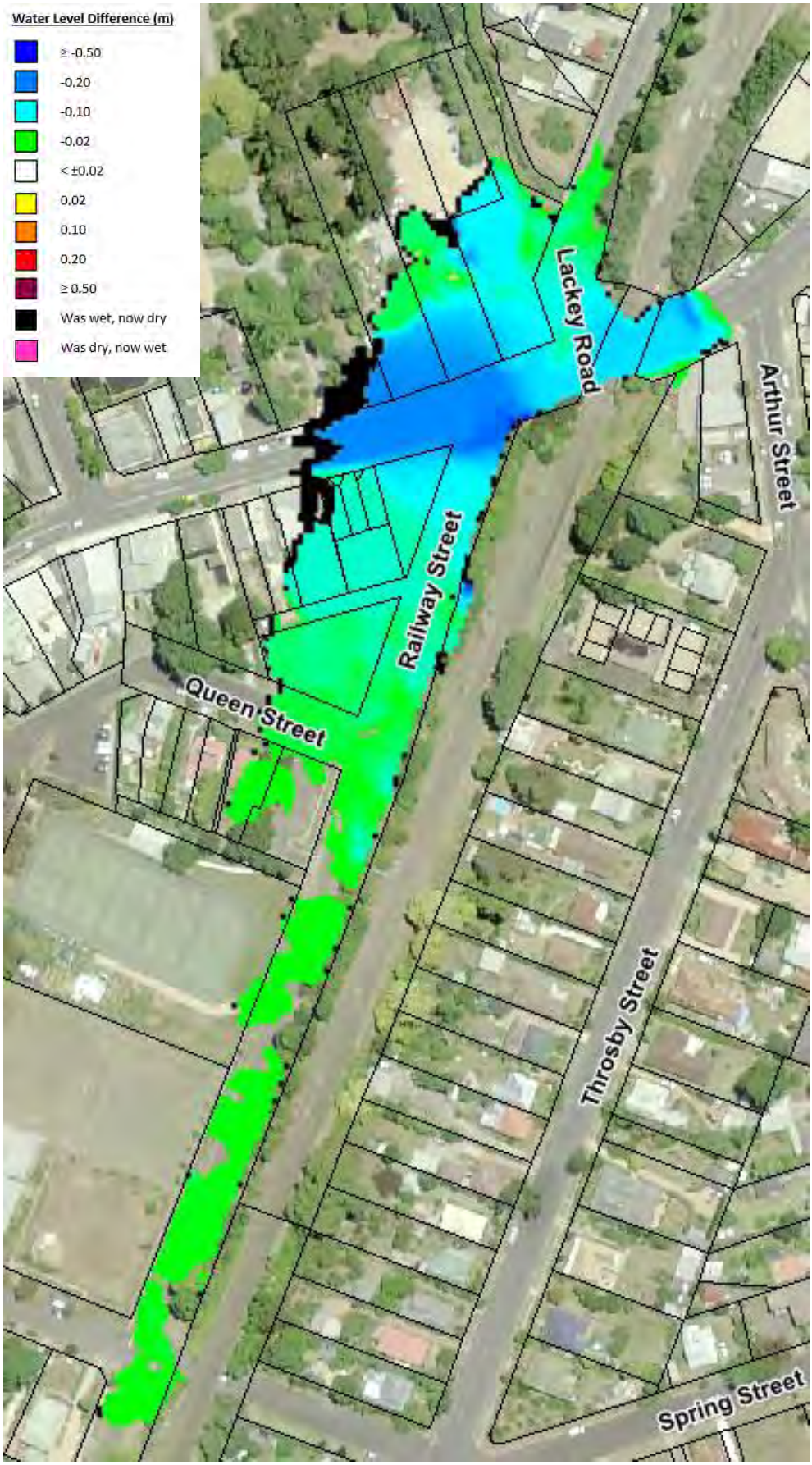


Plate 34 1% AEP Flood Level Difference Map for FM3

Plate 33 shows that in the 5% AEP flood, reductions in flood levels of up to 0.30m can be expected along Argyle Street, with more typical reductions around 0.15m to the west of the railway bridge over Argyle Street. Benefits to commercial properties are also noted near the junction of Railway Street, Argyle Street and extending to Lackey Road with reductions of between 0.10m and 0.15m.

Plate 34 shows that in the 1% AEP flood, reductions of over 0.2 metres are predicted near the intersection of Railway Street and Argyle Street. Flood level reductions of around 0.05m are predicted along Railway St and across Lackey Road.

A revised flood damage assessment was completed based on the updated flood results. This showed implementation of drainage upgrades as predicted to reduce existing flood damages by $140,000 over the next 50 years. This yields a preliminary BCR of about 0.1.

This option is predicted to afford the following reductions in above floor flooding:

- 20% AEP: 1 less property with above floor flooding;
- 5% AEP: 2 less properties with above floor flooding;
- 1% AEP: 2 less properties with above floor flooding; and,
- PMF: 1 less property with above floor flooding.

One of the primary goals for this option was to improve evacuation potential along Argyle Street, by providing increased evacuation time as well as reducing the frequency with which the road would be cut by floodwaters. The results of the flood modelling with the drainage upgrades in place show that the floodwater depths at the low point in Argyle Street (beneath the railway bridge) are still predicted to exceed 0.5m. So, a major flood will still result in Argyle Street being cut by floodwater, although an additional 15 minutes of evacuation time would be provided, and the road would be cut for approximately 30 minutes less time overall.

Future Catchment Conditions

As described in Section 3.5, future development does have the potential to further increase the existing flood risk across the catchment. This includes the Railway Street and Argyle Street areas. Therefore, the stormwater upgrades do have the potential to mitigate some of the adverse impacts that are predicted under future development conditions.

The potential hydraulic benefits afforded by the stormwater upgrades was quantified by updating and undertaking additional TUFLOW model simulations under future catchment conditions with the stormwater upgrades in place.

The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 5% AEP flood, 1% AEP flood and PMF are provided in Plate 35 and Plate 36. The difference maps were prepared by subtracting peak flood levels for existing catchment conditions from peak future catchment flood levels with the stormwater upgrades in place (to verify if the upgrades would mitigate the adverse flood impacts that are predicted with future catchment development).

Plate 35 and Plate 36 shows flood level reductions along Railway Street and Argyle Street indicating that the stormwater upgrades are able to assist in offsetting the potential impacts

of future catchment development. However, Plate 35 and Plate 36 shows flood level increases are predicted to remain across other sections of Whites Creek and Willow Gully.

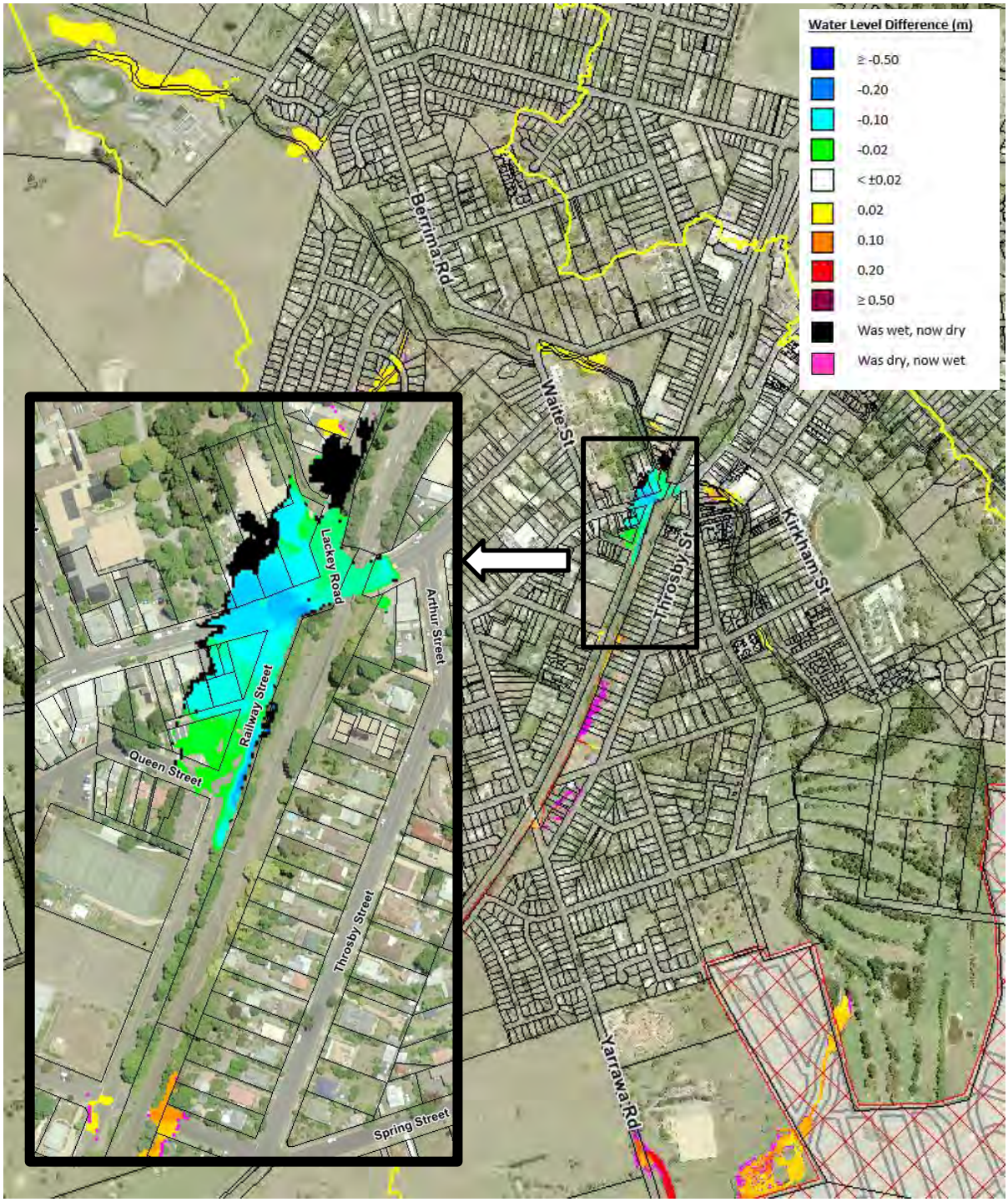


Plate 35 5% AEP Flood Level Difference Map for FM3 with Future Catchment Conditions

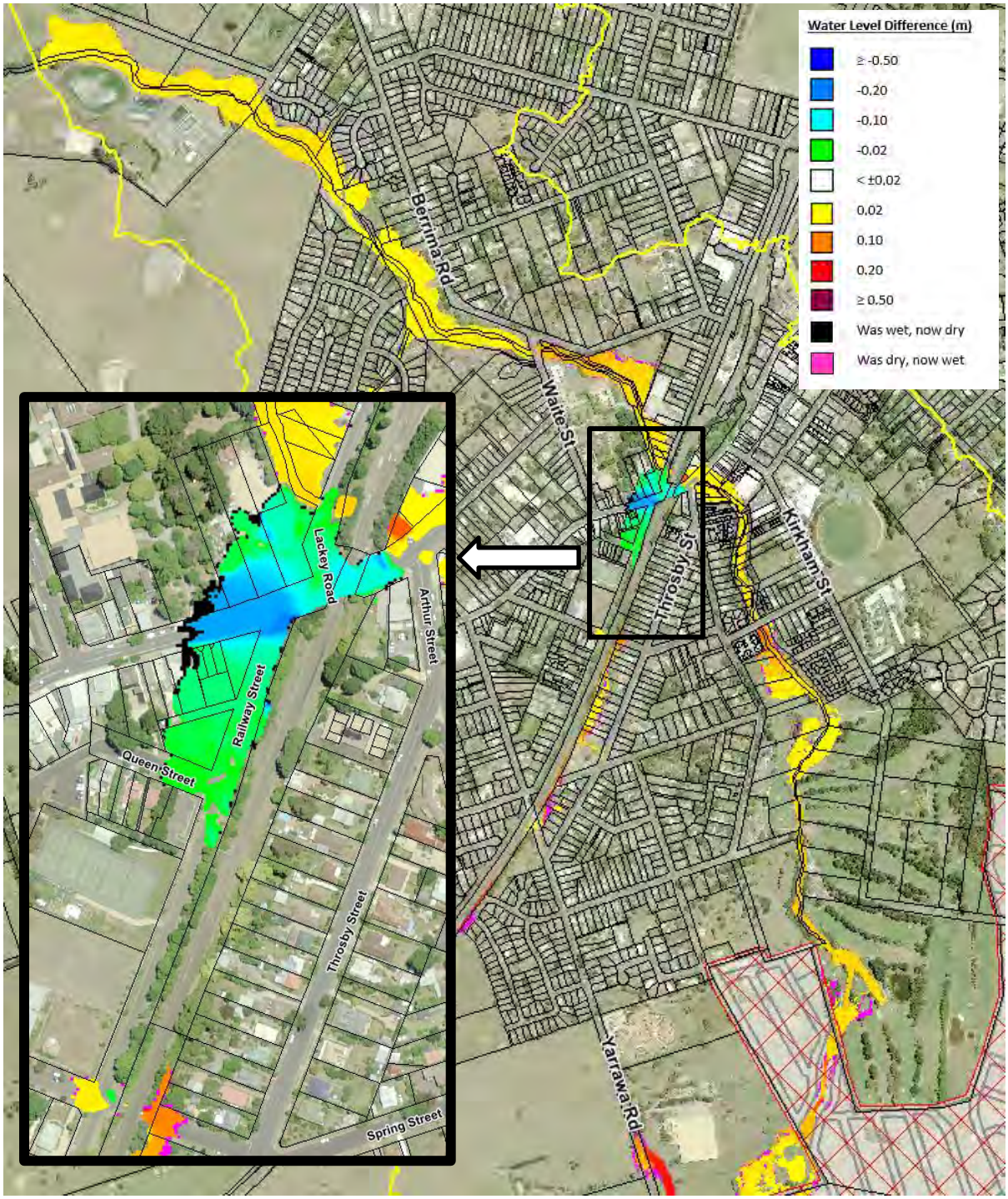


Plate 36 1% AEP Flood Level Difference Map for FM3 with Future Catchment Conditions

Therefore, this option does not appear to be suitable for completely offsetting the impacts of future catchment development if implemented in isolation. If future catchment development impacts are to be fully mitigated, it will be necessary to supplement this option to ensure no adverse impacts on other properties.

It is suggested that a more economic outcome for managing the future flood risk across this area is by continued implementation of Council's on-site detention policy for all future development across the upper catchment.

7.3.2 Upgrade Stormwater System along Argyle Street near Arthur Street (FM4)

Recommendation: Not recommended for implementation

Design Catchment Conditions

This option investigates the benefits of upgrading the local stormwater system along Argyle Street (near Arthur Street) to more efficiently "remove" water from Argyle Street and pass it into the Whites Creek channel. The extent of the suggested stormwater pit and pipe upgrades are shown in **Figure 37**.

It is expected that the proposed upgrades would have a capital cost of about $340,000. A breakdown of the cost estimate is provided in **Appendix N**.

The TUFLOW computer model was updated to include the upgraded stormwater network. The updated TUFLOW model was then used to re simulate each design flood. Peak floodwater difference maps for the 5% AEP and 1% AEP floods are provided in Plate 37 and Plate 38 (no differences were observed during the PMF).

Plate 37 shows that some significant flood level reductions are predicted across Argyle Street during the 5% AEP event. This includes flood level reductions of around 0.4m where Argyle Street crosses Whites Creek and 0.2m reductions near the intersection of Argyle Street and Lackey Road.

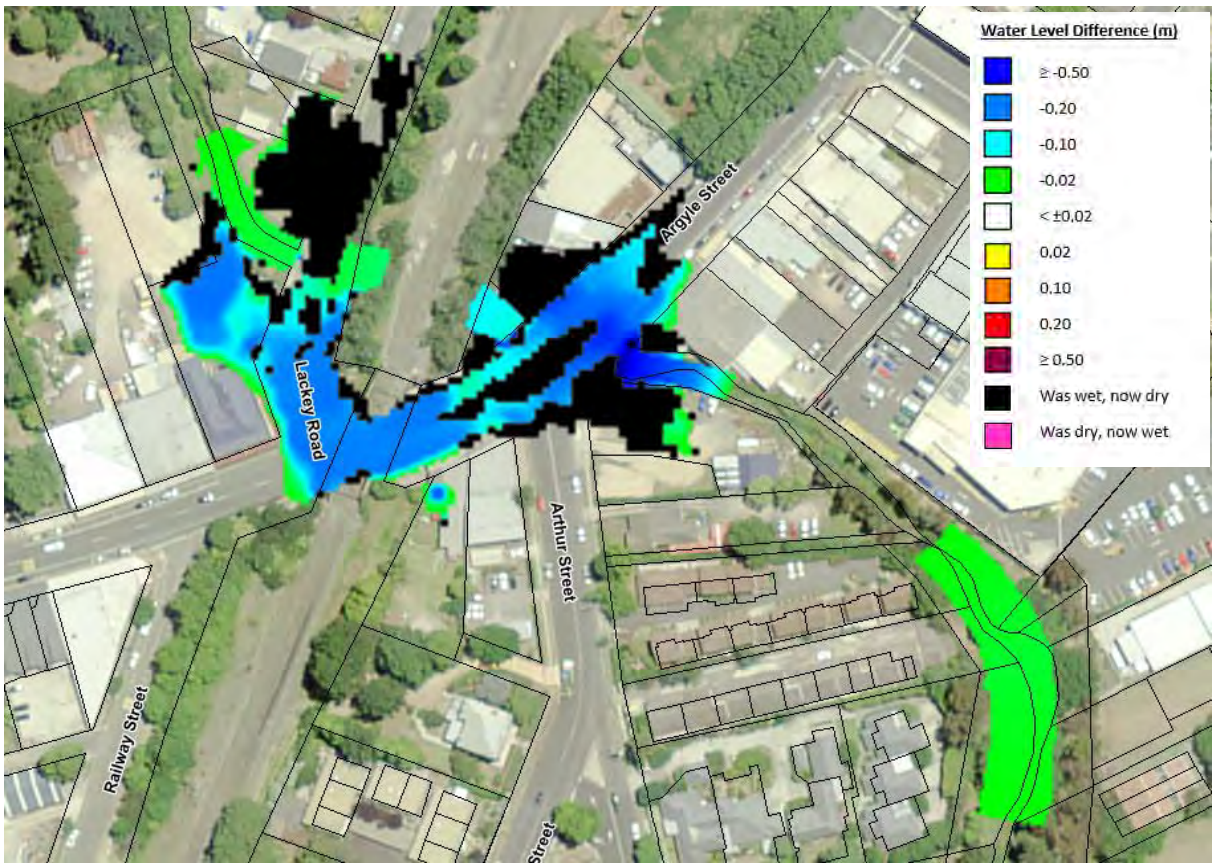


Plate 37 5% AEP Flood Level Difference Map for FM4

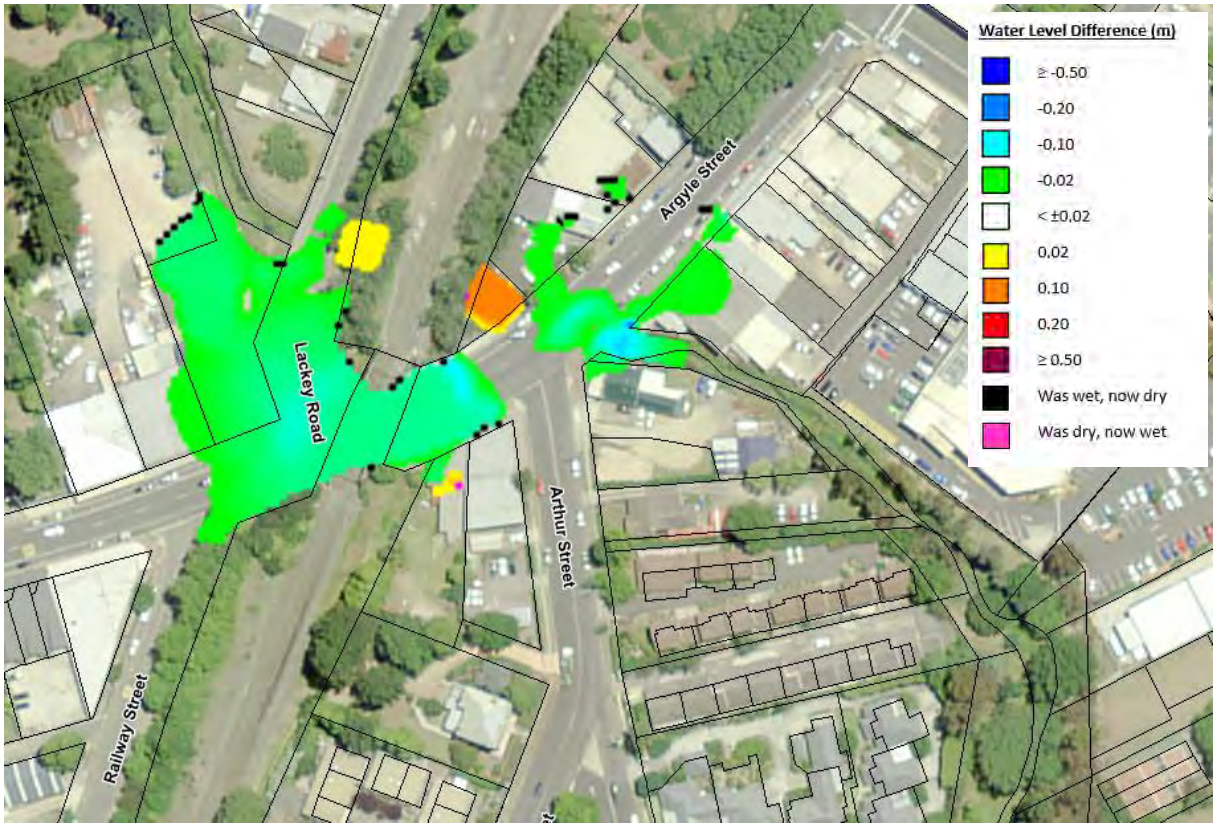


Plate 38 1% AEP Flood Level Difference Map for FM4

Plate 38 shows that during the 1% AEP event, the flood level reductions are less pronounced, with all flood level reductions below 0.1m. Flood level increases are also predicted in the Whites Creek channel upstream of the railway line. The increases in flood level at this location and the reduced performance across Argyle Street indicates that the capacity of the main railway culvert is limiting the performance of the stormwater upgrades during larger floods.

A revised flood damages assessment was completed with the updated TUFLOW model results. The outcomes of the revised damage assessment indicate that this option is predicted to reduce existing flood damages by $90,000 over the next 50 years. This affords a preliminary benefit cost ration of 0.3. This means that the costs to implement this option are above the benefits.

The reduction in flood levels is predicted to result in two fewer properties with above floor flooding in the 5% AEP. No reductions in above floor flooding are predicted during larger floods (e.g., 1% AEP flood and PMF).

There are some emergency response benefits associated with this option. More specifically, the flood level reductions are sufficient to prevent Argyle Street being cut by floodwater during more frequent events (i.e., 20% AEP flood). However, water is still predicted to be sufficiently deep to cut Argyle Street during events equal to or greater than 5% AEP design flood.

Although this option is predicted to afford some benefits during more frequent floods, the capacity of the main railway culvert reduces the effectiveness of this option during larger

events. As a result, this option is not recommended "as is". However, if upgrades of the railway culvert are pursued (discussed in the following section), it would likely improve the hydraulic performance and financial viability of this option.

Future Catchment Conditions

The potential benefits of this option in reducing the potential future flood risk were also explored. This involved updating the "future catchment conditions" TUFLOW model to include the stormwater upgrades and re-simulating each design floods. Flood level difference mapping was prepared for the 5% AEP and 1% AEP floods and this is presented in Plate 39 and Plate 40.

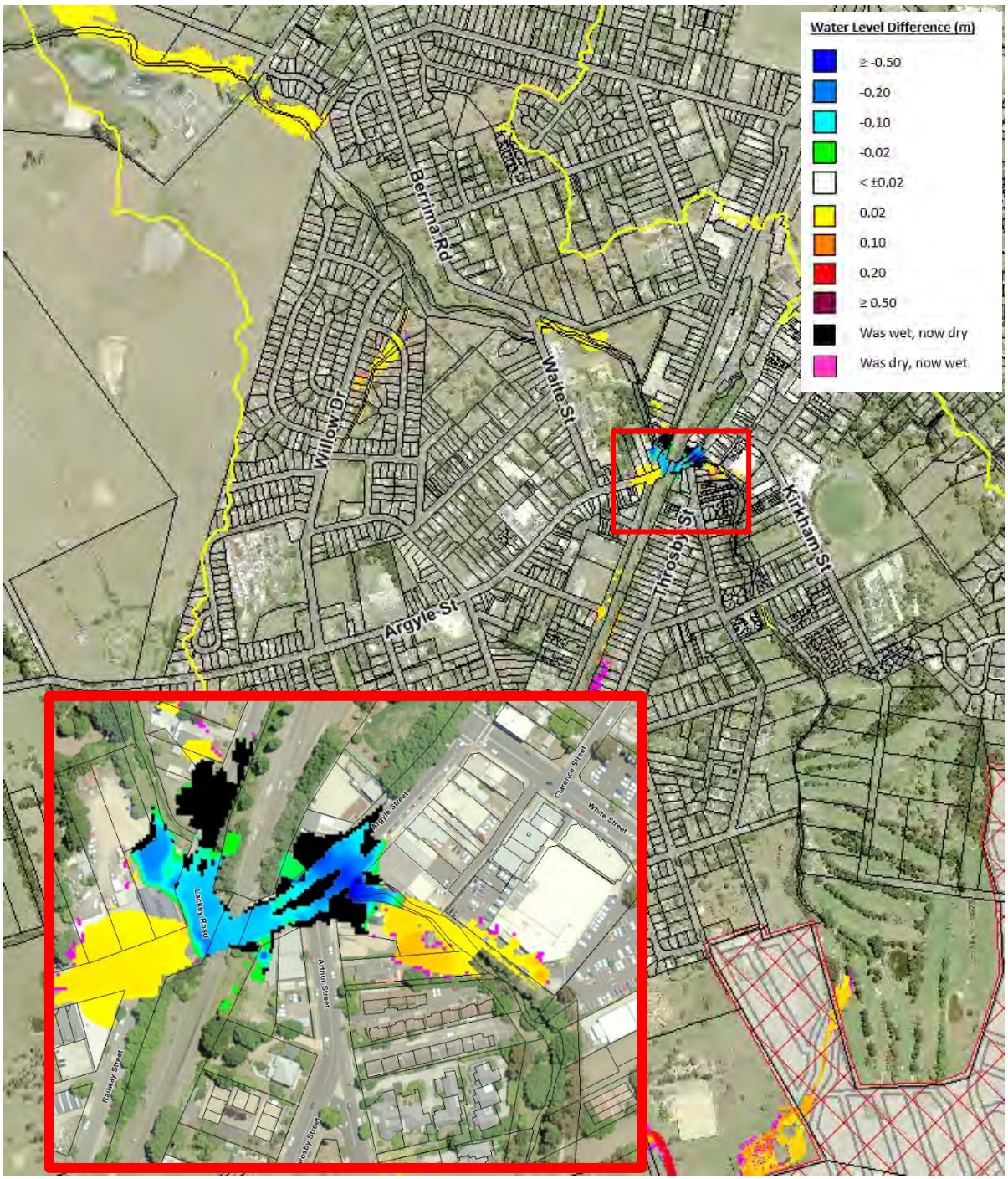


Plate 39 5% AEP Flood Level Difference Map for FM4 with Future Catchment Conditions

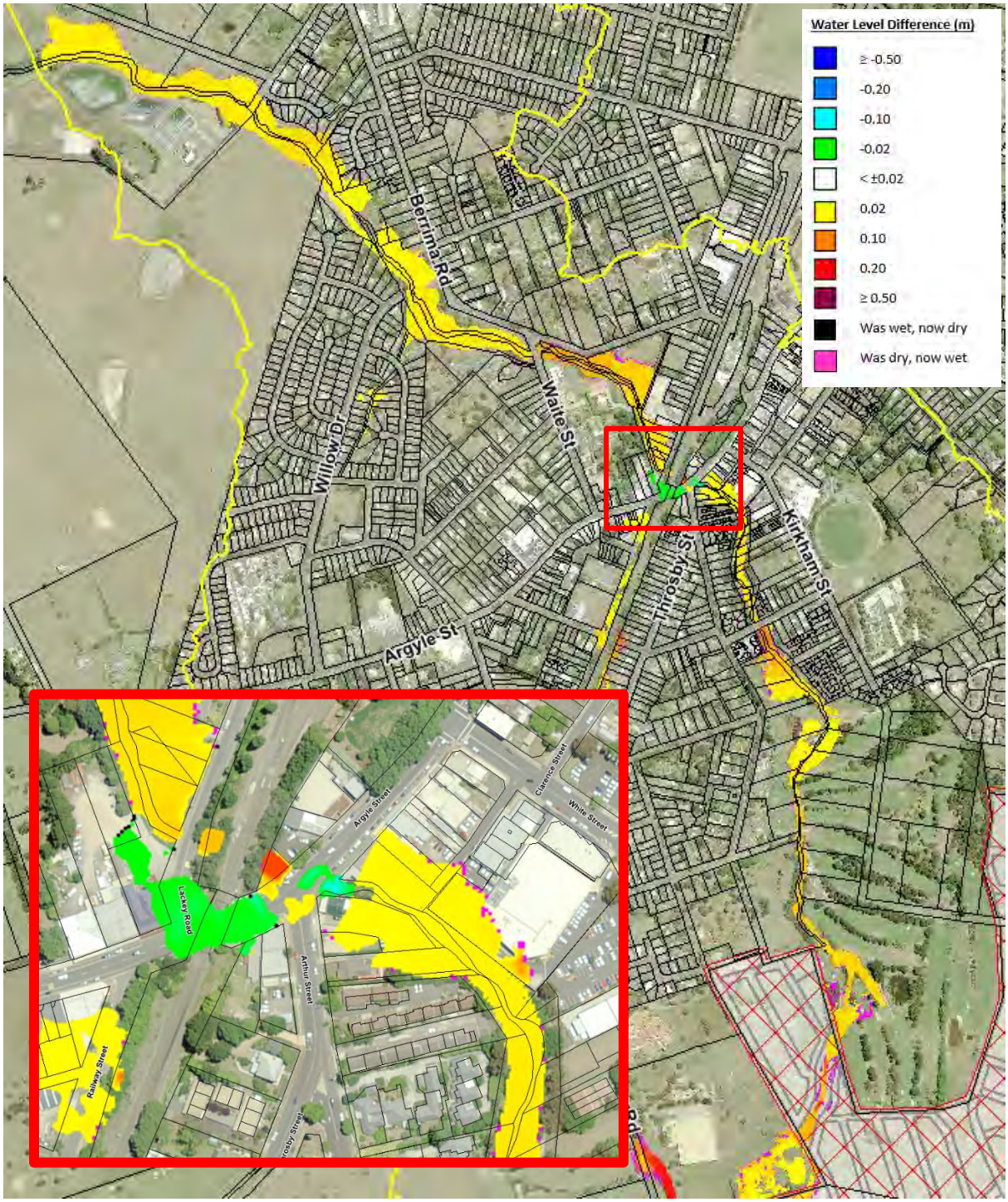


Plate 40 1% AEP Flood Level Difference Map for FM4 with Future Catchment Conditions

Plate 39 and Plate 40 shows that the stormwater upgrades are predicted to reduce future 5% AEP and 1% AEP flood levels and depths in the vicinity of Argyle Street and Lackey Road. However, the flood level reductions are localised and are not predicted to afford any significant hydraulic benefits upstream and downstream of Argyle Street.

Accordingly, this option is not considered suitable for mitigating the potential increase in flood risk associated with future catchment development.

7.3.3 Upgrade Culverts along Whites Creek at Argyle Street and the Railway (FM5)

Recommendation: Feasibility assessment recommended

Design Catchment Conditions

Flood behaviour in the vicinity of Argyle Street is controlled during large floods by the capacity of the existing culverts that drain Whites Creek beneath Argyle Street and the railway line. The lack of capacity of these structures reduces the efficiency of the local stormwater system, exacerbating the frequency and depths of inundations that are predicted across Argyle Street.

This option looks to increase the conveyance of floodwater under Argyle Street and the railway embankment by increasing the size of the existing culverts. The suggested upgrades are shown in **Figure 38** and includes:

- The culvert under Argyle Street was increased from the current 3.4 metre width to 5.1 metres wide.
- The existing twin 2.1 metre diameter railway culverts (shown below) were retained, and an additional 2.1 metre diameter culvert was included parallel to the existing culverts.



Plate 41 Existing railway culverts

The suggested changes were included in the TUFLOW computer model and the updated model was used to re-simulate each of the design floods for "design" catchment conditions. The resultant peak flood level difference maps are presented in Plate 42 and Plate 43 for the 5% AEP and 1% AEP floods respectively.

Plate 42 shows considerable reductions in flood levels during the 5% AEP event. Peak 5% AEP flood levels are typically 0.5m lower in the Whites Creek channel, 0.30m lower across the eastern side of Argyle Street and 0.05m lower on the western side of Argyle Street.

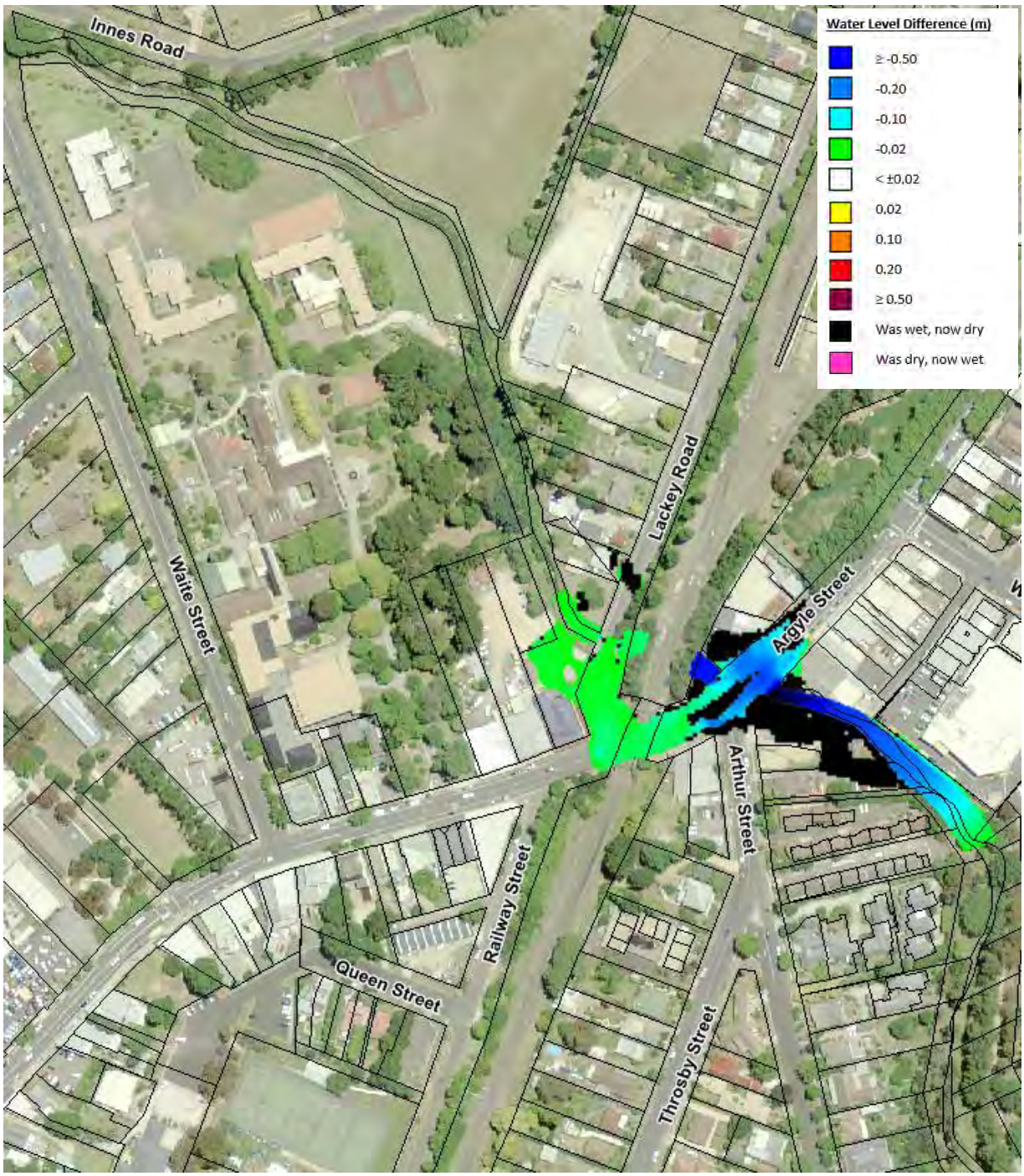


Plate 42 5% AEP Flood Level Difference Map for FM5

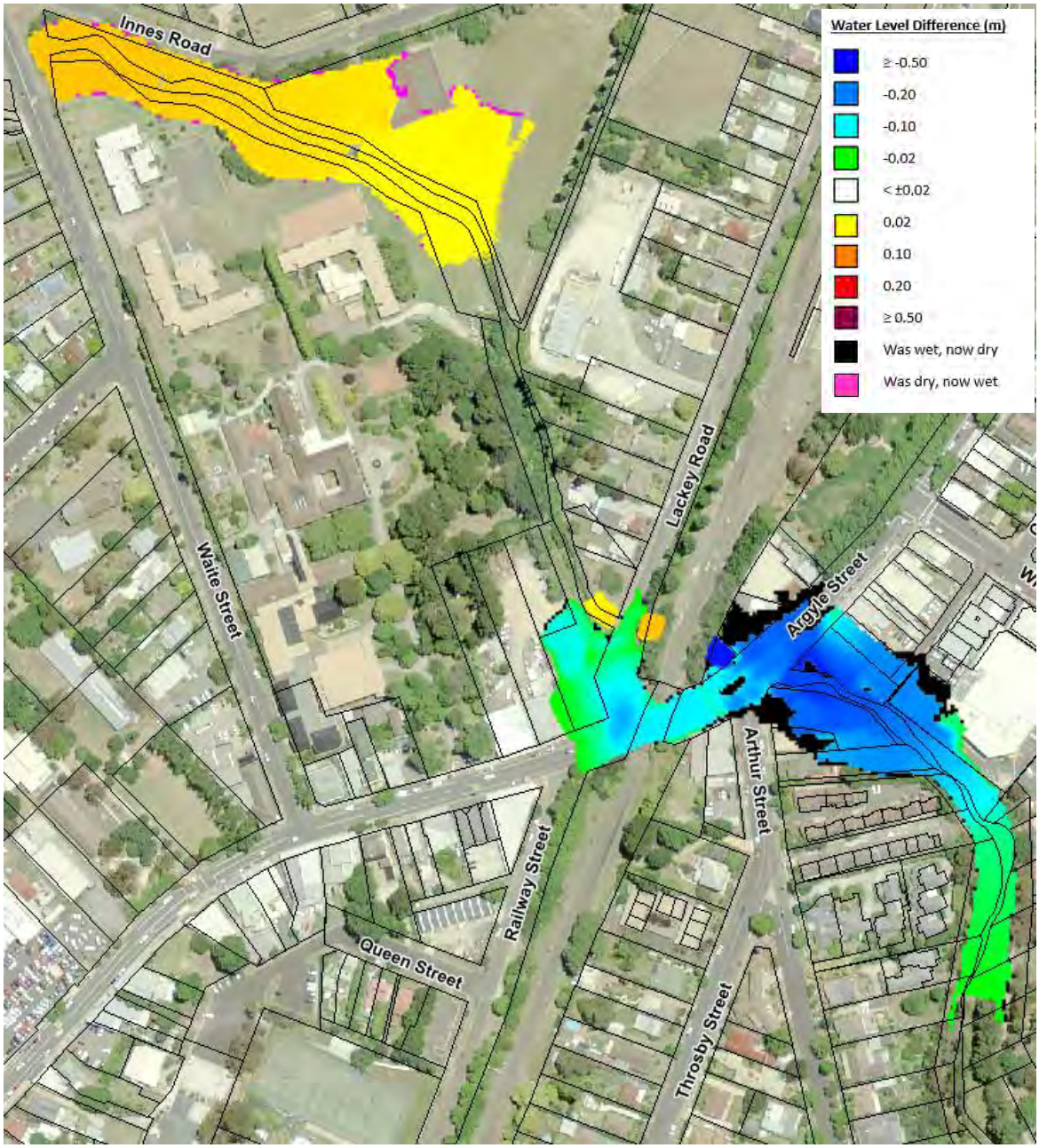


Plate 43 1% AEP Flood Level Difference Map for FM5

Plate 43 shows that during the 1% AEP flood, flood level reductions of up to 0.4m are predicted along Whites Creek, while typical reductions of 0.25m are predicted across Argyle Street. Plate 43 also shows that increases in flood level are predicted along Whites Creek immediately downstream of the railway and between Lackey Road and Waite Street (the increases are associated with the additional flow that is directed beneath the railway embankment). However, these increases are not predicted to exceed 0.03m and are typically contained to the main channel and/or open space.

The suggested culvert upgrades are predicted to have capital costs of about $650,000. A full breakdown of costs is provided in **Appendix N**. It is worth noting that the implementation costs are heavily influenced by the difficult nature of working in a major waterway and in close

proximity to major transportation corridors (i.e., Argyle Street and the railway) and costs may vary as a result of these constraints.

Two fewer buildings are predicted to be exposed to above floor flooding during the 5% AEP flood and PMF. One fewer building is predicted to be exposed to above floor flooding during the 1% AEP.

A revised damage estimate with this option in place gives an expected damage reduction of $120,000 over the next 50 years. This yields a preliminary BCR of just under 0.2, which means the costs outweigh the benefits in implementing this option. This is based on the reduction in damages as a result of over floor flooding only, and does not take into account the intangible benefits, such as significant improvement in floodwater depths on the roadways adjacent to these culverts and increased trafficability of these roadways during more frequent floods.

Overall, this option is predicted to afford some localised hydraulic benefits in one of the most problematic areas of the catchment. This area is also one of the most important thoroughfares of the catchment, as it is only one of two opportunities in Moss Vale to cross from the east to the west of the railway line. Thus, the option has the potential to have significant community and emergency response support. However, the poor economic performance of this option makes it difficult to recommend when using the benefit cost ratio only from this study as the basis for recommendation.

This option would require work in land owned by Australian Rail Track Corporation (ARTC) and the Roads and Maritime Service (RMS) and has the potential to impact assets owned by each organisation. Furthermore, comments received from RMS noted that the railway culvert has a high potential for being considered a heritage item which may reduce the potential for direct modifications of the culvert. Therefore, to facilitate implementation of the additional culvert capacity, additional property acquisitions may be required which would further increase the implementation costs.

However, the outcomes of this option would be of significant benefit to the RMS as trafficability of the Illawarra Highway would be improved during flood events. Discussions could be conducted with ARTC and RMS to confirm if they would be willing to contribute to the implementation of this option, which would improve the financial viability of implementing both the culverts under the railway line and the culverts under the Illawarra Highway/Argyle Street. As a first step, it is recommended that a detailed feasibility assessment be completed in consultation with RMS and ARTC.

Future Catchment Conditions

The potential for the culvert upgrades to mitigate the potential future flood risk were also explored. Peak floodwater level difference mapping for future catchment conditions with the culvert upgrades in place are shown for the 5% AEP and 1% AEP in Plate 44 and Plate 45.

Plate 44 and Plate 45 shows that the culverts upgrades are predicted to reduce potential future flood levels in the 5% AEP and 1% AEP floods to below existing levels in the immediate vicinity of Argyle Street and the railway. However, the upgrades do little to offset the predicted impacts of future catchment development upstream and downstream of the culvert, particularly during the 1% AEP flood.

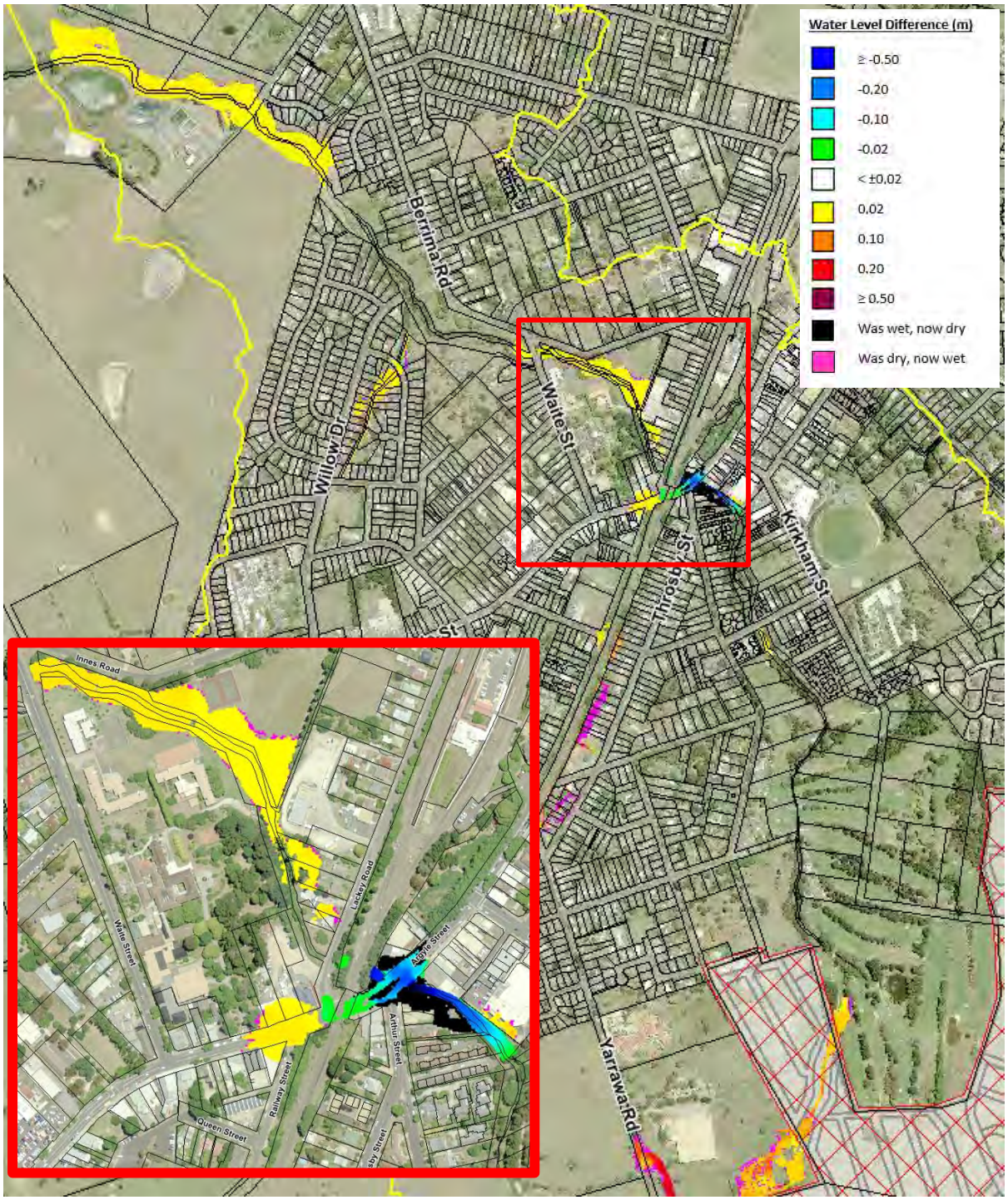


Plate 44 5% AEP Flood Level Difference Map for FM5 with Future Catchment Conditions

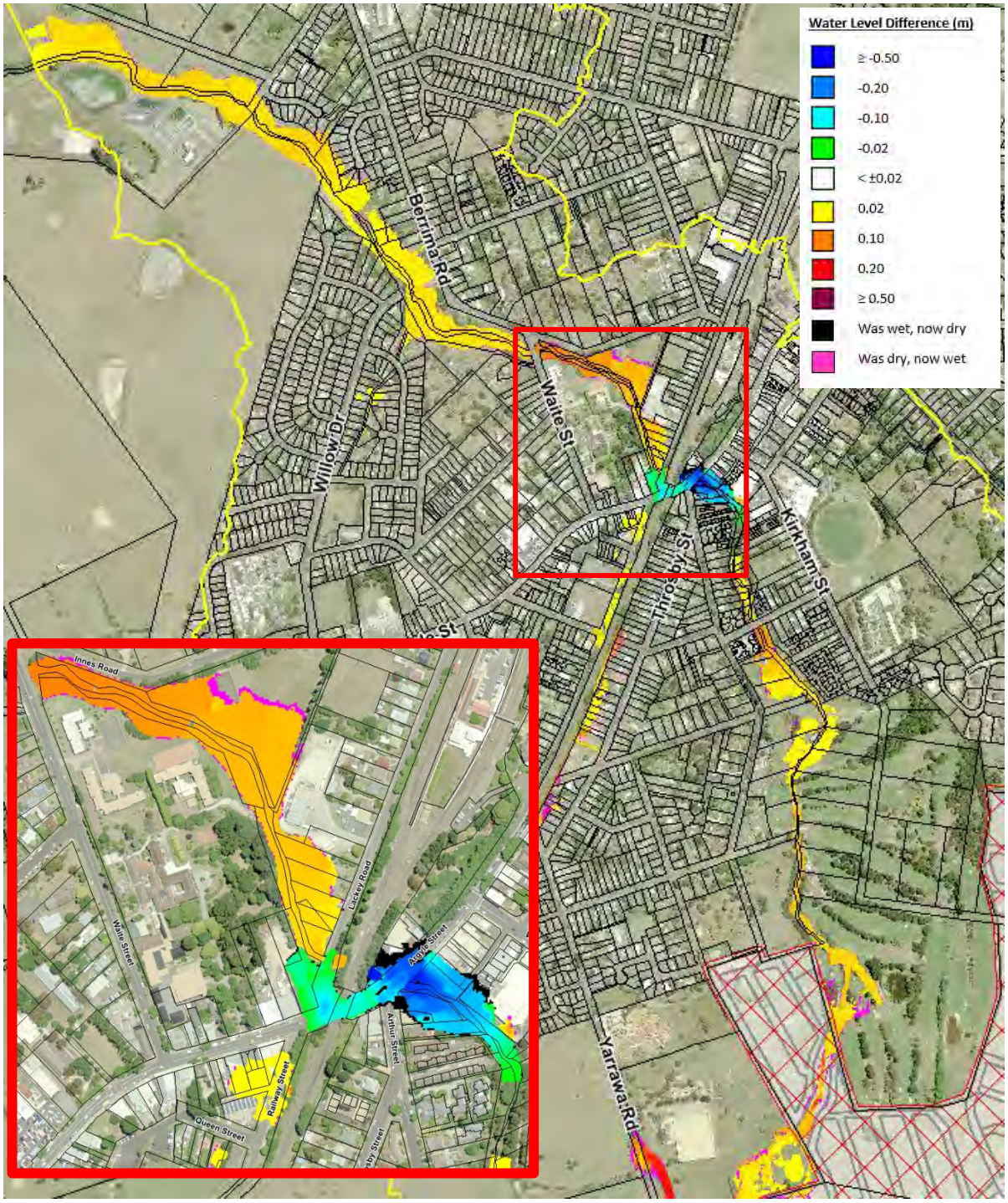


Plate 45 1% AEP Flood Level Difference Map for FM5 with Future Catchment Conditions

7.3.4 Upgrade Stormwater System on Willow Drive and Dangar Street (FM6)

Recommendation: Not recommended for implementation

The results of the design flood simulations show that water travelling though Broulee Park exceeds the capacity of the culverts under Dangar Street. The excess water is predicted to travel north towards the sag point in Willow Drive (just north of Roe Street intersection)

before overtopping the gutter and spilling through adjoining properties and re-joining Willow Creek.

This option incorporates upgrades to the stormwater network along Willow Drive and Dangar Street to capture more runoff and convey it, below ground, and into Willow Creek. The suggested upgrades are shown in **Figure 39**.

The cost to implement the stormwater upgrades is predicted to be about $390,000. A full breakdown of the costs is provided in **Appendix N**.

The TUFLOW computer model was updated to include the stormwater upgrades and the updated model was used to re-simulate each flood for design catchment conditions. Floodwater level difference mapping was prepared for the 5% AEP and 1% AEP floods and are provided in Plate 46 and Plate 47 respectively. Difference mapping was also prepared for the PMF, but this showed negligible changes in design flood levels, so is not included.

Plate 46 shows that the stormwater upgrades are predicted to reduce 5% AEP flood levels by up to 0.25 metres along Willow Drive. The flood level reductions are sufficient to prevent water overtopping the gutter of Willow Drive resulting in 3 fewer properties being subject to inundation. The additional water that is directed into Willow Creek is predicted to generate increases in water level along this waterway. However, the differences are predicted to be no greater than 0.08 metres and are contained to the creek channel.

Plate 47 shows that more modest flood level changes are anticipated during the 1% AEP flood. More specifically, flood level reductions along Willow Drive typically do not exceed 0.1 metres and are not sufficient to prevent water from spilling through Willow Drive properties. However, they are sufficient enough to reduce flood levels/depths across the Willow Drive properties by around 0.15 metres. Flood level increases of up to 0.07 metres are predicted within the Willow Creek channel, however, they are fully contained to the creek channel.

Despite the flood level reductions afforded by this option, there are predicted to be no changes in the number of properties exposed to above floor inundation.

A revised flood damage assessment was prepared using the results from the revised flood simulations. This indicates the stormwater upgrades would reduce flood damages by about $40,000 over the next 50 years. This produces a preliminary BCR of just over 0.1. The lack of significant financial benefits is likely associated with this option only affording benefits to ~4 properties.

This option would provide some emergency response improvement by reducing the frequency and depth of inundation along Willow Drive. However, the poor financial performance of this option makes it difficult to support. As a result, this option is not recommended for implementation.

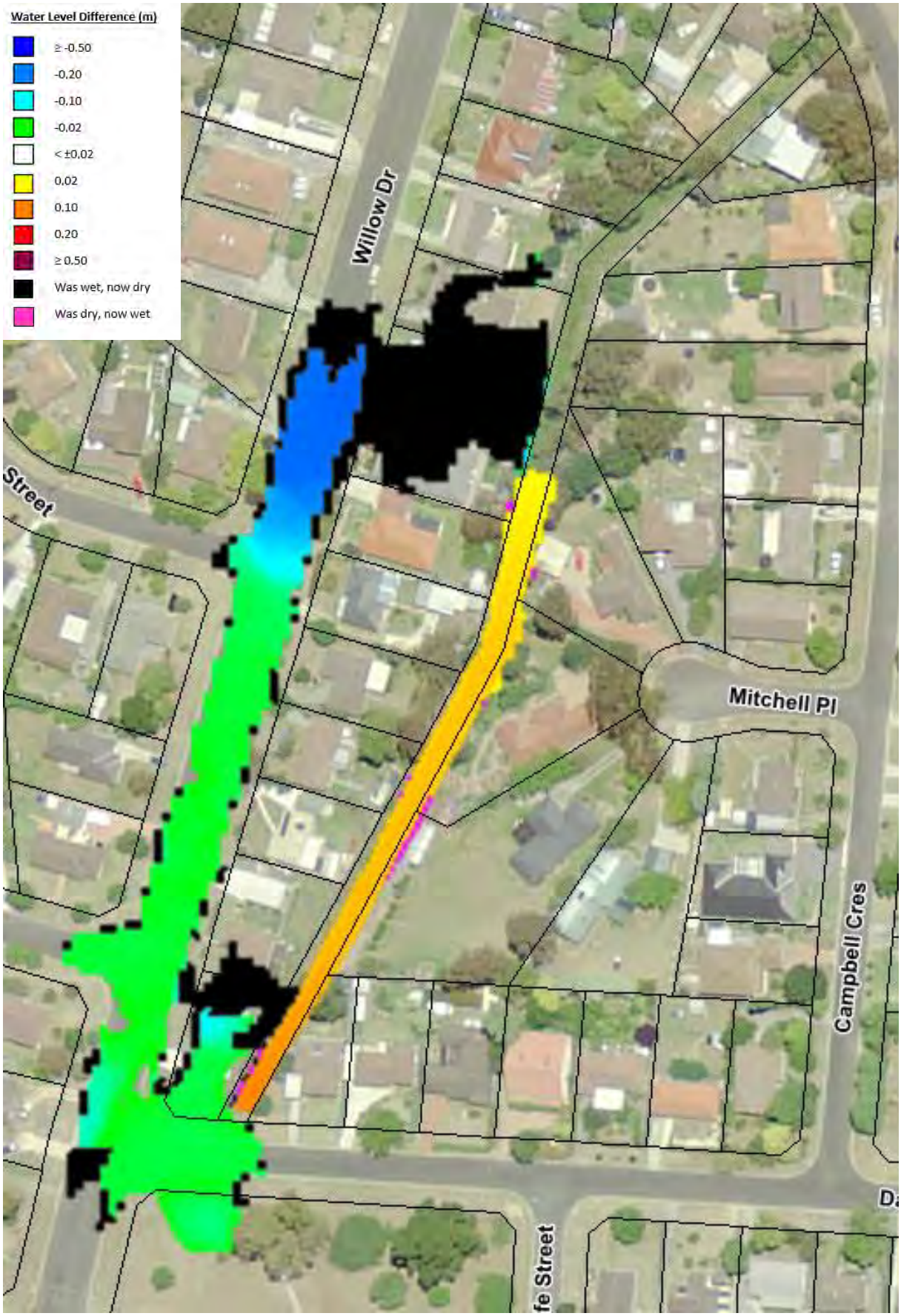


Plate 46 5% AEP Flood Level Difference Map for FM6

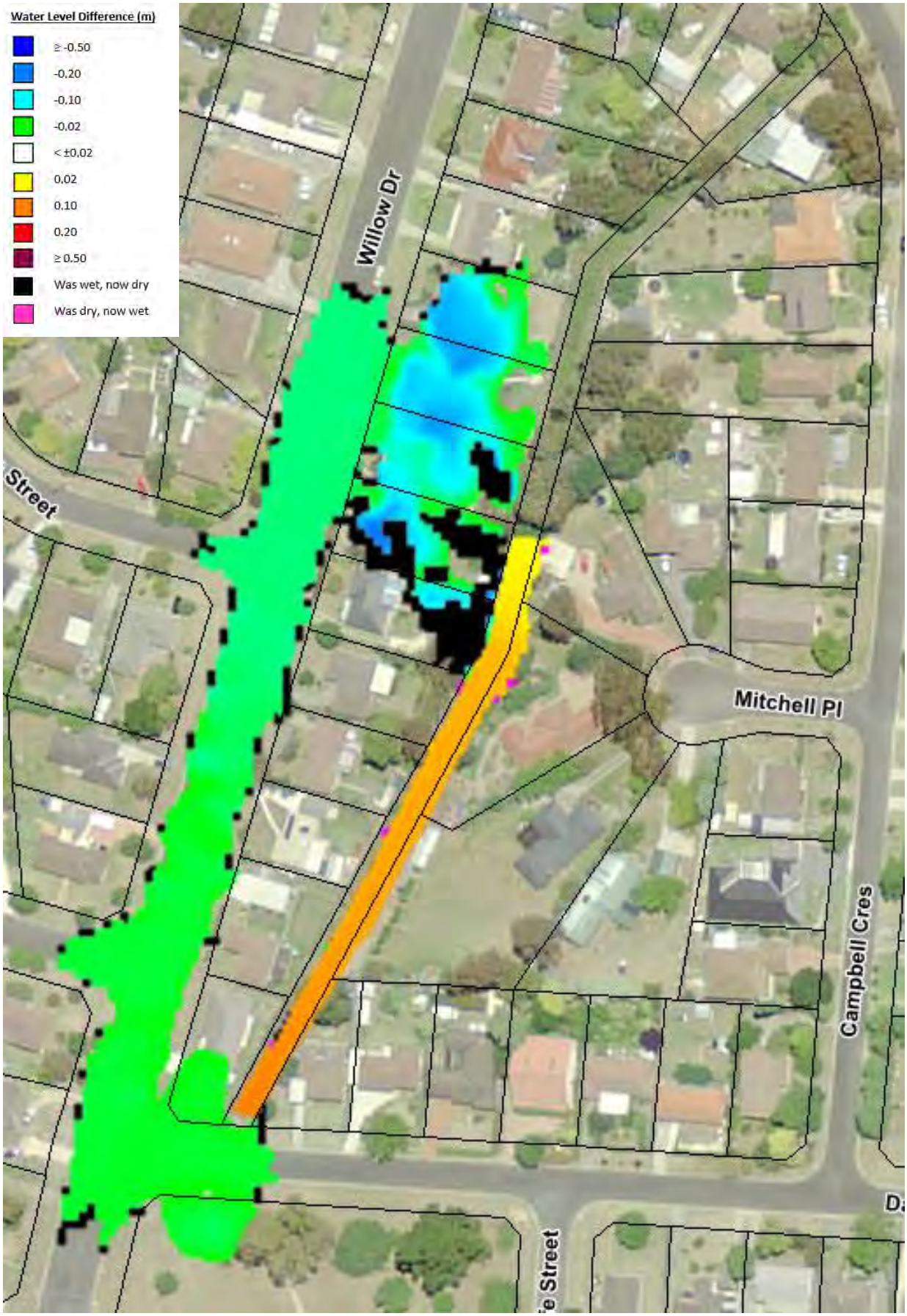


Plate 47 1% AEP Flood Level Difference Map for FM6

7.4 Channel Modifications

7.4.1 Channel Reshaping of Whites Creek upstream of Argyle Street (FM7)

Recommendation: Not recommended for implementation

This option looks to increase the width of the Whites Creek channel immediately upstream of Argyle Street. The goal of this option is to increase the flow carrying capacity of the Whites Creek channel thereby reducing the amount of flow spilling out of the channel and inundating Argyle Street. The extent of the channel widening investigated as part of this option is shown in **Figure 40**.

The peak floodwater level difference results for this options are provided for the 5% AEP and 1% AEP in Plate 48 and Plate 49.

Plate 49 shows that the channel modifications are predicted to reduce peak 1% AEP flood levels upstream of Argyle Street. The maximum flood level reduction is predicted to be about 0.2 metres and benefits properties immediately adjoining the creek channel. Some increases in flood level are predicted immediately upstream of Argyle Street and appear to be associated with the larger channel directing additional flow towards the culvert resulting in additional localised afflux. This is predicted to produce localised increases in flood level on the eastern side of Argyle Street.

Plate 48 shows that the channel widening is predicted to afford more significant flood level increases during the 5% AEP flood. Most of the lower lying section of Argyle Street are predicted to be exposed to flood level increases of more than 0.10m, with the flood level increases also extending along Lackey Road including several residential and commercial properties.

Variations of this option were also explored including installing a small flood barrier/wall near the Argyle Street culvert to contain more water to the channel and prevent it from spilling onto Argyle Street. Although this did reduce the adverse impacts across Argyle Street, it exposed commercial properties located on the eastern side of Argyle Street to higher flood levels, thereby negating the benefits of the channel enlargement works.

Given this option appears to increase the flood problem across one of the most problematic areas of the catchment, this option was not explored further as part of the current study and is not recommended.

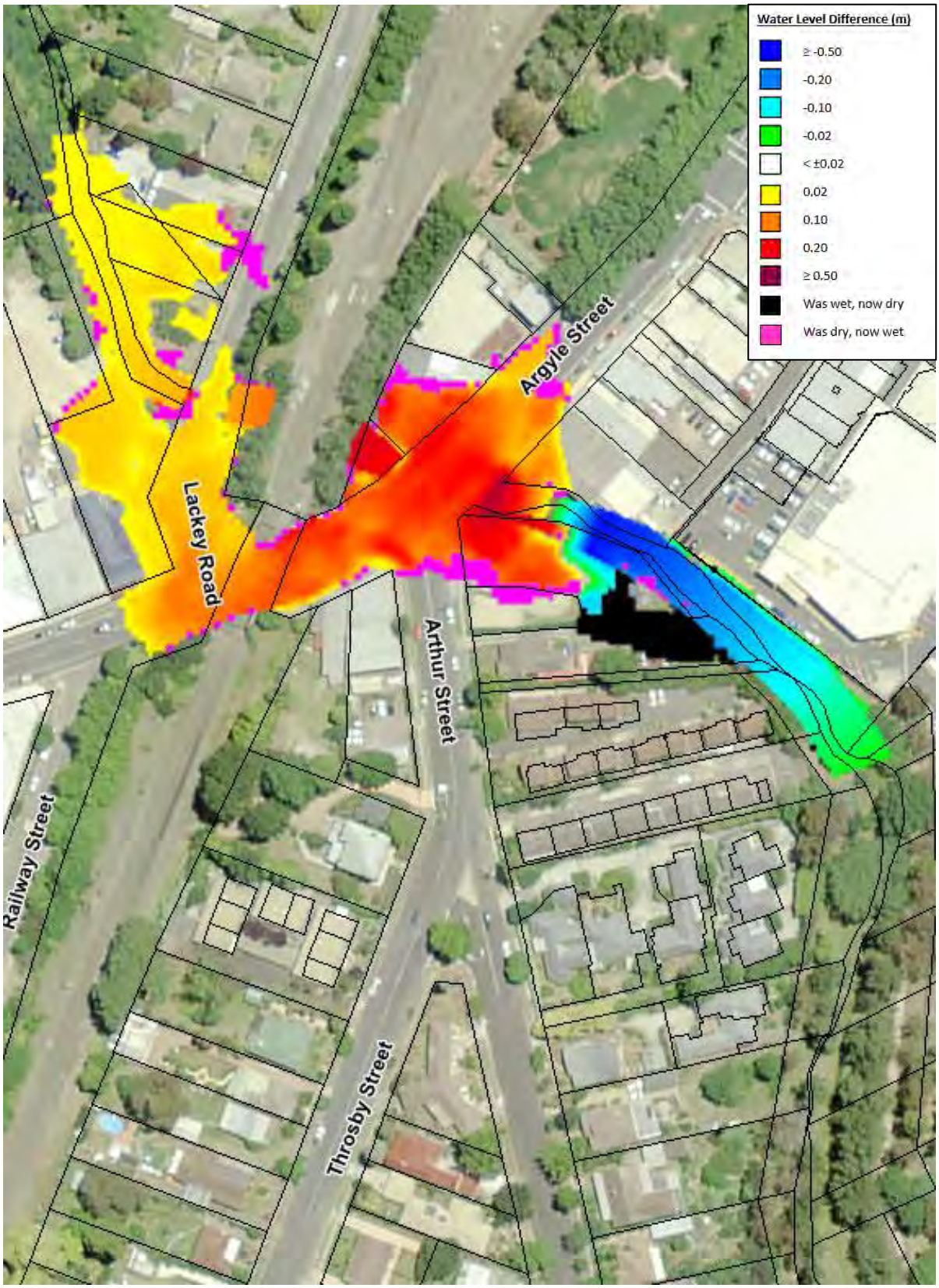


Plate 48 5% AEP Flood Level Difference Map for FM7

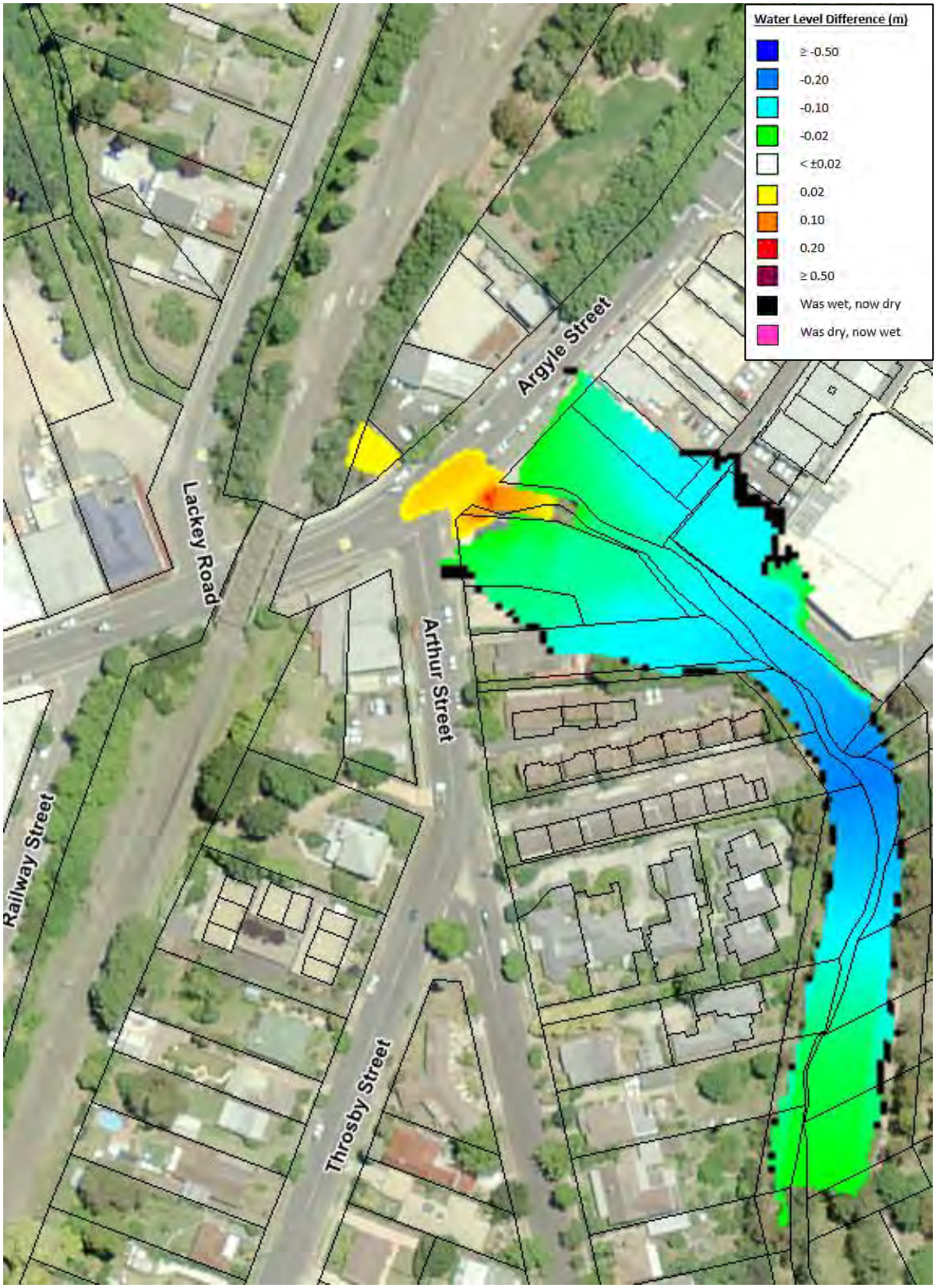


Plate 49 1% AEP Flood Level Difference Map for FM7

7.4.2 Channel and Floodplain Modifications between 6-12 Berrima Road (FM8)

Recommendation: Not recommended for implementation

Residents located between 6 and 12 Berrima Road reported frequent inundation of the western parts of their properties (i.e., adjoining Whites Creek) including damage to fences. Accordingly, this option explored potential measures for improving the flow carrying capacity of the Whites Creek channel and floodplain to reduce the extent and depth of inundation in the vicinity of these properties.

Initially, vegetation modification was explored along the Whites Creek channel. Due to the potential environmental impacts, it was assumed that only low-level shrubs, weeds and reeds would be removed, and native trees and vegetation would be retained. The extent of the area where vegetation modification was explored is shown as "Option A" in **Figure 41**.

The TUFLOW model was updated to include a representation of the vegetation by reducing the Manning's "n" roughness assigned to the channel. The modified model was used to re-simulate each design flood. Flood level difference mapping was prepared for the 5% AEP and 1% AEP floods and is included Plate 50 and Plate 51.

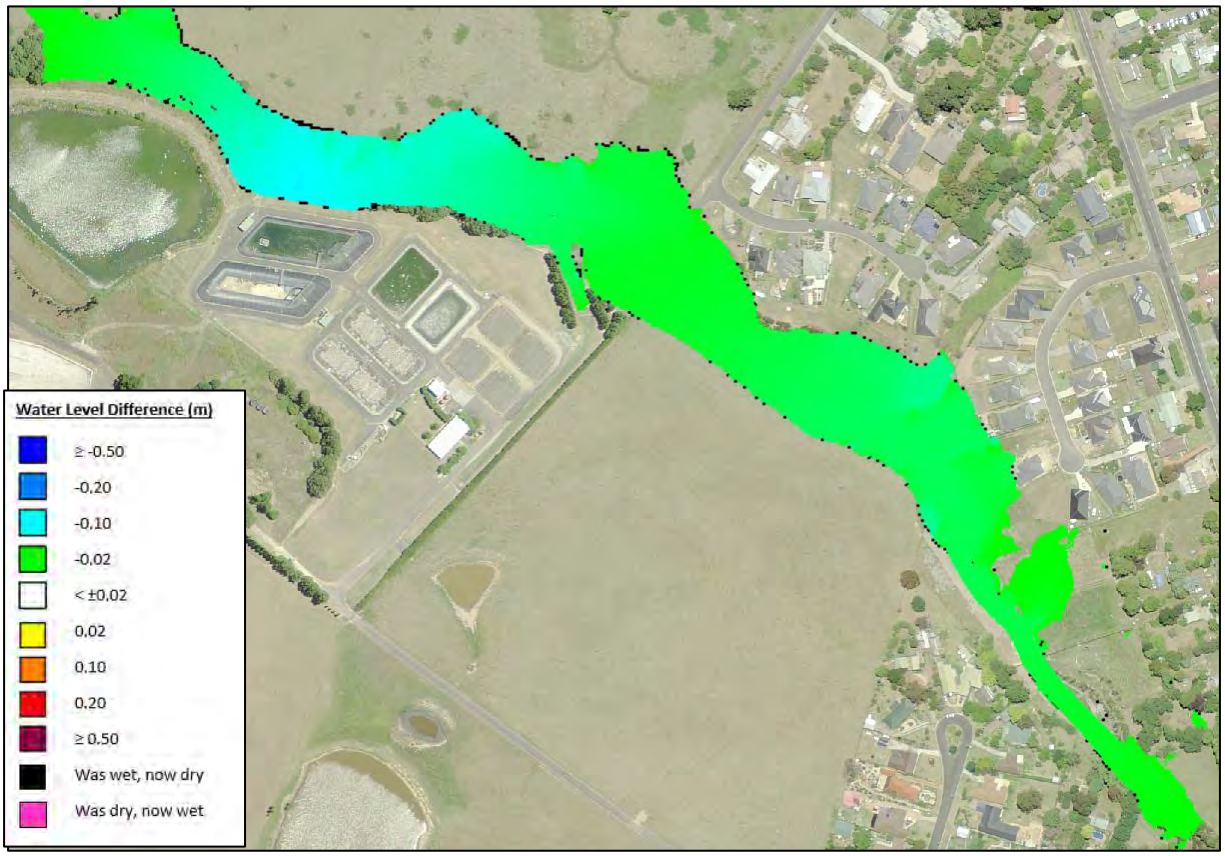


Plate 50 5% AEP Flood Level Difference Map for FM8 (Option A)

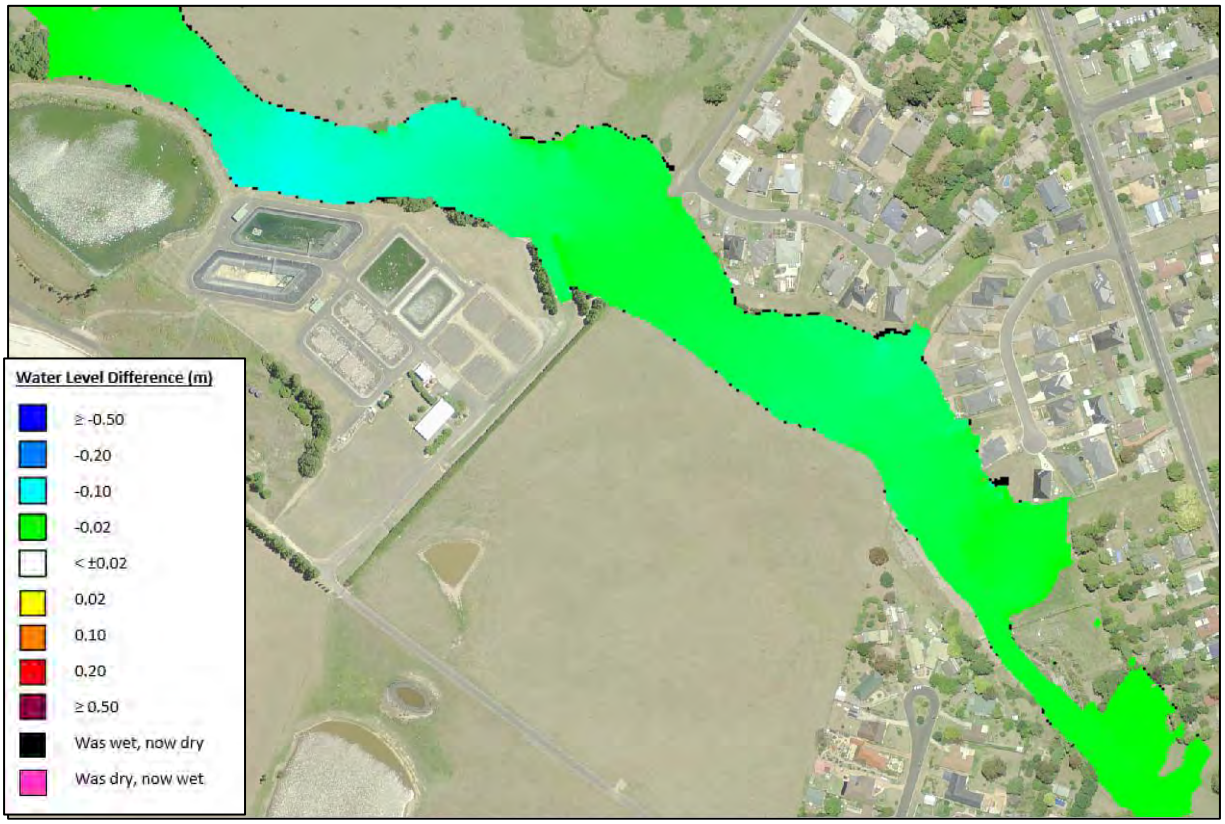


Plate 51 1% AEP Flood Level Difference Map for FM8 (Option A)

Plate 50 and Plate 51 show that the vegetation modification is predicted to produce minor reductions in existing flood levels. In all cases, the flood level reductions are predicted to be less than 0.05 metres and are predicted to afford negligible reductions in flood damages (as the flood level reductions are typically located away from the residential properties and associated infrastructure). As a result, vegetation modification was not pursued further.

In an effort to "maximise" the potential hydraulic benefits across this area of the catchment, topographic modifications were also explored. This involved lowering sections of the floodplain to provide additional conveyance capacity. The extent of the topographic changes that were explored as part of this are shown as "Option B" in **Figure 41**.

This option was included in an updated version of the TUFLOW model and the TUFLOW model was used to re-simulate each design flood. Flood level difference mapping was prepared for the 5% AEP and 1% AEP floods and is included Plate 52 and Plate 53.

The difference mapping in Plate 52 and Plate 53 shows that the topographic modifications are predicted to generate wider and more expansive flood level reductions (in excess of 0.4 metres at some locations). However, like Option A, the flood level reductions typically extend across areas of open space and not within the areas of private property that currently experience flood damage as a result of elevated water levels in Whites Creek. As a result, this option is only predicted to reduce flood damage costs by $5,000 over the next 50 years. The implementation costs are likely to far exceed this reduction in flood damages.

Neither option is predicted to provide any significant emergency response benefits.

As a result of the lack of hydraulic, financial and emergency response improvements, neither Option A nor Option B of this option are recommended for implementation.

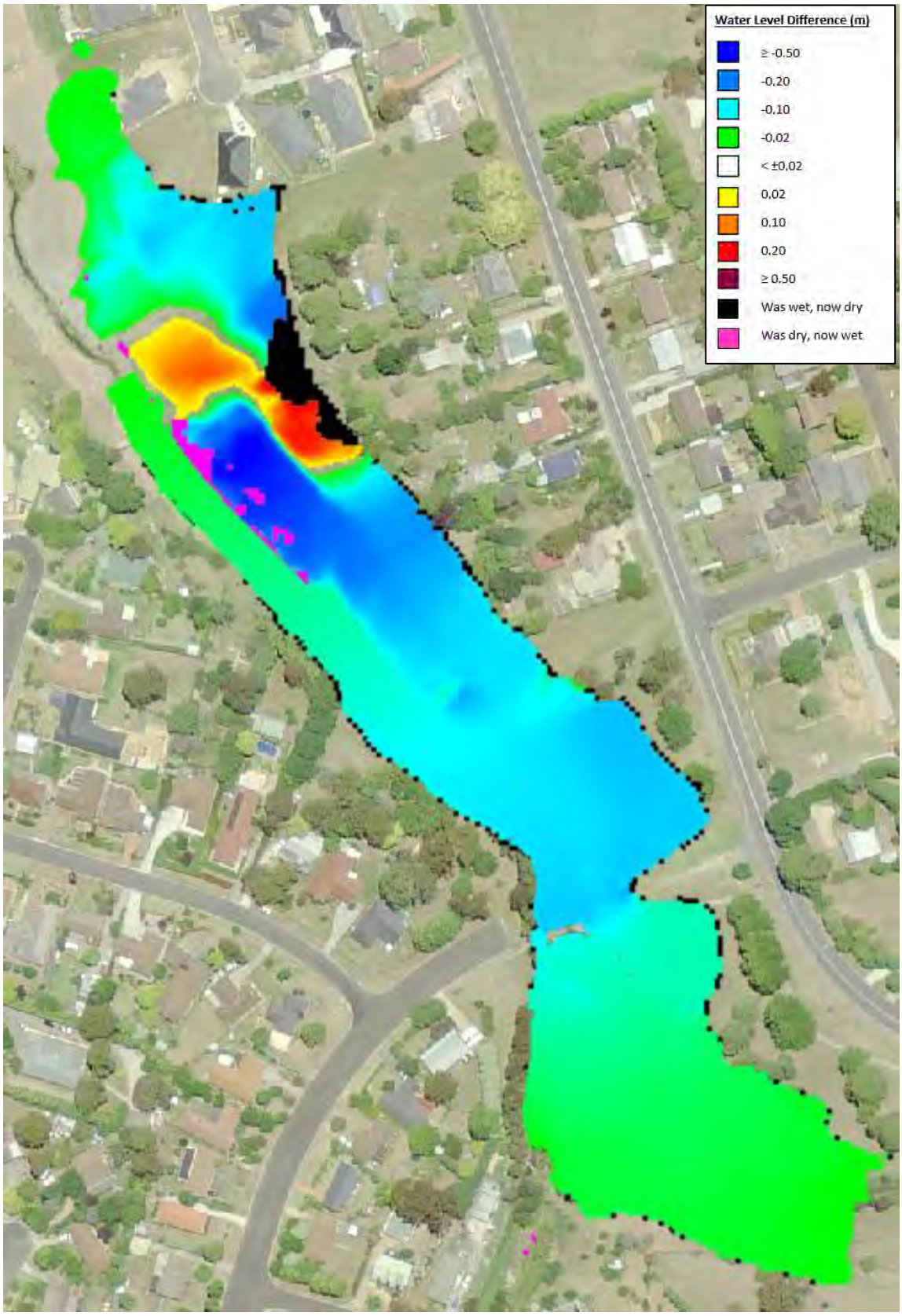


Plate 52 5% AEP Flood Level Difference Map for FM8 (Option B)

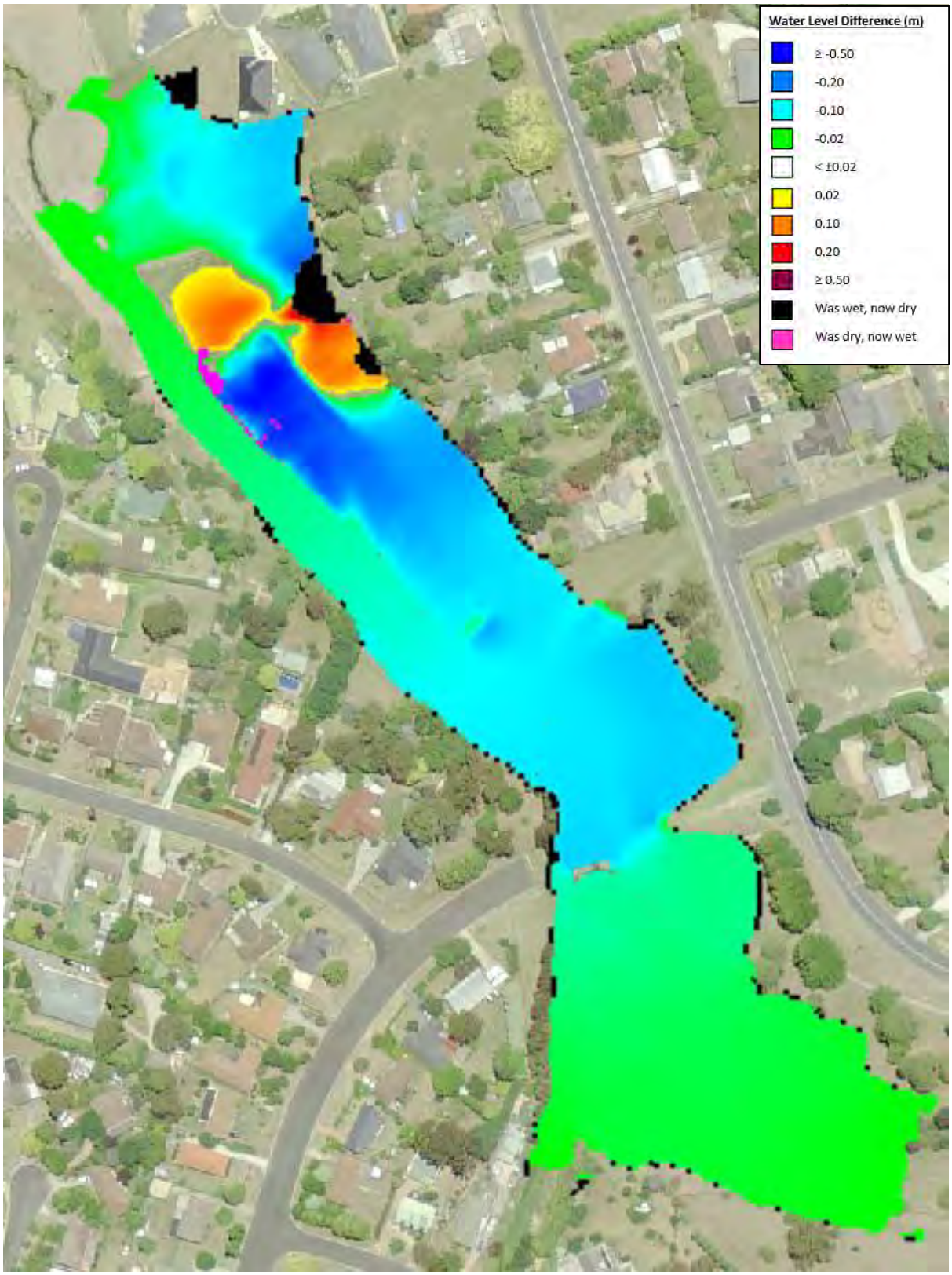


Plate 53 1% AEP Flood Level Difference Map for FM8 (Option B)

7.5 Topographic Modifications

7.5.1 Elevate Pedestrian Walkway in Walton Park between Railway and Throsby Street to Direct Flows into Downstream Channel (FM9)

Recommendation: Not recommended for implementation.

This option looks to create a small detention/storage area just upstream of the walkway that provides pedestrian across the railway between Railway Street and Throsby Street. This aims to reduce the frequency of water overtopping the walkway and flowing through downstream properties that adjoin Throsby Street. Although this area already serves as a small detention area during floods, the elevation of the current walkway directs excess flows towards existing properties that adjoin Throsby Street. As shown in Plate 54, it appears that local residents have attempted to overcome this problem by creating a small earth embankment to redirect flows away from the rear of their properties



Plate 54 Small earth embankment (lower right) that has been constructed to direct floodwater away from the rear of properties adjoining Throsby Street

The proposed changes associated with this option are shown in **Figure 42**. As shown in **Figure 42**, the modifications include elevating the pedestrian walkway (by up to 1 metre) and installing addition "high level" culverts to pass flows into the downstream channel. A spillway is also to be provided to direct flows in excess of the capacity of the storage area into the downstream open channel.

The TUFLOW computer model used to simulate design conditions was updated to include the changes shown in **Figure 42**. The revised model was then used to re-run each design flood. Floodwater level difference mapping were prepared and are provided in Plate 55 and Plate 56 for the 5% AEP and 1% AEP events respectively.

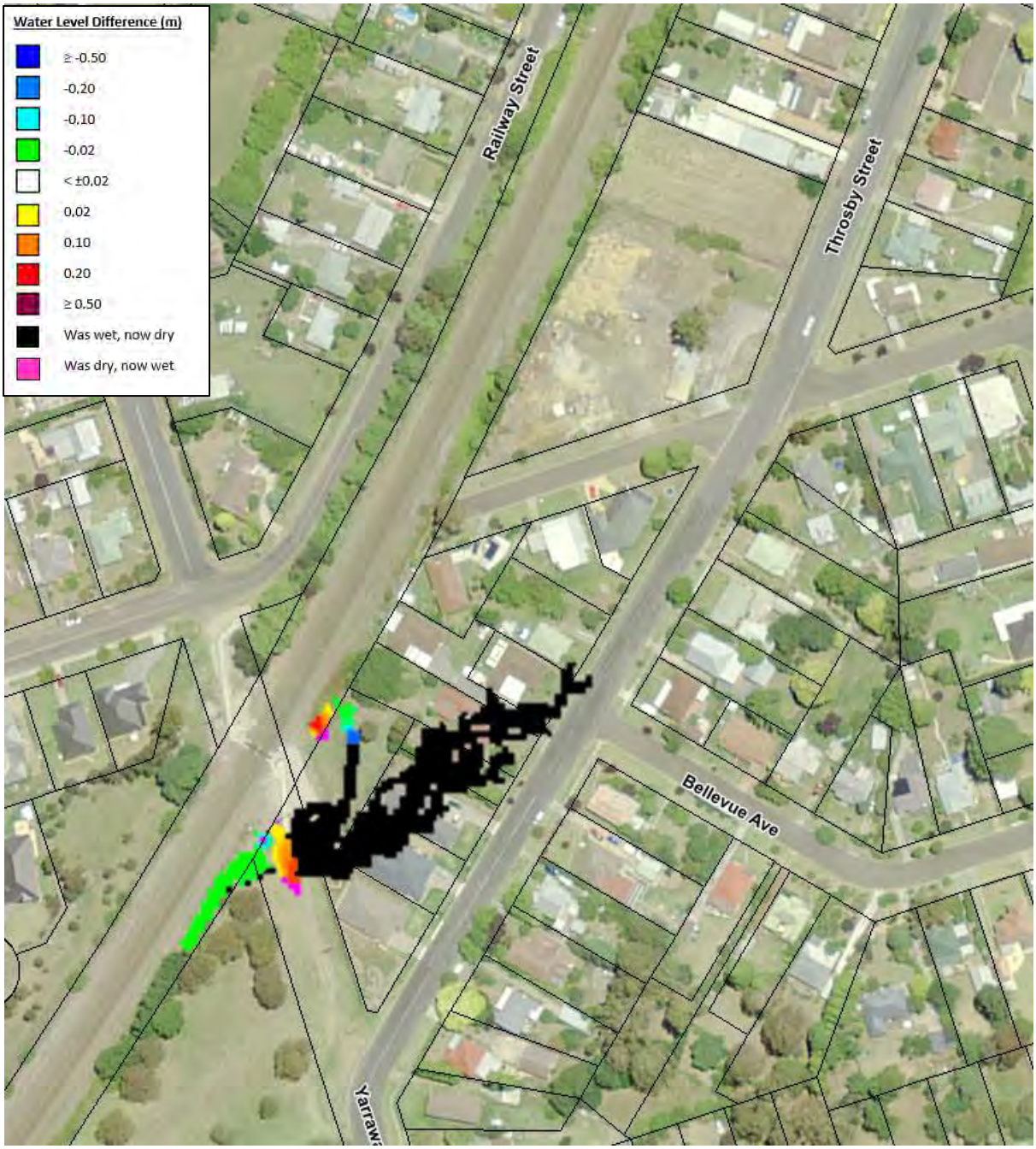


Plate 55 5% AEP Flood Level Difference Map for FM9

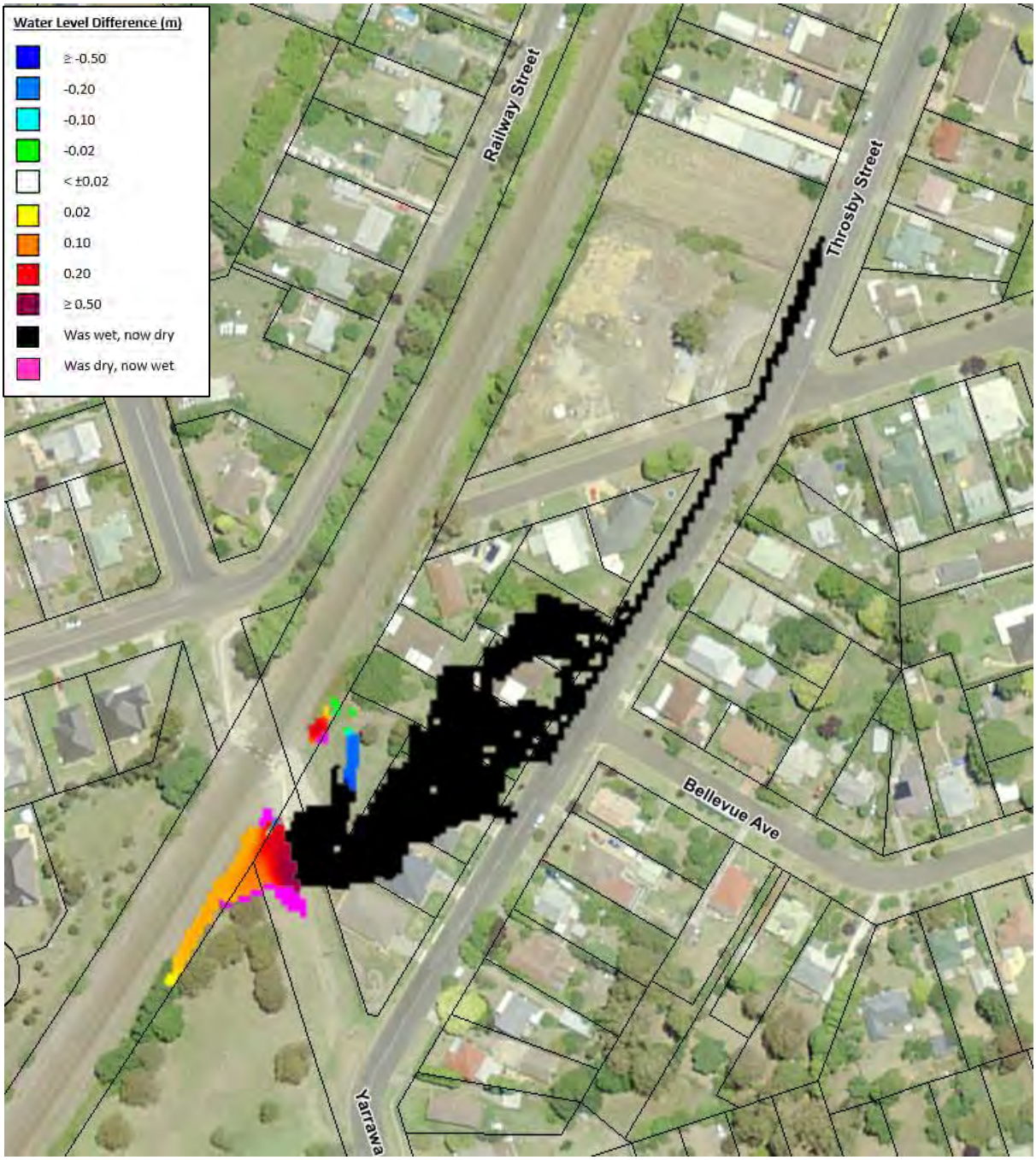


Plate 56 1% AEP Flood Level Difference Map for FM9

The results in Plate 55 show the proposed modifications are predicted to prevent inundation of the properties adjoining Throsby Street. Small reductions in flood levels are also predicted along part sections of the downstream open channel. Flood levels upstream of the walkway are predicted to increase as a result of the elevated walkway. However, the increases are contained to open space and are not sufficient to impact on the adjoining railway line.

Plate 56 shows similar hydraulic benefits during the 1% AEP event. More specifically, inundation across the properties adjoining Throsby Street downstream of the walkway is predicted to be eliminated and the downstream channel is predicted to experience small flood level reductions. Plate 56 also shows that water is predicted to overtop the spillway (i.e., the capacity of the storage would be exceeded). However, the additional flow would be directed

into the downstream channel. Again, flood level increases are predicted upstream of the walkway, however, they are contained to open space and do not impact the adjoining railway line (approximately 0.5m of freeboard would be available between the spillway elevation and the elevation of the railway line).

This option is predicted to result in one less property being exposed to above floor inundation during the 5% AEP flood and PMF.

It is expected that the proposed works will have a capital expense of about $100,000. A breakdown of the proposed cost estimate is provided in **Appendix N**.

A revised damage assessment was completed with the revised modelling results. This produced a predicted reduction in flood damages of $30,000. This provides a preliminary BCR of 0.3, indicating that the implementation costs are predicted to exceed the reduction in flood damages.

Overall, this option is predicted to afford hydraulic and flood damage reduction benefits for several properties adjoining Throsby Street. However, it is recommended that FM11 be pursued in preference to this option due to the higher benefit cost ratio and lower capital cost.

In the short-term, it is recommended that the current culvert that drains beneath the walkway is regularly maintained to ensure the frequency of walkway overtopping is reduced as much as possible.

7.5.2 Construct Levee on Eastern Bank of Whites Creek near Lackey Road (FM10)

Recommendation: Not recommended for implementation

Residential properties on the western side of Lackey Road experience inundation in events as frequent as the 10% AEP flood. This option looks to building a small levee or embankment along the eastern bank of Whites Creek in an attempt to contain floodwaters to the main creek channel.

The details for the proposed levee are provided in **Figure 43**. The works would likely include:

- A 0.2m to 0.6m high embankment extending along the eastern bank of Whites Creek. The embankment could commence near Lackey Road and terminate near existing high ground approximately 100m north-west of Lackey Road.
- Localised regrading of Lackey Road to redirect overland flows back into the creek.

The capital costs associated with implementation of this option are expected to be in the order of $270,000. A breakdown of the costs is provided in **Appendix N**. As noted, the cost estimate includes an allowance for the purchase of land at the rear of the Lacky Street properties to provide an easement for the levee.

The TUFLOW computer model was updated to include this option and the updated model was used to re-simulate each design flood. Peak floodwater level difference maps for the 5% AEP and 1% AEP floods are provided in Plate 57 and Plate 58.

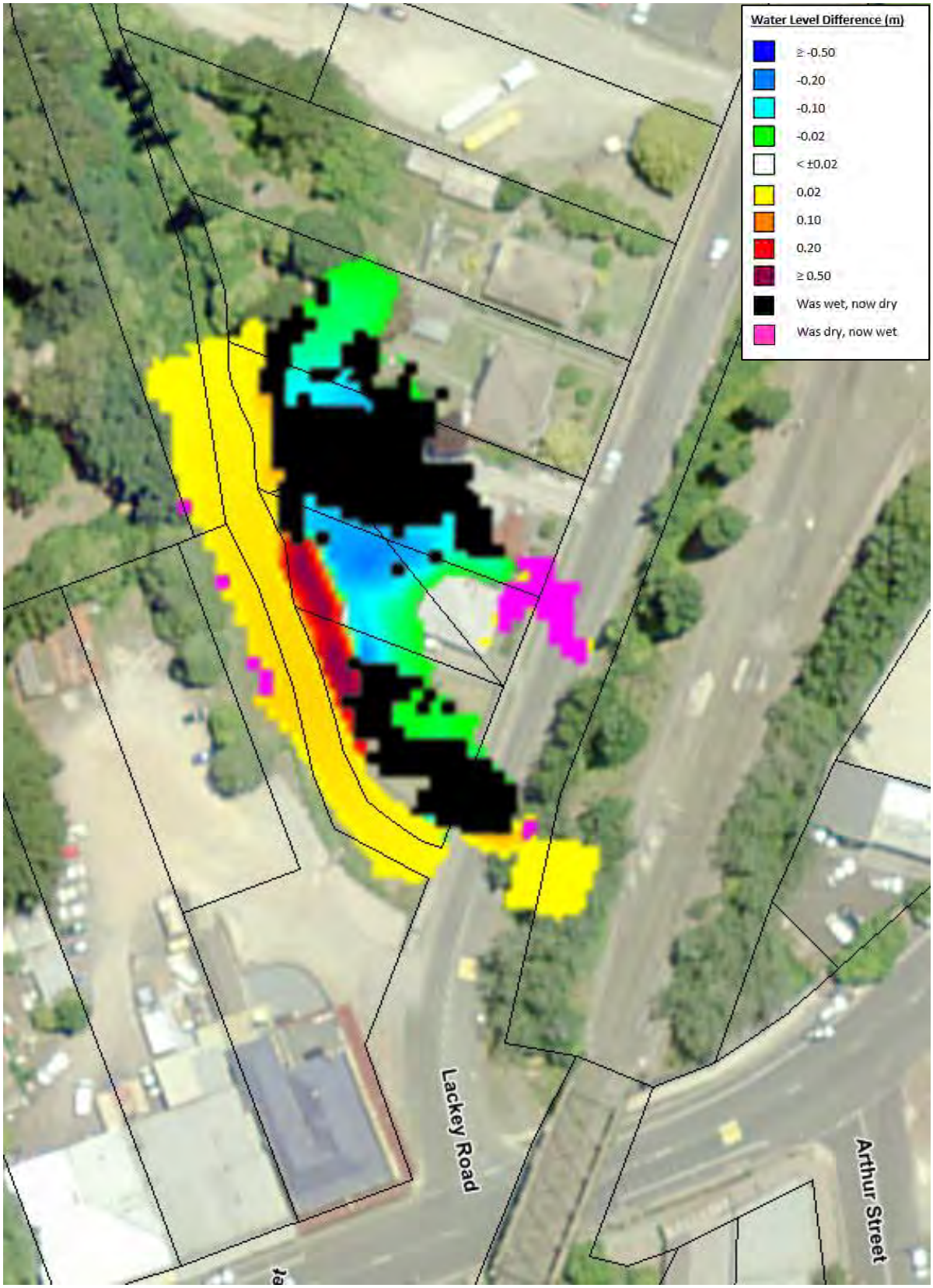


Plate 57 5% AEP Flood Level Difference Map for FM10

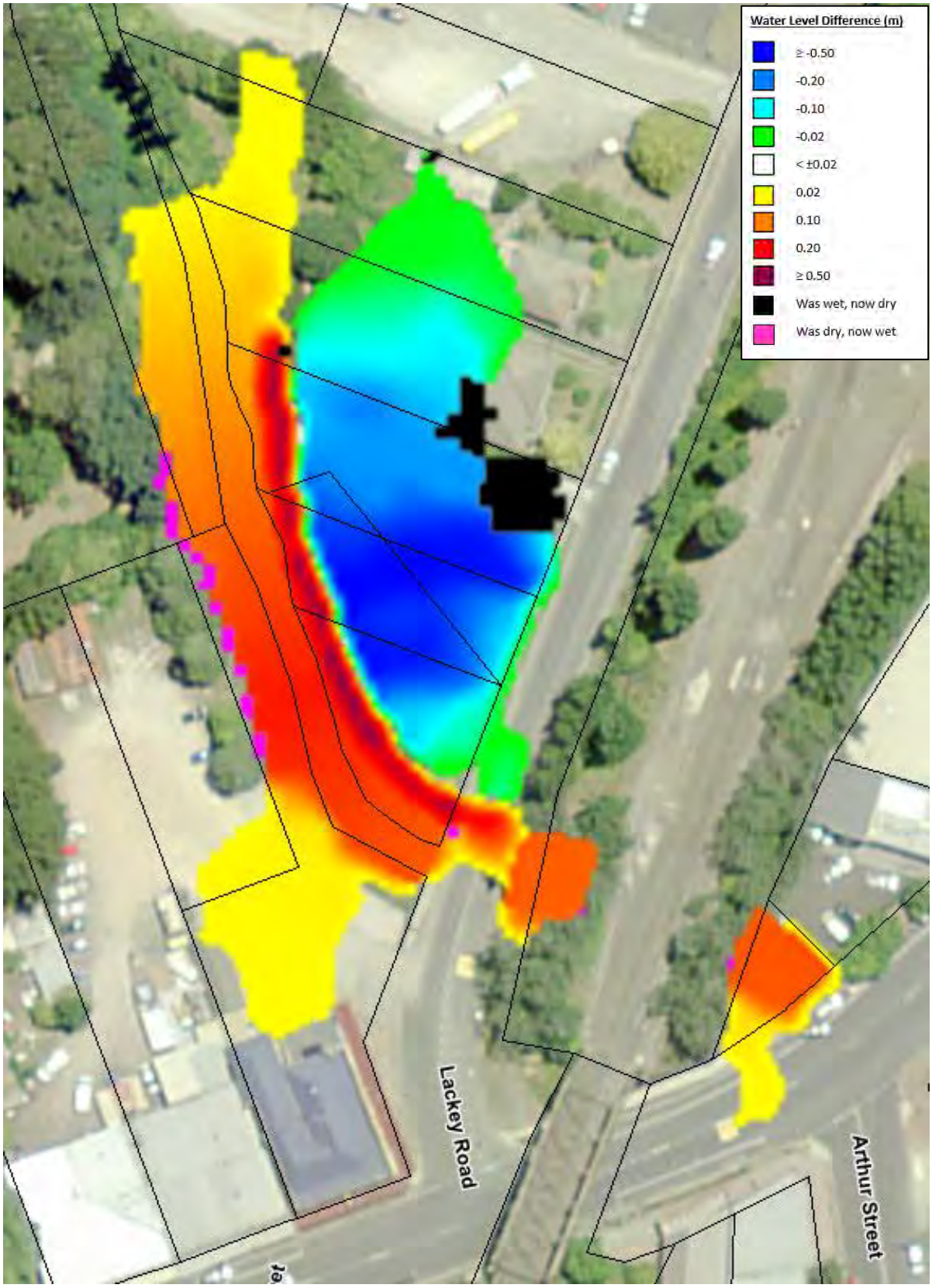


Plate 58 1% AEP Flood Level Difference Map for FM10

Plate 57 shows during the 5% AEP flood, the levee is predicted to reduce the extent and depth of inundation across the Lackey Road properties. Some increases in 5% AEP flood levels are predicted but the increases are contained to the creek channel.

Plate 58 also shows flood level reductions during the 1% AEP across the Lackey Road properties (maximum 0.30m reduction). However, it is noted that water levels are sufficiently high in the creek to still spill across the levee. Plate 58 also shows increases in flood levels within Whites Creek. The flood level increases are sufficient to extend beyond the main channel and encroach on adjoining buildings to the south. The increases are also predicted to extend upstream of the railway line and produce small increases across Argyle Street (although the increases are predicted to be less than 0.03 metres at this location).

A revised damage estimate was prepared for this option and it showed that existing flood damages costs would likely be reduced by about $10,000. Accordingly, the cost of implementing this option far outweighs the reduction in damage costs.

Overall, the limited financial benefits and the potential for the option to impact on adjoining vegetation means that this option is not recommended for implementation.

7.5.3 Elevated Embankment at the Rear of 71-77 Throsby Street (FM11)

Recommendation: Recommended for implementation

As discussed in Section 7.5.1, properties located at 71-77 Throsby Road are predicted to be inundated in frequent storm events. It appears that they have attempted to overcome this issue by constructing a small earthen embankment to redirect flows back into the open channel that adjoins the railway line. This option looks to provide a higher, more formalised embankment to provide additional protection from floodwaters. As shown in **Figure 44**, this would involve elevating the existing ground surface in this area by a further 0.2m.

The anticipated cost of this option is $10,000. A breakdown of costs is provided in **Appendix N**.

The topographic changes shown in **Figure 44** were included in the TUFLOW computer model and the updated model was used to re-simulate each design flood. Flood level difference maps were prepared for the 5% AEP and 1% AEP floods as well as the PMF and are shown in Plate 59, Plate 60 and Plate 61.

Plate 59 and Plate 60 shows that the embankment is predicted to prevent inundation of multiple Throsby Street properties during the 5% AEP and 1% AEP flood. Plate 61 shows that the embankment is not sufficiently elevated to prevent inundation of the Throsby Street properties during the PMF. However, it would reduce PMF water levels across the properties by up to 0.2 metres. Some localised increases are predicted upstream of the embankment during the PMF, but the increases are contained to areas of open space.

A revised damage assessment was completed based upon the updated results, which shows a reduction in damages of $30,000. This produces a preliminary benefit cost ratio of 3, indicating a significant positive economic outcome.

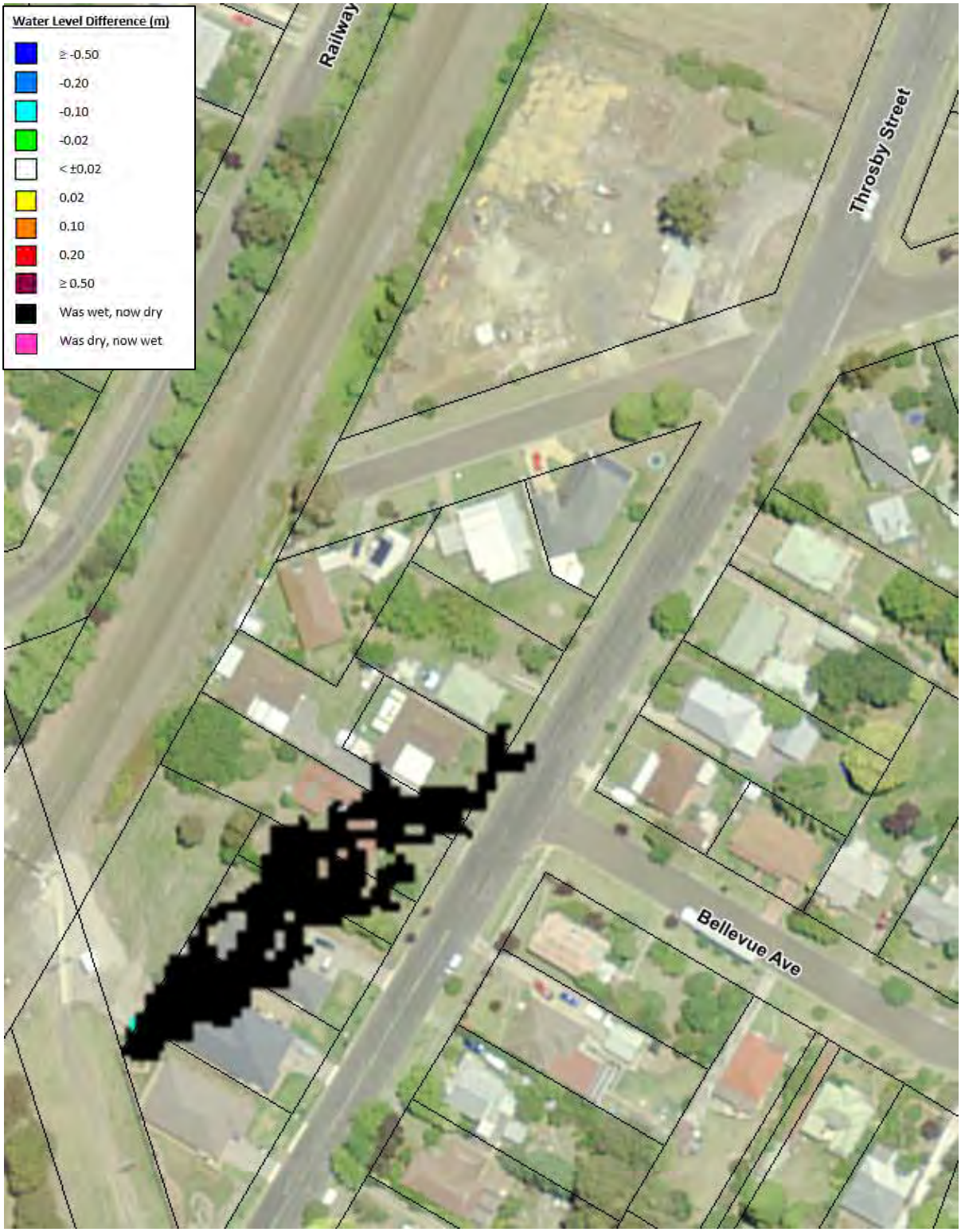


Plate 59 5% AEP Flood Level Difference Map for FM11

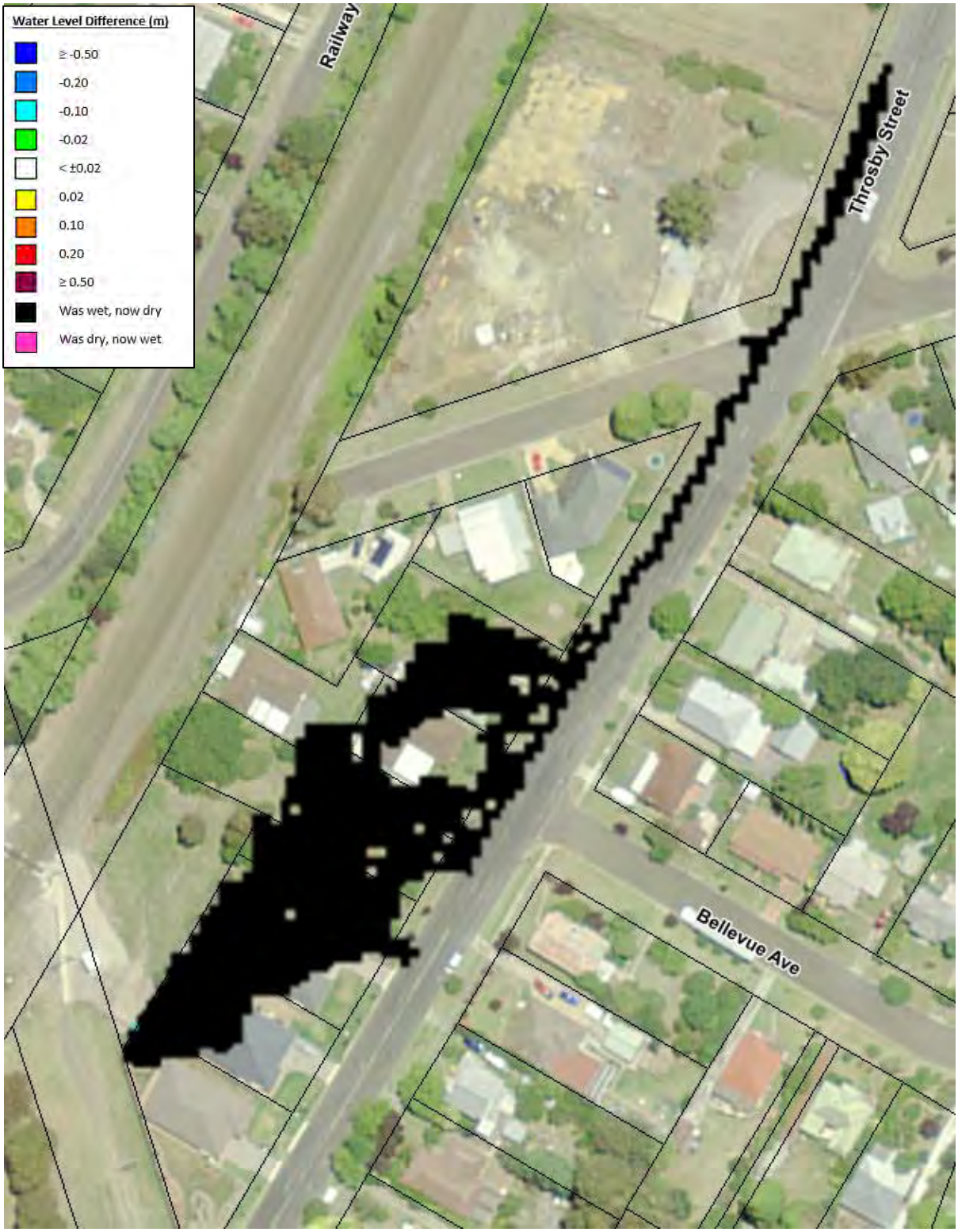


Plate 60 1% AEP Flood Level Difference Map for FM11



Plate 61 PMF Flood Level Difference Map for FM11

Due to the low anticipated capital cost and high benefit cost ratio, this option appears to be viable. It is recommended that consultation with local residents be completed to confirm that they have no major objections to the proposed works. If these discussions yield a positive outcome, it is recommended that this option is implemented. However, it should be noted that all properties that would benefit from this option were constructed after 1986. As a result, they would not be eligible for state government funding. Therefore, complete funding of this option would likely need to be provided by Council.

7.5.4 Construct Levee at Rear of 51-55 Throsby Street (FM12)

Recommendation: Not recommended for implementation

This option looks to build a small levee adjoining the open channel that runs alongside the railway line at the rear of 51-55 Throsby Street. This would aim to reduce the frequency of water overtopping the banks of the channel and inundating these properties. The extent of the modifications associated with this option are shown in **Figure 45** and would involve elevating the existing terrain near the western property boundaries by between 0.2 and 0.4 metres.

This option was included in an updated version of the TUFLOW model and the TUFLOW model was used to re-simulate each design flood. Flood level difference mapping for the 1% AEP flood and PMF with this option in place are provided in Plate 62 and Plate 63. Difference mapping was also prepared for the 5% AEP flood, but this showed no changes (i.e., water is not predicted to overtop the channel during the 5% AEP flood and, therefore, the levee affords no benefits).

Plate 62 shows that the levee is predicted to prevent inundation of the Throsby Street properties during the 1% AEP flood. Flood level increases are predicted within the open channel. However, they are not sufficient to impact on the level of service afforded by the railway line.

Plate 63 shows that the levee would not afford any hydraulic benefits during the PMF. In fact, the levee would impede the path of floodwater draining across these properties towards the channel resulting in flood level increases of up to 0.1 metres. This is sufficient to result in 1 additional property being exposed to above floor inundation.

It is expected the levee would cost in the order of $30,000 to construct. A breakdown of the cost estimate is provided in **Appendix N**.

A revised damage estimate was prepared and showed that the proposed levee was predicted to reduced total flood damage costs by $10,000. This yields a preliminary benefit cost ratio of 0.3.

The lower benefit cost ratio and the predicted adverse flood impacts during the PMF mean that this option is not recommended for implementation.

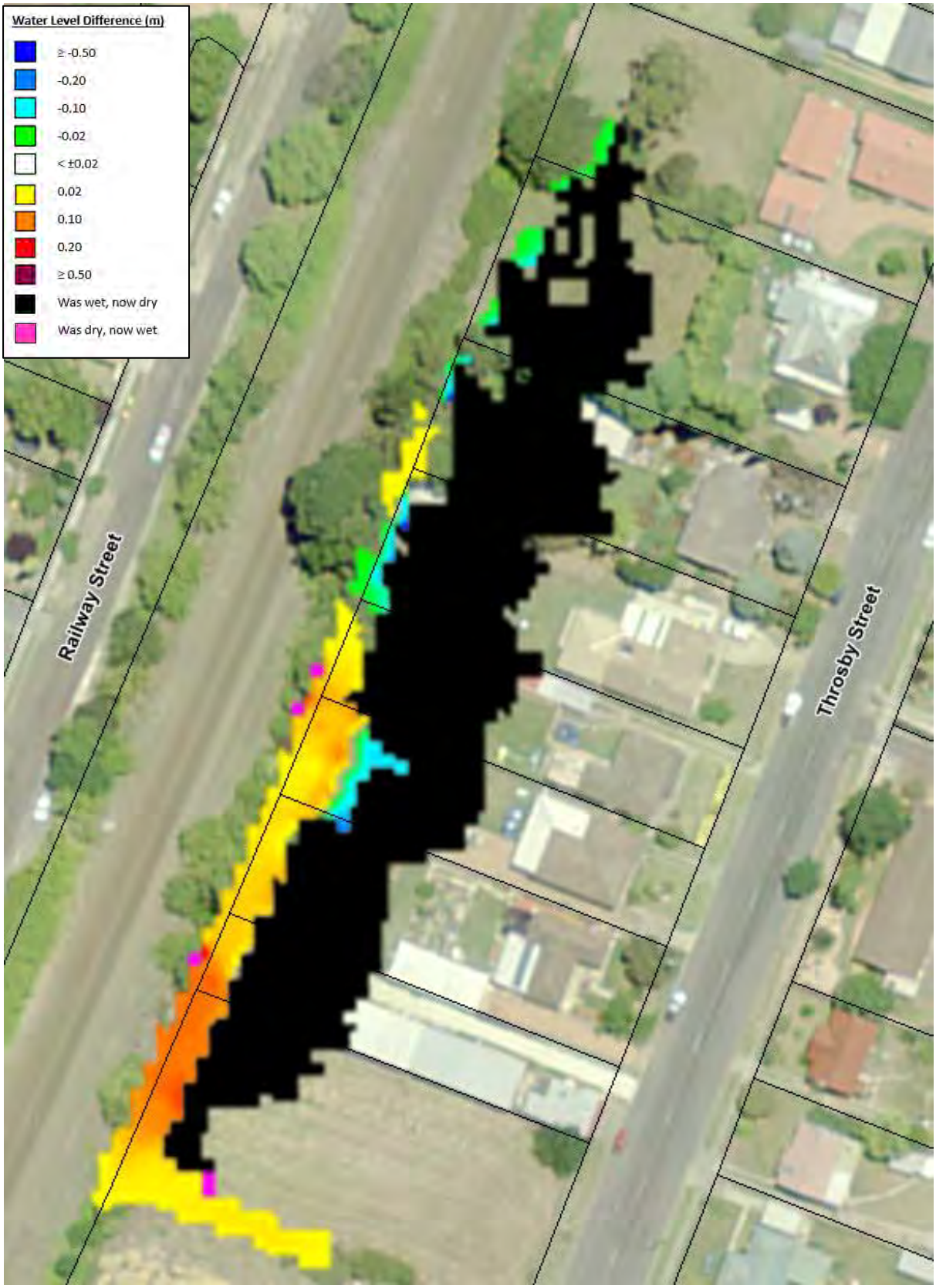


Plate 62 1% AEP Flood Level Difference Map for FM12



Plate 63 PMF Flood Level Difference Map for FM12

7.5.5 Regrading of Lackey Road from Argyle Street to Whites Creek (FM13)

Recommendation: Not recommended for implementation

This option looks to regrade Lackey Road from Argyle Street towards the Whites Creek channel. This would aim to allow water that currently "ponds" beneath the railway line to more readily drain away, thereby reducing inundation depths and extents across Argyle Street. The extent of the suggested changes is shown in **Figure 46**. As shown in Figure 46, this would typically require lowering the existing ground levels by less than 0.3 although some localised reduction of more than 0.6 metres would be required near the Whites Creek channel.

It is expected that the regrading would cost in the order of $450,000. A breakdown of the cost estimate is provided in **Appendix N**.

The terrain modifications were also included in a modified version of the TUFLOW model and the modified model was used to re-simulate each design flood. Floodwater difference mapping for the 5% AEP and 1% AEP floods with this option in place are provided in Plate 64 and Plate 65.

Plate 64 and Plate 65 show that this option is predicted to provide flood level reductions across Argyle Street and Lackey Road. Flood level reductions of up to 0.2 metres are predicted during the 5% AEP flood and a large section of Lackey Road is predicted to be "flood free". However, the lowering of Lackey Road near its intersection with Argyle Street would increase the frequency and depth of inundation at this location (i.e., this option would reduce the flood liability of Argyle Street but is unlikely to reduce the flood liability of Lackey Road).

There are predicted to be no changes in the number of properties subject to above floor inundation as most of the flood level reductions are contained to the respective roadways.

The results of a revised damage assessment with this option in place indicates that it would likely reduce existing damages by about $20,000, which provides a benefit cost ratio less than 0.1. In addition, this option does not appear to afford significant emergency response benefits. As a result, it is not recommended for implementation.

7.6 Recommendations

The following flood mitigation options are recommended for further consideration to assist in managing the existing and future flood risk across the Whites Creek catchment:

- New detention basin in Broulee Park (FM2); and,
- Elevated embankment at the read of 51-55 Throsby Street (FM12).

It is recommended that Council hold discussions with Australian Rail Track Corporation (ARTC) and Rods and Maritime Service (RMS) to determine the potential to upgrade the existing railway culverts near Argyle Street (FM5).

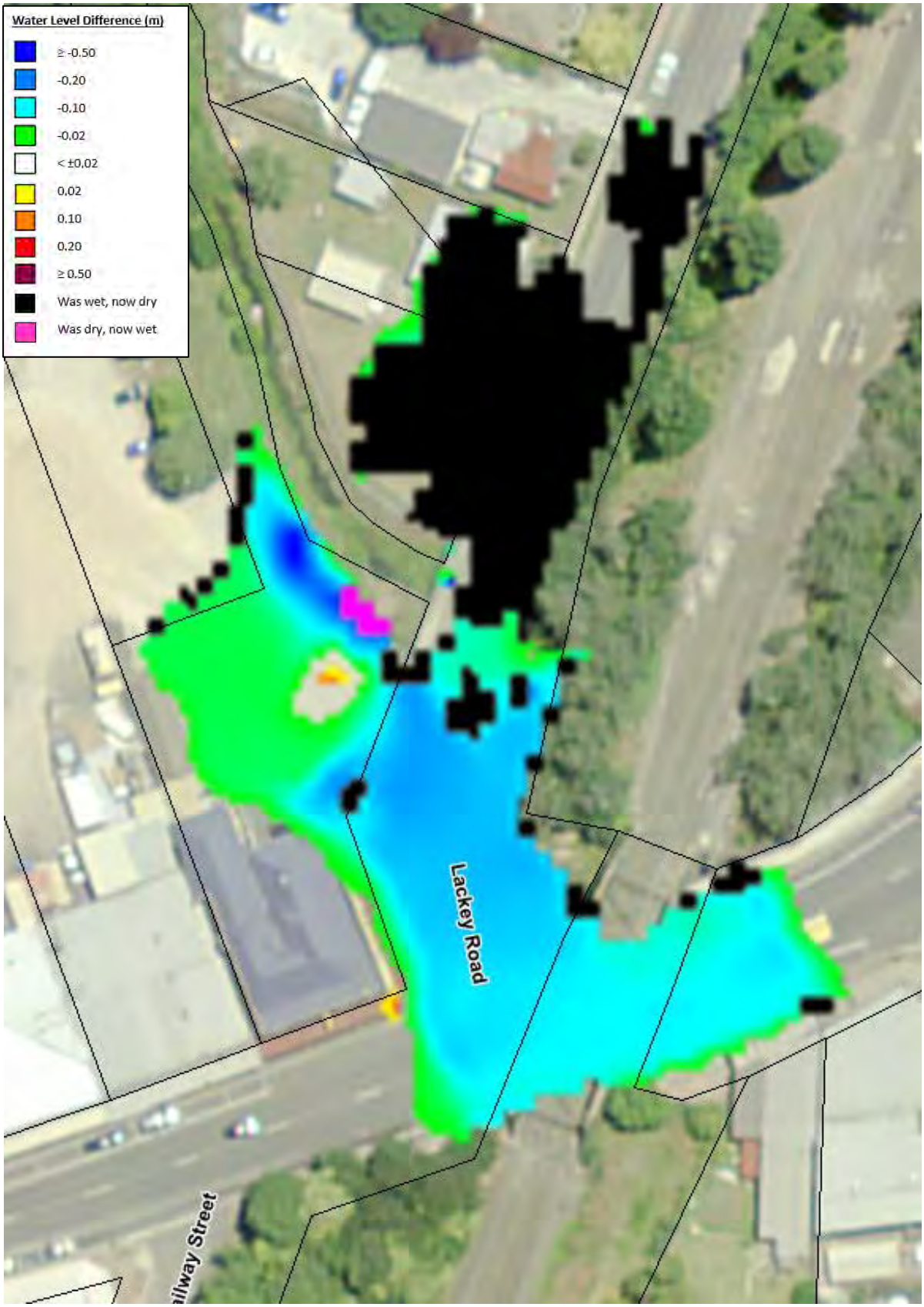


Plate 64 5% AEP Flood Level Difference Map for FM13

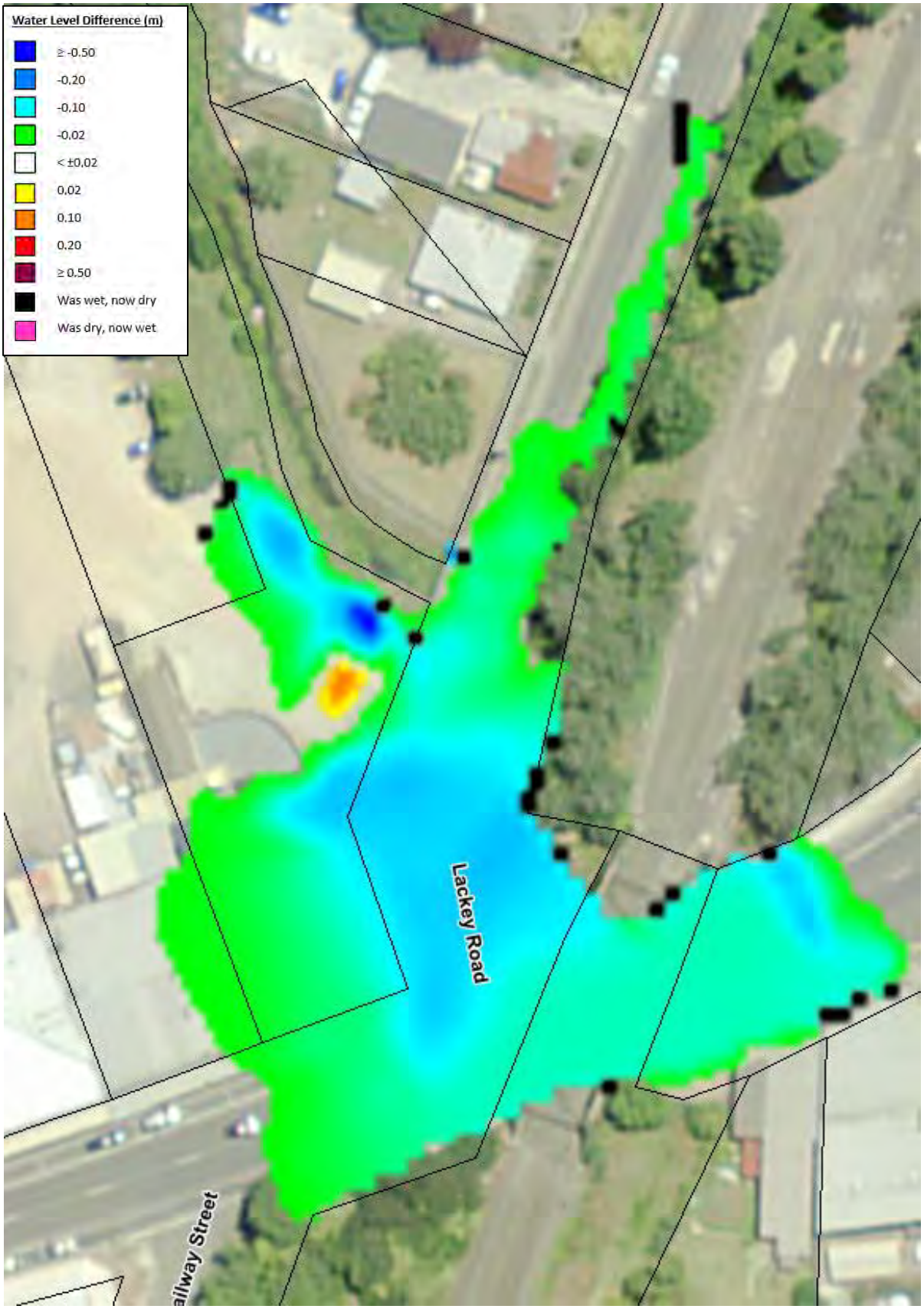


Plate 65 1% AEP Flood Level Difference Map for FM13

8 PROPERTY MODIFICATION OPTIONS

8.1 Introduction

Property modification options refer to modifications to planning controls and/or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. Modifications to individual properties are typically used to manage existing flood risk while planning measures are employed to manage future flood risk.

Further discussion on the potential property and planning modifications that could be implemented are provided in the following sections.

8.2 Planning Modifications

8.2.1 Changes to Wingecarribee Shire Council LEP (PM1)

Recommendations:
A) Amend Wingecarribee Shire Council LEP to remove the flood planning area map from the LEP and make publicly available elsewhere and/or on council's website.
B) Include an additional "Floodplain Risk Management" clause in the LEP for areas between the flood planning area and the edge of the low flood risk precinct.

A review of the Wingecarribee Shire Council LEP (2010) was completed and the outcomes of this review are summarised in Section 4.3.1. As discussed in Section 4.3.1, it is recommended that any future updates of the LEP consider the following changes:

- Remove the flood planning area maps from the LEP and make these maps available to the public on council's website, and/or through other means. This will help to ensure that council will be able to update the flood planning area maps immediately, ensuring that the most current and up to date flood information is available to the public. The current process of amending and updating flood maps through the LEP gazettal process is timely and cannot accurately include the changes to the flood planning area in a timely manner that can result as development progresses with site specific flood studies.
- Include an additional "Floodplain Risk Management" clause in the LEP which would would relate to the areas between the flood planning area and the edge of the low flood risk precinct. The current DCP refers to these areas as "low flood risk precinct" with specific development controls, however this area is currently not included on the flood planning area map related to these development controls or reflected in the wording of clause 7.9 of Councils current LEP, as discussed in Section 4.3.1 of this report. The Flood Planning Area Map will also need to be updated to include these areas.

8.2.2 Changes to Moss Vale Town Plan DCP (PM2)

Recommendations: Amend Moss Vale Town Plan DCP considering the detailed review presented in Section 4.3.2 of this report.

A review of the relevant clauses of Moss Vale Town Plan DCP 2017 was completed and a detailed discussion on the outcomes of this review are documented in Section 4.3.2. As discussed, it is recommended that any future updates of this DCP consider the following changes:

- Update text of Figure 4.2 to make it clear and legible.
- Extend the 'structural soundness' requirements so that structures within vulnerable sections of the floodplain (i.e., areas with evacuation difficulties or subject to H5 or H6 hazard during the PMF) are designed to withstand the forces of floodwater during all events up to and including the PMF for other development types. This control currently only applies to sensitive land uses where refuge-in-place may be necessary if early evacuation is not completed.
- Consider modifying Figure A4.2 of the DCP to provide specific advice on what floods need to be considered as part of the flood impact assessment.

8.2.3 Update Section 10.7 Certificate Information (PM3)

Recommendations: Updated Section 10.7 certificate to reference updated design flood information generated as part of the current study.

It is recommended that Council update Section 10.7 certificates to reference the updated design flood information generated as part of the current study. This will help to ensure the most up-to-date information is available and used for properties located within the Whites Creek catchment.

This needs to be implemented with the other changes identified in the preceding sections of this report regarding the updating of the LEP and DCP flood mapping information to include all flood constraints up to and including the PMF, as indicated as "low flood risk precincts" in Council's DCP.

8.3 Modification Options for Individual Properties

8.3.1 Voluntary House Raising (PM4)

Recommendation: Not recommended for implementation

Voluntary house raising (VHR) is a well-established method of reducing the frequency, depth and duration of above floor inundation. VHR can be a suitable measure for reducing the flood damage for individual dwellings or can be used as a compensatory measure where other flood mitigation works are predicted to adversely impact on flood behaviour across individual dwellings. An example of house raising is provided in **Plate 66**.

VHR is best suited to single-storey, timber or clad walled houses with a pier and beam foundation in areas of low flood hazard where structural mitigation works are impractical or uneconomic. It should also be noted that Government funding is only available for VHR for residential properties that were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted (Office of Environment & Heritage, 2013b).



Plate 66 Examples of houses before (top image), during (middle image) and after (bottom image) house raising (photos courtesy of Fairfield City Council)

The computer flood modelling outputs were interrogated in conjunction with building footprints to identify houses that may be eligible for VHR. Specifically, houses that met the following criteria were pursued:

- Subject to frequent above floor inundation. In this regard, properties that were predicted to be inundated above floor level during events more frequent than the 1% AEP flood; and,
- Low flood hazard area at the peak of the 1% AEP event;

The outcomes of this assessment revealed that the majority of buildings subject to frequent above floor inundation are commercial buildings that are not located within low flood hazard areas (refer Plate 67). Furthermore, all buildings except one are brick buildings on a concrete slab so are not suitable for house raising, with the remaining residential property a double storey property that could not be raised. As a result, there are no properties within the Whites Creek catchment that are considered to be suitable or eligible for voluntary house raising.



Plate 67 Properties subject to frequent above floor flooding and exposed to low hazard in 1% AEP flood (commercial = blue and residential green)

As most of these commercial properties are of an older style and some are already being considered for re-development (such as on the corner of Argyle Street and Lackey Street), it is considered that the flood risk can be best managed through the application of appropriate development controls through the planning and development process. These include floor level controls associated with the flood planning level and appropriate floor-space ratio controls.

8.4 Recommendations

The following property modification options have been evaluated as part of the study and are considered viable for further consideration to assist in managing the future flood risk across the Whites Creek catchment:

- LEP Amendments;
- DCP Amendments; and,
- Update Section 10.7 Certificate Information.

9 RESPONSE MODIFICATION OPTIONS

9.1 Introduction

It is generally not economically feasible to treat all flood risk up to and including the PMF through flood modification and property modification measures. Therefore, response modification measures are implemented to manage the residual/continuing flood risk by improving the way in which emergency services and the public respond before, during and after floods. Response modification measures are often the simplest and most cost-effective measures that can be implemented and, therefore, form a critical component of the flood risk management strategy for the Whites Creek catchment.

Response modifications options considered as part of the study include:

- Emergency response planning (i.e., planning before a flood) (Section 9.2);
- Options to improve emergency response during a flood (Section 9.3);
- Flood Insurance (Section 9.4).

Further discussion on response modification options that could be potentially implemented is provided below.

9.2 Emergency Response Planning

Effective planning for emergency response is a vital way of reducing risks to life and property, particularly for infrequent floods that are not managed through flood or property modification measures. Potential opportunities for improvements to existing emergency response planning are discussed below.

9.2.1 Community Education Strategy (RM1)

Recommendations: Develop local Floodsafe documents, develop educational messages targeting dangerous behaviours during a flood and undertake localised and tailored education campaigns for high hazard areas.

An effective community education program is often the most effective emergency response planning strategy as it allows individuals to become more self-sufficient and less reliant on emergency services.

Although the population contained within the Whites Creek catchment is not particularly large and there are relatively few properties that would be impacted during floods up to and including a 1% AEP flood, it is unlikely that the local SES unit has sufficient resources to assist all “at risk” properties within this catchment as well as adjoining catchments, particularly during very rare floods (e.g., the PMF). The main emergency response issue in this catchment is the vulnerability of the Argyle Street rail underpasses to inundation relatively quickly and in frequent flood events, with a lack of an alternate flood free access from the east to the west

of Moss Vale during a flood event. Thus, there is an increased risk of people driving though floodwaters at this location during all flood events. The SES are aware of the flooding problems at this location. However, even if SES resources can be deployed, the "flashy" nature of flooding within the catchment may mean that roads will already be cut by the time the SES arrive or have time to close off inundated roads. This emphasises the importance of the at-risk communities being equipped to respond appropriately to flooding without reliance on the emergency services.

A community survey conducted for this floodplain risk management study indicated that 40% of respondents would remain at home and 23% of respondents were unsure of how they would respond during a future flood. Some members of the community did not believe their house could be flooded, including the residents of two properties that are contained within the PMF extent; one in a low hazard area and another in a high hazard area. This also highlights the need for community education activities to ensure the community better understands their flood risk/exposure and knows how to respond during future floods.

It should be noted that historically the NSW Governments' Floodplain Management Program has been reluctant to fund community education initiatives related to flooding. One reason is that this is seen as primarily the responsibility of the NSW SES, with Councils supporting the SES. The second reason is the recognised need for sustained investment to build and maintain community flood awareness and readiness, especially in the absence of major floods that serve as a natural reminder of the risk. In addition, the dynamics of communities can lead to people with no prior knowledge or experience of flooding moving into a flood prone area. Historically the NSW Governments' Floodplain Management Program has funded capital infrastructure works but not maintenance expenditure and rarely community flood education programs, to help manage the flood risk in communities. This means that Council funding to assist the NSW SES may have to be sourced elsewhere.

From the flood hazard assessments and the outcomes of the community questionnaire, a number of key messages need to be disseminated to the community in the Whites Creek catchment as part of future education activities:

- "Never drive, ride, walk or play in floodwaters." The need to continue broadcasting this message is suggested by the knowledge that motorists in Australia continue to lose their lives when attempting to cross floodwaters, particularly given the susceptibility of Argyle Street (one of the major roadways in the catchment) being subject to relatively frequent inundation. Messages could also provide technical information to dissuade drivers from crossing or driving through flooded roads, such as the depths at which cars float. Messages could also target the motivations for crossing water, such as by encouraging childcare centres and schools to advise parents during storms or floods that their children are safe. If alternate evacuation routes are provided (refer Section 9.3.2), this could also be highlighted as part of the education messages.
- "One day a bigger, faster flood will happen than what anyone has ever seen. Council has modelled what these floods might be like. Learn whether your house or access to your business could be flooded in an extreme flood. Identify whether it's safe for you to stay or whether you need to evacuate before flooding. Plan ahead to keep your family/staff safe". A message such as this is important because of the high proportion of respondents

to the questionnaire who indicated they would shelter-in-place rather than evacuate or had no flood plan at all.

- "The safest place to be in a flood is away from the floodwaters. Therefore, early evacuation is recommended for flood prone properties. However, if early evacuation is not completed it may be safer to stay than to attempt to evacuate late." The potential depths of above-floor inundation for dwellings in the study area are generally lower than potential depths on roadways, which in combination with high flow velocities and adverse weather conditions, could lead to highly hazardous driving conditions. Also, the duration of local catchment flooding is relatively short, lending itself to messaging such as "Wait a few hours rather than go out in the rain".

As discussed, the primary flood "hot spot" is concentrated around the Argyle Street railway underpass. The flood hazard across this area is significant during particularly rare flood events (see Section 3.4.1). Therefore, in addition to the general education messages suggested above, targeted education programs for this area are considered to be worthwhile. This may include a SES business breakfast where the flood risk could be explained with the assistance of flood maps and animations produced as part of the current study. Suggestions on how owners and occupiers could best prepare and respond to the infrequent flooding could also be provided (e.g., preparation of flood emergency response plans, as discussed in Section 9.2.3).

It is also suggested that the SES could prepare Floodsafe documents for the local area to provide general flood education information. The documents could be developed to be generic enough to indicate how residents can plan for floods even if their property is not flood prone, what to do during a flood, such as evacuation routes and centres, and what options are available to residents and business owners to assist with post-flood recovery.

9.2.2 Make Property Level Flood Information Available (RM2)

Recommendations: Make additional flood information available at a property scale for all properties impacted by flooding up to and including the PMF, including flood depths, hazards and emergency response classifications, with suitable explanations and guidance as to how this information can be used to inform flood emergency plans.

A starting point for improving people's readiness for floods is to help them better understand how they could be directly affected by floods. Knowing how their house or business could be directly affected by floods is more likely to cut through the scepticism that can grow when communities are not flooded for some years, than more generic advice.

Advancements in flood modelling software and associated spatial datasets have significantly enhanced the quantity and quality of information from flood studies and floodplain risk management studies available at the property level. Council makes components of flood and floodplain risk management studies available via their website. However, this is considered to be relatively limited in nature and the information that is provided can be difficult to navigate down to the individual "property level".

A more extensive library of flood mapping covering the full range of potential design floods would provide local residents and business owners with a more comprehensive understanding

of the potential impacts of flooding on their property and roads that may impact the access to or from their property. Alternatively, the existing flood extent information could be provided on an online mapping webpage to make it easier for the community to find all flood mapping in a single place. This mapping could include design flood depths, hydraulic hazard, information describing when and where access to individual properties will be cut during a flood. This would also assist with providing proponents or purchasers of property in the catchment with the full suite of flood information related to flood constrains that council is aware of for each property in this catchment.

This, however, might require additional Council resources and training to answer inquiries about what this information means and how it could be used to assist in the preparation of property-level flood response plans (discussed in Section 9.2.3). However, as there are relatively few properties impacted by these events, it is considered a worthwhile investment of council resources.

Material to answer "Frequently Asked Questions" (FAQ) may also need to be developed and updated to accompany any upscaling of flood information availability. For example, people are often concerned about the perceived impact of flood information on property values and insurance premiums. Potential answers have been developed by Floodplain Management Australia and the Insurance Council of Australia and could be used as a starting point for preparation of a specific FAQ sheet.

If Council's existing website cannot accommodate this information, it could be included in a separate flood information portal website. It would be desirable to have a single authoritative website of all of councils flooding information across the LGA to minimise confusion for residents and business owners and maintain consistency in the information being disseminated.

A flood information portal would aim to provide information that will allow property owners to understand their existing flood risk which can "feed" into the preparation of personalised flood plans.

An advantage of websites is their ability to be a living document incorporating current information sources such as flood mapping, BoM warnings, live information on nearby rain gauges and river gauges, and the latest advice from relevant organisations such as NSW SES and RMS. If well maintained, a website can serve as a central repository for a range of contemporary flood information.

9.2.3 Flood Emergency Response Plans (RM3 and RM4)

This floodplain risk management study has estimated that less than 10 properties are predicted to be impacted by over floor flooding in a 1% AEP event, and just over 100 impacted in a PMF event. Accordingly, the property level impacts are relatively low.

However, the inundation of both the Argyle Street and Spring Street rail underpasses means significant impacts to access through and around Moss Vale are anticipated during even frequent floods. Although there are relatively few isolated areas during the 1% AEP flood, the number of "flood islands" increases significant during the PMF. As such, the preparation of residential and commercial flood plans are assessed here, with emphasis on travelling on flood

prone roads as well as the protection of personal and business/commercial property around the Argyle Street area.

Home Flood Plan Preparation (RM3)

Recommendations: Host community or locality meetings to promote the preparation of Home Emergency Plans. These plans should highlight the vulnerability of and disruption to the road network during flood times in Moss Vale and provide advice on potential alternate evacuation routes.

It is unlikely that many private dwellings within the flood prone areas have formal flood emergency response plans given the lack of recent flood events and the limited number of residential properties that are vulnerable to flood hazards. Accordingly, the preparation of home flood plans is encouraged as a way of making the broader community more "flood aware" and allowing the community to be more proactive during future floods and less reliant on emergency services. The plan should set out protocols to follow by the household before, during and after a flood to help mitigate damages and the potential for risk to life at the property level. The Home Flood Plans in this catchment should clearly highlight the roads vulnerable to flooding in the area and the need to stay off flooded roads.

The SES has developed an online Home Emergency Plan website that can guide home owners through the development of the plan:
http://www.seshomeemergencyplan.com.au/index.php

It is fortunate that there are very few residential properties in Moss Vale that will be directly impacted by flooding up to a 1% AEP flood, and just over 100 residential and commercial properties anticipated to be impacted by a PMF flood. However, with the vulnerability of some of the roads through Moss Vale particularly Argyle Street, it is anticipated that there will be a lot more people who will be indirectly impacted by flooding. As such, the preparation of the SES' Home Flood Plan could be extended to the wider community of Moss Vale to focus on the likely disruption to the road network expected during flood times and the need to travel on roads.

Implementation of this option will require innovative approaches to persuade residents to plan ahead for floods. It is considered that the most effective method, albeit a labour-intensive method, will be via direct outreach from the NSW SES to particular residents. The SES could, with Council's assistance, host "flood planning mornings". Council could staff the meetings with laptops enabling the inspection of flood risks at property scales (booking times might be required to ensure adequate resources are made available), and SES personnel could then help homeowners translate that information into effective home emergency plans.

Business Flood Plan Preparation (RM4)

Recommendations: Host a Business FloodSafe Breakfast to promote the preparation of Business FloodSafe Plans

The most vulnerable section of the Whites Creek catchment is the commercial area along and adjacent to Argyle Street. As such, businesses across flood liable sections of the catchment would also benefit from preparing and maintaining flood plans. The plans set out protocols to follow by the business before, during and after a flood to help mitigate damages and the potential for risk to life at the property level.

The susceptibility of Argyle Street to relative frequent inundation coupled with the potential for a handful of commercial properties to be vulnerable to over floor flooding, indicates that these specific properties would benefit from direct contact with regard to the preparation of Business FloodSafe Plans to help minimise potential losses during a flood.

As for private home flood plans, Council should be able to provide significant information describing the flood risk at the property scale based on the outputs from this study including the potential frequency and depth of inundation as well which roadways will be cut and the likely duration of any isolation.

The SES has developed a Business FloodSafe Toolkit to assist with the preparation of Business FloodSafe plans. These can be completed either online or as a hardcopy (see http://www.floodsafe.com.au/what-floodsafe-means-for-you/business).

A SES Business Breakfast could be hosted to promote the development of Business FloodSafe Plans, with sufficient Council and SES staff present to help guide business owners through the process.

Council could also consider regulation to promote the development of a business flood plans when businesses change ownership and/or use. It is anticipated that most, if not all of these businesses vulnerable to flooding, will be re-developed in the future, and with the application of appropriate floor level controls, will no longer be subject to frequent above floor flooding. However, the evacuation challenges will likely remain, and continued development and implementation of Business Flood Plans is still considered a worthwhile requirement before occupation of these sites.

9.2.4 Local Flood Plan Updates (RM5)

Recommendations: Update Wingecarribee Shire Local Flood Plan to align with new SES LFP template and to incorporate the review findings documented in Section 5.1 of this study.

The *Wingecarribee Shire Local Flood Plan* (NSW SES, 2013) (LFP) was reviewed as part of the current study and the outcomes of this review are summarised in **Table 19** in Section 5.1. This review identified areas of the LFP requiring revision, especially to Volume 2, which needs to align with the structure and contents of the new NSW SES LFP template, and to incorporate flood intelligence from more recent flood studies, floodplain risk management studies, and actual floods. Among the flood intelligence available from the current study is:

- Design flood extents, depths, velocities, hazard and warning times;
- Predicted building inundation in design floods up to PMF;
- Predicted road inundation in design floods up to PMF; and

- Evacuation constraints in design floods up to PMF.

As the SES is the agency responsible for flood emergency management, it is recommended that they undertake the suggested updates to the LFP based upon the recommendations documented in this study.

9.2.5 Develop a Safe On-site Refuge Policy (RM6)

Recommendations: Develop an on-site refuge strategy with appropriate guidance from the NSW SES and the community and update the DCP to ensure structural adequacy of such refuges during the PMF

The potential for evacuation across most sections of the catchment may be limited owing to the short warning times (i.e., less than 1 hour before some roads are cut). As a result, there may be insufficient advanced warning to permit evacuation. In such cases, the safest option may be for residents/staff in such locations to seek refuge on-site.

The DCP does include a requirement for most development types to provide a refuge area above the PMF level or a minimum of 20% of the gross floor levels to be above the PMF level, which may allow for safe onsite refuge / shelter in place if evacuation cannot be achieved. This should be sufficient for residents/staff to wait for floodwaters to recede assuming the buildings remain structurally stable during all potential floods up to and including the PMF (refer discussion in Section 8.2.2).

The NSW SES also recognises that, while its preferred flood emergency response strategy remains for people to evacuate, it has stated:

> *"NSW SES has recognised that in an existing flash flood context, and only in that context, causing residents to attempt to evacuate at the time of flash flooding is occurring, could be a serious risk to life. Only in areas where urban redevelopment cannot be prevented under existing planning policy, it has therefore been proposed that the DCP for any new or redeveloped dwelling will require an internal refuge area above the level of the PMF." (Opper and Toniato 2008)*

This statement illustrates the NSW SES support for on-site refuge during a flash flood in situations where it would be more dangerous to attempt to evacuate. It also recognises that any new development or redevelopment which is permissible under existing zoning in such locations should provide a safe location for sheltering during a flood. What it does not support is the rezoning of land in flash flood environments to allow more people to occupy the land and rely upon "Sheltering-In-Place" (SIP) / "On-site Refuge" (OSR) as the primary means of keeping those people safe during a flood.

NSW SES cites the following risks of SIP (Opper et al. 2011):

- *Floodwater reaching the place of shelter (unless the shelter is above the PMF level);*
- *Structural collapse of the building that is providing the place of shelter (unless the building is designed to withstand the forces of floodwater, buoyancy and debris in a PMF);*
- *Isolation, with no known basis for determining a tolerable duration of isolation;*

- *People's behaviour (drowning if they change their mind and attempt to leave after inundation first occurs);*
- *People's mobility (not being able to reach the highest part of the building);*
- *People's personal safety (fire and accident); and*
- *People's health (pre-existing condition or sudden onset e.g. heart attack).*

For evacuation to be a defensible strategy, the risk associated with the evacuation must be lower than the risk people may be exposed to if they were left to take refuge within a building which could either be directly exposed to or isolated by floodwater (Opper et al., 2011). Pre-incident planning therefore needs to include a realistic assessment of evacuation timelines (both time available and time required for evacuation), including assessment of resources available. Successful evacuation strategies require a warning system that delivers enough lead time to accommodate the operational decisions, the mobilisation of the necessary resources, the warning and the movement of people at risk.

As the Moss Vale area and Whites Creek catchment has no formal flood warning system and any advance warning that is provided would likely be insufficient to undertake an evacuation, it is recommended that an on-site refuge policy be developed which tries to strike a balance between decreasing the risk to individuals in the floodplain and increasing the number of individuals at risk in the floodplain. It is taking a risk-based approach to this by considering the probability, hazard, and duration of flooding in determining where in the floodplain on-site refuge is an appropriate flood emergency response. The policy will look at what types of developments would not be appropriate for on-site refuge, and where it may be appropriate for particular features to be incorporated into developments.

As mentioned, flood hazard is an important input component into making the decision as to whether on-site refuge is an appropriate response method. Hazard categories published by Australian Institute for Disaster Resilience's (AIDR) *'Technical Flood Risk Management Guideline: Flood Hazard'* (2014) consider the safety of vehicles, pedestrians and building stability. A comprehensive structural analysis of all houses located within the catchment has not been completed as part of the current study. However, the hazard mapping shows that most of the existing buildings within the catchment would likely remain structurally stable during in all floods up to the PMF based upon hazard mapping only (i.e., not be subject to a H5 or H6 hazard category. In addition, over 100 dwellings are predicted to experience above floor flooding during a PMF and in a 1% AEP flood, 6 properties would likely experience above floor flooding.

The above statistics indicate that sheltering in place in some of the existing dwellings during particularly large floods can be problematic as there would be a lack of a "flood free" refuge area. This problem can be reduced through implementation of development controls to ensure a flood free refuge is provided above the peak levels of the PMF as new development and redevelopment occurs.

It is recommended to develop an on-site refuge strategy to be implemented with appropriate guidance from the NSW SES and the community where it is appropriate to do so (i.e., in areas where the structural stability of buildings can be ensured during the PMF). Council should also seek guidance on structural requirements for such buildings for inclusion in the DCP. Council

and SES could also work with owners and occupiers of land where onsite refuge may be feasible to ensure safe occupation of these premises during floods.

9.3 Emergency Response Modifications

9.3.1 Regrading of Argyle Street (RM7)

Recommendation: Not recommended for implementation.

This option looks at regrading Argyle Street near the railway underpass, specifically elevating the low point in the roadway by about 0.3 metres. The aim of this option is to reduce inundation depths at this location, thereby reducing the frequency of this evacuation route being cut.

It is expected that the regrading works would cost in the order of $120,000 to implement. A breakdown of costs is included in **Appendix N**.

Revised TUFLOW modelling with this option in place indicates that it would, as expected, reduce inundation depths by around 0.3 metres near the railway underpass (refer Plate 68). However, access would still be cut near the Argyle Street/Lackey Road intersection. Accordingly, this would afford no significant improvement to emergency response / evacuation potential unless the regrading was also extended along Lackey Road. However, this option was explored in Section 7.5.5 and it was determined that any lowering of Lackey Road would increase the frequency of inundation at this location.

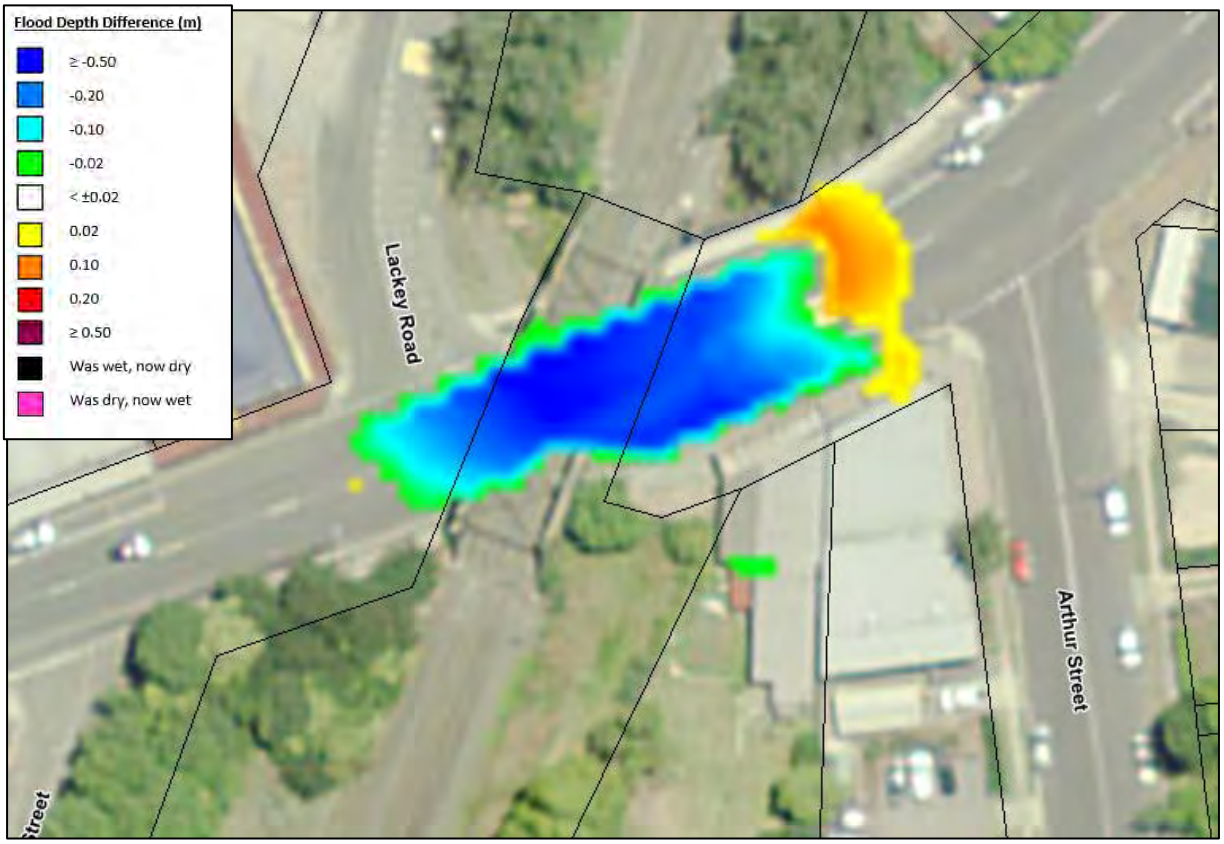


Plate 68 1% AEP Flood Depth Difference Map for RM6

Accordingly, this option does not appear to afford any significant improvement to evacuation potential. Therefore, it is not recommended for implementation.

9.3.2 Creation of an emergency railway level crossing between Vale Road and Lytton/Lackey Road (RM8).

Recommendation: Recommended for further investigation and true feasibility evaluation in conjunction with planning for the Moss Vale bypass.

As discussed, there is the potential for both the railway underpass at Argyle Street and at Spring Street to become inundated during relatively frequent floods. These means that there is no "flood free" road to travel from the east to the west of Moss Vale during even minor flood events. Therefore, there is a significant probability that motorists will attempt to travel through flooded roads without understanding the true risk this poses to them.

It is noted that planning for the Moss Vale Enterprise Corridor (MVEC) road upgrade is well underway. The proposed roadwork includes construction of a new bridge over the Main Southern Railway between Moss Vale Road/Argyle Street and Beaconsfield Road. This will ultimately provide an alternate evacuation route that will allow access from the east to the west of Moss Vale. However, these works are not anticipated to be undertaken before 2025 to 2030.

In recognition of the significant amount of work and time before the MVEC road upgrade is likely implemented, alternate short-term evacuation upgrade options were explored. These investigations determined that there is the potential to provide an alternate evacuation route by constructing a level crossing across the railway line from Vale Road to Lytton Road until the road bridge across the railway line is constructed as part of the MVEC. As shown in Plate 69, this crossing could then form part of an emergency evacuation route that could direct cars coming from the north and east to the south of Moss Vale (and vice versa) until a permanent road and bridge are constructed as part of the MVEC. This would require cars to travel an additional 1.5 km. However, the reduction in flood risk is considered a worthwhile trade off and is only a temporary measure during flood times until a permanent bridge is constructed.

With the vulnerability of the current road system, this option would benefit from the messages that are developed and promoted in the community education strategy recommended in RM1. The community should always be reminded that driving on flooded roads is considered dangerous behaviour. If construction of this emergency access road is included in the floodplain risk management plan, then it should be promoted as a flood emergency access road only in the community education strategy.

The railway track at the suggested level crossing location is almost level with the roads adjacent to it (Lackey Road and Vale Road). Therefore, it is anticipated that the access track design would require minimal excavation for the sub-base and base components, and a minor amount of fill required for the approaches to and across the railway track themselves. The cost to provide the level crossing is estimated to be about $70,000, which would include access and security gates to keep the area locked during non-flood times.

The Waite Street crossing of Whites Creek is flood free up to the 1% AEP flood event and is estimated to be cut during a 0.5% AEP event. Therefore, although this emergency access route does not provide completely "flood free" evacuation, it would significantly increase the trafficability through Moss Vale in a flood event relative to the current situation.

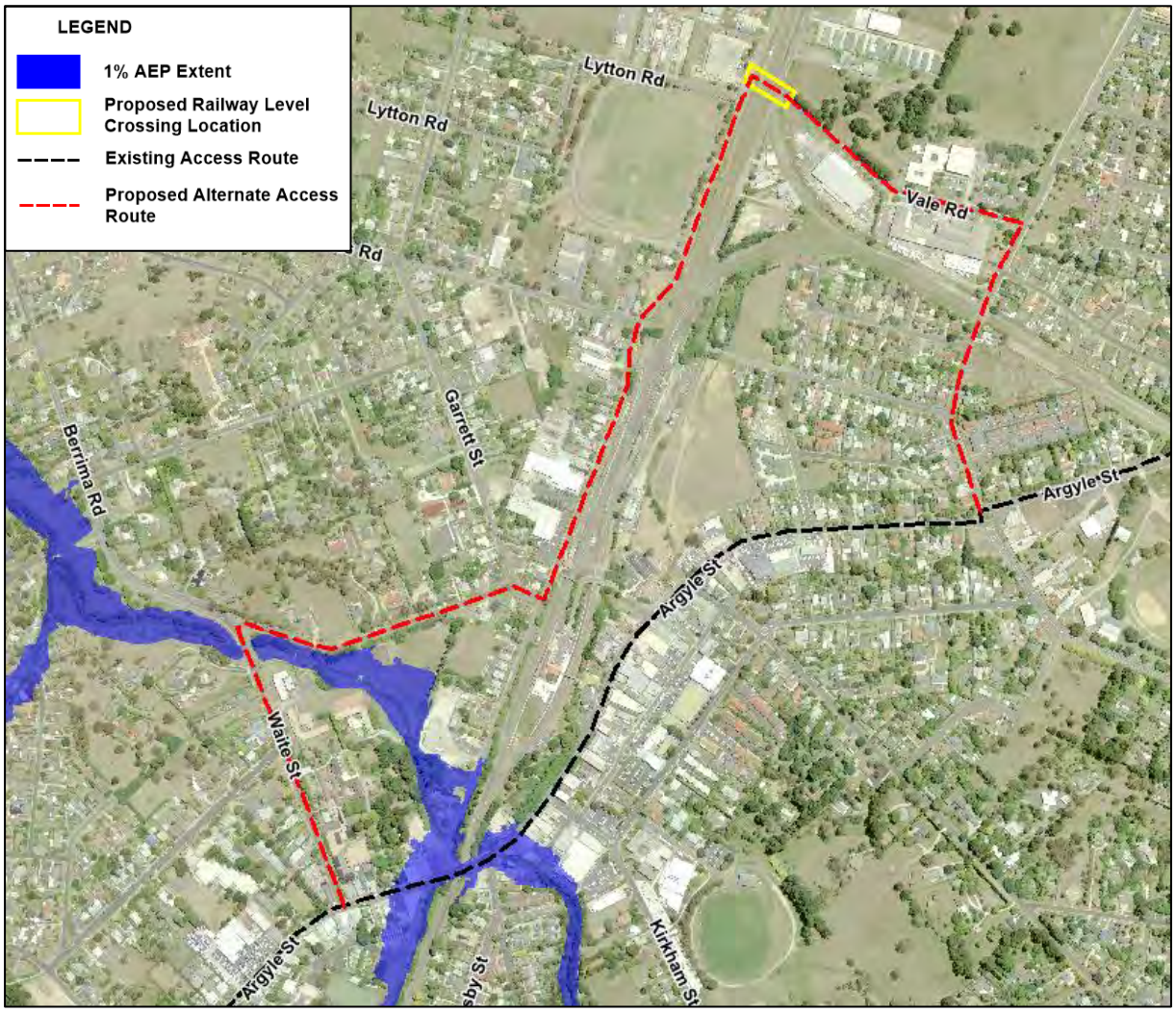


Plate 69 Potential alternate evacuation route

It is noted that Transport for NSW does not support the installation of new level crossings due to the increased risk of collision between trains and vehicles. However, it is suggested that this level crossing would only be trafficable when the regular Argyle Street route is cut (day-to-day access across the railway would not be available). Discussions would have to be held with Australian Rail Track Corporation (ARTC) who manage this railway line as to the possibility of this option proceeding. These discussions would have to focus on the existing risk to motorists during flood events and the current lack of trafficable roads between the east and west of Moss Vale during a flood event. When this emergency access route is in operation, the SES could work with the ARTC to ensure that the opening to the crossing of the railway line worked in conjunction with the thoroughfare of trains along the railway line. Both approach roads to the east and west of the railway line have adequate width and length to facilitate a queue of waiting traffic should the crossing be closed to allow the safe passing of a train.

This option would also need to determine what road signage would need to be in place to provide adequate directions for the alternate route when in use. These signs could be of a type that are permanently in place but with a cover over them (or folded over) and would be unlocked/opened when the alternate route was in use. This would mean that minimal resources would have to be expended putting these signs into use during a flood event (opposed to having to manually collect signs from a work depot and place them along the appropriate roads) and could focus resources on the road crossing of the railway line itself.

The roads which form the suggested emergency access route are all local roads and, therefore, are in the care and control of Council. Argyle Street/Illawarra Highway, is a State Road, in the care and control of the RMS. As such, Council should also work with RMS to determine the true feasibility of this emergency access route.

Overall, the option is considered worthwhile pursuing further.

9.4 Flood Insurance

Recommendation: Recommend those properties located within the floodplain consider reviewing the flood insurance component of their house or business insurance with regard to the updated flood information provided in this report. Consider taking out flood insurance if the property does not currently have it (RM9).

Flood insurance is now available for residential, commercial and industrial buildings as part of most home and contents insurance policies. Flood insurance can also be taken out on public infrastructure and buildings.

Although flood insurance does not reduce the potential for flood damage nor reduce the residual flood risk, it can help in post-flood recovery by providing financial assistance to offset flood damage costs. If a property owner or occupier takes out flood insurance on their property, it is an indication of the success of the communication of the flood information from this study and an acknowledgement of the vulnerability of their property to flooding. It also suggests an increasing resilience of the occupiers of those vulnerable properties.

The cost of flood insurance varies significantly, based on a range of factors, including:

- The likelihood of flooding
- Expected depth of flooding across insured building (refer to **Plate 70**)
- the size and the floor level of the house
- the material used to build the house

Buildings with a high likelihood of flooding and/or high flood damage potential will face higher insurance premiums. Owners of such properties, who would benefit most from flood insurance, may find the premiums unaffordable.

Nevertheless, flood insurance should be considered by property owners in high risk areas, where a single large flood may result in an unaffordable loss through damage to contents or

the loss of the building itself (refer to **Plate 70**). Council could assist property owners as part of this process by providing property level flood information (refer to Section 9.2.2), so property owners can understand their flood risk and the potential financial implications of a significant flood. Based on this, the property owners can make an informed decision on the need to acquire flood insurance. Assuming flood insurance is desired by the property owners, the property level flood information could also be used to assist in negotiating premiums with insurance companies.

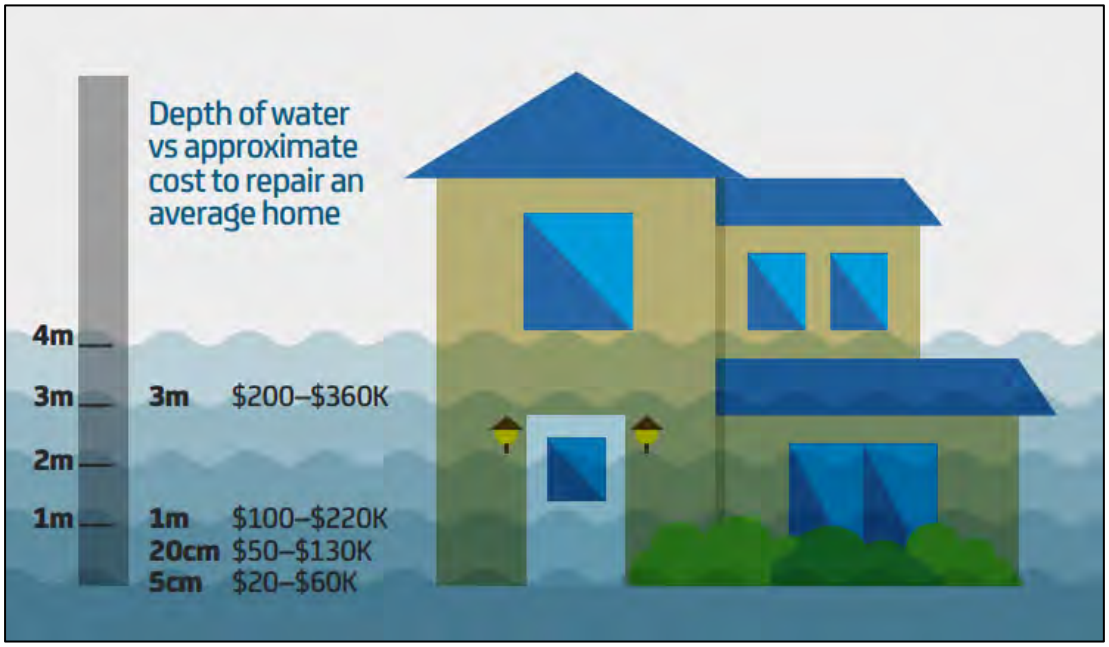


Plate 70 Examples of Repair Costs Versus Depth of Above Floor Inundation Used by Insurance Companies to Estimate Premiums (NRMA, 2015)

9.5 Recommendations

The following response modification options have been evaluated as part of the study and are considered viable for further consideration to assist in managing the existing and future flood risk across the Whites Creek catchment:

- Local Flood Plan Updates:
  - Update the Local Flood Plan, especially to incorporate flood behaviour and risk exposure information for the Whites Creek catchment (NSW SES); and,
  - Amend the Local Flood Plan to reflect additional flood recovery responsibilities for various agencies (NSW SES).
- Community Education:
  - Conduct an audit of flood education initiatives recommended (and potentially implemented) in the LGA over the past 5-10 years (NSW SES, Council);
  - Commission a baseline survey of community flood awareness and readiness, to inform an ongoing strategic approach to community flood education across the whole LGA (Council);
  - Expand the type of flood information made available on spatial data platforms, with appropriate resources to explain the meaning of the data (Council);

- Continue to disseminate messages about the dangers of entering or playing in floodwater with an emphasis on not driving through floodwaters (NSW SES);
- Consider targeted messages to convey that staying may be safer than attempting to evacuate late (NSW SES); and,

- Encourage the community to develop their own household/business Flood Plans with a focus on not driving through flooded roads particularly for commercial properties on Argyle Street (NSW SES, Council).
- Develop a safe on-site refuge policy with associated development controls (Council).
- Determine the true feasibility of an emergency access route across the railway line at Vale Road and Lytton Road/Lackey Road until the permanent bridge crossing of the railway line is constructed as part of the Moss Vale Enterprise Corridor roadworks (Council, RMS, ARTC, SES).
- Flood Insurance - Recommend those properties located within the floodplain consider reviewing the flood insurance component of their house or business insurance with regard to the updated flood information provided in this report. Consider taking out flood insurance if the property is located within the floodplain and does not currently have flood coverage (Property owners).

10 Options for Managing the Potential Future Flood Risk

10.1 Overview

As described in Section 3.5, future development across the Whites Creek catchment is predicted to increase peak design flows and flood levels across part sections of the catchment, thereby potentially increasing the existing flood risk across the catchment particularly during more frequent floods, rather than rarer floods.

The options evaluated in Section 7.2.1 considered the potential to enlarge the Chelsea gardens subdivision basins to assist in mitigating the potential adverse impacts associated with future catchment development. However, this is reliant on the cooperation of the developer of that area to participate in this option. As such, the feasibility of this option cannot be guaranteed. As a result, other opportunities to mitigate the potential impacts of future catchment development were explored and are summarised below.

10.1.1 Do not increase runoff characteristics for developments (Fut1)

Recommendation: Recommended to include updates to the current Moss Vale DCP to specify what design storm events are to be considered in a Stormwater Management Plan.

The assessment of future catchment development determined that the catchment is more susceptible to changes in flows and flood levels during the more frequent flood events, rather than the rarer floods. Therefore, it is important that any future development does not increase flows from existing conditions, particularly during the more frequent rainfall events.

Moss Vale Town Plan DCP Section A4.5 refers to the management of stormwater and refers to the need for a 'Stormwater Management Plan'. It states that a Stormwater Management Plan report will be required by Council for all development that will result in an increase in the impervious area of the site, or a change in the direction of overland flow.

The DCP goes on to state that the intent of the Stormwater Management Plan is to demonstrate that 'post development' overland water flows will not exceed 'pre-development' flows in terms of:
a) Volume,
b) Quality (including nutrient content), and
c) Direction.

These controls should be strengthened to state what design storm events should be considered for this analysis and included in the stormwater management plan. At a minimum, it is recommended that stormwater management plans consider the 20% AEP, 5% AEP and 1% AEP events to manage post development flows.

10.1.2 Do not increase development densities in flood constrained lands (Fut2)

Recommendation: Ensure development densities do not increase in flood constrained land.

The current study looked at the appropriateness of the current land use zonings in the flood constrained lands within the Whites Creek catchment (refer Section 4.3.1). This review demonstrated that the current land use zonings are generally appropriate given the flood constraints on each lot within the catchment. However, there are some commercial areas where H5 or H6 hazard is expected in a PMF event (e.g., areas adjoining Argyle Street). Therefore, future planning and re-development should ensure that these zonings, or development standards or permissible uses within each zone, are not changed to facilitate increased densities within the flood prone areas, particularly for areas that are flood free in the 1% AEP design flood event.

Furthermore, strict development controls should be enforced in these areas to ensure that future development is more compatible with the flood risk and the flood risk is ultimately reduced rather than increased in the future.

11 Floodplain Risk Management Plan

11.1 Introduction

The Floodplain Risk Management Plan sets out a preferred set of options that can be implemented to better manage the flood risk across the Whites Creek catchment. It also outlines responsibilities for the implementation of each option along with cost estimates. This Floodplain Risk Management Plan is based on the outcomes of the Floodplain Risk Management Study which is documented in the previous sections of this report.

11.2 Recommended Options

The options that are recommended for implementation as part of the Whites Creek Floodplain Risk Management Plan are summarised in **Table 30** and are also shown on the following page. The options have been selected from a range of potential flood modification, property modification and response modifications measures based upon their impact on flood hydraulics, reduction in flood damages, implementation costs, community feedback as well as any potential social and environmental impacts. All options that were considered and evaluated in detail are shown on plan on the following page**.** The outcomes of the detailed options assessment are also discussed in more detail in Chapters 7, 8, 9 and 10 of this report.

11.3 Plan Implementation

11.3.1 Prioritisation / Timing

Each of the recommended options has been assigned a preliminary implementation priority based upon an initial consideration of the above factors (i.e., costs, benefits, technical feasibility etc). The implementation priorities are summarised in **Table 30**.

A timeframe has also been estimated that reflects the likely time to implement each option. However, the implementation time estimates will most likely need to be refined moving forward based upon available resources (i.e., financial and human resources) as well as the need to undertake additional investigations and/or consultation.

Table 30 also summarises the agency that will be responsible for implementation of each option.

11.3.2 Costs and Funding

The total capital cost to implement the structural components of the Plan is expected to be about $720,000. In addition to the capital costs, some options will require an investment in time from various agencies including Wingecarribee Shire Council and the State Emergency Service in addition to monetary contributions.

It should be noted that the costs included in **Table 30** are estimates only. The cost for each recommended option will need to be refined through further detailed investigations and preparation of detailed design plans which is beyond the scope of the current study. There are also two options that require significant discussions with third parties to gain their support for the option, before the detailed design, refined cost estimate and true benefit cost ratio can be determined.

PM1 - Changes to Wingecarribee Shire Council LEP

Recommendations:
A) Amend Wingecarribee Shire Council LEP to remove the flood planning area map from the LEP and make publicly available elsewhere and/or on council's website.
B) Include an additional "Floodplain Risk Management" clause in the LEP for areas between the flood planning area and the edge of the low flood risk precinct.

PM2 - Changes to Moss Vale Town Plan DCP

Recommendation: Amend Moss Vale Town Plan DCP considering the detailed review presented in Section 4.3.2 of this report

PM3 - Update Section 10.7 Certificate Information

Recommendation: Updated Section 10.7 certificate to reference updated design flood information generated as part of the current study.

PM4 - Voluntary House Raising

Recommendation: Not recommended for implementation.

RM1 - Community Education Strategy

Recommendation: Develop local Floodsafe documents, develop educational messages targeting dangerous behaviours during a flood and undertake localised and tailored education campaigns for high hazard areas.

RM2 - Make Property Level Flood Information Available

Recommendation: Make additional flood information available at a property scale for all properties impacted by flooding up to and including the PMF, including flood depths, hazards and emergency response classifications, with suitable explanations and guidance as to how this information can be used to inform flood emergency plans.

RM3 - Home Flood Plan Preparation

Recommendation: Host community or locality meetings to promote the preparation of Home Emergency Plans. These plans should highlight the vulnerability of and disruption to the road network during flood times in Moss Vale and provide advice on potential alternate evacuation routes.

RM4 - Business Flood Plan Preparation

Recommendation: Host a Business FloodSafe Breakfast to promote the preparation of Business FloodSafe Plans

RM5 - Local Flood Plan Updates

Recommendation: Update Wingecarribee Shire Local Flood Plan based upon Table 19 in Section 5.1 of this report

RM6 - Develop a Safe On-site Refuge Policy

Recommendation: Develop an on-site refuge strategy with appropriate guidance from the NSW SES and the community and update the DCP to ensure structural adequacy of such refuges during the PMF.

RM9 - Flood Insurance

Recommendation: Recommend those properties located within the floodplain consider reviewing the flood insurance component of their house or business insurance with regard to the updated flood information provided in this report. Consider taking out flood insurance if the property does not currently have it.

Fut1 - Do not increase runoff characteristics for developments

Recommendation: Recommended to include updates to the current Moss Vale DCP to specify what design storm events are to be considered in a Stormwater Management Plan.

Fut2 - Do not increase development densities in flood constrained lands

Recommendation: Ensure development densities do not increase in flood constrained land.

FM8 - Channel and Floodplain Modifications between 6-12 Berrima Road

Recommendation: Not recommended for implementation.

RM8 - Creation of an emergency railway level crossing between Vale Road and Lytton/Lackey Road

Recommendation: Recommended for further investigation and true feasibility evaluation in conjunction with planning for the Moss Vale bypass.

RM7 - Regrading of Argyle Street

Recommendation: Not recommended for implementation.

FM13 - Regrading of Lackey Road from Argyle Street to Whites Creek

Recommendation: Not recommended for implementation.

FM6 - Upgrade Stormwater System on Willow Drive and Dangar Street

Recommendation: Not recommended for implementation.

FM2a - New Detention Basin within Broulee Park

Recommendation: Recommended for further detailed investigation.

FM2b - New Detention Basin in Strode Park

Recommendation: Not recommended for implementation.

FM3 - Upgrade Stormwater System along Railway Street (near Argyle Street)

Recommendation: Not recommended for implementation.

FM9 - Elevate Pedestrian Walkway between Railway and Throsby Street to Direct Flows into Downstream Channel

Recommendation: Not recommended for implementation.

FM10 - Construct Levee on Eastern Bank of Whites Creek near Lackey Road

Recommendation: Not recommended for implementation.

FM5 - Upgrade Culverts along Whites Creek at Argyle Street and the Railway

Recommendation: Feasibility assessment recommended.

FM4 - Upgrade Stormwater System along Argyle Street near Arthur Street

Recommendation: Not recommended for implementation.

FM7 - Channel Reshaping of Whites Creek upstream of Argyle Street

Recommendation: Not recommended for implementation.

FM12 - Construct Levee at Rear of 51-55 Throsby Street

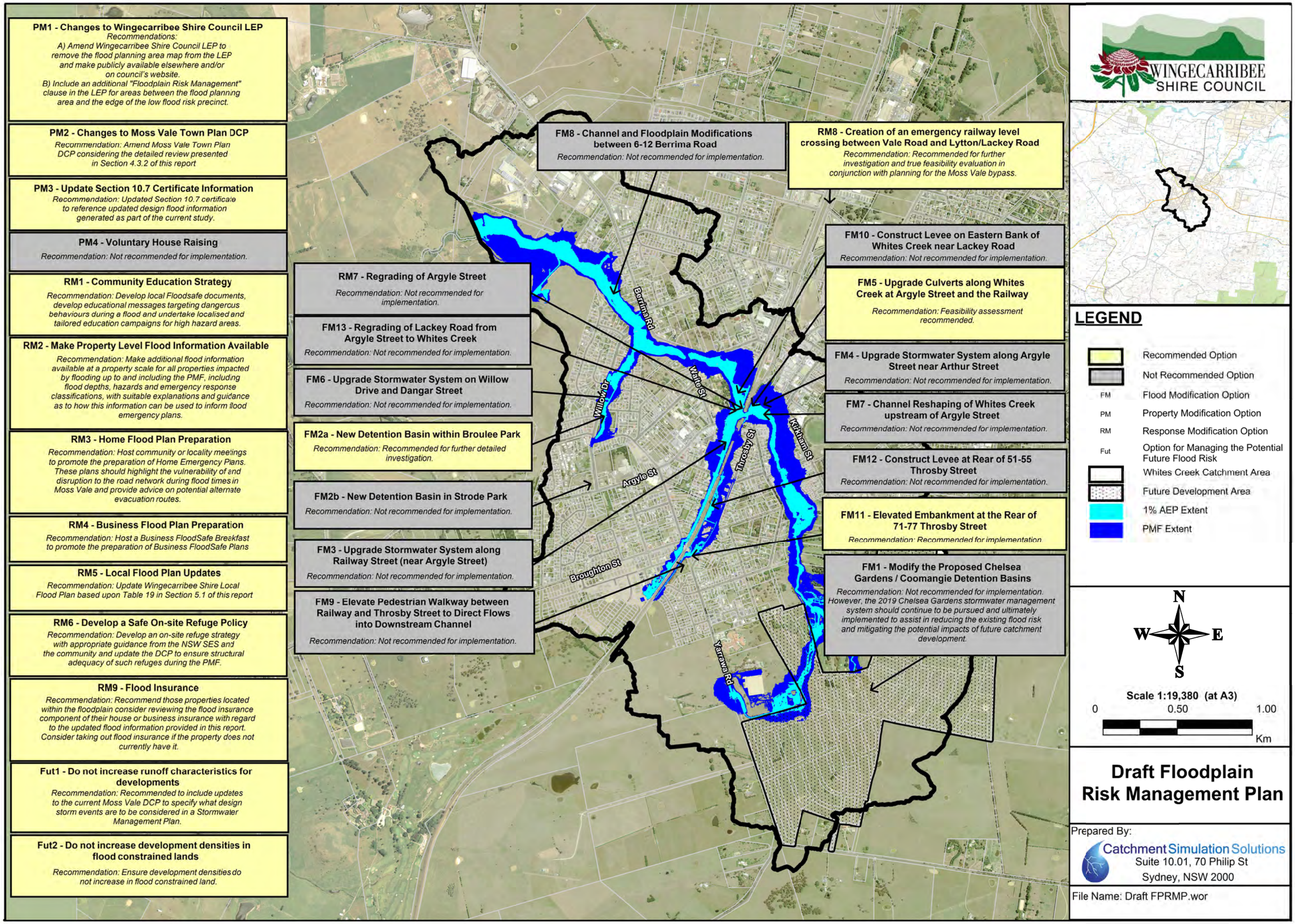
Recommendation: Not recommended for implementation.

FM11 - Elevated Embankment at the Rear of 71-77 Throsby Street

Recommendation: Recommended for implementation

FM1 - Modify the Proposed Chelsea Gardens / Coomangie Detention Basins

Recommendation: Not recommended for implementation. However, the 2019 Chelsea Gardens stormwater management system should continue to be pursued and ultimately implemented to assist in reducing the existing flood risk and mitigating the potential impacts of future catchment development.



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Recommended Option
- Not Recommended Option
- FM — Flood Modification Option
- PM — Property Modification Option
- RM — Response Modification Option
- Fut — Option for Managing the Potential Future Flood Risk
- Whites Creek Catchment Area
- Future Development Area
- 1% AEP Extent
- PMF Extent

N
W E
S

Scale 1:19,380 (at A3)

0 0.50 1.00 Km

Draft Floodplain Risk Management Plan

Prepared By:
Catchment Simulation Solutions
Suite 10.01, 70 Philip St
Sydney, NSW 2000

File Name: Draft FPRMP.wor

Funding for implementation of the plan could be potentially obtained from the following sources:

- NSW State Government's Floodplain Management Grants (through Department of Planning, Industry and Environment)
- Wingecarribee Shire Council's capital and operating budgets
- Developer (i.e., Section 7.11) contributions
- Australian Rail Track Corporation (ARTC)
- Roads and Maritime Services (RMS)
- Volunteer labour from community groups
- Volunteer labour from property owners / interested parties

It is expected that some of the options targeted at addressing the existing flood risk will be eligible for funding through the NSW State Government's Floodplain Management Grants on a 2:1 basis (State Government: Council). This can include additional investigations, design activities as well as construction. However, funding under this program cannot be guaranteed as funding must be distributed to competing projects across the state. Furthermore, the NSW Government's Floodplain Management Grants are targeted at managing the risk to residential properties and are generally not awarded to manage the flood risk to commercial and industrial properties. Furthermore, State Government funding will not be made available for those options that benefit properties constructed after 1986.

It should also be noted that ongoing costs will generally be the responsibility of Council.

11.3.3 Review of Plan

It is important that the Floodplain Risk Management Plan is continually monitored, reviewed and updated over time to ensure that it evolves with the catchment and new flood knowledge. Some events that may prompt a review of the Plan could include:

- If significant impediments are identified for any of the recommended options;
- A significant flood occurs which provides updated data of flood behaviour;
- A new flood study is prepared;
- New knowledge becomes available (e.g., climate change); or,
- New issues come to light that were not considered or not know at the time the Plan was prepared.
- Development in the catchment increases or varies considerably from what is considered as part of the assessments in this study and plan (e.g., Chelsea Gardens).

As noted in **Table 30** most options are scheduled for implementation within a 5-year time frame. This is considered a reasonable estimate considering the resources that are currently available to undertake this work. Therefore, as a minimum, it is recommended that a thorough review of the Plan be completed after 5 years.

Table 30 Whites Creek Floodplain Risk Management Plan

FM Flood modification option PM Property modification option RM Response modification option

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
Flood Modification Options								
FM2	Further detail investigation of new detention basin in Broulee Park	7.2.2	Council	$60,000	0.7	High	2 years	Further detail investigation recommended to determine detail design and revised cost estimate, which may potentially reduce construction cost. Approximate construction cost of option $60,000.
FM5	Feasibility assessment for upgrading the existing railway culverts near Argyle Street	7.3.3	Council & ARTC	$650,000	0.2	Medium	<2 year	This option is predicted to afford some localised hydraulic benefits in one of the most problematic areas of the catchment, however, the poor economic performance based on reduction in flood damages only makes it difficult to recommend as part of this study. Discussions could be conducted with Australian Rail Track Corporation (ARTC) and RMS to confirm if they would be willing to contribute to the implementation of this option, which would improve the financial viability of its implementation.
FM11	Elevated Embankment at the Rear of 71-77 Throsby Street	7.5.3	Council	$10,000	3.0	High	1 year	Council to initiate discussions with local property owners to gauge the level of support for this option. As all benefitted properties were constructed after 1986, state government funding is unlikely and, therefore, this option would need to be funded fully by Council.

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
Property Modification Options								
PM1	LEP Amendments	8.2.1	Council	Council Time	n/a	High	3 years	Amend Wingecarribee Shire Council LEP considering the detailed review presented in Section 4.3.1 of the Whites Creek FRMS
PM2	DCP Amendments	8.2.2	Council	Council Time	n/a	High	2 years	Amend Moss Vale Town Plan DCP considering the detailed review presented in Section 4.3.2 of the Whites Creek FRMS
PM3	Update Section 10.7 certificate information	8.2.3	Council	Council Time	n/a	High	<1 year	Update Section 10.7 certificates to reference updated flood information produced as part of current study
Response Modification Options								
RM1	Community Education	9.2.1	Council & SES	Council & SES Time	n/a	High	1-2 years	Develop local FloodSafe documents and educational messages targeting dangerous behaviours such as driving through floodwaters
RM2	Make property level flood information available	9.2.2	Council	Council	n/a	Medium	1 year	Make available additional flood information at a property scale, such as flood depths, hazards and emergency response classifications, with suitable explanations and guidance as to how this information can be used to inform individual flood emergency plans.

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
RM3	Encourage the community to develop household Flood Plans	9.2.3	SES / Individual Residents	Council & SES Time	n/a	Medium	2 years	Host meetings to promote the preparation of Home Emergency Plans. These plans should highlight the vulnerability of and disruption to the road network during flood times in Moss Vale and provide advice on potential alternate evacuation routes.
RM4	Encourage the community to develop business Flood Plans	9.2.3	SES / Individual Business Owners	Council & SES Time	n/a	Medium	2 years	Host a Business FloodSafe Breakfast to promote the preparation of Business FloodSafe Plans. The businesses around Argyle Street should be initially targeted for this FloodSafe Breakfast.
RM5	Local Flood Plan Updates	9.2.4	SES	SES Time	n/a	High	2 years	Update Wingecarribee Shire Local Flood Plan to align with new SES LFP template and to incorporate new flood intelligence from Section 5.1 this study.
RM6	Develop a safe on-site refuge policy	9.2.5	Council	Council & SES Time	n/a	Medium	2 years	Develop an on-site refuge strategy with appropriate guidance from the NSW SES and the community and update development controls to ensure structural adequacy of such refuges
RM8	Creation of an emergency railway level crossing between Vale Road and Lytton/Lackey Road	9.3.2	Council	Council time	n/a	High	<1 year	Discussions will have to be held with ARTC to determine the potential for this option to proceed on railway land. Recommended for further investigation and true feasibility evaluation in conjunction with planning for the Moss Vale bypass.

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
RM9	Flood Insurance	9.4	Property owner	variable	n/a	Low	1-3 years	Recommend those properties located within the floodplain consider reviewing the flood insurance component of their house or business insurance with regard to the updated flood information provided in this report. Consider taking out flood insurance if the property does not currently have it.
Options for Reducing the Future Flood Risk								
Fut1	Update Stormwater Management Plan requirements in DCP	10.1.1	Council	Council Time	n/a	High	1 year	Recommended to strengthen current Moss Vale DCP to specify what design storm events are to be considered in a Stormwater Management Plan required as part of development applications.
Fut2	Do not increase future development densities in flood constrained land	10.1.2	Council	Council Time	n/a	High	1 year	Strict development controls should be enforced in existing flood prone areas to ensure that future development is more compatible with the flood risk and the flood risk is ultimately reduced rather than increased in the future as development occurs.

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APPENDIX A

COMMUNITY CONSULTATION

9. TO ASSIST US IN DEVELOPING A SHORT LIST OF POTENTIAL FLOOD RISK REDUCTION MEASURES, PLEASE RATE THE FOLLOWING OPTIONS

Flood Modification Options:

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Flood Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Flood detention basins						
Levees						
Stormwater upgrades						
Channel realignment						
Enlarging channel						
Regular maintenance and clearing of the creek						
Culvert/bridge upgrades						
Debris control structures to prevent blockage of culverts/bridges						

Property Modification Options

Property Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Voluntary house raising						
Voluntary flood proofing						
Voluntary house purchase						
Development/planning controls						
Rainwater tanks						

Response Modification Options: are options aimed at improving the way emergency

Response Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Flood forecasting / warning system						
Boom gates / signs at roadway overtopping points						
SES local flood plan updates						
Community education						
Upgrade evacuation routes						

Whites Creek
Floodplain Risk Management Study

Community Questionnaire

The following questionnaire should only take around 10 minutes to complete. The responses that you provide will help Wingecarribee Shire Council understand how best to reduce the impact of flooding on the community. Once complete, please return the questionnaire via email or mail by **27 July 2018**. Alternatively, if you have internet access, an online version of the questionnaire can be completed at: https://whitescreek.fprms.com.au/

CONTACT DETAILS

Please provide your address to help us identify where floods have been (or haven't been) problematic. It would also be helpful to have a means of contacting you if required. Your contact details will remain confidential at all times.

Name: _____

Address: _____

_____

Phone No. _____

Email: _____

I wish to stay informed for the duration of the study:

☐ Yes ☐ No

1. WHAT TYPE OF PROPERTY DO YOU LIVE IN / OWN?

☐ Residential

☐ Commerical

☐ Industrial

☐ Other (Please specify:_____)

How long have you lived at this property? _____years

2. HAVE YOU EXPERIENCED PREVIOUS FLOODS IN THIS AREA?

☐ Yes

☐ No (go to Question 4)

3. HOW WERE YOU AFFECTED BY FLOODING?

Date of flood(s)		
Type of flood impact	☐ Flooding over main building floor ☐ Flooding of garages/sheds ☐ Lost access due to flooding of roads ☐ Sewage system was not working at our property ☐ Other	☐ Flooding over main building floor ☐ Flooding of garages/sheds ☐ Lost access due to flooding of roads ☐ Sewage system was not working at our property ☐ Other
Flood depth / height & location		
How confident are you with the height / depth of the flood?	☐ High (exact) ☐ Medium (within 10cm) ☐ Low (within 50cm)	☐ High (exact) ☐ Medium (within 10cm) ☐ Low (within 50cm)

4. DO YOU HAVE ANY PHOTOGRAPHS OR VIDEOS OF THESE?

☐ Yes ☐ No

If you answered Yes, can you provide a copy of these photos/videos to assist with the computer flood model calibration?

☐ Yes ☐ No

5. HOW DO YOU ANTICIPATE YOU WOULD RESPOND IN A FUTURE MAJOR FLOOD IN THIS AREA?

Tick one:

☐ evacuate early to an official evacuation centre

☐ evacuate elsewhere – please describe: _____

☐ remain at my house

☐ other – please describe _____

☐ don't know/not sure

6. IF YOU ARE LIKELY TO EVACUATE, WHAT FACTORS ARE MOST IMPORTANT TO YOU?

Please select all factors that would apply:

☐ discomfort/inconvenience/cost of being isolated by floodwater

☐ need for uninterrupted access to medical facilities

☐ safety of our family

☐ other – please describe _____

☐ not applicable (I intend to remain at my house)

7. IF YOU ARE LIKELY TO REMAIN AT YOUR HOUSE, WHAT FACTORS ARE MOST IMPORTANT TO YOU?

Please select all factors that would apply:

☐ discomfort/inconvenience/cost of evacuating

☐ need to care for animals

☐ my house cannot be flooded and we can cope with isolation

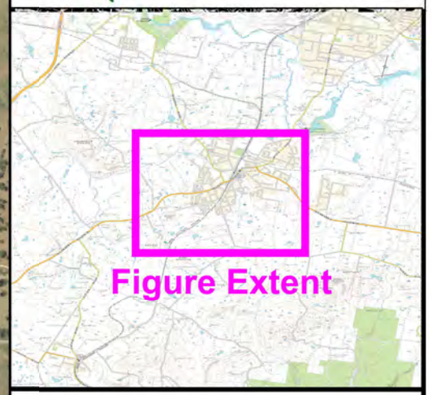
☐ concern for security of my property if I evacuate

☐ other – please describe _____

☐ not applicable (I intend to evacuate from my house)

8. A LIST OF POTENTIAL OPTIONS FOR MANAGING THE FLOOD RISK IS PROVIDED ON THE NEXT PAGE. IF YOU HAVE ANY OTHER SUGGESTIONS FOR REDUCTING FLOODING PROBLEMS, PLEASE DESCRIBE BELOW.

WINGECARRIBEE SHIRE COUNCIL



LEGEND

- 1% AEP Flood Extent from the Whites Creek FPRM Study, 2013

Q3 - How were you affected by flooding?

- Flooding Over Main Building
- Flooding of Garages / Sheds
- Flooding of Garden / Backyard
- Sewage System Was Not Working at Our Property
- Lost Access Due to Flooding of Roads
- Other
- Not Flood Affected

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:16,800 (at A3)

0 0.45 0.90

Km

Figure A1: Spatial Distribution of Historic Flood Impacts

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig - Historic Flood Impacts.wor

Table A1 - Property Types and Historic Flood Impacts

#	What type of property do you have?					Have you experienced previous floods in this area?			How were you affected by flooding?					
									Type of Flood Impact					
	Residential	Commerical	Industrial	Other	How long have you lived/worked at this property? (years)	Yes	What years?	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage system was not working at our property	Water supply lost	Other
1				Golf Course	40	X	Aug-2015 May-2016							X
2	X				7	X	2014			X		X		
3	X							X						
4	X				10			X						
5	X					X								
6	X				3			X						
7	X							X						
8	X				3			X						
9	X				7	X	2013/2014				X			
10	X				18			X						
11	X				1			X						
12	X							X						
13	X				21			X						
14	X				5			X						
15	X				5	X								X
16	X				7			X						
17				Units	6									
18	X				9			X						
19	X				8			X						
20	X				4	X			X	X				X
21		X			40		May-2015		X	X				
22	X					X								
23	X				9.5		2010, 2012			X				
24	X				3.5			X						
25	X				10	X								X
26	X				4	X	Dec-2014, Apr, Aug-2015, Jun-2016							X
27				Work on the creek	18	X								X
28														
29	X				5	X								
30	X				4.5	X	Aug-2015							X
31	X				1			X						
32	X					X								X
33	X				7			X						
34	X				7			X						
35	X				24	X	2016, 2002				X			X

File Reference: "..\Whites Creek FPRMS\Community Consultation\Whites Creek Questionnaire Responses.xlsm"

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Figure Extent

LEGEND

PMF Flood Extent from the Whites Creek FPRM Study, 2013

Q5 - How do you anticipate you would respond in a future flood in this area?

- Don't Know / Not Sure
- Remain at My House
- Evacuate Elsewhere
- Evacuate Early to an Official Evacuation Centre
- Other

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:16,800 (at A3)

0 0.45 0.90 Km

Figure A2: Spatial Distribution of Preferred Flood Response

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig - Preferred Flood Response.wor

Table A2 - Preferred Flood Response

#	How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you?					If you are likely to remain at your house, what factors are most important to you?					
	Evacuate early to an official evacuation centre	Evacuate elsewhere	Remain at my house	Other	Don't know/ not sure	Discomfort/ inconvenience/ cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Other	Not applicable (I intend to remain at my house)	Discomfort/ inconvenience/ cost of evacuating	Need to care for animals	My house cannot be flooded and we can cope with isolation	Concern for security of my property if I evacuate	Other	Not applicable (I intend to evacuate from my house)
1				X						X						X
2		X	X							X		X		X		
3					X	X					X			X		
4	X						X									
5										X						
6			X							X		X	X			
7			X			X					X			X		
8	X					X					X					
9					X		X	X		X	X		X	X		
10					X	X	X	X			X			X		
11			X							X			X		X	
12					X											
13	X					X					X			X		
14	X					X										X
15					X	X					X	X		X	X	
16					X			X								X
17			X							X			X			
18			X				X				X	X		X		
19				X		X		X	X							X
20			X							X					X	
21		X				X		X			X			X		
22			X							X			X			
23	X						X	X			X			X		
24			X							X			X			
25			X										X			
26					X			X		X	X					
27				X						X						
28																
29		X			X			X		X	X					
30			X							X						
31			X											X		
32				X		X				X						
33			X							X						
34	X							X		X	X					
35			X										X			

Table A3 - Feedback on Potential Flood Risk Mitigation Measures

#	To assist us in developing a short list of potential flood risk reduction measures, please rate the following options. Which of these options do you support/not support?																	
	Flood modification options: Options aimed at modifying the way floodwaters move, thereby reducing the extent, depth and velocity of floodwater.								Property modification options: Refers to planning controls and property modifications that reduce the potential for flooding or improve the resilience of buildings to flooding.					Response modification options: Are options aimed at improving the way emergency services and the general public responds before, during and after a flood.				
	Flood detention basins	Levees	Stormwater upgrades	Channel realignment	Enlarging channel	Regular maintenance and clearing of the creek	Culvert/ bridge upgrades	Debris control structures to prevent blockage of culverts/ bridges	Voluntary house raising	Voluntary flood proofing	Voluntary house purchase	Development/ planning controls	Rainwater tanks	Flood forecasting / warning system	Boom gates / signs at roadway overtopping points	SES local flood plan updates	Community education	Upgrade evacuation routes
1	Support	Support	Support	Neutral	Neutral	Strongly Support	Neutral	Support	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Neutral	Support	Support	Neutral
2	Unsure	Unsure	Strongly Support	Against	Unsure	Strongly Support	Neutral	Strongly Support	Strongly Against	Against	Against	Support	Neutral	Support	Support	Support	Strongly Support	Strongly Support
3	Unsure	Unsure	Support	Unsure	Support	Support	Support	Support	Neutral	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Support
4	Unsure	Support	Strongly Support	Support	Neutral	Strongly Support	Support	Neutral	Unsure	Unsure	Unsure	Support	Support	Strongly Support	Support	Support	Support	
5			Strongly Support															
6	Unsure	Unsure	Unsure	Against	Against	Neutral	Neutral	Support	Neutral	Neutral	Neutral	Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Support
7	Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support										
8	Strongly Support		Strongly Support	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Against	Neutral	Neutral	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
9	Unsure	Strongly Against	Strongly Support	Unsure	Strongly Support	Strongly Support	Unsure	Strongly Support	Against	Against	Against	Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
10		Support	Unsure	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Unsure		Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
11	Against	Against	Support	Against	Support	Strongly Support	Against	Strongly Support	Support	Support	Neutral	Strongly Support	Neutral	Neutral	Support	Strongly Support	Strongly Support	Neutral
12		Support				Strongly Support		Strongly Support					Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
13			Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support		Strongly Support		Strongly Support		Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support
14	Unsure	Support	Support	Unsure	Support	Support		Support	Strongly Against	Neutral		Neutral		Support	Support	Support	Support	Support
15	Unsure	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
16	Support	Support	Support	Support	Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Unsure	Support	Support	Support	Support	Support
17		Support								Support				Support				
18	Support	Neutral	Strongly Support	Support	Strongly Support	Strongly Support	Support	Strongly Support	Neutral	Support	Neutral	Neutral	Neutral	Support	Support	Support	Neutral	Neutral
19	Unsure	Unsure	Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Unsure	Strongly Support	Unsure	Neutral	Strongly Support	Strongly Support
20	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Support	Strongly Against	Strongly Support	Neutral	Strongly Support	Neutral	Neutral	Neutral	Neutral
21	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Support	Strongly Against	Strongly Support	Unsure	Strongly Support		Strongly Support		
22	Neutral	Strongly Support	Strongly Support	Neutral	Neutral	Strongly Support	Neutral	Strongly Support	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
23	Support	Strongly Support	Unsure	Neutral	Unsure	Strongly Support	Support	Strongly Support	Support	Strongly Support	Strongly Support	Support	Neutral	Strongly Against	Against	Support	Neutral	Neutral
24	Support	Against	Neutral	Against	Neutral	Support	Neutral	Support	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Neutral	Support	Support	Neutral
25	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Strongly Support
26	Support	Support	Support	Against	Unsure	Strongly Support	Neutral	Support	Strongly Against	Strongly Against	Strongly Against	Strongly Support	Strongly Support	Neutral	Neutral	Support	Support	Neutral
27	Strongly Support	Strongly Against	Neutral	Strongly Against	Strongly Against	Strongly Against	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
28	Neutral	Support	Strongly Support	Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Against	Support	Strongly Against	Strongly Support	Strongly Support	Support	Support	Neutral	Neutral	Neutral
29	Neutral	Against	Support	Neutral	Neutral	Strongly Support	Support	Support	Against	Against	Neutral	Neutral	Support	Support	Neutral	Support	Strongly Support	Support
30			Strongly Support			Strongly Support		Strongly Support				Unsure					Unsure	
31	Strongly Support		Support	Neutral	Support	Neutral	Support	Support	Neutral	Neutral	Support	Strongly Support	Support	Against	Support	Support	Support	Neutral
32	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
33																		
34	Neutral	Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
35	Strongly Support	Against	Strongly Support	Strongly Against	Strongly Against	Against	Strongly Support	Strongly Support	Neutral	Support	Unsure	Strongly Support	Support	Strongly Support	Support	Strongly Support	Strongly Support	Support

File Reference: "..\Whites Creek FPRMS\Community Consultation\Whites Creek Questionnaire Responses.xlsm"

APPENDIX B

HYDROLOGIC MODEL

B1. HYDROLOGIC MODEL

1.1. Introduction

The transformation of rainfall into runoff was defined as part of the study using a hydrologic computer model of the Whites Creek catchment. The hydrologic model was developed using the XP-RAFTS software (Innovyze, 2018).

The following sections describe how the hydrologic model was developed and also outlines the results of the model validation.

1.2. XP-RAFTS Model Development

Subcatchment Parameterisation

The Whites Creek catchment was subdivided into 166 subcatchments based on the alignment of major streams, topographic divides and the location of key infrastructure (e.g., culvert crossings). The subcatchments were delineated with the assistance of the CatchmentSIM software using a 2 metre Digital Elevation Model (DEM). The subcatchment layout is presented in **Figure B1**.

Key hydrologic properties including area, impervious proportion, roughness and average vectored slope were calculated automatically for each subcatchment using CatchmentSIM in conjunction with detailed remote sensing land use information. The spatial distribution of the different land use types is shown in **Figure B2**. As shown in **Figure B2**, the study area was subdivided into six different material types:

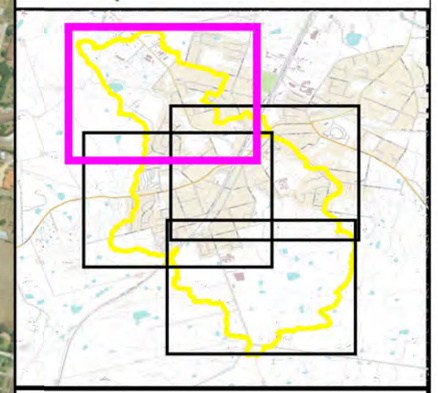
- Buildings;
- Water;
- Trees;
- Grass;
- Roadways; and,
- Concrete.

It was noted that the "Darraby" subdivision was largely complete at the time this study was being prepared. However, this was not picked up by the remote sensing information, which was derived from 2014 LiDAR information. Therefore, an additional land use type was introduced for this area (refer "new construction" area in **Figure B2**).

Percentage impervious and pervious 'n' roughness values were assigned to each land use (refer **Table B1**) and were used to calculate weighted average percentage impervious and pervious 'n' values for each subcatchment. The "new construction" areas (i.e., Darraby subdivision) were assigned a weighted impervious proportion and pervious 'n' value assuming that the finished residential lots will comprise 60% concrete/roof area, 35% grass and 5% trees.

The adopted subcatchment parameters are summarised at this end of this appendix.

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LEGEND

- XP-RAFTS Subcatchment Boundaries
- Study Boundary
- XP-RAFTS Link
- XP-RAFTS Node
- Basin (Design Only)

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:6,500 (at A3)

0 175 350

m

Figure B1.1: XP-RAFTS Subcatchment Layout

Prepared By:

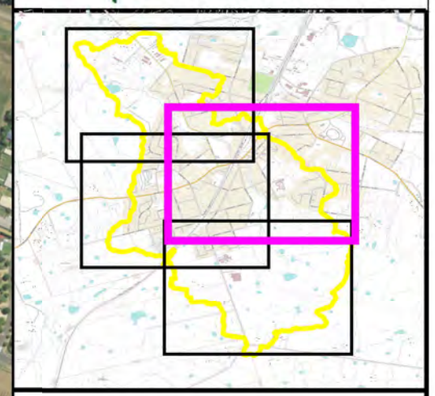
Catchment Simulation Solutions

Suite 2.01, 210 George St

Sydney, NSW 2000

File Name: FigB1 - XP-RAFTS Sub. Layout.wor

WINGECARRIBEE SHIRE COUNCIL



LEGEND

- XP-RAFTS Subcatchment Boundaries
- Study Boundary
- XP-RAFTS Link
- XP-RAFTS Node
- Basin (Design Only)

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:6,500 (at A3)

0 175 350

m

Figure B1.2: XP-RAFTS Subcatchment Layout

Prepared By:

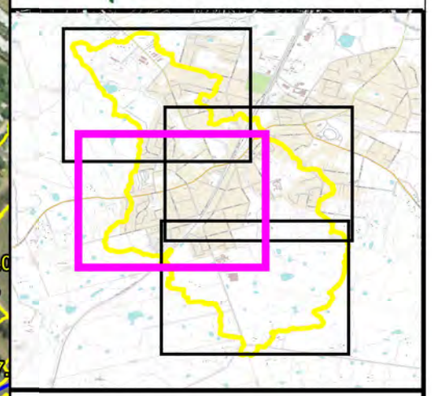
Catchment Simulation Solutions

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Sydney, NSW 2000

File Name: FigB1 - XP-RAFTS Sub. Layout.wor

WINGECARRIBEE SHIRE COUNCIL



LEGEND

- XP-RAFTS Subcatchment Boundaries
- Study Boundary
- XP-RAFTS Link
- XP-RAFTS Node
- Basin (Design Only)

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:6,500 (at A3)

0 175 350

m

Figure B1.3: XP-RAFTS Subcatchment Layout

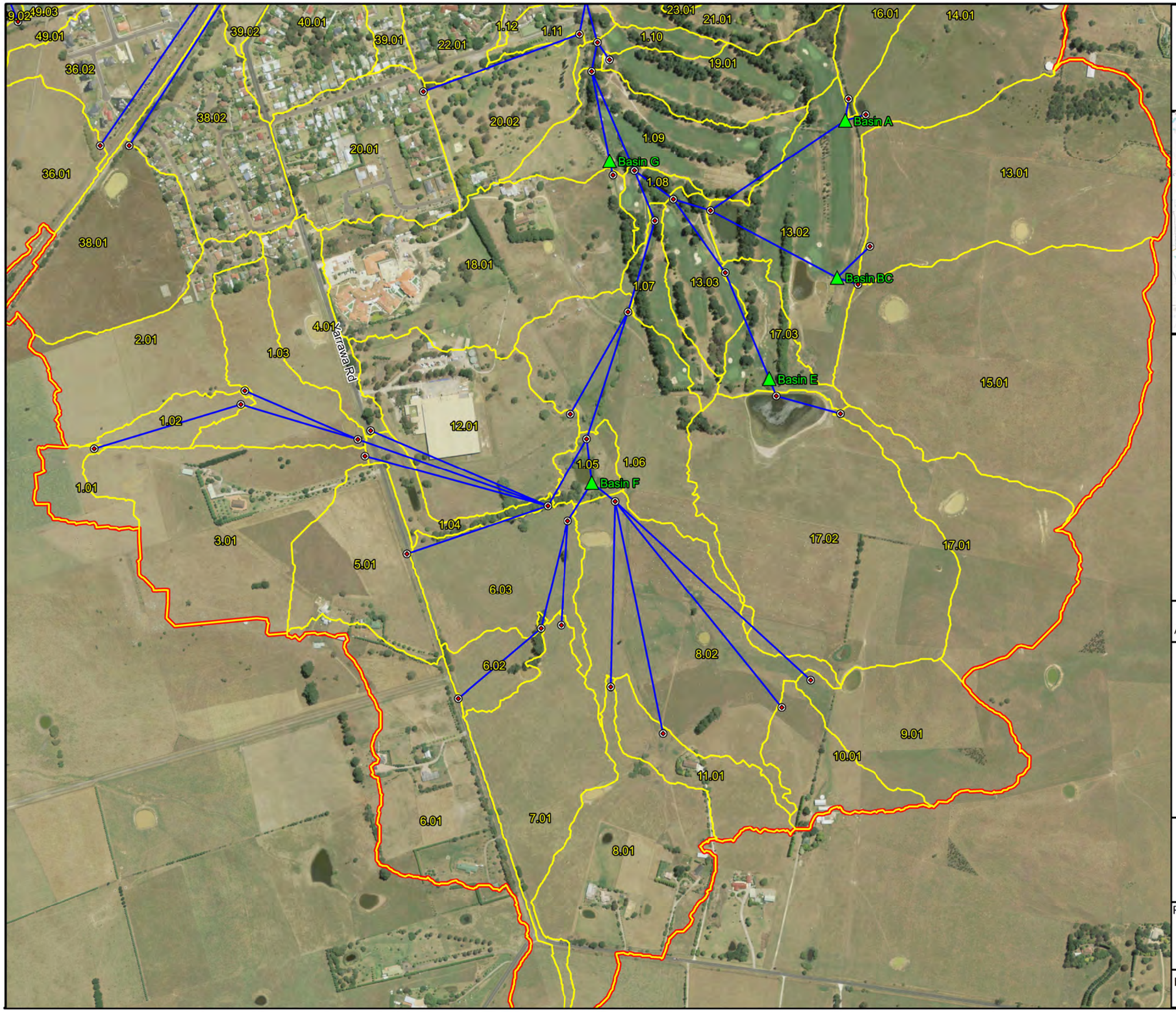
Prepared By:

Catchment Simulation Solutions

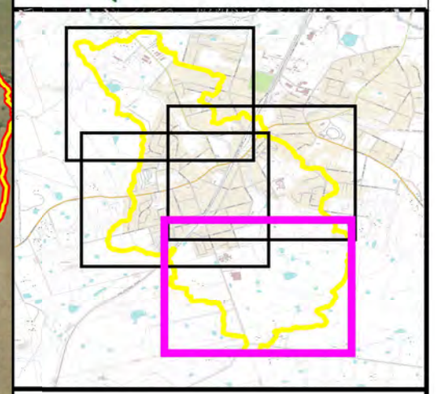
Suite 2.01, 210 George St

Sydney, NSW 2000

File Name: FigB1 - XP-RAFTS Sub. Layout.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- XP-RAFTS Subcatchment Boundaries
- Study Boundary
- XP-RAFTS Link
- XP-RAFTS Node
- Basin (Design Only)

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:6,500 (at A3)

0 175 350

m

Figure B1.4: XP-RAFTS Subcatchment Layout

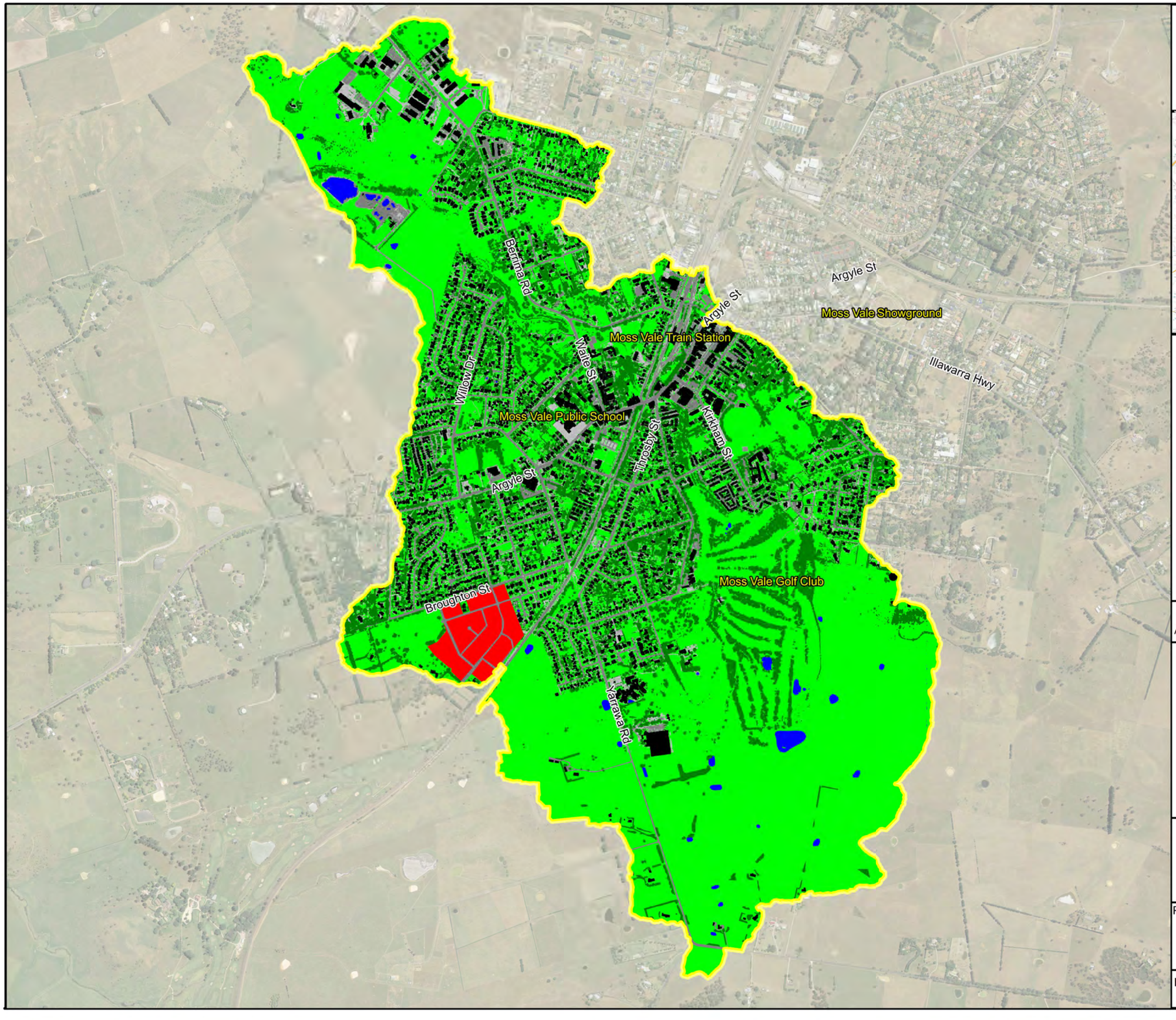
Prepared By:

Catchment Simulation Solutions

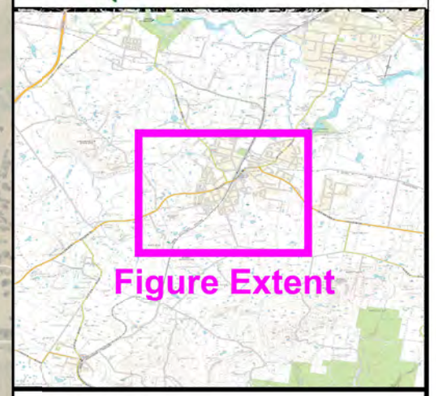
Suite 2.01, 210 George St

Sydney, NSW 2000

File Name: FigB1 - XP-RAFTS Sub. Layout.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Material

- Buildings
- Water
- Trees / Dense Shrubbery
- Grass
- Roads
- Impervious
- Urban Area

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:16,800 (at A3)

0 0.45 0.90

Km

Figure B2: Remote Sensing

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig - Remote Sensing.wor

Table B1 Adopted Impervious Percentage and Manning's 'n' Values for Hydrologic Model

Land Use	Pervious 'n'	Impervious (%)
Buildings	0.025	100
Roads	0.018	100
Concrete	0.013	100
Trees	0.080	0
Water	0.030	100
Grass	0.035	0
New Construction area	0.024	60

Effective Impervious Area

Historically, impervious areas in hydrologic models were represented as the "total impervious area" (TIA). This concept assumes that with the exception of the initial wetting of the catchment, all impervious areas contribute fully to runoff. However, research dating back to the 1970s (e.g., Cherkaver, 1975, Beard and Shin, 1979) highlights the importance of using the "Effective Impervious Area" (EIA) in preference to the TIA to better account for impervious areas that are not directly connected to the drainage system (referred to as indirectly connected impervious areas).

An example of an indirectly connected impervious area is a foot path which is adjoined by a grassed area. In instances such as this, any runoff from the footpath will flow onto the grassed area and this runoff will have an additional opportunity to infiltrate into the underlying soils, thereby reducing the contribution of runoff.

Accordingly, Book 5 of 'Australian Rainfall and Runoff – A Guide to Flood Estimation' (Geoscience Australia, 2016) advocates the use of EIA when modelling urbanised catchments to ensure urban runoff volumes and peak flows are not overestimated. Although ARR2016 presents a range of approaches for estimating the EIA, the most straight forward approach is estimating the EIA as a percentage of the TIA. Section 3.4.2.2 of Book 5 outlines that EIA will typically be 50% to 70% of the TIA. That is, only 50% to 70% of the total impervious area is directly connected to the drainage system. The remaining 30% to 50% of the impervious area is, therefore, indirectly connected and has additional infiltration opportunity.

For this study, the 70% adjustment factor (i.e., the most conservative factor) was adopted. A review of the remote sensing land use outputs indicates that this assumption is reasonable with roadways and building roof areas (which are both typically directly connected to the stormwater pipe system) comprising 77% of the total impervious area.

Stream Routing

In addition to local subcatchment runoff, most subcatchments will also carry flow from upstream catchments along the main watercourses. The flow along the watercourses in XP-RAFTS is represented using a "link" between successive subcatchment "nodes".

For this study, time delay routing was employed to represent the routing of runoff along the main watercourses into downstream subcatchments. The time delay value for each subcatchment was

calculated using a modified version of the Bransby-Williams formula (Queensland Government, 2007) and enforcing a minimum stream velocity of 0.8 m/s to overcome unrealistically large lag times in very flat areas.

Rainfall Loss Model

During a typical rainfall event, not all of the rain falling on a catchment is converted to runoff. Some of the rainfall may be intercepted and stored by vegetation, some may be stored in small depressions and some may infiltrate into the underlying soils.

To account for rainfall "losses" of this nature, the hydrologic model incorporates a rainfall loss model. For this study, the "Initial-Continuing" loss model was adopted. This loss model assumes that a specified amount of rainfall is lost during the initial saturation/wetting of the catchment (referred to as the 'Initial Loss'). Further losses are applied at a constant rate to simulate infiltration/interception once the catchment is saturated (referred to as the 'Continuing Loss Rate'). The initial and continuing losses are deducted from the total rainfall over the catchment, leaving the residual rainfall to be distributed across the catchment as runoff.

1.3. XP-RAFTS Model Validation

Overview

Hydrologic computer models are typically developed using parameters that are not known with a high degree of certainty including rainfall loss rates and catchment roughness. Accordingly, the model should be calibrated using rainfall and stream flow data from historic flood events to ensure the adopted parameters are producing reliable estimates of rainfall-runoff behaviour. Calibration is typically completed by routing recorded rainfall through the hydrologic model. Simulated discharge hydrographs are extracted from the model results at locations where recorded stream flow records are available. Calibration is completed by adjusting model parameters to achieve the best match possible between recorded and model-generated hydrographs.

Unfortunately, no stream gauges are located within the catchment. The lack of stream flow data means that a comprehensive calibration of the hydrologic model could not be completed. Nevertheless, it is possible to complete a 'validation' of the model by routing historic rainfall through the hydrologic model and then routing the resultant discharge hydrographs through the hydraulic model. Peak flood extents and depths produced by the hydraulic model can then be compared against reported flood depths/flood photographs to verify the combined performance of the hydrologic and hydraulic models. Validation is achieved by jointly adjusting hydrologic and/or hydraulic inputs parameters until the recorded flood depths and extents are reproduced by the hydraulic model as closely as possible.

A flood that occurred in June 2016 was selected for the model validation. Details of the 2016 hydrologic simulation is presented below. However, as a joint calibration/validation was performed using the hydrologic and hydraulic models, the hydrologic model validation should be read in conjunction with the hydrologic model validation discussed in **Appendix C**.

Modifications to Represent Historic Floodplain Conditions

As the June 2016 event occurred relatively recently, no modifications to the "existing" conditions TUFLOW model was completed to reflect catchment conditions at the time of the 2016 flood.

Rainfall Losses

The following rainfall losses were adopted in the XP-RAFTS model as part of the June 2016 flood simulation

- Rainfall Losses for pervious surfaces:
  - Initial Loss = 15 mm
  - Continuing Loss Rates = 2.5 mm/hour
- Rainfall Losses for directly connect impervious surfaces:
  - Initial Loss = 1 mm
  - Continuing Loss Rates = 0 mm/hour

Results

A summary of peak discharges generated by the XP-RAFTS model for the 2016 simulation are also included at the end of this appendix.

Appendix B - XP-RAFTS Inputs

Subcatchment ID	Total Area (ha)	Impervious Proportion (%)		Slope (%)	Pervious Mannings 'n' values		Impervious Mannings 'n' values
		Existing	Design		Existing	Design	
1.01	1.63	0.29	0.29	1.31	0.035	0.035	0.015
1.02	1.59	0.00	0.00	1.26	0.035	0.035	0.015
1.03	4.82	4.12	4.12	1.19	0.036	0.036	0.015
1.04	1.51	7.19	7.19	0.96	0.047	0.047	0.015
1.05	1.30	9.04	18.52	0.89	0.040	0.039	0.015
1.06	8.59	0.00	58.54	2.08	0.038	0.027	0.015
1.07	1.83	0.00	7.57	2.27	0.052	0.047	0.015
1.08	0.88	0.00	0.00	2.90	0.062	0.062	0.015
1.09	6.37	0.51	0.55	1.80	0.049	0.049	0.015
1.10	1.14	1.68	1.68	4.41	0.050	0.050	0.015
1.11	1.34	17.66	17.66	3.97	0.049	0.049	0.015
1.12	1.05	26.92	26.92	3.20	0.037	0.037	0.015
1.13	2.55	16.15	16.15	1.77	0.049	0.049	0.015
1.14	0.17	8.01	8.01	1.56	0.055	0.055	0.015
1.15	0.15	22.62	22.62	1.94	0.035	0.035	0.015
1.16	9.40	27.16	27.16	1.94	0.048	0.048	0.015
1.17	0.38	39.25	39.25	0.82	0.046	0.046	0.015
1.18	4.78	35.50	35.50	3.20	0.046	0.046	0.015
1.19	2.68	28.19	28.19	2.04	0.054	0.054	0.015
1.20	0.89	69.17	69.17	4.52	0.038	0.038	0.015
1.21	2.01	78.75	78.75	1.36	0.032	0.032	0.015
1.22	0.15	46.49	46.49	2.84	0.050	0.050	0.015
1.23	4.41	43.71	43.71	0.99	0.045	0.045	0.015
1.24	8.79	25.20	25.20	1.27	0.044	0.044	0.015
1.25	7.65	15.65	15.65	1.76	0.050	0.050	0.015
1.26	2.60	39.86	39.86	3.47	0.045	0.045	0.015
1.27	3.97	30.66	30.66	2.61	0.044	0.044	0.015
1.28	2.52	33.13	33.13	1.90	0.035	0.035	0.015
1.29	2.64	5.81	5.81	0.69	0.037	0.037	0.015
1.30	0.82	2.23	2.23	0.73	0.043	0.043	0.015
1.31	5.94	14.81	14.81	1.60	0.039	0.039	0.015
1.32	0.70	0.23	0.23	1.39	0.057	0.057	0.015
2.01	6.60	6.39	6.39	1.18	0.036	0.036	0.015
3.01	10.77	3.24	3.24	2.52	0.036	0.036	0.015
4.01	3.82	26.77	26.77	2.10	0.036	0.036	0.015
5.01	5.90	4.74	4.74	3.21	0.035	0.035	0.015
6.01	9.80	5.57	5.57	1.96	0.040	0.040	0.015
6.02	1.91	4.24	61.64	2.42	0.039	0.026	0.015
6.03	6.05	0.67	49.63	1.33	0.036	0.028	0.015
7.01	7.47	2.40	64.06	2.39	0.035	0.025	0.015
8.01	9.62	5.00	39.58	3.21	0.037	0.031	0.015
8.02	12.13	1.21	76.02	1.95	0.035	0.023	0.015
9.01	6.86	1.29	5.65	4.68	0.036	0.035	0.015
10.01	3.37	1.39	41.18	4.73	0.037	0.029	0.015
11.01	3.15	1.10	80.00	4.77	0.036	0.022	0.015
12.01	9.08	21.53	21.53	0.98	0.038	0.038	0.015

Subcatchment ID	Total Area (ha)	Impervious Proportion (%)		Slope (%)	Pervious Mannings 'n' values		Impervious Mannings 'n' values
		Existing	Design		Existing	Design	
13.01	15.61	0.60	63.22	4.48	0.039	0.028	0.015
13.02	8.12	5.64	9.40	0.91	0.042	0.041	0.015
13.03	2.99	0.00	0.00	2.33	0.050	0.050	0.015
14.01	9.06	4.51	69.43	9.66	0.037	0.026	0.015
15.01	20.75	0.74	77.62	2.05	0.035	0.022	0.015
16.01	3.27	4.05	60.37	7.89	0.042	0.032	0.015
17.01	8.39	1.02	47.51	2.48	0.035	0.027	0.015
17.02	17.88	5.82	53.25	1.00	0.036	0.026	0.015
17.03	2.82	0.00	6.82	1.44	0.047	0.045	0.015
18.01	12.91	14.93	42.41	3.41	0.041	0.034	0.015
19.01	4.75	0.86	0.86	2.75	0.055	0.055	0.015
20.01	7.35	42.18	42.18	3.23	0.040	0.040	0.015
20.02	4.93	3.06	3.14	3.64	0.050	0.050	0.015
21.01	2.72	0.00	0.00	4.12	0.055	0.055	0.015
22.01	5.50	29.35	29.35	2.30	0.052	0.052	0.015
22.02	0.66	25.15	25.15	3.25	0.043	0.043	0.015
23.01	7.38	2.12	2.30	6.31	0.052	0.052	0.015
24.01	5.99	8.54	8.54	8.91	0.051	0.051	0.015
25.01	2.51	44.34	44.34	13.76	0.035	0.035	0.015
25.02	1.61	39.90	39.90	6.41	0.039	0.039	0.015
26.01	5.83	34.43	34.43	4.63	0.043	0.043	0.015
27.01	4.20	34.91	34.91	5.83	0.049	0.049	0.015
27.02	4.12	27.18	27.18	7.21	0.046	0.046	0.015
27.03	2.37	1.72	1.72	6.96	0.043	0.043	0.015
27.04	0.82	52.21	52.21	1.65	0.039	0.039	0.015
28.01	2.87	51.79	51.79	6.08	0.038	0.038	0.015
29.01	5.19	17.00	17.00	7.73	0.050	0.050	0.015
30.01	3.10	39.16	39.16	4.23	0.045	0.045	0.015
31.01	4.15	2.70	2.70	4.09	0.039	0.039	0.015
31.02	0.81	39.59	39.59	2.29	0.040	0.040	0.015
32.01	6.96	40.72	40.73	4.96	0.048	0.048	0.015
32.02	0.55	71.78	71.78	2.30	0.030	0.030	0.015
33.01	5.87	25.48	25.48	5.03	0.048	0.048	0.015
34.01	3.88	59.12	59.12	0.53	0.033	0.033	0.015
34.02	1.76	39.17	39.17	0.07	0.049	0.049	0.015
35.01	3.61	81.17	81.17	3.42	0.029	0.029	0.015
35.02	0.41	91.25	91.25	2.51	0.024	0.024	0.015
36.01	11.09	57.85	57.85	3.90	0.026	0.026	0.015
36.02	6.39	53.15	53.15	2.15	0.032	0.032	0.015
36.03	1.07	46.62	46.62	2.06	0.044	0.044	0.015
36.04	2.24	41.96	41.96	1.57	0.038	0.038	0.015
36.05	1.35	65.76	65.76	0.35	0.035	0.035	0.015
37.01	7.36	39.49	39.49	2.57	0.040	0.040	0.015
37.02	8.84	39.08	39.08	2.50	0.045	0.045	0.015
38.01	7.70	6.59	6.59	2.45	0.036	0.036	0.015
38.02	6.94	39.17	39.17	3.01	0.041	0.041	0.015
38.03	0.75	51.63	51.63	2.25	0.034	0.034	0.015
38.04	2.16	35.82	35.82	2.26	0.044	0.044	0.015
38.05	3.36	41.18	41.18	1.31	0.047	0.047	0.015

Subcatchment ID	Total Area (ha)	Impervious Proportion (%)		Slope (%)	Pervious Mannings 'n' values		Impervious Mannings 'n' values
		Existing	Design		Existing	Design	
39.01	2.64	37.60	37.60	3.12	0.044	0.044	0.015
39.02	2.36	44.70	44.70	2.12	0.035	0.035	0.015
40.01	5.89	35.63	35.63	3.01	0.046	0.046	0.015
41.01	4.26	37.06	37.06	3.15	0.044	0.044	0.015
42.01	2.61	60.26	60.26	2.97	0.034	0.034	0.015
42.02	4.49	57.02	57.02	2.00	0.037	0.037	0.015
43.01	5.43	50.93	50.93	3.87	0.044	0.044	0.015
44.01	2.06	66.99	66.99	1.45	0.031	0.031	0.015
44.02	3.08	31.07	31.07	1.31	0.042	0.042	0.015
45.01	4.66	39.87	39.87	3.07	0.041	0.041	0.015
46.01	4.64	26.45	26.45	5.20	0.046	0.046	0.015
47.01	11.39	5.25	5.25	4.17	0.044	0.044	0.015
47.02	7.95	31.71	31.71	3.98	0.051	0.051	0.015
47.03	0.31	48.34	48.34	3.89	0.042	0.042	0.015
47.04	4.92	44.81	44.81	1.88	0.040	0.040	0.015
47.05	7.02	43.05	43.05	2.89	0.042	0.042	0.015
47.06	1.29	27.35	27.35	5.13	0.043	0.043	0.015
47.07	6.92	40.47	40.47	2.74	0.039	0.039	0.015
47.08	1.81	41.35	41.35	2.38	0.042	0.042	0.015
47.09	0.11	32.73	32.73	7.48	0.052	0.052	0.015
47.10	1.65	36.22	36.22	2.63	0.046	0.046	0.015
47.11	5.36	27.37	27.37	2.44	0.047	0.047	0.015
48.01	2.91	46.15	46.15	4.09	0.039	0.039	0.015
49.01	2.47	60.67	60.67	2.70	0.027	0.027	0.015
49.02	1.90	52.95	52.95	2.95	0.039	0.039	0.015
49.03	3.51	46.23	46.23	3.22	0.039	0.039	0.015
49.04	1.80	10.38	10.38	1.76	0.047	0.047	0.015
50.01	4.49	31.89	31.89	2.64	0.048	0.048	0.015
51.01	3.06	53.42	53.42	3.45	0.037	0.037	0.015
52.01	2.57	32.97	32.97	2.99	0.037	0.037	0.015
53.01	1.72	62.16	62.16	2.27	0.034	0.034	0.015
53.02	2.95	22.78	22.78	3.51	0.046	0.046	0.015
53.03	1.32	29.06	29.06	2.19	0.046	0.046	0.015
54.01	0.85	66.07	66.07	2.18	0.032	0.032	0.015
54.02	4.03	33.67	33.67	4.45	0.044	0.044	0.015
55.01	3.29	40.82	40.82	3.91	0.043	0.043	0.015
55.02	0.37	45.18	45.18	3.02	0.041	0.041	0.015
56.01	4.13	40.31	40.31	1.70	0.043	0.043	0.015
56.02	0.19	65.33	65.33	1.59	0.027	0.027	0.015
57.01	2.95	31.08	31.08	4.07	0.037	0.037	0.015
57.02	2.60	51.33	51.33	2.70	0.036	0.036	0.015
58.01	6.99	32.81	32.81	5.53	0.045	0.045	0.015
58.02	2.09	17.02	17.02	3.13	0.047	0.047	0.015
59.01	2.65	11.84	11.84	1.26	0.048	0.048	0.015
60.01	6.03	28.99	28.99	0.93	0.045	0.045	0.015
60.02	1.62	31.86	31.86	2.74	0.038	0.038	0.015
60.03	0.45	42.62	42.62	2.70	0.041	0.041	0.015
60.04	5.52	33.85	33.85	4.85	0.038	0.038	0.015
60.05	3.41	34.92	34.92	2.62	0.046	0.046	0.015

Subcatchment ID	Total Area (ha)	Impervious Proportion (%)		Slope (%)	Pervious Mannings 'n' values		Impervious Mannings 'n' values
		Existing	Design		Existing	Design	
61.01	3.29	43.90	43.90	3.79	0.040	0.040	0.015
62.01	6.25	35.18	35.18	3.57	0.041	0.041	0.015
63.01	6.88	28.35	28.35	2.24	0.037	0.037	0.015
63.02	5.03	42.95	42.95	2.06	0.031	0.031	0.015
63.03	4.34	40.82	40.82	4.29	0.040	0.040	0.015
64.01	7.06	52.66	52.66	4.33	0.029	0.029	0.015
64.02	2.49	14.18	14.18	3.73	0.034	0.034	0.015
64.03	0.31	0.00	0.00	2.50	0.035	0.035	0.015
65.01	2.03	21.79	21.79	1.88	0.037	0.037	0.015
65.02	3.12	24.05	24.05	4.70	0.034	0.034	0.015
66.01	3.54	29.67	29.67	4.40	0.034	0.034	0.015
67.01	10.13	11.99	11.99	0.81	0.034	0.034	0.015
67.02	12.64	13.46	13.46	0.81	0.034	0.034	0.015
67.03	3.90	7.58	7.58	2.58	0.034	0.034	0.015
67.04	1.88	25.13	25.13	1.87	0.035	0.035	0.015
67.05	1.27	4.25	4.25	1.37	0.042	0.042	0.015
68.01	2.94	13.95	13.95	2.43	0.035	0.035	0.015
69.01	3.56	2.22	2.22	2.39	0.036	0.036	0.015
70.01	4.42	41.88	41.88	2.20	0.032	0.032	0.015
70.02	5.80	4.15	4.15	8.25	0.037	0.037	0.015
70.03	5.29	6.09	6.09	2.82	0.038	0.038	0.015
71.01	5.52	1.33	1.33	8.13	0.039	0.039	0.015
72.01	6.40	38.47	38.47	1.14	0.035	0.035	0.015

Appendix B - XP-RAFTS Outputs for the June 2016 Calibration Event

Subcatchment ID	Peak Outflow [m^3/s]
1.01	0.10
1.02	0.18
1.03	0.77
1.04	2.28
1.05	3.41
1.06	6.28
1.07	11.09
1.08	11.99
1.09	12.26
1.10	12.92
1.11	13.07
1.12	13.44
1.13	13.74
1.14	13.98
1.15	14.52
1.16	14.79
1.17	15.81
1.18	16.08
1.19	16.50
1.20	16.90
1.21	16.91
1.22	21.28
1.23	22.29
1.24	22.84
1.25	28.12
1.26	28.71
1.27	28.93
1.28	30.23
1.29	31.72
1.30	33.63
1.31	34.66
2.01	0.35
3.01	0.61
4.01	0.28
5.01	0.36
6.01	0.54
6.02	0.65
6.03	1.14
7.01	0.43
8.01	0.57
8.02	2.01
9.01	0.43
10.01	0.21
11.01	0.20
12.01	0.57
13.01	0.66

Subcatchment ID	Peak Outflow [m^3/s]
13.02	1.50
13.03	3.19
13.04	4.85
14.01	0.61
14.02	0.85
15.01	1.12
16.01	0.22
17.01	0.49
17.02	1.39
17.03	1.54
18.01	0.80
19.01	0.26
20.01	0.61
20.02	0.87
21.01	0.16
22.01	0.39
22.02	0.43
23.01	0.45
24.01	0.39
25.01	0.25
25.02	0.37
26.01	0.47
27.01	0.34
27.02	0.87
27.03	1.32
27.04	1.55
28.01	0.29
29.01	0.35
30.01	0.27
31.01	0.26
31.02	0.31
32.01	0.58
32.02	1.04
33.01	0.42
34.01	0.35
34.02	0.44
35.01	0.41
35.02	0.44
36.01	1.09
36.02	1.41
36.03	1.47
36.04	2.52
36.05	5.42
37.01	0.59
37.02	1.05
38.01	0.45

Subcatchment ID	Peak Outflow [m^3/s]
38.02	0.88
38.03	0.92
38.04	1.78
38.05	2.20
39.01	0.22
39.02	0.84
40.01	0.46
41.01	0.34
42.01	0.26
42.02	0.56
43.01	0.50
44.01	0.21
44.02	0.76
45.01	0.39
46.01	0.35
47.01	0.67
47.02	1.14
47.03	1.16
47.04	1.61
47.05	3.00
47.06	3.44
47.07	4.54
47.08	4.63
47.09	4.86
47.10	5.48
47.11	5.74
48.01	0.27
49.01	0.25
49.02	0.40
49.03	0.63
49.04	0.73
50.01	0.34
51.01	0.30
52.01	0.21
53.01	0.17
53.02	0.36
53.03	0.78
54.01	0.09
54.02	0.37
55.01	0.29
55.02	0.31
56.01	0.34
56.02	0.80

Subcatchment ID	Peak Outflow [m^3/s]
57.01	0.24
57.02	0.45
58.01	0.55
58.02	0.68
59.01	0.15
60.01	0.41
60.02	0.52
60.03	0.82
60.04	1.56
60.05	1.74
61.01	0.30
62.01	0.49
63.01	0.49
63.02	0.80
63.03	1.05
64.01	0.67
64.02	1.16
64.03	1.40
65.01	0.14
65.02	0.36
66.01	0.29
67.01	0.57
67.02	1.21
67.03	1.44
67.04	1.72
67.05	1.99
68.01	0.19
69.01	0.21
70.01	0.38
70.02	0.75
70.03	1.38
71.01	0.36
72.01	0.49

APPENDIX C

HYDRAULIC MODEL

C1. HYDRAULIC MODEL

1.1 Introduction

Hydraulic computer models are the most common method of simulating flood behaviour through a particular area of interest. They can be used to route discharge hydrographs generated by the hydrologic model across the study area and predict flood characteristics such as peak flood level and flow velocity. The results of the modelling can also be used to define the variation in flood hazard and hydraulic categories within the study area.

A new hydraulic computer model of the Whites Ck catchment was developed as part of the study. The new computer model was developed using the TUFLOW software. TUFLOW is a fully dynamic, 1D/2D finite difference model developed by BMT WBM. It is used extensively across Australia to assist in defining flood behaviour.

The following sections describe the model development process as well as the outcomes of the model validation.

1.2 TUFLOW Model Development

1.2.1 Model Grid Size and Extent

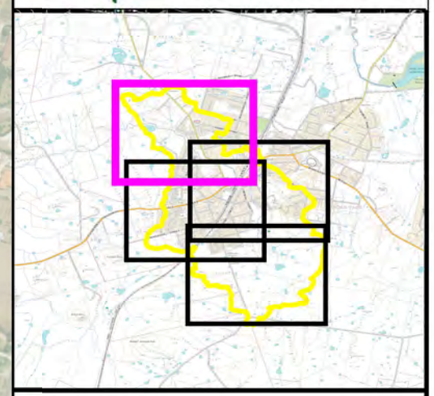
A linked 1-dimensional/2-dimensional hydraulic model of the main watercourses, floodplain and stormwater network was developed for the Whites Creek catchment using the TUFLOW software. The model extends across the full extent of the Whites Creek catchment draining to the Moss Vale Sewage Treatment Plant (STP). The extent of the hydraulic model is shown in **Figures C1.1** to **C1.4** inclusive.

The TUFLOW software uses a uniform grid to define the spatial variation in topography and hydraulic properties (e.g., Manning's 'n') across the 2D model domain. A 2 metre grid size was adopted for this study and is considered to provide a reasonable representation of the variation in terrain and hydraulic roughness across the catchment while keeping simulations times within reasonable limits.

1.2.2 Model Topography

Elevations were assigned to grid cells within the 2D domain based on a Digital Elevation Model derived from LiDAR data. As the LiDAR data was collected in 2014, the terrain representation in TUFLOW is indicative of topographic conditions at that time. That is, any topographic modifications completed since 2014 will not be reflected in the model. A review of recent aerial photography indicates there has been negligible significant topographic modifications across the catchment since the LiDAR data was collected. Therefore, the LiDAR is considered to provide a reliable representation of contemporary topographic conditions across the majority of the catchment.

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LEGEND

- 2D Model Domain

1D Model Features

- 1D Channel
- Stormwater Pits
- Stormwater Pipes
- Hydraulic Structure
- Cross Section

Model Boundary Conditions

- Normal Depth Downstream Boundary
- "Total" flow hydrograph
- "Local" flow hydrograph

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:6,500 (at A3)

0 175 350

m

Figure C1.1: TUFLOW Model Layout

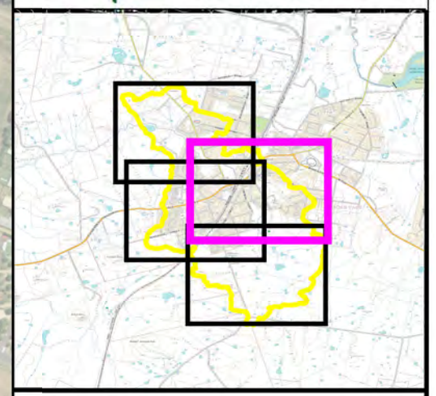
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File Name: Fig - TUFLOW Model Layout.wor



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LEGEND

- 2D Model Domain

1D Model Features

- 1D Channel
- Stormwater Pits
- Stormwater Pipes
- Hydraulic Structure
- Cross Section

Model Boundary Conditions

- Normal Depth Downstream Boundary
- "Total" flow hydrograph
- "Local" flow hydrograph

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:6,500 (at A3)

0 175 350 m

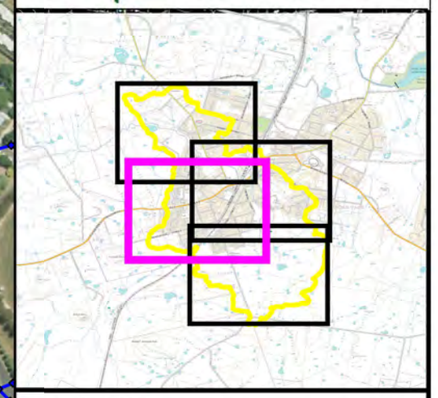
Figure C1.2: TUFLOW Model Layout

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Sydney, NSW 2000

File Name: Fig - TUFLOW Model Layout.wor

Moss Vale Train Station
Moss Vale Public School
Willow Dr
Waite St
Argyle St
Throsby St
Kirkham St
Broughton St
Yarra

WINGECARRIBEE SHIRE COUNCIL



LEGEND

2D Model Domain

1D Model Features

- 1D Channel
- Stormwater Pits
- Stormwater Pipes
- Hydraulic Structure
- Cross Section

Model Boundary Conditions

- Normal Depth Downstream Boundary
- "Total" flow hydrograph
- "Local" flow hydrograph

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:6,500 (at A3)

0 175 350

m

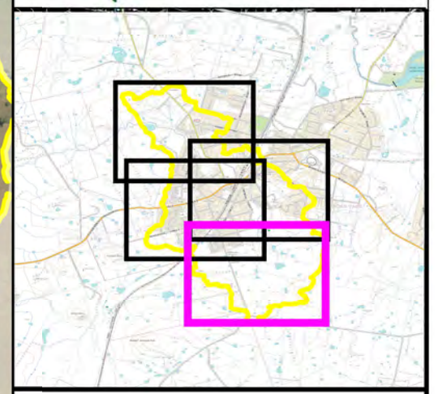
Figure C1.3: TUFLOW Model Layout

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Sydney, NSW 2000

File Name: Fig - TUFLOW Model Layout.wor



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LEGEND

- 2D Model Domain

1D Model Features

- 1D Channel
- Stormwater Pits
- Stormwater Pipes
- Hydraulic Structure
- Cross Section

Model Boundary Conditions

- Normal Depth Downstream Boundary
- "Total" flow hydrograph
- "Local" flow hydrograph

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:6,500 (at A3)

0 175 350

m

Figure C1.4: TUFLOW Model Layout

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Sydney, NSW 2000

File Name: Fig - TUFLOW Model Layout.wor

1.2.3 1-Dimensional Domain

The TUFLOW model utilises 1D domains to represent each of the major watercourses in the study area, namely Whites Creek and the main tributary referred to as "Willow Creek". The locations of the 1D domains included in the TUFLOW model are shown in **Figures C1.1** to **C1.4**.

The topography within the 1D domain was defined using cross-sections extracted from the HEC-RAS model developed as part of the *'Whites Creek Floodplain Risk Management Study and Plan'* (URS, 2012). The cross-section data extracted from HEC-RAS was supplemented with cross-sections extracted from the LiDAR in areas that were not obstructed by vegetation. **Figures C1.1** to **C1.4** show the location of cross-sections used to define the conveyance of each 1D channel.

The cross-sections extracted from the HEC-RAS model were also compared to cross-sections extracted from the LiDAR. In some instances, the ground elevations in the HEC-RAS cross-section were found to be higher than the ground surface elevations in the LiDAR data. An example of this is shown below in **Plate C1**. In these instances, a cross-section extracted from the LiDAR data was adopted in the TUFLOW model to define the conveyance characteristics of the watercourse.

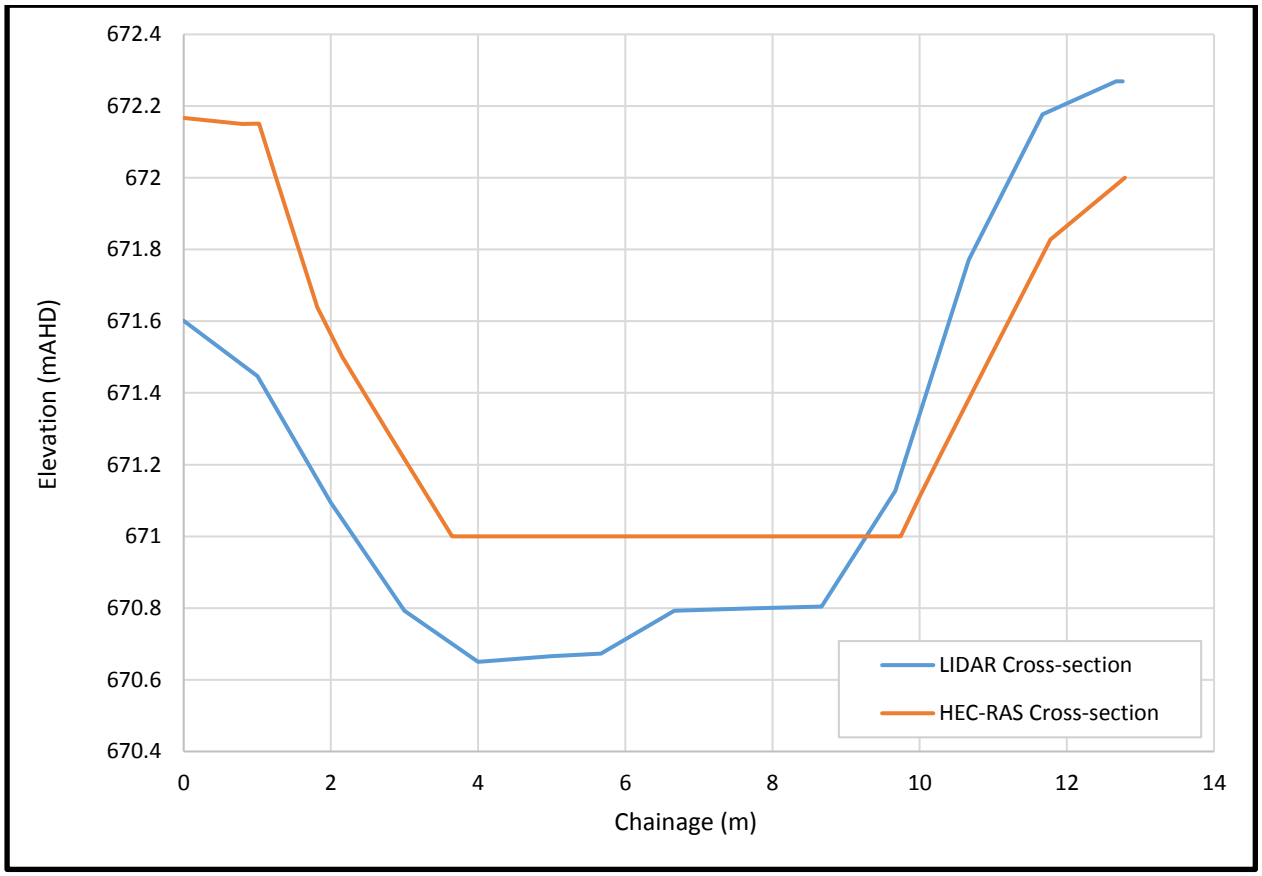


Plate C1 Comparison between HEC-RAS and LiDAR cross-sections at Cross-Section XS10 on Whites Creek

1.2.4 Material Types / Manning's 'n' Roughness

The TUFLOW software employs material polygons to define the variation in hydraulic roughness (i.e., Manning's 'n' values) across the study area. As discussed in **Appendix B**, remote sensing analysis was used to subdivide the catchment into different land uses for the XP-RAFTS modelling. These classifications were also used as the basis for assigning Manning's 'n' values to each material type within the TUFLOW model. However, some manual updates were completed

to the remote sensing land use categories in areas that were not well defined. This included subdividing grass into urban and rural grass subcategories.

The land uses and the corresponding Manning's 'n' values are provided in **Table C1**.

Table C1 Manning's 'n' Roughness Values

Material Description	Manning's 'n'
Buildings	2.000
Waterbodies	0.030
Trees / Dense Shrub	0.100
Urban grassed areas	0.045
Rural Grassland / Brush	0.060
Impervious/concrete	0.013
Roads	0.016
New urban area	0.028

1D cross-sections, pipes and culverts within the 1D domain of the TUFLOW model also require the specification of Manning's 'n' values. These values were defined based on field assessments, photography and inspection of aerial photography. For natural channels, the assigned Manning's n values range from 0.025 to 0.08. For concrete pipes and culverts, a Manning's n value of 0.013 was adopted.

1.2.5 Culverts/Bridges

Culverts and bridges can have a significant influence on flood behaviour. Therefore, all significant bridges and culverts located within the Whites Creek catchment were included within the TUFLOW model. The locations of all hydraulic structures included in the TUFLOW model are shown in **Figures C1.1**. to **C1.4**

For circular or rectangular culverts, the physical dimensions and invert elevations of the structures were included as 1D elements in the TUFLOW model based on data extracted from the HEC-RAS model. Details of the structures in the vicinity of Argyle Street were defined based on detailed structure survey undertaken by Richard Cox Surveyors Pty Ltd in August 2010.

Entry and exit loss coefficients were defined based on default values provided in the TUFLOW Manual (BMT WBM, 2016). Typically, an entry loss coefficient of 0.5 and an exit loss coefficient 1.0 was adopted for all culverts.

Structure Blockage

During a typical flood, sediment, vegetation and urban debris (e.g., litter) from the catchment can become mobilised leading to blockage of downstream culverts and bridges. Consequently, bridges and culverts will not operate at full efficiency during most floods. This can increase the severity of flooding across areas located adjacent to these structures.

In recognition of this, blockage factors were applied to all bridges and culverts. The blockage factors were applied based on guidelines contained in the Australian Rainfall & Runoff document titled 'Blockage of Hydraulic Structures' (Engineers Australia, 2015). This guideline requires an assessment of potential debris type, debris availability, debris mobility and debris transportability at each structure location. This assessment was completed using the land use information described in **Appendix B** as well the LiDAR information. The outcome of the blockage assessment is summarised in **Appendix D** for each structure located within the catchment.

1.2.6 Ponds / Farm Dams

The upper catchment includes a number of farm dams that also have the potential to store water and attenuate flows during floods. There are also three (3) ponds within the Moss Vale Golf Club. A representation of the major dams and ponds was included in the TUFLOW model.

The absence of any water level monitoring gauges within each basin/dam means that the normal operating water level (or range of operating water levels) of each storage is not known. In the absence of any water level information, it was assumed that all 'wet' water storages (e.g., farm dams and ponds) were full at the start of each simulated flood.

1.2.7 Stormwater System

The majority of the Whites Creek catchment is drained by a network of open creek channels. However, this is supplemented by a stormwater drainage system that is designed to capture runoff across the urban sections of the catchment during frequent rainfall events and convey it below ground and into the receiving waterway. Therefore, it was considered important to incorporate the conveyance provided by the stormwater system in the TUFLOW model to ensure the interaction between piped stormwater and overland flows across the urban sections of the catchment was represented.

The full stormwater system contained within the catchment was included within the TUFLOW model as a dynamically linked 1D network. This allowed representation of the conveyance of flows by the stormwater system below ground as well as simulation of overland flows in two dimensions once the capacity of the stormwater system is exceeded. The stormwater system representation largely drew from Council's asset GIS database but was supplemented with additional information extracted from the detailed survey undertaken by Richard Cox Surveyors Pty Ltd in the vicinity of Argyle Street in August 2010. The extent of the stormwater system included within the TUFLOW model is shown in **Figures C1.1** to **C1.4** inclusive.

It was noted that some key information describing the stormwater system (e.g., invert elevations, pit types) was not available for all pipes and pits. As a result, the stormwater GIS layers did not contain all of the information necessary to fully define the stormwater system in TUFLOW.

Therefore, the missing pit and pipe GIS information was estimated to ensure all required information describing the stormwater system was included in the TUFLOW model. Where pipe diameter information was not available, the diameter was interpolated based upon inspection of the upstream and downstream pipe diameters.

The missing pit information was populated using the following approach:

- All stormwater pits without a type classification were assumed to comprise a grated kerb inlet with a lintel length of 1.2 metres.
- Pit invert elevations were interpolated between known pit invert elevations. Where known pit information was not available to assist the interpolation, the pit inverts were estimated using the following equation:
  -> Invert elevation = Ground elevation – 1 metre

The estimated pit inverts were subsequently reviewed to ensure there were no adverse pipe grades across the catchment. This resulted in some modifications to the estimated pit invert elevations by hand. Pit types in critical flooding locations were also reviewed based on Google Street View.

Once all stormwater pits were included in the TUFLOW model, inlet capacity curves were prepared to define the pit inflow capacity with respect to water depth for each pit type. The 'Drains Generic Pit Spreadsheet' (Watercom Pty Ltd, July 2005), was used to develop the inlet capacity curves. The inlet capacity curves were developed to take account of:

- The different pit inlet types (e.g., grated, side entry, combination);
- The different topographic locations (e.g., sag or on-grade); and,
- The different grate dimensions and lintel sizes.

The inlet capacity curves that were developed for each pit type are provided in **Appendix E**.

Hydraulic 'losses' throughout the stormwater system were estimated using the Engelhund loss approach (BMT WBM, 2016). This loss approach automatically accounts for the following loss components for each stormwater pit for each model time step:

- Pit entrance loss
- Loss associated with a drop in elevation between inlet and outlet pipes
- Loss associated with a change in flow direction between the inlet and output pipes
- Pit exit loss

Stormwater inlets may also become blocked by debris during the course of a flood. In recognition of this, a 50% blockage factor was also applied to all sag stormwater inlets and 20% blockage was applied to on-grade stormwater inlets.

1.2.8 Model Boundary Conditions

Upstream Boundary Conditions

As outlined in **Appendix B**, a new XP-RAFTS hydrologic model was developed to represent the transformation of rainfall into runoff and generate discharge hydrographs throughout the study area.

The discharge hydrographs generated by the XP-RAFTS model was used to define upstream (i.e., inflow) boundary conditions for the TUFLOW model. It was necessary to use a combination of "total" flow hydrographs to represent the total flow from the upstream catchment into the main open watercourses and "local" flow hydrographs to represent flow from the local subcatchment

only in the TUFLOW model. The location where "total" and "local" discharge hydrographs were applied to the TUFLOW model is shown in **Figures C1.1** to **C1.4** inclusive.

Downstream Boundary Conditions

Hydraulic computer models also require the adoption of a suitable downstream boundary condition in order to reliably define flood behaviour throughout the area of interest. The downstream boundary is typically defined as a known water surface elevation (i.e., stage).

As shown in **Figure C1.1**, the downstream boundary of the TUFLOW model is located downstream of the Moss Vale STP. Accordingly, water travelling along the main watercourse at this location can discharge freely downstream and there should be no 'backwater' effects from other watercourses or structures that may influence the water surface elevation in this area.

Accordingly, a 'normal depth' boundary was applied at the downstream end of the Whites Creek TUFLOW model. This approach assumes that the downstream water level is influenced only by the geometry, roughness and slope of the main waterway. Any uncertainty associated with the downstream boundary definitions should not impact on flood behaviour across the "built up" sections of the catchment, which are located at least 250 metres upstream of this boundary.

1.3 TUFLOW Model Validation

A full calibration of the XP-RAFTS hydrologic and TUFLOW hydraulic computer models could not be completed due to the lack of any stream gauge(s) within the Whites Creek catchment. Nevertheless, a joint calibration/validation of the hydrologic and hydraulic models was attempted to verify that the computer models were providing realistic reproductions of past floods.

Several photographs and descriptions of flooding from a June 2016 event were provided by several residents as part of the community consultation. Accordingly, this event was selected for the model verification. Further details of the hydraulic model validation process are provided below.

As a joint calibration/validation was performed using the hydrologic and hydraulic models, the hydraulic model validation should be read in conjunction with the hydrologic model validation discussed in **Appendix B**.

1.3.1 Modifications to Represent Historic Floodplain Conditions

As the June 2016 event occurred relatively recently, no modifications to the "existing" conditions TUFLOW model were necessary.

The 2016 flood event was likely less than a 5% AEP flood and therefore the "low blockage" scenario was adopted for the simulation of this historic flood in line with the ARR2016 blockage recommendations.

1.3.2 Validation Approach

Validation of the TUFLOW model was completed by using the XP-RAFTS and TUFLOW models to reproduce reports and photographs of historic flood behaviour from the 2016 event. The descriptions of historic flood behaviour largely drew upon information provided as part of the community questionnaire responses (refer **Appendix A**). The descriptions of historic flood

behaviour and flood photographs were used to estimate the water depth or level at each location, which are summarised in **Table C2** and **Table C3**. In all cases the water depth and level information should be considered approximate only.

The historic water depth and level estimates were compared against simulated water depths/levels generated by the TUFLOW model to ensure a reasonable was achieved. The results of the model validation are presented below.

1.3.3 Validation Results

The validation was completed by routing the discharge hydrographs generated by the XP-RAFTS model for the June 2016 event through the TUFLOW model. Validation of the TUFLOW hydraulic model was attempted based upon four (4) anecdotal reports of flood behaviour or reported flood depths for the 2016 event. Several photos of the 2016 flood were also reviewed against the TUFLOW model results to provide further assistance in validating the TUFLOW model.

Peak floodwater depths were extracted from the results of the 2016 flood simulation and are shown on **Figures C2.1** to **C2.3** inclusive. A comparison between the peak floodwater depths generated by the TUFLOW and the depths reported by the community for the 2016 flood is also provided in **Table C2**.

Table C2 Comparison between simulated and observed floodwater levels for the 2016 flood

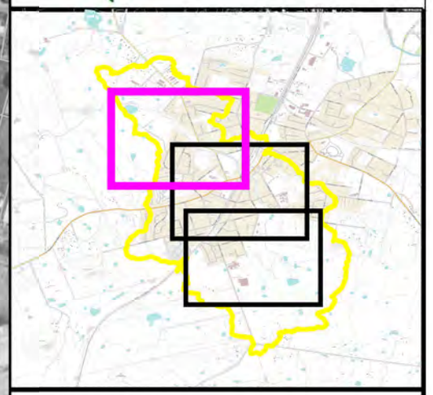
Location #[1]	Anecdotal description of flood behaviour	Reported Floodwater Depth[2] (m)	Simulated Floodwater Depth (m)	Difference (m)
1	Floodwaters up retaining wall	0.50	0.31	-0.19
2	Car flooded at this location on Argyle Street	>0.30	0.46	<0.16
3	Flooding reported across roadway at the corner of Argyle Street and Lackey Road. Depth not stated.	-	0.58	-
4	Above floor flooding reported across building footprint to a depth of 0.22 metres	0.22	0.13	-0.09

NOTE:
[1] Refer locations shown in Figures C2.1 to 2.3
[2] Flood depths are based upon interpretation of reported depths of flooding and flood descriptions provided by the community. Therefore, they should be considered approximate only.

A comparison between simulated flood levels and historic flood level information extracted from flood photographs is provided in **Table C3**.

The comparisons provided in **Table C2** and **Table C3** show that the TUFLOW model is producing flood level and depth estimates that are typically within 0.11 metres of the historic floodwater depth and level estimates. There is a single location where the difference exceeds 0.15 metres, however this only occurs at a location where a specific depth of inundation was not provided by the community. The TUFLOW model is generally producing higher flood depths and levels. This may be associated with the photograph or anecdotal flooding reports not corresponding to the peak of the flood.

WINGECARRIBEE SHIRE COUNCIL



LEGEND

Whites Creek Study Area

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0

Historic Flood Marks

- Reported flood depth for the June 2016 flood
- Historic flood level for June 2016 flood extracted from photograph
- Reported flooding location with no date information

Notes:

Aerial photograph date: Jan 2009

N

W E

S

Scale 1:5,000 (at A3)

0 0.15 0.30

Km

Figure C2.1: Depth Results for the June 2016 Flood

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Sydney, NSW 2000

File Name: Fig - Depth Results for the June 2016 Flood.wor

5

1

6

2

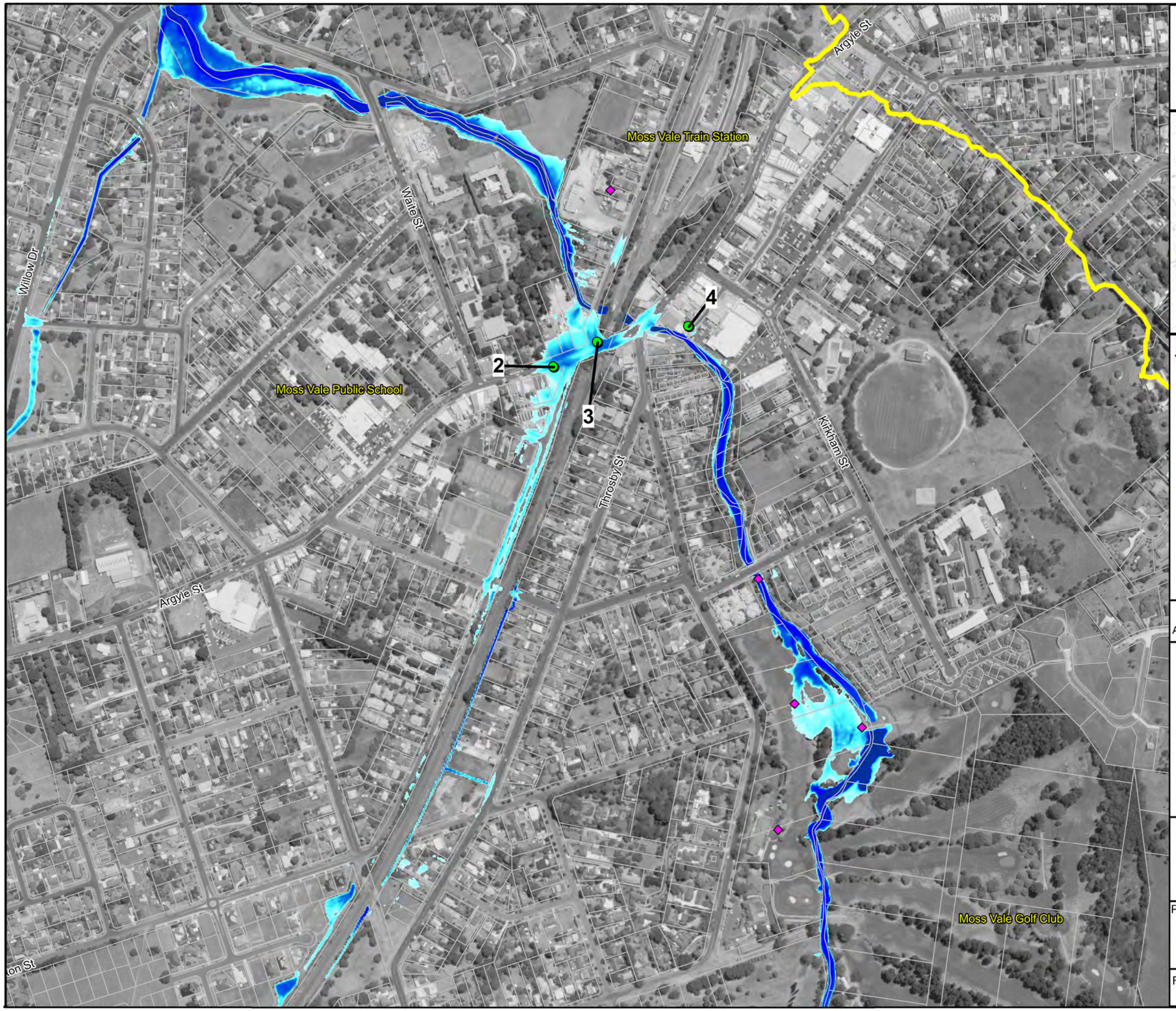
3

Berrima Rd

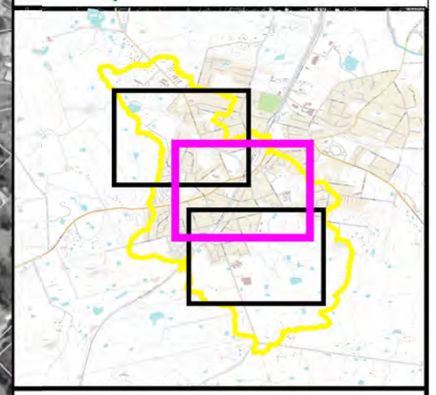
Willow Dr

Waite St

Moss Vale Public School



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LEGEND

Whites Creek Study Area

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0

Historic Flood Marks

- Reported flood depth for the June 2016 flood
- Historic flood level for June 2016 flood extracted from photograph
- Reported flooding location with no date information

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:5,000 (at A3)

0 0.15 0.30 Km

Figure C2.2: Depth Results for the June 2016 Flood

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File Name: Fig - Depth Results for the June 2016 Flood.wor

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Moss Vale Golf Club

Yarrawa Rd

LEGEND

Whites Creek Study Area

Depths (m)
- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0

Historic Flood Marks
- Reported flood depth for the June 2016 flood
- Historic flood level for June 2016 flood extracted from photograph
- Reported flooding location with no date information

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:5,000 (at A3)

0 0.15 0.30 Km

Figure C2.3: Depth Results for the June 2016 Flood

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Sydney, NSW 2000

File Name: Fig - Depth Results for the June 2016 Flood.wor

Overall, it is considered that the TUFLOW model is providing a reasonable reproduction of historic flood behaviour for the 2016 event.

Table C3 Comparison between Simulated Flood Levels and Flood Levels Estimated from Photographs of 2016 flood

Location #[1]	**Description**	**Estimated Flood Level**[2] (mAHD)	**Simulated Flood Level** (mAHD)
5	 View looking west at Whites Creek from Gibbons Road. Flood level estimated at the end of Gibbons Road.	657.40	657.51
6	 View looking west across Cosgrove Park at footbridge crossing of Whites Creek immediately upstream of the confluence of Whites Creek and Willow Creek.	662.10	662.16

[1] Refer locations shown in Figures C2.1 to 2.3

[2] Flood levels are based upon interpretation of flooding shown in photographs and ground surface elevations extracted from the available LiDAR information. Therefore, they should be considered approximate only.

1.3.4 Additional Validation

A number of community members provided flood photographs and anecdotal information for past floods that did not include specific information on the date of the flood. Therefore, it was not possible to use this information to assist with the 2016 validation of the TUFLOW model.

However, this additional information was still considered useful for identifying areas where flooding problems have been experienced. If the simulated flood extents cover these locations, it can provide an additional level of confidence that the flood models are suitably identifying these flooding "problem" locations.

The locations where historic flooding was reported but where specific dates were not provided are shown in **Figures C2.1** to **C2.3**. A review of the information contained in **Figures C2.1** to **C2.3** shows that the June 2016 flood extends across most of the flooding problem locations. However, there are some points that lie outside the extent of the June 2016 flood. These points are located away from the main Whites Creek channel, therefore they are likely to have been impacted by overland flooding rather than mainstream flooding from Whites Creek.

1.3.5 Summary

A definitive calibration of the XP-RAFTS hydrologic model and TUFLOW hydraulic model could not be completed due to the lack of historic stream gauging data. Nevertheless, a validation of the models was attempted using historic rainfall data in conjunction with descriptions of past floods and flood photographs provided by the community for the June 2016 event.

The outcomes of the validation simulation indicate that the XP-RAFTS hydrologic model and TUFLOW hydraulic model provide a reasonable reproduction of historic flood behaviour during the 2016 event. Accordingly, it is considered that the XP-RAFTS and TUFLOW models are suitable for use in simulating design flood behaviour across the Whites Creek catchment.

APPENDIX D

ARR2016 BLOCKAGE CALCULATIONS



WINGECARRIBEE SHIRE COUNCIL

ST 24
ST 25
ST 23
ST 7
ST 30
ST 28
ST 5
ST 6
ST 29
ST 11
ST 4
Whites Creek
Berrima Rd
Willow Dr
Waite St
Moss Vale Train S

LEGEND

Hydraulic Structure

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:6,500 (at A3)

0 175 350

m

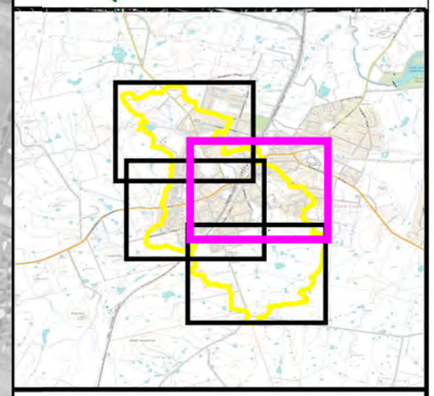
Figure D1.1: Structure Locations

Prepared By:

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Sydney, NSW 2000

File Name: Fig - Structure Locations.wor

WINGECARRIBEE SHIRE COUNCIL



LEGEND

Hydraulic Structure

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:6,500 (at A3)

0 175 350

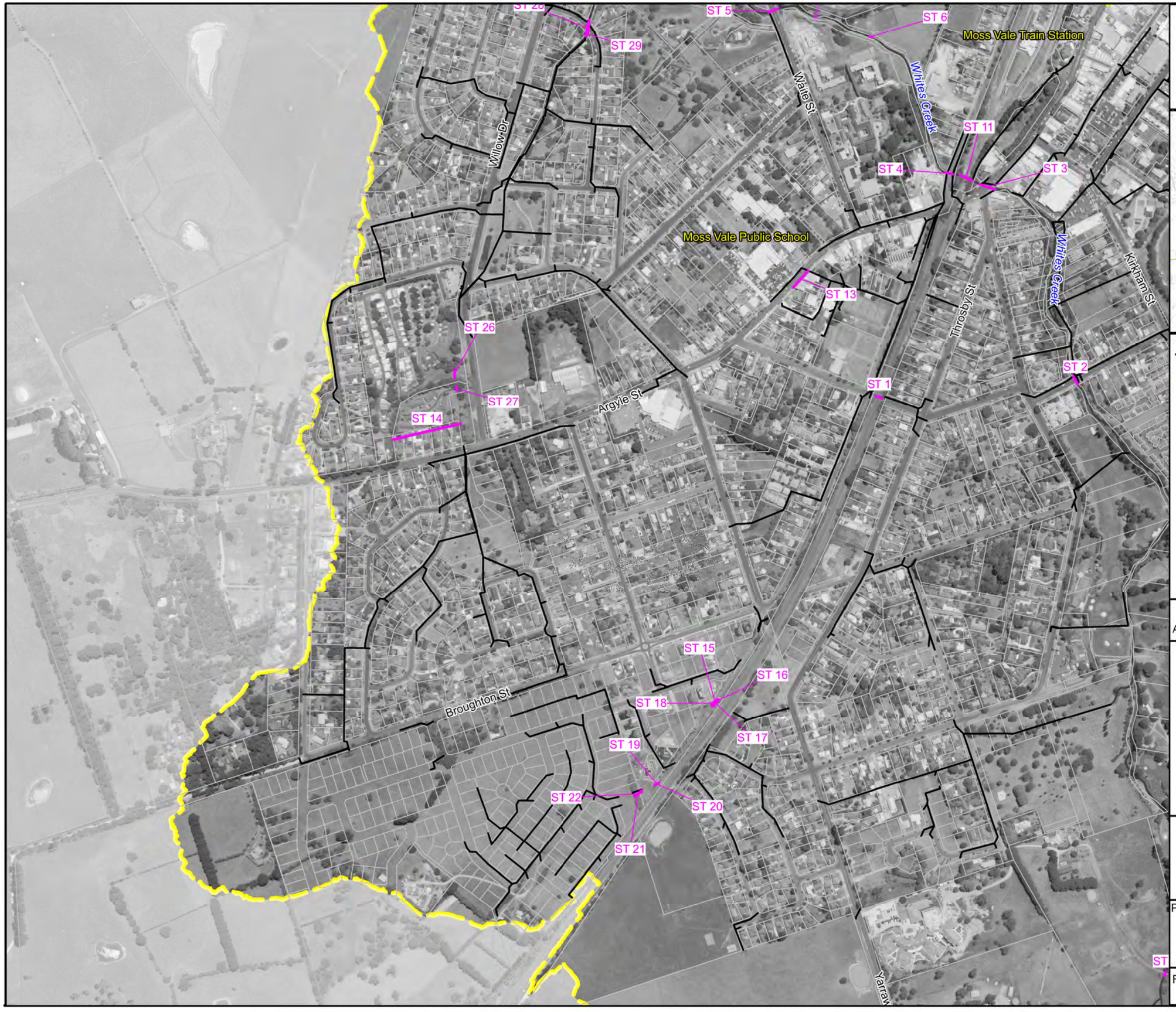
m

Figure D1.2: Structure Locations

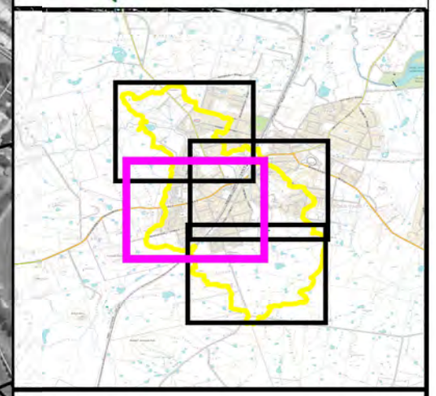
Prepared By:

Catchment Simulation Solutions
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Sydney, NSW 2000

File Name: Fig - Structure Locations.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Hydraulic Structure

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:6,500 (at A3)

0 175 350

m

Figure D1.3: Structure Locations

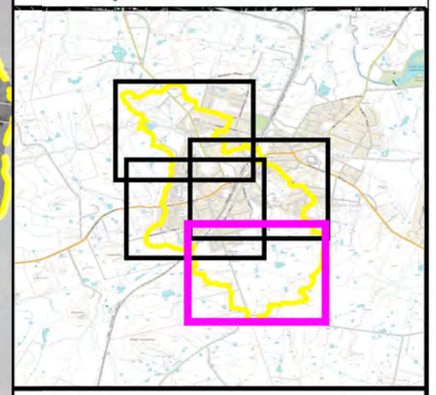
Prepared By:

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Sydney, NSW 2000

File Name: Fig - Structure Locations.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Hydraulic Structure

Notes:

Aerial photograph date: Jan 2009

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Scale 1:6,500 (at A3)

0 175 350

m

Figure D1.4: Structure Locations

Prepared By:

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Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig - Structure Locations.wor

STRUCTURE BLOCKAGE ASSESSMENT

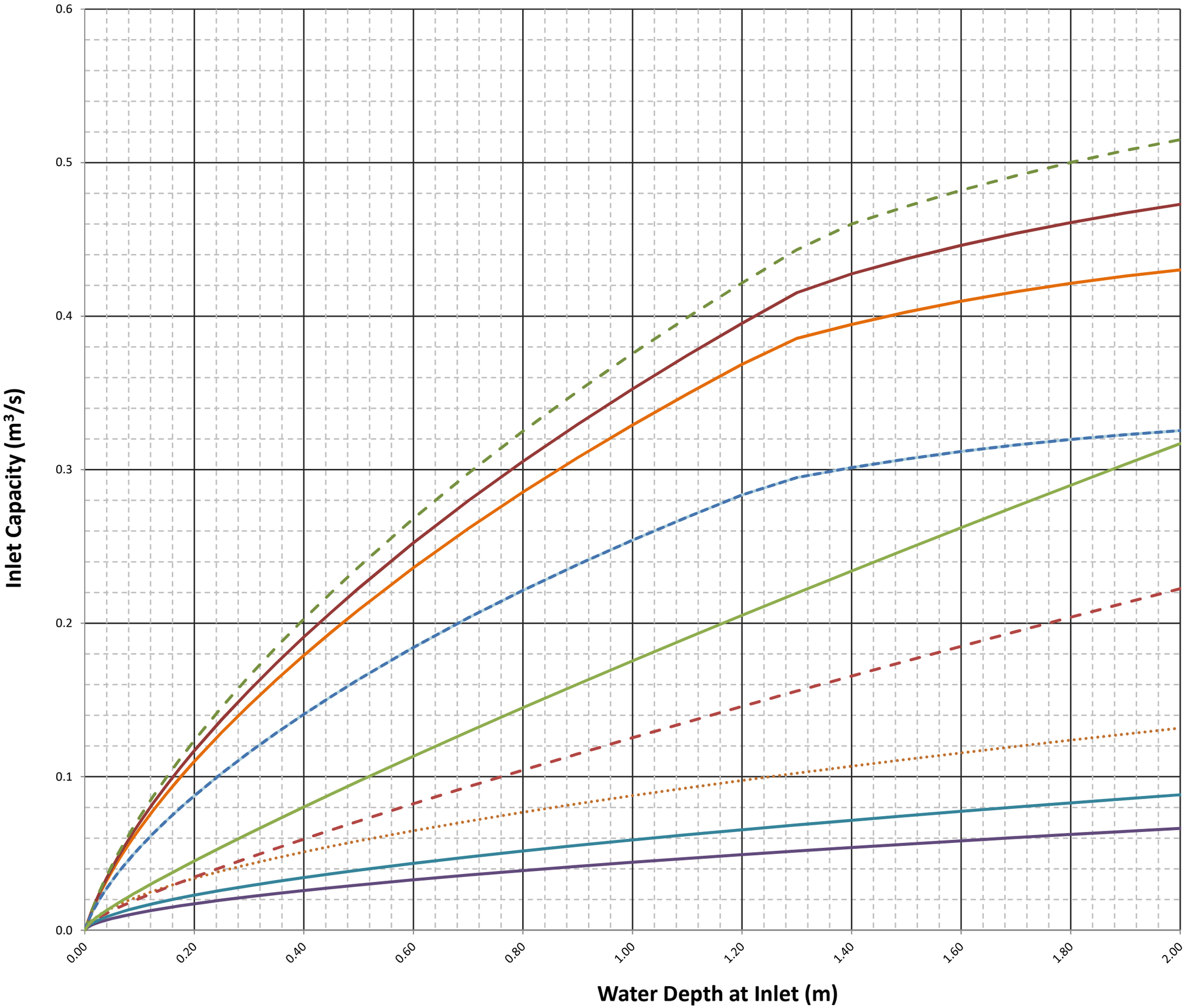
Review of Whites Creek Floodplain Risk Management Study & Plan

Structure ID	Roadway	Waterway	Structure Type	Structure Dimensions			Land Use Across Upstream Catchment	Max. L10 (m)	Control Dimension	Main Stream Slope (%)	Debris Availability (L, M, H)	Debris Mobility (L, M, H)	Debris Transportability (L, M, H)	Debris Potential	Debris Potential at Structure	Adjustment for AEP			Design Blockage Level		
				Dia/Width /Span	Height	Cells / Spans										AEP >5%	AEP 5%-0.5%	AEP < 0.5%	AEP >5%	AEP 5%-0.5%	AEP < 0.5%
ST 1	Spring Street	-	Box Culvert	4	ban Areas, 29% Ru	1	14% Buildings, 37% Rural Grasslands / Brush, 32% Dense Trees, 6% Impervious Urban Areas, 11% Roads (high impervious)	3.00	L<W<3L	0.71	M	M	L	**MML**	Low	Low	Low	Medium	0%	0%	10%
ST 2	Mack Street	Whites Creek	Box Culvert	3.8	ense Trees, 6% Im	2	30% Dense Trees, 20% Buildings, 30% Rural Grasslands / Brush, 7% Impervious Urban Areas, 13% Roads (high impervious)	3.00	L<W<3L	0.00	M	M	L	**MML**	Low	Low	Low	Medium	0%	0%	10%
ST 3	Argyle Street	Whites Creek	Box Culvert	3.4	ense Trees, 6% Im	1	33% Roads (high impervious), 67% Dense Trees	3.00	L<W<3L	0.00	M	M	L	**MML**	Low	Low	Low	Medium	0%	0%	10%
ST 4	Lackey Road	Whites Creek	Box Culvert	7.6	gh impervious), 67	1	31% Dense Trees, 41% Rural Grasslands / Brush, 8% Impervious Urban Areas, 12% Roads (high impervious), 8% Buildings	3.00	L<W<3L	0.00	M	M	L	**MML**	Low	Low	Low	Medium	0%	0%	10%
ST 5	Waite Street	Whites Creek	Box Culvert	2.8	% Impervious Urba	3	17% Buildings, 29% Dense Trees, 10% Impervious Urban Areas, 29% Rural Grasslands / Brush, 15% Roads (high impervious)	3.00	W<L	0.00	M	M	L	**MML**	Low	Low	Low	Medium	25%	25%	50%
ST 6	Pathway	Whites Creek	Box Culvert	3.6	ban Areas, 29% Ru	1	15% Buildings, 28% Dense Trees, 34% Rural Grasslands / Brush, 8% Impervious Urban Areas, 13% Roads (high impervious), 2% Urban Area - in development (exc.Roads)	3.00	L<W<3L	0.71	M	M	L	**MML**	Low	Low	Low	Medium	0%	0%	10%
ST 7	Pathway	Whites Creek	Box Culvert	4.8	ious Urban Areas,	1	89% Rural Grasslands / Brush, 2% Roads (high impervious), 1% Impervious Urban Areas, 2% Buildings, 6% Dense Trees, 1% Water	3.00	L<W<3L	0.14	M	M	L	**MML**	Low	Low	Low	Medium	0%	0%	10%
ST 8	Pathway	Whites Creek	Pipe Culvert	0.6	us), 1% Impervious	2	28% Dense Trees, 72% Rural Grasslands / Brush	3.00	W<L	1.06	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 9	Pathway	Whites Creek	Pipe Culvert	0.6	ees, 72% Rural Gras	2	90% Rural Grasslands / Brush, 8% Dense Trees, 2% Water	3.00	W<L	1.47	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 10	Pathway	Whites Creek	Pipe Culvert	0.6	ds / Brush, 8% Den	3	14% Impervious Urban Areas, 22% Rural Grasslands / Brush, 33% Roads (high impervious), 25% Dense Trees, 6% Buildings	3.00	W<L	1.05	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 11	Railway	Whites Creek	Pipe Culvert	2.4	/ Brush, 33% Road	2	32% Dense Trees, 54% Rural Grasslands / Brush, 4% Impervious Urban Areas, 7% Buildings, 3% Roads (high impervious)	3.00	W<L	0.00	M	M	L	**MML**	Low	Low	Low	Medium	25%	25%	50%
ST 12	-	Whites Creek	Pipe Culvert	0.25	% Impervious Urba	1	10% Roads (high impervious), 5% Impervious Urban Areas, 56% Rural Grasslands / Brush, 9% Buildings, 13% Dense Trees, 5% Urban Area - in development (exc.Roads), 1% Water	3.00	W<L	0.17	M	M	L	**MML**	Low	Low	Low	Medium	25%	25%	50%
ST 13	-	-	Pipe Culvert	0.3	/ Brush, 23% Dens	1	10% Roads (high impervious), 5% Impervious Urban Areas, 56% Rural Grasslands / Brush, 9% Buildings, 13% Dense Trees, 5% Urban Area - in development (exc.Roads), 1% Water	3.00	W<L	2.47	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 14	-	-	Box Culvert	1	5% Impervious Urb	1	10% Roads (high impervious), 5% Impervious Urban Areas, 56% Rural Grasslands / Brush, 9% Buildings, 13% Dense Trees, 5% Urban Area - in development (exc.Roads), 1% Water	3.00	W<L	2.86	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 15	-	-	Pipe Culvert	0.6	s / Brush, 9% Build	1	10% Roads (high impervious), 5% Impervious Urban Areas, 56% Rural Grasslands / Brush, 9% Buildings, 13% Dense Trees, 5% Urban Area - in development (exc.Roads), 1% Water	3.00	W<L	1.56	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 16	-	-	Pipe Culvert	0.6	s / Brush, 9% Build	1	68% Urban Area - in development (exc.Roads), 8% Dense Trees, 10% Impervious Urban Areas, 8% Rural Grasslands / Brush, 6% Roads (high impervious)	3.00	W<L	1.56	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 17	-	-	Pipe Culvert	0.6	s / Brush, 9% Build	1	68% Urban Area - in development (exc.Roads), 8% Dense Trees, 10% Impervious Urban Areas, 8% Rural Grasslands / Brush, 6% Roads (high impervious)	3.00	W<L	1.56	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 18	-	-	Pipe Culvert	0.6	s / Brush, 9% Build	1	74% Urban Area - in development (exc.Roads), 12% Roads (high impervious), 4% Dense Trees, 9% Rural Grasslands / Brush, 1% Impervious Urban Areas, 1% Buildings	3.00	W<L	1.56	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 19	-	-	Pipe Culvert	0.75	% Impervious Urb	1	74% Urban Area - in development (exc.Roads), 12% Roads (high impervious), 4% Dense Trees, 9% Rural Grasslands / Brush, 1% Impervious Urban Areas, 1% Buildings	3.00	W<L	0.72	M	M	L	**MML**	Low	Low	Low	Medium	25%	25%	50%
ST 20	-	-	Pipe Culvert	0.75	% Impervious Urb	1	7% Roads (high impervious), 13% Buildings, 44% Rural Grasslands / Brush, 5% Impervious Urban Areas, 29% Dense Trees, 1% Urban Area - in development (exc.Roads)	3.00	W<L	0.72	M	M	L	**MML**	Low	Low	Low	Medium	25%	25%	50%
ST 21	-	-	Pipe Culvert	0.75	us), 4% Dense Tree	1	53% Rural Grasslands / Brush, 11% Dense Trees, 13% Roads (high impervious), 11% Impervious Urban Areas, 12% Buildings	3.00	W<L	3.93	M	M	H	**MMH**	Medium	Low	Medium	High	25%	50%	100%
ST 22	-	-	Pipe Culvert	0.75	us), 4% Dense Tree	1	20% Roads (high impervious), 23% Impervious Urban Areas, 40% Rural Grasslands / Brush, 7% Dense Trees, 10% Buildings	3.00	W<L	3.93	M	M	H	**MMH**	Medium	Low	Medium	High	25%	50%	100%
ST 23	-	-	Pipe Culvert	0.375	% Roads (high impe	1	20% Roads (high impervious), 23% Impervious Urban Areas, 40% Rural Grasslands / Brush, 7% Dense Trees, 10% Buildings	3.00	W<L	2.28	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%
ST 24	-	-	Box Culvert	1.2	n Areas, 40% Rural	1	29% Impervious Urban Areas, 18% Rural Grasslands / Brush, 23% Dense Trees, 13% Roads (high impervious), 18% Buildings	3.00	W<L	2.59	M	M	M	**MMM**	Medium	Low	Medium	High	25%	50%	100%

Structure ID	Roadway	Waterway	Structure Type	Structure Dimensions			Land Use Across Upstream Catchment	Max. L10 (m)	Control Dimension	Main Stream Slope (%)	Debris Availability (L, M, H)	Debris Mobility (L, M, H)	Debris Transportability (L, M, H)	Debris Potential	Debris Potential at Structure	Adjustment for AEP			Design Blockage Level		
				Dia/Width /Span	Height	Cells / Spans										AEP >5%	AEP 5%-0.5%	AEP < 0.5%	AEP >5%	AEP 5%-0.5%	AEP < 0.5%
ST 25	-	-	Box Culvert	1.2	n Areas, 40% Rural	1	29% Impervious Urban Areas, 18% Rural Grasslands / Brush, 23% Dense Trees, 13% Roads (high impervious), 18% Buildings	3.00	W<L	2.59	M	M	M	MMM	Medium	Low	Medium	High	25%	50%	100%
ST 26	Access Road	Willow Creek	Pipe Culvert	0.9	ious Urban Areas,	3	29% Impervious Urban Areas, 18% Rural Grasslands / Brush, 23% Dense Trees, 13% Roads (high impervious), 18% Buildings	3.00	W<L	0.14	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%
ST 27	Access Road	Willow Creek	Pipe Culvert	0.9	ious Urban Areas,	3	29% Impervious Urban Areas, 18% Rural Grasslands / Brush, 23% Dense Trees, 13% Roads (high impervious), 18% Buildings	3.00	W<L	0.14	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%
ST 28	Campbell Crescent	Willow Creek	Pipe Culvert	1.2	5% Impervious Urb	1	10% Roads (high impervious), 5% Impervious Urban Areas, 56% Rural Grasslands / Brush, 9% Buildings, 13% Dense Trees, 5% Urban Area - in development (exc.Roads), 1% Water	3.00	W<L	2.86	M	M	M	MMM	Medium	Low	Medium	High	25%	50%	100%
ST 29	Campbell Crescent	Willow Creek	Pipe Culvert	1.2	5% Impervious Urb	1	10% Roads (high impervious), 5% Impervious Urban Areas, 56% Rural Grasslands / Brush, 9% Buildings, 13% Dense Trees, 5% Urban Area - in development (exc.Roads), 1% Water	3.00	W<L	2.86	M	M	M	MMM	Medium	Low	Medium	High	25%	50%	100%
ST 30	Pathway	Whites Creek	Bridge	8	ds / Brush, 8% Den	1	14% Impervious Urban Areas, 22% Rural Grasslands / Brush, 33% Roads (high impervious), 25% Dense Trees, 6% Buildings	3.00	L<W<3L	1.05	M	M	M	MMM	Medium	Low	Medium	High	0%	10%	20%

APPENDIX E

PIT INLET CAPACITY CURVES



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Road Combination inlet with 0.9m lintel & 0.9x0.45m grate
- Road Combination inlet with 1.2m lintel & 0.9x0.6m grate
- Road Combination inlet with 1.8m lintel & 0.9x0.6m grate
- Road Combination inlet with 2.4m lintel & 0.9x0.6m grate
- Road inlet with 0.9m lintel
- Road inlet with 1.2m lintel
- Road inlet with 1.8m lintel
- Road inlet with 0.9x0.45m grate
- Parkland inlet with 0.6x0.6m grate
- Parkland inlet with 0.9x0.6m grate

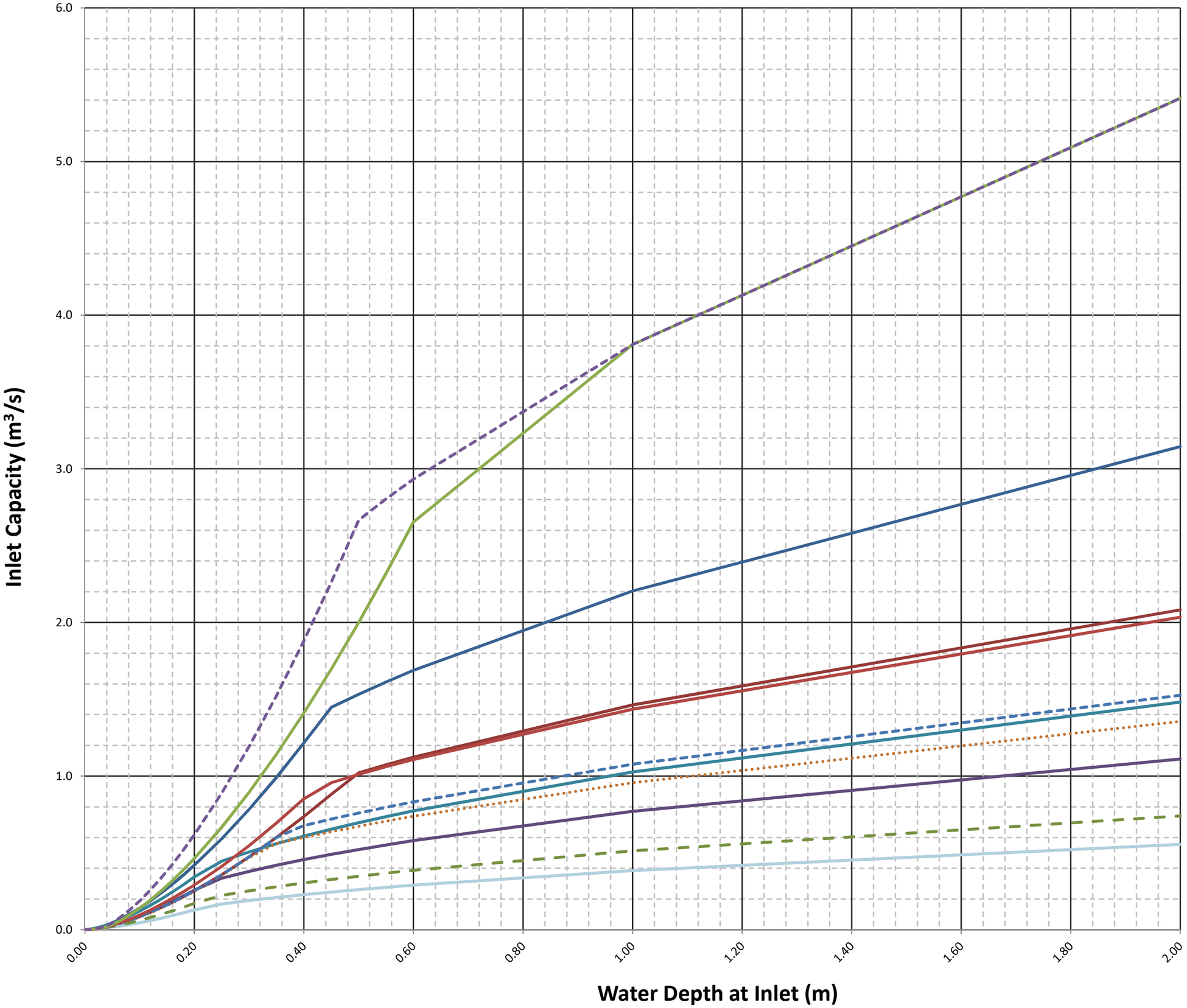
Notes:

Inlet capacity curves do not consider blockage.

Figure E1.1:
On-Grade Inlet Capacity Curves

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Sydney, NSW, 2000

File Name: Inlet Capcacity Curves.xls



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Road Combination inlet with 0.9m lintel & 0.9x0.45m grate
- Road Combination inlet with 1.8m lintel & 0.9x0.6m grate
- Road inlet with 0.9m lintel
- Road inlet with 1.2m lintel
- Road inlet with 1.8m lintel
- Road inlet with 2.4m lintel
- Road inlet with 0.6x0.6m grate
- Road inlet with 0.9x0.45m grate
- Road inlet with 0.9x0.6m grate
- Road inlet with 1.2x1.2m grate
- Parkland inlet with 1.2x1.2m grate

Notes:
Inlet capacity curves do not consider blockage.

Figure E1.2:
Sag Inlet Capacity Curves

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Sydney, NSW, 2000

File Name: Inlet Capcacity Curves.xls

APPENDIX F

ARR2016 AND ARR1987 HYDROLOGIC AND HYDRAULIC ASSESSMENT

F1. ARR2016 AND ARR1987 HYDROLOGIC AND HYDRAULIC ASSESSMENT

1.1 Overview

Flood Behaviour across the Wingecarribee Shire Council LGA for the past three decades has been defined based upon guidance contained in the 1987 version of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia) (referred to herein as ARR1987). This included the previous 'Whites Creek Floodplain Risk Management Study and Plan' (URS, 2012).

In December 2016, a revised version of Australian Rainfall and Runoff was released (Geoscience Australia, 2016) (referred to herein as ARR2016). Therefore, investigations were completed to determine the impact that the revised hydrologic procedures may have on design flood estimates across the Whites Creek catchment. The ultimate goal of this assessment was to determine if the revised ARR2016 procedures would provide improved estimates of design flood behaviour for application as part of the Whites Creek Floodplain Risk Management Study.

The outcomes of the assessment are summarised in the following sections as follows:

- Section 1.2: Provides a comparison between the various ARR1987 and ARR2016 hydrologic inputs (e.g., design rainfall);
- Section 1.3: Provides a comparison between the ARR1987 and ARR2016 hydrologic results (e.g., peak discharges); and,
- Section 1.4: Summarises how the differences in hydrologic results will impact on hydraulic results (e.g., peak flood levels and extents).

1.2 Hydrologic Inputs

1.2.1 Rainfall

Australian Rainfall & Runoff 1987

Design rainfall is one of the primary hydrologic inputs for simulating design floods and is established through statistical analysis of historic rainfall records. Design rainfall for the 20%, 10%, 5%, 2% and 1% AEP events were extracted at the centroid of the catchment from the Bureau of Meteorology's ARR1987 intensity-frequency-duration page and are presented in **Table F1**.

The 'Whites Creek Floodplain Risk Management Study and Plan' (URS, 2012), determined that the 120-minute storm duration produced the highest 1% AEP peak flow across the majority of the catchment to Argyle Street., and that the 540-minute storm duration dominates along the downstream sections of the catchment.

Table F1 IFD Parameters for the Whites Creek Catchment from ARR1987 and ARR2016

Design Rainfall Depths (mm)										
Duration	20% AEP		10% AEP		5% AEP		2% AEP		1% AEP	
	ARR1987	ARR2016	ARR1987	ARR2016	ARR1987	ARR2016	ARR1987	ARR2016	ARR1987	ARR2016
5 min	11.0	9.4	12.5	11.1	14.4	13.0	17.0	15.6	19.0	17.8
10 min	16.9	15.1	19.2	18.1	22.2	21.2	26.2	25.6	29.2	29.1
15 min	21.2	18.8	24.1	22.5	27.9	26.3	32.9	31.8	36.7	36.2
30 min	30.2	24.7	34.2	29.5	39.6	34.5	46.8	41.5	52.2	47.3
1 hour	41.2	30.8	46.8	36.6	54.2	42.5	64.0	51.0	71.5	57.9
2 hour	54.7	39.1	62.3	46.1	72.3	53.4	85.6	63.5	95.8	71.8
3 hour	64.2	46.2	73.3	54.5	85.2	62.8	101	74.5	113	83.9
6 hour	84.2	65.3	96.4	77.1	112	88.9	134	105	150	117
12 hour	111	97.0	127	116	149	135	177	159	198	177
24 hour	147	143	168	174	196	205	232	243	260	271
48 hour	192	196	218	242	252	291	297	348	332	391
72 hour	217	221	246	276	285	335	334	403	372	456

Australian Rainfall & Runoff 2016

Revised design rainfall was established as part of the 2016 revision of Australian Rainfall and Runoff. This revised design rainfall takes advantage of more rainfall gauges and approximately 30 years of additional data, as well as more advanced statistical techniques. Accordingly, the revised ARR2016 rainfall information should provide a more statistically robust estimate of design rainfall for the catchment.

Design rainfall for the 20%, 10%, 5%, 2% and 1% AEP events were extracted at the centroid of the catchment from the Bureau of Meteorology's ARR2016 intensity-frequency-duration page. The ARR2016 rainfall depths are presented in **Table F1** alongside the ARR1987 design rainfall depths for comparison purposes.

The rainfall information presented in **Table F1** shows that the ARR2016 rainfall depths are typically lower than the equivalent ARR1987 rainfall depths. The rainfall comparison shows that:

- As the severity of the event reduces, the magnitude of the differences increases. For example, the differences between ARR1987 and ARR2016 rainfall depths is more significant in the 20% AEP event then the 1% AEP event.
- Durations equal to and greater than 24 hours (for the 10%AEP and more severe) are the only instance where the ARR2016 rainfall depths were larger than the equivalent ARR1987 rainfall depths.

- For the 2-hour duration (i.e., the ARR1987 storm duration that was determined to be most often critical across the Whites Creek catchment upstream of Argyle Street), the ARR2016 rainfall depths are typically 26% lower than the ARR1987 rainfall depths.

1.2.2 Rainfall Losses

Australian Rainfall & Runoff 1987

During a typical rainfall event, not all of the rain falling on a catchment is converted to runoff. Some of the rainfall may be intercepted and stored by vegetation, some may be stored in small depression areas and some may infiltrate into the underlying soils.

ARR1987 recommends the "Initial-Continuing" loss model to represent rainfall losses. This loss model assumes that a specified amount of rainfall is lost during the initial saturation or wetting of the catchment (referred to as the "Initial Loss"). Further losses are applied at a constant rate to simulate infiltration and interception once the catchment is saturated (referred to as the "Continuing Loss Rate"). The initial and continuing losses are effectively deducted from the total rainfall over the catchment, leaving the residual rainfall to be distributed across the catchment as runoff.

The adopted ARR1987 rainfall losses are provided below. As shown, separate initial and continuing loss rates were applied to pervious and impervious surfaces to reflect the significant variation in rainfall loss potential across these different surfaces. However, it is noted that the ARR1987 rainfall losses are "static" and do not vary with respect to storm duration or storm intensity.

- ARR1987 Rainfall Losses for Pervious Surfaces:
  - Initial Loss = 15 mm
  - Continuing Loss Rates = 2.5 mm/hour
- ARR1987 Rainfall Losses for Impervious Surfaces:
  - Initial Loss = 1 mm
  - Continuing Loss Rates = 0 mm/hour

Australian Rainfall & Runoff 2016

ARR2016 introduced a revised approach for defining rainfall losses for design flood simulations. Although the same initial/continuing loss approach is retained in ARR2016, ARR2016 employs a variable initial rainfall loss (referred to as the "burst" loss) that varies accordingly to the storm severity and duration.

Initial Losses

The ARR2016 initial rainfall losses are calculated by subtracting median pre-burst rainfall depths from the overall "storm" loss for the area. This aims to recognise that the most intense "downpour" is frequently preceded by rainfall that would serve to "wet" the catchment, thereby reducing the potential for rainfall during the main "burst" to infiltrate into the underlying soils (i.e., the median pre-burst rainfall depth is intended to reflect the "lead up" rainfall). Accordingly, the ARR2016 approach for calculating the design initial rainfall losses is considered to more closely mimic actual rainfall events.

Unlike ARR1987, which typically applies the same rainfall losses across large geographic areas, ARR2016 provides regionalised estimates of storm rainfall loss and median pre-burst rainfall. This information is available for download from the ARR2016 Data Hub and is intended to reflect the potentially large differences in catchment characteristics (e.g., soils types) and associated rainfall losses. The ARR2016 data hub information for the Whites Creek catchment is provided at the end of this Appendix.

The data hub rainfall loss information for the Whites Creek catchment indicate a rural initial loss of 24mm and rural continuing loss rate of 4.7mm/hr. However, the data hub notes that these rainfall losses are applicable for rural catchments only. A review of Section 3.5.3.2.1 of Book 5 of ARR2016 suggests that for catchments with an urban component, the pervious storm initial loss should be 60 to 80% of the rural storm initial loss to account for the reduced infiltration potential across catchments with an urban proportion (most notably from indirectly connected impervious areas). For this study, the 60% factor was adopted providing an adjusted "storm" initial loss of 14.4 mm (24mm x 0.6).

To convert the adjusted "storm" initial loss to a "burst" initial loss, it is necessary to subtract the median pre-burst rainfall depths obtained from the Data Hub (which varies based on storm duration and AEP) from the storm loss. For example, the "burst" initial loss for the 1% AEP, 120-minute storm would be calculated as:

- Burst initial loss = adjusted storm initial loss – median pre-burst rainfall depth

  Burst initial loss = 14.4mm – 1.7mm

  Burst initial loss = 12.7mm

It was noted that no pre-burst rainfall losses are provided on the ARR2016 data hub for storm durations less than 1 hour. Therefore, it was assumed that the pre-burst rainfall losses for the 1 hour storm also applied for storm durations less than 1 hour. The resulting "burst" initial rainfall losses for the study area are summarised in **Table F2**.

Table F2 Pervious Burst Losses

Storm Duration (hours)	Burst Rainfall Loss (mm)				
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
<1	13.5	13.5	13.4	13.8	14.1
1	13.5	13.5	13.4	13.8	14.1
2	13.5	12.9	12.3	12.5	12.7
3	13.2	12.5	11.8	11.4	11.1
6	4.0	0	0	0	0
12	3.5	0.2	0	0	0
24	7.7	3.9	0.3	0	0

As shown in **Table F2**, the ARR2016 pervious burst loss varies according to the AEP and storm duration. **Table F2** shows that the ARR2016 burst losses vary between 0 mm and 14.1 mm with a value of between 12.7mm and 13.5 mm for the most commonly critical storm duration of 2 hours. Therefore, the ARR2016 pervious burst loss is similar, although slightly smaller

than, the adopted ARR1987 pervious initial loss of 15 mm. Regardless, the outcomes of the loss comparison indicates the calculated ARR2016 burst losses are realistic.

For impervious areas, Section 3.5.3.1.2 of Book 5 of ARR2016 recommends a storm initial loss of 1 mm. However, the storm loss of 1 mm needs to be adjusted to a burst loss by subtracting the preburst rainfall. This yielded an impervious burst loss of 0mm for all storm durations. This is lower than the ARR1987 impervious initial loss of 2.5 mm.

Continuing Loss Rates

The data hub rainfall loss information for the Whites Creek catchment indicates a rural continuing loss rate of 4.7mm/hr. However, as for the storm losses discussed above, this loss rate in only applicable to rural catchments. Section 3.5.3.2.2 of Book 5 of ARR2016 recommends a continuing loss rate for south-eastern Australia of between 1 and 3 mm/hour for catchments with an urban proportion (with a value of 2.5 mm/hour being recommended for most applications). A 2.5 mm/hr continuing loss rates is considered appropriate as this was utilised as part of the previous 'Whites Creek Floodplain Risk Management Study and Plan' (URS, 2012) and also generated reasonable validation results as part of the current study. Therefore, the pervious continuing loss rates are identical for both ARR1987 and ARR2016.

For impervious areas, Section 3.5.3.1.2 of Book 5 of ARR2016 recommends a continuing loss rate of 0 mm/hr. The continuing loss rate of 0 mm/hr was adopted directly allowing the impervious continuing loss rate to be identical for both ARR1987 and ARR2016.

1.2.3 Temporal Patterns

Australian Rainfall & Runoff 1987

The rainfall depths presented in **Table F1** represent the total rainfall depth falling across the full length of the particular storm duration. Therefore, a temporal pattern must be applied to this rainfall to provide a more realistic description of how the rainfall varies with respect to time through the storm event (i.e., it is unrealistic to assume that the rainfall will be uniformly distributed throughout a storm).

ARR1987 provides temporal patterns for eight different zones across Australia. Two sets of temporal patterns are provided for each zone for each storm duration to describe the temporal distribution of rainfall – one for events more frequent than a 30 year ARI and another one for events less frequent than a 30 year ARI event. These two sets of temporal patterns are further subdivided based upon the storm duration. However, ARR1987 only provides a single temporal pattern to describe the temporal distribution of rainfall for each design storm.

The Whites Creek study area falls within zone 1 of the ARR1987 temporal patterns. Therefore, the zone 1 temporal patterns were applied to the appropriate storm frequencies and durations to describe the distribution of rainfall during each event.

Australian Rainfall & Runoff 2016

One of the most significant differences between ARR2016 and ARR1987 is in the use of storm temporal patterns (i.e., the patterns describing the distribution of rainfall throughout the storm). As discussed, ARR1987 used a single temporal pattern for each AEP/storm duration

while ARR2016 uses 10 temporal patterns for each AEP/storm duration. This is intended to provide a better representation of the natural variability of rainfall (i.e., no two storms will be exactly the same). However, this does require simulation of ten times more storms under ARR2016 relative to ARR1987.

The temporal patterns for the study area were downloaded from the ARR2016 data hub and were used to simulate the temporal distribution of rainfall for each design storm. In accordance with ARR2016 for catchments with an area less than 75 km^2, the "point" temporal patterns rather than "areal" temporal patterns were selected to describe the temporal variation in rainfall.

ARR2016 groups the temporal patterns into "frequent", "intermediate" and "rare" groupings, which were applied to each design storm as follows:

- Frequent temporal patterns: 20% AEP
- Intermediate temporal patterns: 10% AEP and 5% AEP
- Rare temporal patterns: 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP

Further discussion on how the suite of ARR2016 temporal patterns were analysed is provided in the following section.

1.3 Hydrologic Results

1.3.1 ARR1987 Hydrology

The XP-RAFTS model was used to simulate rainfall-runoff process for the design 20%, 5% and 1% AEP storms based upon ARR1987 hydrology.

The results from each simulation were reviewed at each subcatchment in the RAFTS model to determine the "critical" storm duration. In accordance with recommendations in ARR1987, the critical storm duration was defined as the storm duration that produced the highest peak design discharge at each subcatchment outlet. The critical storm durations and peak discharges for each subcatchment with ARR1987 hydrologic conditions are presented in **Appendix G**.

1.3.2 ARR2016 Hydrology

The XP-RAFTS model was also used to simulate rainfall runoff processes based upon the 2016 version of Australian Rainfall and Runoff. The design 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP storms were simulated using the XP-RAFTS model.

It is noted that the Bureau of Meteorology's 2016 IFD webpage does not currently publish design rainfall information published for events rarer than the 1% AEP for durations less than 24 hours. In the absence of this information, Section 3.6.3 of Book 8 of ARR2016 was used to derive rainfall estimates for these rarer events. This involved applying "growth curve" factors to the 1% AEP rainfall as follows:

- 0.2% AEP rainfall = 1.140 x 1% AEP rainfall
- 0.5% AEP rainfall = 1.344 x 1% AEP rainfall

As outlined in the previous section, a suite of ten temporal patterns were used to represent the temporal variation in rainfall for each design flood frequency and duration. The peak discharges generated by each of the ten (10) temporal patterned were then averaged. The average discharges for each storm duration were then compared to determine the critical duration. The critical duration was selected as the duration that produced the highest average peak discharge.

Once the critical duration was established, it was then necessary to select the most appropriate temporal pattern. The temporal pattern that generated the peak discharge immediately above the mean discharge for the critical duration was selected as the most representative temporal pattern for each subcatchment. The resulting critical storm durations, temporal patterns and peak discharges for each subcatchment are presented in **Appendix G**.

Discharges at nine (9) "focus" locations were also extracted and are presented in **Table F3**. The focus locations are shown in **Plate F1**.

Table F3 ARR2016 and ARR1987 Peak Design Discharges at Focus Locations

Location		XP-RAFTS ID	Peak Discharge (m^3/s)					
			20%AEP		5%AEP		1%AEP	
			ARR1987	ARR2016	ARR1987	ARR2016	ARR1987	ARR2016
1	Moss Vale Sewage Treatment Plant	1.31	41.0	27.3	57.2	39.3	77.5	54.8
2	Northern end of Cosgrove Park	1.26	35.3	21.5	49.1	33.7	66.6	47.1
3	Corner of Willow Dr and Danger St	47.07	7.2	4.2	11.1	6.6	15.5	10.1
4	Culvert under the railway between Argyle St and Lackey Rd	1.22	22.4	13.2	32.9	21.1	48.5	34.4
5	Northern end of Roy Baker Walkway	1.19	21.3	12.5	31.4	19.7	46.7	33.4
6	Mack Street Bridge	1.17	19.2	11.3	28.7	17.6	43.9	23.7
7	Northern end of Moss Vale Golf Club	1.15	18.1	10.7	27.4	16.5	42.4	22.7
8	Moss Vale Golf Club near Dormie House	1.10	15.7	10.1	24.1	15.0	38.3	22.6
9	Southern end of Moss Vale Golf Club	1.08	14.1	9.1	22.0	13.2	35.1	20.8

Box plots for the 1%AEP event were also prepared for the 9 focus locations shown in **Plate F1** to better display the full range of results produced as part of the ARR2016 hydrologic analysis. The box plots are provided at the end of this appendix. The box plots show:

- Median discharge for each storm duration (represented by the blue horizontal line contained within each green box);
- Mean discharge for each storm duration (defined by the "✳");
- The first and third quartiles (defined by the green box), which illustrated the 25th percentile and 75th percentile discharge values;
- The highest and lowest discharge value (represented by the "T" attached to the end of the green box)

- The critical storm duration is highlighted in yellow

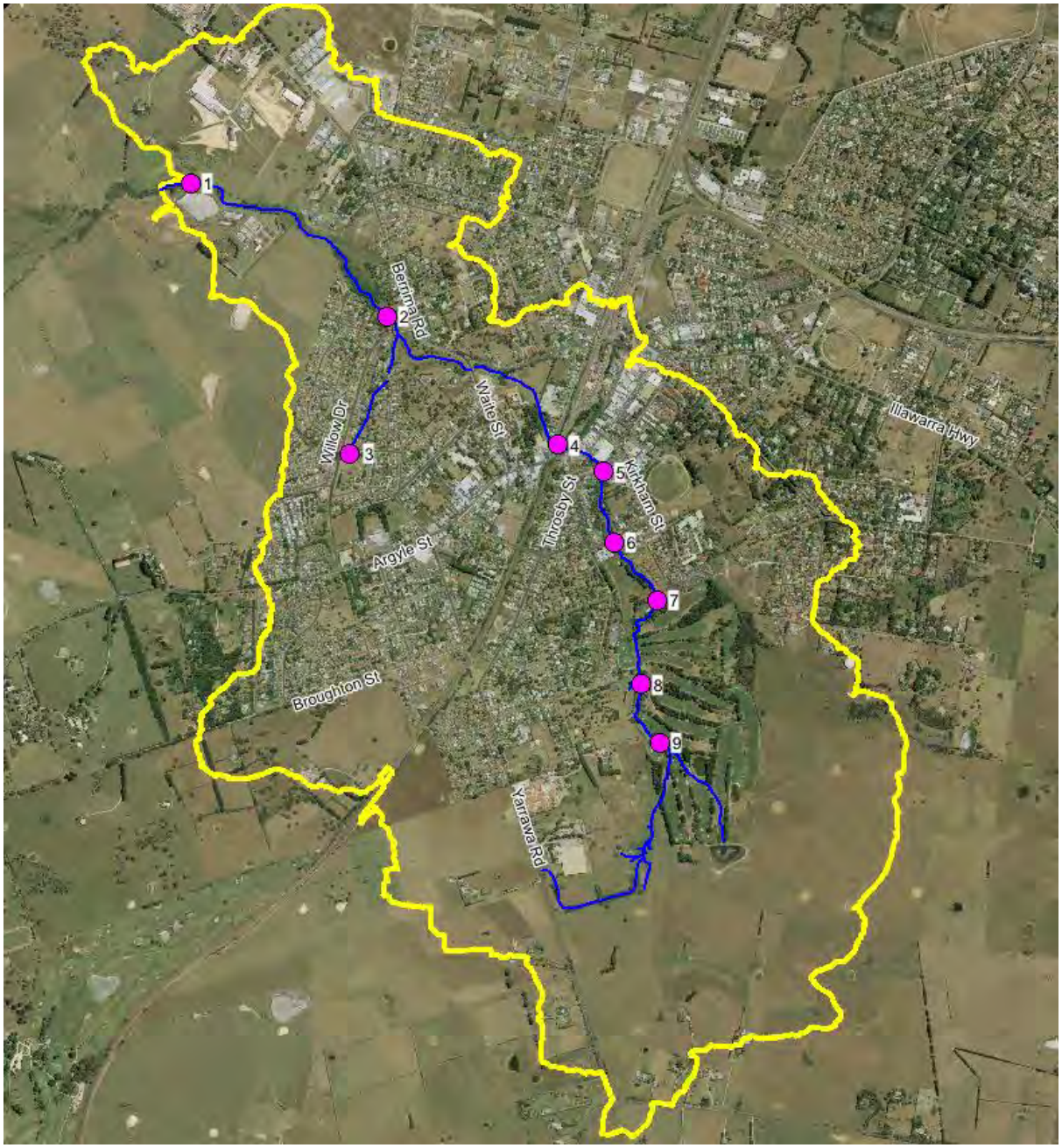


Plate F1 "Focus" locations (pink) selected for critical duration & temporal pattern analysis

The results of the hydrologic analysis indicate that the critical durations across the study area typically vary between 10 minutes (for smaller subcatchments in the upper catchment areas) and 12 hours (for the lower catchment areas).

The peak ARR2016 discharges were reviewed relative to the ARR1987 discharges. This review showed that for all AEPs and subcatchments, the critical ARR2016 discharges are lower than the critical ARR1987 discharges. The following average differences in discharges were noted between ARR2016 and ARR1987 when considering all subcatchments:

- 20% AEP: ARR2016 discharges are 45% lower than ARR1987 discharges
- 5% AEP: ARR2016 discharges are 42% lower than ARR1987 discharges

- 1% AEP: ARR2016 discharges are 35% lower than ARR1987 discharges

The differences in peak discharges are considered to be primarily associated with the lower ARR2016 rainfall depths. Although the ARR2016 rainfall depths are lower the available information suggests that these design rainfall estimates are more reliable than the ARR1987 datasets (i.e. the take advantage of an additional 30 years or rainfall data as well as data from additional gauges). Accordingly, although ARR2016 provides less conservative discharge estimates, it is considered that they provide an improved estimate of design discharges across the Whites Creek catchment.

1.4 Hydraulic Assessment

1.4.1 Introduction

As discussed in the previous section, ARR2016 is predicted to generate lower peak design discharge estimates relative to ARR1987 across the Whites Creek catchment. To gain an understanding of how these reductions may impacts on flood hydraulics (i.e., flood levels, depths and velocities), the ARR2016 design hydrographs were applied to the TUFLOW model and were used to re-simulate flood behaviour for the 1% AEP flood. The results of the revised simulations were subsequently compared to the 1% AEP flood results based on ARR1987 hydrology so that an understanding of the flood impacts could be quantified. The outcomes of the hydraulic assessment are presented below.

1.4.2 Hydraulics

Australian Rainfall & Runoff 1987

The TUFLOW model was used to simulate design flood behaviour for the design 1% AEP event with ARR1987 hydrology. The critical 1.5 and 2-hour storms were routed through the TUFLOW model and the results were combined into a design flood envelope. Peak floodwater depths were extracted from the enveloped results and are presented in **Figure F1.1** to **F1.3**.

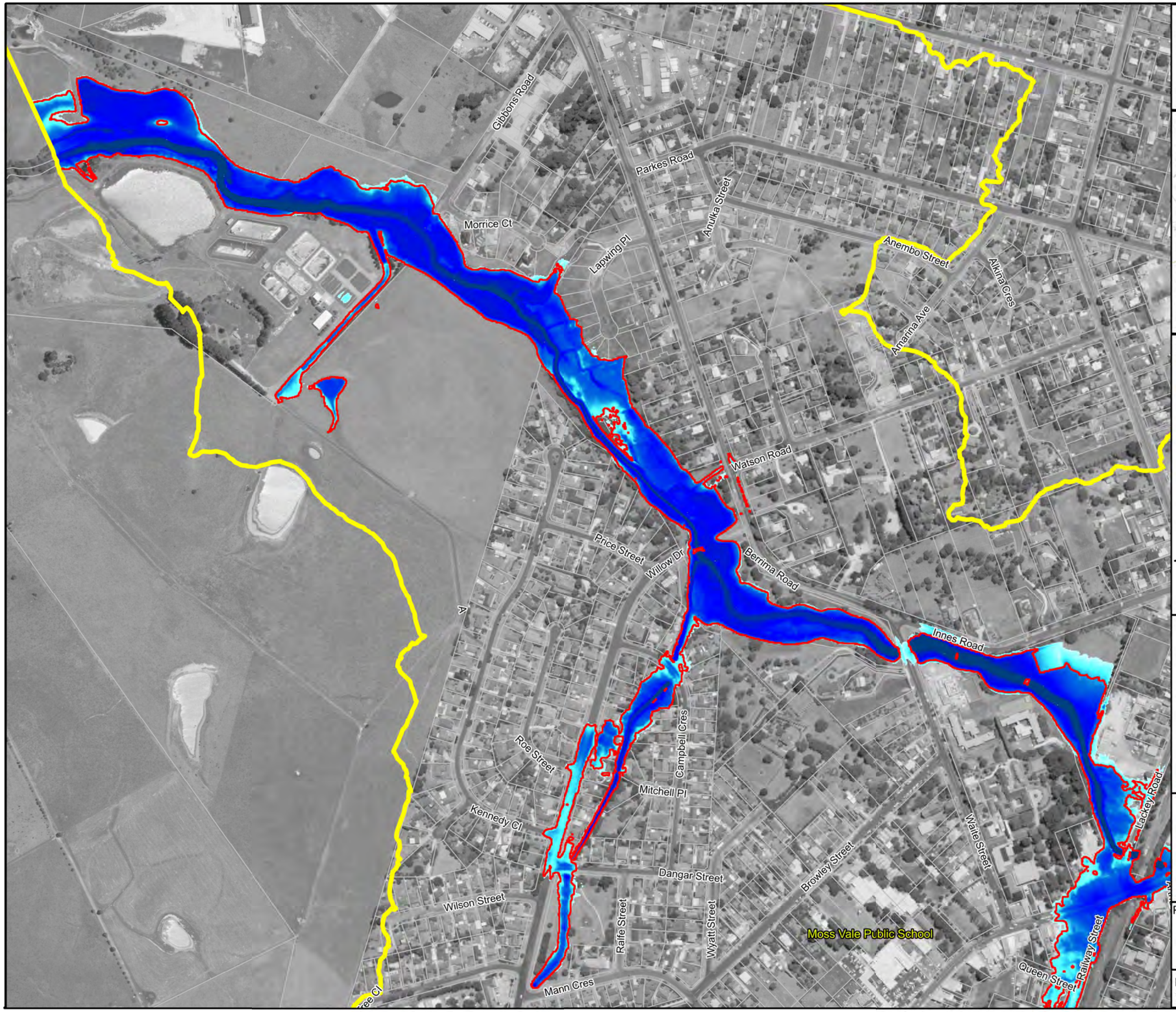
Australian Rainfall & Runoff 2016

The TUFLOW model was then updated to reflect the ARR2016 hydrology and was used to re-simulate each design flood.

However, before the design floods could be simulated, it was necessary for outcomes of the ARR2016 hydrologic analysis were reviewed to determine the total number of unique critical storm durations and temporal patterns that would need to be applied to the TUFLOW model. This determined that there were a large number of unique combinations of storm durations temporal patterns when considering all subcatchments in the XP-RAFTS model. More specifically, 215 unique critical storms were identified over all AEPs.

Although the XP-RAFTS model runs in a matter of seconds and can run a large number of storms in a relatively short amount of time, the TUFLOW model takes several hours to run a single storm. Therefore, it was not considered feasible to run all unique combinations of storm durations and temporal patterns through the hydraulic model in a timely manner.

Therefore, the critical durations and temporal patterns were reviewed to determine if a reduced number of durations and temporal patterns could be applied without significantly impacting on the overall hydrologic outcomes. This assessment considered all subcatchments



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LEGEND

- Whites Creek Study Area
- 1% AEP Extent based on ARR2016 Hydrology

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:5,000 (at A3)

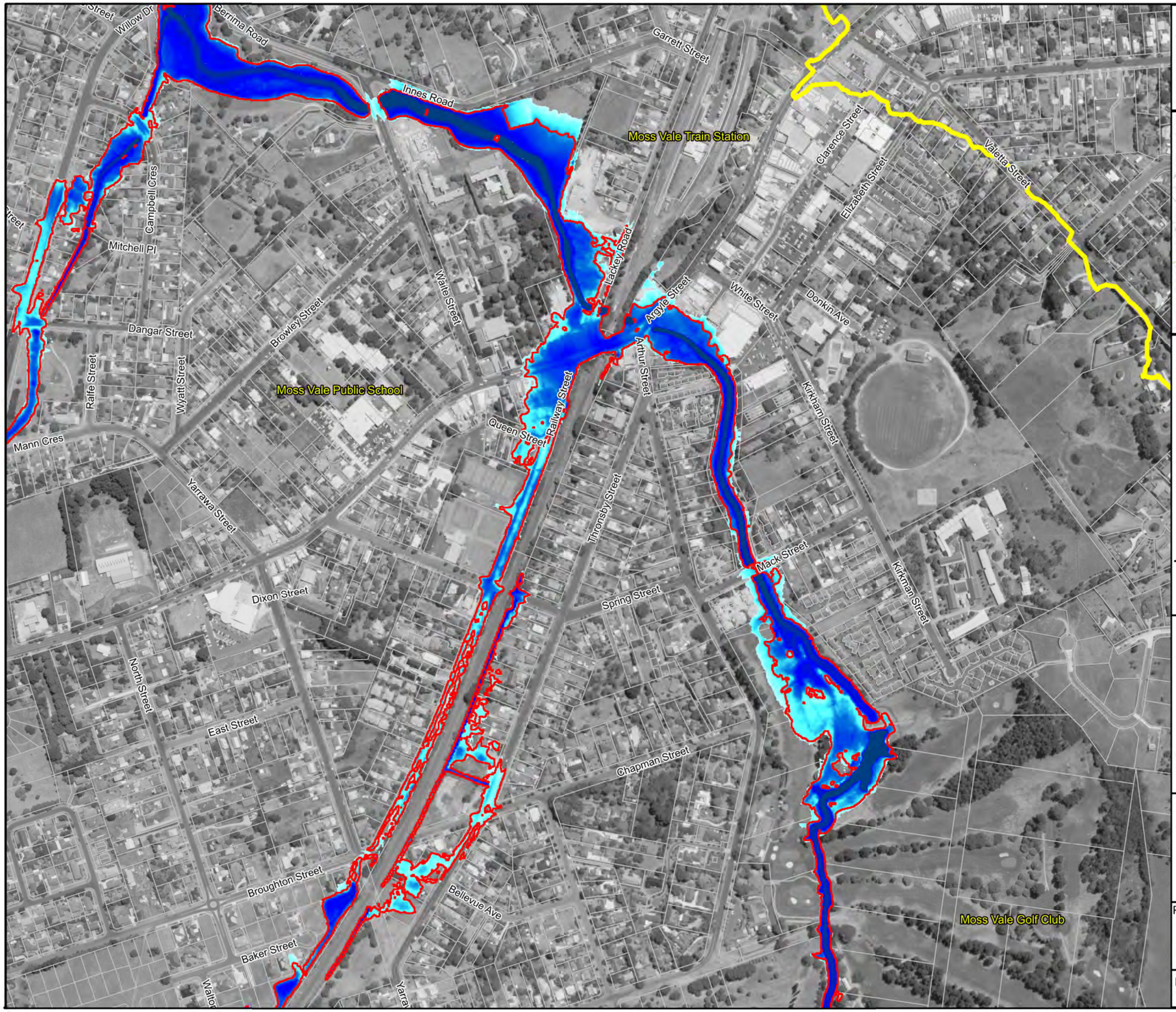
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Figure F1.1: Floodwater Depths for the 1% AEP Flood with ARR1987 Hydroogy

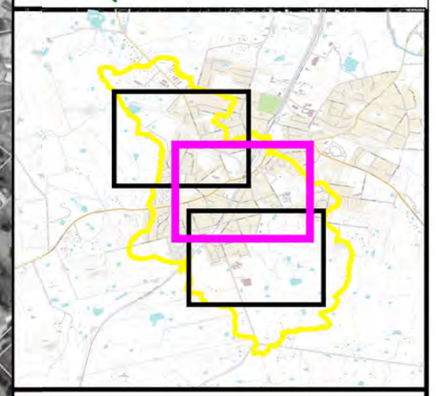
Prepared By:

Catchment Simulation Solutions
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Sydney, NSW 2000

File Name: Fig F1.1- Floodwater Depths for the 1% AEP Flood with ARR1987 Hydrology.wor



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LEGEND

- Whites Creek Study Area
- 1% AEP Extent based on ARR2016 Hydrology

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:5,000 (at A3)

0 0.15 0.30

Km

Figure F1.2: Floodwater Depths for the 1% AEP Flood with ARR1987 Hydroogy

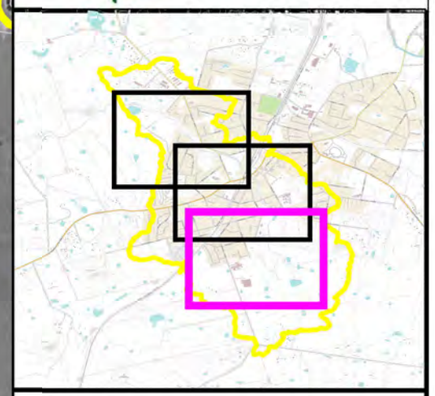
Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig F1.2- Floodwater Depths for the 1% AEP Flood with ARR1987 Hydrology.wor

East Street
Broughton Street
Baker Street
Walton Pl
Darraby Dr
Bellevue Ave
Yarrawa Road
Pleasant Ave
Albany Road
Monterey Ave
Darran Road
Spencer Street
Lovelle Street
Lansdown Pl
Daylesford Dr
Craig Street
Patuna Ave
Chapman Street
Moss Vale Golf Club

WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Whites Creek Study Area
- 1% AEP Extent based on ARR2016 Hydrology

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:5,000 (at A3)

0 0.15 0.30

Km

Figure F1.3: Floodwater Depths for the 1% AEP Flood with ARR1987 Hydroogy

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Sydney, NSW 2000

File Name: Fig F1.3- Floodwater Depths for the 1% AEP Flood with ARR1987 Hydrology.wor

within the hydrologic model but was more strongly guided by results at each of the "focus" locations shown in **Plate F1**.

The peak discharges generated by the most common critical durations and temporal patterns were compared against the peak discharges generated by the "actual" critical durations and temporal patterns for each subcatchment to determine the difference in peak discharge that would results from using a reduced set of durations and temporal patterns. A preference was given to adopting durations and temporal patterns that produced a peak discharge slightly higher than the "critical" discharge in preference to a lower discharge to ensure a conservative estimates of flood behaviour were being provided. A preference was also given to adopting longer storm durations over shorter duration due to the larger runoff volumes having a greater potential to generate higher peak flood levels.

The durations and temporal patterns that were ultimately selected are summarised in **Table F4**. The resulting discharges based on the reduced set of temporal patterns and storm durations at each XP-RAFTS model subcatchment are tabulated in **Appendix G**.

Table F4 Adopted temporal patterns and storm durations for hydraulic analysis

Design Storm	Storm Duration / Temporal Pattern ID						
	15 mins	20 mins	45 mins	60 mins	120 mins	360 mins	720 mins
20% AEP					4642	4740	4811
10% AEP	4411			4565		4730	
5% AEP	4413			4565		4672	
2% AEP		4371	4528		4618		4443
1% AEP		4371	4528		4617		4443
0.5% AEP		4371		4405			4443
0.2% AEP		4371	4533	4559			4443

The peak discharges summarised in **Appendix G** show that the peak discharges generated by the adopted/reduced set of durations and temporal patterns are typically higher than the "actual" discharges (i.e., discharges based upon the full set of temporal patterns and durations). However, in most cases, the differences in peak discharges are less than 3% when considering all subcatchments (the average difference for the 1% AEP event was determined to be 1.7%) and the differences were less than 5% at focus locations. Therefore, although adopting a reduced set of durations and temporal patterns is providing conservative ARR2016 discharge estimates, the discharges are not significantly inflated. Therefore, it is considered that the reduced set of durations and temporal patterns is reasonable for application to the hydraulic model as part of the ARR2016 analysis.

The TUFLOW model was subsequently used to simulate design flood behaviour for the design 1% AEP event with the reduced set of ARR2016 storms. The results of each of the individual storm simulations were combined into a final design flood envelope. Peak floodwater depths and levels were extracted from the enveloped results and are presented in **Figures 8.1** to **8.3** in Volume 2.

Discussion on Flood Impacts

Difference mapping was also prepared to quantify the differences in peak 1% AEP flood levels and extents associated with adopting ARR2016 versus ARR1987 hydrology. The difference map was prepared by subtracting peak water levels generated as part of the ARR2016 model runs from the ARR1987 model runs. This creates a contour map of predicted changes in flood levels and extents. The flood level difference mapping is provided in **Figure F2.1** to **F2.3**. Negative values indicate ARR2016 is producing lower flood levels relative to ARR1987 while positive values indicate ARR2016 is producing higher flood levels relative to ARR1987.

The difference mapping presented in **Figure F2.1** to **F2.3** shows that the ARR2016 peak 1% AEP flood levels are lower than the ARR1987 1% AEP discharges. Generally, ARR2016 flood levels are at least 0.2 metres lower than the ARR1987 flood levels along each of the major watercourses. However, the flood level differences typically approach 0.5 metres in the vicinity of major hydraulic controls, such as the railway line, Mack Street and Waite Street.

1.5 Conclusion and Recommendation

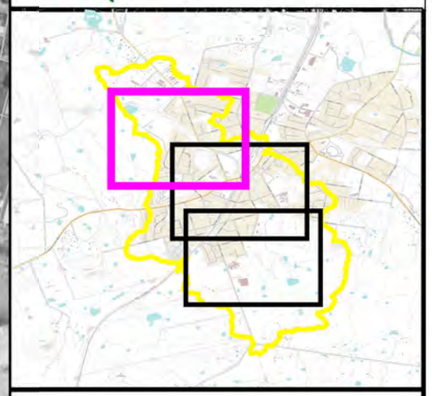
Application of ARR2016 hydrologic procedures to the Whites Creek catchment is predicted to generate lower peak discharges across all design floods up to and including the 1% AEP event relative to ARR1987. This is predicted to also result in a reduction in design flood levels across the catchment relative to ARR1987. The differences are primarily a result of the lower ARR2016 design rainfall depths.

Although there are concerns that adopting lower design discharges and flood levels could underestimate the flood risk across the catchment, available information for the area indicates that the more extensive data that informs the ARR2016 inputs provide more reliable information relative to ARR1987. Accordingly, it is considered that application of ARR2016 procedures as part of the Whites Creek FPRMS will provide an improved representation of design flood behaviour relative to the ARR1987 procedures.

1.6 References

- Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2016) Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia).
- Engineers Australia (1987). Australian Rainfall and Runoff - A Guide to Flood Estimation. Edited by D. Pilgrim.

WINGECARRIBEE SHIRE COUNCIL



LEGEND

Whites Creek Study Area

Differences (m)

-0.02 to 0.02

0.02	-0.02
0.10	-0.10
0.20	-0.20
0.50	-0.50
Was Dry Now Wet	Was Wet Now Dry

Notes:

Aerial photograph date: Jan 2009

N

W E

S

Scale 1:5,000 (at A3)

0 0.15 0.30

Km

Figure F2.1: 1% AEP ARR1987 Level Differences

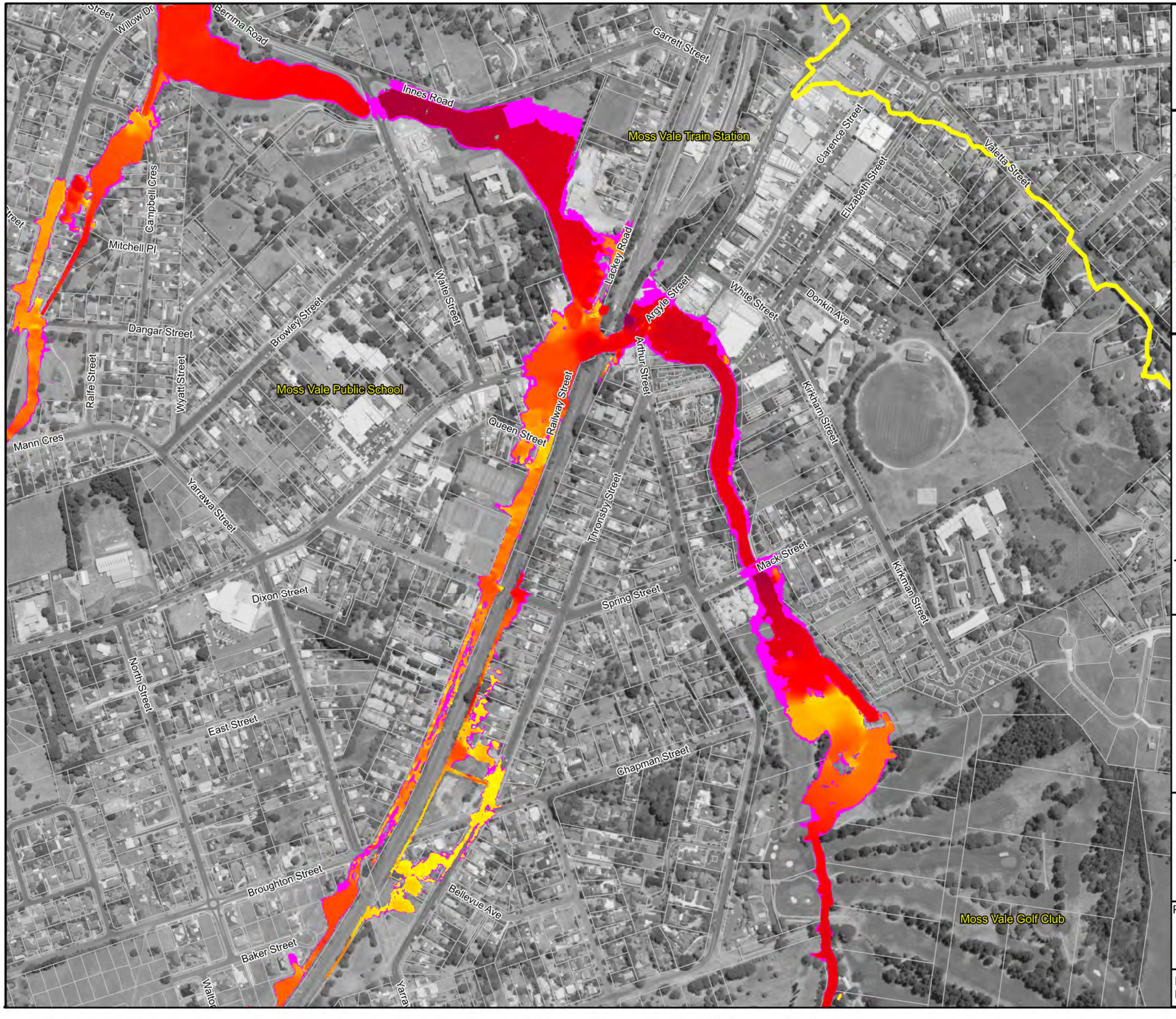
Prepared By:

Catchment Simulation Solutions

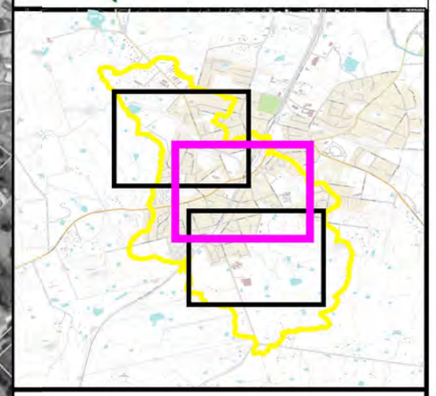
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File Name: Fig F2.1- 1% AEP ARR1987 Level Differences.wor



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LEGEND

Whites Creek Study Area

Differences (m)

-0.02 to 0.02	
0.02	-0.02
0.10	-0.10
0.20	-0.20
0.50	-0.50
Was Dry Now Wet	Was Wet Now Dry

Notes:

Aerial photograph date: Jan 2009

N W E S

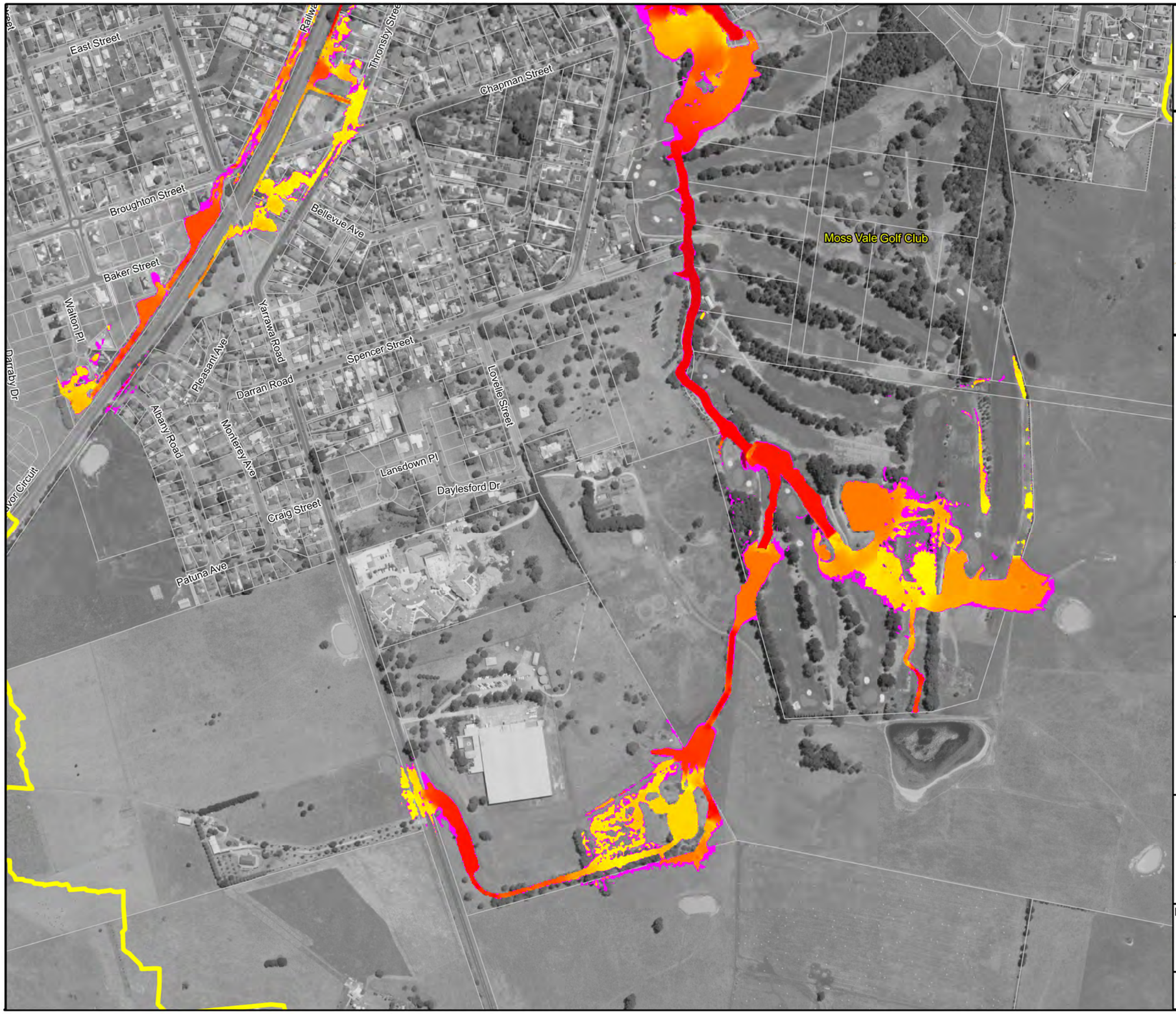
Scale 1:5,000 (at A3)

0 0.15 0.30 Km

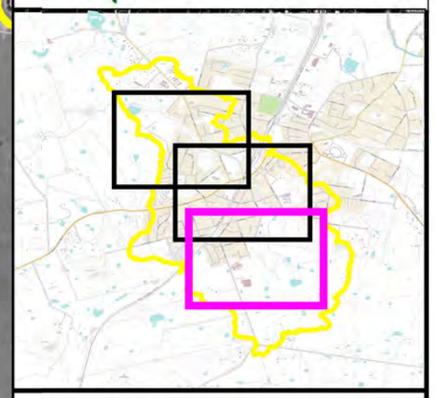
Figure F2.2: 1% AEP ARR1987 Level Differences

Prepared By:
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Sydney, NSW 2000

File Name: Fig F2.2- 1% AEP ARR1987 Level Differences.wor



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LEGEND

Whites Creek Study Area

Differences (m)

-0.02 to 0.02

0.02	-0.02
0.10	-0.10
0.20	-0.20
0.50	-0.50
Was Dry Now Wet	Was Wet Now Dry

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:5,000 (at A3)

0 0.15 0.30

Km

Figure F2.3: 1% AEP ARR1987 Level Differences

Prepared By:

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Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig F2.3- 1% AEP ARR1987 Level Differences.wor

ARR2016 Data Hub Download

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	150.367
Latitude	-34.553
Selected Regions	
River Region	
ARF Parameters	
Storm Losses	
Temporal Patterns	
Areal Temporal Patterns	
Interim Climate Change Factors	

Region Information

Data Category	Region
River Region	Hawkesbury River
ARF Parameters	SE Coast
Temporal Patterns	East Coast South

Data

River Region

division	South East Coast (NSW)
rivregnum	12
River Region	Hawkesbury River

Layer Info

Time Accessed	18 October 2018 03:12PM
Version	2016_v1

ARF Parameters

Long Duration ARF

$$Areal\ reduction\ factor = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	SE Coast
a	0.06
b	0.361
c	0.0
d	0.317
e	8.11e-05
f	0.651
g	0.0
h	0.0
i	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	18 October 2018 03:12PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are NOT FOR USE in urban areas

id	5838.0
Storm Initial Losses (mm)	24.0
Storm Continuing Losses (mm/h)	4.7

Layer Info

Time Accessed	18 October 2018 03:12PM
Version	2016_v1

Temporal Patterns

code	ECsouth
Label	East Coast South

Layer Info

Time Accessed	18 October 2018 03:12PM
Version	2016_v2

Areal Temporal Patterns

code	ECsouth
arealabel	East Coast South

Layer Info

Time Accessed	18 October 2018 03:12PM
Version	2016_v2

BOM IFD Depths

Click here to obtain the IFD depths for catchment centroid from the BoM website

No data	No data found at this location!

Layer Info

Time Accessed	18 October 2018 03:12PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.8 (0.036)	0.9 (0.029)	0.9 (0.026)	1.0 (0.023)	0.6 (0.011)	0.3 (0.005)
90 (1.5)	2.4 (0.093)	2.0 (0.058)	1.8 (0.042)	1.5 (0.031)	1.1 (0.019)	0.8 (0.013)
120 (2.0)	0.0 (0.002)	0.9 (0.024)	1.5 (0.033)	2.1 (0.039)	1.9 (0.030)	1.7 (0.024)
180 (3.0)	0.2 (0.005)	1.2 (0.026)	1.9 (0.035)	2.6 (0.041)	3.0 (0.040)	3.3 (0.039)
360 (6.0)	4.3 (0.088)	10.4 (0.159)	14.5 (0.188)	18.4 (0.207)	21.3 (0.203)	23.5 (0.201)
720 (12.0)	5.9 (0.084)	10.9 (0.113)	14.2 (0.123)	17.4 (0.129)	20.5 (0.129)	22.8 (0.129)
1080 (18.0)	4.0 (0.046)	9.4 (0.076)	12.9 (0.088)	16.4 (0.095)	21.5 (0.105)	25.4 (0.111)
1440 (24.0)	1.0 (0.010)	6.7 (0.047)	10.5 (0.060)	14.1 (0.068)	18.1 (0.074)	21.1 (0.078)
2160 (36.0)	0.0 (0.000)	2.2 (0.012)	3.6 (0.017)	4.9 (0.019)	7.0 (0.023)	8.5 (0.025)
2880 (48.0)	0.0 (0.000)	0.2 (0.001)	0.3 (0.001)	0.4 (0.001)	2.3 (0.007)	3.8 (0.010)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	18 October 2018 03:12PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

Values are of the format temperature increase in degrees Celcius (% increase in rainfall)

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.892 (4.5%)**	0.775 (3.9%)	**0.979 (4.9%)**
2040	**1.121 (5.6%)**	1.002 (5.0%)	**1.351 (6.8%)**
2050	**1.334 (6.7%)**	1.28 (6.4%)	**1.765 (8.8%)**
2060	**1.522 (7.6%)**	1.527 (7.6%)	**2.23 (11.2%)**
2070	**1.659 (8.3%)**	1.745 (8.7%)	**2.741 (13.7%)**
2080	**1.78 (8.9%)**	1.999 (10.0%)	**3.249 (16.2%)**
2090	**1.825 (9.1%)**	2.271 (11.4%)	**3.727 (18.6%)**

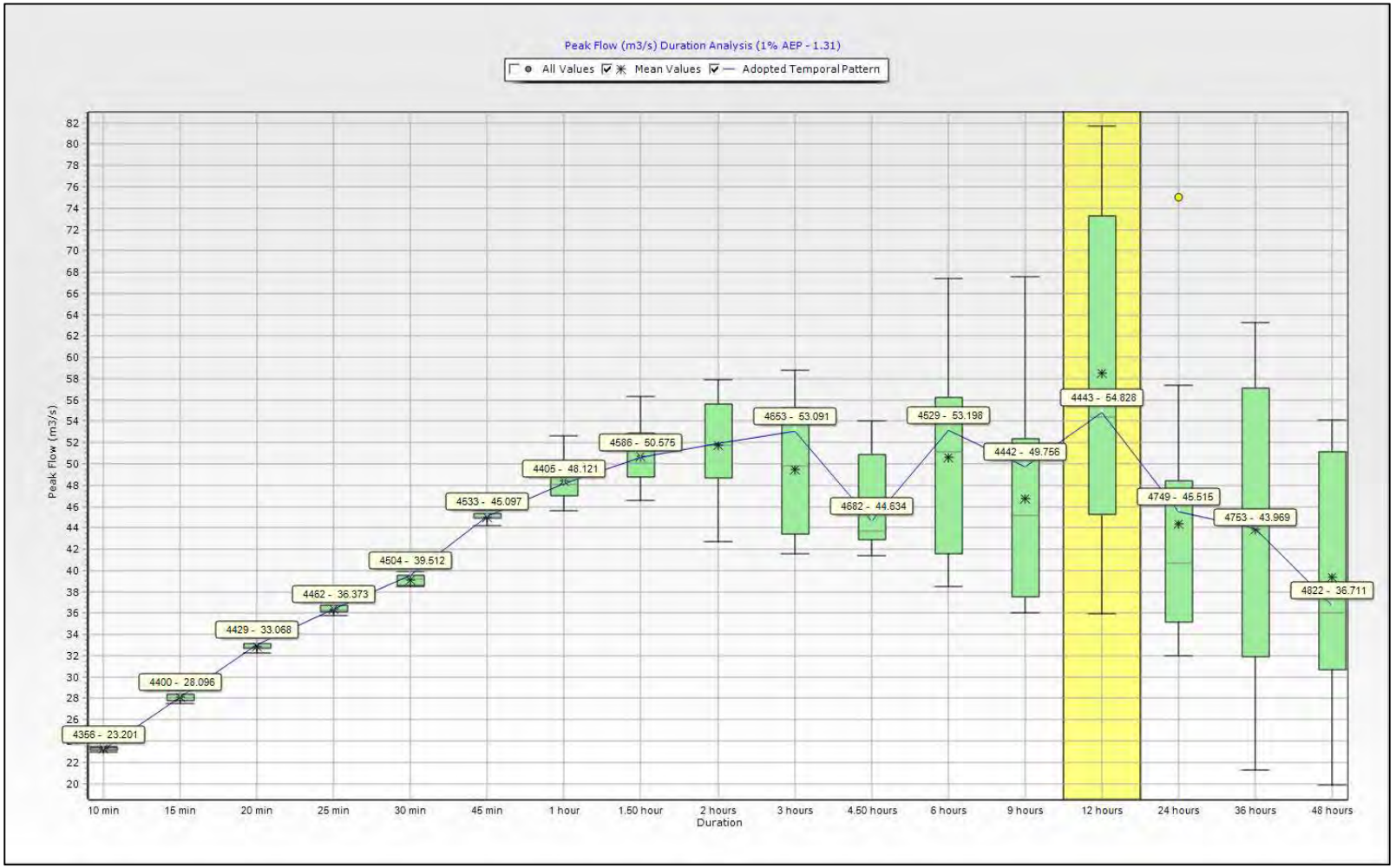
Layer Info

Time Accessed	18 October 2018 03:12PM
Version	2016_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values

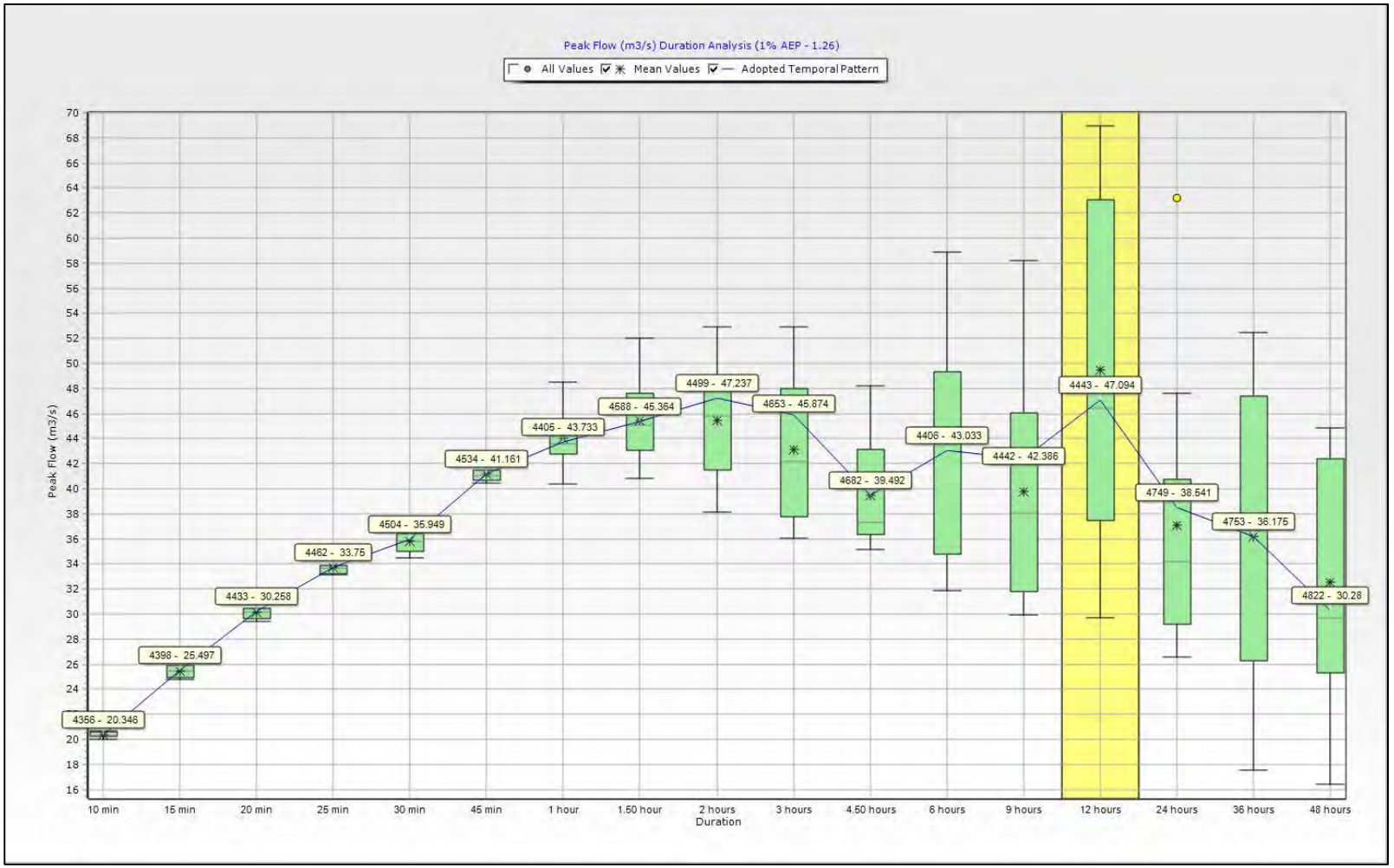
ARR2016 Box Plots

ARR2016 Box Plots at Focus Locations for Whites Creek 1% AEP Design Event

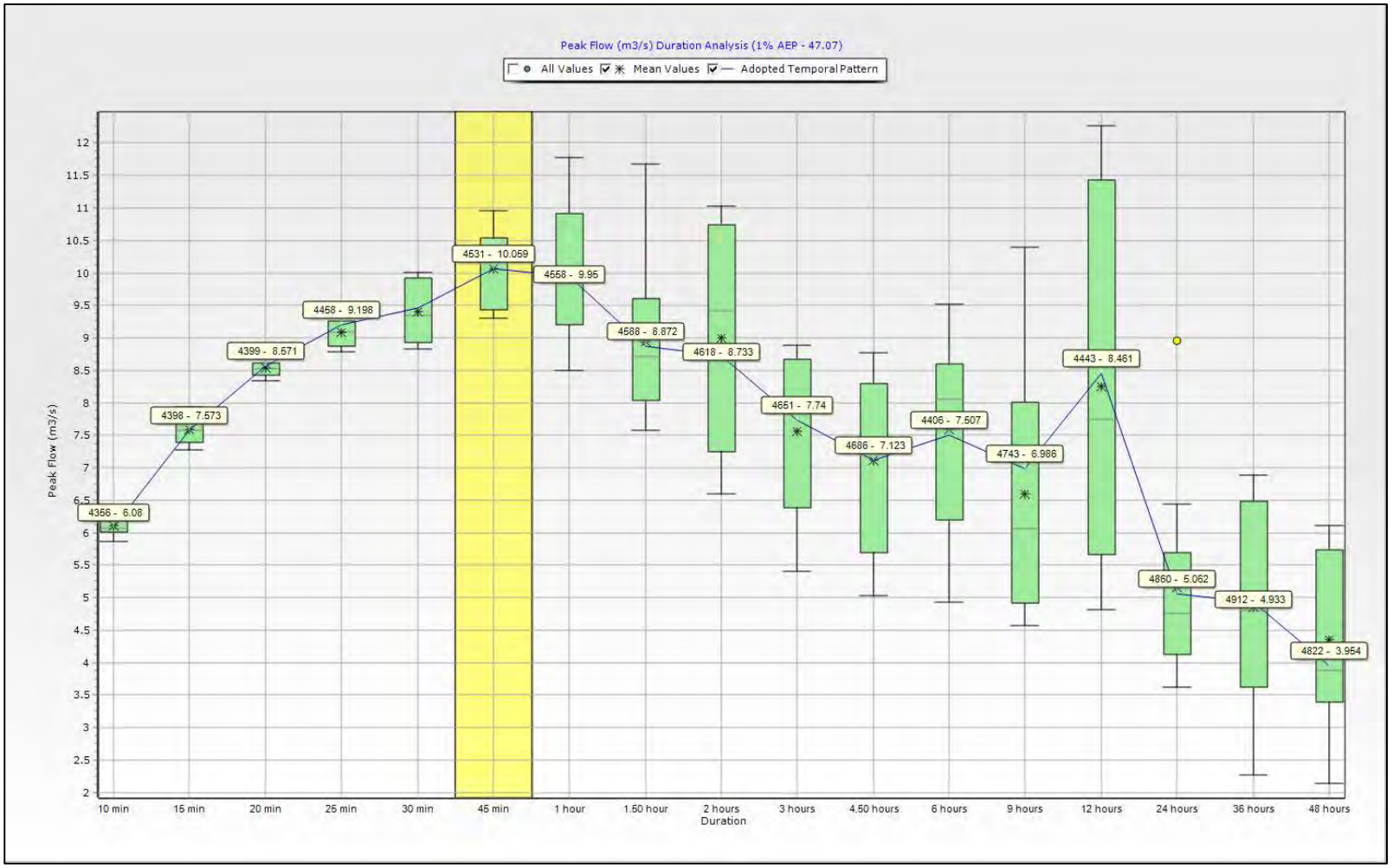
Moss Vale Sewage Treatment Plant



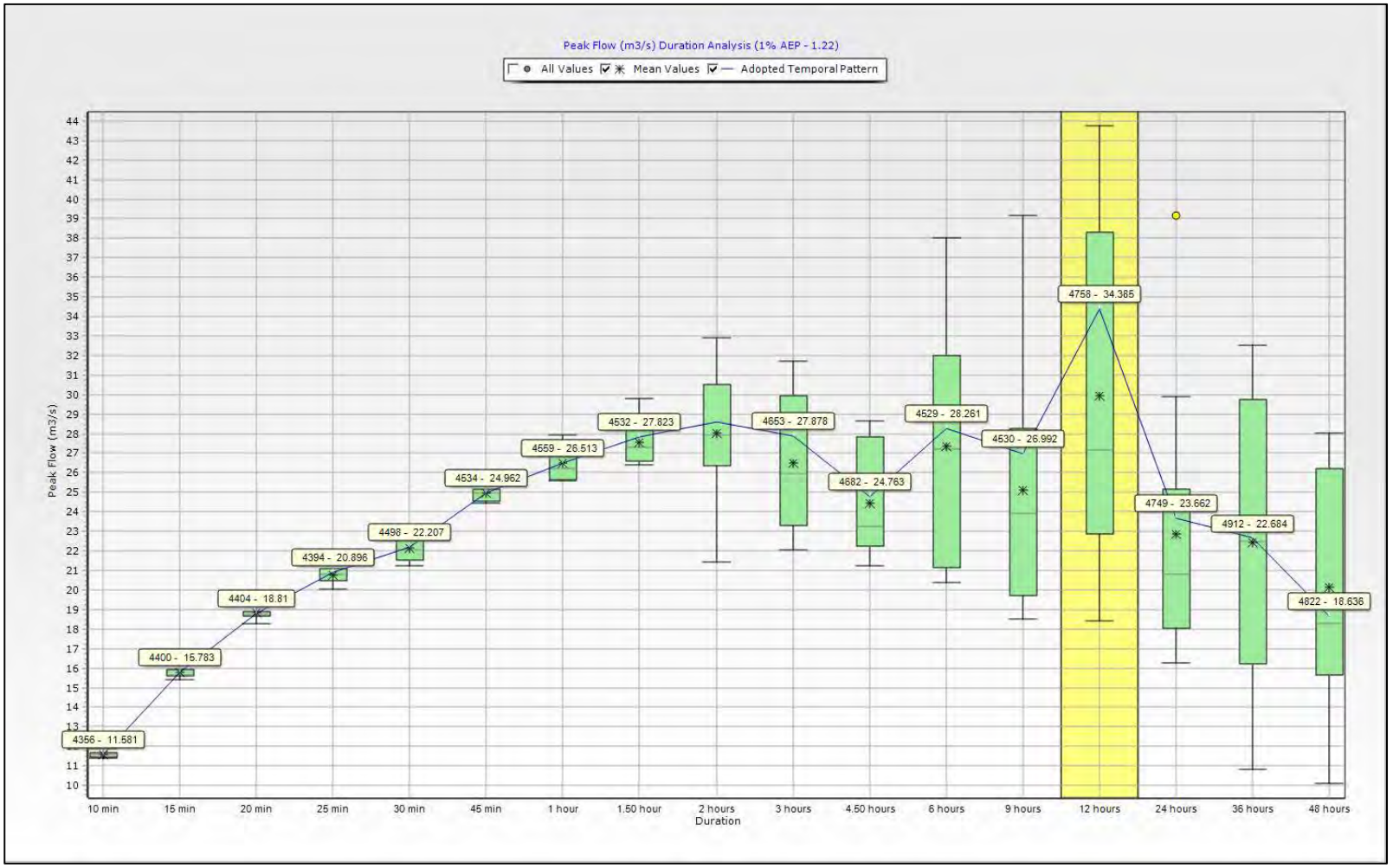
Northern end of Cosgrove Park



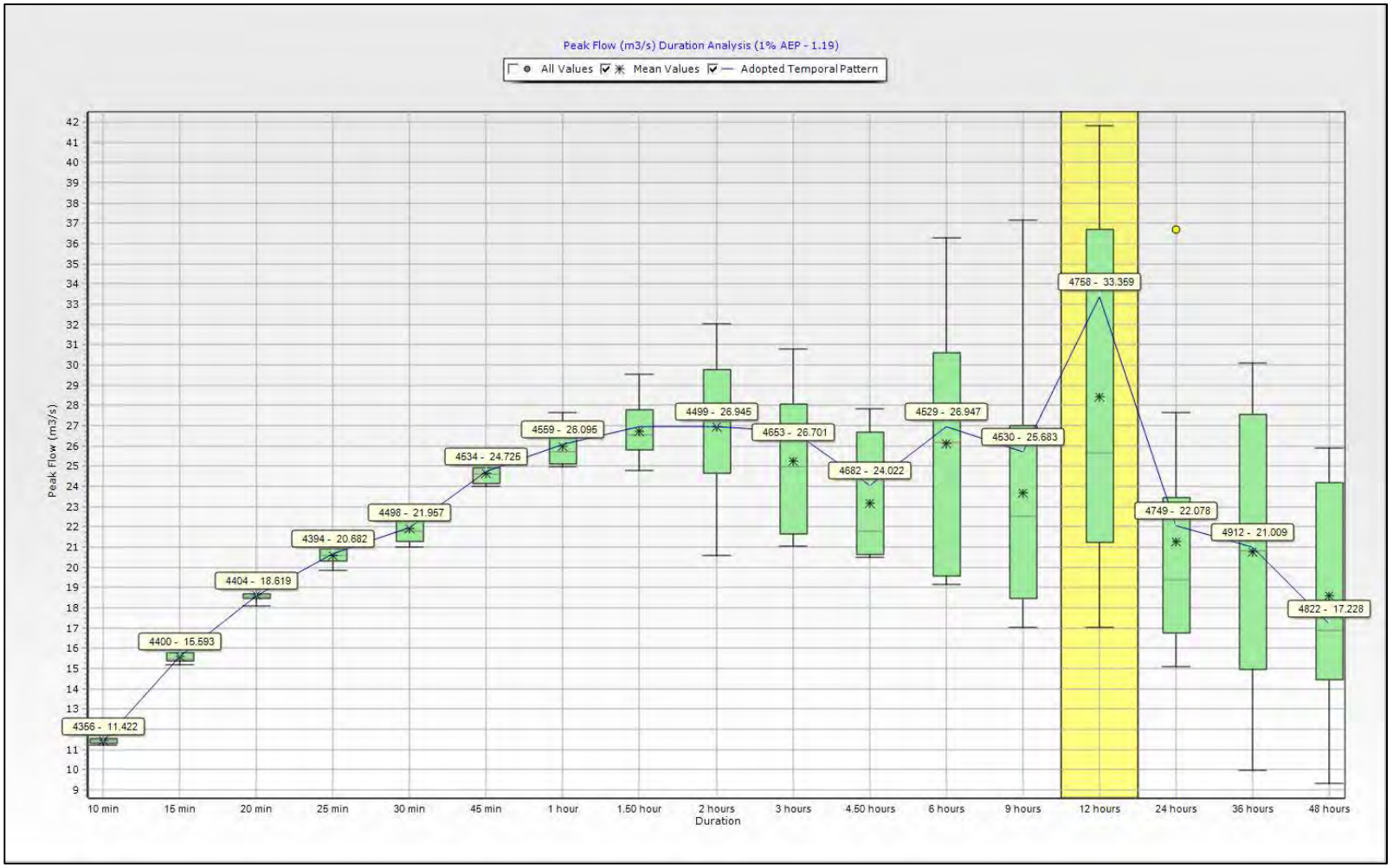
Corner of Willow Dr and Danger St



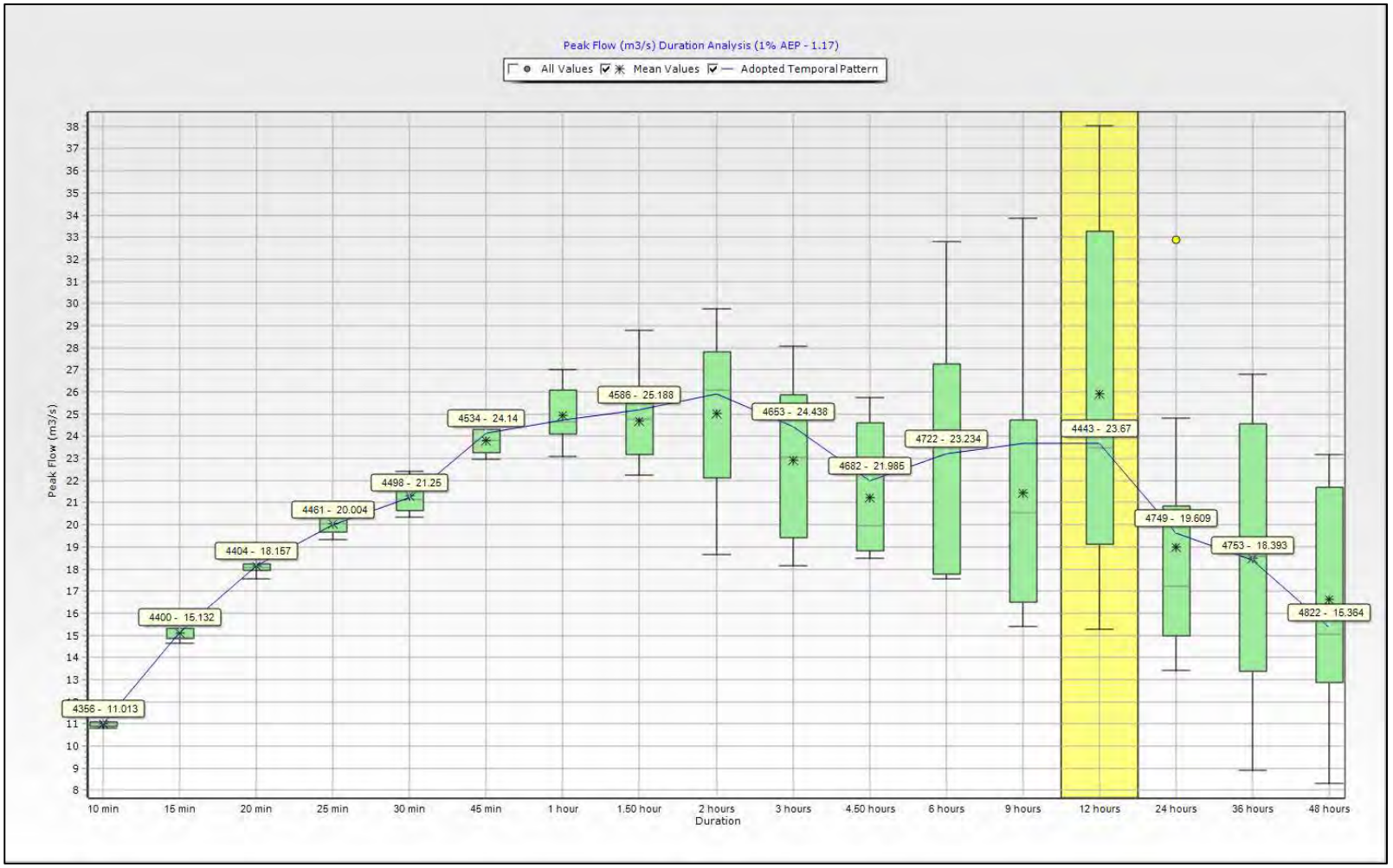
Culvert under the railway between Argyle St and Lackey Rd



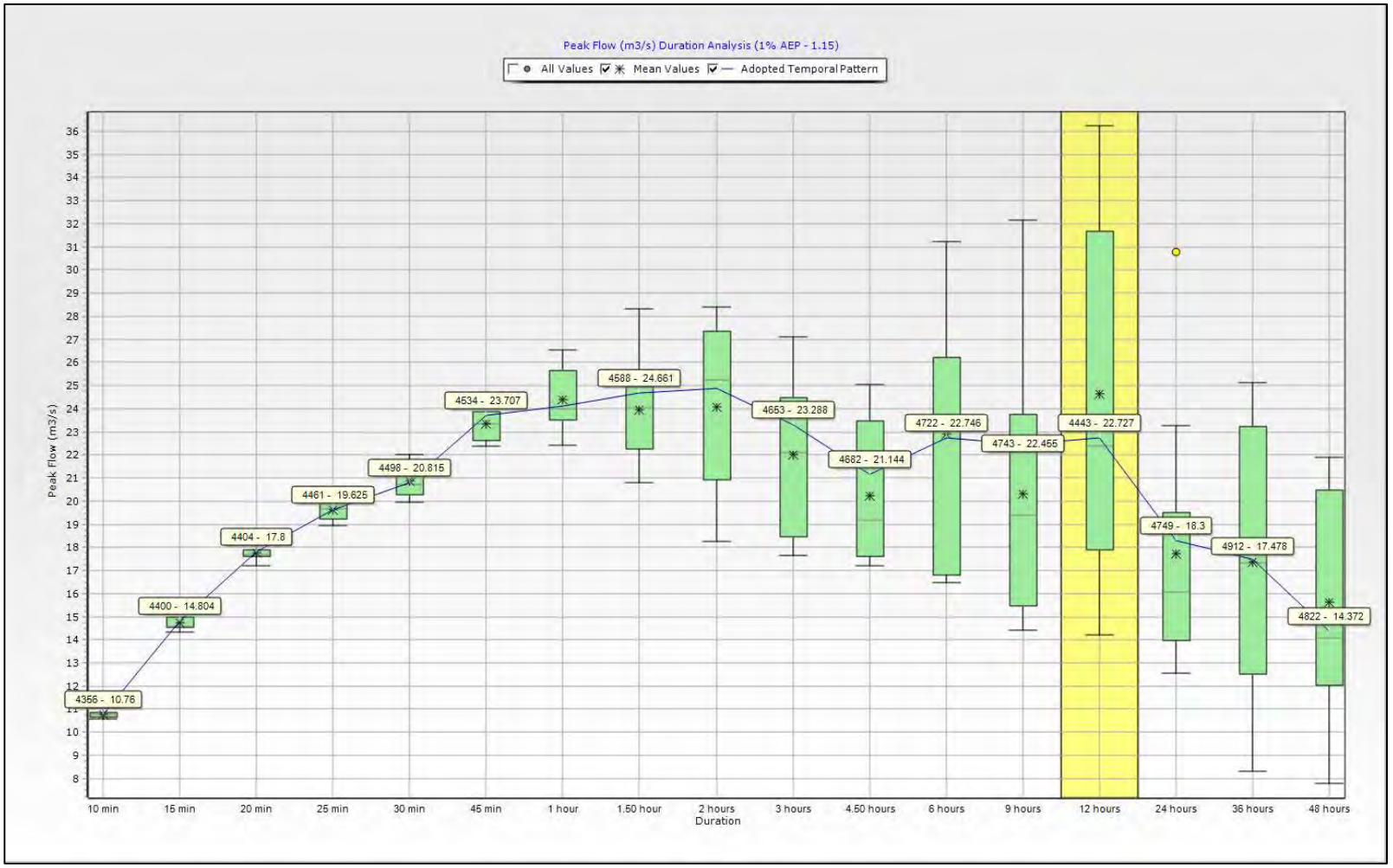
Northern end of Roy Baker Walkway



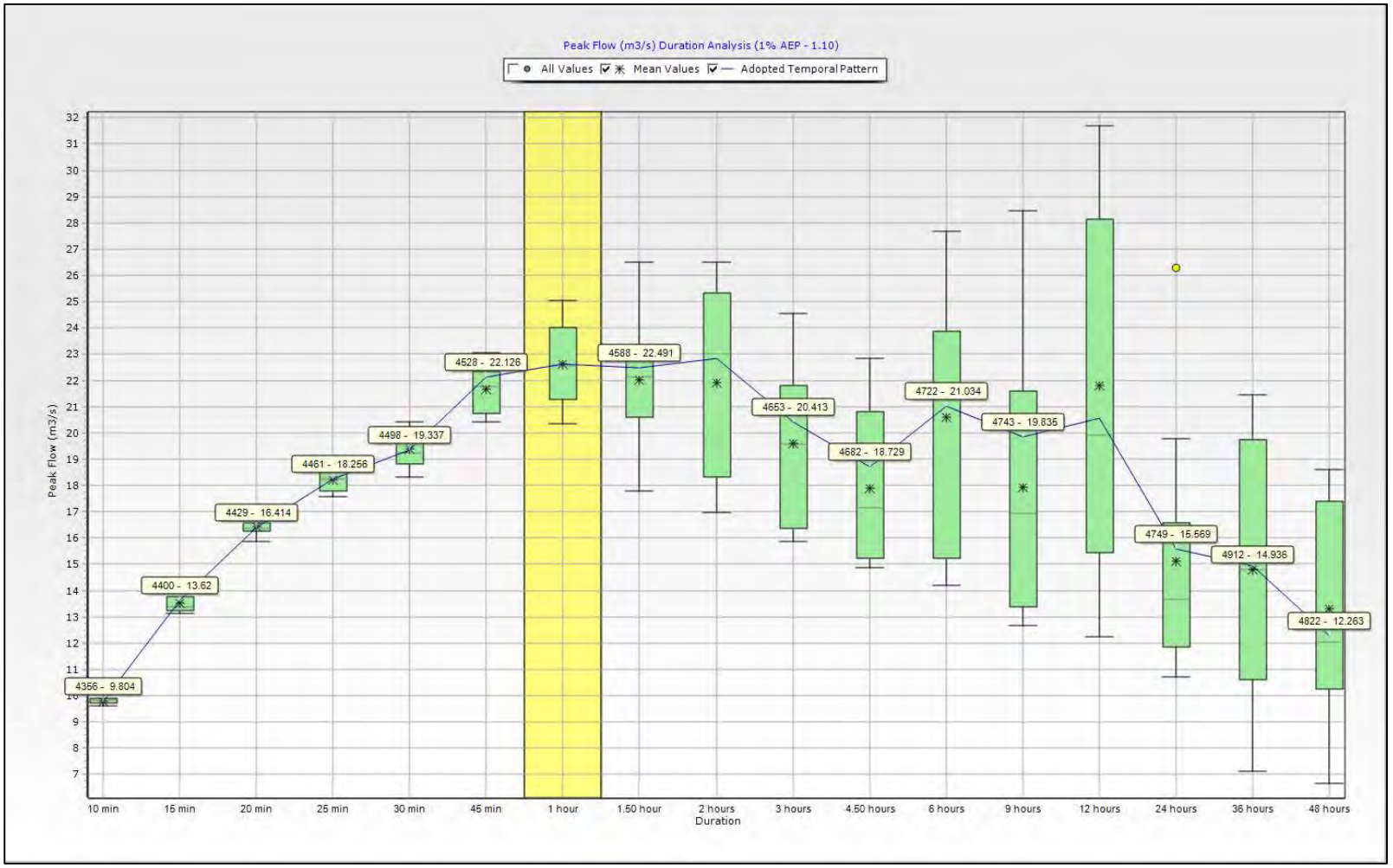
Mack Street Bridge



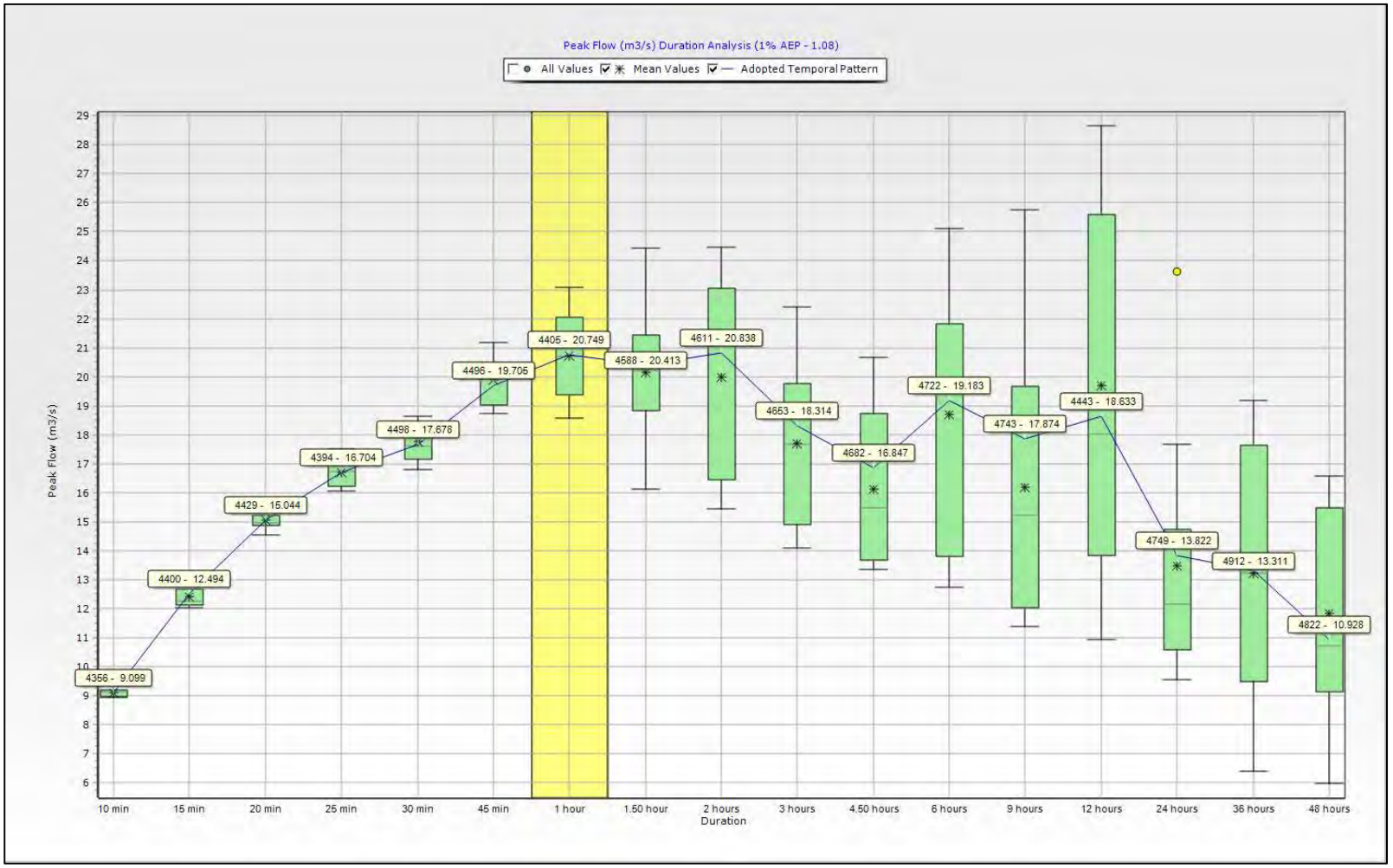
Northern end of Moss Vale Golf Club



Moss Vale Golf Club near Dormie House



Southern end of Moss Vale Golf Club



APPENDIX G

XP-RAFTS OUTPUTS

ARR2016 Results for the 20% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
1.01	4608	90	0.10	0.10	0.02	0.10	0.09	0.10	0.09	360	0.10	0.0%
1.02	4607	90	0.18	0.17	0.04	0.18	0.18	0.19	0.16	360	0.19	5.6%
1.03	2749	270	0.69	0.68	0.13	0.70	0.66	0.67	0.68	720	0.68	-2.9%
1.04	2749	270	1.84	1.76	0.39	1.79	1.83	1.88	1.77	360	1.88	5.0%
1.05	2749	270	4.12	4.11	0.68	4.30	3.94	3.98	4.09	720	4.09	-4.9%
1.06	4711	270	4.70	4.77	0.74	4.58	4.79	4.64	4.73	120	4.79	4.6%
1.07	4711	270	4.76	4.83	0.74	4.65	4.86	4.71	4.80	120	4.86	4.5%
1.08	2749	270	8.72	8.77	1.40	9.13	8.75	8.56	8.57	120	8.75	-4.2%
1.09	2749	270	9.43	9.51	1.51	9.91	9.44	9.27	9.31	120	9.44	-4.7%
1.10	2749	270	9.64	9.73	1.55	10.13	9.66	9.51	9.53	120	9.66	-4.6%
1.11	4711	270	10.11	10.26	1.59	9.85	10.08	10.05	10.01	120	10.08	2.3%
1.12	4711	270	10.21	10.38	1.59	9.97	10.17	10.16	10.13	120	10.17	2.0%
1.13	4711	270	10.49	10.70	1.60	10.29	10.42	10.50	10.44	360	10.50	2.0%
1.14	4711	270	10.71	10.96	1.61	10.53	10.61	10.74	10.68	360	10.74	2.0%
1.15	4711	270	10.85	11.13	1.59	10.70	10.72	10.91	10.87	360	10.91	2.0%
1.16	4711	270	11.19	11.52	1.58	11.10	10.99	11.36	11.31	360	11.36	2.3%
1.17	4717	270	11.30	11.65	1.57	11.28	11.06	11.52	11.49	360	11.52	2.1%
1.18	4717	270	12.20	12.25	1.69	12.11	11.78	12.32	12.43	720	12.43	2.6%
1.19	4706	270	12.43	12.42	1.72	12.49	11.97	12.54	12.69	720	12.69	1.6%
1.20	4717	270	12.80	12.69	1.75	12.76	12.22	12.90	13.15	720	13.15	3.1%
1.21	4740	360	13.06	13.03	1.88	13.21	12.82	13.21	13.52	720	13.52	2.3%
1.22	4740	360	13.07	13.04	1.88	13.22	12.82	13.22	13.53	720	13.53	2.3%
1.23	4706	270	16.92	16.49	2.47	16.51	16.84	16.25	17.47	720	17.47	5.8%
1.24	4706	270	17.55	17.15	2.55	17.17	17.52	16.83	18.16	720	18.16	5.8%
1.25	4711	270	17.88	17.50	2.57	17.52	17.81	17.18	18.57	720	18.57	6.0%
1.26	4706	270	21.76	21.31	3.17	21.50	21.04	20.46	22.92	720	22.92	6.6%
1.27	4706	270	22.06	21.60	3.20	21.67	21.20	20.85	23.36	720	23.36	7.8%
1.28	4706	270	22.18	21.72	3.21	21.76	21.29	21.00	23.54	720	23.54	8.2%
1.29	4717	270	22.88	22.53	3.28	22.62	22.00	21.93	24.58	720	24.58	8.7%
1.30	4717	270	23.65	23.49	3.35	23.69	22.84	22.95	25.69	720	25.69	8.4%
1.31	4811	720	24.96	24.08	7.00	27.25	24.08	24.28	27.25	720	27.25	0.0%
1.32	4811	720	25.80	24.96	7.20	28.20	24.79	24.97	28.20	720	28.20	0.0%
2.01	4706	270	0.30	0.30	0.06	0.31	0.31	0.28	0.30	120	0.31	0.0%
3.01	4605	90	0.58	0.59	0.09	0.57	0.58	0.58	0.54	120	0.58	1.8%
4.01	4645	120	0.26	0.26	0.07	0.28	0.30	0.24	0.20	120	0.30	7.1%
5.01	4643	120	0.37	0.37	0.10	0.38	0.37	0.39	0.31	360	0.39	2.6%
6.01	2749	270	0.48	0.46	0.10	0.47	0.47	0.45	0.47	120	0.47	0.0%
6.02	2749	270	0.57	0.55	0.12	0.57	0.54	0.53	0.55	720	0.55	-3.5%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
6.03	4385	10	1.66	1.66	0.07	1.67	1.53	1.43	1.26	120	1.53	-8.4%
7.01	4386	10	1.00	0.97	0.10	0.99	0.91	0.70	0.42	120	0.91	-8.1%
8.01	4386	10	0.79	0.76	0.08	0.77	0.96	0.71	0.52	120	0.96	24.7%
8.02	4420	15	2.69	2.63	0.15	2.72	2.81	2.56	1.91	120	2.81	3.3%
9.01	4642	120	0.50	0.49	0.15	0.52	0.52	0.52	0.36	120	0.52	0.0%
10.01	4581	60	0.34	0.36	0.07	0.34	0.37	0.34	0.19	120	0.37	8.8%
11.01	4386	10	0.55	0.54	0.06	0.55	0.54	0.40	0.18	120	0.54	-1.8%
12.01	4386	10	0.41	0.40	0.04	0.41	0.44	0.39	0.39	120	0.44	7.3%
13.01	4380	10	2.06	1.98	0.20	2.13	1.95	1.53	0.87	120	1.95	-8.5%
13.02	4643	120	2.86	2.80	0.53	2.91	2.69	2.76	2.61	360	2.76	-5.2%
13.03	2749	270	4.08	3.92	0.78	4.08	3.88	3.96	3.90	360	3.96	-2.9%
14.01	4386	10	1.41	1.38	0.14	1.41	1.40	1.11	0.51	120	1.40	-0.7%
15.01	4380	10	3.30	3.17	0.34	3.41	2.81	2.08	1.18	120	2.81	-17.6%
16.01	4386	10	0.45	0.44	0.05	0.45	0.47	0.38	0.19	120	0.47	4.4%
17.01	4386	10	0.83	0.80	0.08	0.82	0.87	0.65	0.46	120	0.87	6.1%
17.02	4380	10	2.78	2.67	0.27	2.89	2.46	1.89	1.37	120	2.46	-14.9%
17.03	4706	270	1.17	1.16	0.18	1.21	1.08	1.08	1.17	720	1.17	-3.3%
18.01	4380	10	1.14	1.09	0.11	1.19	1.28	0.94	0.70	120	1.28	7.6%
19.01	2749	270	0.23	0.23	0.05	0.23	0.22	0.24	0.22	360	0.24	4.3%
20.01	4386	10	0.65	0.62	0.07	0.64	0.70	0.53	0.40	120	0.70	9.4%
20.02	4645	120	0.83	0.86	0.24	0.93	0.95	0.76	0.64	120	0.95	2.2%
21.01	4642	120	0.17	0.17	0.04	0.16	0.16	0.18	0.14	360	0.18	12.5%
22.01	4386	10	0.34	0.33	0.03	0.34	0.38	0.29	0.27	120	0.38	11.8%
22.02	4645	120	0.37	0.37	0.10	0.39	0.41	0.35	0.30	120	0.41	5.1%
23.01	4643	120	0.47	0.47	0.12	0.48	0.47	0.50	0.38	360	0.50	4.2%
24.01	4642	120	0.45	0.43	0.15	0.46	0.46	0.46	0.32	120	0.46	0.0%
25.01	4489	25	0.31	0.31	0.07	0.31	0.36	0.31	0.14	120	0.36	16.1%
25.02	4578	60	0.44	0.43	0.12	0.45	0.44	0.46	0.22	360	0.46	2.2%
26.01	4645	120	0.47	0.45	0.16	0.51	0.55	0.43	0.32	120	0.55	7.8%
27.01	4581	60	0.35	0.37	0.06	0.34	0.40	0.32	0.23	120	0.40	17.6%
27.02	4645	120	0.92	0.92	0.29	1.02	1.02	0.95	0.60	120	1.02	0.0%
27.03	4642	120	1.46	1.40	0.44	1.49	1.49	1.52	1.01	360	1.52	2.0%
27.04	4642	120	1.69	1.65	0.47	1.71	1.71	1.79	1.21	360	1.79	4.7%
28.01	4386	10	0.33	0.32	0.04	0.33	0.36	0.31	0.16	120	0.36	9.1%
29.01	4642	120	0.41	0.39	0.13	0.43	0.43	0.40	0.28	120	0.43	0.0%
30.01	4578	60	0.27	0.28	0.05	0.30	0.32	0.25	0.17	120	0.32	6.7%
31.01	4643	120	0.29	0.28	0.08	0.28	0.28	0.31	0.22	360	0.31	10.7%
31.02	4643	120	0.33	0.32	0.09	0.33	0.31	0.36	0.26	360	0.36	9.1%
32.01	4386	10	0.62	0.61	0.07	0.63	0.68	0.51	0.38	120	0.68	7.9%
32.02	4386	10	1.04	1.01	0.11	1.03	1.20	0.94	0.72	120	1.20	16.5%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
33.01	4645	120	0.43	0.43	0.14	0.47	0.49	0.39	0.31	120	0.49	4.3%
34.01	4380	10	0.47	0.45	0.05	0.49	0.39	0.27	0.20	120	0.39	-20.4%
34.02	4387	10	0.57	0.57	0.04	0.58	0.44	0.35	0.25	120	0.44	-24.1%
35.01	4386	10	0.62	0.60	0.07	0.61	0.55	0.41	0.21	120	0.55	-9.8%
35.02	4386	10	0.70	0.67	0.07	0.69	0.60	0.45	0.23	120	0.60	-13.0%
36.01	4380	10	1.33	1.28	0.13	1.39	1.35	1.05	0.61	120	1.35	-2.9%
36.02	4426	15	1.65	1.64	0.13	1.69	1.77	1.45	0.96	120	1.77	4.7%
36.03	4426	15	1.66	1.66	0.13	1.70	1.83	1.51	1.00	120	1.83	7.6%
36.04	4643	120	2.42	2.52	0.58	2.40	2.74	2.47	1.93	120	2.74	14.2%
36.05	4643	120	4.94	5.25	0.93	5.22	5.29	5.30	4.41	360	5.30	1.5%
37.01	4380	10	0.60	0.58	0.06	0.62	0.63	0.48	0.39	120	0.63	1.6%
37.02	4386	10	1.12	1.12	0.01	1.13	1.12	0.91	0.83	120	1.12	-0.9%
38.01	4605	90	0.43	0.44	0.08	0.42	0.42	0.44	0.39	360	0.44	4.8%
38.02	4642	120	0.82	0.85	0.17	0.82	0.82	0.81	0.75	120	0.82	0.0%
38.03	4642	120	0.86	0.89	0.17	0.86	0.86	0.85	0.78	120	0.86	0.0%
38.04	4643	120	1.67	1.75	0.37	1.68	1.82	1.55	1.44	120	1.82	8.3%
38.05	4643	120	2.03	2.16	0.42	2.05	2.25	1.95	1.80	120	2.25	9.8%
39.01	4386	10	0.22	0.22	0.02	0.22	0.27	0.20	0.15	120	0.27	22.7%
39.02	4380	10	0.86	0.82	0.09	0.90	0.98	0.74	0.58	120	0.98	8.9%
40.01	4380	10	0.44	0.42	0.05	0.46	0.49	0.37	0.31	120	0.49	6.5%
41.01	4380	10	0.33	0.32	0.04	0.35	0.39	0.30	0.23	120	0.39	11.4%
42.01	4380	10	0.33	0.32	0.04	0.34	0.33	0.26	0.15	120	0.33	-2.9%
42.02	4389	10	0.75	0.75	0.03	0.75	0.61	0.55	0.39	120	0.61	-18.7%
43.01	4386	10	0.59	0.57	0.06	0.59	0.58	0.44	0.30	120	0.58	-1.7%
44.01	4386	10	0.29	0.28	0.03	0.29	0.26	0.18	0.11	120	0.26	-10.3%
44.02	4382	10	0.77	0.77	0.05	0.77	0.78	0.65	0.52	120	0.78	1.3%
45.01	4380	10	0.39	0.37	0.04	0.41	0.43	0.34	0.26	120	0.43	4.9%
46.01	4645	120	0.36	0.35	0.11	0.39	0.41	0.32	0.25	120	0.41	5.1%
47.01	4608	90	0.66	0.66	0.12	0.68	0.65	0.68	0.59	360	0.68	0.0%
47.02	4605	90	1.06	1.08	0.16	1.07	1.11	1.10	0.98	120	1.11	3.7%
47.03	4641	120	1.07	1.10	0.20	1.08	1.13	1.11	1.00	120	1.13	4.6%
47.04	4641	120	1.49	1.56	0.26	1.53	1.60	1.50	1.39	120	1.60	4.6%
47.05	4642	120	2.70	2.87	0.51	2.85	2.85	2.73	2.47	120	2.85	0.0%
47.06	4642	120	3.08	3.27	0.56	3.26	3.26	3.13	2.84	120	3.26	0.0%
47.07	4642	120	4.08	4.29	0.77	4.20	4.20	4.23	3.75	360	4.23	0.7%
47.08	4642	120	4.15	4.35	0.78	4.27	4.27	4.31	3.83	360	4.31	0.9%
47.09	4642	120	4.35	4.53	0.81	4.44	4.44	4.54	4.00	360	4.54	2.3%
47.10	4642	120	4.91	5.12	0.87	4.95	4.95	5.18	4.59	360	5.18	4.6%
47.11	4642	120	5.13	5.34	0.89	5.15	5.15	5.44	4.81	360	5.44	5.6%
48.01	4386	10	0.29	0.28	0.03	0.29	0.33	0.27	0.16	120	0.33	13.8%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
49.01	4380	10	0.32	0.30	0.03	0.33	0.33	0.27	0.14	120	0.33	0.0%
49.02	4380	10	0.52	0.50	0.05	0.54	0.53	0.42	0.24	120	0.53	-1.9%
49.03	4380	10	0.78	0.77	0.02	0.78	0.69	0.64	0.44	120	0.69	-11.5%
49.04	4380	10	0.78	0.77	0.02	0.79	0.78	0.74	0.52	120	0.78	-1.3%
50.01	4380	10	0.30	0.29	0.03	0.31	0.36	0.26	0.23	120	0.36	16.1%
51.01	4386	10	0.35	0.33	0.04	0.34	0.36	0.28	0.17	120	0.36	5.9%
52.01	4581	60	0.22	0.23	0.04	0.21	0.26	0.20	0.14	120	0.26	23.8%
53.01	4386	10	0.23	0.23	0.02	0.23	0.22	0.16	0.10	120	0.22	-4.3%
53.02	4642	120	0.35	0.35	0.10	0.37	0.37	0.34	0.25	120	0.37	0.0%
53.03	4581	60	0.79	0.79	0.14	0.79	0.78	0.76	0.59	120	0.78	-1.3%
54.01	4386	10	0.13	0.12	0.01	0.13	0.11	0.08	0.05	120	0.11	-15.4%
54.02	4642	120	0.39	0.37	0.12	0.40	0.40	0.36	0.26	120	0.40	0.0%
55.01	4386	10	0.29	0.28	0.03	0.29	0.34	0.27	0.18	120	0.34	17.2%
55.02	4386	10	0.33	0.31	0.03	0.32	0.36	0.30	0.20	120	0.36	12.5%
56.01	4386	10	0.35	0.34	0.03	0.35	0.35	0.27	0.21	120	0.35	0.0%
56.02	4386	10	0.83	0.80	0.08	0.82	0.93	0.76	0.53	120	0.93	13.4%
57.01	4645	120	0.26	0.25	0.09	0.28	0.28	0.25	0.16	120	0.28	0.0%
57.02	4386	10	0.48	0.47	0.04	0.48	0.57	0.46	0.30	120	0.57	18.8%
58.01	4645	120	0.55	0.54	0.19	0.61	0.65	0.49	0.37	120	0.65	6.6%
58.02	4645	120	0.68	0.69	0.21	0.77	0.77	0.62	0.49	120	0.77	0.0%
59.01	2749	270	0.13	0.13	0.03	0.13	0.13	0.12	0.12	120	0.13	0.0%
60.01	4386	10	0.37	0.36	0.04	0.37	0.34	0.30	0.26	120	0.34	-8.1%
60.02	4386	10	0.47	0.45	0.05	0.46	0.49	0.42	0.36	120	0.49	6.5%
60.03	4386	10	0.79	0.76	0.07	0.78	0.86	0.71	0.56	120	0.86	10.3%
60.04	4642	120	1.50	1.41	0.43	1.45	1.45	1.47	1.17	360	1.47	1.4%
60.05	4642	120	1.69	1.63	0.45	1.67	1.67	1.68	1.33	360	1.68	0.6%
61.01	4386	10	0.31	0.30	0.03	0.31	0.36	0.28	0.18	120	0.36	16.1%
62.01	4386	10	0.47	0.45	0.05	0.46	0.57	0.43	0.33	120	0.57	23.9%
63.01	4645	120	0.45	0.44	0.12	0.47	0.51	0.39	0.36	120	0.51	8.5%
63.02	4382	10	0.76	0.76	0.01	0.76	0.70	0.69	0.62	120	0.70	-7.9%
63.03	4643	120	0.99	0.97	0.22	0.98	0.97	0.98	0.84	360	0.98	0.0%
64.01	4386	10	0.80	0.78	0.08	0.80	0.82	0.65	0.39	120	0.82	2.5%
64.02	4642	120	1.21	1.14	0.39	1.25	1.25	1.22	0.80	120	1.25	0.0%
64.03	4642	120	1.49	1.41	0.48	1.51	1.51	1.54	1.00	360	1.54	2.0%
65.01	4645	120	0.15	0.15	0.04	0.16	0.17	0.13	0.11	120	0.17	6.3%
65.02	4642	120	0.38	0.35	0.11	0.35	0.35	0.38	0.28	360	0.38	8.6%
66.01	4642	120	0.31	0.29	0.11	0.33	0.33	0.29	0.19	120	0.33	0.0%
67.01	2749	270	0.42	0.39	0.10	0.45	0.43	0.37	0.41	120	0.43	-4.4%
67.02	4732	360	0.90	0.83	0.17	0.84	0.85	0.81	0.90	720	0.90	7.1%
67.03	4740	360	1.08	1.01	0.20	1.02	0.99	1.02	1.07	720	1.07	4.9%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
67.04	4740	360	1.32	1.27	0.24	1.34	1.22	1.34	1.29	360	1.34	0.0%
67.05	4740	360	1.56	1.55	0.29	1.63	1.47	1.63	1.52	360	1.63	0.0%
68.01	4642	120	0.20	0.20	0.05	0.21	0.21	0.21	0.16	120	0.21	0.0%
69.01	4641	120	0.21	0.22	0.05	0.23	0.21	0.23	0.18	360	0.23	0.0%
70.01	4386	10	0.39	0.38	0.04	0.39	0.43	0.34	0.25	120	0.43	10.3%
70.02	4581	60	0.83	0.82	0.20	0.85	0.81	0.88	0.55	360	0.88	3.5%
70.03	4642	120	1.57	1.45	0.49	1.48	1.48	1.69	1.10	360	1.69	14.2%
71.01	4579	60	0.46	0.46	0.12	0.51	0.41	0.50	0.29	360	0.50	-2.0%
72.01	4386	10	0.52	0.51	0.05	0.53	0.48	0.38	0.31	120	0.48	-9.4%
BasinA	4552	45	1.09	1.12	0.19	1.09	0.85	1.00	0.68	360	1.00	-8.3%
BasinBC	4605	90	1.71	1.70	0.17	1.71	1.68	1.60	1.62	120	1.68	-1.8%
BasinE	4706	270	1.05	1.04	0.15	1.07	1.00	0.98	1.05	720	1.05	-1.9%
BasinF	4706	270	2.29	2.27	0.32	2.32	2.16	2.18	2.31	720	2.31	-0.4%
BasinG	4739	360	0.49	0.45	0.11	0.56	0.44	0.46	0.50	720	0.50	-10.7%

Average Difference (All Subcatchments)		**2.59%**
Average Difference (Focus Locations)		**2.69%**
Average Difference (Whites Creek)		**2.58%**
Average Difference (Willow Tributary)		**2.47%**

ARR2016 Results for the 10% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4411 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4730 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
1.01	4568	60	0.12	0.12	0.02	0.12	0.03	0.12	0.12	60	0.12	0.0%
1.02	4568	60	0.23	0.23	0.03	0.23	0.07	0.22	0.24	360	0.24	4.3%
1.03	4731	360	0.90	0.87	0.21	0.89	0.25	0.76	0.97	360	0.97	9.0%
1.04	4593	90	2.36	2.38	0.43	2.48	0.93	2.17	2.54	360	2.54	2.4%
1.05	4731	360	5.29	5.42	0.95	5.38	2.12	4.68	5.83	360	5.83	8.4%
1.06	4731	360	6.08	6.13	1.05	5.98	2.35	5.12	6.46	360	6.46	8.0%
1.07	4672	360	6.15	6.21	1.05	6.06	2.39	5.18	6.53	360	6.53	7.8%
1.08	4731	360	11.16	11.29	1.95	11.14	5.51	9.93	12.00	360	12.00	7.7%
1.09	4731	360	12.13	12.22	2.10	12.00	5.80	10.69	13.05	360	13.05	8.8%
1.10	4678	360	12.41	12.47	2.15	12.73	5.89	10.94	13.34	360	13.34	4.8%
1.11	4678	360	13.01	13.09	2.22	13.36	6.14	11.54	13.92	360	13.92	4.2%
1.12	4672	360	13.16	13.25	2.24	12.99	6.20	11.66	14.06	360	14.06	8.2%
1.13	4672	360	13.54	13.65	2.29	13.40	6.30	11.96	14.41	360	14.41	7.5%
1.14	4672	360	13.84	14.00	2.32	13.77	6.45	12.19	14.69	360	14.69	6.7%
1.15	4672	360	14.08	14.27	2.33	14.07	6.51	12.30	14.89	360	14.89	5.8%
1.16	4672	360	14.63	14.88	2.39	14.73	6.60	12.61	15.35	360	15.35	4.2%
1.17	4672	360	14.86	15.14	2.41	15.01	6.65	12.68	15.52	360	15.52	3.4%
1.18	4672	360	16.14	16.44	2.45	16.44	6.96	13.20	16.88	360	16.88	2.7%
1.19	4678	360	16.49	16.83	2.47	16.82	7.04	13.32	17.26	360	17.26	2.6%
1.20	4672	360	17.05	17.52	2.53	17.47	7.13	13.45	17.75	360	17.75	1.6%
1.21	4672	360	17.45	17.96	2.59	17.90	7.17	13.55	18.02	360	18.02	0.7%
1.22	4672	360	17.45	17.97	2.59	17.91	7.17	13.55	18.02	360	18.02	0.6%
1.23	4731	360	22.35	23.13	3.25	22.21	8.64	17.47	23.95	360	23.95	7.8%
1.24	4672	360	23.16	24.00	3.39	23.57	8.85	18.14	24.72	360	24.72	4.9%
1.25	4672	360	23.64	24.55	3.46	24.09	9.02	18.46	25.19	360	25.19	4.6%
1.26	4672	360	28.45	29.42	4.15	28.65	12.02	22.46	30.20	360	30.20	5.4%
1.27	4672	360	28.90	29.87	4.19	29.14	12.25	22.63	30.59	360	30.59	5.0%
1.28	4672	360	29.07	30.04	4.22	29.33	12.33	22.71	30.75	360	30.75	4.8%
1.29	4672	360	30.11	31.06	4.33	30.47	12.70	23.16	31.65	360	31.65	3.9%
1.30	4672	360	31.37	32.19	4.44	31.73	13.10	23.56	32.64	360	32.64	2.9%
1.31	4672	360	33.18	33.84	4.64	33.41	13.57	24.41	34.27	360	34.27	2.6%
1.32	4672	360	34.05	34.64	4.70	34.30	13.79	24.61	34.98	360	34.98	2.0%
2.01	4731	360	0.40	0.40	0.09	0.41	0.16	0.31	0.44	360	0.44	7.3%
3.01	4593	90	0.74	0.75	0.14	0.78	0.27	0.69	0.77	360	0.77	-1.3%
4.01	4567	60	0.32	0.30	0.05	0.32	0.30	0.29	0.29	15	0.30	-6.2%
5.01	4565	60	0.50	0.50	0.09	0.50	0.21	0.50	0.44	60	0.50	0.0%
6.01	4731	360	0.62	0.61	0.14	0.63	0.27	0.53	0.67	360	0.67	6.3%
6.02	4731	360	0.73	0.73	0.16	0.75	0.38	0.59	0.80	360	0.80	6.7%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4411 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4730 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
6.03	4378	10	2.00	1.98	0.08	2.01	1.70	1.92	1.80	60	1.92	-4.5%
7.01	4381	15	1.21	1.23	0.14	1.21	1.23	0.97	0.63	15	1.23	1.7%
8.01	4413	15	1.01	1.02	0.12	1.00	1.07	0.99	0.77	15	1.07	7.0%
8.02	4408	15	3.28	3.26	0.24	3.36	3.61	3.10	2.78	15	3.61	7.4%
9.01	4565	60	0.67	0.66	0.13	0.70	0.30	0.70	0.53	60	0.70	0.0%
10.01	4542	45	0.45	0.41	0.08	0.48	0.45	0.46	0.29	60	0.46	-4.2%
11.01	4381	15	0.69	0.71	0.09	0.70	0.72	0.55	0.29	15	0.72	2.9%
12.01	4678	360	0.53	0.55	0.10	0.54	0.50	0.42	0.59	360	0.59	9.3%
13.01	4411	15	2.50	2.57	0.28	2.57	2.57	2.09	1.33	15	2.57	0.0%
13.02	4568	60	3.80	3.85	0.45	3.75	2.76	3.94	3.65	60	3.94	5.1%
13.03	4565	60	5.18	5.22	0.55	5.36	3.59	5.36	5.48	360	5.48	2.2%
14.01	4381	15	1.74	1.78	0.22	1.76	1.81	1.54	0.81	15	1.81	2.8%
15.01	4381	15	3.98	4.01	0.46	4.01	3.87	2.79	1.77	15	3.87	-3.5%
16.01	4381	15	0.56	0.57	0.07	0.56	0.58	0.53	0.29	15	0.58	3.6%
17.01	4413	15	1.02	1.04	0.11	1.04	1.08	0.89	0.67	15	1.08	3.8%
17.02	4381	15	3.33	3.37	0.35	3.32	3.30	2.43	1.97	15	3.30	-0.6%
17.03	4672	360	1.52	1.57	0.23	1.50	0.81	1.28	1.66	360	1.66	10.7%
18.01	4413	15	1.41	1.43	0.16	1.43	1.47	1.27	1.01	15	1.47	2.8%
19.01	4731	360	0.30	0.29	0.07	0.29	0.08	0.26	0.32	360	0.32	10.3%
20.01	4413	15	0.81	0.83	0.10	0.81	0.84	0.69	0.56	15	0.84	3.7%
20.02	4565	60	1.03	0.99	0.16	1.01	0.97	1.01	0.91	60	1.01	0.0%
21.01	4568	60	0.21	0.22	0.03	0.22	0.07	0.21	0.20	60	0.21	-4.5%
22.01	4408	15	0.41	0.42	0.05	0.42	0.42	0.37	0.38	15	0.42	0.0%
22.02	4411	15	0.45	0.46	0.05	0.45	0.45	0.44	0.43	15	0.45	0.0%
23.01	4565	60	0.62	0.62	0.11	0.61	0.23	0.61	0.55	60	0.61	0.0%
24.01	4565	60	0.61	0.61	0.13	0.64	0.31	0.64	0.46	60	0.64	0.0%
25.01	4444	20	0.44	0.45	0.08	0.48	0.44	0.41	0.22	15	0.44	-8.3%
25.02	4536	45	0.59	0.56	0.11	0.58	0.51	0.62	0.36	60	0.62	6.9%
26.01	4475	60	0.58	0.56	0.11	0.57	0.59	0.56	0.45	15	0.59	3.5%
27.01	4565	60	0.44	0.44	0.09	0.44	0.46	0.44	0.33	15	0.46	4.5%
27.02	4565	60	1.20	1.20	0.20	1.23	1.06	1.23	0.91	60	1.23	0.0%
27.03	4565	60	1.93	1.93	0.36	2.00	1.33	2.00	1.49	60	2.00	0.0%
27.04	4568	60	2.22	2.24	0.38	2.20	1.43	2.30	1.77	60	2.30	4.5%
28.01	4408	15	0.42	0.43	0.05	0.44	0.46	0.42	0.25	15	0.46	4.5%
29.01	4565	60	0.54	0.54	0.12	0.55	0.37	0.55	0.40	60	0.55	0.0%
30.01	4542	45	0.33	0.31	0.05	0.36	0.34	0.33	0.24	15	0.34	-5.6%
31.01	4565	60	0.39	0.38	0.08	0.39	0.16	0.39	0.32	60	0.39	0.0%
31.02	4565	60	0.45	0.45	0.08	0.45	0.18	0.45	0.37	60	0.45	0.0%
32.01	4381	15	0.77	0.79	0.10	0.79	0.80	0.67	0.54	15	0.80	1.3%
32.02	4567	60	1.27	1.22	0.23	1.34	1.30	1.23	1.02	15	1.30	-3.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4411 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4730 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
33.01	4567	60	0.54	0.51	0.10	0.57	0.48	0.51	0.44	60	0.51	-10.5%
34.01	4416	15	0.56	0.56	0.06	0.56	0.54	0.36	0.29	15	0.54	-3.6%
34.02	4373	10	0.68	0.66	0.05	0.68	0.61	0.43	0.36	15	0.61	-10.3%
35.01	4411	15	0.75	0.76	0.10	0.75	0.75	0.57	0.32	15	0.75	0.0%
35.02	4415	15	0.84	0.83	0.11	0.83	0.82	0.62	0.36	15	0.82	-1.2%
36.01	4413	15	1.64	1.68	0.19	1.67	1.70	1.45	0.94	15	1.70	1.8%
36.02	4413	15	2.02	2.01	0.19	2.03	2.07	1.84	1.42	15	2.07	2.0%
36.03	4413	15	2.04	2.04	0.19	2.05	2.09	1.91	1.48	15	2.09	2.0%
36.04	4568	60	2.92	2.92	0.32	2.94	3.00	2.91	2.79	15	3.00	2.0%
36.05	4565	60	5.94	6.10	0.59	6.01	4.96	6.01	6.36	360	6.36	5.8%
37.01	4413	15	0.75	0.76	0.09	0.76	0.79	0.63	0.54	15	0.79	3.9%
37.02	4375	10	1.40	1.40	0.00	1.40	1.39	1.14	1.17	15	1.39	-0.7%
38.01	4593	90	0.55	0.55	0.11	0.57	0.26	0.51	0.56	360	0.56	-1.8%
38.02	4595	90	1.04	1.05	0.20	1.01	0.80	0.95	1.07	360	1.07	5.9%
38.03	4593	90	1.08	1.09	0.21	1.14	0.83	1.00	1.11	360	1.11	-2.6%
38.04	4593	90	2.00	2.00	0.37	2.08	1.72	1.90	2.03	360	2.03	-2.4%
38.05	4594	90	2.39	2.40	0.44	2.55	1.89	2.36	2.54	360	2.54	-0.4%
39.01	4478	45	0.27	0.26	0.04	0.28	0.28	0.27	0.21	15	0.28	0.0%
39.02	4381	15	1.04	1.05	0.12	1.05	1.04	0.96	0.82	15	1.04	-1.0%
40.01	4381	15	0.55	0.56	0.07	0.55	0.56	0.48	0.43	15	0.56	1.8%
41.01	4413	15	0.42	0.43	0.05	0.42	0.43	0.39	0.32	15	0.43	2.4%
42.01	4411	15	0.41	0.41	0.05	0.41	0.41	0.35	0.22	15	0.41	0.0%
42.02	4376	10	0.91	0.90	0.02	0.91	0.92	0.71	0.57	15	0.92	1.1%
43.01	4413	15	0.73	0.74	0.10	0.73	0.74	0.59	0.43	15	0.74	1.4%
44.01	4416	15	0.35	0.35	0.04	0.35	0.34	0.25	0.17	15	0.34	-2.9%
44.02	4381	15	0.93	0.92	0.07	0.96	0.88	0.88	0.74	15	0.88	-8.3%
45.01	4413	15	0.49	0.50	0.06	0.49	0.50	0.44	0.36	15	0.50	2.0%
46.01	4565	60	0.45	0.44	0.09	0.44	0.41	0.44	0.36	60	0.44	0.0%
47.01	4593	90	0.84	0.83	0.17	0.87	0.35	0.80	0.84	360	0.84	-3.4%
47.02	4593	90	1.35	1.37	0.27	1.44	0.77	1.28	1.41	360	1.41	-2.1%
47.03	4593	90	1.36	1.39	0.27	1.46	0.79	1.29	1.43	360	1.43	-2.1%
47.04	4594	90	1.85	1.88	0.33	1.97	1.20	1.77	1.96	360	1.96	-0.5%
47.05	4594	90	3.28	3.35	0.61	3.56	2.38	3.19	3.51	360	3.51	-1.4%
47.06	4595	90	3.76	3.84	0.70	3.62	2.84	3.70	4.03	360	4.03	11.3%
47.07	4565	60	5.05	5.07	0.54	5.04	3.71	5.04	5.31	360	5.31	5.4%
47.08	4565	60	5.13	5.16	0.54	5.14	3.75	5.14	5.41	360	5.41	5.3%
47.09	4565	60	5.36	5.41	0.55	5.40	3.85	5.40	5.69	360	5.69	5.4%
47.10	4565	60	6.04	6.19	0.58	6.09	4.11	6.09	6.48	360	6.48	6.4%
47.11	4565	60	6.30	6.46	0.61	6.35	4.19	6.35	6.76	360	6.76	6.5%
48.01	4413	15	0.36	0.37	0.04	0.36	0.37	0.35	0.24	15	0.37	2.8%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4411 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4730 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
49.01	4413	15	0.39	0.40	0.05	0.40	0.40	0.35	0.22	15	0.40	0.0%
49.02	4411	15	0.63	0.64	0.07	0.63	0.63	0.58	0.37	15	0.63	0.0%
49.03	4377	10	0.92	0.92	0.02	0.93	0.85	0.91	0.65	60	0.91	-2.2%
49.04	4565	60	1.00	1.00	0.19	1.02	0.88	1.02	0.78	60	1.02	0.0%
50.01	4413	15	0.37	0.38	0.04	0.38	0.38	0.35	0.33	15	0.38	0.0%
51.01	4411	15	0.43	0.43	0.05	0.43	0.43	0.38	0.26	15	0.43	0.0%
52.01	4565	60	0.27	0.27	0.05	0.27	0.25	0.27	0.20	60	0.27	0.0%
53.01	4411	15	0.27	0.28	0.03	0.28	0.28	0.22	0.14	15	0.28	0.0%
53.02	4565	60	0.46	0.45	0.08	0.46	0.34	0.46	0.36	60	0.46	0.0%
53.03	4565	60	1.05	1.03	0.19	1.05	0.86	1.05	0.84	60	1.05	0.0%
54.01	4411	15	0.15	0.15	0.02	0.15	0.15	0.12	0.07	15	0.15	0.0%
54.02	4565	60	0.51	0.50	0.10	0.50	0.47	0.50	0.38	60	0.50	0.0%
55.01	4413	15	0.36	0.37	0.04	0.36	0.37	0.35	0.27	15	0.37	2.8%
55.02	4542	45	0.39	0.37	0.06	0.42	0.39	0.40	0.30	60	0.40	-4.8%
56.01	4411	15	0.42	0.43	0.05	0.42	0.42	0.34	0.30	15	0.42	0.0%
56.02	4411	15	1.01	1.03	0.10	1.03	1.03	0.97	0.76	15	1.03	0.0%
57.01	4475	60	0.33	0.33	0.07	0.33	0.29	0.33	0.24	60	0.33	0.0%
57.02	4478	45	0.59	0.58	0.08	0.61	0.60	0.60	0.44	15	0.60	-1.6%
58.01	4475	60	0.70	0.68	0.13	0.68	0.69	0.67	0.54	15	0.69	1.5%
58.02	4565	60	0.86	0.84	0.16	0.84	0.74	0.84	0.70	60	0.84	0.0%
59.01	4678	360	0.17	0.17	0.03	0.16	0.09	0.14	0.18	360	0.18	12.5%
60.01	4416	15	0.44	0.45	0.06	0.45	0.44	0.34	0.38	15	0.44	-2.2%
60.02	4381	15	0.58	0.59	0.07	0.58	0.58	0.51	0.50	15	0.58	0.0%
60.03	4381	15	0.97	1.00	0.10	0.96	1.00	0.91	0.79	15	1.00	4.2%
60.04	4565	60	1.95	1.89	0.35	1.96	1.60	1.96	1.68	60	1.96	0.0%
60.05	4565	60	2.16	2.10	0.36	2.17	1.66	2.17	1.93	60	2.17	0.0%
61.01	4413	15	0.39	0.39	0.05	0.39	0.41	0.37	0.27	15	0.41	5.1%
62.01	4381	15	0.60	0.61	0.07	0.59	0.63	0.56	0.47	15	0.63	6.8%
63.01	4626	120	0.53	0.51	0.12	0.54	0.56	0.50	0.50	15	0.56	3.7%
63.02	4565	60	0.95	0.91	0.15	0.94	0.79	0.94	0.87	60	0.94	0.0%
63.03	4565	60	1.26	1.25	0.17	1.27	1.11	1.27	1.20	60	1.27	0.0%
64.01	4381	15	1.00	1.02	0.12	1.00	1.04	0.93	0.59	15	1.04	4.0%
64.02	4565	60	1.60	1.60	0.31	1.66	1.38	1.66	1.19	60	1.66	0.0%
64.03	4565	60	1.99	1.98	0.39	2.08	1.58	2.08	1.49	60	2.08	0.0%
65.01	4565	60	0.18	0.17	0.03	0.17	0.13	0.17	0.15	60	0.17	0.0%
65.02	4565	60	0.51	0.50	0.10	0.52	0.36	0.52	0.40	60	0.52	0.0%
66.01	4565	60	0.40	0.40	0.09	0.40	0.36	0.40	0.29	60	0.40	0.0%
67.01	4672	360	0.57	0.59	0.10	0.56	0.34	0.35	0.63	360	0.63	12.5%
67.02	4672	360	1.23	1.29	0.21	1.25	0.67	0.74	1.37	360	1.37	9.6%
67.03	4672	360	1.47	1.54	0.27	1.46	0.79	1.01	1.65	360	1.65	13.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4411 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4730 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
67.04	4660	360	1.77	1.87	0.33	1.86	0.91	1.35	1.98	360	1.98	6.5%
67.05	4678	360	2.08	2.19	0.40	2.18	1.04	1.68	2.31	360	2.31	6.0%
68.01	4568	60	0.26	0.25	0.05	0.26	0.15	0.26	0.23	60	0.26	0.0%
69.01	4568	60	0.28	0.28	0.04	0.29	0.11	0.27	0.26	60	0.27	-6.9%
70.01	4408	15	0.48	0.48	0.05	0.48	0.50	0.44	0.34	15	0.50	4.2%
70.02	4565	60	1.10	1.10	0.22	1.16	0.80	1.16	0.82	60	1.16	0.0%
70.03	4565	60	2.11	2.11	0.41	2.20	1.21	2.20	1.64	60	2.20	0.0%
71.01	4565	60	0.64	0.64	0.14	0.67	0.27	0.67	0.44	60	0.67	0.0%
72.01	4381	15	0.62	0.63	0.07	0.63	0.61	0.48	0.44	15	0.61	-3.2%
BasinA	4542	45	1.57	1.49	0.24	1.64	1.32	1.63	1.00	60	1.63	-0.6%
BasinBC	4565	60	2.08	2.12	0.13	2.12	1.46	2.12	2.27	360	2.27	7.1%
BasinE	4672	360	1.37	1.42	0.21	1.36	0.77	1.16	1.50	360	1.50	10.3%
BasinF	4731	360	2.97	3.06	0.41	2.98	1.24	2.47	3.22	360	3.22	8.1%
BasinG	4660	360	0.71	0.72	0.12	0.71	0.21	0.51	0.82	360	0.82	15.5%

Average Difference (All Subcatchments)		**2.11%**
Average Difference (Focus Locations)		**4.84%**
Average Difference (Whites Creek)		**4.79%**
Average Difference (Willow Tributary)		**2.79%**

ARR2016 Results for the 5% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4413 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4672 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
1.01	4565	60	0.16	0.16	0.02	0.16	0.06	0.16	0.12	60	0.16	0.0%
1.02	4565	60	0.30	0.31	0.04	0.31	0.11	0.31	0.24	60	0.31	0.0%
1.03	4595	90	1.09	1.12	0.19	1.05	0.39	1.05	1.02	60	1.05	0.0%
1.04	4565	60	2.97	3.00	0.34	2.92	1.25	2.92	2.67	60	2.92	0.0%
1.05	4731	360	6.30	6.39	1.22	6.36	2.83	6.04	6.41	360	6.41	0.8%
1.06	4678	360	7.22	7.21	1.33	7.38	3.15	6.66	7.38	360	7.38	0.0%
1.07	4678	360	7.31	7.29	1.33	7.47	3.21	6.72	7.47	360	7.47	0.0%
1.08	4731	360	13.22	13.31	2.42	13.16	7.34	12.73	13.46	360	13.46	2.3%
1.09	4678	360	14.38	14.39	2.62	14.63	7.78	13.77	14.63	360	14.63	0.0%
1.10	4678	360	14.70	14.67	2.66	14.96	7.94	14.07	14.96	360	14.96	0.0%
1.11	4678	360	15.40	15.36	2.74	15.68	8.35	14.78	15.68	360	15.68	0.0%
1.12	4678	360	15.58	15.55	2.75	15.87	8.44	14.93	15.87	360	15.87	0.0%
1.13	4678	360	16.03	16.05	2.81	16.35	8.62	15.29	16.35	360	16.35	0.0%
1.14	4678	360	16.37	16.45	2.83	16.72	8.80	15.55	16.72	360	16.72	0.0%
1.15	4672	360	16.64	16.77	2.85	16.54	8.88	15.69	17.00	360	17.00	2.8%
1.16	4672	360	17.28	17.48	2.91	17.31	9.06	16.06	17.65	360	17.65	2.0%
1.17	4672	360	17.56	17.79	2.93	17.64	9.11	16.14	17.96	360	17.96	1.8%
1.18	4678	360	19.07	19.33	2.95	19.32	9.47	16.75	19.32	360	19.32	0.0%
1.19	4678	360	19.47	19.77	2.97	19.74	9.56	16.87	19.74	360	19.74	0.0%
1.20	4672	360	20.12	20.58	3.03	20.54	9.66	17.01	20.61	360	20.61	0.3%
1.21	4672	360	20.59	21.11	3.11	21.07	9.72	17.11	21.16	360	21.16	0.4%
1.22	4672	360	20.59	21.12	3.11	21.07	9.72	17.11	21.16	360	21.16	0.4%
1.23	4731	360	26.35	27.21	3.86	26.18	11.05	22.43	27.66	360	27.66	5.7%
1.24	4672	360	27.27	28.22	3.99	27.72	11.37	23.26	28.72	360	28.72	3.6%
1.25	4672	360	27.83	28.86	4.05	28.33	11.56	23.66	29.39	360	29.39	3.7%
1.26	4672	360	33.48	34.62	4.85	33.71	15.61	28.60	35.54	360	35.54	5.4%
1.27	4672	360	34.01	35.14	4.90	34.28	15.95	28.80	36.19	360	36.19	5.6%
1.28	4672	360	34.21	35.35	4.93	34.51	16.05	28.89	36.45	360	36.45	5.6%
1.29	4672	360	35.44	36.53	5.06	35.84	16.63	29.42	37.91	360	37.91	5.8%
1.30	4672	360	36.91	37.84	5.18	37.32	17.19	29.85	39.51	360	39.51	5.9%
1.31	4672	360	39.05	39.81	5.41	39.33	17.87	30.91	41.59	360	41.59	5.7%
1.32	4672	360	40.06	40.79	5.47	40.44	18.13	31.15	42.66	360	42.66	5.5%
2.01	4595	90	0.49	0.51	0.08	0.50	0.21	0.44	0.46	360	0.46	-8.0%
3.01	4568	60	0.95	0.95	0.12	0.98	0.36	0.92	0.80	60	0.92	-6.1%
4.01	4567	60	0.41	0.40	0.06	0.42	0.34	0.39	0.30	60	0.39	-7.1%
5.01	4568	60	0.65	0.66	0.11	0.64	0.29	0.67	0.47	60	0.67	4.7%
6.01	4595	90	0.76	0.78	0.12	0.76	0.31	0.72	0.70	60	0.72	-5.3%
6.02	4595	90	0.88	0.90	0.13	0.87	0.49	0.81	0.84	360	0.84	-3.4%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4413 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4672 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
6.03	4565	60	2.42	2.38	0.35	2.51	2.54	2.51	1.90	15	2.54	1.2%
7.01	4408	15	1.46	1.49	0.16	1.48	1.49	1.25	0.66	15	1.49	0.7%
8.01	4542	45	1.29	1.22	0.20	1.37	1.26	1.28	0.79	60	1.28	-6.6%
8.02	4565	60	3.96	4.01	0.46	3.99	3.55	3.99	2.88	60	3.99	0.0%
9.01	4539	45	0.88	0.86	0.14	0.89	0.45	0.93	0.56	60	0.93	4.5%
10.01	4542	45	0.58	0.54	0.10	0.59	0.49	0.60	0.30	60	0.60	1.7%
11.01	4408	15	0.84	0.85	0.10	0.87	0.83	0.64	0.32	15	0.83	-4.6%
12.01	4630	120	0.67	0.67	0.09	0.70	0.61	0.54	0.64	360	0.64	-8.6%
13.01	4408	15	3.05	3.09	0.33	3.05	3.12	2.64	1.40	15	3.12	2.3%
13.02	4568	60	4.78	4.86	0.58	4.81	3.53	4.93	4.01	60	4.93	2.5%
13.03	4568	60	6.51	6.59	0.69	6.48	4.60	6.69	6.06	60	6.69	3.2%
14.01	4408	15	2.15	2.12	0.24	2.17	2.07	1.83	0.90	15	2.07	-4.6%
15.01	4381	15	4.76	4.83	0.52	4.78	4.88	3.45	1.89	15	4.88	2.1%
16.01	4444	20	0.71	0.69	0.13	0.75	0.66	0.64	0.32	15	0.66	-12.0%
17.01	4413	15	1.24	1.25	0.13	1.27	1.27	1.18	0.68	15	1.27	0.0%
17.02	4411	15	3.95	4.04	0.41	4.00	4.07	3.10	2.10	15	4.07	1.8%
17.03	4731	360	1.78	1.84	0.27	1.82	0.98	1.63	1.87	360	1.87	2.7%
18.01	4408	15	1.72	1.73	0.18	1.69	1.77	1.64	1.03	15	1.77	4.7%
19.01	4593	90	0.38	0.38	0.08	0.40	0.15	0.36	0.33	60	0.36	-10.0%
20.01	4413	15	0.98	1.00	0.11	0.98	0.98	0.92	0.59	15	0.98	0.0%
20.02	4565	60	1.36	1.36	0.21	1.39	1.17	1.39	0.95	60	1.39	0.0%
21.01	4565	60	0.28	0.28	0.04	0.28	0.13	0.28	0.21	60	0.28	0.0%
22.01	4413	15	0.51	0.51	0.06	0.51	0.51	0.46	0.39	15	0.51	0.0%
22.02	4408	15	0.56	0.56	0.06	0.56	0.57	0.56	0.45	15	0.57	1.8%
23.01	4568	60	0.82	0.83	0.13	0.81	0.36	0.85	0.58	60	0.85	4.9%
24.01	4539	45	0.79	0.76	0.13	0.79	0.42	0.84	0.49	60	0.84	6.3%
25.01	4435	20	0.59	0.58	0.12	0.62	0.47	0.49	0.25	60	0.49	-21.0%
25.02	4509	30	0.74	0.75	0.12	0.74	0.62	0.72	0.40	60	0.72	-2.7%
26.01	4478	45	0.77	0.75	0.12	0.79	0.67	0.77	0.47	60	0.77	-2.5%
27.01	4478	45	0.58	0.55	0.10	0.61	0.49	0.58	0.35	60	0.58	-4.9%
27.02	4542	45	1.54	1.50	0.18	1.51	1.33	1.57	0.95	60	1.57	4.0%
27.03	4542	45	2.46	2.38	0.31	2.47	1.93	2.57	1.57	60	2.57	4.0%
27.04	4568	60	2.80	2.90	0.46	2.85	2.10	2.94	1.88	60	2.94	3.2%
28.01	4444	20	0.53	0.51	0.10	0.55	0.50	0.52	0.27	60	0.52	-5.5%
29.01	4539	45	0.70	0.67	0.12	0.69	0.39	0.73	0.43	60	0.73	5.8%
30.01	4542	45	0.43	0.40	0.07	0.46	0.40	0.43	0.26	60	0.43	-6.5%
31.01	4568	60	0.51	0.52	0.10	0.50	0.25	0.55	0.34	60	0.55	10.0%
31.02	4568	60	0.59	0.60	0.10	0.58	0.28	0.62	0.39	60	0.62	6.9%
32.01	4381	15	0.93	0.95	0.11	0.93	0.92	0.92	0.56	15	0.92	-1.1%
32.02	4478	45	1.67	1.62	0.24	1.72	1.50	1.69	1.07	60	1.69	-1.7%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4413 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4672 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
33.01	4539	45	0.70	0.70	0.10	0.71	0.52	0.71	0.47	60	0.71	0.0%
34.01	4381	15	0.66	0.67	0.07	0.66	0.69	0.44	0.31	15	0.69	4.5%
34.02	4373	10	0.80	0.78	0.06	0.79	0.84	0.52	0.40	15	0.84	6.3%
35.01	4413	15	0.91	0.93	0.11	0.91	0.91	0.69	0.35	15	0.91	0.0%
35.02	4416	15	0.99	1.00	0.12	0.99	1.01	0.75	0.39	15	1.01	2.0%
36.01	4408	15	2.02	2.04	0.22	2.02	2.06	1.85	0.98	15	2.06	2.0%
36.02	4411	15	2.45	2.41	0.21	2.45	2.42	2.39	1.48	15	2.42	-1.2%
36.03	4411	15	2.48	2.44	0.21	2.48	2.45	2.47	1.56	60	2.47	-0.4%
36.04	4565	60	3.75	3.84	0.41	3.80	2.94	3.80	2.86	60	3.80	0.0%
36.05	4565	60	7.63	7.87	0.74	7.81	5.48	7.81	6.57	60	7.81	0.0%
37.01	4413	15	0.91	0.92	0.10	0.92	0.92	0.80	0.56	15	0.92	0.0%
37.02	4372	10	1.69	1.69	0.01	1.70	1.60	1.50	1.20	15	1.60	-5.9%
38.01	4568	60	0.71	0.72	0.10	0.74	0.32	0.69	0.58	60	0.69	-6.8%
38.02	4570	60	1.31	1.33	0.16	1.29	0.95	1.28	1.10	60	1.28	-0.8%
38.03	4565	60	1.36	1.38	0.17	1.33	1.04	1.33	1.14	60	1.33	0.0%
38.04	4568	60	2.56	2.55	0.31	2.60	2.16	2.51	2.11	60	2.51	-3.5%
38.05	4565	60	3.09	3.11	0.36	3.10	2.45	3.10	2.60	60	3.10	0.0%
39.01	4542	45	0.34	0.33	0.05	0.37	0.33	0.35	0.21	60	0.35	-5.4%
39.02	4413	15	1.25	1.27	0.13	1.27	1.27	1.22	0.85	15	1.27	0.0%
40.01	4413	15	0.68	0.68	0.08	0.68	0.68	0.62	0.45	15	0.68	0.0%
41.01	4536	45	0.52	0.50	0.08	0.51	0.51	0.51	0.34	15	0.51	0.0%
42.01	4413	15	0.50	0.51	0.06	0.50	0.50	0.43	0.24	15	0.50	0.0%
42.02	4378	10	1.08	1.09	0.01	1.08	1.09	0.90	0.59	15	1.09	0.9%
43.01	4381	15	0.88	0.90	0.11	0.88	0.87	0.75	0.44	15	0.87	-1.1%
44.01	4411	15	0.41	0.42	0.04	0.41	0.42	0.33	0.18	15	0.42	2.4%
44.02	4381	15	1.13	1.14	0.07	1.13	1.20	1.15	0.76	15	1.20	6.2%
45.01	4408	15	0.61	0.61	0.07	0.62	0.61	0.57	0.37	15	0.61	-1.6%
46.01	4541	45	0.60	0.58	0.10	0.59	0.43	0.60	0.38	60	0.60	1.7%
47.01	4565	60	1.09	1.10	0.17	1.07	0.49	1.07	0.87	60	1.07	0.0%
47.02	4565	60	1.73	1.77	0.21	1.75	0.91	1.75	1.45	60	1.75	0.0%
47.03	4565	60	1.75	1.80	0.21	1.77	0.95	1.77	1.47	60	1.77	0.0%
47.04	4475	60	2.32	2.40	0.23	2.29	1.66	2.39	1.99	60	2.39	4.4%
47.05	4565	60	4.20	4.27	0.48	4.23	3.37	4.23	3.58	60	4.23	0.0%
47.06	4565	60	4.80	4.86	0.50	4.83	3.72	4.83	4.15	60	4.83	0.0%
47.07	4565	60	6.48	6.60	0.70	6.57	4.74	6.57	5.49	60	6.57	0.0%
47.08	4565	60	6.59	6.72	0.72	6.70	4.80	6.70	5.59	60	6.70	0.0%
47.09	4565	60	6.88	7.02	0.72	7.01	4.98	7.01	5.89	60	7.01	0.0%
47.10	4565	60	7.75	7.95	0.74	7.84	5.42	7.84	6.70	60	7.84	0.0%
47.11	4565	60	8.09	8.28	0.77	8.22	5.57	8.22	7.03	60	8.22	0.0%
48.01	4408	15	0.45	0.45	0.05	0.45	0.44	0.46	0.25	60	0.46	2.2%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4413 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4672 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
49.01	4408	15	0.49	0.49	0.06	0.49	0.49	0.44	0.23	15	0.49	0.0%
49.02	4408	15	0.75	0.77	0.08	0.77	0.78	0.72	0.40	15	0.78	1.3%
49.03	4536	45	1.13	1.10	0.17	1.13	1.12	1.14	0.68	60	1.14	0.9%
49.04	4478	45	1.27	1.23	0.18	1.28	1.19	1.29	0.80	60	1.29	0.8%
50.01	4413	15	0.46	0.46	0.05	0.46	0.46	0.43	0.34	15	0.46	0.0%
51.01	4413	15	0.53	0.54	0.06	0.53	0.53	0.48	0.27	15	0.53	0.0%
52.01	4478	45	0.35	0.33	0.05	0.37	0.29	0.35	0.21	60	0.35	-5.4%
53.01	4408	15	0.33	0.34	0.04	0.34	0.34	0.29	0.15	15	0.34	0.0%
53.02	4478	45	0.60	0.58	0.08	0.60	0.54	0.62	0.38	60	0.62	3.3%
53.03	4565	60	1.36	1.36	0.26	1.41	1.12	1.41	0.88	60	1.41	0.0%
54.01	4413	15	0.18	0.18	0.02	0.18	0.18	0.15	0.07	15	0.18	0.0%
54.02	4478	45	0.65	0.63	0.10	0.64	0.56	0.66	0.41	60	0.66	3.1%
55.01	4536	45	0.46	0.44	0.07	0.45	0.44	0.46	0.28	60	0.46	2.2%
55.02	4536	45	0.51	0.48	0.08	0.50	0.48	0.51	0.30	60	0.51	2.0%
56.01	4408	15	0.50	0.51	0.05	0.51	0.52	0.43	0.31	15	0.52	2.0%
56.02	4408	15	1.23	1.24	0.12	1.21	1.27	1.24	0.79	15	1.27	5.0%
57.01	4478	45	0.43	0.40	0.07	0.44	0.31	0.44	0.25	60	0.44	0.0%
57.02	4478	45	0.76	0.72	0.11	0.82	0.72	0.77	0.46	60	0.77	-6.1%
58.01	4478	45	0.91	0.89	0.13	0.94	0.78	0.92	0.57	60	0.92	-2.1%
58.02	4478	45	1.12	1.10	0.15	1.10	0.88	1.14	0.74	60	1.14	3.6%
59.01	4626	120	0.20	0.20	0.03	0.20	0.11	0.18	0.19	360	0.19	-5.0%
60.01	4411	15	0.53	0.54	0.06	0.53	0.54	0.42	0.42	15	0.54	1.9%
60.02	4381	15	0.69	0.71	0.07	0.69	0.71	0.63	0.56	15	0.71	2.9%
60.03	4413	15	1.18	1.19	0.11	1.22	1.22	1.18	0.87	15	1.22	0.0%
60.04	4565	60	2.50	2.50	0.44	2.60	2.22	2.60	1.79	60	2.60	0.0%
60.05	4565	60	2.79	2.78	0.46	2.88	2.34	2.88	2.05	60	2.88	0.0%
61.01	4536	45	0.48	0.46	0.08	0.48	0.48	0.49	0.27	60	0.49	2.1%
62.01	4541	45	0.77	0.75	0.11	0.75	0.72	0.75	0.50	60	0.75	0.0%
63.01	4567	60	0.70	0.67	0.10	0.72	0.64	0.66	0.52	60	0.66	-8.3%
63.02	4565	60	1.23	1.19	0.20	1.24	1.11	1.24	0.91	60	1.24	0.0%
63.03	4568	60	1.60	1.62	0.21	1.60	1.41	1.64	1.24	60	1.64	2.5%
64.01	4444	20	1.23	1.19	0.23	1.26	1.23	1.20	0.61	15	1.23	-2.4%
64.02	4478	45	2.08	1.96	0.31	2.15	1.79	2.19	1.24	60	2.19	1.9%
64.03	4478	45	2.59	2.46	0.39	2.61	2.15	2.75	1.56	60	2.75	5.4%
65.01	4565	60	0.23	0.23	0.04	0.23	0.16	0.23	0.16	60	0.23	0.0%
65.02	4539	45	0.65	0.61	0.11	0.64	0.46	0.67	0.42	60	0.67	4.7%
66.01	4478	45	0.53	0.48	0.09	0.53	0.38	0.54	0.30	60	0.54	1.9%
67.01	4678	360	0.68	0.70	0.12	0.69	0.40	0.50	0.69	360	0.69	0.0%
67.02	4672	360	1.47	1.52	0.26	1.48	0.60	1.06	1.52	360	1.52	2.7%
67.03	4672	360	1.75	1.82	0.32	1.72	0.78	1.39	1.82	360	1.82	5.8%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4413 for the 15 minute duration	TP 4565 for the 1 hour duration	TP 4672 for the 6 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
67.04	4678	360	2.10	2.21	0.39	2.19	1.00	1.80	2.19	360	2.19	0.0%
67.05	4678	360	2.46	2.57	0.47	2.55	1.21	2.28	2.55	360	2.55	0.0%
68.01	4540	45	0.34	0.34	0.05	0.34	0.20	0.34	0.23	60	0.34	0.0%
69.01	4565	60	0.37	0.37	0.06	0.37	0.17	0.37	0.28	60	0.37	0.0%
70.01	4413	15	0.59	0.59	0.07	0.60	0.60	0.57	0.35	15	0.60	0.0%
70.02	4542	45	1.42	1.33	0.23	1.44	1.05	1.48	0.86	60	1.48	2.8%
70.03	4542	45	2.74	2.62	0.40	2.85	1.69	2.88	1.72	60	2.88	1.1%
71.01	4542	45	0.83	0.77	0.14	0.86	0.50	0.85	0.47	60	0.85	-1.2%
72.01	4413	15	0.74	0.76	0.08	0.76	0.76	0.59	0.47	15	0.76	0.0%
BasinA	4510	30	2.02	1.98	0.30	2.02	1.70	2.06	1.07	60	2.06	2.0%
BasinBC	4565	60	2.59	2.60	0.22	2.60	1.76	2.60	2.48	60	2.60	0.0%
BasinE	4672	360	1.61	1.67	0.24	1.60	0.92	1.46	1.69	360	1.69	5.6%
BasinF	4731	360	3.54	3.58	0.58	3.50	1.65	3.11	3.69	360	3.69	5.4%
BasinG	4660	360	0.85	0.88	0.15	0.87	0.28	0.73	0.88	360	0.88	1.1%

Average Difference (All Subcatchments)		**0.40%**
Average Difference (Focus Locations)		**1.33%**
Average Difference (Whites Creek)		**1.98%**
Average Difference (Willow Tributary)		**0.40%**

ARR2016 Results for the 2% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
1.01	4531	45	0.21	0.22	0.02	0.22	0.15	0.22	0.17	0.18	45	0.22	0.0%
1.02	4531	45	0.40	0.40	0.03	0.40	0.29	0.41	0.33	0.34	45	0.41	2.5%
1.03	4558	60	1.47	1.47	0.12	1.48	0.83	1.40	1.48	1.39	120	1.48	0.0%
1.04	4558	60	4.05	4.00	0.47	4.02	2.52	4.08	3.85	3.65	45	4.08	1.5%
1.05	4443	720	8.49	7.68	2.94	8.03	5.10	7.77	8.91	8.03	120	8.91	11.0%
1.06	4443	720	9.74	8.74	3.27	9.11	5.62	8.55	9.77	9.11	120	9.77	7.2%
1.07	4443	720	9.85	8.82	3.30	9.18	5.68	8.62	9.84	9.18	120	9.84	7.2%
1.08	4443	720	17.06	15.35	5.44	15.75	11.72	16.40	18.03	15.75	120	18.03	14.5%
1.09	4443	720	18.52	16.73	5.82	17.20	12.52	17.68	19.39	17.20	120	19.39	12.7%
1.10	4443	720	18.91	17.10	5.90	17.59	12.78	18.03	19.71	17.59	120	19.71	12.1%
1.11	4443	720	19.83	17.93	6.11	18.45	13.30	18.68	20.30	18.45	120	20.30	10.0%
1.12	4443	720	20.08	18.15	6.17	18.67	13.38	18.82	20.42	18.67	120	20.42	9.4%
1.13	4443	720	20.68	18.69	6.32	19.21	13.65	19.23	20.93	19.21	120	20.93	9.0%
1.14	4443	720	21.13	19.10	6.42	19.58	13.84	19.46	21.52	19.58	120	21.52	9.9%
1.15	4443	720	21.47	19.41	6.48	19.86	13.90	19.57	21.89	19.86	120	21.89	10.2%
1.16	4443	720	22.29	20.11	6.64	20.47	14.16	19.91	22.64	20.47	120	22.64	10.6%
1.17	4443	720	22.62	20.38	6.68	20.69	14.22	19.98	22.91	20.69	120	22.91	10.7%
1.18	4758	720	24.44	22.10	7.08	28.55	14.61	20.47	24.90	22.10	120	24.90	-12.8%
1.19	4758	720	24.91	22.56	7.17	29.01	14.70	20.59	25.28	22.49	120	25.28	-12.9%
1.20	4758	720	25.67	23.33	7.21	29.60	14.82	20.70	25.74	23.18	120	25.74	-13.0%
1.21	4758	720	26.28	23.92	7.25	30.08	14.90	20.81	25.99	23.75	120	25.99	-13.6%
1.22	4758	720	26.29	23.93	7.25	30.09	14.90	20.81	25.99	23.76	120	25.99	-13.6%
1.23	4443	720	33.47	31.25	9.05	31.34	18.94	27.24	33.44	31.34	120	33.44	6.7%
1.24	4443	720	34.80	32.44	9.39	32.49	19.51	28.08	34.50	32.49	120	34.50	6.2%
1.25	4654	720	35.59	33.12	9.56	33.12	19.80	28.46	35.04	33.12	120	35.04	5.8%
1.26	4443	720	43.84	41.13	11.97	41.61	23.74	34.18	42.12	41.61	120	42.12	1.2%
1.27	4443	720	44.60	41.84	12.09	42.28	24.08	34.47	42.60	42.28	120	42.60	0.8%
1.28	4443	720	44.91	42.12	12.15	42.55	24.20	34.61	42.79	42.55	120	42.79	0.6%
1.29	4443	720	46.87	43.86	12.62	44.27	24.85	35.35	43.88	44.27	720	44.27	0.0%
1.30	4443	720	48.93	45.53	12.95	45.79	25.45	35.91	44.69	45.79	720	45.79	0.0%
1.31	4443	720	51.96	48.22	13.76	48.51	26.49	37.40	47.26	48.51	720	48.51	0.0%
1.32	4443	720	53.73	49.74	14.17	49.98	26.78	37.67	48.45	49.98	720	49.98	0.0%
2.01	4584	90	0.64	0.64	0.08	0.64	0.40	0.60	0.69	0.61	120	0.69	7.8%
3.01	4558	60	1.27	1.25	0.15	1.27	0.81	1.29	1.16	1.11	45	1.29	1.6%
4.01	4531	45	0.54	0.54	0.07	0.55	0.54	0.51	0.51	0.42	20	0.54	-1.8%
5.01	4531	45	0.89	0.89	0.11	0.89	0.64	0.90	0.69	0.66	45	0.90	1.1%
6.01	4558	60	1.01	1.02	0.09	1.02	0.68	0.98	1.05	0.95	120	1.05	2.9%
6.02	4588	90	1.15	1.16	0.15	1.16	0.85	1.10	1.23	1.10	120	1.23	6.0%
6.03	4528	45	3.04	3.02	0.40	3.12	2.91	3.12	2.82	2.56	45	3.12	0.0%
7.01	4371	20	1.83	1.79	0.33	1.87	1.87	1.47	1.33	0.89	20	1.87	0.0%
8.01	4359	20	1.75	1.68	0.27	1.80	1.83	1.60	1.43	1.11	20	1.83	1.7%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
8.02	4531	45	5.16	5.32	0.38	5.32	5.08	5.33	4.23	4.01	45	5.33	0.2%
9.01	4528	45	1.16	1.14	0.14	1.17	0.94	1.17	0.82	0.79	45	1.17	0.0%
10.01	4371	20	0.85	0.84	0.12	0.85	0.85	0.74	0.53	0.41	20	0.85	0.0%
11.01	4367	20	1.06	1.01	0.22	1.08	1.02	0.72	0.62	0.40	20	1.02	-5.6%
12.01	4532	90	0.82	0.82	0.09	0.82	0.78	0.66	0.92	0.79	120	0.92	12.2%
13.01	4359	20	3.84	3.81	0.69	3.95	3.95	3.11	2.71	1.86	20	3.95	0.0%
13.02	4528	45	6.57	6.63	0.65	6.81	5.33	6.81	5.82	5.41	45	6.81	0.0%
13.03	4531	45	8.73	8.81	0.72	8.62	6.98	9.00	8.33	7.75	45	9.00	4.4%
14.01	4371	20	2.87	2.73	0.51	2.83	2.83	2.07	1.71	1.11	20	2.83	0.0%
15.01	4368	10	5.90	6.00	0.50	5.94	5.77	3.97	3.79	2.46	20	5.77	-2.9%
16.01	4371	20	1.00	0.95	0.17	0.96	0.96	0.74	0.57	0.39	20	0.96	0.0%
17.01	4367	20	1.66	1.62	0.27	1.64	1.70	1.42	1.31	0.97	20	1.70	3.7%
17.02	4361	10	4.87	4.93	0.38	4.88	4.68	3.63	3.73	2.83	20	4.68	-4.1%
17.03	4443	720	2.22	2.09	0.61	2.10	1.45	2.00	2.32	2.10	120	2.32	10.5%
18.01	4371	20	2.31	2.24	0.38	2.37	2.37	2.00	1.94	1.48	20	2.37	0.0%
19.01	4558	60	0.52	0.52	0.05	0.53	0.28	0.51	0.51	0.47	45	0.51	-3.8%
20.01	4367	20	1.31	1.27	0.21	1.29	1.36	1.13	1.11	0.84	20	1.36	5.4%
20.02	4528	45	1.73	1.72	0.20	1.79	1.75	1.79	1.61	1.35	45	1.79	0.0%
21.01	4531	45	0.38	0.39	0.04	0.38	0.26	0.38	0.30	0.30	45	0.38	0.0%
22.01	4367	20	0.66	0.64	0.11	0.66	0.68	0.57	0.64	0.56	20	0.68	3.0%
22.02	4371	20	0.75	0.72	0.12	0.76	0.76	0.69	0.71	0.64	20	0.76	0.0%
23.01	4531	45	1.10	1.11	0.12	1.11	0.80	1.12	0.82	0.82	45	1.12	0.9%
24.01	4503	30	1.05	1.06	0.08	1.06	0.91	1.05	0.75	0.70	45	1.05	-0.9%
25.01	4429	20	0.79	0.76	0.15	0.77	0.74	0.57	0.44	0.30	20	0.74	-3.9%
25.02	4461	25	1.01	1.02	0.12	1.01	0.92	0.87	0.61	0.50	20	0.92	-8.9%
26.01	4371	20	1.04	1.01	0.15	1.08	1.08	0.98	0.87	0.68	20	1.08	0.0%
27.01	4371	20	0.78	0.75	0.11	0.79	0.79	0.76	0.63	0.50	20	0.79	0.0%
27.02	4367	20	1.95	1.89	0.24	1.97	1.91	2.03	1.52	1.31	45	2.03	3.0%
27.03	4528	45	3.13	3.10	0.36	3.18	2.64	3.18	2.26	2.16	45	3.18	0.0%
27.04	4528	45	3.56	3.50	0.32	3.62	2.91	3.62	2.63	2.55	45	3.62	0.0%
28.01	4371	20	0.75	0.72	0.11	0.74	0.74	0.62	0.47	0.35	20	0.74	0.0%
29.01	4464	25	0.92	0.90	0.07	0.92	0.87	0.90	0.71	0.61	45	0.90	-2.2%
30.01	4371	20	0.58	0.55	0.08	0.60	0.60	0.53	0.46	0.36	20	0.60	0.0%
31.01	4528	45	0.68	0.68	0.08	0.70	0.55	0.70	0.51	0.48	45	0.70	0.0%
31.02	4528	45	0.78	0.78	0.08	0.81	0.62	0.81	0.59	0.55	45	0.81	0.0%
32.01	4359	20	1.27	1.21	0.20	1.31	1.31	1.13	1.05	0.80	20	1.31	0.0%
32.02	4371	20	2.23	2.15	0.31	2.31	2.31	2.12	1.92	1.54	20	2.31	0.0%
33.01	4503	30	0.92	0.92	0.06	0.92	0.94	0.90	0.81	0.67	20	0.94	2.2%
34.01	4368	10	0.82	0.83	0.07	0.82	0.80	0.50	0.54	0.39	20	0.80	-2.4%
34.02	4363	10	1.00	1.00	0.06	1.03	0.96	0.60	0.62	0.49	20	0.96	-6.8%
35.01	4368	10	1.14	1.16	0.10	1.15	1.11	0.79	0.69	0.45	20	1.11	-3.5%
35.02	4363	10	1.25	1.26	0.11	1.31	1.25	0.87	0.76	0.50	20	1.25	-4.6%
36.01	4367	20	2.67	2.59	0.45	2.64	2.73	2.21	1.87	1.32	20	2.73	3.4%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
36.02	4359	20	3.15	3.03	0.43	3.13	3.09	3.04	2.48	2.04	20	3.09	-1.3%
36.03	4359	20	3.21	3.09	0.43	3.18	3.14	3.11	2.60	2.11	20	3.14	-1.3%
36.04	4525	45	4.79	4.82	0.25	4.80	4.87	4.78	4.55	3.90	20	4.87	1.5%
36.05	4559	60	9.95	9.68	0.83	10.17	8.55	9.78	9.71	8.74	45	9.78	-3.8%
37.01	4359	20	1.16	1.15	0.20	1.19	1.20	1.01	1.04	0.81	20	1.20	0.8%
37.02	4356	10	2.14	2.13	0.01	2.14	1.86	1.95	1.88	1.73	45	1.95	-8.9%
38.01	4528	45	0.97	0.99	0.09	0.99	0.70	0.99	0.84	0.82	45	0.99	0.0%
38.02	4558	60	1.75	1.74	0.21	1.76	1.37	1.76	1.61	1.54	45	1.76	0.0%
38.03	4558	60	1.82	1.82	0.21	1.83	1.44	1.81	1.65	1.61	45	1.81	-1.1%
38.04	4558	60	3.37	3.42	0.39	3.34	3.08	3.34	3.20	2.97	45	3.34	0.0%
38.05	4558	60	4.05	4.09	0.39	3.99	3.51	3.99	3.88	3.60	45	3.99	0.0%
39.01	4359	20	0.46	0.44	0.07	0.47	0.48	0.42	0.39	0.30	20	0.48	2.1%
39.02	4371	20	1.63	1.59	0.24	1.66	1.66	1.53	1.48	1.23	20	1.66	0.0%
40.01	4367	20	0.87	0.85	0.14	0.87	0.89	0.77	0.81	0.65	20	0.89	2.3%
41.01	4359	20	0.70	0.67	0.11	0.72	0.72	0.64	0.62	0.48	20	0.72	0.0%
42.01	4367	20	0.63	0.62	0.11	0.64	0.64	0.51	0.44	0.32	20	0.64	0.0%
42.02	4357	10	1.35	1.35	0.03	1.35	1.21	1.08	0.93	0.81	20	1.21	-10.4%
43.01	4368	10	1.10	1.11	0.09	1.11	1.13	0.94	0.87	0.63	20	1.13	1.8%
44.01	4363	10	0.50	0.51	0.04	0.50	0.50	0.38	0.36	0.24	20	0.50	0.0%
44.02	4371	20	1.44	1.41	0.20	1.45	1.45	1.40	1.30	1.07	20	1.45	0.0%
45.01	4371	20	0.79	0.77	0.13	0.82	0.82	0.71	0.69	0.53	20	0.82	0.0%
46.01	4502	30	0.79	0.78	0.06	0.79	0.80	0.77	0.66	0.53	20	0.80	1.3%
47.01	4528	45	1.48	1.50	0.13	1.50	1.03	1.50	1.24	1.22	45	1.50	0.0%
47.02	4405	60	2.32	2.31	0.25	2.32	1.55	2.31	2.09	2.01	45	2.31	-0.4%
47.03	4405	60	2.35	2.34	0.25	2.36	1.58	2.34	2.12	2.05	45	2.34	-0.8%
47.04	4558	60	3.13	3.11	0.29	3.12	2.25	3.03	2.93	2.83	45	3.03	-2.9%
47.05	4405	60	5.55	5.57	0.56	5.66	4.32	5.51	5.09	5.00	45	5.51	-2.7%
47.06	4405	60	6.26	6.22	0.61	6.29	5.23	6.23	5.87	5.64	45	6.23	-1.0%
47.07	4558	60	8.37	8.27	0.86	8.39	6.98	8.43	7.66	7.50	45	8.43	0.5%
47.08	4558	60	8.52	8.43	0.87	8.54	7.12	8.56	7.79	7.66	45	8.56	0.2%
47.09	4558	60	8.89	8.85	0.87	8.93	7.44	8.85	8.21	8.00	45	8.85	-0.9%
47.10	4405	60	10.01	10.02	0.89	10.05	8.30	9.98	9.47	9.07	45	9.98	-0.7%
47.11	4405	60	10.44	10.42	0.89	10.48	8.60	10.37	9.99	9.49	45	10.37	-1.0%
48.01	4371	20	0.62	0.59	0.09	0.64	0.64	0.55	0.45	0.35	20	0.64	0.0%
49.01	4371	20	0.64	0.61	0.11	0.65	0.65	0.52	0.42	0.30	20	0.65	0.0%
49.02	4371	20	1.00	0.97	0.15	1.02	1.02	0.86	0.72	0.53	20	1.02	0.0%
49.03	4404	20	1.45	1.40	0.13	1.45	1.31	1.40	1.07	0.94	45	1.40	-3.4%
49.04	4500	30	1.59	1.57	0.17	1.60	1.44	1.61	1.25	1.12	45	1.61	0.6%
50.01	4371	20	0.61	0.59	0.10	0.63	0.63	0.54	0.59	0.48	20	0.63	0.0%
51.01	4371	20	0.69	0.66	0.12	0.70	0.70	0.58	0.50	0.37	20	0.70	0.0%
52.01	4433	20	0.46	0.45	0.06	0.46	0.48	0.44	0.37	0.30	20	0.48	4.3%
53.01	4367	20	0.42	0.42	0.07	0.43	0.43	0.34	0.31	0.20	20	0.43	0.0%
53.02	4528	45	0.76	0.75	0.11	0.78	0.69	0.78	0.61	0.54	45	0.78	0.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
53.03	4528	45	1.75	1.74	0.24	1.79	1.43	1.79	1.31	1.24	45	1.79	0.0%
54.01	4367	20	0.23	0.22	0.04	0.23	0.24	0.18	0.15	0.10	20	0.24	4.3%
54.02	4402	30	0.85	0.85	0.07	0.85	0.79	0.83	0.66	0.58	45	0.83	-2.4%
55.01	4371	20	0.62	0.59	0.09	0.64	0.64	0.57	0.50	0.39	20	0.64	0.0%
55.02	4371	20	0.67	0.64	0.09	0.69	0.69	0.64	0.53	0.43	20	0.69	0.0%
56.01	4359	20	0.62	0.61	0.12	0.64	0.64	0.51	0.55	0.44	20	0.64	0.0%
56.02	4359	20	1.67	1.60	0.26	1.71	1.72	1.50	1.38	1.12	20	1.72	0.6%
57.01	4464	25	0.57	0.56	0.06	0.58	0.58	0.55	0.43	0.35	20	0.58	0.0%
57.02	4359	20	1.00	0.95	0.14	1.03	1.04	0.96	0.80	0.66	20	1.04	1.0%
58.01	4433	20	1.21	1.17	0.17	1.19	1.24	1.14	1.01	0.81	20	1.24	4.2%
58.02	4503	30	1.45	1.42	0.11	1.42	1.45	1.42	1.23	1.05	20	1.45	2.1%
59.01	4588	90	0.26	0.26	0.03	0.26	0.21	0.23	0.28	0.25	120	0.28	7.7%
60.01	4363	10	0.64	0.65	0.05	0.65	0.63	0.49	0.62	0.51	20	0.63	-3.1%
60.02	4367	20	0.89	0.88	0.15	0.89	0.92	0.76	0.81	0.71	20	0.92	3.4%
60.03	4359	20	1.60	1.55	0.25	1.65	1.65	1.43	1.32	1.15	20	1.65	0.0%
60.04	4528	45	3.16	3.10	0.44	3.21	2.89	3.21	2.61	2.44	45	3.21	0.0%
60.05	4528	45	3.55	3.53	0.44	3.65	3.10	3.65	2.95	2.75	45	3.65	0.0%
61.01	4371	20	0.66	0.63	0.10	0.68	0.68	0.60	0.50	0.39	20	0.68	0.0%
62.01	4359	20	1.03	0.99	0.16	1.06	1.07	0.94	0.91	0.71	20	1.07	0.9%
63.01	4371	20	0.90	0.86	0.14	0.92	0.92	0.86	0.89	0.75	20	0.92	0.0%
63.02	4528	45	1.58	1.58	0.23	1.60	1.27	1.60	1.37	1.29	45	1.60	0.0%
63.03	4405	60	2.01	1.96	0.23	1.98	1.86	2.04	1.78	1.72	45	2.04	3.0%
64.01	4359	20	1.68	1.61	0.26	1.74	1.74	1.44	1.20	0.84	20	1.74	0.0%
64.02	4500	30	2.66	2.58	0.37	2.64	2.63	2.67	2.00	1.70	45	2.67	1.1%
64.03	4500	30	3.34	3.21	0.45	3.26	3.12	3.35	2.44	2.16	45	3.35	2.8%
65.01	4531	45	0.29	0.29	0.03	0.30	0.29	0.29	0.26	0.23	20	0.29	-3.3%
65.02	4394	25	0.85	0.85	0.06	0.85	0.72	0.82	0.60	0.59	45	0.82	-3.5%
66.01	4464	25	0.72	0.71	0.08	0.72	0.73	0.69	0.52	0.42	20	0.73	1.4%
67.01	4443	720	0.84	0.80	0.26	0.82	0.62	0.68	0.97	0.82	120	0.97	18.3%
67.02	4443	720	1.85	1.72	0.56	1.74	1.12	1.37	2.02	1.74	120	2.02	16.1%
67.03	4443	720	2.16	2.03	0.64	2.06	1.52	1.75	2.37	2.06	120	2.37	15.0%
67.04	4443	720	2.57	2.43	0.75	2.50	1.99	2.37	2.74	2.50	120	2.74	9.6%
67.05	4443	720	3.03	2.86	0.91	2.97	2.41	3.04	3.21	2.97	120	3.21	8.1%
68.01	4531	45	0.45	0.45	0.06	0.45	0.38	0.45	0.37	0.33	45	0.45	0.0%
69.01	4531	45	0.51	0.52	0.06	0.52	0.34	0.52	0.39	0.39	45	0.52	0.0%
70.01	4371	20	0.79	0.77	0.13	0.81	0.81	0.71	0.66	0.51	20	0.81	0.0%
70.02	4462	25	1.83	1.83	0.18	1.85	1.80	1.81	1.34	1.17	45	1.81	-2.2%
70.03	4464	25	3.50	3.54	0.28	3.50	3.28	3.61	2.59	2.36	45	3.61	3.1%
71.01	4394	25	1.10	1.11	0.08	1.11	0.99	1.08	0.69	0.65	45	1.08	-2.7%
72.01	4363	10	0.91	0.92	0.07	0.92	0.90	0.69	0.78	0.64	20	0.90	-2.2%
BasinA	4433	20	2.75	2.75	0.17	2.76	2.63	2.52	1.70	1.49	20	2.63	-4.7%
BasinBC	4531	45	3.93	3.98	0.27	3.94	2.47	4.03	3.87	3.31	45	4.03	2.3%
BasinE	4443	720	2.00	1.87	0.55	1.88	1.29	1.77	2.11	1.88	120	2.11	12.2%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
BasinF	4443	720	4.90	4.37	1.65	4.40	2.64	3.72	5.02	4.40	120	5.02	14.1%
BasinG	4443	720	1.03	1.02	0.25	1.07	0.55	0.93	1.11	1.07	120	1.11	3.7%

Average Difference (All Subcatchments)		**1.15%**
Average Difference (Focus Locations)		**2.26%**
Average Difference (Whites Creek)		**2.93%**
Average Difference (Willow Tributary)		**-0.88%**

ARR2016 Results for the 1% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
1.01	4531	45	0.26	0.26	0.02	0.26	0.19	0.27	0.26	0.20	45	0.27	3.8%
1.02	4528	45	0.48	0.48	0.03	0.50	0.36	0.50	0.48	0.38	45	0.50	0.0%
1.03	4558	60	1.80	1.79	0.16	1.80	1.11	1.79	1.96	1.59	120	1.96	8.9%
1.04	4531	45	4.94	5.04	0.37	5.01	3.31	5.08	5.21	4.14	120	5.21	4.0%
1.05	4558	60	10.46	10.35	0.93	10.37	6.43	10.33	11.85	9.62	120	11.85	14.3%
1.06	4558	60	11.46	11.33	0.94	11.36	7.08	11.25	13.05	10.84	120	13.05	14.9%
1.07	4558	60	11.54	11.41	0.95	11.45	7.15	11.32	13.16	10.93	120	13.16	14.9%
1.08	4405	60	20.73	20.69	1.54	20.75	14.54	20.29	23.36	18.63	120	23.36	12.6%
1.09	4405	60	22.27	22.21	1.60	22.28	15.58	21.76	25.06	20.17	120	25.06	12.5%
1.10	4405	60	22.62	22.55	1.61	22.63	15.87	22.13	25.43	20.55	120	25.43	12.4%
1.11	4405	60	23.32	23.17	1.53	23.26	16.43	22.85	26.14	21.35	120	26.14	12.4%
1.12	4405	60	23.48	23.29	1.50	23.39	16.53	23.02	26.30	21.56	120	26.30	12.4%
1.13	4405	60	23.96	23.69	1.44	23.79	16.89	23.48	26.75	22.09	120	26.75	12.4%
1.14	4443	720	24.25	22.02	7.52	22.43	17.11	23.74	27.01	22.43	120	27.01	20.4%
1.15	4443	720	24.64	22.36	7.59	22.73	17.19	23.85	27.13	22.73	120	27.13	19.4%
1.16	4443	720	25.56	23.15	7.77	23.42	17.50	24.23	27.52	23.42	120	27.52	17.5%
1.17	4443	720	25.92	23.46	7.81	23.67	17.56	24.30	27.58	23.67	120	27.58	16.5%
1.18	4758	720	27.91	25.19	8.27	32.93	17.99	24.82	28.16	25.19	120	28.16	-14.5%
1.19	4758	720	28.44	25.68	8.37	33.36	18.10	24.95	28.29	25.63	120	28.29	-15.2%
1.20	4758	720	29.25	26.48	8.41	33.91	18.20	25.07	28.43	26.24	120	28.43	-16.2%
1.21	4758	720	29.92	27.15	8.45	34.38	18.30	25.19	28.60	26.87	120	28.60	-16.8%
1.22	4758	720	29.93	27.15	8.45	34.39	18.30	25.19	28.60	26.88	120	28.60	-16.8%
1.23	4443	720	37.88	35.25	10.36	35.47	23.29	32.61	37.81	35.47	120	37.81	6.6%
1.24	4443	720	39.36	36.59	10.73	36.76	24.04	33.57	39.04	36.76	120	39.04	6.2%
1.25	4443	720	40.22	37.35	10.90	37.45	24.40	33.99	39.58	37.45	120	39.58	5.7%
1.26	4443	720	49.47	46.42	13.55	47.09	29.38	41.44	49.53	47.09	120	49.53	5.2%
1.27	4443	720	50.33	47.21	13.69	47.84	29.60	41.75	49.98	47.84	120	49.98	4.5%
1.28	4443	720	50.68	47.53	13.75	48.14	29.71	41.93	50.18	48.14	120	50.18	4.2%
1.29	4443	720	52.86	49.47	14.24	50.05	30.35	42.76	51.28	50.05	120	51.28	2.5%
1.30	4443	720	55.16	51.34	14.61	51.75	31.00	43.35	52.05	51.75	120	52.05	0.6%
1.31	4443	720	58.54	54.37	15.49	54.83	32.29	45.11	54.55	54.83	720	54.83	0.0%
1.32	4443	720	60.50	56.05	15.90	56.44	32.60	45.40	55.02	56.44	720	56.44	0.0%
2.01	4405	60	0.77	0.77	0.07	0.78	0.53	0.75	0.86	0.70	120	0.86	10.3%
3.01	4531	45	1.57	1.60	0.12	1.59	1.07	1.61	1.61	1.26	45	1.61	1.3%
4.01	4503	30	0.68	0.68	0.04	0.68	0.66	0.65	0.64	0.48	20	0.66	-2.9%
5.01	4528	45	1.07	1.08	0.12	1.10	0.86	1.10	1.00	0.74	45	1.10	0.0%
6.01	4558	60	1.24	1.23	0.12	1.24	0.84	1.21	1.34	1.09	120	1.34	8.1%
6.02	4558	60	1.41	1.43	0.11	1.43	1.03	1.37	1.56	1.25	120	1.56	9.1%
6.03	4528	45	3.67	3.63	0.46	3.78	3.53	3.78	3.69	2.89	45	3.78	0.0%
7.01	4371	20	2.17	2.14	0.38	2.23	2.23	1.75	1.36	1.00	20	2.23	0.0%
8.01	4359	20	2.14	2.06	0.30	2.21	2.22	1.95	1.69	1.25	20	2.22	0.5%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
8.02	4531	45	6.22	6.37	0.44	6.35	6.02	6.45	5.87	4.50	45	6.45	1.6%
9.01	4503	30	1.41	1.42	0.12	1.41	1.21	1.41	1.21	0.89	45	1.41	0.0%
10.01	4371	20	1.02	1.01	0.15	1.01	1.01	0.85	0.62	0.46	20	1.01	0.0%
11.01	4367	20	1.23	1.17	0.26	1.27	1.19	0.83	0.61	0.44	20	1.19	-6.3%
12.01	4532	90	0.97	0.99	0.11	0.97	0.95	0.82	1.09	0.89	120	1.09	12.4%
13.01	4367	20	4.60	4.54	0.78	4.70	4.70	3.72	2.85	2.09	20	4.70	0.0%
13.02	4528	45	8.22	8.27	0.71	8.52	6.59	8.52	8.20	6.30	45	8.52	0.0%
13.03	4528	45	10.75	10.83	0.81	11.09	8.55	11.09	11.13	8.94	120	11.13	0.4%
14.01	4367	20	3.38	3.22	0.64	3.29	3.25	2.37	1.73	1.24	20	3.25	-1.2%
15.01	4363	10	6.78	6.88	0.56	6.85	6.54	4.69	3.75	2.76	20	6.54	-4.5%
16.01	4371	20	1.18	1.12	0.20	1.14	1.14	0.85	0.60	0.44	20	1.14	0.0%
17.01	4371	20	2.00	1.93	0.31	2.06	2.06	1.74	1.49	1.09	20	2.06	0.0%
17.02	4365	10	5.59	5.62	0.42	5.61	5.51	4.38	4.16	3.18	20	5.51	-1.8%
17.03	4758	720	2.57	2.35	0.77	2.91	1.74	2.39	2.70	2.37	120	2.70	-7.2%
18.01	4371	20	2.78	2.68	0.43	2.85	2.85	2.46	2.23	1.66	20	2.85	0.0%
19.01	4558	60	0.64	0.63	0.07	0.63	0.39	0.64	0.68	0.54	120	0.68	7.9%
20.01	4359	20	1.56	1.51	0.24	1.61	1.62	1.37	1.26	0.94	20	1.62	0.6%
20.02	4500	30	2.12	2.05	0.22	2.16	2.17	2.17	1.99	1.52	20	2.17	0.5%
21.01	4531	45	0.47	0.48	0.06	0.47	0.34	0.48	0.45	0.33	45	0.48	2.1%
22.01	4367	20	0.80	0.78	0.13	0.80	0.82	0.71	0.83	0.65	120	0.83	3.7%
22.02	4371	20	0.92	0.89	0.14	0.93	0.93	0.86	0.92	0.74	20	0.93	0.0%
23.01	4528	45	1.34	1.34	0.14	1.36	1.05	1.36	1.24	0.93	45	1.36	0.0%
24.01	4464	25	1.28	1.28	0.07	1.29	1.17	1.26	1.07	0.78	45	1.26	-2.3%
25.01	4429	20	0.93	0.88	0.18	0.89	0.86	0.65	0.47	0.33	20	0.86	-3.4%
25.02	4461	25	1.22	1.23	0.13	1.22	1.07	1.01	0.76	0.56	20	1.07	-12.3%
26.01	4371	20	1.27	1.23	0.17	1.29	1.29	1.19	1.03	0.77	20	1.29	0.0%
27.01	4433	20	0.98	0.96	0.13	0.97	1.00	0.92	0.75	0.56	20	1.00	3.1%
27.02	4359	20	2.43	2.36	0.29	2.56	2.35	2.39	1.96	1.47	45	2.39	-6.6%
27.03	4498	30	3.77	3.63	0.42	3.66	3.26	3.79	3.24	2.42	45	3.79	3.6%
27.04	4528	45	4.25	4.21	0.33	4.33	3.56	4.33	3.77	2.87	45	4.33	0.0%
28.01	4433	20	0.92	0.89	0.13	0.90	0.90	0.73	0.53	0.39	20	0.90	0.0%
29.01	4464	25	1.16	1.15	0.09	1.17	1.10	1.12	0.93	0.68	45	1.12	-4.3%
30.01	4359	20	0.71	0.68	0.10	0.73	0.74	0.66	0.55	0.41	20	0.74	1.4%
31.01	4502	30	0.83	0.83	0.07	0.83	0.70	0.84	0.72	0.54	45	0.84	1.2%
31.02	4528	45	0.94	0.93	0.10	0.96	0.77	0.96	0.83	0.62	45	0.96	0.0%
32.01	4371	20	1.53	1.45	0.23	1.56	1.56	1.37	1.22	0.90	20	1.56	0.0%
32.02	4371	20	2.71	2.61	0.36	2.76	2.76	2.57	2.30	1.73	20	2.76	0.0%
33.01	4503	30	1.14	1.13	0.07	1.14	1.12	1.10	1.02	0.75	20	1.12	-1.8%
34.01	4363	10	0.93	0.94	0.08	0.93	0.89	0.59	0.57	0.44	20	0.89	-4.3%
34.02	4363	10	1.14	1.14	0.07	1.17	1.08	0.70	0.66	0.56	20	1.08	-7.7%
35.01	4361	10	1.31	1.33	0.10	1.31	1.27	0.92	0.68	0.50	20	1.27	-3.1%
35.02	4363	10	1.42	1.44	0.12	1.48	1.42	1.01	0.76	0.56	20	1.42	-4.1%
36.01	4371	20	3.18	3.08	0.51	3.25	3.25	2.62	2.02	1.48	20	3.25	0.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
36.02	4359	20	3.78	3.63	0.50	3.80	3.70	3.60	3.08	2.29	20	3.70	-2.6%
36.03	4359	20	3.85	3.70	0.50	3.85	3.75	3.67	3.17	2.37	20	3.75	-2.6%
36.04	4533	45	5.79	5.78	0.27	5.78	5.78	5.77	5.61	4.39	20	5.78	0.0%
36.05	4559	60	11.93	11.65	1.03	12.24	10.29	11.88	11.99	9.85	120	11.99	-2.0%
37.01	4359	20	1.41	1.37	0.23	1.45	1.48	1.23	1.21	0.92	20	1.48	2.1%
37.02	4365	10	2.48	2.47	0.00	2.48	2.23	2.39	2.45	1.95	120	2.45	-1.2%
38.01	4528	45	1.19	1.21	0.11	1.21	0.89	1.21	1.20	0.93	45	1.21	0.0%
38.02	4528	45	2.14	2.19	0.16	2.19	1.73	2.19	2.22	1.74	120	2.22	1.4%
38.03	4528	45	2.21	2.25	0.15	2.25	1.80	2.25	2.31	1.81	120	2.31	2.7%
38.04	4528	45	4.09	4.10	0.34	4.09	3.80	4.09	4.20	3.34	120	4.20	2.7%
38.05	4528	45	4.86	4.81	0.34	4.91	4.34	4.91	5.03	4.05	120	5.03	2.4%
39.01	4433	20	0.56	0.54	0.07	0.55	0.58	0.52	0.46	0.34	20	0.58	5.5%
39.02	4371	20	1.96	1.87	0.27	1.99	1.99	1.90	1.81	1.38	20	1.99	0.0%
40.01	4371	20	1.08	1.03	0.16	1.11	1.11	0.97	0.97	0.73	20	1.11	0.0%
41.01	4371	20	0.86	0.82	0.13	0.88	0.88	0.81	0.73	0.55	20	0.88	0.0%
42.01	4371	20	0.75	0.73	0.13	0.75	0.75	0.61	0.48	0.35	20	0.75	0.0%
42.02	4361	10	1.58	1.57	0.03	1.58	1.42	1.32	1.22	0.91	20	1.42	-10.1%
43.01	4367	20	1.33	1.30	0.22	1.32	1.39	1.13	0.96	0.70	20	1.39	5.3%
44.01	4361	10	0.58	0.59	0.05	0.59	0.59	0.45	0.37	0.27	20	0.59	0.0%
44.02	4371	20	1.75	1.72	0.24	1.77	1.77	1.72	1.58	1.20	20	1.77	0.0%
45.01	4371	20	0.98	0.94	0.15	1.01	1.01	0.90	0.81	0.60	20	1.01	0.0%
46.01	4464	25	0.97	0.94	0.08	0.96	0.99	0.94	0.82	0.61	20	0.99	3.1%
47.01	4528	45	1.84	1.86	0.19	1.85	1.31	1.85	1.81	1.38	45	1.85	0.0%
47.02	4531	45	2.81	2.88	0.17	2.85	1.99	2.91	2.86	2.28	45	2.91	2.1%
47.03	4531	45	2.84	2.91	0.16	2.88	2.02	2.94	2.90	2.32	45	2.94	2.1%
47.04	4405	60	3.77	3.75	0.37	3.76	2.80	3.73	3.89	3.19	120	3.89	3.5%
47.05	4528	45	6.68	6.64	0.41	6.79	5.38	6.79	6.86	5.63	120	6.86	1.0%
47.06	4405	60	7.53	7.43	0.75	7.49	6.19	7.71	7.80	6.37	120	7.80	4.1%
47.07	4531	45	10.07	10.18	0.58	10.06	8.49	10.30	10.44	8.46	120	10.44	3.8%
47.08	4531	45	10.24	10.34	0.59	10.22	8.67	10.45	10.64	8.65	120	10.64	4.1%
47.09	4558	60	10.65	10.52	1.03	10.56	9.08	10.79	11.08	9.02	120	11.08	4.9%
47.10	4405	60	11.96	11.90	1.05	11.95	10.14	12.12	12.33	10.22	120	12.33	3.2%
47.11	4405	60	12.48	12.39	1.07	12.47	10.51	12.59	12.82	10.68	120	12.82	2.8%
48.01	4371	20	0.76	0.73	0.11	0.78	0.78	0.67	0.53	0.39	20	0.78	0.0%
49.01	4367	20	0.77	0.75	0.13	0.76	0.76	0.61	0.46	0.34	20	0.76	0.0%
49.02	4371	20	1.19	1.15	0.17	1.21	1.21	1.02	0.79	0.59	20	1.21	0.0%
49.03	4429	20	1.75	1.69	0.15	1.77	1.59	1.68	1.40	1.05	45	1.68	-5.1%
49.04	4464	25	1.94	1.96	0.19	1.95	1.76	1.94	1.66	1.25	45	1.94	-0.5%
50.01	4371	20	0.74	0.72	0.12	0.76	0.76	0.68	0.73	0.55	20	0.76	0.0%
51.01	4367	20	0.83	0.81	0.14	0.82	0.84	0.70	0.55	0.41	20	0.84	2.4%
52.01	4433	20	0.57	0.55	0.07	0.56	0.58	0.55	0.46	0.33	20	0.58	3.6%
53.01	4367	20	0.50	0.49	0.08	0.50	0.51	0.40	0.31	0.23	20	0.51	2.0%
53.02	4402	30	0.93	0.90	0.12	0.99	0.84	0.94	0.81	0.61	45	0.94	-5.1%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
53.03	4500	30	2.15	2.11	0.21	2.15	1.80	2.15	1.87	1.39	45	2.15	0.0%
54.01	4359	20	0.28	0.27	0.05	0.29	0.29	0.21	0.16	0.11	20	0.29	0.0%
54.02	4460	25	1.05	1.05	0.10	1.05	0.99	1.01	0.87	0.64	45	1.01	-3.8%
55.01	4371	20	0.77	0.74	0.11	0.79	0.79	0.71	0.59	0.44	20	0.79	0.0%
55.02	4371	20	0.83	0.80	0.11	0.85	0.85	0.79	0.65	0.49	20	0.85	0.0%
56.01	4359	20	0.74	0.73	0.13	0.75	0.75	0.61	0.65	0.50	20	0.75	0.0%
56.02	4371	20	2.00	1.92	0.29	2.05	2.05	1.82	1.67	1.25	20	2.05	0.0%
57.01	4371	20	0.73	0.72	0.08	0.73	0.73	0.68	0.53	0.39	20	0.73	0.0%
57.02	4359	20	1.21	1.17	0.16	1.25	1.25	1.17	0.98	0.73	20	1.25	0.0%
58.01	4433	20	1.48	1.44	0.20	1.47	1.53	1.42	1.24	0.90	20	1.53	4.1%
58.02	4503	30	1.78	1.75	0.15	1.76	1.80	1.78	1.57	1.17	20	1.80	2.3%
59.01	4405	60	0.31	0.31	0.03	0.31	0.25	0.29	0.34	0.28	120	0.34	9.7%
60.01	4365	10	0.74	0.75	0.06	0.75	0.74	0.59	0.76	0.59	120	0.76	1.3%
60.02	4367	20	1.06	1.03	0.18	1.05	1.09	0.90	1.03	0.81	20	1.09	3.8%
60.03	4371	20	1.95	1.87	0.30	1.99	1.99	1.73	1.68	1.30	20	1.99	0.0%
60.04	4402	30	3.83	3.72	0.45	3.98	3.57	3.88	3.60	2.74	45	3.88	-2.5%
60.05	4528	45	4.28	4.25	0.51	4.42	3.85	4.42	4.07	3.09	45	4.42	0.0%
61.01	4371	20	0.82	0.78	0.12	0.83	0.83	0.74	0.58	0.44	20	0.83	0.0%
62.01	4359	20	1.26	1.21	0.18	1.30	1.31	1.16	1.07	0.80	20	1.31	0.8%
63.01	4433	20	1.12	1.08	0.16	1.10	1.16	1.06	1.11	0.84	20	1.16	5.5%
63.02	4528	45	1.92	1.91	0.27	1.95	1.63	1.95	1.90	1.46	45	1.95	0.0%
63.03	4531	45	2.44	2.48	0.22	2.44	2.23	2.52	2.45	1.94	45	2.52	3.3%
64.01	4371	20	2.04	1.96	0.30	2.09	2.09	1.71	1.29	0.94	20	2.09	0.0%
64.02	4371	20	3.27	3.21	0.37	3.23	3.23	3.17	2.55	1.91	20	3.23	0.0%
64.03	4394	25	4.05	4.09	0.38	4.05	3.91	3.97	3.26	2.42	45	3.97	-2.0%
65.01	4502	30	0.36	0.36	0.02	0.36	0.35	0.35	0.34	0.26	20	0.35	-2.8%
65.02	4394	25	1.03	1.04	0.09	1.03	0.92	0.98	0.88	0.66	45	0.98	-4.9%
66.01	4433	20	0.90	0.89	0.09	0.90	0.91	0.83	0.64	0.47	20	0.91	1.1%
67.01	4588	90	1.01	1.03	0.10	1.02	0.77	0.84	1.13	0.94	120	1.13	10.8%
67.02	4443	720	2.11	1.95	0.65	1.99	1.33	1.70	2.31	1.99	120	2.31	16.1%
67.03	4584	90	2.47	2.48	0.21	2.47	1.88	2.18	2.80	2.35	120	2.80	13.4%
67.04	4611	120	3.00	3.14	0.46	3.08	2.50	2.89	3.47	2.84	120	3.47	12.7%
67.05	4528	45	3.62	3.62	0.29	3.70	3.06	3.70	4.13	3.38	120	4.13	11.6%
68.01	4498	30	0.56	0.57	0.03	0.57	0.50	0.56	0.50	0.37	45	0.56	-1.8%
69.01	4528	45	0.62	0.63	0.07	0.64	0.47	0.64	0.59	0.44	45	0.64	0.0%
70.01	4371	20	0.98	0.94	0.14	1.00	1.00	0.89	0.78	0.57	20	1.00	0.0%
70.02	4462	25	2.25	2.25	0.24	2.27	2.19	2.17	1.80	1.33	20	2.19	-3.5%
70.03	4464	25	4.32	4.37	0.39	4.32	4.05	4.33	3.60	2.66	45	4.33	0.2%
71.01	4394	25	1.35	1.37	0.12	1.36	1.22	1.28	1.00	0.73	45	1.28	-5.9%
72.01	4365	10	1.06	1.07	0.08	1.06	1.07	0.85	0.94	0.74	20	1.07	0.9%
BasinA	4429	20	3.05	3.03	0.10	3.06	2.96	2.91	2.26	1.67	20	2.96	-3.3%
BasinBC	4531	45	5.01	5.07	0.41	5.05	3.43	5.10	5.18	3.94	120	5.18	2.6%
BasinE	4758	720	2.31	2.11	0.69	2.60	1.54	2.11	2.43	2.12	120	2.43	-6.5%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
BasinF	4443	720	5.74	5.26	1.96	5.38	3.19	5.24	6.62	5.38	120	6.62	23.0%
BasinG	4558	60	1.16	1.16	0.04	1.16	0.73	1.13	1.27	1.15	120	1.27	9.5%

Average Difference (All Subcatchments)		**1.69%**
Average Difference (Focus Locations)		**4.90%**
Average Difference (Whites Creek)		**5.16%**
Average Difference (Willow Tributary)		**2.87%**

ARR2016 Results for the 0.5% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
1.01	4528	45	0.32	0.32	0.03	0.32	0.24	0.31	0.23	60	0.31	-3.1%
1.02	4528	45	0.59	0.59	0.04	0.61	0.45	0.60	0.44	60	0.60	-1.6%
1.03	4558	60	2.21	2.19	0.22	2.21	1.43	2.33	1.85	60	2.33	5.4%
1.04	4531	45	6.09	6.18	0.49	6.14	4.29	6.24	4.82	60	6.24	1.6%
1.05	4558	60	13.39	13.25	1.34	13.33	8.11	14.10	11.70	60	14.10	5.8%
1.06	4558	60	14.63	14.44	1.33	14.51	8.91	15.31	13.09	60	15.31	5.5%
1.07	4558	60	14.75	14.55	1.32	14.62	8.99	15.44	13.20	60	15.44	5.6%
1.08	4405	60	25.98	25.79	2.16	25.88	18.48	27.16	22.32	60	27.16	4.9%
1.09	4405	60	27.79	27.56	2.20	27.65	19.77	28.98	24.06	60	28.98	4.8%
1.10	4405	60	28.21	27.94	2.16	28.03	20.09	29.37	24.49	60	29.37	4.8%
1.11	4405	60	29.02	28.61	2.04	28.70	20.69	30.06	25.50	60	30.06	4.7%
1.12	4405	60	29.20	28.76	2.00	28.86	20.82	30.23	25.77	60	30.23	4.7%
1.13	4405	60	29.71	29.20	1.96	29.30	21.18	30.70	26.44	60	30.70	4.8%
1.14	4405	60	30.00	29.45	1.92	29.53	21.38	30.93	26.87	60	30.93	4.7%
1.15	4559	60	30.16	29.56	1.87	31.05	21.44	31.05	27.20	60	31.05	0.0%
1.16	4559	60	30.63	29.96	1.80	31.44	21.77	31.44	28.00	60	31.44	0.0%
1.17	4559	60	30.75	30.03	1.75	31.51	21.83	31.51	28.29	60	31.51	0.0%
1.18	4443	720	32.91	29.76	9.85	29.90	22.19	32.02	29.90	60	32.02	7.1%
1.19	4654	720	33.52	30.30	9.97	30.30	22.29	32.16	30.29	60	32.16	6.1%
1.20	4654	720	34.44	31.25	10.04	31.35	22.40	32.30	30.86	60	32.30	3.0%
1.21	4758	720	35.22	32.03	10.09	41.17	22.49	32.49	31.42	60	32.49	-21.1%
1.22	4758	720	35.23	32.04	10.09	41.18	22.49	32.49	31.44	60	32.49	-21.1%
1.23	4654	720	44.08	40.99	12.21	41.02	28.52	41.46	40.96	60	41.46	1.1%
1.24	4654	720	45.75	42.54	12.58	42.63	29.38	42.78	42.44	60	42.78	0.4%
1.25	4654	720	46.76	43.47	12.77	43.59	29.76	43.51	43.36	60	43.51	-0.2%
1.26	4443	720	57.26	53.84	15.69	54.59	36.41	53.67	54.59	720	54.59	0.0%
1.27	4443	720	58.23	54.73	15.81	55.42	36.65	54.09	55.42	720	55.42	0.0%
1.28	4443	720	58.63	55.10	15.86	55.78	36.77	54.31	55.78	720	55.78	0.0%
1.29	4443	720	61.20	57.32	16.49	57.94	37.48	55.40	57.94	720	57.94	0.0%
1.30	4443	720	63.86	59.50	16.94	59.98	38.18	56.14	59.98	720	59.98	0.0%
1.31	4443	720	67.75	63.00	17.93	63.58	39.80	58.44	63.58	720	63.58	0.0%
1.32	4443	720	69.95	64.86	18.38	65.36	40.14	58.79	65.36	720	65.36	0.0%
2.01	4558	60	0.96	0.95	0.09	0.96	0.69	1.00	0.82	60	1.00	4.2%
3.01	4531	45	1.97	1.99	0.17	1.99	1.36	2.00	1.47	60	2.00	0.5%
4.01	4503	30	0.83	0.82	0.06	0.82	0.84	0.76	0.56	20	0.84	2.4%
5.01	4503	30	1.31	1.31	0.08	1.31	1.12	1.23	0.86	60	1.23	-6.1%
6.01	4558	60	1.52	1.50	0.16	1.52	1.11	1.58	1.26	60	1.58	3.9%
6.02	4558	60	1.73	1.74	0.15	1.73	1.33	1.81	1.46	60	1.81	4.6%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
6.03	4402	30	4.46	4.26	0.54	4.64	4.34	4.28	3.35	20	4.34	-6.5%
7.01	4367	20	2.61	2.55	0.44	2.63	2.65	1.83	1.15	20	2.65	0.8%
8.01	4371	20	2.61	2.52	0.35	2.68	2.68	2.16	1.44	20	2.68	0.0%
8.02	4531	45	7.46	7.56	0.52	7.54	7.19	7.48	5.18	60	7.48	-0.8%
9.01	4394	25	1.76	1.77	0.11	1.76	1.57	1.54	1.03	20	1.57	-10.8%
10.01	4429	20	1.24	1.21	0.18	1.22	1.20	0.87	0.52	20	1.20	-1.6%
11.01	4396	15	1.44	1.37	0.26	1.46	1.37	0.87	0.50	20	1.37	-6.2%
12.01	4532	90	1.17	1.19	0.14	1.18	1.19	1.12	1.05	20	1.19	0.8%
13.01	4367	20	5.52	5.40	0.90	5.51	5.65	3.88	2.39	20	5.65	2.5%
13.02	4528	45	9.94	9.95	0.68	10.16	8.11	9.96	7.44	60	9.96	-2.0%
13.03	4528	45	12.97	13.00	0.78	13.23	10.48	13.14	10.46	60	13.14	-0.7%
14.01	4367	20	3.95	3.72	0.76	3.95	3.75	2.45	1.41	20	3.75	-5.1%
15.01	4361	10	7.82	7.90	0.62	7.84	7.48	5.01	3.16	20	7.48	-4.6%
16.01	4404	20	1.38	1.30	0.25	1.49	1.31	0.87	0.51	20	1.31	-12.1%
17.01	4371	20	2.43	2.32	0.36	2.49	2.49	1.91	1.26	20	2.49	0.0%
17.02	4365	10	6.53	6.55	0.48	6.53	6.57	4.85	3.67	20	6.57	0.6%
17.03	4443	720	3.10	2.71	1.04	2.75	2.10	2.99	2.75	60	2.99	8.7%
18.01	4359	20	3.37	3.25	0.50	3.46	3.49	2.78	1.92	20	3.49	0.9%
19.01	4531	45	0.79	0.80	0.05	0.80	0.54	0.82	0.63	60	0.82	2.5%
20.01	4359	20	1.89	1.80	0.27	1.96	1.97	1.57	1.08	20	1.97	0.5%
20.02	4500	30	2.60	2.53	0.29	2.60	2.67	2.52	1.75	20	2.67	2.7%
21.01	4528	45	0.58	0.57	0.06	0.59	0.48	0.55	0.39	60	0.55	-6.8%
22.01	4359	20	0.97	0.94	0.14	1.00	1.00	0.93	0.75	20	1.00	0.0%
22.02	4371	20	1.12	1.09	0.15	1.15	1.15	1.03	0.85	20	1.15	0.0%
23.01	4528	45	1.62	1.60	0.17	1.65	1.34	1.54	1.08	60	1.54	-6.7%
24.01	4394	25	1.60	1.61	0.11	1.61	1.46	1.38	0.90	20	1.46	-9.3%
25.01	4404	20	1.09	1.00	0.22	1.17	0.99	0.67	0.39	20	0.99	-15.4%
25.02	4429	20	1.47	1.45	0.20	1.48	1.21	1.07	0.64	20	1.21	-18.2%
26.01	4433	20	1.56	1.53	0.20	1.55	1.62	1.32	0.88	20	1.62	4.5%
27.01	4433	20	1.20	1.19	0.15	1.20	1.22	0.99	0.64	20	1.22	1.7%
27.02	4367	20	2.95	2.86	0.33	2.89	2.84	2.58	1.70	20	2.84	-1.7%
27.03	4498	30	4.58	4.44	0.50	4.51	3.90	4.17	2.79	60	4.17	-7.5%
27.04	4498	30	5.10	4.93	0.47	5.00	4.28	4.96	3.31	60	4.96	-0.8%
28.01	4433	20	1.10	1.07	0.16	1.07	1.07	0.74	0.45	20	1.07	0.0%
29.01	4464	25	1.41	1.41	0.12	1.42	1.37	1.21	0.78	20	1.37	-3.5%
30.01	4371	20	0.90	0.88	0.12	0.91	0.91	0.73	0.47	20	0.91	0.0%
31.01	4460	25	1.03	1.04	0.05	1.04	0.92	0.92	0.61	20	0.92	-11.5%
31.02	4460	25	1.15	1.16	0.07	1.15	1.03	1.09	0.72	60	1.09	-5.2%
32.01	4359	20	1.86	1.79	0.26	1.93	1.93	1.54	1.03	20	1.93	0.0%
32.02	4433	20	3.32	3.24	0.43	3.28	3.44	2.92	1.99	20	3.44	4.9%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
33.01	4464	25	1.41	1.37	0.12	1.41	1.43	1.27	0.87	20	1.43	1.4%
34.01	4361	10	1.07	1.09	0.09	1.06	1.03	0.64	0.51	20	1.03	-2.8%
34.02	4368	10	1.31	1.32	0.10	1.29	1.27	0.78	0.64	20	1.27	-1.6%
35.01	4363	10	1.52	1.53	0.11	1.52	1.50	0.95	0.57	20	1.50	-1.3%
35.02	4368	10	1.64	1.65	0.14	1.62	1.61	1.06	0.64	20	1.61	-0.6%
36.01	4371	20	3.84	3.71	0.60	3.89	3.89	2.73	1.70	20	3.89	0.0%
36.02	4359	20	4.58	4.42	0.59	4.64	4.49	3.96	2.64	20	4.49	-3.2%
36.03	4359	20	4.65	4.47	0.59	4.70	4.55	4.06	2.72	20	4.55	-3.2%
36.04	4528	45	7.02	7.01	0.30	7.09	6.79	7.07	5.07	60	7.07	-0.3%
36.05	4558	60	14.40	14.16	1.24	14.24	12.42	14.77	11.37	60	14.77	3.7%
37.01	4359	20	1.69	1.64	0.26	1.74	1.76	1.42	1.06	20	1.76	1.1%
37.02	4528	45	2.93	2.95	0.32	2.94	2.69	2.94	2.25	60	2.94	0.0%
38.01	4531	45	1.46	1.47	0.14	1.47	1.16	1.46	1.08	60	1.46	-0.7%
38.02	4531	45	2.63	2.68	0.20	2.67	2.14	2.69	2.03	60	2.69	0.7%
38.03	4531	45	2.71	2.74	0.19	2.74	2.23	2.79	2.11	60	2.79	1.8%
38.04	4528	45	4.98	4.98	0.42	5.00	4.69	5.05	3.86	60	5.05	1.0%
38.05	4528	45	5.92	5.88	0.42	6.03	5.37	6.02	4.68	60	6.02	-0.2%
39.01	4371	20	0.69	0.67	0.09	0.71	0.71	0.58	0.39	20	0.71	0.0%
39.02	4371	20	2.40	2.31	0.29	2.44	2.44	2.17	1.59	20	2.44	0.0%
40.01	4359	20	1.32	1.25	0.19	1.36	1.37	1.12	0.85	20	1.37	0.7%
41.01	4371	20	1.07	1.03	0.15	1.10	1.10	0.90	0.63	20	1.10	0.0%
42.01	4371	20	0.91	0.88	0.14	0.91	0.91	0.64	0.40	20	0.91	0.0%
42.02	4357	10	1.84	1.84	0.03	1.84	1.68	1.55	1.06	20	1.68	-8.7%
43.01	4359	20	1.59	1.55	0.25	1.64	1.64	1.23	0.82	20	1.64	0.0%
44.01	4361	10	0.69	0.69	0.05	0.70	0.69	0.49	0.32	20	0.69	-1.4%
44.02	4367	20	2.12	2.10	0.27	2.14	2.17	1.95	1.40	20	2.17	1.4%
45.01	4359	20	1.21	1.16	0.17	1.25	1.25	1.00	0.69	20	1.25	0.0%
46.01	4464	25	1.20	1.18	0.11	1.19	1.21	1.05	0.70	20	1.21	1.7%
47.01	4531	45	2.24	2.25	0.23	2.24	1.74	2.21	1.60	60	2.21	-1.3%
47.02	4531	45	3.47	3.53	0.21	3.52	2.61	3.60	2.64	60	3.60	2.3%
47.03	4531	45	3.51	3.58	0.21	3.55	2.64	3.64	2.69	60	3.64	2.5%
47.04	4405	60	4.58	4.54	0.46	4.59	3.61	4.85	3.69	60	4.85	5.7%
47.05	4528	45	8.14	8.10	0.49	8.31	6.86	8.43	6.53	60	8.43	1.4%
47.06	4531	45	9.12	9.21	0.45	9.06	7.48	9.49	7.38	60	9.49	4.7%
47.07	4531	45	12.23	12.29	0.69	12.13	10.33	12.67	9.79	60	12.67	4.5%
47.08	4528	45	12.44	12.46	0.69	12.61	10.54	12.87	10.00	60	12.87	2.1%
47.09	4528	45	12.90	12.91	0.67	13.11	11.03	13.39	10.43	60	13.39	2.1%
47.10	4405	60	14.36	14.21	1.26	14.31	12.36	15.09	11.84	60	15.09	5.5%
47.11	4405	60	15.02	14.80	1.29	14.91	12.82	15.70	12.37	60	15.70	5.3%
48.01	4371	20	0.96	0.93	0.13	0.96	0.96	0.71	0.45	20	0.96	0.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
49.01	4371	20	0.93	0.89	0.15	0.92	0.92	0.62	0.38	20	0.92	0.0%
49.02	4371	20	1.44	1.38	0.19	1.44	1.44	1.07	0.67	20	1.44	0.0%
49.03	4429	20	2.16	2.10	0.17	2.19	1.96	1.86	1.20	20	1.96	-10.5%
49.04	4464	25	2.38	2.41	0.23	2.38	2.17	2.17	1.43	20	2.17	-8.8%
50.01	4433	20	0.92	0.88	0.13	0.91	0.95	0.83	0.64	20	0.95	4.4%
51.01	4371	20	1.03	0.98	0.15	1.03	1.03	0.75	0.47	20	1.03	0.0%
52.01	4433	20	0.72	0.72	0.08	0.72	0.73	0.60	0.39	20	0.73	1.4%
53.01	4367	20	0.59	0.58	0.10	0.59	0.59	0.42	0.26	20	0.59	0.0%
53.02	4402	30	1.14	1.10	0.15	1.20	1.02	1.03	0.70	60	1.03	-14.2%
53.03	4460	25	2.62	2.63	0.22	2.61	2.28	2.43	1.60	60	2.43	-6.9%
54.01	4371	20	0.33	0.32	0.05	0.34	0.34	0.22	0.13	20	0.34	0.0%
54.02	4460	25	1.29	1.30	0.12	1.29	1.21	1.14	0.74	20	1.21	-6.2%
55.01	4371	20	0.97	0.94	0.13	0.99	0.99	0.77	0.50	20	0.99	0.0%
55.02	4371	20	1.05	1.01	0.14	1.05	1.05	0.85	0.56	20	1.05	0.0%
56.01	4359	20	0.89	0.88	0.15	0.91	0.91	0.74	0.57	20	0.91	0.0%
56.02	4371	20	2.45	2.35	0.33	2.51	2.51	2.06	1.45	20	2.51	0.0%
57.01	4433	20	0.91	0.90	0.10	0.91	0.92	0.72	0.45	20	0.92	1.1%
57.02	4371	20	1.51	1.47	0.18	1.55	1.55	1.29	0.84	20	1.55	0.0%
58.01	4433	20	1.84	1.80	0.23	1.82	1.89	1.57	1.04	20	1.89	3.8%
58.02	4433	20	2.19	2.15	0.24	2.17	2.23	1.99	1.36	20	2.23	2.8%
59.01	4558	60	0.38	0.38	0.04	0.38	0.31	0.39	0.33	60	0.39	2.6%
60.01	4371	20	0.87	0.86	0.16	0.89	0.89	0.75	0.71	20	0.89	0.0%
60.02	4359	20	1.27	1.23	0.20	1.30	1.30	1.05	0.95	20	1.30	0.0%
60.03	4371	20	2.38	2.26	0.35	2.41	2.41	1.90	1.52	20	2.41	0.0%
60.04	4402	30	4.69	4.53	0.56	4.94	4.36	4.37	3.19	60	4.37	-11.5%
60.05	4402	30	5.19	5.01	0.59	5.48	4.73	5.02	3.58	60	5.02	-8.4%
61.01	4371	20	1.02	0.98	0.14	1.04	1.04	0.79	0.50	20	1.04	0.0%
62.01	4433	20	1.54	1.49	0.21	1.52	1.60	1.33	0.92	20	1.60	5.3%
63.01	4504	30	1.38	1.35	0.10	1.42	1.42	1.30	0.97	20	1.42	0.0%
63.02	4528	45	2.34	2.32	0.31	2.39	2.05	2.26	1.68	60	2.26	-5.4%
63.03	4531	45	2.96	2.99	0.25	2.93	2.72	3.04	2.25	60	3.04	3.8%
64.01	4371	20	2.46	2.36	0.35	2.47	2.47	1.77	1.08	20	2.47	0.0%
64.02	4429	20	4.03	3.92	0.43	3.98	3.85	3.37	2.19	20	3.85	-3.3%
64.03	4394	25	4.95	5.04	0.50	4.99	4.79	4.25	2.77	20	4.79	-4.0%
65.01	4503	30	0.45	0.44	0.02	0.45	0.44	0.41	0.30	20	0.44	-2.2%
65.02	4460	25	1.25	1.25	0.13	1.25	1.14	1.09	0.76	20	1.14	-8.8%
66.01	4433	20	1.11	1.10	0.12	1.11	1.10	0.87	0.54	20	1.10	-0.9%
67.01	4588	90	1.22	1.24	0.12	1.23	0.98	1.18	1.11	60	1.18	-4.1%
67.02	4532	90	2.52	2.57	0.18	2.55	1.68	2.39	2.34	60	2.39	-6.3%
67.03	4584	90	2.98	2.99	0.26	2.98	2.34	2.91	2.74	60	2.91	-2.3%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)			ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted						
67.04	4532	90	3.57	3.58	0.38	3.56	3.14	3.66	3.30	60	3.66	2.8%
67.05	4528	45	4.39	4.40	0.33	4.51	3.88	4.49	3.94	60	4.49	-0.4%
68.01	4464	25	0.69	0.68	0.04	0.69	0.66	0.63	0.43	20	0.66	-4.3%
69.01	4528	45	0.76	0.75	0.08	0.78	0.63	0.72	0.52	60	0.72	-7.7%
70.01	4359	20	1.21	1.16	0.17	1.25	1.25	0.98	0.66	20	1.25	0.0%
70.02	4404	20	2.77	2.70	0.26	2.85	2.68	2.33	1.53	20	2.68	-6.0%
70.03	4394	25	5.34	5.40	0.55	5.34	4.99	4.73	3.06	20	4.99	-6.6%
71.01	4464	25	1.66	1.69	0.19	1.66	1.51	1.34	0.84	20	1.51	-9.0%
72.01	4371	20	1.25	1.23	0.21	1.27	1.27	1.03	0.86	20	1.27	0.0%
BasinA	4399	20	3.32	3.32	0.12	3.32	3.15	2.95	1.90	20	3.15	-5.1%
BasinBC	4531	45	6.22	6.27	0.57	6.24	4.82	6.24	4.70	60	6.24	0.0%
BasinE	4758	720	2.79	2.44	0.94	3.42	1.85	2.68	2.45	60	2.68	-21.6%
BasinF	4558	60	7.40	7.35	0.57	7.37	4.01	7.75	6.77	60	7.75	5.2%
BasinG	4405	60	1.32	1.32	0.05	1.32	0.98	1.35	1.27	60	1.35	2.3%

Average Difference (All Subcatchments)		**-1.01%**
Average Difference (Focus Locations)		**0.60%**
Average Difference (Whites Creek)		**0.88%**
Average Difference (Willow Tributary)		**3.16%**

ARR2016 Results for the 0.2% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4533 for the 45 minute duration	TP 4559 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
1.01	4528	45	0.41	0.41	0.04	0.42	0.33	0.45	0.39	0.27	45	0.45	7.1%
1.02	4533	45	0.76	0.76	0.05	0.78	0.61	0.78	0.75	0.53	45	0.78	0.0%
1.03	4531	45	2.85	2.86	0.14	2.83	1.99	2.98	2.95	2.25	45	2.98	5.3%
1.04	4531	45	7.78	7.84	0.62	7.76	5.85	8.35	7.82	5.82	45	8.35	7.6%
1.05	4528	45	17.64	17.72	0.94	17.99	12.03	18.49	18.40	14.55	45	18.49	2.8%
1.06	4405	60	19.16	18.71	1.61	18.77	13.05	19.97	19.94	16.17	45	19.97	6.4%
1.07	4559	60	19.33	18.88	1.58	20.09	13.15	20.13	20.09	16.31	45	20.13	0.2%
1.08	4405	60	34.32	33.82	2.88	33.91	24.40	34.83	36.10	28.12	60	36.10	6.5%
1.09	4405	60	36.54	35.96	2.92	36.00	26.07	36.97	38.30	30.27	60	38.30	6.4%
1.10	4405	60	37.03	36.40	2.90	36.41	26.45	37.39	38.74	30.81	60	38.74	6.4%
1.11	4558	60	37.99	37.26	2.79	37.30	27.10	38.15	39.53	32.01	60	39.53	6.0%
1.12	4558	60	38.23	37.47	2.75	37.50	27.22	38.32	39.72	32.33	60	39.72	5.9%
1.13	4559	60	38.87	38.03	2.69	40.28	27.66	38.86	40.28	33.08	60	40.28	0.0%
1.14	4559	60	39.22	38.32	2.62	40.57	27.87	39.10	40.57	33.60	60	40.57	0.0%
1.15	4559	60	39.42	38.47	2.57	40.71	27.94	39.21	40.71	33.99	60	40.71	0.0%
1.16	4559	60	39.99	38.96	2.51	41.20	28.30	39.64	41.20	34.93	60	41.20	0.0%
1.17	4559	60	40.12	39.05	2.47	41.29	28.36	39.72	41.29	35.25	60	41.29	0.0%
1.18	4360	60	41.08	40.40	2.20	40.84	28.74	40.22	41.96	37.13	60	41.96	2.7%
1.19	4360	60	41.28	40.71	2.14	41.24	28.84	40.35	42.11	37.61	60	42.11	2.1%
1.20	4443	720	42.00	38.04	12.21	38.26	28.95	40.46	42.27	38.26	60	42.27	10.5%
1.21	4758	720	42.96	38.82	12.32	50.92	29.06	40.64	42.48	38.88	60	42.48	-16.6%
1.22	4758	720	42.97	38.82	12.32	50.92	29.06	40.64	42.48	38.88	60	42.48	-16.6%
1.23	4443	720	53.42	49.62	14.75	49.64	36.24	48.36	51.13	49.64	60	51.13	3.0%
1.24	4654	720	55.40	51.45	15.22	51.52	37.35	49.83	52.97	51.39	60	52.97	2.8%
1.25	4654	720	56.55	52.50	15.43	52.65	37.93	50.49	53.81	52.35	60	53.81	2.2%
1.26	4443	720	69.03	64.92	18.92	65.55	46.60	62.20	66.31	65.55	60	66.31	1.2%
1.27	4443	720	70.18	65.96	19.10	66.49	46.92	62.73	66.77	66.49	60	66.77	0.4%
1.28	4443	720	70.66	66.40	19.19	66.92	47.14	63.02	67.01	66.92	60	67.01	0.1%
1.29	4443	720	73.60	69.04	19.81	69.53	48.18	64.66	68.31	69.53	720	69.53	0.0%
1.30	4443	720	76.62	71.64	20.17	71.96	48.93	65.71	69.11	71.96	720	71.96	0.0%
1.31	4443	720	81.28	75.79	21.40	76.22	50.97	68.81	71.93	76.22	720	76.22	0.0%
1.32	4443	720	83.89	77.89	21.95	78.22	51.33	69.25	72.30	78.22	720	78.22	0.0%
2.01	4528	45	1.24	1.26	0.08	1.25	0.92	1.32	1.27	1.00	45	1.32	5.6%
3.01	4531	45	2.48	2.49	0.21	2.47	1.90	2.69	2.46	1.77	45	2.69	8.9%
4.01	4503	30	1.06	1.05	0.08	1.05	1.10	1.11	0.95	0.67	45	1.11	5.7%
5.01	4498	30	1.68	1.69	0.14	1.69	1.48	1.74	1.50	1.04	45	1.74	3.0%
6.01	4528	45	2.01	2.03	0.16	2.02	1.48	2.17	2.04	1.53	45	2.17	7.4%
6.02	4528	45	2.23	2.21	0.14	2.22	1.73	2.38	2.33	1.76	45	2.38	7.2%
6.03	4402	30	5.65	5.35	0.73	5.99	5.49	6.12	5.34	4.01	45	6.12	2.2%
7.01	4371	20	3.23	3.16	0.52	3.25	3.25	2.60	2.20	1.36	20	3.25	0.0%
8.01	4433	20	3.37	3.29	0.43	3.34	3.44	3.05	2.66	1.72	20	3.44	3.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4533 for the 45 minute duration	TP 4559 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
8.02	4498	30	9.37	9.33	0.57	9.35	9.11	9.51	9.06	6.17	45	9.51	1.7%
9.01	4464	25	2.28	2.30	0.17	2.30	2.12	2.13	1.89	1.23	45	2.13	-7.4%
10.01	4429	20	1.55	1.49	0.22	1.51	1.46	1.16	1.03	0.62	20	1.46	-3.3%
11.01	4357	10	1.77	1.74	0.16	1.76	1.63	1.23	1.04	0.59	20	1.63	-7.4%
12.01	4558	60	1.47	1.47	0.12	1.47	1.51	1.59	1.46	1.29	45	1.59	8.2%
13.01	4367	20	6.82	6.67	1.08	6.80	6.87	5.43	4.61	2.84	20	6.87	1.0%
13.02	4528	45	12.34	12.26	0.78	12.56	10.31	13.00	12.13	9.09	45	13.00	3.5%
13.03	4528	45	16.50	16.55	1.12	16.87	13.28	17.54	16.80	13.00	45	17.54	4.0%
14.01	4367	20	4.79	4.45	0.91	4.95	4.49	3.39	2.90	1.67	20	4.49	-9.3%
15.01	4365	10	9.36	9.42	0.70	9.35	9.07	7.26	6.03	3.76	20	9.07	-3.0%
16.01	4367	20	1.68	1.56	0.31	1.65	1.57	1.20	1.03	0.61	20	1.57	-4.8%
17.01	4371	20	3.06	2.92	0.43	3.12	3.12	2.70	2.33	1.51	20	3.12	0.0%
17.02	4371	20	8.00	7.85	1.33	8.11	8.11	7.10	6.02	4.42	20	8.11	0.0%
17.03	4558	60	4.40	4.38	0.37	4.40	2.63	4.37	4.62	3.71	60	4.62	5.0%
18.01	4371	20	4.32	4.14	0.59	4.45	4.45	3.97	3.45	2.29	20	4.45	0.0%
19.01	4531	45	1.02	1.04	0.08	1.03	0.74	1.11	1.03	0.76	45	1.11	7.8%
20.01	4371	20	2.40	2.30	0.33	2.47	2.47	2.23	1.94	1.29	20	2.47	0.0%
20.02	4371	20	3.35	3.25	0.35	3.39	3.39	3.49	3.12	2.10	45	3.49	2.9%
21.01	4503	30	0.74	0.74	0.05	0.73	0.65	0.79	0.68	0.47	45	0.79	8.2%
22.01	4359	20	1.26	1.21	0.17	1.28	1.30	1.34	1.17	0.89	45	1.34	4.7%
22.02	4371	20	1.44	1.39	0.18	1.47	1.47	1.48	1.29	1.01	45	1.48	0.7%
23.01	4500	30	2.11	2.12	0.17	2.11	1.84	2.18	1.89	1.29	45	2.18	3.3%
24.01	4464	25	2.07	2.07	0.19	2.08	1.94	1.88	1.68	1.08	20	1.94	-6.7%
25.01	4367	20	1.33	1.22	0.26	1.31	1.18	0.94	0.80	0.46	20	1.18	-9.9%
25.02	4427	20	1.83	1.84	0.23	1.83	1.44	1.45	1.29	0.75	45	1.45	-20.8%
26.01	4371	20	2.01	1.97	0.24	2.04	2.04	1.83	1.61	1.04	20	2.04	0.0%
27.01	4371	20	1.56	1.53	0.18	1.56	1.56	1.36	1.20	0.76	20	1.56	0.0%
27.02	4367	20	3.69	3.54	0.43	3.73	3.51	3.52	3.09	2.02	45	3.52	-5.6%
27.03	4460	25	5.79	5.89	0.37	5.88	4.92	5.54	5.10	3.31	45	5.54	-5.8%
27.04	4462	25	6.51	6.54	0.38	6.51	5.59	6.29	6.05	3.94	45	6.29	-3.4%
28.01	4433	20	1.36	1.30	0.21	1.31	1.30	1.01	0.88	0.53	20	1.30	-0.8%
29.01	4433	20	1.83	1.82	0.12	1.83	1.75	1.62	1.47	0.93	20	1.75	-4.4%
30.01	4371	20	1.14	1.11	0.14	1.16	1.16	1.01	0.88	0.56	20	1.16	0.0%
31.01	4460	25	1.33	1.35	0.09	1.34	1.19	1.28	1.13	0.74	45	1.28	-4.5%
31.02	4464	25	1.48	1.50	0.11	1.48	1.34	1.45	1.33	0.86	45	1.45	-2.0%
32.01	4371	20	2.36	2.28	0.30	2.42	2.42	2.16	1.89	1.24	20	2.42	0.0%
32.02	4371	20	4.27	4.16	0.51	4.34	4.34	4.08	3.59	2.38	20	4.34	0.0%
33.01	4371	20	1.82	1.78	0.17	1.84	1.84	1.76	1.56	1.03	20	1.84	0.0%
34.01	4363	10	1.29	1.30	0.10	1.29	1.23	0.95	0.78	0.61	20	1.23	-4.7%
34.02	4363	10	1.55	1.56	0.11	1.61	1.51	1.14	0.95	0.78	20	1.51	-6.2%
35.01	4361	10	1.84	1.84	0.13	1.86	1.81	1.34	1.14	0.67	20	1.81	-2.7%
35.02	4368	10	1.97	1.99	0.16	1.97	1.97	1.47	1.27	0.75	20	1.97	0.0%
36.01	4371	20	4.81	4.63	0.71	4.82	4.82	3.85	3.29	2.01	20	4.82	0.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4533 for the 45 minute duration	TP 4559 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
36.02	4359	20	5.74	5.52	0.72	5.88	5.58	5.18	4.76	3.14	20	5.58	-5.1%
36.03	4359	20	5.83	5.58	0.72	5.94	5.63	5.29	4.92	3.23	20	5.63	-5.2%
36.04	4527	45	8.79	8.74	0.36	8.75	8.45	8.48	8.71	6.07	60	8.71	-0.5%
36.05	4527	45	18.18	18.16	0.54	18.27	15.90	17.69	18.38	13.61	60	18.38	0.6%
37.01	4359	20	2.16	2.07	0.30	2.22	2.25	2.05	1.78	1.27	20	2.25	1.4%
37.02	4528	45	3.73	3.75	0.38	3.75	3.36	4.10	3.67	2.71	45	4.10	9.3%
38.01	4528	45	1.88	1.87	0.19	1.89	1.55	2.08	1.80	1.29	45	2.08	10.1%
38.02	4531	45	3.35	3.38	0.25	3.35	2.84	3.58	3.34	2.43	45	3.58	6.9%
38.03	4528	45	3.44	3.44	0.24	3.47	2.96	3.67	3.46	2.52	45	3.67	5.8%
38.04	4528	45	6.29	6.25	0.50	6.36	6.10	6.82	6.21	4.64	45	6.82	7.2%
38.05	4528	45	7.51	7.47	0.46	7.69	7.02	7.89	7.51	5.62	45	7.89	2.6%
39.01	4433	20	0.91	0.89	0.12	0.91	0.94	0.84	0.73	0.47	20	0.94	3.3%
39.02	4371	20	3.08	3.01	0.34	3.11	3.11	3.18	2.74	1.91	45	3.18	2.3%
40.01	4433	20	1.67	1.61	0.22	1.65	1.72	1.66	1.43	1.01	20	1.72	4.2%
41.01	4371	20	1.36	1.31	0.18	1.40	1.40	1.29	1.12	0.75	20	1.40	0.0%
42.01	4371	20	1.15	1.11	0.18	1.16	1.16	0.91	0.77	0.48	20	1.16	0.0%
42.02	4429	20	2.23	2.14	0.18	2.24	2.10	2.20	1.90	1.26	45	2.20	-1.8%
43.01	4371	20	2.01	1.93	0.29	2.05	2.05	1.76	1.51	0.97	20	2.05	0.0%
44.01	4371	20	0.84	0.83	0.15	0.85	0.85	0.70	0.58	0.37	20	0.85	0.0%
44.02	4371	20	2.70	2.63	0.32	2.74	2.74	2.88	2.45	1.68	45	2.88	5.1%
45.01	4371	20	1.53	1.48	0.20	1.57	1.57	1.43	1.24	0.82	20	1.57	0.0%
46.01	4433	20	1.57	1.54	0.15	1.56	1.56	1.43	1.29	0.83	20	1.56	0.0%
47.01	4528	45	2.82	2.81	0.26	2.87	2.40	3.08	2.71	1.93	45	3.08	7.3%
47.02	4531	45	4.43	4.48	0.27	4.43	3.55	4.64	4.47	3.19	45	4.64	4.7%
47.03	4531	45	4.48	4.53	0.27	4.47	3.58	4.69	4.52	3.24	45	4.69	4.9%
47.04	4528	45	5.82	5.82	0.23	5.85	4.76	6.00	6.04	4.44	60	6.04	3.2%
47.05	4528	45	10.33	10.27	0.61	10.60	8.94	10.84	10.52	7.83	45	10.84	2.3%
47.06	4531	45	11.49	11.58	0.54	11.40	9.66	11.78	11.74	8.86	45	11.78	3.3%
47.07	4528	45	15.35	15.40	0.85	15.66	13.31	15.97	15.66	11.73	45	15.97	2.0%
47.08	4528	45	15.60	15.64	0.84	15.91	13.58	16.21	15.90	11.98	45	16.21	1.9%
47.09	4528	45	16.18	16.26	0.82	16.56	14.22	16.74	16.52	12.48	45	16.74	1.1%
47.10	4496	45	18.01	18.14	0.78	17.89	15.92	18.39	18.62	14.22	60	18.62	4.1%
47.11	4496	45	18.77	18.93	0.75	18.77	16.55	19.22	19.35	14.86	60	19.35	3.1%
48.01	4371	20	1.20	1.16	0.16	1.20	1.20	0.98	0.85	0.53	20	1.20	0.0%
49.01	4371	20	1.16	1.11	0.18	1.14	1.14	0.88	0.75	0.46	20	1.14	0.0%
49.02	4371	20	1.84	1.78	0.22	1.80	1.80	1.48	1.28	0.79	20	1.80	0.0%
49.03	4404	20	2.73	2.69	0.20	2.75	2.50	2.55	2.26	1.43	45	2.55	-7.3%
49.04	4464	25	3.03	3.09	0.31	3.03	2.78	2.95	2.65	1.71	45	2.95	-2.6%
50.01	4359	20	1.19	1.15	0.16	1.22	1.24	1.22	1.04	0.77	20	1.24	1.6%
51.01	4371	20	1.28	1.23	0.18	1.30	1.30	1.05	0.91	0.56	20	1.30	0.0%
52.01	4371	20	0.94	0.93	0.10	0.95	0.95	0.83	0.73	0.47	20	0.95	0.0%
53.01	4367	20	0.74	0.72	0.12	0.75	0.73	0.60	0.50	0.32	20	0.73	-2.7%
53.02	4464	25	1.44	1.47	0.13	1.44	1.33	1.46	1.26	0.84	45	1.46	1.4%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4533 for the 45 minute duration	TP 4559 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
53.03	4464	25	3.36	3.39	0.29	3.37	2.96	3.30	2.96	1.92	45	3.30	-2.1%
54.01	4371	20	0.40	0.39	0.06	0.40	0.40	0.31	0.26	0.15	20	0.40	0.0%
54.02	4429	20	1.66	1.65	0.13	1.68	1.56	1.55	1.38	0.88	20	1.56	-7.1%
55.01	4371	20	1.23	1.19	0.16	1.24	1.24	1.07	0.94	0.59	20	1.24	0.0%
55.02	4371	20	1.32	1.27	0.17	1.32	1.32	1.19	1.03	0.66	20	1.32	0.0%
56.01	4359	20	1.14	1.10	0.17	1.18	1.19	1.08	0.94	0.70	20	1.19	0.8%
56.02	4371	20	3.18	3.09	0.39	3.27	3.27	2.91	2.56	1.73	20	3.27	0.0%
57.01	4433	20	1.16	1.14	0.13	1.16	1.13	0.96	0.86	0.54	20	1.13	-2.6%
57.02	4433	20	1.98	1.96	0.21	1.99	2.03	1.77	1.57	1.01	20	2.03	2.0%
58.01	4433	20	2.37	2.32	0.27	2.36	2.40	2.18	1.92	1.25	20	2.40	1.7%
58.02	4371	20	2.87	2.82	0.28	2.88	2.88	2.79	2.45	1.61	20	2.88	0.0%
59.01	4528	45	0.51	0.51	0.04	0.51	0.42	0.56	0.52	0.40	45	0.56	9.8%
60.01	4359	20	1.10	1.08	0.18	1.12	1.13	1.08	0.96	0.86	20	1.13	0.9%
60.02	4371	20	1.60	1.54	0.22	1.64	1.64	1.53	1.32	1.15	20	1.64	0.0%
60.03	4371	20	3.01	2.89	0.40	3.04	3.04	2.71	2.35	1.82	20	3.04	0.0%
60.04	4464	25	5.99	6.04	0.56	5.95	5.57	6.20	5.37	3.82	45	6.20	4.2%
60.05	4394	25	6.62	6.67	0.58	6.58	6.08	6.84	6.17	4.29	45	6.84	4.0%
61.01	4371	20	1.29	1.25	0.17	1.30	1.30	1.09	0.95	0.59	20	1.30	0.0%
62.01	4433	20	1.98	1.92	0.25	1.96	2.03	1.88	1.65	1.10	20	2.03	3.6%
63.01	4433	20	1.77	1.73	0.22	1.77	1.85	1.87	1.59	1.17	45	1.87	5.6%
63.02	4402	30	2.99	2.91	0.32	3.09	2.64	3.30	2.81	2.02	45	3.30	6.8%
63.03	4528	45	3.73	3.74	0.28	3.82	3.37	3.86	3.76	2.69	45	3.86	1.0%
64.01	4371	20	3.09	2.97	0.44	3.04	3.04	2.42	2.11	1.29	20	3.04	0.0%
64.02	4404	20	5.13	4.99	0.55	5.28	4.82	4.66	4.08	2.61	20	4.82	-8.7%
64.03	4404	20	6.32	6.17	0.54	6.43	6.01	5.88	5.13	3.31	20	6.01	-6.5%
65.01	4464	25	0.60	0.59	0.05	0.60	0.58	0.60	0.52	0.35	45	0.60	0.0%
65.02	4427	20	1.60	1.61	0.10	1.60	1.43	1.56	1.34	0.91	45	1.56	-2.5%
66.01	4433	20	1.43	1.40	0.16	1.42	1.37	1.15	1.04	0.65	20	1.37	-3.5%
67.01	4588	90	1.53	1.52	0.16	1.53	1.26	1.56	1.53	1.35	45	1.56	2.0%
67.02	4532	90	3.16	3.22	0.26	3.20	2.22	3.03	3.10	2.84	60	3.10	-3.1%
67.03	4532	90	3.74	3.76	0.36	3.74	3.00	3.57	3.76	3.35	60	3.76	0.5%
67.04	4405	60	4.49	4.50	0.35	4.54	4.05	4.62	4.62	4.01	45	4.62	1.8%
67.05	4528	45	5.54	5.56	0.38	5.70	4.99	5.92	5.63	4.76	45	5.92	3.9%
68.01	4464	25	0.90	0.89	0.06	0.90	0.87	0.89	0.78	0.52	45	0.89	-1.1%
69.01	4502	30	0.97	0.97	0.07	0.98	0.83	1.04	0.89	0.62	45	1.04	6.1%
70.01	4371	20	1.53	1.48	0.20	1.56	1.56	1.39	1.21	0.79	20	1.56	0.0%
70.02	4429	20	3.58	3.50	0.32	3.56	3.40	3.26	2.84	1.82	20	3.40	-4.5%
70.03	4429	20	6.86	6.78	0.50	6.90	6.38	6.29	5.76	3.66	20	6.38	-7.5%
71.01	4399	20	2.16	2.16	0.16	2.17	1.93	1.78	1.62	1.00	20	1.93	-11.1%
72.01	4367	20	1.58	1.56	0.26	1.60	1.62	1.51	1.29	1.03	20	1.62	1.3%
BasinA	4427	20	3.72	3.77	0.11	3.74	3.45	3.45	3.23	2.26	20	3.45	-7.8%
BasinBC	4528	45	7.95	7.95	0.75	8.05	6.75	8.74	7.79	5.80	45	8.74	8.6%
BasinE	4558	60	4.03	4.02	0.35	4.05	2.33	3.95	4.25	3.35	60	4.25	4.9%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns ("Actual" Results)						Peak Discharge for the "Adopted" Set of Durations and Temporal Patterns (m3/s)				ARR2016 Results ("Adopted" Results)		
	Adopted Temp. Pattern	Critical Duration (mins)	Discharge (m^3/s)				TP 4371 for the 20 minute duration	TP 4533 for the 45 minute duration	TP 4559 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
			Average	Median	Standard Dev	Adopted							
BasinF	4558	60	9.90	9.81	0.82	9.82	6.20	10.00	10.40	8.59	60	10.40	5.9%
BasinG	4558	60	1.57	1.56	0.06	1.56	1.21	1.55	1.61	1.46	60	1.61	3.2%

Average Difference (All Subcatchments)		**0.69%**
Average Difference (Focus Locations)		**-0.34%**
Average Difference (Whites Creek)		**1.64%**
Average Difference (Willow Tributary)		**3.45%**

ARR2016 Results for the PMF

Subcatch ID	Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	240 min	300 min	360 min
1.01	1.63	**2.04**	1.98	1.88	1.69	1.52	1.23	1.08	0.97	0.88
1.02	2.81	3.73	**3.80**	3.61	3.32	2.99	2.44	2.14	1.92	1.73
1.03	9.87	14.74	**16.12**	15.69	14.91	13.62	11.41	9.86	8.76	7.86
1.04	27.97	38.15	**40.54**	38.95	37.28	33.82	28.20	24.39	21.68	19.50
1.05	65.69	95.87	**103.74**	101.47	96.23	89.34	74.25	64.35	57.10	51.37
1.06	70.26	103.66	**116.52**	116.12	112.28	105.02	87.92	76.67	67.97	60.97
1.07	70.52	104.08	117.39	**117.49**	113.86	106.57	89.33	77.94	69.09	61.96
1.08	107.91	181.89	**209.39**	206.96	201.81	187.48	157.60	137.53	121.41	107.71
1.09	111.94	188.62	220.62	**221.79**	219.38	203.51	172.45	150.84	133.28	118.17
1.1	112.82	190.09	223.31	**226.06**	224.58	208.22	177.00	154.80	136.90	121.35
1.11	114.15	192.72	228.94	235.77	**236.44**	219.23	187.42	164.14	145.29	128.73
1.12	114.37	193.10	229.88	237.77	**239.51**	222.09	190.16	166.62	147.60	130.77
1.13	115.40	194.74	232.86	242.88	**246.72**	229.14	196.66	172.42	152.96	135.49
1.14	115.72	195.35	234.15	245.88	**252.19**	235.07	201.84	177.30	157.59	139.56
1.15	115.85	195.61	234.74	247.55	**256.29**	239.76	205.89	181.18	161.35	142.87
1.16	116.66	196.87	236.72	251.81	**265.00**	250.15	215.43	189.96	169.41	150.18
1.17	116.75	197.06	237.07	252.74	**268.48**	254.67	219.55	193.93	173.09	153.49
1.18	117.37	198.38	240.36	262.22	**286.60**	275.08	238.38	211.15	188.95	167.68
1.19	117.52	198.70	240.91	263.50	**290.73**	280.49	243.44	215.97	193.41	171.73
1.2	117.66	199.00	241.43	264.71	**296.56**	289.44	252.39	224.89	200.97	178.97
1.21	118.02	199.54	242.18	265.88	**300.88**	296.25	259.52	231.91	206.82	184.65
1.22	118.02	199.54	242.18	265.88	**300.92**	296.33	259.61	231.99	206.90	184.73
1.23	147.34	205.65	253.80	294.44	357.75	**363.71**	322.90	291.20	260.51	233.32
1.24	150.54	208.83	254.84	296.36	363.97	**373.75**	333.85	301.79	270.22	242.17
1.25	151.72	210.55	255.25	297.15	366.13	**379.12**	340.74	308.33	276.79	247.80
1.26	176.45	254.94	309.67	332.22	403.30	**434.12**	400.37	364.61	329.62	295.26
1.27	176.82	255.58	311.10	334.96	404.41	**438.05**	407.30	371.38	336.46	301.30
1.28	177.08	255.95	311.76	335.97	404.88	**439.38**	409.94	373.98	338.94	303.76
1.29	178.79	258.93	316.52	343.24	408.12	**448.98**	425.63	389.28	354.21	317.49
1.3	179.46	260.29	318.87	347.62	409.92	**456.90**	443.41	407.00	370.85	334.66
1.31	184.57	268.54	329.97	362.03	417.56	**471.85**	465.69	429.26	391.74	354.44
1.32	184.90	269.05	330.75	363.32	419.80	475.14	**477.16**	442.55	404.16	366.53
2.01	4.18	6.50	**7.19**	6.89	6.68	6.11	5.10	4.40	3.90	3.49
3.01	9.00	12.38	**12.46**	11.83	11.00	10.02	8.12	7.08	6.32	5.70
4.01	4.36	**5.25**	5.09	4.83	4.35	3.87	3.16	2.76	2.53	2.27
5.01	6.73	**7.82**	7.43	7.01	6.27	5.56	4.54	4.00	3.59	3.25
6.01	6.52	9.90	**10.69**	10.24	9.78	8.85	7.33	6.35	5.64	5.08
6.02	6.95	10.87	**12.09**	11.99	11.50	10.52	8.76	7.58	6.72	6.04
6.03	19.57	24.08	**25.33**	25.28	24.33	22.48	18.90	16.35	14.42	12.91
7.01	10.40	**10.40**	10.27	9.18	7.96	7.04	5.88	5.29	4.75	4.25
8.01	11.35	**12.74**	12.53	11.63	10.21	9.02	7.35	6.57	5.96	5.36
8.02	29.43	39.97	**42.70**	39.67	37.08	33.00	26.85	23.65	21.24	19.07
9.01	9.06	**9.55**	9.07	8.23	7.29	6.46	5.33	4.73	4.25	3.83
10.01	**5.43**	5.18	4.70	4.21	3.62	3.25	2.78	2.44	2.17	1.93
11.01	**5.89**	5.21	4.51	3.97	3.61	3.28	2.69	2.32	2.04	1.81
12.01	5.52	7.68	9.22	**9.27**	9.09	8.71	7.31	6.34	5.61	4.97
13.01	**22.99**	22.65	22.03	19.53	17.00	15.04	12.73	11.36	10.18	9.08
13.02	46.12	67.10	**67.56**	64.11	58.64	53.79	43.79	37.78	33.24	29.42
13.03	60.74	95.48	**99.21**	94.87	90.06	82.70	68.04	58.99	51.87	45.87
14.01	**17.00**	15.13	13.33	11.70	10.30	9.60	7.92	6.86	6.05	5.35
15.01	**29.75**	28.04	27.95	25.66	22.28	19.64	16.14	14.69	13.23	11.84
16.01	**6.54**	5.75	5.04	4.41	3.87	3.62	3.01	2.60	2.30	2.02
17.01	10.03	**11.13**	10.98	10.18	8.91	7.87	6.40	5.73	5.21	4.68

Subcatch ID	Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	240 min	300 min	360 min
17.02	25.96	28.66	**28.86**	28.27	26.94	24.17	19.94	17.19	15.19	13.87
17.03	13.72	27.88	**30.49**	29.81	29.03	26.37	22.06	19.13	16.82	14.88
18.01	16.46	**18.11**	17.74	16.71	14.85	13.10	10.71	9.46	8.68	7.77
19.01	4.14	5.68	**5.82**	5.50	5.22	4.73	3.88	3.36	3.01	2.69
20.01	9.11	**10.24**	9.98	9.48	8.43	7.46	6.09	5.31	4.90	4.39
20.02	13.99	**16.50**	16.41	15.30	13.89	12.44	10.16	8.85	8.10	7.25
21.01	3.42	**3.85**	3.67	3.43	3.10	2.75	2.26	1.99	1.80	1.61
22.01	4.77	6.31	**6.57**	6.34	6.09	5.46	4.50	3.88	3.46	3.09
22.02	5.74	7.05	**7.30**	7.03	6.76	6.09	5.03	4.34	3.87	3.46
23.01	9.73	**10.67**	10.03	9.37	8.46	7.47	6.15	5.41	4.90	4.38
24.01	**9.44**	9.32	8.71	7.85	6.92	6.13	5.12	4.53	4.08	3.64
25.01	**5.36**	4.53	3.88	3.42	3.12	2.82	2.32	1.99	1.76	1.55
25.02	**7.78**	7.12	6.27	5.59	5.01	4.49	3.68	3.20	2.88	2.54
26.01	7.84	**8.44**	8.22	7.48	6.62	5.83	4.80	4.27	3.89	3.47
27.01	5.41	**5.81**	5.66	5.11	4.48	3.96	3.26	2.94	2.65	2.37
27.02	12.85	**15.07**	14.37	13.33	11.83	10.54	8.77	7.79	6.94	6.19
27.03	20.54	**24.04**	23.60	22.21	19.84	17.74	14.69	12.93	11.52	10.42
27.04	23.60	27.93	**28.13**	26.69	24.11	21.65	17.91	15.70	14.05	12.66
28.01	**4.73**	4.49	4.05	3.60	3.10	2.78	2.38	2.09	1.86	1.65
29.01	6.95	**7.32**	6.98	6.31	5.52	4.90	4.04	3.60	3.25	2.92
30.01	4.51	**4.65**	4.52	4.06	3.58	3.16	2.61	2.35	2.13	1.89
31.01	5.72	**5.99**	5.69	5.15	4.60	4.06	3.36	2.97	2.69	2.41
31.02	6.29	**7.01**	6.72	6.18	5.49	4.89	4.03	3.56	3.21	2.88
32.01	7.92	**9.01**	8.94	8.41	7.40	6.54	5.31	4.70	4.30	3.88
32.02	15.28	**17.55**	17.21	16.16	14.30	12.67	10.32	9.09	8.31	7.49
33.01	6.80	**7.84**	7.58	7.14	6.33	5.59	4.56	4.01	3.66	3.30
34.01	**4.13**	3.60	3.86	3.85	3.82	3.54	2.91	2.51	2.21	1.97
34.02	**5.20**	4.28	4.49	4.56	4.51	4.29	3.68	3.31	2.99	2.71
35.01	**5.94**	5.64	5.09	4.53	3.88	3.54	3.02	2.64	2.34	2.08
35.02	**6.60**	6.25	5.67	5.08	4.36	3.97	3.38	2.96	2.63	2.33
36.01	**16.21**	16.03	15.52	13.82	12.00	10.62	8.99	8.01	7.17	6.39
36.02	19.95	**24.07**	23.23	21.44	19.15	17.06	14.22	12.58	11.22	9.98
36.03	20.17	**24.60**	24.29	22.57	20.31	18.07	15.10	13.33	11.89	10.57
36.04	33.32	41.79	**44.75**	43.32	40.55	36.27	30.09	26.42	23.52	20.92
36.05	63.74	83.36	**94.67**	94.66	91.63	83.71	70.11	60.94	54.58	48.54
37.01	8.06	**9.69**	9.56	9.17	8.28	7.45	6.05	5.26	4.76	4.31
37.02	14.37	18.76	**19.82**	18.98	18.13	16.15	13.30	11.52	10.31	9.27
38.01	7.53	**9.76**	9.57	9.05	8.29	7.53	6.12	5.34	4.79	4.30
38.02	11.58	16.70	**17.78**	16.92	16.05	14.37	11.80	10.26	9.18	8.24
38.03	11.73	17.08	**18.40**	17.67	16.75	15.05	12.41	10.78	9.65	8.65
38.04	23.38	30.76	**32.78**	31.51	30.46	27.76	23.06	19.96	17.86	15.95
38.05	27.52	36.32	**39.35**	39.00	37.87	34.84	29.14	25.30	22.59	20.14
39.01	3.64	**3.84**	3.76	3.44	3.05	2.69	2.21	1.97	1.79	1.60
39.02	13.08	**14.72**	14.24	13.56	12.30	11.01	8.95	7.81	7.15	6.44
40.01	6.33	**7.79**	7.67	7.34	6.66	5.96	4.84	4.22	3.81	3.46
41.01	5.27	**5.98**	5.80	5.49	4.89	4.32	3.54	3.11	2.86	2.56
42.01	**4.34**	4.14	3.92	3.48	3.03	2.68	2.29	2.03	1.82	1.61
42.02	8.96	**10.22**	9.60	9.22	8.15	7.21	5.94	5.25	4.74	4.25
43.01	7.29	**7.80**	7.69	7.04	6.19	5.46	4.47	4.02	3.66	3.26
44.01	2.69	**2.77**	2.77	2.53	2.19	1.93	1.57	1.44	1.30	1.16
44.02	9.74	11.76	**11.83**	11.29	10.11	9.12	7.39	6.46	5.89	5.33
45.01	5.07	**5.94**	5.82	5.58	4.91	4.36	3.54	3.13	2.87	2.59
46.01	5.70	**6.28**	6.14	5.62	4.94	4.37	3.58	3.19	2.89	2.60
47.01	10.62	**13.85**	13.58	12.90	11.68	10.61	8.58	7.52	6.73	6.09
47.02	14.90	21.00	**22.30**	21.30	19.86	17.81	14.55	12.71	11.36	10.26

Subcatch ID	Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	240 min	300 min	360 min
47.03	14.94	21.19	**22.59**	21.59	20.14	18.08	14.78	12.91	11.53	10.42
47.04	17.40	26.34	**29.56**	29.17	27.72	25.08	20.65	17.98	16.01	14.45
47.05	33.17	45.31	**50.31**	49.97	47.92	44.47	36.90	32.00	28.49	25.60
47.06	34.95	50.03	55.82	**56.38**	54.20	50.68	42.09	36.47	32.42	29.10
47.07	49.36	66.43	**73.77**	73.39	70.86	66.25	55.70	48.36	42.91	38.55
47.08	49.86	67.23	**75.06**	74.69	72.34	67.67	56.97	49.53	43.93	39.46
47.09	51.02	69.95	**78.01**	77.59	75.43	70.65	59.69	51.95	46.06	41.35
47.1	54.55	78.33	86.50	**87.66**	85.18	80.08	67.95	59.36	52.56	47.15
47.11	55.92	81.21	89.62	**91.82**	89.70	84.41	71.68	62.81	55.59	49.84
48.01	4.09	**4.15**	3.99	3.57	3.10	2.75	2.29	2.06	1.85	1.65
49.01	**4.07**	3.88	3.52	3.15	2.71	2.41	2.08	1.83	1.63	1.45
49.02	**6.69**	6.54	5.97	5.49	4.75	4.22	3.57	3.18	2.84	2.53
49.03	10.55	**11.21**	10.64	9.65	8.66	7.68	6.40	5.67	5.10	4.57
49.04	11.92	**13.24**	12.75	11.62	10.48	9.32	7.70	6.85	6.16	5.53
50.01	3.96	5.53	**5.55**	5.28	4.86	4.39	3.57	3.10	2.78	2.54
51.01	**4.62**	4.57	4.44	3.94	3.27	2.90	2.41	2.17	1.95	1.74
52.01	3.37	**3.58**	3.47	3.14	2.75	2.44	2.00	1.80	1.63	1.46
53.01	**2.80**	2.69	2.58	2.27	1.99	1.76	1.50	1.33	1.20	1.06
53.02	6.22	**6.80**	6.36	5.98	5.29	4.67	3.88	3.43	3.07	2.75
53.03	14.29	**15.65**	14.83	13.75	12.20	10.82	8.98	7.90	7.14	6.39
54.01	**1.54**	1.43	1.29	1.14	0.99	0.88	0.76	0.67	0.60	0.53
54.02	6.86	**7.25**	6.97	6.34	5.58	4.93	4.11	3.63	3.29	2.94
55.01	4.19	**4.47**	4.40	4.00	3.50	3.09	2.53	2.29	2.07	1.85
55.02	4.68	**4.97**	4.85	4.40	3.89	3.44	2.82	2.55	2.29	2.05
56.01	3.71	4.52	**4.62**	4.47	4.23	3.81	3.09	2.69	2.39	2.18
56.02	10.84	**12.30**	11.88	11.32	10.18	9.17	7.39	6.50	5.94	5.40
57.01	4.15	**4.23**	4.03	3.62	3.14	2.80	2.32	2.09	1.87	1.67
57.02	7.15	**7.69**	7.35	6.64	5.90	5.23	4.31	3.84	3.47	3.12
58.01	8.24	**9.31**	9.14	8.45	7.42	6.56	5.36	4.76	4.33	3.89
58.02	10.67	**12.08**	11.75	10.84	9.63	8.53	6.96	6.17	5.60	5.04
59.01	1.61	2.53	**2.80**	2.69	2.61	2.38	1.98	1.71	1.52	1.36
60.01	3.53	4.40	5.32	**5.56**	5.47	5.29	4.40	3.88	3.41	3.04
60.02	5.66	6.30	6.92	**6.98**	6.88	6.66	5.58	4.92	4.32	3.85
60.03	10.49	**11.16**	10.79	10.49	10.52	9.98	8.35	7.32	6.43	5.72
60.04	23.22	**25.91**	25.10	23.45	21.64	20.01	17.04	14.88	13.07	11.73
60.05	25.62	**29.48**	29.04	27.21	25.03	23.01	19.44	17.06	14.99	13.53
61.01	4.35	**4.56**	4.45	4.00	3.49	3.09	2.53	2.30	2.07	1.85
62.01	6.71	**7.99**	7.77	7.47	6.61	5.85	4.74	4.17	3.81	3.45
63.01	6.00	8.03	**8.09**	7.73	7.06	6.41	5.18	4.51	4.03	3.67
63.02	10.42	13.35	**13.71**	13.25	12.11	11.04	8.95	7.79	6.96	6.33
63.03	12.66	16.27	**17.95**	17.36	16.19	14.90	12.20	10.58	9.45	8.55
64.01	**10.34**	10.23	9.78	8.74	7.53	6.69	5.64	5.03	4.50	4.02
64.02	19.31	**19.79**	18.87	17.21	15.39	13.73	11.19	10.11	9.11	8.20
64.03	24.17	**25.07**	23.69	21.82	19.45	17.33	14.15	12.75	11.46	10.34
65.01	2.23	**2.64**	2.52	2.41	2.14	1.90	1.55	1.36	1.24	1.12
65.02	5.97	**6.37**	6.25	5.93	5.34	4.81	3.88	3.45	3.11	2.83
66.01	5.10	**5.13**	4.86	4.36	3.77	3.36	2.81	2.52	2.25	2.01
67.01	4.38	7.30	8.90	**9.34**	9.13	8.78	7.36	6.51	5.73	5.11
67.02	8.94	14.31	18.27	19.39	**19.87**	19.10	16.43	14.52	12.86	11.45
67.03	10.05	16.07	20.60	22.17	**22.95**	22.00	19.19	16.94	15.05	13.40
67.04	14.35	19.70	23.73	25.62	**26.77**	25.51	22.50	19.95	17.77	15.81
67.05	18.54	24.52	27.33	29.33	**30.55**	29.08	25.74	22.94	20.47	18.22
68.01	3.41	**3.89**	3.72	3.51	3.11	2.76	2.25	1.99	1.80	1.63
69.01	3.79	**4.57**	4.41	4.15	3.72	3.32	2.70	2.39	2.14	1.95
70.01	5.09	**5.72**	5.67	5.33	4.68	4.14	3.37	3.02	2.75	2.47

Subcatch ID	Discharge (m^3/s)									
	15 min	30 min	45 min	60 min	90 min	120 min	180 min	240 min	300 min	360 min
70.02	**13.66**	13.52	12.93	11.92	10.76	9.55	7.80	7.05	6.33	5.70
70.03	27.19	**28.19**	26.79	24.58	21.96	19.62	16.14	14.44	12.97	11.66
71.01	**8.59**	8.14	7.50	6.83	5.88	5.27	4.39	3.90	3.48	3.12
72.01	5.05	6.21	**6.80**	6.64	6.43	5.82	4.79	4.14	3.66	3.29

ARR1987 Results

Subcatch ID	20% AEP Results		5% AEP Results		1% AEP Results	
	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)
1.01	270	0.16	270	0.25	120	0.38
1.02	270	0.31	120	0.47	120	0.71
1.03	360	1.14	270	1.83	120	2.60
1.04	270	3.12	270	4.96	120	6.93
1.05	540	6.56	270	10.97	120	16.53
1.06	540	7.67	270	12.21	120	18.66
1.07	540	7.80	270	12.33	120	18.88
1.08	540	14.06	270	21.97	120	34.12
1.09	540	15.35	270	23.68	120	36.57
1.10	540	15.71	270	24.12	120	37.30
1.11	540	16.55	120	25.23	120	38.77
1.12	540	16.78	120	25.56	120	39.17
1.13	540	17.30	120	26.34	120	40.15
1.14	540	17.76	120	26.92	120	40.88
1.15	540	18.12	120	27.36	120	41.47
1.16	540	18.88	120	28.32	120	42.75
1.17	540	19.18	120	28.69	120	43.24
1.18	540	20.87	360	30.85	120	45.73
1.19	540	21.30	360	31.41	120	46.35
1.20	540	21.95	360	32.26	120	47.20
1.21	540	22.40	360	32.88	120	47.84
1.22	540	22.41	360	32.88	120	47.85
1.23	540	27.82	360	39.92	120	55.82
1.24	540	28.71	360	41.11	120	57.06
1.25	540	29.30	360	41.80	120	57.74
1.26	720	35.34	720	49.09	120	67.42
1.27	720	35.88	720	49.81	120	68.57
1.28	720	36.09	720	50.08	120	69.00
1.29	720	37.35	720	51.78	120	71.73
1.30	540	38.71	360	53.91	120	74.13
1.31	540	41.02	360	57.16	120	78.20
1.32	540	42.07	360	58.61	120	79.89
2.01	360	0.50	270	0.80	270	1.14
3.01	270	0.99	270	1.55	120	2.21
4.01	90	0.50	90	0.76	90	1.11
5.01	270	0.66	120	1.05	120	1.54
6.01	720	0.77	270	1.27	270	1.78
6.02	360	0.91	270	1.41	270	2.01
6.03	120	3.09	120	4.48	120	6.16
7.01	90	1.88	90	2.68	90	3.48

Subcatch ID	20% AEP Results		5% AEP Results		1% AEP Results	
	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)
8.01	90	1.71	90	2.57	90	3.49
8.02	60	4.82	90	6.88	90	9.47
9.01	120	0.84	120	1.41	120	2.13
10.01	90	0.73	90	1.16	90	1.51
11.01	90	1.03	90	1.37	90	1.69
12.01	90	0.82	90	1.18	90	1.63
13.01	90	3.95	90	5.60	90	7.30
13.02	120	6.04	120	9.41	120	12.80
13.03	120	7.98	120	12.24	120	17.21
14.01	90	2.75	90	3.81	90	4.71
15.01	25	5.90	90	8.02	90	10.08
16.01	90	0.93	90	1.30	90	1.64
17.01	90	1.65	90	2.45	90	3.29
17.02	90	5.08	90	7.14	90	9.26
17.03	540	1.94	120	2.73	270	4.51
18.01	90	2.32	90	3.43	90	4.62
19.01	270	0.38	270	0.64	120	0.89
20.01	90	1.31	90	1.94	90	2.60
20.02	90	1.64	90	2.59	90	3.64
21.01	270	0.29	120	0.45	120	0.69
22.01	90	0.70	90	1.00	90	1.39
22.02	90	0.77	90	1.14	90	1.58
23.01	270	0.82	120	1.30	120	1.96
24.01	120	0.77	120	1.27	120	1.93
25.01	90	0.70	90	1.00	90	1.25
25.02	90	0.92	120	1.34	120	1.75
26.01	90	0.97	90	1.50	90	2.06
27.01	90	0.73	90	1.14	90	1.57
27.02	90	1.91	90	2.91	90	3.91
27.03	120	2.81	120	4.42	120	6.12
27.04	120	3.21	120	5.03	120	6.94
28.01	90	0.70	90	1.03	90	1.36
29.01	120	0.68	120	1.16	120	1.70
30.01	90	0.56	90	0.84	90	1.20
31.01	120	0.49	120	0.84	120	1.23
31.02	120	0.57	120	0.94	120	1.41
32.01	90	1.24	90	1.87	90	2.52
32.02	90	2.09	90	3.24	90	4.44
33.01	90	0.79	90	1.29	90	1.82
34.01	25	0.84	90	1.12	90	1.42
34.02	20	1.02	20	1.35	90	1.68
35.01	90	1.12	90	1.52	90	1.89
35.02	90	1.22	90	1.69	90	2.12

Subcatch ID	20% AEP Results		5% AEP Results		1% AEP Results	
	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)
36.01	90	2.65	90	3.85	90	5.01
36.02	90	3.21	90	4.73	90	6.26
36.03	90	3.29	90	4.83	90	6.40
36.04	60	4.63	90	6.92	90	9.48
36.05	60	8.91	120	13.22	120	18.49
37.01	90	1.20	90	1.75	90	2.36
37.02	25	2.05	120	3.02	120	4.12
38.01	270	0.75	270	1.16	120	1.65
38.02	270	1.41	270	2.14	120	2.88
38.03	270	1.45	270	2.21	120	2.99
38.04	90	2.98	90	4.45	90	6.27
38.05	90	3.57	90	5.39	90	7.67
39.01	90	0.46	90	0.68	90	0.93
39.02	90	1.71	90	2.47	90	3.35
40.01	90	0.91	90	1.32	90	1.82
41.01	90	0.71	90	1.04	90	1.45
42.01	90	0.66	90	0.92	90	1.19
42.02	25	1.36	25	1.85	120	2.44
43.01	90	1.13	90	1.62	90	2.18
44.01	90	0.52	90	0.74	90	0.95
44.02	120	1.53	90	2.20	90	3.01
45.01	90	0.82	90	1.19	90	1.64
46.01	90	0.67	90	1.09	90	1.55
47.01	270	1.15	270	1.73	120	2.56
47.02	270	1.82	270	2.82	120	4.02
47.03	270	1.84	270	2.85	120	4.06
47.04	270	2.44	270	3.74	120	5.27
47.05	120	4.61	120	6.96	90	9.95
47.06	120	5.38	120	8.11	120	11.39
47.07	120	7.22	120	11.12	120	15.60
47.08	120	7.37	120	11.35	120	15.90
47.09	120	7.71	120	11.82	120	16.50
47.10	120	8.67	120	13.19	120	18.32
47.11	120	9.10	120	13.84	120	19.22
48.01	90	0.61	90	0.90	90	1.24
49.01	90	0.65	90	0.92	90	1.18
49.02	90	1.01	90	1.48	90	1.92
49.03	120	1.41	120	2.11	120	2.89
49.04	120	1.54	120	2.34	120	3.25
50.01	90	0.64	90	0.92	90	1.29
51.01	90	0.71	90	1.00	90	1.34
52.01	90	0.44	90	0.66	90	0.94
53.01	90	0.42	90	0.62	90	0.80

Subcatch ID	20% AEP Results		5% AEP Results		1% AEP Results	
	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)
53.02	120	0.71	120	1.08	120	1.56
53.03	120	1.57	120	2.48	120	3.54
54.01	90	0.23	90	0.32	90	0.42
54.02	90	0.76	120	1.20	120	1.67
55.01	90	0.61	90	0.92	90	1.29
55.02	90	0.65	90	0.98	90	1.38
56.01	90	0.68	90	0.96	90	1.25
56.02	90	1.72	90	2.49	90	3.36
57.01	90	0.51	90	0.80	90	1.14
57.02	90	1.00	90	1.48	90	2.05
58.01	90	1.12	90	1.72	90	2.42
58.02	90	1.29	90	2.00	90	2.88
59.01	720	0.21	270	0.32	270	0.46
60.01	90	0.68	90	0.97	90	1.26
60.02	90	0.93	90	1.38	90	1.81
60.03	90	1.63	90	2.42	90	3.26
60.04	120	2.98	120	4.61	120	6.45
60.05	120	3.29	120	5.12	120	7.21
61.01	90	0.66	90	0.97	90	1.34
62.01	90	1.00	90	1.52	90	2.09
63.01	90	0.90	90	1.36	90	1.86
63.02	120	1.51	120	2.28	120	3.19
63.03	120	1.93	120	2.89	120	4.04
64.01	90	1.63	90	2.41	90	3.17
64.02	90	2.40	90	3.77	90	5.13
64.03	90	2.85	120	4.61	120	6.40
65.01	90	0.25	90	0.39	90	0.56
65.02	120	0.67	120	1.14	120	1.58
66.01	90	0.61	90	0.99	90	1.38
67.01	720	0.71	360	1.03	270	1.43
67.02	540	1.55	360	2.25	360	3.07
67.03	540	1.82	360	2.61	360	3.55
67.04	540	2.15	360	3.06	270	4.25
67.05	720	2.51	120	3.66	120	5.30
68.01	270	0.33	120	0.54	120	0.83
69.01	270	0.38	120	0.61	120	0.90
70.01	90	0.81	90	1.18	90	1.62
70.02	90	1.60	90	2.53	120	3.50
70.03	120	2.88	120	4.64	120	6.75
71.01	120	0.84	120	1.38	120	1.98
72.01	90	0.97	90	1.35	90	1.81
BasinA	90	2.60	90	3.18	120	3.70
BasinBC	270	3.30	120	5.65	120	8.41

Subcatch ID	20% AEP Results		5% AEP Results		1% AEP Results	
	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)	Critical Duration (mins)	Discharge (m^3/s)
BasinE	540	1.76	360	2.45	270	4.11
BasinF	540	3.72	360	6.04	120	9.44
BasinG	540	0.92	540	1.22	120	1.57

APPENDIX H

SENSITIVITY ANALYSIS



H1. SENSITIVITY ANALYSIS

1.1 Introduction

Hydrologic and hydraulic computer models require the estimation of several parameters that are not necessarily known with a high degree of certainty. Each of these parameters can impact on the results generated by the model.

Typically, hydrologic and hydraulic computer models are calibrated using recorded rainfall, stream flow and/or flood mark information. Calibration is achieved by adjusting the parameters that are not known with a high degree of certainty until the computer models reproduce the recorded flood information.

As discussed in **Appendix B** and **Appendix C**, the XP-RAFTS hydrologic and TUFLOW hydraulic models developed for this study could not be comprehensively calibrated as there was insufficient recorded stream flow information. However, the models were verified against anecdotal information for a flood that occurred in 2016 and were found to provide a reasonable description of historic flood behaviour.

Nevertheless, it is important to understand how any uncertainties in model input parameters may impact on the results produced by the model. Therefore, a sensitivity analysis was undertaken to establish the sensitivity of the results generated by the computer models to changes in model input parameter values.

With the exception of the simulation to assess model sensitivity to no blockage and complete blockage of hydraulic structures, all TUFLOW sensitivity simulations were completed with "design" blockage as well as no blockage of hydraulic structures and the results merged to form a "flood envelope". The outcomes of the sensitivity analysis are provided below.

1.2 Model Parameter Sensitivity

1.2.1 Initial Loss / Antecedent Conditions

An analysis was undertaken for the 1% AEP storm to assess the sensitivity of the results generated by the XP-RAFTS model to variations in antecedent wetness conditions (i.e., the dryness or wetness of the land within the catchment prior to the design storm event). A catchment that has been saturated prior to a major storm will have less capacity to absorb rainfall. Therefore, under wet antecedent conditions, there will be less "loss" of rainfall and consequently more runoff.

The variation in antecedent wetness conditions was represented by modifying the adopted initial rainfall losses in the XP-RAFTS model. Specifically, initial losses were changed from the "design" values of 15mm/1mm (for pervious/impervious areas respectively) to:

- "Wet" catchment: 0mm for pervious and impervious areas; and,
- "Dry" catchment: 20mm for pervious areas and 2mm for impervious areas

The XP-RAFTS model was used to re-simulate the 1% AEP event with the modified initial losses. Peak 1% AEP discharges were extracted from the results of the updated model runs and are summarised at the end of this appendix.

The results of the initial loss sensitivity analysis show that decreasing the initial losses would increase the peak 1% AEP discharges generated by 2.6%, on average. Increasing the initial loss would decrease peak discharge by 1.2% (on average). Therefore, the XP-RAFTS model appears to be relatively insensitive to changes in initial rainfall losses.

The revised 1% AEP flows were also applied to the TUFLOW model to determine the impact that changes to the initial losses would have on "design" 1% AEP flood levels/depths. Flood levels were extracted from the results of the revised modelling and were compared against peak flood levels for "base" design conditions. This allowed water level difference mapping to be prepared showing the magnitude of any change in water levels/depths associated with the change in initial rainfall loss values.

The difference mapping is presented in **Plate H1** and **H2** for the "dry" and "wet" catchment scenarios respectively. Decreases in 1% AEP "design" flood levels are shown in shades of blue and increases in 1% AEP flood levels are shown in shades of yellow/red.

The difference mapping shows that a lower initial loss value will produce increases in 1% AEP flood levels along Whites Creek only (i.e. not along Willow Creek). Increases in peak flood level are typically less than 0.1 metres, however, an increase in peak flood level of 0.2 metres is predicted between the Argyle Street and railway line culverts. Increases in flood level up to 0.15 metres are also predicted upstream of Waite Street and Mack Street.

Conversely, higher initial loss values will generate decreases in 1% AEP water levels that are again concentrated along Whites Creek. Decreases in peak flood level are typically less than 0.05 metres, however decreases up to 0.15 are predicted upstream of Waite Street. Very localised increases in peak flood level up to 0.12 metres are predicted upstream of the Argyle Street culvert.

Overall, it can be concluded that the model is somewhat sensitive to changes in the adopted initial losses along Whites Creek. However, flooding along Willow Creek is not impacted by changes to initial loss values.



Plate H1 Flood level difference map for the "wet" catchment sensitivity simulation



Plate H2 Flood level difference map for the "dry" catchment sensitivity simulation

1.2.2 Continuing Loss Rate

An analysis was also undertaken to assess the sensitivity of the results generated by the XP-RAFTS and TUFLOW models to variations in the adopted continuing loss rates. Accordingly, the continuing loss rates within the models were changed from the "design" values of 2.5 mm/hr (pervious areas) and 0 mm/hr (impervious areas) to:

- Increased Continuing Loss Rates: 3.5mm/hr for pervious areas and 1mm/hr for impervious areas.
- Decreased Continuing Loss Rates: 1.5mm/hr for pervious areas and 0mm/hr for impervious areas.

The XP-RAFTS model was used to re-simulate the 1% AEP event with the modified continuing losses. Peak 1% AEP discharges were extracted from the results of the updated model runs and are summarised at the end of this appendix.

The results show that increasing the continuing loss rates will decrease peak 1% AEP flows by 2.2% (on average) and decreasing the initial loss rates will increase peak 1% AEP flows by 1.6% (on average). Accordingly, the XP-RAFTS model appears to be relatively insensitive to changes in continuing loss rates.

The revised flow estimates were also applied to the TUFLOW model and the updated TUFLOW model was used to re-simulate the 1% AEP flood. Peak flood levels were extracted from the results of the modelling and were used to prepare flood level difference mapping. The difference mapping is presented in **Plate H3** and **H4** for the increased and decreased continuing loss scenarios respectively.

The results of the sensitivity analysis show that the TUFLOW model is relatively insensitive to changes in continuing loss rates. Across the majority of the floodplain, the change in 1% AEP flood levels are predicted to be less than 0.05 metres.

Therefore, it can be concluded that any uncertainties associated with the adopted continuing loss rates are not predicted to have a significant impact on the results generated by the XP-RAFTS or TUFLOW models.



Plate H3 Flood level difference map for the increased continuing loss sensitivity simulation



Plate H4 Flood level difference map for the decreased continuing loss sensitivity simulation

1.2.3 Manning's 'n'

Manning's' 'n' roughness coefficients are one of the primary hydraulic model inputs and calibration parameters. They are used to describe the resistance to flow afforded by different land uses / surfaces across the catchment. However, they can be subject to variability (e.g., vegetation density in the summer would typically be higher than the winter leading to higher Manning's 'n' values). Therefore, additional analyses were completed to quantify the impact that any uncertainties associated with Manning's 'n' roughness values may have on predicted design flood behaviour.

The TUFLOW model was updated to reflect a 20% increase and a 20% decrease in the adopted design Manning's 'n' values and additional 1% AEP simulations were completed with the modified 'n' values. Flood level difference mapping was prepared based on the results of the revised simulations and are presented in **Plate H5** and **Plate H6**.

In general, the changes in 1% AEP flood levels are predicted to be less than 0.1 metres, but localised increases/decreases of up to 0.2 metres are predicted. It is noted that reducing "n" values will typically reduce flood levels. However, there are some areas (e.g. in the vicinity of Argyle Street and within the Moss Vale Golf Club) where the more rapid response of rainfall associated with the lower "n" values is predicted to generate localised increases in flood levels.

As a result, it is considered that the overall model is moderately sensitive to changes in Manning's 'n' values. However, as the TUFLOW model validation (refer discussion in **Appendix C**) indicated that the model provided a reasonable reproduction of historic flood behaviour during the 2016 event it is considered that the adopted Manning's n values are suitable for use in simulating design flood behaviour across the Whites Creek catchment.

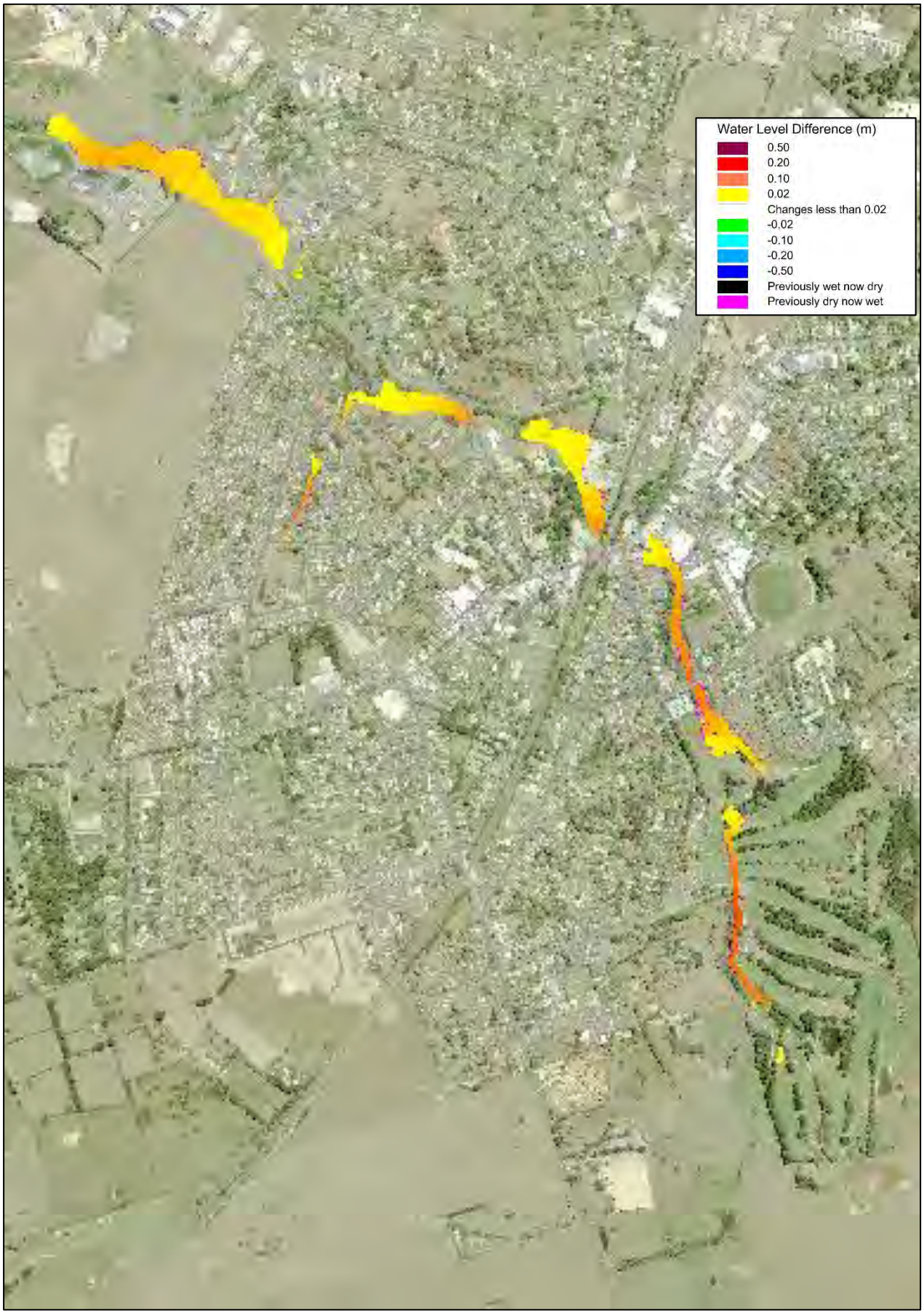


Plate H5 Flood level difference map with increased Manning's "n" roughness values



Plate H6 Flood level difference map with decreased Manning's "n" roughness values

1.2.4 Hydraulic Structure Blockage

As discussed in Section 4.2.4, blockage factors ranging between 0% and 100% were applied to all bridges, culverts and stormwater inlets as part of the design flood simulations. Additional simulations were also completed with no blockage and the results were combined to form the final design flood envelope. However, as it is not known which structures will be subject to what percentage of blockage during any particular flood, additional 1% AEP TUFLOW simulations were completed to determine the impact that alternate blockage scenarios would have on simulated flood behaviour. Specifically, additional simulations were undertaken with no blockage as well as complete blockage of all stormwater inlets, bridges and culverts. Flood level difference mapping was also prepared and is presented in **Plate H7** and **Plate H8**.

Plate H7 shows that no blockage will generally decrease water levels upstream of major hydraulic structures. In general, decreases in 1% AEP flood level are predicted to be less than 0.2 metres. However, decreases in flood level are predicted to range up to 0.5 metres upstream of the Waite Street culvert crossing of Whites Creek and up to 0.3 metres upstream of Campbell Crescent.

Plate H8 shows that complete blockage will cause some significant changes to 1% AEP flood levels. There are predicted to be some commensurate decreases in water level downstream of some significant embankments structures (e.g. downstream of Waite Street) and are associated with the "damming" effect provided by the embankment.

Plate H8 shows that the structures most sensitive to blockage include the culverts at Mack Street, Argyle Street, Lackey Road and Waite Street along Whites Creek and Campbell Crescent on Willow Creek. Peak 1% AEP flood level increases in these areas are predicted to range up to 0.5 metre. Significant increases in peak flood level of up to 0.5 metres are also predicted along the eastern side of the railway line as a result of the blockage of the Spring Street underpass.

Changes to stormwater inlet blockage are not predicted to have a significant impact on 1% AEP water levels across the majority of the urban areas. This is likely associated with the stormwater system only having sufficient capacity to carry a relatively small proportion of the overall flow during a large storm event (such as the 1% AEP flood). Consequently, changes to stormwater inlet blockage generally do not result in a large change in the amount of water travelling overland.

Overall, it is considered that the TUFLOW model is not particularly sensitive to stormwater inlet blockage. However, it should be noted that the stormwater system may convey a significant proportion of flow during more frequent rainfall events. Therefore, it is still important for the stormwater system to be well maintained to ensure it is capable of carrying the majority of flows during these more frequent events.

The results of the blockage sensitivity analysis also show that the model results are sensitive to variations in blockage in the immediate vicinity of major structures, particularly if complete blockage of structures occurs. This outcome emphasises the need to ensure key drainage infrastructure and bridges/culverts are well maintained (i.e., debris is removed on a regular basis).

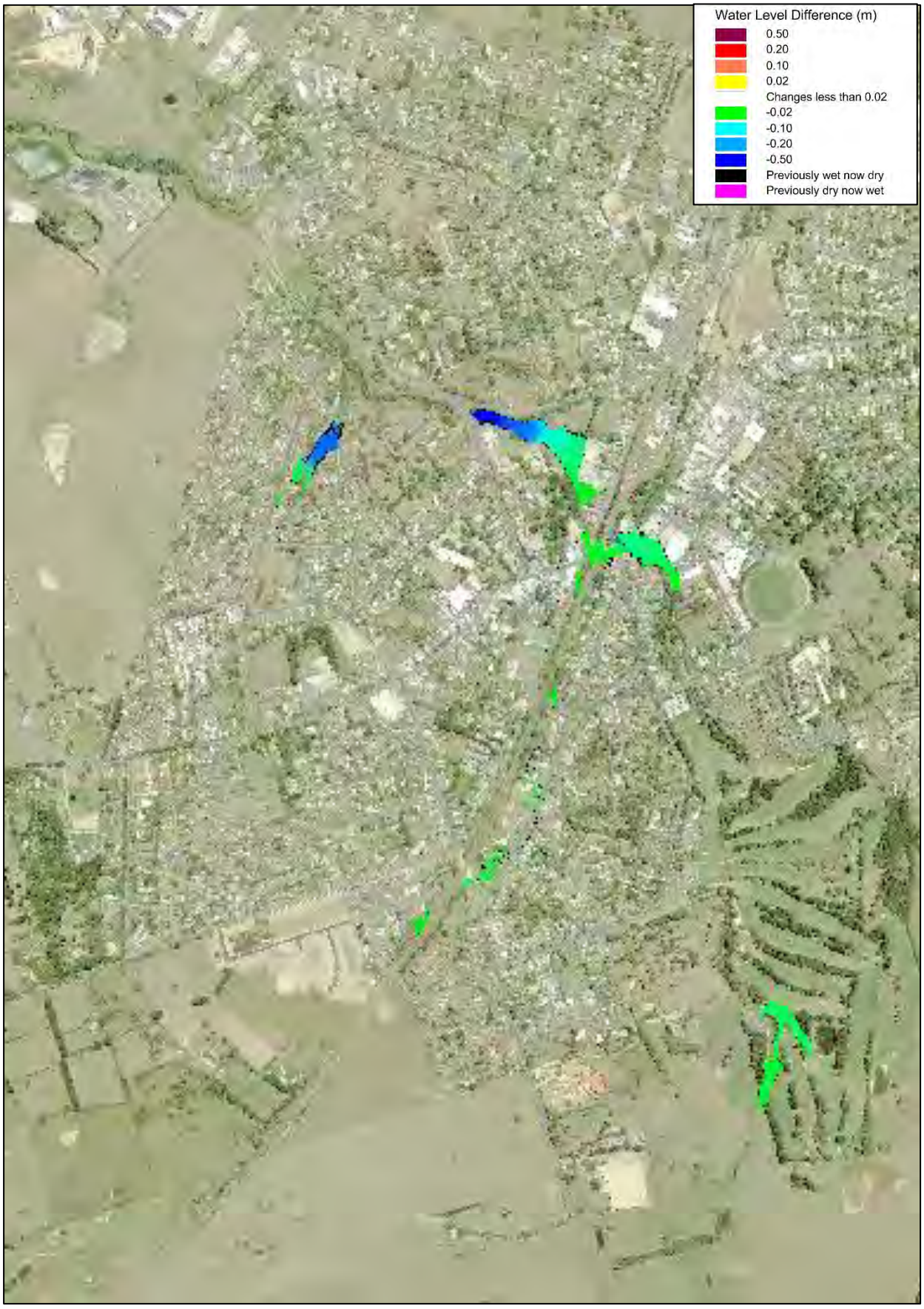


Plate H7 Flood level difference map with no blockage of hydraulic structures

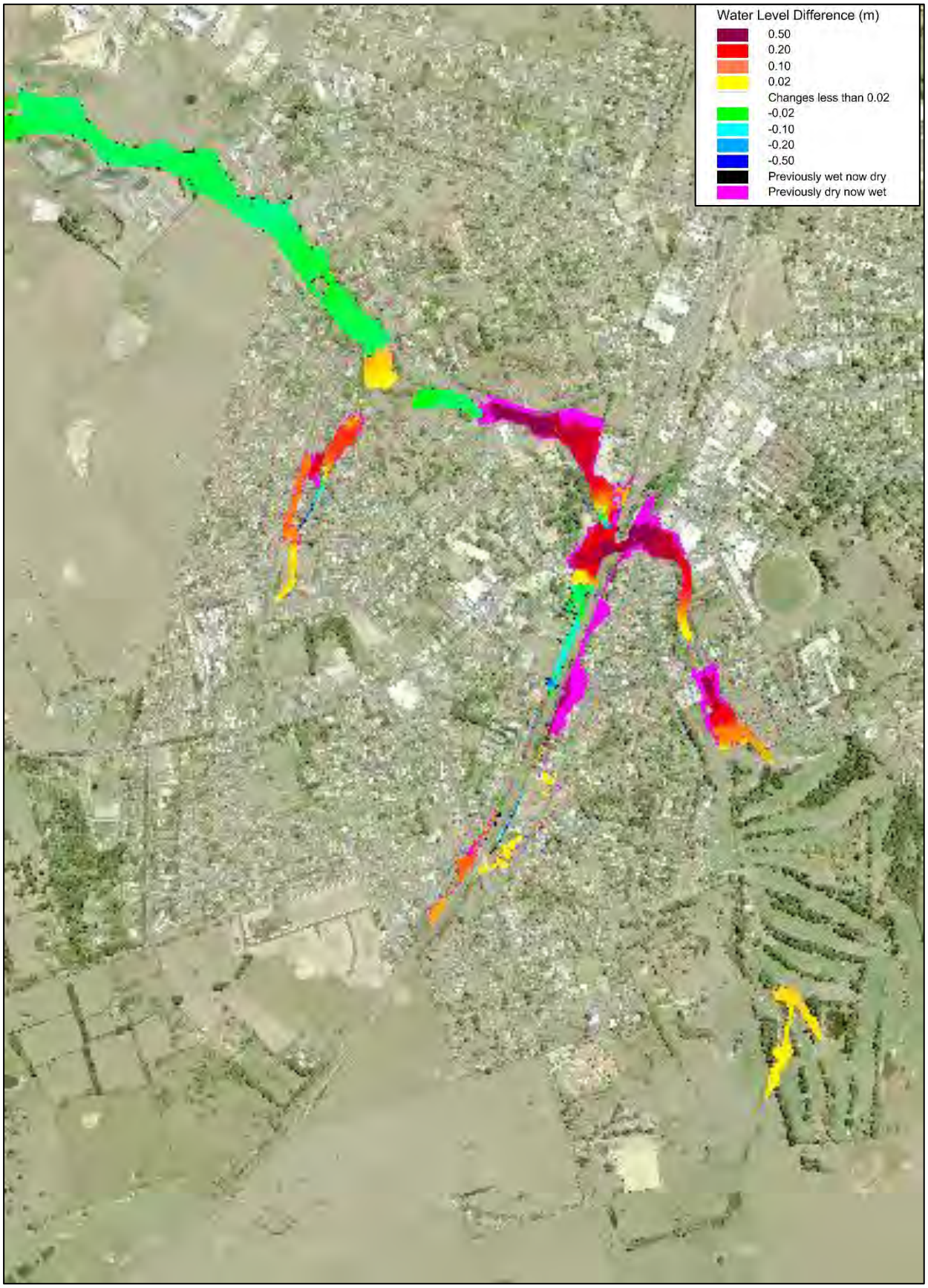


Plate H8 Flood level difference map with complete blockage of hydraulic structures

1.2.5 Downstream Boundary Condition

As discussed in **Appendix C**, the downstream boundary condition was defined using a 'normal depth' calculation. This requires the specification of a channel slope at the downstream model boundary. Therefore, additional sensitivity simulations were completed to see how variations in the downstream channel slope may impact on model results.

The TUFLOW model was updated to reflect a 20% increase and a 20% decrease in the adopted design downstream boundary slope and additional 1% AEP simulations were completed with the modified values. Flood level difference mapping was also prepared.

The difference mapping showed that negligible changes in flood levels are predicted (i.e. changes less than or equal to ±0.03 metres) and that these changes are very localised and are not predicted to extend further than 60 metres from the downstream boundary of the TUFLOW model. Therefore, the results of this analysis indicate that the model is insensitive to changes in the downstream boundary conditions.

1.3 Computer Model Confidence Limits

As discussed, the development of computer models requires the estimation of parameters that are not always known with a high degree of certainty. The computer models that were created as part of this study were developed based upon best estimates of model parameters. The models were subsequently shown to produce realistic results relative to the limited amount of historic flood information that is available. Accordingly, the computer models are considered to provide a reasonable estimate of design flood behaviour across the catchment.

However, the outcomes of the sensitivity analysis indicate that the design flood level estimates may be subject to variations if one or more of the input variables change (e.g., blockage, rainfall losses, hydraulic roughness). Accordingly, the model input parameters and design flood level estimates presented in this report are subject to some uncertainty.

In recognition of this uncertainty, additional statistical analyses were completed based upon the outcomes of the various sensitivity simulations in an attempt to assign "confidence limits" to the peak 1% AEP flood level estimates. In order to reliably define confidence limits to the 1% AEP results, it would be necessary to undertake thousands (potentially tens of thousands) of simulations to reflect the numerous combinations/permutations of potential parameter estimates and provide a sufficiently large population to enable meaningful statistical analysis. Unfortunately, the long simulation times only permit a limited number of parameter scenarios to be investigated.

In instances where a sufficiently large "population" of results is not available, it is still possible to derive confidence limits using the Student's t-test (Zhang, 2013). This approach involves interrogating peak flood level estimates from all 1% AEP simulations at each TUFLOW grid cell. This information is used to calculate a mean water level and standard deviation at each grid cell. This information can then be combined with the population size (i.e., number of different 1% AEP simulations) to develop 99% confidence limit estimates at each TUFLOW grid cell.

The resulting "99% Confidence Limit" grid is shown in **Plate H9**. Yellow colours indicate small confidence limits (i.e., more confidence in results) and magenta colours indicate higher confidence limits (i.e., less confidence in results).



Plate H9 95% Confidence Interval Grid Developed Based Upon Student's t-test

The confidence limit grid shows that the 99% confidence limit is typically less than 0.3 metres across the majority of the catchment. That is. we can be 99% confident that the "correct" 1% AEP flood levels will be contained within ±0.3 metres of the design flood levels shown in **Figures 8.1** to **8.3**. However, there is less confidence in 1% AEP flood level estimates along the eastern

side of the railway line where the 95% confidence interval ranges up to 0.5 metres. The uncertainty at this location is driven primarily by the sensitivity of the results at this location to blockage of the Spring Street underpass (as shown in **Plate H8**).

1.4 Freeboard

Freeboard is a factor of safety that is used to account for uncertainties in computer modelling results. The freeboard is typically used in conjunction with 1% AEP flood level estimates to derive the flood planning level for a particular location.

To assist in the selection of an appropriate freeboard, the 99% confidence limit grid was interrogated. The confidence limit grid (refer **Plate H9**) shows that the model confidence limits across most of the study area is low (i.e. <0.1 metres), indicating a relatively high degree of confidence in the model results. However, confidence limits in the vicinity of major culverts and bridges are higher (i.e., >0.2 metres) indicating reduced confidence in the model results. Therefore, there is a significant amount of spatial variability in the model confidence limits.

Council's current freeboard requirement is 0.5 metres. The 95% confidence interval grid is not predicted to exceed 0.3 metres across the majority of the catchment. A small area to the east of the railway line and upstream of the Spring Street underpass is predicted to have a confidence limit up to 0.5 metres, however this is due to overland flooding and results from complete blockage of the Spring Street underpass. As this underpass is a large structure rather than a culvert crossing, it is unlikely that it would become completely blocked even in major flood events.

Accordingly, the adoption of a 0.5 metre freeboard would make an allowance for modelling uncertainty of up to 0.3 metres and at least a 0.2 metre allowance for areas of "other" uncertainty that cannot be explicitly represented in the modelling (e.g., wind and wave action). Therefore, it is considered that the 0.5 metre freeboard is suitable for application across areas subject to mainstream flooding.

The confidence interval across areas subject to overland flooding (e.g., across the urban areas of the catchment) is generally much lower than along major watercourses and at major hydraulic structures. More specifically, the confidence interval across most urban areas is not predicted to exceed 0.2 metres. This is primarily associated with the comparatively shallow flow depths across most of the urban areas relative to the mainstream areas. Accordingly, a reduced freeboard of 0.3 metres may be suitable across some of the urban areas of the Whites Creek catchment. This will provide a 0.2 metre allowance for modelling uncertainty plus a minimum of a 0.1 metre allowance for other uncertainties. However, considering the reduced degree of confidence in the model results for overland flooding around Spring Street, in particular, it is recommended to apply a uniform 0.5 metre freeboard catchment-wide.

Sensitivity Results

Subcatch ID	Discharge for the 1% AEP TP 4617 for the 2 hour duration (m^3/s)	Lower Continuing Loss		Higher Continuing Loss		Lower Initial Loss		Higher Initial Loss	
		Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)
1.01	0.26	0.26	0.0%	0.25	-3.8%	0.26	0.0%	0.26	0.0%
1.02	0.48	0.49	2.1%	0.47	-2.1%	0.48	0.0%	0.48	0.0%
1.03	1.96	2.00	2.0%	1.91	-2.6%	1.97	0.5%	1.92	-2.0%
1.04	5.21	5.32	2.1%	5.09	-2.3%	5.25	0.8%	5.16	-1.0%
1.05	11.85	12.19	2.9%	11.38	-4.0%	12.67	6.9%	11.31	-4.6%
1.06	13.05	13.42	2.8%	12.53	-4.0%	13.93	6.7%	12.44	-4.7%
1.07	13.16	13.54	2.9%	12.64	-4.0%	14.05	6.8%	12.55	-4.6%
1.08	23.36	23.89	2.3%	22.59	-3.3%	24.85	6.4%	22.44	-3.9%
1.09	25.06	25.64	2.3%	24.25	-3.2%	26.58	6.1%	24.11	-3.8%
1.10	25.43	26.02	2.3%	24.61	-3.2%	26.97	6.1%	24.48	-3.7%
1.11	26.14	26.74	2.3%	25.30	-3.2%	27.71	6.0%	25.19	-3.6%
1.12	26.30	26.91	2.3%	25.44	-3.3%	27.87	6.0%	25.34	-3.7%
1.13	26.75	27.38	2.4%	25.87	-3.3%	28.33	5.9%	25.78	-3.6%
1.14	27.01	27.64	2.3%	26.12	-3.3%	28.58	5.8%	26.02	-3.7%
1.15	27.13	27.78	2.4%	26.23	-3.3%	28.71	5.8%	26.13	-3.7%
1.16	27.52	28.18	2.4%	26.61	-3.3%	29.09	5.7%	26.51	-3.7%
1.17	27.58	28.24	2.4%	26.68	-3.3%	29.18	5.8%	26.58	-3.6%
1.18	28.16	28.88	2.6%	27.21	-3.4%	29.87	6.1%	27.15	-3.6%
1.19	28.29	29.02	2.6%	27.34	-3.4%	30.02	6.1%	27.27	-3.6%
1.20	28.43	29.18	2.6%	27.46	-3.4%	30.18	6.2%	27.39	-3.7%
1.21	28.60	29.37	2.7%	27.61	-3.5%	30.36	6.2%	27.52	-3.8%
1.22	28.60	29.37	2.7%	27.61	-3.5%	30.37	6.2%	27.53	-3.7%
1.23	37.81	38.64	2.2%	36.68	-3.0%	40.67	7.6%	36.02	-4.7%
1.24	39.04	39.91	2.2%	37.87	-3.0%	42.17	8.0%	37.24	-4.6%
1.25	39.58	40.46	2.2%	38.40	-3.0%	43.02	8.7%	37.78	-4.5%
1.26	49.53	50.63	2.2%	48.10	-2.9%	53.40	7.8%	47.40	-4.3%
1.27	49.98	51.09	2.2%	48.53	-2.9%	53.84	7.7%	47.85	-4.3%
1.28	50.18	51.30	2.2%	48.74	-2.9%	54.05	7.7%	48.05	-4.2%
1.29	51.28	52.43	2.2%	49.78	-2.9%	55.43	8.1%	49.14	-4.2%
1.30	52.05	53.24	2.3%	50.53	-2.9%	56.47	8.5%	49.90	-4.1%
1.31	54.55	55.83	2.3%	52.90	-3.0%	59.10	8.3%	52.09	-4.5%
1.32	55.02	56.32	2.4%	53.34	-3.1%	59.59	8.3%	52.54	-4.5%
2.01	0.86	0.88	2.3%	0.83	-3.5%	0.88	2.3%	0.84	-2.3%
3.01	1.61	1.64	1.9%	1.57	-2.5%	1.62	0.6%	1.60	-0.6%
4.01	0.64	0.65	1.6%	0.63	-1.6%	0.64	0.0%	0.64	0.0%
5.01	1.00	1.02	2.0%	0.98	-2.0%	1.00	0.0%	1.00	0.0%
6.01	1.34	1.37	2.2%	1.30	-3.0%	1.36	1.5%	1.32	-1.5%
6.02	1.56	1.59	1.9%	1.52	-2.6%	1.58	1.3%	1.54	-1.3%
6.03	3.69	3.75	1.6%	3.61	-2.2%	3.74	1.4%	3.64	-1.4%
7.01	1.36	1.37	0.7%	1.34	-1.5%	1.36	0.0%	1.36	0.0%
8.01	1.69	1.72	1.8%	1.67	-1.2%	1.69	0.0%	1.69	0.0%
8.02	5.87	5.95	1.4%	5.76	-1.9%	5.87	0.0%	5.87	0.0%
9.01	1.21	1.23	1.7%	1.19	-1.7%	1.20	-0.8%	1.21	0.0%
10.01	0.62	0.63	1.6%	0.61	-1.6%	0.63	1.6%	0.62	0.0%
11.01	0.61	0.61	0.0%	0.60	-1.6%	0.79	29.5%	0.61	0.0%
12.01	1.09	1.12	2.8%	1.06	-2.8%	1.17	7.3%	1.05	-3.7%
13.01	2.85	2.88	1.1%	2.81	-1.4%	2.85	0.0%	2.85	0.0%
13.02	8.20	8.32	1.5%	7.98	-2.7%	8.42	2.7%	8.04	-2.0%
13.03	11.13	11.30	1.5%	10.83	-2.7%	11.55	3.8%	10.84	-2.6%

Subcatch ID	Discharge for the 1% AEP TP 4617 for the 2 hour duration (m^3/s)	Lower Continuing Loss		Higher Continuing Loss		Lower Initial Loss		Higher Initial Loss	
		Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)
14.01	1.73	1.75	1.2%	1.70	-1.7%	2.11	22.0%	1.74	0.6%
15.01	3.75	3.78	0.8%	3.70	-1.3%	3.94	5.1%	3.75	0.0%
16.01	0.60	0.61	1.7%	0.60	0.0%	0.69	15.0%	0.61	1.7%
17.01	1.49	1.51	1.3%	1.47	-1.3%	1.49	0.0%	1.49	0.0%
17.02	4.16	4.22	1.4%	4.07	-2.2%	4.19	0.7%	4.13	-0.7%
17.03	2.70	2.75	1.9%	2.63	-2.6%	2.88	6.7%	2.59	-4.1%
18.01	2.23	2.27	1.8%	2.19	-1.8%	2.23	0.0%	2.23	0.0%
19.01	0.68	0.69	1.5%	0.66	-2.9%	0.68	0.0%	0.67	-1.5%
20.01	1.26	1.28	1.6%	1.24	-1.6%	1.27	0.8%	1.26	0.0%
20.02	1.99	2.01	1.0%	1.94	-2.5%	1.98	-0.5%	1.98	-0.5%
21.01	0.45	0.46	2.2%	0.44	-2.2%	0.45	0.0%	0.45	0.0%
22.01	0.83	0.84	1.2%	0.81	-2.4%	0.83	0.0%	0.82	-1.2%
22.02	0.92	0.94	2.2%	0.90	-2.2%	0.92	0.0%	0.91	-1.1%
23.01	1.24	1.26	1.6%	1.21	-2.4%	1.24	0.0%	1.24	0.0%
24.01	1.07	1.08	0.9%	1.05	-1.9%	1.07	0.0%	1.07	0.0%
25.01	0.47	0.47	0.0%	0.46	-2.1%	0.57	21.3%	0.47	0.0%
25.02	0.76	0.78	2.6%	0.75	-1.3%	0.86	13.2%	0.77	1.3%
26.01	1.03	1.04	1.0%	1.01	-1.9%	1.03	0.0%	1.03	0.0%
27.01	0.75	0.76	1.3%	0.75	0.0%	0.75	0.0%	0.76	1.3%
27.02	1.96	1.99	1.5%	1.92	-2.0%	1.96	0.0%	1.96	0.0%
27.03	3.24	3.29	1.5%	3.18	-1.9%	3.24	0.0%	3.24	0.0%
27.04	3.77	3.83	1.6%	3.70	-1.9%	3.77	0.0%	3.78	0.3%
28.01	0.53	0.54	1.9%	0.53	0.0%	0.53	0.0%	0.53	0.0%
29.01	0.93	0.94	1.1%	0.91	-2.2%	0.92	-1.1%	0.92	-1.1%
30.01	0.55	0.56	1.8%	0.54	-1.8%	0.55	0.0%	0.55	0.0%
31.01	0.72	0.73	1.4%	0.70	-2.8%	0.72	0.0%	0.73	1.4%
31.02	0.83	0.84	1.2%	0.81	-2.4%	0.83	0.0%	0.82	-1.2%
32.01	1.22	1.24	1.6%	1.19	-2.5%	1.22	0.0%	1.22	0.0%
32.02	2.30	2.34	1.7%	2.27	-1.3%	2.31	0.4%	2.31	0.4%
33.01	1.02	1.03	1.0%	1.00	-2.0%	1.01	-1.0%	1.01	-1.0%
34.01	0.57	0.57	0.0%	0.55	-3.5%	0.58	1.8%	0.55	-3.5%
34.02	0.66	0.67	1.5%	0.65	-1.5%	0.68	3.0%	0.64	-3.0%
35.01	0.68	0.69	1.5%	0.67	-1.5%	0.80	17.6%	0.68	0.0%
35.02	0.76	0.77	1.3%	0.75	-1.3%	0.88	15.8%	0.76	0.0%
36.01	2.02	2.04	1.0%	1.99	-1.5%	2.02	0.0%	2.02	0.0%
36.02	3.08	3.10	0.6%	3.03	-1.6%	3.08	0.0%	3.08	0.0%
36.03	3.17	3.20	0.9%	3.12	-1.6%	3.17	0.0%	3.16	-0.3%
36.04	5.61	5.69	1.4%	5.50	-2.0%	5.62	0.2%	5.61	0.0%
36.05	11.99	12.19	1.7%	11.72	-2.3%	12.03	0.3%	11.93	-0.5%
37.01	1.21	1.23	1.7%	1.19	-1.7%	1.22	0.8%	1.22	0.8%
37.02	2.45	2.49	1.6%	2.40	-2.0%	2.46	0.4%	2.45	0.0%
38.01	1.20	1.22	1.7%	1.18	-1.7%	1.21	0.8%	1.20	0.0%
38.02	2.22	2.26	1.8%	2.16	-2.7%	2.22	0.0%	2.21	-0.5%
38.03	2.31	2.35	1.7%	2.26	-2.2%	2.31	0.0%	2.30	-0.4%
38.04	4.20	4.27	1.7%	4.11	-2.1%	4.21	0.2%	4.19	-0.2%
38.05	5.03	5.11	1.6%	4.91	-2.4%	5.04	0.2%	5.00	-0.6%
39.01	0.46	0.47	2.2%	0.45	-2.2%	0.46	0.0%	0.46	0.0%
39.02	1.81	1.84	1.7%	1.78	-1.7%	1.82	0.6%	1.81	0.0%
40.01	0.97	0.98	1.0%	0.95	-2.1%	0.97	0.0%	0.97	0.0%
41.01	0.73	0.75	2.7%	0.73	0.0%	0.73	0.0%	0.73	0.0%
42.01	0.48	0.48	0.0%	0.47	-2.1%	0.48	0.0%	0.48	0.0%

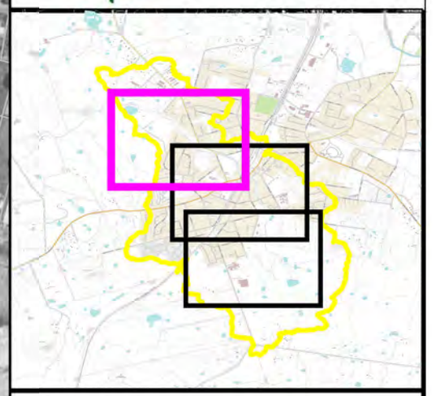
Subcatch ID	Discharge for the 1% AEP TP 4617 for the 2 hour duration (m^3/s)	Lower Continuing Loss		Higher Continuing Loss		Lower Initial Loss		Higher Initial Loss	
		Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)
42.02	1.22	1.24	1.6%	1.21	-0.8%	1.23	0.8%	1.23	0.8%
43.01	0.96	0.97	1.0%	0.94	-2.1%	0.96	0.0%	0.96	0.0%
44.01	0.37	0.37	0.0%	0.37	0.0%	0.37	0.0%	0.37	0.0%
44.02	1.58	1.60	1.3%	1.55	-1.9%	1.58	0.0%	1.57	-0.6%
45.01	0.81	0.82	1.2%	0.80	-1.2%	0.81	0.0%	0.81	0.0%
46.01	0.82	0.83	1.2%	0.80	-2.4%	0.82	0.0%	0.82	0.0%
47.01	1.81	1.84	1.7%	1.77	-2.2%	1.81	0.0%	1.80	-0.6%
47.02	2.86	2.91	1.7%	2.79	-2.4%	2.86	0.0%	2.84	-0.7%
47.03	2.90	2.96	2.1%	2.83	-2.4%	2.90	0.0%	2.89	-0.3%
47.04	3.89	3.98	2.3%	3.80	-2.3%	3.90	0.3%	3.88	-0.3%
47.05	6.86	6.99	1.9%	6.71	-2.2%	6.88	0.3%	6.83	-0.4%
47.06	7.80	7.93	1.7%	7.62	-2.3%	7.81	0.1%	7.76	-0.5%
47.07	10.44	10.63	1.8%	10.20	-2.3%	10.49	0.5%	10.37	-0.7%
47.08	10.64	10.83	1.8%	10.40	-2.3%	10.68	0.4%	10.56	-0.8%
47.09	11.08	11.28	1.8%	10.82	-2.3%	11.12	0.4%	11.00	-0.7%
47.10	12.33	12.56	1.9%	12.04	-2.4%	12.37	0.3%	12.26	-0.6%
47.11	12.82	13.06	1.9%	12.52	-2.3%	12.88	0.5%	12.70	-0.9%
48.01	0.53	0.53	0.0%	0.52	-1.9%	0.53	0.0%	0.53	0.0%
49.01	0.46	0.46	0.0%	0.45	-2.2%	0.46	0.0%	0.46	0.0%
49.02	0.79	0.81	2.5%	0.78	-1.3%	0.80	1.3%	0.80	1.3%
49.03	1.40	1.42	1.4%	1.38	-1.4%	1.41	0.7%	1.40	0.0%
49.04	1.66	1.68	1.2%	1.63	-1.8%	1.66	0.0%	1.66	0.0%
50.01	0.73	0.74	1.4%	0.71	-2.7%	0.73	0.0%	0.73	0.0%
51.01	0.55	0.56	1.8%	0.55	0.0%	0.56	1.8%	0.55	0.0%
52.01	0.46	0.46	0.0%	0.45	-2.2%	0.46	0.0%	0.45	-2.2%
53.01	0.31	0.32	3.2%	0.31	0.0%	0.31	0.0%	0.31	0.0%
53.02	0.81	0.82	1.2%	0.79	-2.5%	0.81	0.0%	0.81	0.0%
53.03	1.87	1.89	1.1%	1.84	-1.6%	1.87	0.0%	1.87	0.0%
54.01	0.16	0.16	0.0%	0.15	-6.3%	0.16	0.0%	0.16	0.0%
54.02	0.87	0.88	1.1%	0.86	-1.1%	0.87	0.0%	0.87	0.0%
55.01	0.59	0.60	1.7%	0.58	-1.7%	0.59	0.0%	0.59	0.0%
55.02	0.65	0.66	1.5%	0.64	-1.5%	0.64	-1.5%	0.65	0.0%
56.01	0.65	0.66	1.5%	0.64	-1.5%	0.65	0.0%	0.65	0.0%
56.02	1.67	1.69	1.2%	1.63	-2.4%	1.67	0.0%	1.66	-0.6%
57.01	0.53	0.54	1.9%	0.52	-1.9%	0.53	0.0%	0.53	0.0%
57.02	0.98	0.99	1.0%	0.97	-1.0%	0.98	0.0%	0.98	0.0%
58.01	1.24	1.25	0.8%	1.21	-2.4%	1.23	-0.8%	1.23	-0.8%
58.02	1.57	1.59	1.3%	1.54	-1.9%	1.57	0.0%	1.57	0.0%
59.01	0.34	0.36	5.9%	0.33	-2.9%	0.35	2.9%	0.34	0.0%
60.01	0.76	0.78	2.6%	0.74	-2.6%	0.79	3.9%	0.71	-6.6%
60.02	1.03	1.03	0.0%	0.99	-3.9%	1.06	2.9%	0.96	-6.8%
60.03	1.68	1.70	1.2%	1.63	-3.0%	1.71	1.8%	1.62	-3.6%
60.04	3.60	3.65	1.4%	3.53	-1.9%	3.66	1.7%	3.55	-1.4%
60.05	4.07	4.13	1.5%	3.99	-2.0%	4.13	1.5%	4.01	-1.5%
61.01	0.58	0.59	1.7%	0.57	-1.7%	0.59	1.7%	0.59	1.7%
62.01	1.07	1.09	1.9%	1.05	-1.9%	1.07	0.0%	1.07	0.0%
63.01	1.11	1.13	1.8%	1.09	-1.8%	1.11	0.0%	1.11	0.0%
63.02	1.90	1.93	1.6%	1.87	-1.6%	1.90	0.0%	1.90	0.0%
63.03	2.45	2.49	1.6%	2.40	-2.0%	2.46	0.4%	2.44	-0.4%
64.01	1.29	1.31	1.6%	1.27	-1.6%	1.29	0.0%	1.29	0.0%
64.02	2.55	2.60	2.0%	2.52	-1.2%	2.56	0.4%	2.55	0.0%

Subcatch ID	Discharge for the 1% AEP TP 4617 for the 2 hour duration (m^3/s)	Lower Continuing Loss		Higher Continuing Loss		Lower Initial Loss		Higher Initial Loss	
		Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)	Discharge (m^3/s)	Difference (%)
64.03	3.26	3.30	1.2%	3.20	-1.8%	3.25	-0.3%	3.25	-0.3%
65.01	0.34	0.34	0.0%	0.33	-2.9%	0.33	-2.9%	0.34	0.0%
65.02	0.88	0.89	1.1%	0.87	-1.1%	0.88	0.0%	0.88	0.0%
66.01	0.64	0.65	1.6%	0.63	-1.6%	0.64	0.0%	0.64	0.0%
67.01	1.13	1.17	3.5%	1.09	-3.5%	1.23	8.8%	1.07	-5.3%
67.02	2.31	2.38	3.0%	2.23	-3.5%	2.48	7.4%	2.20	-4.8%
67.03	2.80	2.88	2.9%	2.72	-2.9%	3.08	10.0%	2.63	-6.1%
67.04	3.47	3.55	2.3%	3.37	-2.9%	3.74	7.8%	3.29	-5.2%
67.05	4.13	4.22	2.2%	4.02	-2.7%	4.43	7.3%	3.92	-5.1%
68.01	0.50	0.51	2.0%	0.49	-2.0%	0.50	0.0%	0.51	2.0%
69.01	0.59	0.60	1.7%	0.58	-1.7%	0.59	0.0%	0.59	0.0%
70.01	0.78	0.79	1.3%	0.76	-2.6%	0.77	-1.3%	0.78	0.0%
70.02	1.80	1.83	1.7%	1.78	-1.1%	1.81	0.6%	1.81	0.6%
70.03	3.60	3.66	1.7%	3.55	-1.4%	3.60	0.0%	3.61	0.3%
71.01	1.00	1.02	2.0%	0.99	-1.0%	1.00	0.0%	1.00	0.0%
72.01	0.94	0.97	3.2%	0.93	-1.1%	0.96	2.1%	0.94	0.0%
BasinA	2.26	2.28	0.9%	2.24	-0.9%	2.27	0.4%	2.26	0.0%
BasinBC	5.18	5.27	1.7%	5.04	-2.7%	5.37	3.7%	5.05	-2.5%
BasinE	2.43	2.47	1.6%	2.36	-2.9%	2.60	7.0%	2.32	-4.5%
BasinF	6.62	6.82	3.0%	6.30	-4.8%	7.31	10.4%	6.16	-6.9%
BasinG	1.27	1.28	0.8%	1.24	-2.4%	1.31	3.1%	1.22	-3.9%

APPENDIX I

NATIONAL HAZARD ASSESSMENT

WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Whites Creek Study Area
- Future Development Area (Elevations Assumed)

Hazard Categories

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, childern and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special design
- H6 - unsafe for people or vehicles. All buildings vulnerable to failure

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:5,000 (at A3)

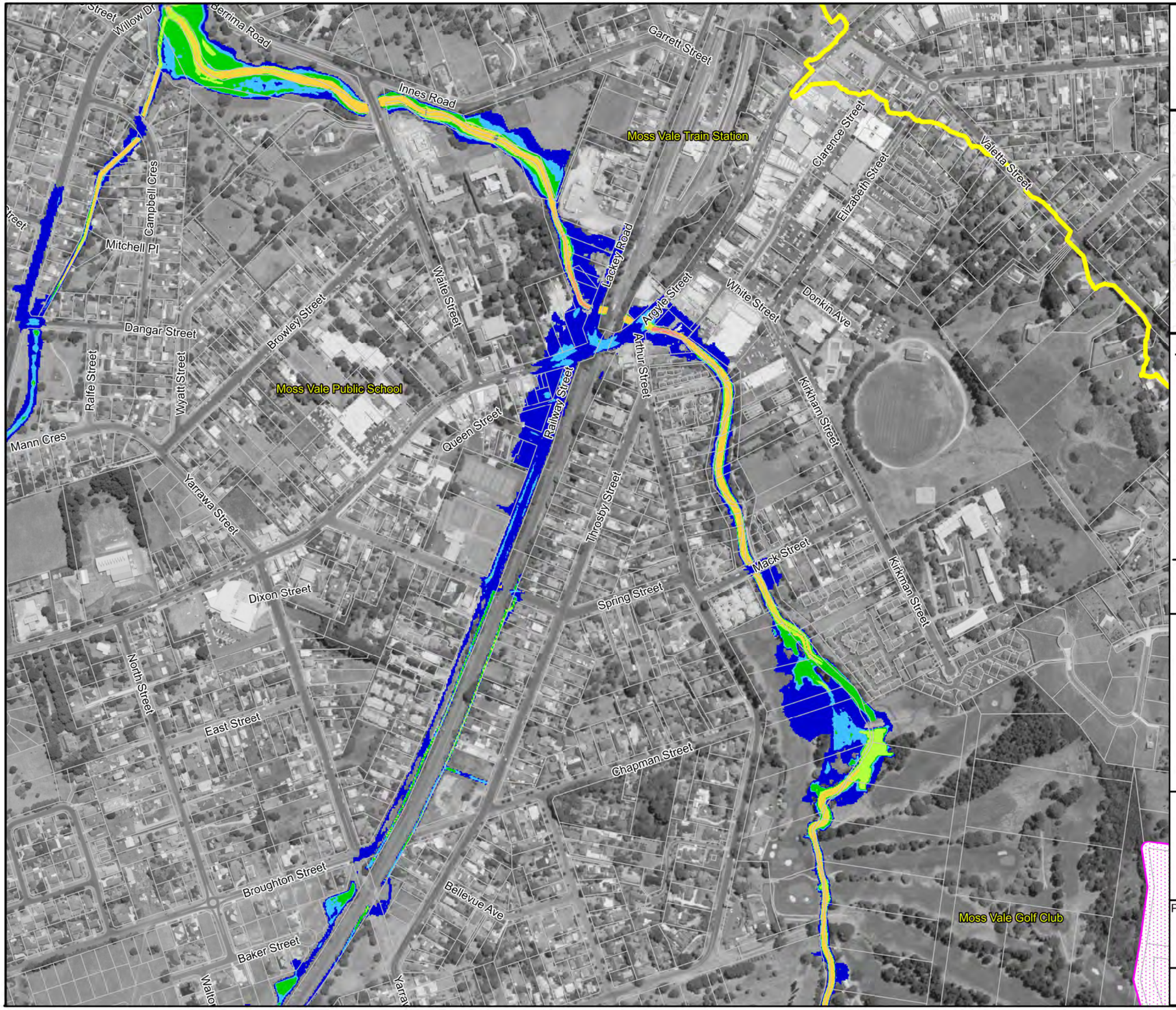
0 0.15 0.30 Km

Figure I1.1: 10% AEP National Flood Hazard

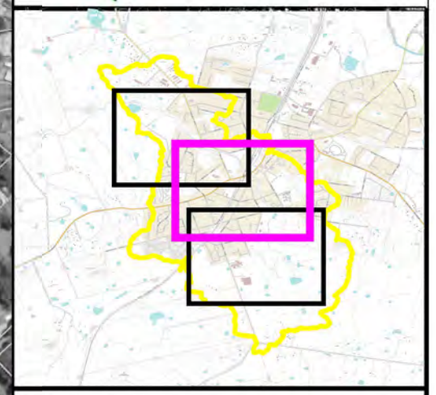
Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig I1.1- 10% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Whites Creek Study Area
- Future Development Area (Elevations Assumed)

Hazard Categories

- H1 - generally safe for people, vehicles and buildings
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- H5 - unsafe for people or vehicles. Buildings require special design
- H6 - unsafe for people or vehicles. All buildings vulnerable to failure

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:5,000 (at A3)

0 0.15 0.30

Km

Figure I1.2: 10% AEP National Flood Hazard

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig I1.2- 10% AEP Flood Hazard.wor

East Street
Throsby Street
Chapman Street
Broughton Street
Bellevue Ave
Moss Vale Golf Club
Baker Street
Walton Pl
Yarrawa Road
Pleasant Ave
Spencer Street
Darraby Dr
Darran Road
Albany Road
Monterey Ave
Lovelle Street
Lansdown Pl
Daylesford Dr
Craig Street
Patuna Ave

Flood behaviour across this area is based upon concept design information which may not reflect the final topography. Therefore, the results shown in this area are preliminary and subject to confirmation once the subdivision is finalised.

WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Whites Creek Study Area
- Future Development Area (Elevations Assumed)

Hazard Categories

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- H5 - unsafe for people or vehicles. Buildings require special design
- H6 - unsafe for people or vehicles. All buildings vulnerable to failure

Notes:

Aerial photograph date: Jan 2009

N
W E
S

Scale 1:5,000 (at A3)

0 0.15 0.30

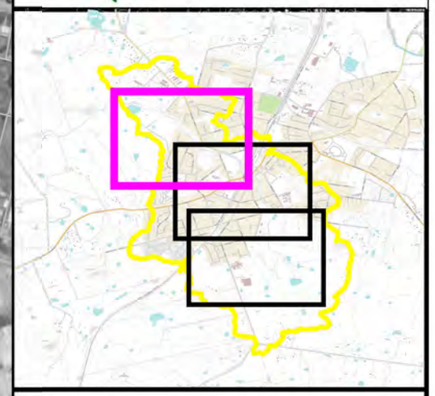
Km

Figure I1.3: 10% AEP National Flood Hazard

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig I1.3- 10% AEP Flood Hazard.wor

WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Whites Creek Study Area
- Future Development Area (Elevations Assumed)

Hazard Categories

- H1 - generally safe for people, vehicles and buildings
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- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special design
- H6 - unsafe for people or vehicles. All buildings vulnerable to failure

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:5,000 (at A3)

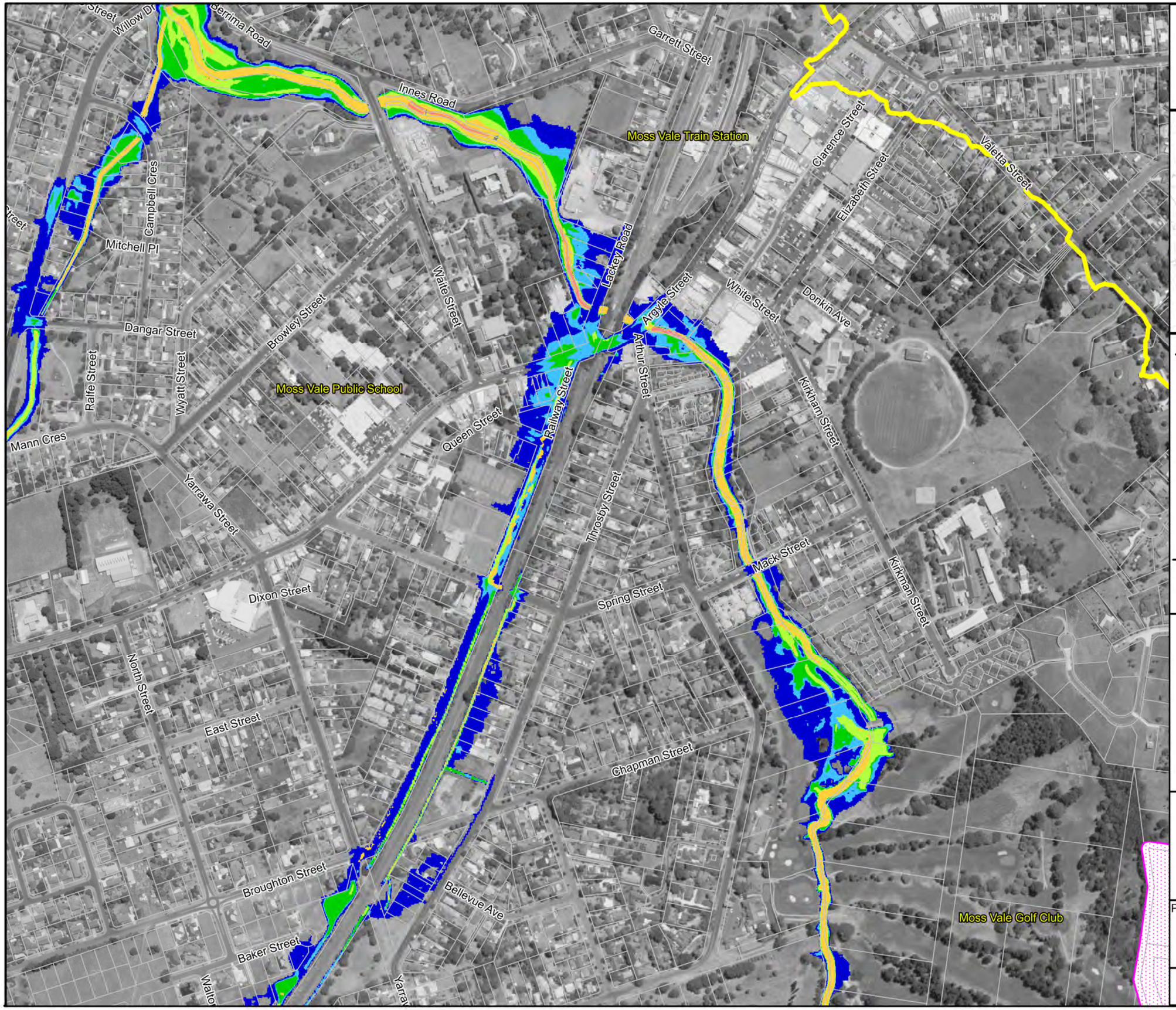
0 0.15 0.30 Km

Figure I2.1: 1% AEP National Flood Hazard

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig I2.1- 1% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Whites Creek Study Area
- Future Development Area (Elevations Assumed)

Hazard Categories

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special design
- H6 - unsafe for people or vehicles. All buildings vulnerable to failure

Notes:

Aerial photograph date: Jan 2009

N W E S

Scale 1:5,000 (at A3)

0 0.15 0.30 Km

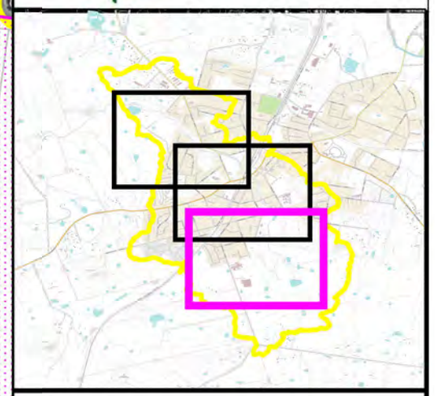
Figure I2.2: 1% AEP National Flood Hazard

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig I2.2- 1% AEP Flood Hazard.wor

East Street
Throsby Street
Chapman Street
Broughton Street
Bellevue Ave
Baker Street
Walton Pl
Yarrawa Road
Pleasant Ave
Spencer Street
Darraby Dr
Darran Road
Albany Road
Monterey Ave
Lovelle Street
Lansdown Pl
Daylesford Dr
Craig Street
Patuna Ave
Moss Vale Golf Club

WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Whites Creek Study Area
- Future Development Area (Elevations Assumed)

Hazard Categories

- H1 - generally safe for people, vehicles and buildings
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- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special design
- H6 - unsafe for people or vehicles. All buildings vulnerable to failure

Notes:

Aerial photograph date: Jan 2009

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Scale 1:5,000 (at A3)

0 0.15 0.30

Km

Flood behaviour across this area is based upon concept design information which may not reflect the final topography. Therefore, the results shown in this area are preliminary and subject to confirmation once the subdivision is finalised.

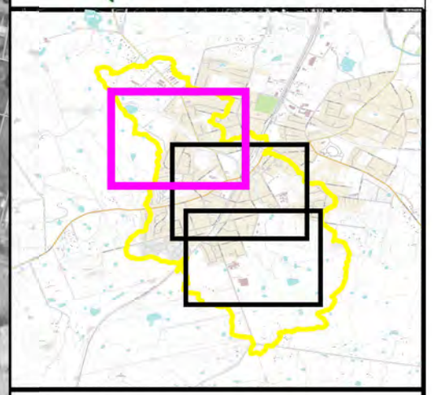
Figure I2.3: 1% AEP National Flood Hazard

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig I2.3- 1% AEP Flood Hazard.wor

WINGECARRIBEE SHIRE COUNCIL



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Aerial photograph date: Jan 2009

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Scale 1:5,000 (at A3)

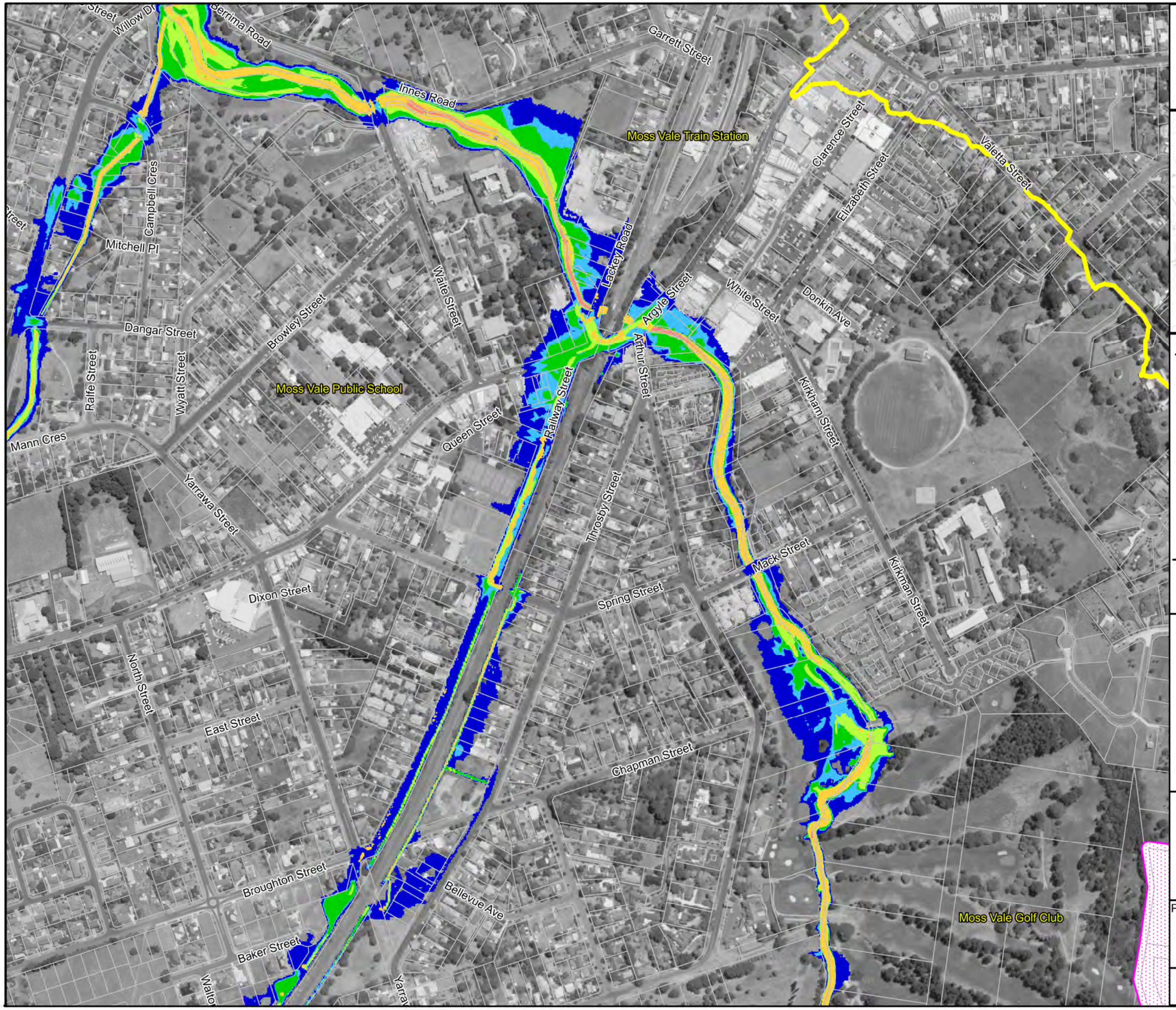
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Figure I3.1: 0.5% AEP National Flood Hazard

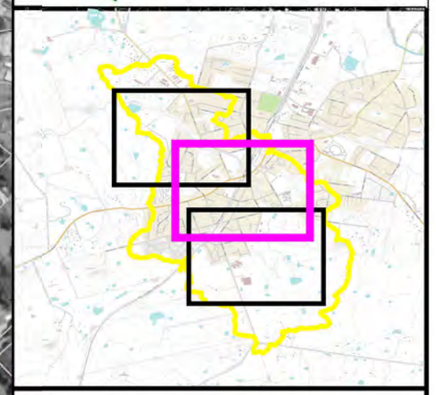
Prepared By:

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Sydney, NSW 2000

File Name: Fig I3.1- 0.5% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

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Notes:

Aerial photograph date: Jan 2009

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Scale 1:5,000 (at A3)

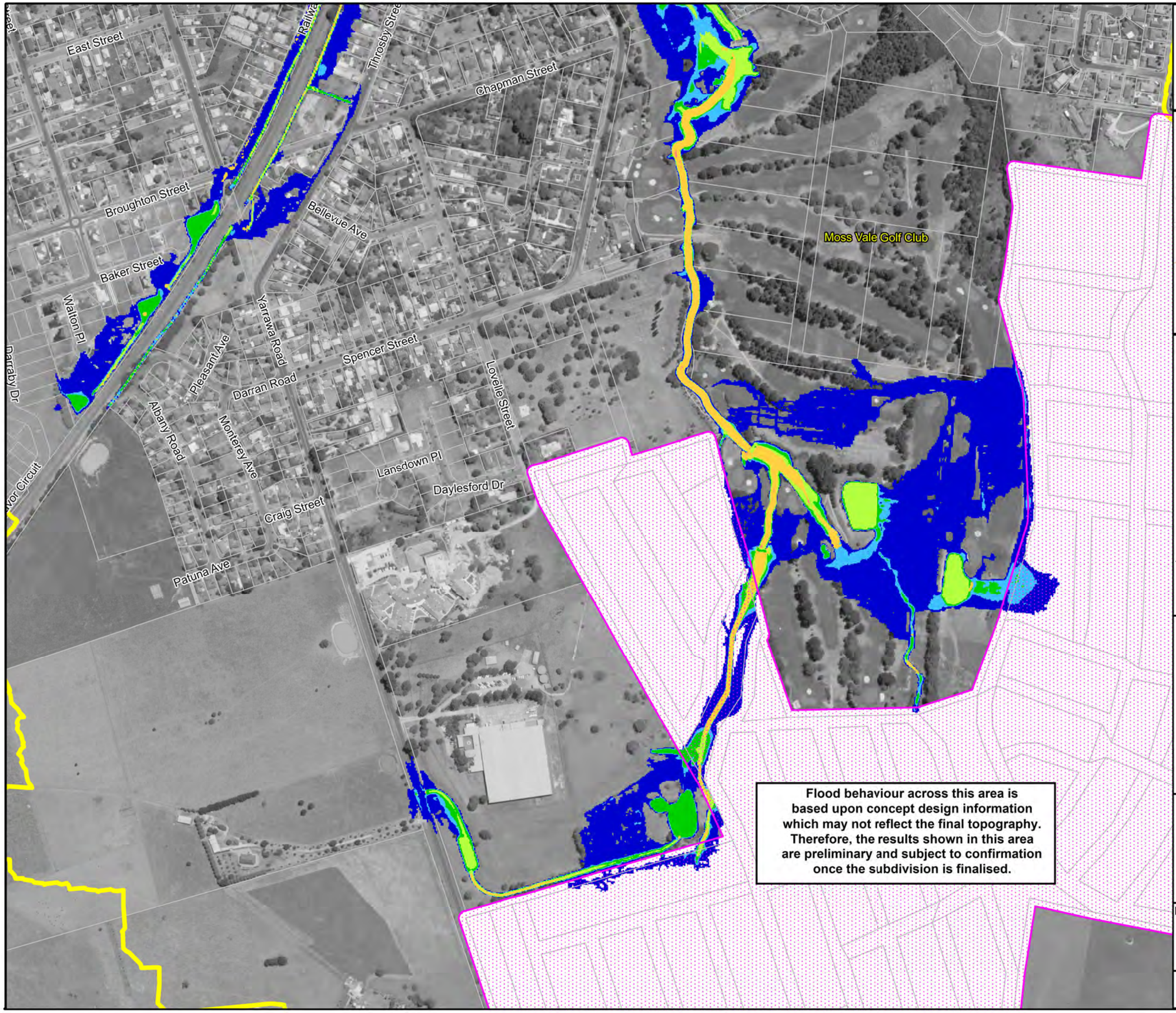
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Km

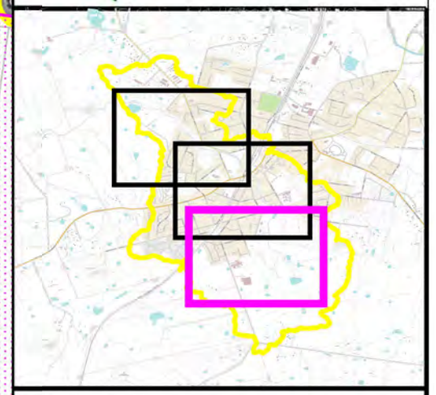
Figure I3.2: 0.5% AEP National Flood Hazard

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig I3.2- 0.5% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



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Scale 1:5,000 (at A3)

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Km

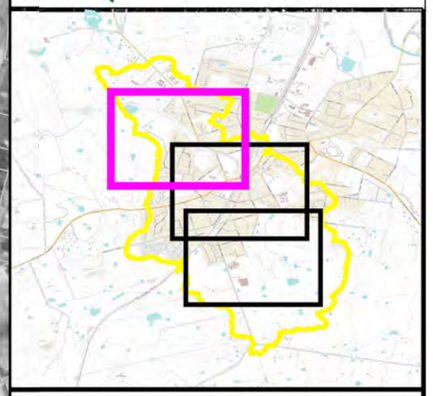
Figure I3.3: 0.5% AEP National Flood Hazard

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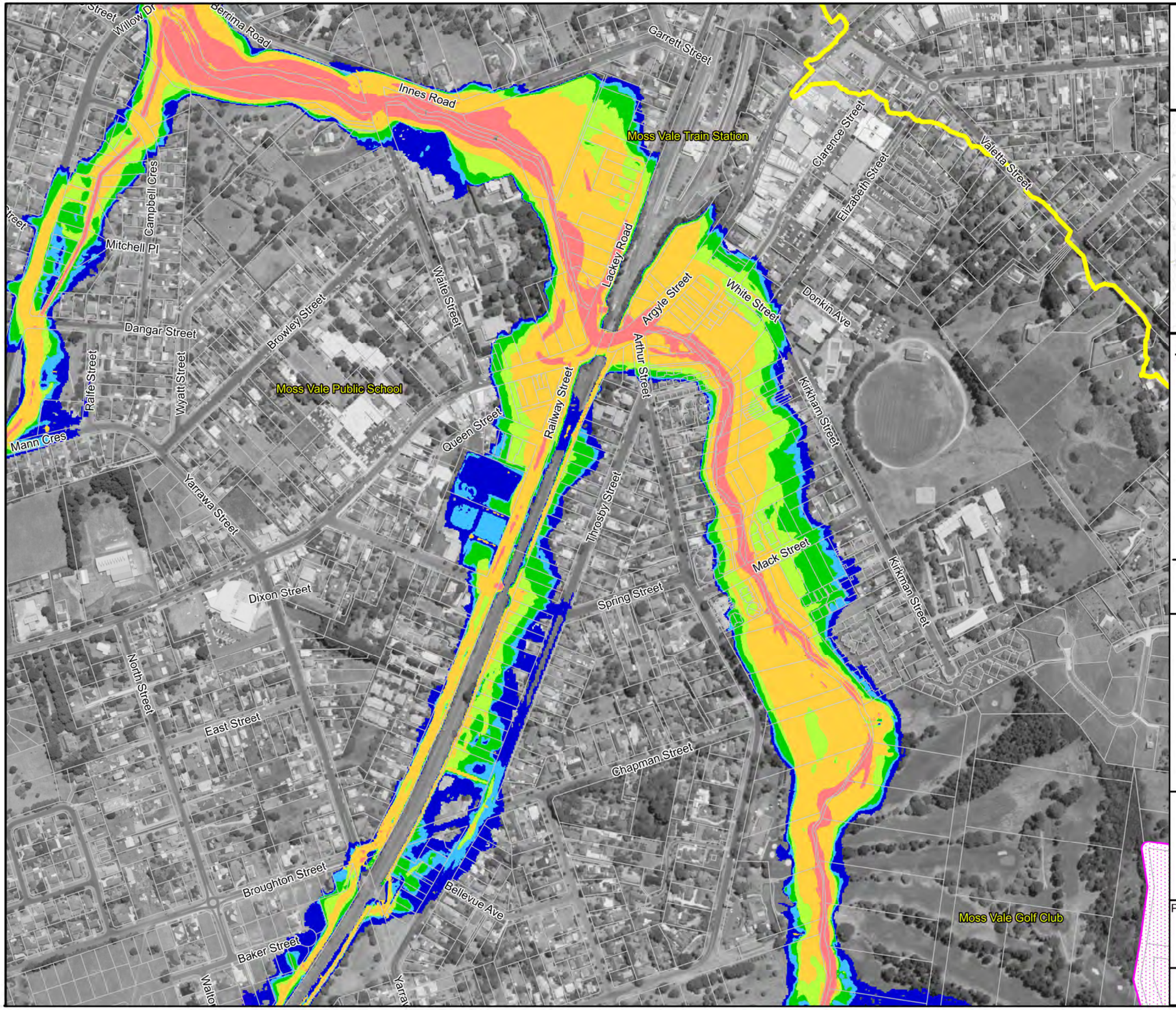
Km

Figure I4.1: PMF National Flood Hazard

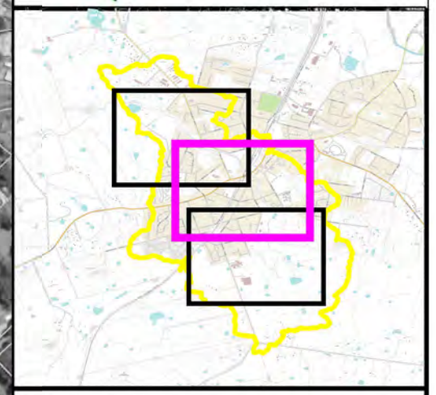
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Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig I4.1- PMF Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

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Notes:

Aerial photograph date: Jan 2009

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Scale 1:5,000 (at A3)

0 0.15 0.30

Km

Figure I4.2: PMF National Flood Hazard

Prepared By:

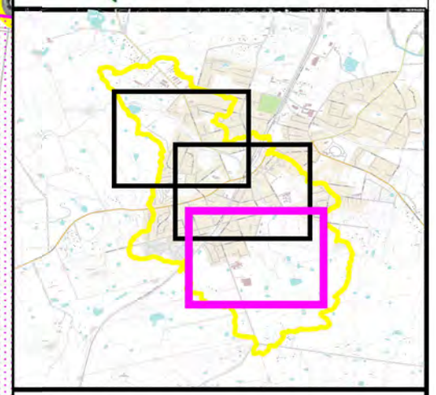
Catchment Simulation Solutions

Suite 2.01, 210 George St

Sydney, NSW 2000

File Name: Fig I4.2- PMF Flood Hazard.wor

WINGECARRIBEE SHIRE COUNCIL



LEGEND

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Flood behaviour across this area is based upon concept design information which may not reflect the final topography. Therefore, the results shown in this area are preliminary and subject to confirmation once the subdivision is finalised.

Figure I4.3: PMF National Flood Hazard

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Catchment Simulation Solutions
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Sydney, NSW 2000

File Name: Fig I4.3- PMF Flood Hazard.wor

APPENDIX J

FLOOD DAMAGES

J1 Flood Damage Cost Calculations

1.1 Property Database

A property database was developed as part of the study to enable flood damages calculations to be completed. The database was developed in GIS and included all habitable (i.e., residential, commercial and industrial) buildings located within the PMF extent. The following information was included as additional fields within the GIS database for each building:

- Generic property type (i.e., residential, commercial or industrial);
- Building floor level – refer to the following sections for further information on how the building floor levels were defined;
- Building floor area;
- Residential building type (i.e., two storey, single level high set or single level lowset); and,
- Commercial or industrial property contents value (normal or high value).

The information contained in the property database was used with the design flood level information and depth-damage curves to establish a tangible flood damage estimate for each building located within the Whites Creek catchments for each design flood. Further information on how the flood damage estimates were established is provided below.

1.2 Building Floor Levels

It is necessary to have information describing the floor height / level of every building within the PMF extent to enable the number of properties subject to above floor flooding (and the associated damage cost) to be estimated.

For this study, floor levels were extracted from a floor level database collected for the *'Whites Creek Floodplain Risk Management Study and Plan'* (URS, 2012). This database covered all the properties located within the flood planning area and included the following property information:

- Address/coordinates
- Surveyed floor levels
- Land use zoning

However, in order to provide a reliable estimate of flood damages, it is necessary to have floor level information for every property located within the PMF extent. Therefore, it was necessary to estimate the floor levels of any "missing" properties. The floor levels for the additional properties were estimated using the following approach:

1. Google Street View was used to estimate how high the floor level of each building was elevated above the adjoining ground (e.g., using standard step or brick heights as a guide);

2. The ground level at the point where the floor height was estimated was extracted from the available LiDAR data;
3. The floor level was subsequently estimated by adding the floor height (calculated in step 1) to the ground elevation (calculated in step 2).

Furthermore, some updates were made to the property database used in the *'Whites Creek Floodplain Risk Management Study and Plan'* (URS, 2012). These included changing the building type from "Single Storey High Set" to "Single Storey Slab/Low Set". Examples of such changes are shown in **Plate I2**.



Plate I1 Example of Properties Reclassified from Single Storey High Set to Single Storey Slab/ Low Set

1.3 Flood Damage Calculations

The damage costs associated with inundation can be broken down into a number of categories, as shown in **Plate I2**. However, broadly speaking, damage costs fall under two major categories;

- tangible damages; and
- intangible damages.

Tangible damages are those which can be quantified in monetary terms (e.g., cost to replace household items damaged by floodwaters). Intangible damages cannot be as readily quantified in monetary terms and include items such as inconvenience and emotional stress.

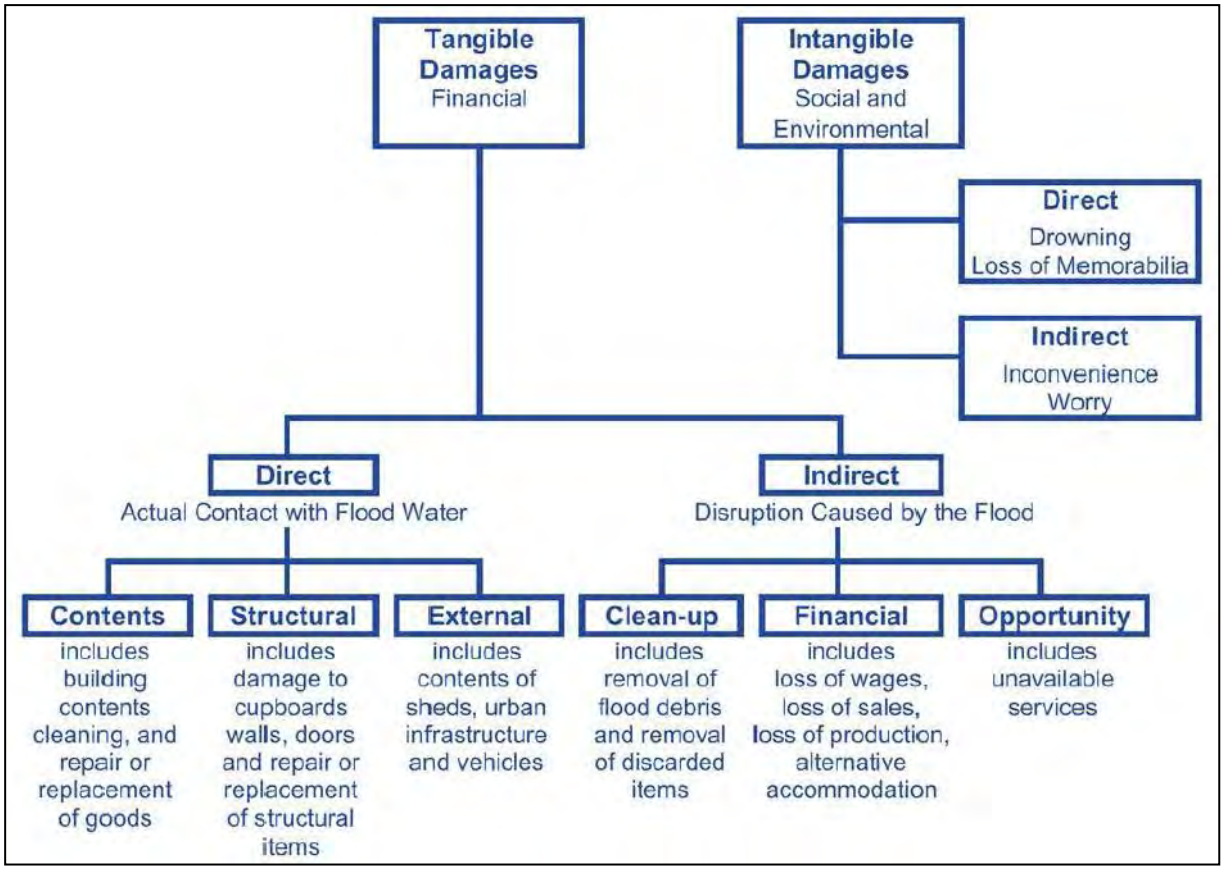


Plate I2 Flood Damage Categories (NSW Government, 2005)

Tangible damages can be further broken down into direct and indirect damage costs. Direct costs are associated with floodwater coming into direct contact with buildings and contents. Indirect flood damage costs are costs incurred outside of the specific flood event. This can include clean-up costs, loss of trade (for commercial/industrial properties) and/or alternate accommodation costs while clean-up/repairs are undertaken.

Due to the difficulty associated with assigning monetary values to intangible damages, only tangible damages were considered as part of this study. Further information on how damages costs were estimated for different property types is presented in the following sections.

1.3.1 Residential Properties

The NSW Office of Environment and Heritage (OEH) has prepared a spreadsheet that provides a standardised approach for deriving depth-damage curves for residential properties (version 3.00, October 2007). The spreadsheet requires a range of default parameters to be defined to enable a meaningful damage estimate to be derived that is appropriate for the local catchment. The parameters that were adopted for the Whites Creek catchments are summarised on the following page.

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.00 October 2007

PROJECT	DETAILS	DATE	JOB No.
Whites Creek FRMS&P	xx	Aug-11	43207390

BUILDINGS

Regional Cost Variation Factor	1.00	*From Rawlinsons for Sydney*
Post late 2001 adjustments	1.48	*Changes in AWE see update AWE Stats Worksheet*
Post Flood Inflation Factor	1.50	*1.0 to 1.5*
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*

	Regional City		Regional Town	
	Houses Affected	Factor	Houses Affected	Factor
Small scale impact	< 50	1.00	< 10	1.00
Medium scale impacts in Regional City	100	1.20	30	1.30
Large scale impacts in Regional City	> 150	1.40	> 50	1.50

Typical Duration of Immersion	1	hours
Building Damage Repair Limitation Factor	0.85	*due to no insurance* — *short duration* — *long duration*
		Suggested range 0.85 to 1.00
Typical House Size	240	m^2 *240 m^2 is Base*
Building Size Adjustment	1.0	
Total Building Adjustment Factor	**1.89**	

CONTENTS

Average Contents Relevant to Site	$ 60,000	*Base for 240 m^2 house $ 60,000*
Post late 2001 adjustments	1.48	*From above*
Contents Damage Repair Limitation Factor	0.75	*due to no insurance* — *short duration* — *long duration*
Sub-Total Adjustment Factor	1.11	*Suggested range 0.75 to 0.90*
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*
Effective Warning Time	0.5	hour
Interpolated DRF adjustment (Awareness/Time)	0.98	IDRF = Interpolated Damage Reduction Factor
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*
Total Contents Adjustment Factor AFD <= TTBH	**1.09**	AFD = Above Floor Depth
Total Contents Adjustment Factor AFD > TTBH	**1.11**	

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*1*		
Site Specific iterations	*1.00*	*0.89*	*0.98*		

ADDITIONAL FACTORS

Post late 2001 adjustments	1.48	*From above*
External Damage	$ 6,700	*$6,700 recommended without justification*
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation	1	weeks
Additional accommodation costs /Loss of Rent	$ 220	*$220 per week recommended without justification*

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70% Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110% Single Storey Slab on Ground

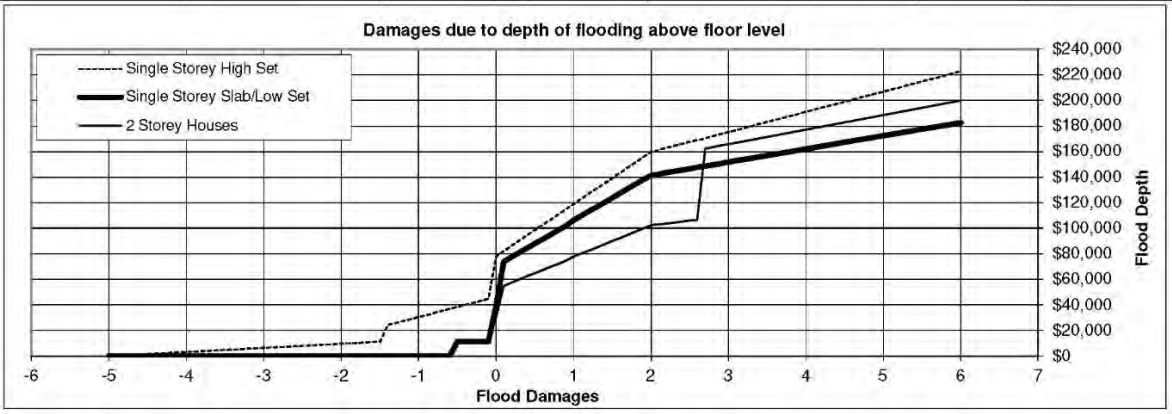
Base Curves

AFD = Above Floor Depth

Single Storey Slab/Low Set	13164	+	4871	x	AFD	in metres
Structure with GST	AFD	greater than	0.0	m		
Validity Limits	AFD	less than or equal to		6	m	
Single Storey High Set	16586	+	7454	x	AFD	
Structure with GST	AFD	greater than	-1.50	m		
Validity Limits	AFD	less than or equal to		6	m	
Contents	20000	+	20000	x	AFD	
Contents with GST	AFD	greater than		0		
Validity Limits	AFD	less than or equal to		2		

Floodplain Specific Damage Curves for Individual Residences

Steps in Curve	0.1	m	
	Single Storey High Set	Single Storey Slab/Low Set	2 Storey Houses
Type	1	2	3
AFD from Modelling	Damage	Damage	Damage
-5.00	$0	$0	$0
-1.50	$11,121	$0	$0
-1.40	$24,137	$0	$0
-1.30	$25,715	$0	$0
-1.20	$27,292	$0	$0
-1.10	$28,870	$0	$0
-1.00	$30,447	$0	$0
-0.90	$32,024	$0	$0
-0.80	$33,602	$0	$0
-0.70	$35,179	$0	$0
-0.60	$36,757	$0	$0
-0.50	$38,334	$11,121	$11,121
-0.40	$39,911	$11,121	$11,121
-0.30	$41,489	$11,121	$11,121
-0.20	$43,066	$11,121	$11,121
-0.10	$44,643	$11,121	$11,121
0.00	$78,123	$38,979	$30,621
0.10	$82,190	$73,894	$55,062
0.20	$86,257	$77,368	$57,494
0.30	$90,324	$80,843	$59,926
0.40	$94,391	$84,317	$62,358
0.50	$98,458	$87,792	$64,790
0.60	$102,525	$91,266	$67,222
0.70	$106,592	$94,740	$69,654
0.80	$110,659	$98,215	$72,087
0.90	$114,727	$101,689	$74,519
1.00	$118,794	$106,086	$77,596
1.10	$122,861	$109,606	$80,061
1.20	$126,928	$113,127	$82,525
1.30	$130,995	$116,647	$84,989
1.40	$135,062	$120,168	$87,454
1.50	$139,129	$123,688	$89,918
1.60	$143,196	$127,209	$92,382
1.70	$147,264	$130,729	$94,847
1.80	$151,331	$134,250	$97,311
1.90	$155,398	$137,770	$99,776
2.00	$159,465	$141,291	$102,240
2.10	$161,042	$142,322	$102,961
2.20	$162,620	$143,353	$103,683
2.30	$164,197	$144,383	$104,405
2.40	$165,774	$145,414	$105,126
2.50	$167,352	$146,445	$105,848
2.60	$168,929	$147,476	$106,569
2.70	$170,507	$148,506	$162,245
2.80	$172,084	$149,537	$163,379
2.90	$173,661	$150,568	$164,513
3.00	$175,239	$151,599	$165,647
3.50	$183,126	$156,753	$171,316
4.00	$191,013	$161,907	$176,985
4.50	$198,899	$167,061	$182,655
5.00	$206,786	$172,215	$188,324
5.50	$214,673	$177,369	$193,993
6.00	$222,560	$182,523	$199,663



It was noted that the resulting depth-damage curves incorporate a damage allowance for 'negative' depths. This is intended to reflect that property damage can be incurred when the water level is below floor level (e.g., damage to fences, sheds, belongings stored below the building floor). The damage curves for 'single storey low set' and 'two storey' properties commence at -0.5 metres, which was considered to be appropriate for the catchment and is in line with the values adopted in the *'Whites Creek Floodplain Risk Management Study and Plan'* (URS, 2012).

The floor level for each property was represented using a single point. This point was positioned in a location considered to be most representative of the flood level in the vicinity of property (usually at the front of the building or the side upstream of the building)

Building floor areas were calculated for each building using GIS building polygons. The building floor area serves as one of the residential damage curve inputs. A typical representative building floor area of 240 m^2 was adopted for the study area and was used as input to develop the residential damage curves.

The OEH flood damage calculation spreadsheet includes allowances for the following flood damage components:

- Damage to building contents (direct cost);
- External damage (e.g., cars, sheds, fences, landscaping) (direct cost);
- Clean up costs (indirect cost); and,
- Alternate accommodation costs while clean up occurs (indirect cost).

As outlined above, the OEH residential depth-damage curves include allowances for both direct and indirect flood damage costs and the resulting depth-damage curves are presented on the following page.

1.3.2 Commercial and Industrial Properties

Unlike residential flood damage calculations, there are no standard curves available for estimating commercial and industrial flood damages in NSW. Commercial property types include offices and shops, and industrial properties include facilities such as warehouses and automotive repairs.

In order to be consistent with the flood damage curves for commercial and industrial properties used for the *'Whites Creek Floodplain Risk Management Study and Plan'* (URS, 2012), a similar set of flood damage curves for commercial and industrial properties was applied here with an additional 12.15% adjustment. This adjustment was to account for the change in inflation from 2012 dollars to 2018 dollars using Consumer Price Index (CPI) values published by the Australian Bureau of Statistics (ABS).

In order to apply the damage curves, it was necessary to categorise each commercial / industrial property according to the value of the contents (i.e., normal and high damage potential). This is intended to reflect the fact that the damage incurred across commercial/industrial properties is likely to be directly related to the value of its contents. **Table I1** and **Table I2** provide a summary of common commercial and industrial property types and the associated contents value that each would fall under.

Table I1 Content Value Categories for Commercial PropertyTypes

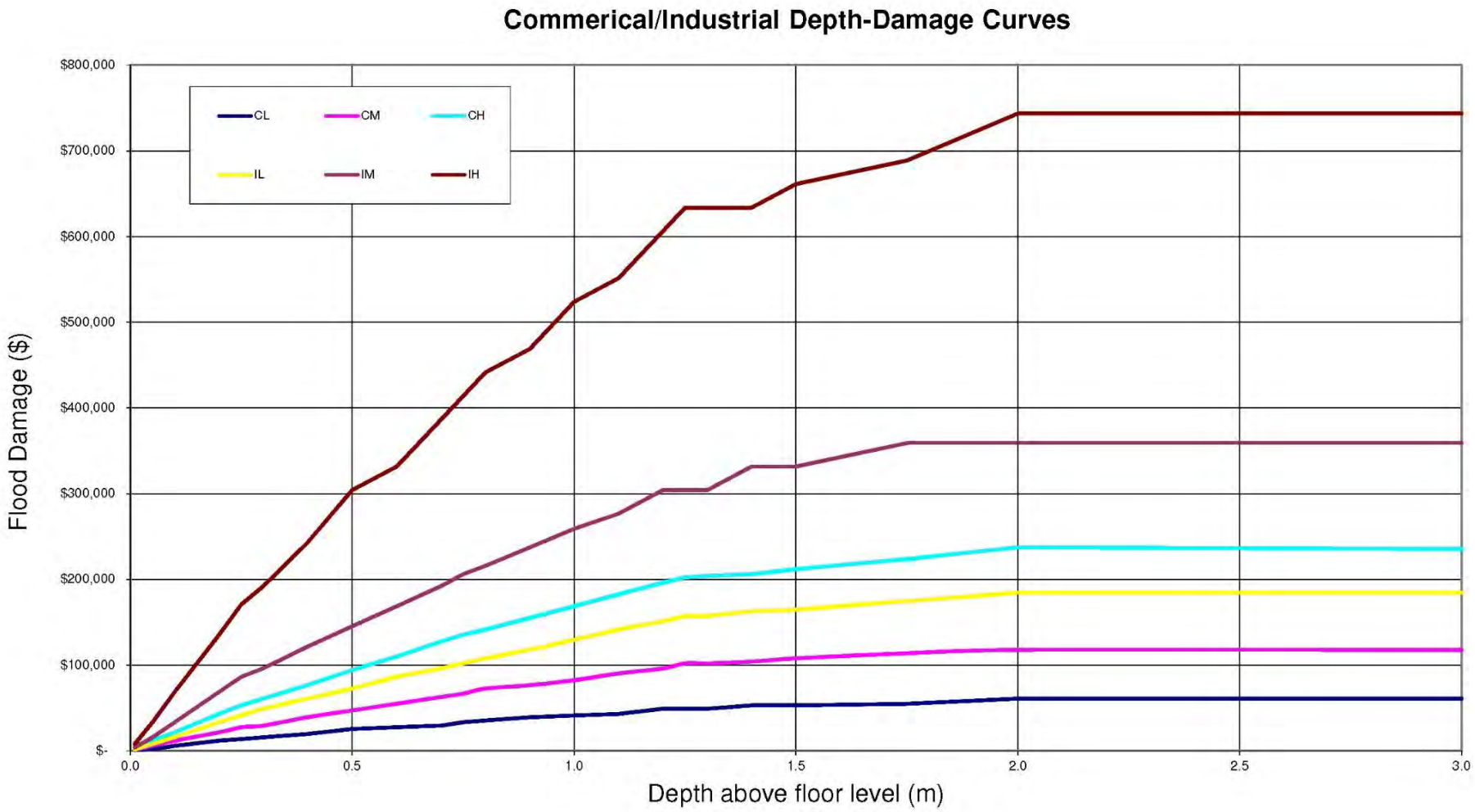
Low Value Contents	Medium Value Contents	High Value Contents
Cafes	Food Shops	Electrical shops
Florists	Grocers	Chemists
offices	Corner Stores	Shoe Shops
Consulting Rooms	Take-away food	Clothing Stores
Post Offices	Cake Chops	Bottle Shops
Pet Shops	Hairdressers	Bookshops
Churches	Banks	Newsagents
Laundrettes	Dry Cleaners	Sporting Goods
Public Halls	Professions	Furniture Stores
	Small Hardware	Video Hire
	Small retail	Kitchen water
		Restaurants
		Schools

Table I2 Content Value Categories for Industrial PropertyTypes

Low Value Contents	Medium Value Contents	High Value Contents
Paints & Signs	Equipment Hire	Smash Repairs
Automotive Repairs	Food Distribution	Panel Beating
Sand, Gravel & Cement	Leather & Upholstery	Car Yard Sales
Storage	Carpet Warehouses	Vehicle Showrooms
Transport & Couriers	Agricultural Equipment	Service Stations
Paving & Landscaping	Truck Yards	
Fuel Depots	Vacant Factories	
Council & Govt depots		
Chemical Storage		
Pool Products		
Sale Yards		
Plumbing Supplies		

The adopted commercial depth-damage curves are presented on the following page.

No specific allowance is included in the commercial/industrial damage curves for indirect losses, such as clean-up costs and loss of income while clean-up occurs. Therefore, indirect damage costs were estimated as 20% of the direct flood damages, and this was added to the base damage curves.


Commerical/Industrial Depth-Damage Curves
$800,000
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$-
Flood Damage ($)
CL
CM
CH
IL
IM
IH
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth above floor level (m)

1.3.3 Infrastructure Damage

Infrastructure damage refers to damage to public infrastructure and utilities such as roads, water supply, sewerage, gas, electricity and telephone. Infrastructure damage has been estimated at 15% of the total residential, commercial and industrial damages.

1.3.4 Potential versus Actual Damages

The flood damage calculations outlined above are damages based on a 'do nothing' scenario. However, building occupants may be able undertake measures to minimise flood damage if they are provided with sufficient advance warning of an impending flood (and assuming they are home at the time of flood). Flooding across the Whites Creek catchment, and in the urban centre of Moss Vale in particular, is typically associated with relatively short rainfall bursts with little warning time. As a result, it was considered that there would be limited opportunity for residents and business owners to minimise damages and no adjustment was taken to adjust the potential flood damages to actual flood damages.

1.4 Summary of Inundation Costs

1.4.1 Damage Costs

Flood damages were calculated using the flood level surfaces for each design flood in conjunction with the appropriate depth-damage curves and floor level for each building. The residential, commercial and industrial property damage estimates were subsequently summed with the infrastructure damage estimates to calculate the total flood damages for each design event.

The flood damage estimates for each design flood are summarised in **Table I3**. The number of buildings that are predicted to incur damage (including those inundated above floor level) are summarised in **Table I4** and **Table I5**.

The results presented in **Table I3** shows that a 1% AEP flood has the potential to cause over $500,000 dollars of damage. For larger events, damage to residential property is the primary contributor to the total damage bill for each event.

1.4.2 Average Annual Damages

The total flood damages for each flood event were plotted on a chart against the probability of each flood occurring (i.e., AEP). The chart was then used as the basis for calculating the average annual damages (AAD) for the study area for existing conditions. The AAD provides an estimate of the average annual cost of inundation across the study area over an extended timeframe.

The AAD for the study area, for existing conditions is calculated as being $124,000.

1.5 Limitations of Damage Costs

The damage costs presented in this document are based on the best information that was available at the time this report was prepared. However, it should be reinforced that the damage costs are estimates only and do not take into account future fluctuations in property and asset values. Therefore, the damage estimates should only be considered an approximation

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Table I3 Summary of Flood Damages for Existing Conditions

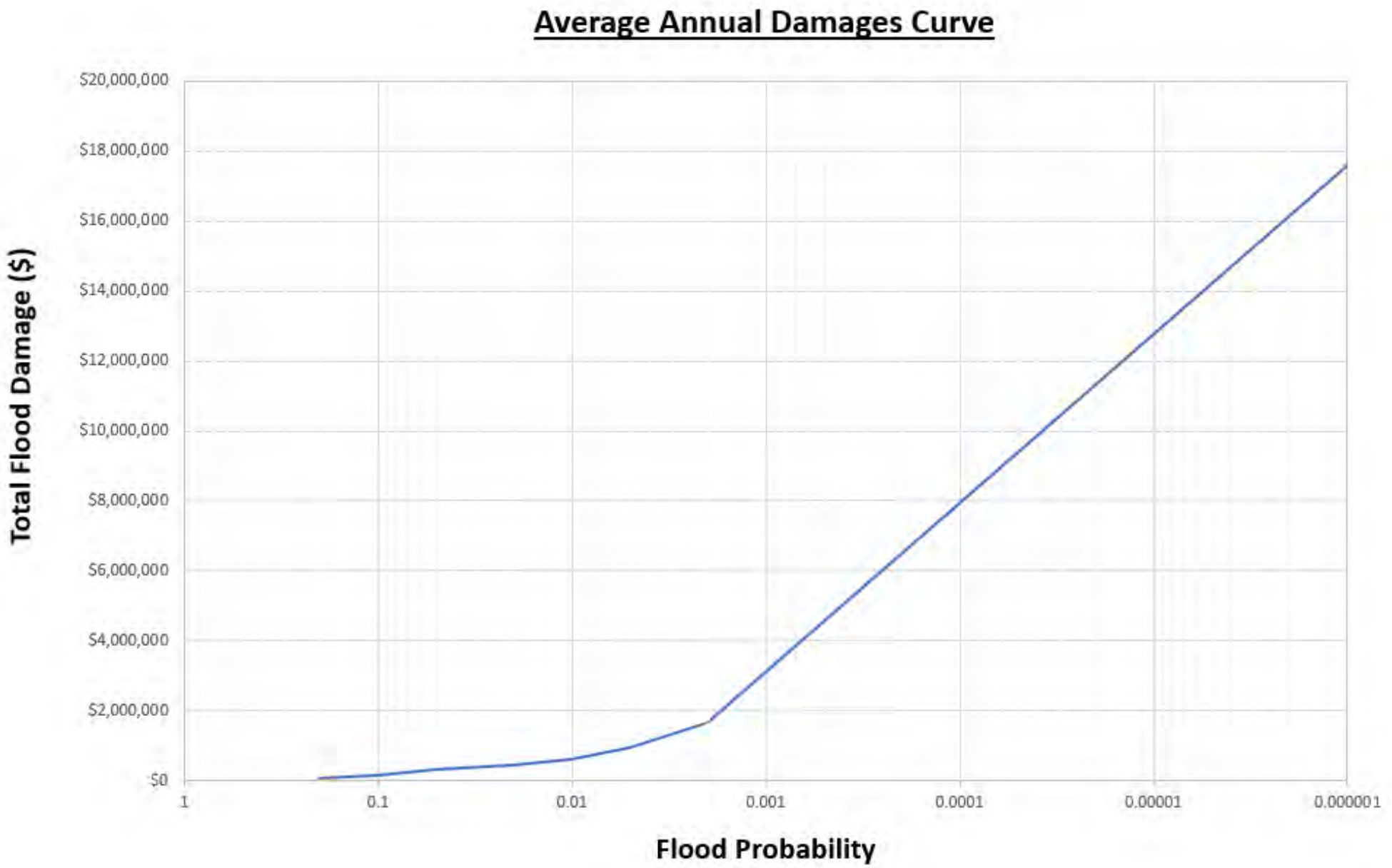
Flood Event	Flood Damage Component (2018 dollars)				
	Residential	Commercial.	Industrial	Infrastructure	TOTAL
20% AEP	$44,484	$3,518	$0	$7,200	$55,202
10% AEP	$60,389	$70,112	$0	$19,575	$150,076
5% AEP	$218,737	$76,157	$0	$44,234	$339,128
2% AEP	$272,301	$104,952	$0	$56,588	$433,841
1% AEP	$356,453	$162,677	$0	$77,870	$597,000
0.5% AEP	$514,584	$304,560	$0	$122,872	$942,016
0.2% AEP	$771,323	$671,907	$0	$216,485	$1,659,715
PMF	$10,446,378	$4,839,655	$0	$2,292,905	$17,578,938

Table I4 Number of Properties Predicted to Experience Flood Damage

Flood Event	Number of Properties Damaged		
	Residential	Commercial/ Industrial	Total Number
20% AEP	4	1	5
10% AEP	7	4	11
5% AEP	13	5	18
2% AEP	16	6	22
1% AEP	21	9	30
0.5% AEP	24	11	35
0.2% AEP	31	17	48
PMF	153	40	193

Table I5 Number of Properties Predicted to be Inundated Above Floor Inundation

Flood Event	Number of Buildings with Above Flood Inundation		
	Residential	Commercial/ Industrial	Total Number
20% AEP	0	1	1
10% AEP	0	3	3
5% AEP	2	3	5
2% AEP	2	5	7
1% AEP	2	6	8
0.5% AEP	3	9	12
0.2% AEP	4	14	18
PMF	101	39	140


Average Annual Damages Curve
Total Flood Damage ($)
$20,000,000
$18,000,000
$16,000,000
$14,000,000
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$0
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
Flood Probability

REFERENCES

- Resources and Mines, Natural (2002). *Guidance on the Assessment of Tangible Flood Damages*.
- URS (2012). Whites Creek Floodplain Risk Management Study and Plan. Prepared for Wingecarribee Shire Council.

APPENDIX K

XP-RAFTS OUTPUTS FOR FUTURE DEVELOPMENT

Future Development Results for the 20% AEP Event

Subcatch ID	Adopted 20% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 20% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.01	0.1	360	0.22	0.16	0.09	120	0.22	120.0%
1.02	0.19	360	0.37	0.31	0.18	120	0.37	94.7%
1.03	0.68	720	1.18	1.20	0.80	360	1.20	76.5%
1.04	1.88	360	3.56	3.20	2.02	120	3.56	89.4%
1.05	4.09	720	5.49	4.77	4.47	120	5.49	34.2%
1.06	4.79	120	6.21	5.58	5.13	120	6.21	29.6%
1.07	4.86	120	6.29	5.68	5.19	120	6.29	29.4%
1.08	8.75	120	10.13	9.51	9.03	120	10.13	15.8%
1.09	9.44	120	10.84	10.24	9.79	120	10.84	14.8%
1.10	9.66	120	11.08	10.51	10.01	120	11.08	14.7%
1.11	10.08	120	11.59	11.17	10.53	120	11.59	15.0%
1.12	10.17	120	11.74	11.32	10.65	120	11.74	15.4%
1.13	10.5	360	12.07	11.69	10.96	120	12.07	15.0%
1.14	10.74	360	12.40	12.00	11.21	120	12.40	15.5%
1.15	10.91	360	12.61	12.23	11.40	120	12.61	15.6%
1.16	11.36	360	13.11	12.74	11.88	120	13.11	15.4%
1.17	11.52	360	13.23	12.95	12.07	120	13.23	14.8%
1.18	12.43	720	14.13	13.88	13.01	120	14.13	13.7%
1.19	12.69	720	14.30	14.13	13.27	120	14.30	12.7%
1.20	13.15	720	14.75	14.54	13.70	120	14.75	12.2%
1.21	13.52	720	15.38	14.87	14.07	120	15.38	13.8%
1.22	13.53	720	15.38	14.87	14.07	120	15.38	13.7%
1.23	17.47	720	19.59	18.05	18.13	120	19.59	12.1%

Subcatch ID	Adopted 20% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 20% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.24	18.16	720	20.25	18.57	18.80	120	20.25	11.5%
1.25	18.57	720	20.45	18.91	19.23	120	20.45	10.1%
1.26	22.92	720	23.60	21.73	23.80	720	23.80	3.8%
1.27	23.36	720	23.85	22.01	24.23	720	24.23	3.7%
1.28	23.54	720	23.95	22.10	24.40	720	24.40	3.7%
1.29	24.58	720	24.49	22.74	25.43	720	25.43	3.5%
1.30	25.69	720	24.87	23.74	26.54	720	26.54	3.3%
1.31	27.25	720	26.30	25.10	28.08	720	28.08	3.0%
1.32	28.2	720	26.75	25.83	28.97	720	28.97	2.7%
2.01	0.31	120	0.81	0.58	0.36	120	0.81	161.3%
3.01	0.58	120	1.45	1.05	0.60	120	1.45	150.0%
4.01	0.3	120	0.47	0.36	0.22	120	0.47	56.7%
5.01	0.39	360	0.80	0.61	0.33	120	0.80	105.1%
6.01	0.47	120	1.14	0.85	0.54	120	1.14	142.6%
6.02	0.55	720	1.21	0.98	0.64	120	1.21	120.0%
6.03	1.53	120	1.86	1.98	1.36	360	1.98	29.4%
7.01	0.91	120	0.90	0.70	0.42	120	0.90	-1.1%
8.01	0.96	120	1.22	0.93	0.54	120	1.22	27.1%
8.02	2.81	120	3.07	2.78	1.93	120	3.07	9.3%
9.01	0.52	120	0.52	0.52	0.36	120	0.52	0.0%
10.01	0.37	120	0.37	0.34	0.19	120	0.37	0.0%
11.01	0.54	120	0.54	0.40	0.18	120	0.54	0.0%
12.01	0.44	120	0.44	0.38	0.39	120	0.44	0.0%
13.01	1.95	120	2.24	1.74	0.88	120	2.24	14.9%
13.02	2.76	360	2.73	2.82	2.63	360	2.82	2.2%
13.03	3.96	360	3.92	4.00	3.92	360	4.00	1.0%

Subcatch ID	Adopted 20% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 20% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
14.01	1.4	120	1.40	1.11	0.51	120	1.40	0.0%
15.01	2.81	120	2.81	2.08	1.18	120	2.81	0.0%
16.01	0.47	120	0.47	0.38	0.19	120	0.47	0.0%
17.01	0.87	120	0.87	0.65	0.46	120	0.87	0.0%
17.02	2.46	120	2.46	1.89	1.37	120	2.46	0.0%
17.03	1.17	720	1.08	1.08	1.17	720	1.17	0.0%
18.01	1.28	120	1.55	1.17	0.72	120	1.55	21.1%
19.01	0.24	360	0.22	0.24	0.22	360	0.24	0.0%
20.01	0.7	120	0.78	0.58	0.40	120	0.78	11.4%
20.02	0.95	120	1.03	0.82	0.65	120	1.03	8.4%
21.01	0.18	360	0.16	0.18	0.14	360	0.18	0.0%
22.01	0.38	120	0.50	0.38	0.29	120	0.50	31.6%
22.02	0.41	120	0.55	0.43	0.32	120	0.55	34.1%
23.01	0.5	360	0.47	0.50	0.38	360	0.50	0.0%
24.01	0.46	120	0.48	0.46	0.32	120	0.48	4.3%
25.01	0.36	120	0.39	0.32	0.14	120	0.39	8.3%
25.02	0.46	360	0.47	0.48	0.22	360	0.48	4.3%
26.01	0.55	120	0.66	0.54	0.32	120	0.66	20.0%
27.01	0.4	120	0.48	0.41	0.23	120	0.48	20.0%
27.02	1.02	120	1.08	1.04	0.61	120	1.08	5.9%
27.03	1.52	360	1.60	1.60	1.03	120	1.60	5.3%
27.04	1.79	360	1.81	1.88	1.25	360	1.88	5.0%
28.01	0.36	120	0.35	0.29	0.16	120	0.35	-2.8%
29.01	0.43	120	0.68	0.56	0.29	120	0.68	58.1%
30.01	0.32	120	0.49	0.37	0.18	120	0.49	53.1%
31.01	0.31	360	0.39	0.34	0.23	120	0.39	25.8%

Subcatch ID	Adopted 20% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 20% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
31.02	0.36	360	0.41	0.39	0.27	120	0.41	13.9%
32.01	0.68	120	0.86	0.67	0.39	120	0.86	26.5%
32.02	1.2	120	1.64	1.31	0.75	120	1.64	36.7%
33.01	0.49	120	0.76	0.61	0.33	120	0.76	55.1%
34.01	0.39	120	0.45	0.30	0.20	120	0.45	15.4%
34.02	0.44	120	0.49	0.38	0.25	120	0.49	11.4%
35.01	0.55	120	0.55	0.41	0.21	120	0.55	0.0%
35.02	0.6	120	0.60	0.45	0.23	120	0.60	0.0%
36.01	1.35	120	1.35	1.05	0.61	120	1.35	0.0%
36.02	1.77	120	1.77	1.44	0.96	120	1.77	0.0%
36.03	1.83	120	1.82	1.51	1.00	120	1.82	-0.5%
36.04	2.74	120	2.89	2.60	1.97	120	2.89	5.5%
36.05	5.3	360	5.86	6.01	4.59	360	6.01	13.4%
37.01	0.63	120	0.71	0.53	0.40	120	0.71	12.7%
37.02	1.12	120	1.44	1.14	0.87	120	1.44	28.6%
38.01	0.44	360	0.94	0.70	0.43	120	0.94	113.6%
38.02	0.82	120	1.35	1.08	0.80	120	1.35	64.6%
38.03	0.86	120	1.39	1.14	0.83	120	1.39	61.6%
38.04	1.82	120	2.17	2.07	1.51	120	2.17	19.2%
38.05	2.25	120	2.50	2.51	1.90	360	2.51	11.6%
39.01	0.27	120	0.31	0.24	0.14	120	0.31	14.8%
39.02	0.98	120	1.06	0.79	0.59	120	1.06	8.2%
40.01	0.49	120	0.51	0.37	0.31	120	0.51	4.1%
41.01	0.39	120	0.45	0.35	0.23	120	0.45	15.4%
42.01	0.33	120	0.41	0.32	0.15	120	0.41	24.2%
42.02	0.61	120	0.80	0.69	0.40	120	0.80	31.1%

Subcatch ID	Adopted 20% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 20% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
43.01	0.58	120	0.77	0.57	0.31	120	0.77	32.8%
44.01	0.26	120	0.27	0.20	0.11	120	0.27	3.8%
44.02	0.78	120	0.85	0.84	0.55	120	0.85	9.0%
45.01	0.43	120	0.52	0.42	0.26	120	0.52	20.9%
46.01	0.41	120	0.65	0.51	0.26	120	0.65	58.5%
47.01	0.68	360	0.96	0.75	0.61	120	0.96	41.2%
47.02	1.11	120	1.43	1.23	1.02	120	1.43	28.8%
47.03	1.13	120	1.45	1.24	1.04	120	1.45	28.3%
47.04	1.6	120	1.92	1.65	1.43	120	1.92	20.0%
47.05	2.85	120	3.03	2.95	2.52	120	3.03	6.3%
47.06	3.26	120	3.36	3.38	2.91	360	3.38	3.7%
47.07	4.23	360	4.35	4.51	3.84	360	4.51	6.6%
47.08	4.31	360	4.46	4.61	3.93	360	4.61	7.0%
47.09	4.54	360	4.66	4.87	4.10	360	4.87	7.3%
47.10	5.18	360	5.35	5.52	4.71	360	5.52	6.6%
47.11	5.44	360	5.66	5.77	4.92	360	5.77	6.1%
48.01	0.33	120	0.32	0.27	0.16	120	0.32	-3.0%
49.01	0.33	120	0.33	0.27	0.14	120	0.33	0.0%
49.02	0.53	120	0.52	0.42	0.24	120	0.52	-1.9%
49.03	0.69	120	0.68	0.65	0.44	120	0.68	-1.4%
49.04	0.78	120	0.78	0.75	0.52	120	0.78	0.0%
50.01	0.36	120	0.41	0.31	0.24	120	0.41	13.9%
51.01	0.36	120	0.36	0.28	0.17	120	0.36	0.0%
52.01	0.26	120	0.37	0.30	0.15	120	0.37	42.3%
53.01	0.22	120	0.23	0.17	0.10	120	0.23	4.5%
53.02	0.37	120	0.45	0.46	0.26	360	0.46	24.3%

Subcatch ID	Adopted 20% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 20% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
53.03	0.78	120	1.26	1.15	0.61	120	1.26	61.5%
54.01	0.11	120	0.12	0.09	0.05	120	0.12	9.1%
54.02	0.4	120	0.66	0.57	0.28	120	0.66	65.0%
55.01	0.34	120	0.35	0.28	0.18	120	0.35	2.9%
55.02	0.36	120	0.37	0.31	0.21	120	0.37	2.8%
56.01	0.35	120	0.36	0.28	0.22	120	0.36	2.9%
56.02	0.93	120	0.93	0.75	0.53	120	0.93	0.0%
57.01	0.28	120	0.27	0.24	0.16	120	0.27	-3.6%
57.02	0.57	120	0.55	0.45	0.30	120	0.55	-3.5%
58.01	0.65	120	0.75	0.58	0.38	120	0.75	15.4%
58.02	0.77	120	0.90	0.73	0.50	120	0.90	16.9%
59.01	0.13	120	0.14	0.12	0.13	120	0.14	7.7%
60.01	0.34	120	0.38	0.32	0.27	120	0.38	11.8%
60.02	0.49	120	0.56	0.46	0.36	120	0.56	14.3%
60.03	0.86	120	0.99	0.81	0.57	120	0.99	15.1%
60.04	1.47	360	1.67	1.68	1.19	360	1.68	14.3%
60.05	1.68	360	1.89	1.89	1.36	120	1.89	12.5%
61.01	0.36	120	0.42	0.34	0.18	120	0.42	16.7%
62.01	0.57	120	0.67	0.52	0.34	120	0.67	17.5%
63.01	0.51	120	0.53	0.41	0.36	120	0.53	3.9%
63.02	0.7	120	0.87	0.86	0.63	120	0.87	24.3%
63.03	0.98	360	1.16	1.19	0.87	360	1.19	21.4%
64.01	0.82	120	1.09	0.81	0.40	120	1.09	32.9%
64.02	1.25	120	1.67	1.59	0.83	120	1.67	33.6%
64.03	1.54	360	2.05	2.07	1.06	360	2.07	34.4%
65.01	0.17	120	0.33	0.25	0.11	120	0.33	94.1%

Subcatch ID	Adopted 20% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 20% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4642 for the 2 hour duration	TP 4740 for the 6 hour duration	TP 4811 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
65.02	0.38	360	0.62	0.59	0.29	120	0.62	63.2%
66.01	0.33	120	0.62	0.45	0.20	120	0.62	87.9%
67.01	0.43	120	0.43	0.37	0.41	120	0.43	0.0%
67.02	0.9	720	0.85	0.81	0.90	720	0.90	0.0%
67.03	1.07	720	0.99	1.02	1.07	720	1.07	0.0%
67.04	1.34	360	1.22	1.34	1.29	360	1.34	0.0%
67.05	1.63	360	1.48	1.63	1.52	360	1.63	0.0%
68.01	0.21	120	0.21	0.21	0.16	120	0.21	0.0%
69.01	0.23	360	0.21	0.23	0.18	360	0.23	0.0%
70.01	0.43	120	0.74	0.54	0.26	120	0.74	72.1%
70.02	0.88	360	1.34	1.27	0.59	120	1.34	52.3%
70.03	1.69	360	1.91	2.12	1.18	360	2.12	25.4%
71.01	0.5	360	0.45	0.52	0.30	360	0.52	4.0%
72.01	0.48	120	0.48	0.38	0.31	120	0.48	0.0%
BasinA	1	360	0.85	1.00	0.68	360	1.00	0.0%
BasinBC	1.68	120	1.72	1.64	1.64	120	1.72	2.4%
BasinE	1.05	720	1.00	0.98	1.05	720	1.05	0.0%
BasinF	2.31	720	2.34	2.30	2.42	720	2.42	4.8%
BasinG	0.5	720	0.51	0.48	0.54	720	0.54	8.0%
					Average Difference (All Subcatchments)			**21.39%**

Future Development Results for the 1% AEP Event

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.01	0.27	45	0.52	0.39	0.30	0.22	20	0.52	92.6%
1.02	0.5	45	0.76	0.67	0.59	0.44	20	0.76	52.0%
1.03	1.96	120	3.20	2.74	2.49	1.88	20	3.20	63.3%
1.04	5.21	120	8.52	7.54	6.40	4.75	20	8.52	63.5%
1.05	11.85	120	11.89	12.76	13.95	10.67	120	13.95	17.7%
1.06	13.05	120	12.62	13.79	15.18	11.89	120	15.18	16.3%
1.07	13.16	120	12.74	13.91	15.30	11.97	120	15.30	16.3%
1.08	23.36	120	21.22	25.05	25.90	20.01	120	25.90	10.9%
1.09	25.06	120	22.37	26.70	27.63	21.54	120	27.63	10.3%
1.10	25.43	120	22.69	27.09	28.01	21.96	120	28.01	10.1%
1.11	26.14	120	23.29	27.77	28.71	22.88	120	28.71	9.8%
1.12	26.3	120	23.42	27.94	28.88	23.12	120	28.88	9.8%
1.13	26.75	120	23.74	28.34	29.27	23.67	120	29.27	9.4%
1.14	27.01	120	23.97	28.59	29.52	24.06	120	29.52	9.3%
1.15	27.13	120	24.03	28.67	29.63	24.36	120	29.63	9.2%
1.16	27.52	120	24.34	29.06	30.01	25.05	120	30.01	9.0%
1.17	27.58	120	24.38	29.10	30.06	25.25	120	30.06	9.0%
1.18	28.16	120	24.61	29.38	30.40	26.51	120	30.40	8.0%
1.19	28.29	120	24.70	29.46	30.49	26.87	120	30.49	7.8%
1.20	28.43	120	24.75	29.52	30.56	27.30	120	30.56	7.5%
1.21	28.6	120	24.83	29.63	30.69	27.80	120	30.69	7.3%
1.22	28.6	120	24.83	29.63	30.69	27.81	120	30.69	7.3%
1.23	37.81	120	26.22	33.66	38.19	36.24	120	38.19	1.0%
1.24	39.04	120	26.31	34.19	39.61	37.59	120	39.61	1.5%
1.25	39.58	120	26.36	34.42	40.08	38.32	120	40.08	1.3%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.26	49.53	120	32.63	42.76	50.32	48.28	120	50.32	1.6%
1.27	49.98	120	33.01	43.27	50.85	48.98	120	50.85	1.7%
1.28	50.18	120	33.18	43.50	51.09	49.32	120	51.09	1.8%
1.29	51.28	120	33.94	44.63	52.34	51.32	120	52.34	2.1%
1.30	52.05	120	34.40	45.23	53.13	53.09	120	53.13	2.1%
1.31	54.83	720	35.73	47.33	56.03	56.18	720	56.18	2.5%
1.32	56.44	720	35.96	47.62	56.41	57.53	720	57.53	1.9%
2.01	0.86	120	1.94	1.30	1.14	0.84	20	1.94	125.6%
3.01	1.61	45	3.29	2.49	1.95	1.44	20	3.29	104.3%
4.01	0.66	20	1.07	0.85	0.69	0.50	20	1.07	62.1%
5.01	1.1	45	1.93	1.46	1.10	0.80	20	1.93	75.5%
6.01	1.34	120	2.61	2.01	1.73	1.27	20	2.61	94.8%
6.02	1.56	120	2.86	2.36	1.99	1.51	20	2.86	83.3%
6.03	3.78	45	4.37	4.78	4.31	3.19	45	4.78	26.5%
7.01	2.23	20	2.22	1.75	1.36	0.99	20	2.22	-0.4%
8.01	2.22	20	2.98	2.31	1.77	1.29	20	2.98	34.2%
8.02	6.45	45	6.58	6.81	6.04	4.56	45	6.81	5.6%
9.01	1.41	45	1.21	1.41	1.21	0.89	45	1.41	0.0%
10.01	1.01	20	1.01	0.85	0.62	0.46	20	1.01	0.0%
11.01	1.19	20	1.19	0.83	0.61	0.44	20	1.19	0.0%
12.01	1.09	120	0.94	0.82	1.10	0.89	120	1.10	0.9%
13.01	4.7	20	5.36	3.98	2.94	2.14	20	5.36	14.0%
13.02	8.52	45	6.95	8.77	8.33	6.35	45	8.77	2.9%
13.03	11.13	120	8.91	11.34	11.26	8.99	45	11.34	1.9%
14.01	3.25	20	3.25	2.37	1.73	1.24	20	3.25	0.0%
15.01	6.54	20	6.54	4.69	3.75	2.76	20	6.54	0.0%
16.01	1.14	20	1.14	0.85	0.61	0.44	20	1.14	0.0%
17.01	2.06	20	2.06	1.74	1.49	1.09	20	2.06	0.0%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
17.02	5.51	20	5.51	4.38	4.16	3.18	20	5.51	0.0%
17.03	2.7	120	1.74	2.39	2.70	2.37	120	2.70	0.0%
18.01	2.85	20	3.58	2.87	2.33	1.71	20	3.58	25.6%
19.01	0.68	120	0.39	0.64	0.68	0.54	120	0.68	0.0%
20.01	1.62	20	1.82	1.49	1.29	0.95	20	1.82	12.3%
20.02	2.17	20	2.37	2.29	2.01	1.54	20	2.37	9.2%
21.01	0.48	45	0.34	0.48	0.45	0.33	45	0.48	0.0%
22.01	0.83	120	1.13	0.92	0.91	0.68	20	1.13	36.1%
22.02	0.93	20	1.25	1.07	1.01	0.77	20	1.25	34.4%
23.01	1.36	45	1.05	1.36	1.24	0.93	45	1.36	0.0%
24.01	1.26	45	1.26	1.31	1.07	0.79	45	1.31	4.0%
25.01	0.86	20	0.89	0.66	0.47	0.34	20	0.89	3.5%
25.02	1.07	20	1.10	1.01	0.77	0.56	20	1.10	2.8%
26.01	1.29	20	1.71	1.39	1.06	0.78	20	1.71	32.6%
27.01	1	20	1.27	1.03	0.77	0.57	20	1.27	27.0%
27.02	2.39	45	2.56	2.50	2.01	1.50	20	2.56	7.1%
27.03	3.79	45	3.85	3.99	3.29	2.46	45	3.99	5.3%
27.04	4.33	45	4.33	4.64	3.90	2.96	45	4.64	7.2%
28.01	0.9	20	0.88	0.73	0.53	0.39	20	0.88	-2.2%
29.01	1.12	45	1.73	1.33	0.96	0.71	20	1.73	54.5%
30.01	0.74	20	1.12	0.81	0.59	0.43	20	1.12	51.4%
31.01	0.84	45	1.02	0.94	0.75	0.55	20	1.02	21.4%
31.02	0.96	45	1.09	1.09	0.88	0.65	20	1.09	13.5%
32.01	1.56	20	2.13	1.69	1.27	0.93	20	2.13	36.5%
32.02	2.76	20	4.11	3.27	2.45	1.80	20	4.11	48.9%
33.01	1.12	20	1.91	1.47	1.09	0.79	20	1.91	70.5%
34.01	0.89	20	1.04	0.67	0.61	0.47	20	1.04	16.9%
34.02	1.08	20	1.22	0.76	0.70	0.58	20	1.22	13.0%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
35.01	1.27	20	1.27	0.92	0.68	0.50	20	1.27	0.0%
35.02	1.42	20	1.41	1.01	0.76	0.56	20	1.41	-0.7%
36.01	3.25	20	3.25	2.62	2.02	1.48	20	3.25	0.0%
36.02	3.7	20	3.70	3.60	3.07	2.29	20	3.70	0.0%
36.03	3.75	20	3.76	3.68	3.19	2.37	20	3.76	0.3%
36.04	5.78	20	6.42	6.02	5.64	4.49	20	6.42	11.1%
36.05	11.99	120	12.05	12.79	12.55	10.26	45	12.79	6.7%
37.01	1.48	20	1.65	1.34	1.26	0.93	20	1.65	11.5%
37.02	2.45	120	3.00	2.70	2.67	2.06	20	3.00	22.4%
38.01	1.21	45	2.25	1.72	1.39	1.02	20	2.25	86.0%
38.02	2.22	120	2.86	2.82	2.50	1.89	20	2.86	28.8%
38.03	2.31	120	2.89	2.90	2.59	1.96	45	2.90	25.5%
38.04	4.2	120	4.85	4.81	4.66	3.50	20	4.85	15.5%
38.05	5.03	120	5.39	5.78	5.48	4.35	45	5.78	14.9%
39.01	0.58	20	0.71	0.60	0.48	0.36	20	0.71	22.4%
39.02	1.99	20	2.21	2.03	1.86	1.40	20	2.21	11.1%
40.01	1.11	20	1.14	1.00	0.98	0.74	20	1.14	2.7%
41.01	0.88	20	1.06	0.91	0.75	0.55	20	1.06	20.5%
42.01	0.75	20	0.94	0.68	0.50	0.37	20	0.94	25.3%
42.02	1.42	20	1.83	1.63	1.30	0.95	20	1.83	28.9%
43.01	1.39	20	1.84	1.36	1.02	0.74	20	1.84	32.4%
44.01	0.59	20	0.63	0.47	0.37	0.28	20	0.63	6.8%
44.02	1.77	20	2.22	2.08	1.75	1.29	20	2.22	25.4%
45.01	1.01	20	1.28	1.05	0.85	0.62	20	1.28	26.7%
46.01	0.99	20	1.59	1.19	0.86	0.63	20	1.59	60.6%
47.01	1.85	45	2.10	2.03	1.95	1.45	20	2.10	13.5%
47.02	2.91	45	2.78	3.26	3.10	2.40	45	3.26	12.0%
47.03	2.94	45	2.81	3.31	3.13	2.44	45	3.31	12.6%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
47.04	3.89	120	3.41	4.24	4.19	3.31	45	4.24	9.0%
47.05	6.86	120	6.04	7.40	7.15	5.81	45	7.40	7.9%
47.06	7.8	120	6.83	8.19	7.98	6.60	45	8.19	5.0%
47.07	10.44	120	10.39	10.69	10.83	8.77	120	10.83	3.7%
47.08	10.64	120	10.58	10.89	11.03	8.95	120	11.03	3.7%
47.09	11.08	120	10.98	11.37	11.47	9.32	120	11.47	3.5%
47.10	12.33	120	12.07	13.14	12.75	10.61	45	13.14	6.6%
47.11	12.82	120	12.40	13.62	13.22	11.00	45	13.62	6.2%
48.01	0.78	20	0.79	0.68	0.53	0.39	20	0.79	1.3%
49.01	0.76	20	0.76	0.61	0.46	0.34	20	0.76	0.0%
49.02	1.21	20	1.19	1.02	0.79	0.59	20	1.19	-1.7%
49.03	1.68	45	1.58	1.68	1.41	1.05	45	1.68	0.0%
49.04	1.94	45	1.75	1.95	1.65	1.25	45	1.95	0.5%
50.01	0.76	20	0.92	0.79	0.76	0.56	20	0.92	21.1%
51.01	0.84	20	0.84	0.70	0.55	0.41	20	0.84	0.0%
52.01	0.58	20	0.87	0.66	0.49	0.35	20	0.87	50.0%
53.01	0.51	20	0.56	0.43	0.32	0.23	20	0.56	9.8%
53.02	0.94	45	1.14	1.10	0.86	0.63	20	1.14	21.3%
53.03	2.15	45	3.09	2.61	2.01	1.47	20	3.09	43.7%
54.01	0.29	20	0.31	0.22	0.16	0.11	20	0.31	6.9%
54.02	1.01	45	1.59	1.25	0.91	0.67	20	1.59	57.4%
55.01	0.79	20	0.83	0.74	0.58	0.44	20	0.83	5.1%
55.02	0.85	20	0.89	0.81	0.65	0.49	20	0.89	4.7%
56.01	0.75	20	0.77	0.63	0.66	0.50	20	0.77	2.7%
56.02	2.05	20	2.03	1.83	1.67	1.26	20	2.03	-1.0%
57.01	0.73	20	0.72	0.68	0.52	0.39	20	0.72	-1.4%
57.02	1.25	20	1.22	1.17	0.98	0.73	20	1.22	-2.4%
58.01	1.53	20	1.85	1.58	1.26	0.92	20	1.85	20.9%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
58.02	1.8	20	2.11	1.96	1.61	1.19	20	2.11	17.2%
59.01	0.34	120	0.30	0.30	0.36	0.29	120	0.36	5.9%
60.01	0.76	120	0.83	0.65	0.79	0.61	20	0.83	9.2%
60.02	1.09	20	1.27	1.00	1.06	0.83	20	1.27	16.5%
60.03	1.99	20	2.35	1.90	1.73	1.33	20	2.35	18.1%
60.04	3.88	45	4.21	4.26	3.73	2.84	45	4.26	9.8%
60.05	4.42	45	4.51	4.81	4.20	3.17	45	4.81	8.8%
61.01	0.83	20	1.01	0.81	0.60	0.45	20	1.01	21.7%
62.01	1.31	20	1.63	1.34	1.12	0.82	20	1.63	24.4%
63.01	1.16	20	1.20	1.08	1.12	0.85	20	1.20	3.4%
63.02	1.95	45	2.08	2.08	1.97	1.49	20	2.08	6.7%
63.03	2.52	45	2.85	2.80	2.58	2.01	20	2.85	13.1%
64.01	2.09	20	2.56	1.84	1.35	0.97	20	2.56	22.5%
64.02	3.23	20	3.97	3.58	2.76	2.00	20	3.97	22.9%
64.03	3.97	45	4.80	4.57	3.48	2.53	20	4.80	20.9%
65.01	0.35	20	0.75	0.54	0.40	0.28	20	0.75	114.3%
65.02	0.98	45	1.45	1.29	0.98	0.70	20	1.45	48.0%
66.01	0.91	20	1.36	0.93	0.69	0.49	20	1.36	49.5%
67.01	1.13	120	0.78	0.84	1.13	0.93	120	1.13	0.0%
67.02	2.31	120	1.33	1.70	2.31	1.99	120	2.31	0.0%
67.03	2.8	120	1.89	2.18	2.80	2.35	120	2.80	0.0%
67.04	3.47	120	2.51	2.89	3.47	2.85	120	3.47	0.0%
67.05	4.13	120	3.07	3.71	4.13	3.38	120	4.13	0.0%
68.01	0.56	45	0.49	0.56	0.50	0.37	45	0.56	0.0%
69.01	0.64	45	0.47	0.64	0.59	0.44	45	0.64	0.0%
70.01	1	20	1.67	1.17	0.86	0.62	20	1.67	67.0%
70.02	2.19	20	3.30	2.64	1.97	1.40	20	3.30	50.7%
70.03	4.33	45	5.20	4.99	3.90	2.81	20	5.20	20.1%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
71.01	1.28	45	1.37	1.33	1.01	0.73	20	1.37	7.0%
72.01	1.07	20	1.07	0.85	0.94	0.74	20	1.07	0.0%
BasinA	2.96	20	2.96	2.91	2.26	1.67	20	2.96	0.0%
BasinBC	5.18	120	3.93	5.30	5.32	4.00	120	5.32	2.7%
BasinE	2.43	120	1.54	2.11	2.43	2.12	120	2.43	0.0%
BasinF	6.62	120	3.67	6.47	7.46	5.83	120	7.46	12.7%
BasinG	1.27	120	0.91	1.24	1.33	1.19	120	1.33	4.7%
						Average Difference (All Subcatchments)			**17.68%**

Future Development Results for the 0.5% AEP Event

Subcatch ID	Adopted 0.5% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 0.5% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.01	0.31	60	0.61	0.43	0.25	20	0.61	96.8%
1.02	0.60	60	0.89	0.66	0.50	20	0.89	48.3%
1.03	2.33	60	3.66	2.89	2.16	20	3.66	57.1%
1.04	6.24	60	10.12	7.87	5.45	20	10.12	62.2%
1.05	14.10	60	14.52	16.10	12.82	60	16.10	14.2%
1.06	15.31	60	15.44	17.51	14.21	60	17.51	14.4%
1.07	15.44	60	15.58	17.66	14.31	60	17.66	14.4%
1.08	27.16	60	25.52	29.50	23.85	60	29.50	8.6%
1.09	28.98	60	26.95	31.36	25.70	60	31.36	8.2%
1.10	29.37	60	27.31	31.77	26.16	60	31.77	8.2%
1.11	30.06	60	27.95	32.46	27.15	60	32.46	8.0%
1.12	30.23	60	28.11	32.63	27.43	60	32.63	7.9%
1.13	30.70	60	28.47	33.04	28.05	60	33.04	7.6%
1.14	30.93	60	28.71	33.30	28.48	60	33.30	7.7%
1.15	31.05	60	28.78	33.41	28.81	60	33.41	7.6%
1.16	31.44	60	29.13	33.81	29.61	60	33.81	7.5%
1.17	31.51	60	29.17	33.85	29.84	60	33.85	7.4%
1.18	32.02	60	29.41	34.27	31.46	60	34.27	7.0%
1.19	32.16	60	29.49	34.51	31.86	60	34.51	7.3%
1.20	32.30	60	29.54	34.65	32.37	60	34.65	7.3%
1.21	32.49	60	29.64	34.89	32.95	60	34.89	7.4%
1.22	32.49	60	29.64	34.90	32.96	60	34.90	7.4%
1.23	41.46	60	31.11	43.36	41.99	60	43.36	4.6%

Subcatch ID	Adopted 0.5% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 0.5% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.24	42.78	60	31.20	43.95	43.54	60	43.95	2.7%
1.25	43.51	60	31.25	44.34	44.36	720	44.36	2.0%
1.26	54.59	720	39.59	54.84	55.83	720	55.83	2.3%
1.27	55.42	720	40.00	55.24	56.69	720	56.69	2.3%
1.28	55.78	720	40.21	55.45	57.09	720	57.09	2.3%
1.29	57.94	720	41.10	56.46	59.37	720	59.37	2.5%
1.30	59.98	720	41.59	56.95	61.43	720	61.43	2.4%
1.31	63.58	720	43.27	59.20	64.99	720	64.99	2.2%
1.32	65.36	720	43.52	59.45	66.53	720	66.53	1.8%
2.01	1.00	60	2.21	1.55	0.98	20	2.21	121.0%
3.01	2.00	60	3.89	2.73	1.64	20	3.89	94.5%
4.01	0.84	20	1.30	0.92	0.57	20	1.30	54.8%
5.01	1.23	60	2.28	1.59	0.91	20	2.28	85.4%
6.01	1.58	60	3.12	2.32	1.46	20	3.12	97.5%
6.02	1.81	60	3.34	2.60	1.75	20	3.34	84.5%
6.03	4.34	20	5.09	4.63	3.67	20	5.09	17.3%
7.01	2.65	20	2.65	1.87	1.15	20	2.65	0.0%
8.01	2.68	20	3.50	2.48	1.48	20	3.50	30.6%
8.02	7.48	60	7.81	7.12	5.23	20	7.81	4.4%
9.01	1.57	20	1.57	1.35	1.03	20	1.57	0.0%
10.01	1.20	20	1.20	0.87	0.52	20	1.20	0.0%
11.01	1.37	20	1.37	0.93	0.50	20	1.37	0.0%
12.01	1.19	20	1.17	1.18	1.05	60	1.18	-0.8%
13.01	5.65	20	6.30	4.33	2.45	20	6.30	11.5%
13.02	9.96	60	8.52	9.12	7.53	60	9.12	-8.4%
13.03	13.14	60	10.88	12.26	10.50	60	12.26	-6.7%

Subcatch ID	Adopted 0.5% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 0.5% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
14.01	3.75	20	3.75	2.58	1.41	20	3.75	0.0%
15.01	7.48	20	7.48	5.20	3.16	20	7.48	0.0%
16.01	1.31	20	1.32	0.90	0.51	20	1.32	0.8%
17.01	2.49	20	2.49	1.91	1.26	20	2.49	0.0%
17.02	6.57	20	6.57	5.29	3.67	20	6.57	0.0%
17.03	2.99	60	2.10	2.91	2.75	60	2.91	-2.7%
18.01	3.49	20	4.31	3.07	1.96	20	4.31	23.5%
19.01	0.82	60	0.54	0.76	0.63	60	0.76	-7.3%
20.01	1.97	20	2.21	1.68	1.10	20	2.21	12.2%
20.02	2.67	20	2.91	2.51	1.78	20	2.91	9.0%
21.01	0.55	60	0.48	0.52	0.39	60	0.52	-5.5%
22.01	1.00	20	1.38	1.16	0.79	20	1.38	38.0%
22.02	1.15	20	1.53	1.27	0.89	20	1.53	33.0%
23.01	1.54	60	1.33	1.40	1.07	60	1.40	-9.1%
24.01	1.46	20	1.57	1.23	0.90	20	1.57	7.5%
25.01	0.99	20	1.01	0.71	0.39	20	1.01	2.0%
25.02	1.21	20	1.24	0.98	0.64	20	1.24	2.5%
26.01	1.62	20	2.04	1.46	0.89	20	2.04	25.9%
27.01	1.22	20	1.51	1.08	0.65	20	1.51	23.8%
27.02	2.84	20	3.07	2.48	1.72	20	3.07	8.1%
27.03	4.17	60	4.63	3.76	2.83	20	4.63	11.0%
27.04	4.96	60	5.19	4.63	3.40	20	5.19	4.6%
28.01	1.07	20	1.05	0.74	0.45	20	1.05	-1.9%
29.01	1.37	20	2.02	1.42	0.81	20	2.02	47.4%
30.01	0.91	20	1.31	0.88	0.49	20	1.31	44.0%
31.01	0.92	20	1.25	0.93	0.64	20	1.25	35.9%

Subcatch ID	Adopted 0.5% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 0.5% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
31.02	1.09	60	1.32	1.06	0.75	20	1.32	21.1%
32.01	1.93	20	2.54	1.78	1.07	20	2.54	31.6%
32.02	3.44	20	4.86	3.44	2.06	20	4.86	41.3%
33.01	1.43	20	2.25	1.57	0.91	20	2.25	57.3%
34.01	1.03	20	1.20	0.81	0.54	20	1.20	16.5%
34.02	1.27	20	1.41	0.91	0.67	20	1.41	11.0%
35.01	1.50	20	1.50	1.02	0.57	20	1.50	0.0%
35.02	1.61	20	1.61	1.09	0.63	20	1.61	0.0%
36.01	3.89	20	3.89	2.77	1.70	20	3.89	0.0%
36.02	4.49	20	4.50	3.69	2.64	20	4.50	0.2%
36.03	4.55	20	4.56	3.87	2.72	20	4.56	0.2%
36.04	7.07	60	7.55	7.06	5.17	20	7.55	6.8%
36.05	14.77	60	14.38	15.22	11.85	60	15.22	3.0%
37.01	1.76	20	1.95	1.62	1.08	20	1.95	10.8%
37.02	2.94	60	3.57	3.08	2.37	20	3.57	21.4%
38.01	1.46	60	2.67	1.88	1.18	20	2.67	82.9%
38.02	2.69	60	3.44	2.94	2.17	20	3.44	27.9%
38.03	2.79	60	3.48	3.06	2.24	20	3.48	24.7%
38.04	5.05	60	5.90	5.16	4.03	20	5.90	16.8%
38.05	6.02	60	6.55	6.33	5.00	20	6.55	8.8%
39.01	0.71	20	0.86	0.62	0.41	20	0.86	21.1%
39.02	2.44	20	2.69	2.31	1.62	20	2.69	10.2%
40.01	1.37	20	1.41	1.23	0.85	20	1.41	2.9%
41.01	1.10	20	1.30	0.98	0.63	20	1.30	18.2%
42.01	0.91	20	1.09	0.74	0.42	20	1.09	19.8%
42.02	1.68	20	2.17	1.57	1.09	20	2.17	29.2%

Subcatch ID	Adopted 0.5% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 0.5% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
43.01	1.64	20	2.15	1.49	0.84	20	2.15	31.1%
44.01	0.69	20	0.73	0.51	0.31	20	0.73	5.8%
44.02	2.17	20	2.58	2.07	1.49	20	2.58	18.9%
45.01	1.25	20	1.56	1.13	0.71	20	1.56	24.8%
46.01	1.21	20	1.85	1.29	0.73	20	1.85	52.9%
47.01	2.21	60	2.63	2.38	1.67	20	2.63	19.0%
47.02	3.60	60	3.52	3.62	2.76	60	3.62	0.6%
47.03	3.64	60	3.55	3.67	2.81	60	3.67	0.8%
47.04	4.85	60	4.34	4.81	3.82	60	4.81	-0.8%
47.05	8.43	60	7.65	8.34	6.71	60	8.34	-1.1%
47.06	9.49	60	8.09	9.30	7.63	60	9.30	-2.0%
47.07	12.67	60	12.42	12.67	10.12	60	12.67	0.0%
47.08	12.87	60	12.64	12.95	10.33	60	12.95	0.6%
47.09	13.39	60	13.12	13.53	10.75	60	13.53	1.0%
47.10	15.09	60	14.49	15.25	12.24	60	15.25	1.1%
47.11	15.70	60	14.87	15.69	12.68	60	15.69	-0.1%
48.01	0.96	20	0.97	0.68	0.45	20	0.97	1.0%
49.01	0.92	20	0.92	0.64	0.38	20	0.92	0.0%
49.02	1.44	20	1.42	1.04	0.67	20	1.42	-1.4%
49.03	1.96	20	1.95	1.61	1.20	20	1.95	-0.5%
49.04	2.17	20	2.15	1.91	1.44	20	2.15	-0.9%
50.01	0.95	20	1.15	0.97	0.66	20	1.15	21.1%
51.01	1.03	20	1.03	0.74	0.47	20	1.03	0.0%
52.01	0.73	20	1.03	0.71	0.41	20	1.03	41.1%
53.01	0.59	20	0.64	0.46	0.26	20	0.64	8.5%
53.02	1.03	60	1.37	1.05	0.72	20	1.37	33.0%

Subcatch ID	Adopted 0.5% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 0.5% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
53.03	2.43	60	3.67	2.58	1.68	20	3.67	51.0%
54.01	0.34	20	0.36	0.24	0.13	20	0.36	5.9%
54.02	1.21	20	1.84	1.31	0.76	20	1.84	52.1%
55.01	0.99	20	1.03	0.75	0.50	20	1.03	4.0%
55.02	1.05	20	1.10	0.81	0.56	20	1.10	4.8%
56.01	0.91	20	0.94	0.85	0.58	20	0.94	3.3%
56.02	2.51	20	2.49	2.09	1.46	20	2.49	-0.8%
57.01	0.92	20	0.89	0.66	0.45	20	0.89	-3.3%
57.02	1.55	20	1.51	1.20	0.84	20	1.51	-2.6%
58.01	1.89	20	2.22	1.63	1.06	20	2.22	17.5%
58.02	2.23	20	2.56	1.99	1.38	20	2.56	14.8%
59.01	0.39	60	0.37	0.41	0.33	60	0.41	5.1%
60.01	0.89	20	0.99	0.90	0.73	20	0.99	11.2%
60.02	1.30	20	1.50	1.22	0.98	20	1.50	15.4%
60.03	2.41	20	2.81	2.08	1.55	20	2.81	16.6%
60.04	4.37	60	5.11	4.19	3.28	20	5.11	16.9%
60.05	5.02	60	5.47	4.71	3.67	20	5.47	9.0%
61.01	1.04	20	1.23	0.85	0.51	20	1.23	18.3%
62.01	1.60	20	1.96	1.44	0.94	20	1.96	22.5%
63.01	1.42	20	1.47	1.40	0.98	20	1.47	3.5%
63.02	2.26	60	2.48	2.24	1.72	20	2.48	9.7%
63.03	3.04	60	3.40	2.87	2.32	20	3.40	11.8%
64.01	2.47	20	2.96	2.02	1.11	20	2.96	19.8%
64.02	3.85	20	4.63	3.55	2.30	20	4.63	20.3%
64.03	4.79	20	5.59	4.35	2.88	20	5.59	16.7%
65.01	0.44	20	0.86	0.60	0.33	20	0.86	95.5%

Subcatch ID	Adopted 0.5% AEP Design Results		Peak Discharge for the Future Development Set of Durations and Temporal Patterns (m^3/s)			Adopted 0.5% AEP Future Development Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4405 for the 1 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
65.02	1.14	20	1.70	1.24	0.80	20	1.70	49.1%
66.01	1.10	20	1.57	1.05	0.56	20	1.57	42.7%
67.01	1.18	60	0.98	1.15	1.11	60	1.15	-2.5%
67.02	2.39	60	1.68	2.42	2.34	60	2.42	1.3%
67.03	2.91	60	2.34	2.83	2.74	60	2.83	-2.7%
67.04	3.66	60	3.14	3.62	3.31	60	3.62	-1.1%
67.05	4.49	60	3.89	4.44	3.95	60	4.44	-1.1%
68.01	0.66	20	0.65	0.60	0.43	20	0.65	-1.5%
69.01	0.72	60	0.63	0.66	0.52	60	0.66	-8.3%
70.01	1.25	20	1.94	1.29	0.70	20	1.94	55.2%
70.02	2.68	20	3.82	2.80	1.61	20	3.82	42.5%
70.03	4.99	20	6.13	4.88	3.21	20	6.13	22.8%
71.01	1.51	20	1.67	1.25	0.84	20	1.67	10.6%
72.01	1.27	20	1.27	1.16	0.86	20	1.27	0.0%
BasinA	3.15	20	3.15	2.76	1.90	20	3.15	0.0%
BasinBC	6.24	60	5.36	6.00	4.79	60	6.00	-3.8%
BasinE	2.68	60	1.85	2.62	2.45	60	2.62	-2.2%
BasinF	7.75	60	5.25	8.43	7.25	60	8.43	8.8%
BasinG	1.35	60	1.13	1.41	1.31	60	1.41	4.4%
					Average Difference (All Subcatchments)			**15.86%**

APPENDIX L

XP-RAFTS OUTPUTS FOR CLIMATE CHANGE

Climate Change Results with 9.1% increase in Rainfall Intensity (RCP 4.5) for the 1% AEP Event

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.01	0.27	45	0.22	0.31	0.28	0.22	45	0.31	14.8%
1.02	0.5	45	0.42	0.57	0.53	0.42	45	0.57	14.0%
1.03	1.96	120	1.33	2.08	2.17	1.76	120	2.17	10.7%
1.04	5.21	120	3.98	5.83	5.77	4.57	45	5.83	11.9%
1.05	11.85	120	7.55	12.38	13.66	10.95	120	13.66	15.3%
1.06	13.05	120	8.29	13.43	14.99	12.28	120	14.99	14.9%
1.07	13.16	120	8.36	13.51	15.12	12.39	120	15.12	14.9%
1.08	23.36	120	17.09	23.90	26.64	21.01	120	26.64	14.0%
1.09	25.06	120	18.28	25.59	28.50	22.69	120	28.50	13.7%
1.10	25.43	120	18.60	25.96	28.89	23.10	120	28.89	13.6%
1.11	26.14	120	19.18	26.64	29.63	24.06	120	29.63	13.4%
1.12	26.3	120	19.29	26.79	29.81	24.32	120	29.81	13.3%
1.13	26.75	120	19.66	27.25	30.29	24.96	120	30.29	13.2%
1.14	27.01	120	19.86	27.49	30.55	25.37	120	30.55	13.1%
1.15	27.13	120	19.94	27.60	30.69	25.70	120	30.69	13.1%
1.16	27.52	120	20.25	27.99	31.09	26.46	120	31.09	13.0%
1.17	27.58	120	20.31	28.06	31.17	26.73	120	31.17	13.0%
1.18	28.16	120	20.69	28.56	31.78	28.27	120	31.78	12.9%
1.19	28.29	120	20.80	28.68	31.92	28.66	120	31.92	12.8%
1.20	28.43	120	20.91	28.80	32.06	29.19	120	32.06	12.8%
1.21	28.6	120	21.00	28.95	32.25	29.84	120	32.25	12.8%
1.22	28.6	120	21.00	28.94	32.25	29.86	120	32.25	12.8%
1.23	37.81	120	26.62	36.81	42.05	39.04	120	42.05	11.2%
1.24	39.04	120	27.45	37.89	43.39	40.46	120	43.39	11.1%
1.25	39.58	120	27.82	38.34	43.97	41.25	120	43.97	11.1%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.26	49.53	120	33.84	47.05	55.10	51.95	120	55.10	11.2%
1.27	49.98	120	34.07	47.38	55.57	52.75	120	55.57	11.2%
1.28	50.18	120	34.20	47.57	55.79	53.10	120	55.79	11.2%
1.29	51.28	120	34.91	48.47	56.97	55.17	120	56.97	11.1%
1.30	52.05	120	35.59	49.08	57.82	57.10	120	57.82	11.1%
1.31	54.83	720	37.11	51.03	60.63	60.54	120	60.63	10.6%
1.32	56.44	720	37.43	51.33	61.12	62.27	720	62.27	10.3%
2.01	0.86	120	0.64	0.88	0.96	0.78	120	0.96	11.6%
3.01	1.61	45	1.26	1.86	1.79	1.39	45	1.86	15.5%
4.01	0.66	20	0.77	0.75	0.71	0.53	20	0.77	16.7%
5.01	1.1	45	1.04	1.24	1.10	0.82	45	1.24	12.7%
6.01	1.34	120	0.99	1.43	1.50	1.20	120	1.50	11.9%
6.02	1.56	120	1.21	1.59	1.74	1.39	120	1.74	11.5%
6.03	3.78	45	4.05	4.30	4.08	3.19	45	4.30	13.8%
7.01	2.23	20	2.50	1.97	1.49	1.09	20	2.50	12.1%
8.01	2.22	20	2.52	2.22	1.86	1.38	20	2.52	13.5%
8.02	6.45	45	6.78	7.25	6.46	4.93	45	7.25	12.4%
9.01	1.41	45	1.43	1.60	1.33	0.98	45	1.60	13.5%
10.01	1.01	20	1.13	0.93	0.68	0.50	20	1.13	11.9%
11.01	1.19	20	1.31	0.91	0.66	0.48	20	1.31	10.1%
12.01	1.09	120	1.10	0.97	1.23	0.99	120	1.23	12.8%
13.01	4.7	20	5.32	4.15	3.12	2.29	20	5.32	13.2%
13.02	8.52	45	7.58	9.59	9.16	7.03	45	9.59	12.6%
13.03	11.13	120	9.81	12.50	12.41	9.93	45	12.50	12.3%
14.01	3.25	20	3.57	2.59	1.90	1.35	20	3.57	9.8%
15.01	6.54	20	7.14	5.30	4.12	3.02	20	7.14	9.2%
16.01	1.14	20	1.25	0.93	0.67	0.49	20	1.25	9.6%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
17.01	2.06	20	2.35	1.96	1.63	1.20	20	2.35	14.1%
17.02	5.51	20	6.18	4.94	4.60	3.49	20	6.18	12.2%
17.03	2.7	120	1.96	2.68	3.00	2.61	120	3.00	11.1%
18.01	2.85	20	3.24	2.81	2.46	1.83	20	3.24	13.7%
19.01	0.68	120	0.51	0.75	0.76	0.60	120	0.76	11.8%
20.01	1.62	20	1.83	1.58	1.39	1.03	20	1.83	13.0%
20.02	2.17	20	2.47	2.51	2.18	1.67	45	2.51	15.7%
21.01	0.48	45	0.42	0.56	0.50	0.37	45	0.56	16.7%
22.01	0.83	120	0.93	0.85	0.91	0.71	20	0.93	12.0%
22.02	0.93	20	1.06	1.00	1.01	0.81	20	1.06	14.0%
23.01	1.36	45	1.24	1.55	1.37	1.03	45	1.55	14.0%
24.01	1.26	45	1.36	1.43	1.17	0.86	45	1.43	13.5%
25.01	0.86	20	0.95	0.71	0.52	0.38	20	0.95	10.5%
25.02	1.07	20	1.16	1.12	0.83	0.61	20	1.16	8.4%
26.01	1.29	20	1.49	1.36	1.13	0.83	20	1.49	15.5%
27.01	1	20	1.14	1.03	0.83	0.61	20	1.14	14.0%
27.02	2.39	45	2.68	2.66	2.15	1.61	20	2.68	12.1%
27.03	3.79	45	3.67	4.22	3.55	2.66	45	4.22	11.3%
27.04	4.33	45	4.01	4.91	4.16	3.16	45	4.91	13.4%
28.01	0.9	20	1.02	0.81	0.58	0.43	20	1.02	13.3%
29.01	1.12	45	1.29	1.27	1.02	0.75	20	1.29	15.2%
30.01	0.74	20	0.84	0.76	0.61	0.45	20	0.84	13.5%
31.01	0.84	45	0.83	0.95	0.79	0.59	45	0.95	13.1%
31.02	0.96	45	0.94	1.11	0.91	0.68	45	1.11	15.6%
32.01	1.56	20	1.78	1.57	1.34	0.99	20	1.78	14.1%
32.02	2.76	20	3.15	2.97	2.54	1.90	20	3.15	14.1%
33.01	1.12	20	1.30	1.28	1.12	0.83	20	1.30	16.1%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
34.01	0.89	20	0.98	0.66	0.63	0.48	20	0.98	10.1%
34.02	1.08	20	1.21	0.78	0.74	0.61	20	1.21	12.0%
35.01	1.27	20	1.42	1.02	0.75	0.54	20	1.42	11.8%
35.02	1.42	20	1.54	1.12	0.84	0.61	20	1.54	8.5%
36.01	3.25	20	3.65	2.93	2.21	1.62	20	3.65	12.3%
36.02	3.7	20	4.20	4.04	3.38	2.51	20	4.20	13.5%
36.03	3.75	20	4.26	4.11	3.48	2.60	20	4.26	13.6%
36.04	5.78	20	6.42	6.62	6.19	4.83	45	6.62	14.5%
36.05	11.99	120	11.68	13.55	13.22	10.83	45	13.55	13.0%
37.01	1.48	20	1.66	1.40	1.34	1.01	20	1.66	12.2%
37.02	2.45	120	2.51	2.74	2.72	2.15	45	2.74	11.8%
38.01	1.21	45	1.06	1.38	1.33	1.03	45	1.38	14.0%
38.02	2.22	120	1.99	2.50	2.45	1.93	45	2.50	12.6%
38.03	2.31	120	2.06	2.55	2.55	2.00	45	2.55	10.4%
38.04	4.2	120	4.37	4.66	4.64	3.68	45	4.66	11.0%
38.05	5.03	120	5.00	5.61	5.56	4.45	45	5.61	11.5%
39.01	0.58	20	0.67	0.60	0.51	0.37	20	0.67	15.5%
39.02	1.99	20	2.28	2.16	1.99	1.52	20	2.28	14.6%
40.01	1.11	20	1.27	1.11	1.07	0.81	20	1.27	14.4%
41.01	0.88	20	1.04	0.92	0.81	0.60	20	1.04	18.2%
42.01	0.75	20	0.86	0.68	0.52	0.39	20	0.86	14.7%
42.02	1.42	20	1.62	1.52	1.35	1.01	20	1.62	14.1%
43.01	1.39	20	1.54	1.28	1.05	0.78	20	1.54	10.8%
44.01	0.59	20	0.66	0.51	0.41	0.31	20	0.66	11.9%
44.02	1.77	20	2.03	1.96	1.75	1.33	20	2.03	14.7%
45.01	1.01	20	1.17	1.01	0.89	0.66	20	1.17	15.8%
46.01	0.99	20	1.13	1.07	0.90	0.67	20	1.13	14.1%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
47.01	1.85	45	1.57	2.12	2.01	1.53	45	2.12	14.6%
47.02	2.91	45	2.36	3.39	3.17	2.51	45	3.39	16.5%
47.03	2.94	45	2.39	3.42	3.21	2.56	45	3.42	16.3%
47.04	3.89	120	3.33	4.31	4.32	3.51	120	4.32	11.1%
47.05	6.86	120	6.31	7.78	7.57	6.21	45	7.78	13.4%
47.06	7.8	120	6.96	8.81	8.58	7.03	45	8.81	12.9%
47.07	10.44	120	9.63	11.72	11.55	9.33	45	11.72	12.3%
47.08	10.64	120	9.84	11.89	11.76	9.53	45	11.89	11.7%
47.09	11.08	120	10.29	12.31	12.23	9.93	45	12.31	11.1%
47.10	12.33	120	11.52	13.77	13.60	11.27	45	13.77	11.7%
47.11	12.82	120	11.94	14.31	14.17	11.77	45	14.31	11.6%
48.01	0.78	20	0.89	0.77	0.58	0.43	20	0.89	14.1%
49.01	0.76	20	0.86	0.68	0.50	0.36	20	0.86	13.2%
49.02	1.21	20	1.35	1.14	0.87	0.64	20	1.35	11.6%
49.03	1.68	45	1.83	1.90	1.55	1.15	45	1.90	13.1%
49.04	1.94	45	2.03	2.19	1.83	1.37	45	2.19	12.9%
50.01	0.76	20	0.87	0.81	0.80	0.61	20	0.87	14.5%
51.01	0.84	20	0.96	0.80	0.61	0.45	20	0.96	14.3%
52.01	0.58	20	0.67	0.63	0.50	0.37	20	0.67	15.5%
53.01	0.51	20	0.57	0.45	0.35	0.25	20	0.57	11.8%
53.02	0.94	45	0.95	1.06	0.89	0.66	45	1.06	12.8%
53.03	2.15	45	2.08	2.43	2.06	1.53	45	2.43	13.0%
54.01	0.29	20	0.32	0.24	0.17	0.12	20	0.32	10.3%
54.02	1.01	45	1.11	1.16	0.96	0.71	45	1.16	14.9%
55.01	0.79	20	0.92	0.81	0.65	0.48	20	0.92	16.5%
55.02	0.85	20	0.98	0.90	0.71	0.53	20	0.98	15.3%
56.01	0.75	20	0.85	0.71	0.73	0.55	20	0.85	13.3%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
56.02	2.05	20	2.33	2.11	1.85	1.38	20	2.33	13.7%
57.01	0.73	20	0.85	0.77	0.58	0.43	20	0.85	16.4%
57.02	1.25	20	1.44	1.35	1.08	0.80	20	1.44	15.2%
58.01	1.53	20	1.77	1.61	1.36	0.99	20	1.77	15.7%
58.02	1.8	20	2.09	2.03	1.72	1.29	20	2.09	16.1%
59.01	0.34	120	0.29	0.35	0.39	0.31	120	0.39	14.7%
60.01	0.76	120	0.84	0.67	0.84	0.67	20	0.84	10.5%
60.02	1.09	20	1.22	1.03	1.12	0.91	20	1.22	11.9%
60.03	1.99	20	2.26	1.96	1.84	1.45	20	2.26	13.6%
60.04	3.88	45	4.07	4.41	3.98	3.03	45	4.41	13.7%
60.05	4.42	45	4.41	5.02	4.50	3.41	45	5.02	13.6%
61.01	0.83	20	0.97	0.83	0.64	0.48	20	0.97	16.9%
62.01	1.31	20	1.49	1.33	1.18	0.88	20	1.49	13.7%
63.01	1.16	20	1.32	1.22	1.23	0.93	20	1.32	13.8%
63.02	1.95	45	1.90	2.23	2.10	1.61	45	2.23	14.4%
63.03	2.52	45	2.53	2.86	2.70	2.14	45	2.86	13.5%
64.01	2.09	20	2.35	1.90	1.42	1.03	20	2.35	12.4%
64.02	3.23	20	3.64	3.53	2.82	2.09	20	3.64	12.7%
64.03	3.97	45	4.50	4.43	3.57	2.65	20	4.50	13.4%
65.01	0.35	20	0.41	0.41	0.38	0.28	20	0.41	17.1%
65.02	0.98	45	1.07	1.11	0.97	0.72	45	1.11	13.3%
66.01	0.91	20	1.03	0.92	0.71	0.52	20	1.03	13.2%
67.01	1.13	120	0.92	0.99	1.28	1.05	120	1.28	13.3%
67.02	2.31	120	1.54	2.02	2.59	2.22	120	2.59	12.1%
67.03	2.8	120	2.14	2.56	3.15	2.60	120	3.15	12.5%
67.04	3.47	120	2.87	3.32	3.88	3.14	120	3.88	11.8%
67.05	4.13	120	3.55	4.24	4.62	3.74	120	4.62	11.9%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
68.01	0.56	45	0.60	0.64	0.57	0.41	45	0.64	14.3%
69.01	0.64	45	0.57	0.72	0.65	0.49	45	0.72	12.5%
70.01	1	20	1.17	1.01	0.86	0.63	20	1.17	17.0%
70.02	2.19	20	2.50	2.41	1.98	1.45	20	2.50	14.2%
70.03	4.33	45	4.64	4.89	3.96	2.92	45	4.89	12.9%
71.01	1.28	45	1.39	1.43	1.10	0.80	45	1.43	11.7%
72.01	1.07	20	1.21	1.00	1.05	0.82	20	1.21	13.1%
BasinA	2.96	20	3.08	3.03	2.48	1.82	20	3.08	4.1%
BasinBC	5.18	120	4.33	5.90	5.85	4.44	45	5.90	13.9%
BasinE	2.43	120	1.74	2.38	2.69	2.33	120	2.69	10.7%
BasinF	6.62	120	3.63	6.46	7.77	6.27	120	7.77	17.4%
BasinG	1.27	120	0.88	1.24	1.37	1.23	120	1.37	7.9%
						Average Difference (All Subcatchments)			**13.05%**

Climate Change Results with 18.6% Increase in Rainfall Intensity (RCP 8.5) for the 1% AEP Event

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.01	0.27	45	0.25	0.34	0.31	0.24	45	0.34	25.9%
1.02	0.5	45	0.48	0.65	0.58	0.46	45	0.65	30.0%
1.03	1.96	120	1.59	2.38	2.41	1.94	120	2.41	23.0%
1.04	5.21	120	4.72	6.61	6.39	5.04	45	6.61	26.9%
1.05	11.85	120	9.08	14.56	15.42	12.39	120	15.42	30.1%
1.06	13.05	120	9.93	15.72	16.91	13.83	120	16.91	29.6%
1.07	13.16	120	10.02	15.82	17.05	13.94	120	17.05	29.6%
1.08	23.36	120	19.73	27.91	30.37	23.57	120	30.37	30.0%
1.09	25.06	120	21.11	29.70	32.37	25.39	120	32.37	29.2%
1.10	25.43	120	21.45	30.07	32.78	25.82	120	32.78	28.9%
1.11	26.14	120	22.06	30.73	33.60	26.84	120	33.60	28.5%
1.12	26.3	120	22.18	30.87	33.79	27.12	120	33.79	28.5%
1.13	26.75	120	22.57	31.32	34.32	27.81	120	34.32	28.3%
1.14	27.01	120	22.78	31.55	34.59	28.26	120	34.59	28.1%
1.15	27.13	120	22.84	31.64	34.73	28.61	120	34.73	28.0%
1.16	27.52	120	23.17	32.01	35.16	29.44	120	35.16	27.8%
1.17	27.58	120	23.23	32.08	35.25	29.73	120	35.25	27.8%
1.18	28.16	120	23.59	32.58	35.97	31.41	120	35.97	27.7%
1.19	28.29	120	23.70	32.69	36.12	31.83	120	36.12	27.7%
1.20	28.43	120	23.80	32.82	36.29	32.47	120	36.29	27.6%
1.21	28.6	120	23.90	32.97	36.50	33.08	120	36.50	27.6%
1.22	28.6	120	23.90	32.97	36.50	33.09	120	36.50	27.6%
1.23	37.81	120	30.32	41.00	46.43	42.86	120	46.43	22.8%
1.24	39.04	120	31.16	42.17	47.87	44.41	120	47.87	22.6%
1.25	39.58	120	31.55	42.67	48.52	45.29	120	48.52	22.6%
1.26	49.53	120	38.77	52.95	60.88	57.09	120	60.88	22.9%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
1.27	49.98	120	39.01	53.30	61.38	57.95	120	61.38	22.8%
1.28	50.18	120	39.15	53.50	61.62	58.32	120	61.62	22.8%
1.29	51.28	120	39.98	54.46	62.90	60.59	120	62.90	22.7%
1.30	52.05	120	40.69	55.08	63.92	62.67	120	63.92	22.8%
1.31	54.83	720	42.43	57.23	67.02	66.42	120	67.02	22.2%
1.32	56.44	720	42.76	57.54	67.54	68.25	720	68.25	20.9%
2.01	0.86	120	0.75	1.02	1.07	0.86	120	1.07	24.4%
3.01	1.61	45	1.51	2.11	2.00	1.53	45	2.11	31.1%
4.01	0.66	20	0.91	0.86	0.77	0.58	20	0.91	37.9%
5.01	1.1	45	1.18	1.40	1.21	0.90	45	1.40	27.3%
6.01	1.34	120	1.19	1.65	1.66	1.32	120	1.66	23.9%
6.02	1.56	120	1.42	1.82	1.91	1.52	120	1.91	22.4%
6.03	3.78	45	4.60	4.83	4.48	3.50	45	4.83	27.8%
7.01	2.23	20	2.78	2.17	1.63	1.20	20	2.78	24.7%
8.01	2.22	20	2.86	2.50	2.04	1.50	20	2.86	28.8%
8.02	6.45	45	7.64	8.09	7.07	5.40	45	8.09	25.4%
9.01	1.41	45	1.71	1.80	1.44	1.07	45	1.80	27.7%
10.01	1.01	20	1.26	1.02	0.74	0.54	20	1.26	24.8%
11.01	1.19	20	1.44	0.99	0.73	0.52	20	1.44	21.0%
12.01	1.09	120	1.26	1.12	1.38	1.10	120	1.38	26.6%
13.01	4.7	20	5.89	4.58	3.41	2.49	20	5.89	25.3%
13.02	8.52	45	8.61	10.69	10.15	7.82	45	10.69	25.5%
13.03	11.13	120	11.11	13.91	14.03	10.94	120	14.03	26.1%
14.01	3.25	20	3.92	2.82	2.08	1.47	20	3.92	20.6%
15.01	6.54	20	7.80	5.86	4.50	3.30	20	7.80	19.3%
16.01	1.14	20	1.37	1.01	0.73	0.53	20	1.37	20.2%
17.01	2.06	20	2.62	2.20	1.78	1.31	20	2.62	27.2%
17.02	5.51	20	6.91	5.53	5.06	3.84	20	6.91	25.4%
17.03	2.7	120	2.21	2.99	3.79	2.87	120	3.79	40.4%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
18.01	2.85	20	3.71	3.22	2.70	2.00	20	3.71	30.2%
19.01	0.68	120	0.59	0.86	0.83	0.65	45	0.86	26.5%
20.01	1.62	20	2.09	1.79	1.53	1.13	20	2.09	29.0%
20.02	2.17	20	2.83	2.85	2.40	1.83	45	2.85	31.3%
21.01	0.48	45	0.51	0.63	0.55	0.41	45	0.63	31.3%
22.01	0.83	120	1.08	0.95	1.01	0.78	20	1.08	30.1%
22.02	0.93	20	1.22	1.12	1.13	0.89	20	1.22	31.2%
23.01	1.36	45	1.47	1.75	1.50	1.12	45	1.75	28.7%
24.01	1.26	45	1.57	1.61	1.28	0.94	45	1.61	27.8%
25.01	0.86	20	1.03	0.77	0.56	0.41	20	1.03	19.8%
25.02	1.07	20	1.26	1.22	0.91	0.66	20	1.26	17.8%
26.01	1.29	20	1.71	1.54	1.24	0.91	20	1.71	32.6%
27.01	1	20	1.30	1.15	0.90	0.67	20	1.30	30.0%
27.02	2.39	45	3.00	2.92	2.35	1.77	20	3.00	25.5%
27.03	3.79	45	4.15	4.69	3.88	2.91	45	4.69	23.7%
27.04	4.33	45	4.59	5.54	4.55	3.45	45	5.54	27.9%
28.01	0.9	20	1.13	0.88	0.63	0.46	20	1.13	25.6%
29.01	1.12	45	1.45	1.41	1.11	0.82	20	1.45	29.5%
30.01	0.74	20	0.98	0.85	0.67	0.49	20	0.98	32.4%
31.01	0.84	45	0.98	1.07	0.87	0.64	45	1.07	27.4%
31.02	0.96	45	1.12	1.26	0.99	0.75	45	1.26	31.3%
32.01	1.56	20	2.04	1.77	1.47	1.08	20	2.04	30.8%
32.02	2.76	20	3.63	3.35	2.78	2.07	20	3.63	31.5%
33.01	1.12	20	1.52	1.45	1.23	0.90	20	1.52	35.7%
34.01	0.89	20	1.07	0.73	0.69	0.53	20	1.07	20.2%
34.02	1.08	20	1.33	0.85	0.81	0.68	20	1.33	23.1%
35.01	1.27	20	1.58	1.12	0.82	0.59	20	1.58	24.4%
35.02	1.42	20	1.70	1.23	0.91	0.66	20	1.70	19.7%
36.01	3.25	20	4.10	3.25	2.42	1.77	20	4.10	26.2%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
36.02	3.7	20	4.74	4.47	3.69	2.75	20	4.74	28.1%
36.03	3.75	20	4.80	4.55	3.81	2.83	20	4.80	28.0%
36.04	5.78	20	7.15	7.50	6.79	5.30	45	7.50	29.8%
36.05	11.99	120	13.19	15.41	14.54	11.87	45	15.41	28.5%
37.01	1.48	20	1.87	1.60	1.47	1.10	20	1.87	26.4%
37.02	2.45	120	2.85	3.11	2.99	2.36	45	3.11	26.9%
38.01	1.21	45	1.24	1.56	1.46	1.12	45	1.56	28.9%
38.02	2.22	120	2.30	2.83	2.70	2.12	45	2.83	27.5%
38.03	2.31	120	2.40	2.89	2.80	2.20	45	2.89	25.1%
38.04	4.2	120	5.02	5.30	5.11	4.04	45	5.30	26.2%
38.05	5.03	120	5.77	6.40	6.11	4.89	45	6.40	27.2%
39.01	0.58	20	0.77	0.69	0.56	0.41	20	0.77	32.8%
39.02	1.99	20	2.61	2.49	2.19	1.66	20	2.61	31.2%
40.01	1.11	20	1.44	1.27	1.17	0.88	20	1.44	29.7%
41.01	0.88	20	1.18	1.03	0.89	0.66	20	1.18	34.1%
42.01	0.75	20	0.97	0.76	0.57	0.42	20	0.97	29.3%
42.02	1.42	20	1.79	1.72	1.47	1.10	20	1.79	26.1%
43.01	1.39	20	1.74	1.43	1.15	0.85	20	1.74	25.2%
44.01	0.59	20	0.72	0.56	0.44	0.33	20	0.72	22.0%
44.02	1.77	20	2.28	2.22	1.92	1.46	20	2.28	28.8%
45.01	1.01	20	1.32	1.15	0.97	0.72	20	1.32	30.7%
46.01	0.99	20	1.30	1.22	0.99	0.73	20	1.30	31.3%
47.01	1.85	45	1.90	2.40	2.20	1.68	45	2.40	29.7%
47.02	2.91	45	2.83	3.85	3.51	2.76	45	3.85	32.3%
47.03	2.94	45	2.86	3.88	3.56	2.81	45	3.88	32.0%
47.04	3.89	120	3.89	4.92	4.77	3.85	45	4.92	26.5%
47.05	6.86	120	7.39	8.82	8.33	6.83	45	8.82	28.6%
47.06	7.8	120	8.04	9.94	9.43	7.71	45	9.94	27.4%
47.07	10.44	120	11.00	13.12	12.68	10.23	45	13.12	25.7%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
47.08	10.64	120	11.23	13.33	12.91	10.45	45	13.33	25.3%
47.09	11.08	120	11.76	13.91	13.43	10.89	45	13.91	25.5%
47.10	12.33	120	13.18	15.52	14.91	12.38	45	15.52	25.9%
47.11	12.82	120	13.70	16.13	15.59	12.93	45	16.13	25.8%
48.01	0.78	20	1.02	0.84	0.63	0.47	20	1.02	30.8%
49.01	0.76	20	0.97	0.75	0.55	0.39	20	0.97	27.6%
49.02	1.21	20	1.52	1.27	0.95	0.70	20	1.52	25.6%
49.03	1.68	45	2.09	2.12	1.69	1.25	45	2.12	26.2%
49.04	1.94	45	2.32	2.46	1.99	1.50	45	2.46	26.8%
50.01	0.76	20	1.01	0.91	0.88	0.67	20	1.01	32.9%
51.01	0.84	20	1.11	0.89	0.66	0.49	20	1.11	32.1%
52.01	0.58	20	0.78	0.71	0.55	0.41	20	0.78	34.5%
53.01	0.51	20	0.62	0.49	0.38	0.27	20	0.62	21.6%
53.02	0.94	45	1.10	1.19	0.98	0.72	45	1.19	26.6%
53.03	2.15	45	2.43	2.73	2.26	1.68	45	2.73	27.0%
54.01	0.29	20	0.35	0.26	0.19	0.14	20	0.35	20.7%
54.02	1.01	45	1.29	1.31	1.05	0.77	45	1.31	29.7%
55.01	0.79	20	1.05	0.91	0.71	0.52	20	1.05	32.9%
55.02	0.85	20	1.11	1.00	0.78	0.58	20	1.11	30.6%
56.01	0.75	20	0.96	0.82	0.80	0.60	20	0.96	28.0%
56.02	2.05	20	2.66	2.39	2.02	1.52	20	2.66	29.8%
57.01	0.73	20	0.96	0.85	0.64	0.47	20	0.96	31.5%
57.02	1.25	20	1.65	1.52	1.18	0.88	20	1.65	32.0%
58.01	1.53	20	2.00	1.81	1.48	1.09	20	2.00	30.7%
58.02	1.8	20	2.36	2.29	1.89	1.42	20	2.36	31.1%
59.01	0.34	120	0.33	0.40	0.43	0.34	120	0.43	26.5%
60.01	0.76	120	0.93	0.76	0.93	0.74	20	0.93	22.4%
60.02	1.09	20	1.36	1.16	1.24	1.00	20	1.36	24.8%
60.03	1.99	20	2.54	2.19	2.03	1.59	20	2.54	27.6%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
60.04	3.88	45	4.65	4.96	4.38	3.34	45	4.96	27.8%
60.05	4.42	45	5.04	5.64	4.94	3.75	45	5.64	27.6%
61.01	0.83	20	1.10	0.93	0.71	0.52	20	1.10	32.5%
62.01	1.31	20	1.70	1.53	1.30	0.96	20	1.70	29.8%
63.01	1.16	20	1.52	1.40	1.35	1.02	20	1.52	31.0%
63.02	1.95	45	2.18	2.53	2.31	1.76	45	2.53	29.7%
63.03	2.52	45	2.86	3.21	2.96	2.35	45	3.21	27.4%
64.01	2.09	20	2.60	2.09	1.55	1.13	20	2.60	24.4%
64.02	3.23	20	4.09	3.91	3.08	2.28	20	4.09	26.6%
64.03	3.97	45	5.09	4.90	3.91	2.90	20	5.09	28.2%
65.01	0.35	20	0.47	0.46	0.41	0.31	20	0.47	34.3%
65.02	0.98	45	1.21	1.23	1.06	0.79	45	1.23	25.5%
66.01	0.91	20	1.17	1.03	0.77	0.57	20	1.17	28.6%
67.01	1.13	120	1.05	1.15	1.42	1.17	120	1.42	25.7%
67.02	2.31	120	1.81	2.33	2.88	2.46	120	2.88	24.7%
67.03	2.8	120	2.49	2.90	3.54	2.88	120	3.54	26.4%
67.04	3.47	120	3.34	3.76	4.32	3.46	120	4.32	24.5%
67.05	4.13	120	4.14	4.78	5.12	4.12	120	5.12	24.0%
68.01	0.56	45	0.72	0.72	0.61	0.45	20	0.72	28.6%
69.01	0.64	45	0.67	0.82	0.71	0.54	45	0.82	28.1%
70.01	1	20	1.32	1.13	0.93	0.68	20	1.32	32.0%
70.02	2.19	20	2.84	2.69	2.16	1.60	20	2.84	29.7%
70.03	4.33	45	5.31	5.45	4.32	3.20	45	5.45	25.9%
71.01	1.28	45	1.60	1.58	1.20	0.87	20	1.60	25.0%
72.01	1.07	20	1.38	1.13	1.16	0.90	20	1.38	29.0%
BasinA	2.96	20	3.21	3.19	2.71	1.99	20	3.21	8.4%
BasinBC	5.18	120	5.24	6.70	6.51	4.96	45	6.70	29.3%
BasinE	2.43	120	1.95	2.67	3.45	2.56	120	3.45	42.0%
BasinF	6.62	120	4.53	7.82	8.88	7.22	120	8.88	34.1%

Subcatch ID	Adopted 1% AEP Design Results		Peak Discharge for the Climate Change Set of Durations and Temporal Patterns (m^3/s)				Adopted 1% AEP Climate Change Results		
	Discharge (m3/s)	Duration (mins)	TP 4371 for the 20 minute duration	TP 4528 for the 45 minute duration	TP 4617 for the 2 hour duration	TP 4443 for the 12 hour duration	Duration of Maximum Discharge (mins)	Discharge (m^3/s)	Difference (%)
BasinG	1.27	120	1.06	1.35	1.47	1.32	120	1.47	15.7%
						Average Difference (All Subcatchments)			**27.40%**

APPENDIX M

HYDRAULIC CATEGORY VERIFICATION

HYDRAULIC CATEGORY VERIFICATION

Floodway

By definition, a floodway is an area that if only partially blocked would produce a significant impact on upstream water levels and/or would divert water from existing flowpaths resulting in the development of new flowpaths (NSW Government, 2005). Accordingly, the suitability of the delineated floodways was verified by partially blocking the floodways and quantifying the impact that this blockage had on peak 1% AEP flood levels and the distribution of flood flows. This approach is in accordance with recommendations outlined in the Office of Environment and Heritage's 'Floodway Definition' guideline (2007).

The TUFLOW hydraulic model was updated to include partial blockage of the delineated floodways at several locations across the catchment and was re-run for the 1% AEP event. The peak 1% AEP flood levels from the partly obstructed floodway models runs were compared against 'existing' 1% AEP flood levels to create flood level difference maps (i.e., maps showing the location and magnitude of changes in flood level). The difference maps are shown in **Plate M1** to **Plate M3**. Also included in **Plate M1** to **Plate M3** are velocity vectors for existing and partly blocked conditions so that the redistribution of flood flows can also be visualised.

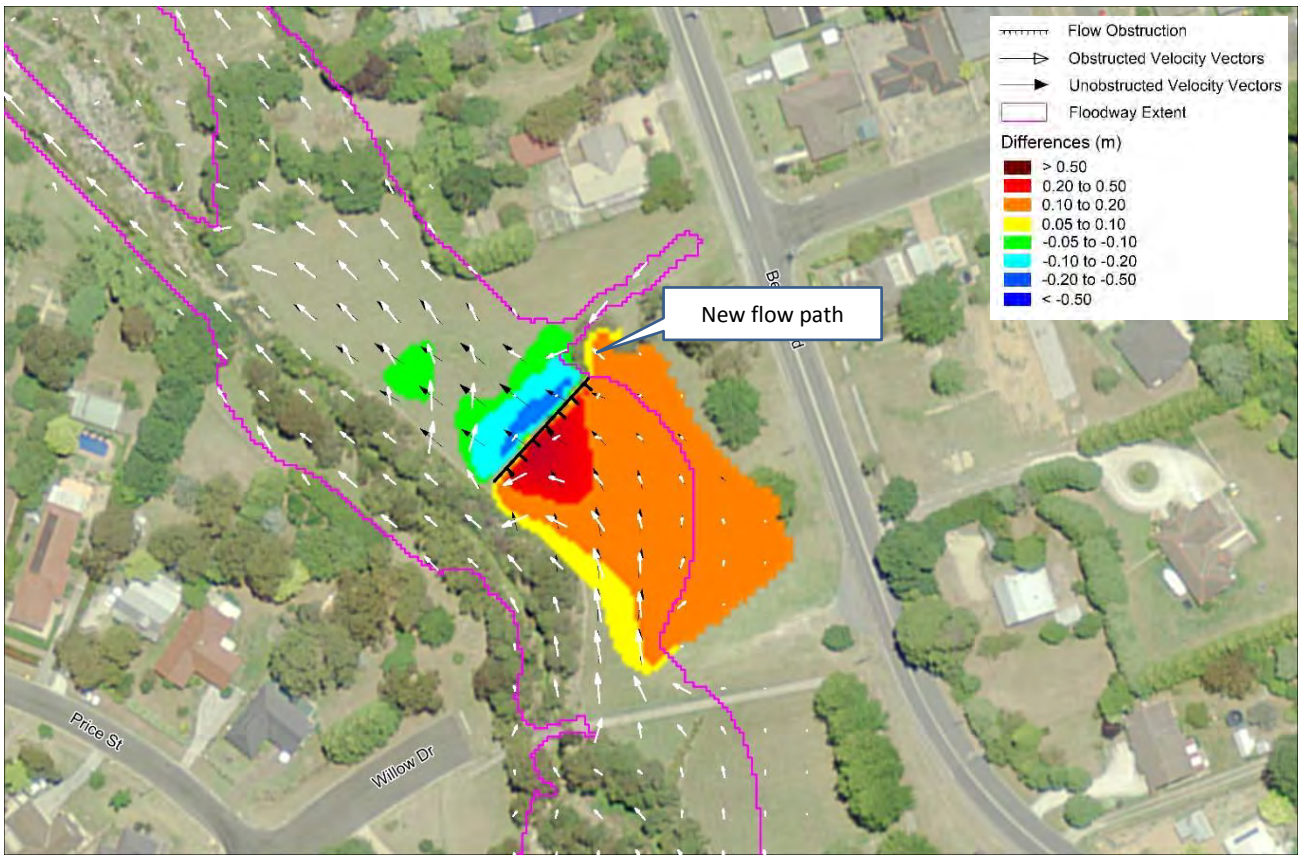


Plate M1 **1% AEP Flood Level Differences associated with obstruction of floodway in the vicinity of Price St and Willow Dr, Moss Vale**



Plate M2 1% AEP Flood Level Differences associated with obstruction of floodway in the vicinity of Queen St and Railway Dr, Moss Vale

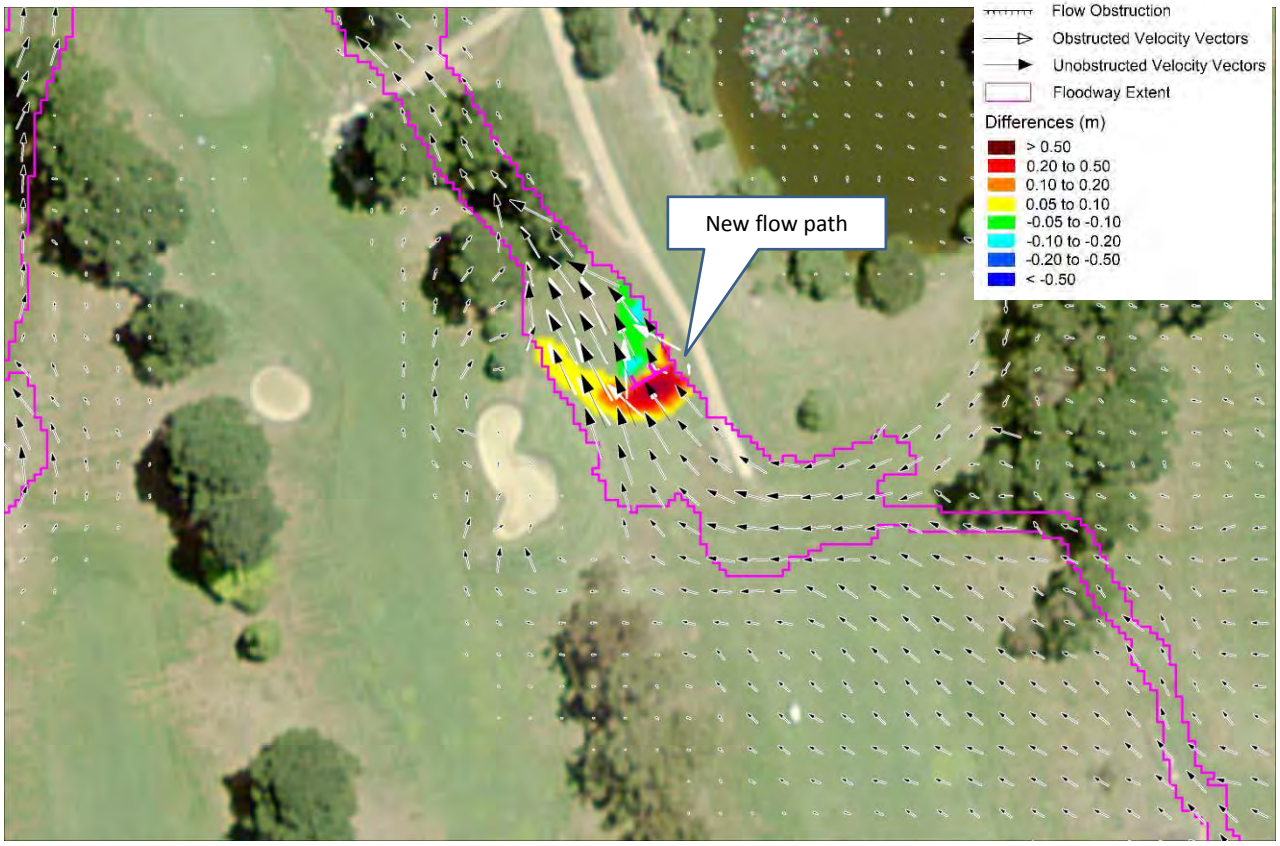


Plate M3 1% AEP Flood Level Differences associated with obstruction of floodway within Moss Vale Golf Club

Plate M1 to **Plate M3** show that the obstructions increase peak 1% AEP flood levels by over 0.3 metres upstream of each blockage location. This is considered to be a 'significant impact' on upstream water levels. The blockages also tend to re-direct flows outside of the delineated floodway extents and/or create new flow paths.

Overall, the partial blockage of the delineated floodways is predicted to produce significant impacts on upstream water levels and would result in the re-direction of flood flows. Therefore, it is considered that the delineated floodway extents conform to the *'Floodplain Development Manual'* definitions and are suitable for application across the Nattai River catchment.

Flood Storage

Flood storage areas are important for the temporary storage of floodwaters during the passage of a flood. They are areas that, if filled/removed, would result in flood levels in nearby areas increasing.

To confirm the suitability of the flood storage areas, all flood storage areas were "filled" to above the peak 1% AEP flood level. Flood Fringe areas were also filled as part of the flood storage assessment. The updated model was used to re-simulate the 1% AEP flood

Peak 1% AEP flood levels were compared against 'existing' 1% AEP flood levels and the resulting difference mapping is shown in **Plate M4** to **Plate M6**. Velocity vectors are also included to confirm if the filling would cause a significant redistribution of flood flows (which may indicate the storage areas are actually floodways).

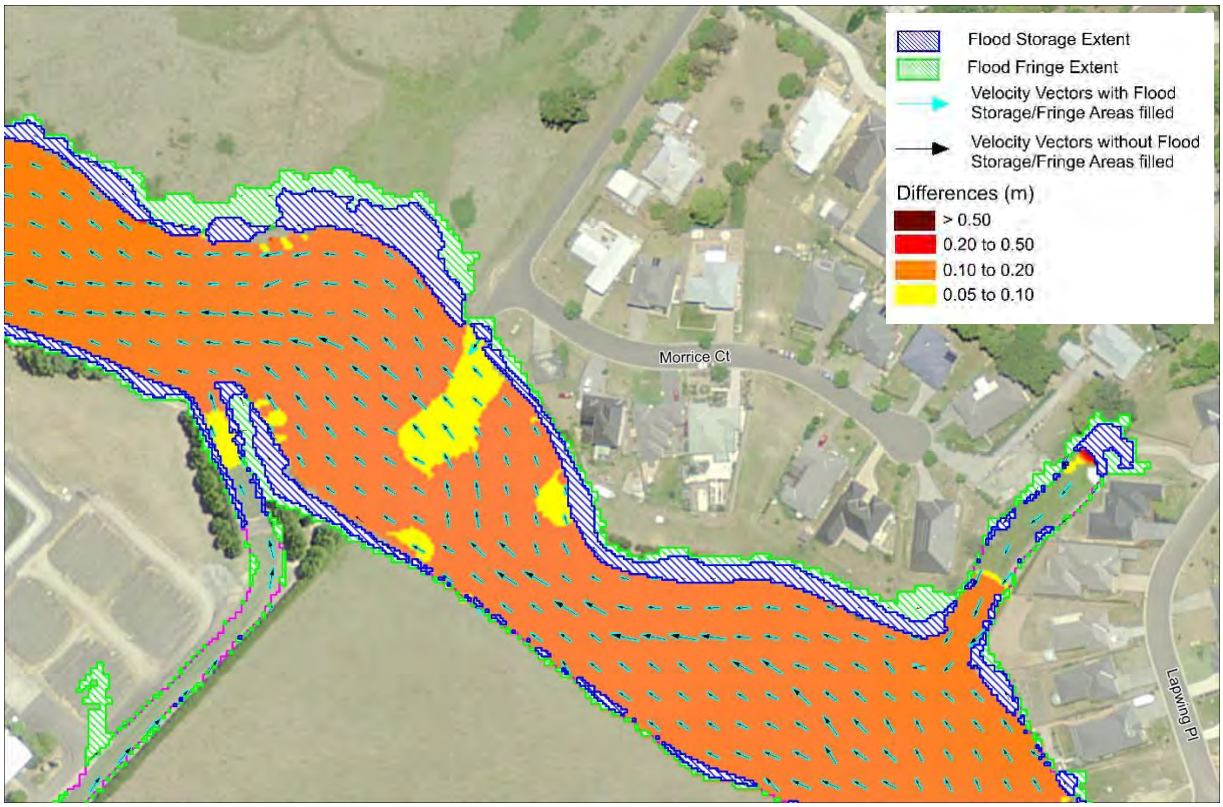


Plate M5 **1% AEP flood level differences associated with filling across Flood Storage and Flood Fringe Areas in the vicinity of Morrice Ct and Lapwing Pl, Moss Vale.**

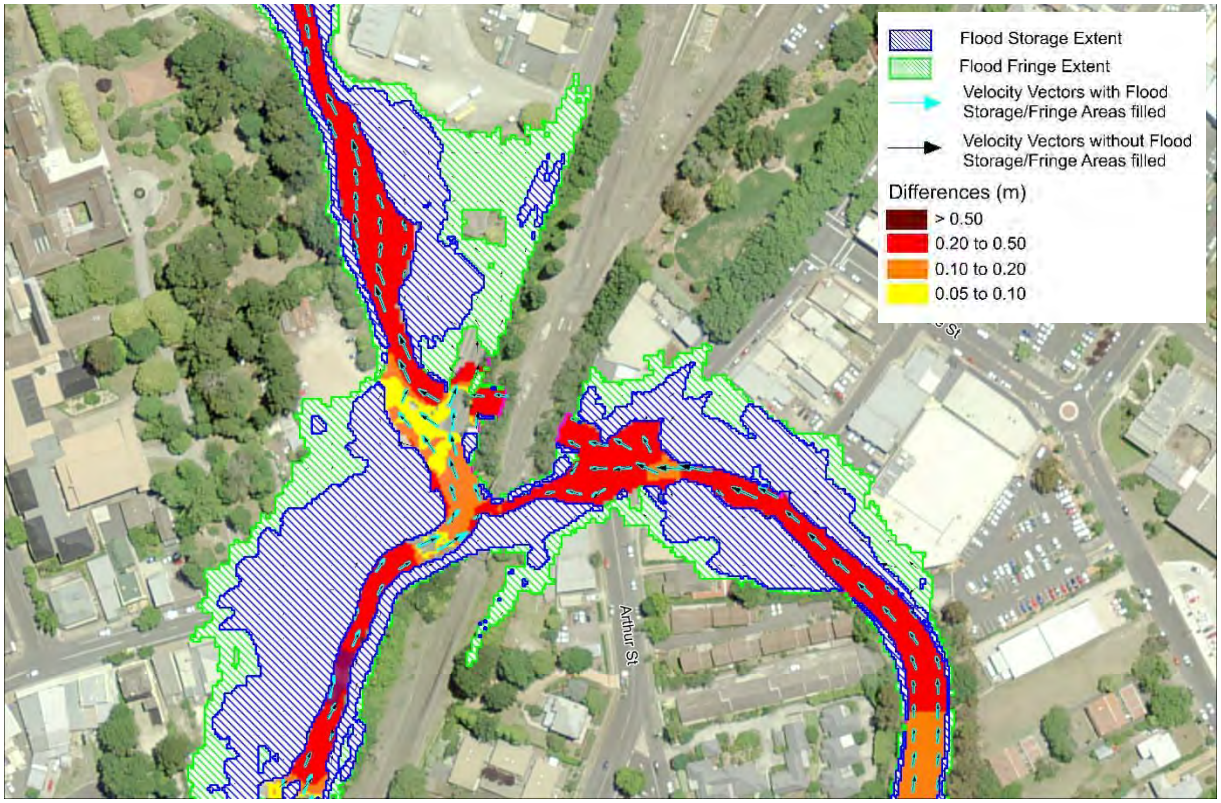


Plate M4 1% AEP flood Level differences associated with filling across Flood Storage and Flood Fringe Areas in the vicinity of Arthur St and Waite St, Moss Vale.

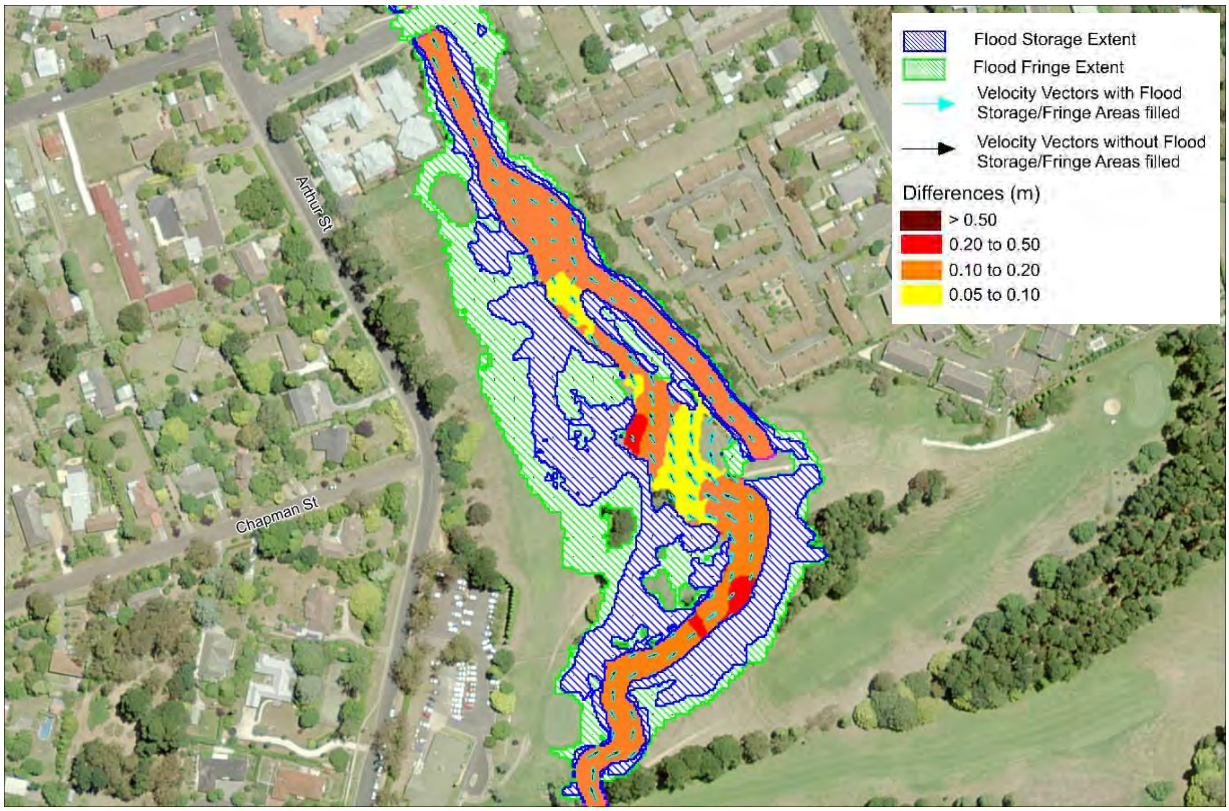


Plate M6 1% AEP flood level differences associated with filling across Flood Storage and Flood Fringe Areas in the vicinity Moss Vale Golf Club

The difference maps show that removal of all flood storage areas across the Whites Creek catchment would increase peak 1% AEP flood levels along each of the major watercourses by a minimum of 0.05 metres, but more commonly between 0.1 and 0.2 metres. Accordingly, the impacts of filling of storage areas are predicted to be less significant than the partial floodway obstruction. Nevertheless, these flood level impacts are still considered to be "significant" indicating that the "filled" areas are affording important storage across the catchment.

Furthermore, a comparison of the velocity vectors provided in **Plate M4** to **Plate M6** shows that removal of the flood storage areas is not predicted to generate a significant redistribution of flood flows.

Accordingly, it is considered that the extent of the delineated flood storage extents is appropriate and suitable for application across the Whites Creek catchment.

Flood Fringe

Flood Fringe areas are the remaining sections of flood-affected land after floodway and flood storage areas have been defined. They are areas that, if filled, would not have a significant impact on the pattern of flood flow and/or flood levels. Accordingly, verification of the delineated flood fringe extents was completed by filling all flood fringe areas, re-running the 1% AEP event and quantifying the impact that the filling had on flood behaviour.

Flood level difference mapping was prepared and is shown in **Plate M7** to **Plate M8**.

The difference mapping shows that filling of all flood fringe areas will typically increase peak flood level by less than 0.05 metres and, in all cases, less than 0.1 metres. This is considered to be a relatively minor impact on peak flood levels. That is, filling of flood fringe areas is not predicted to have any significant impact on flooding and indicates that the delineated flood fringe extents conform to the *'Floodplain Development Manual'* definitions and are suitable for application across the catchment.

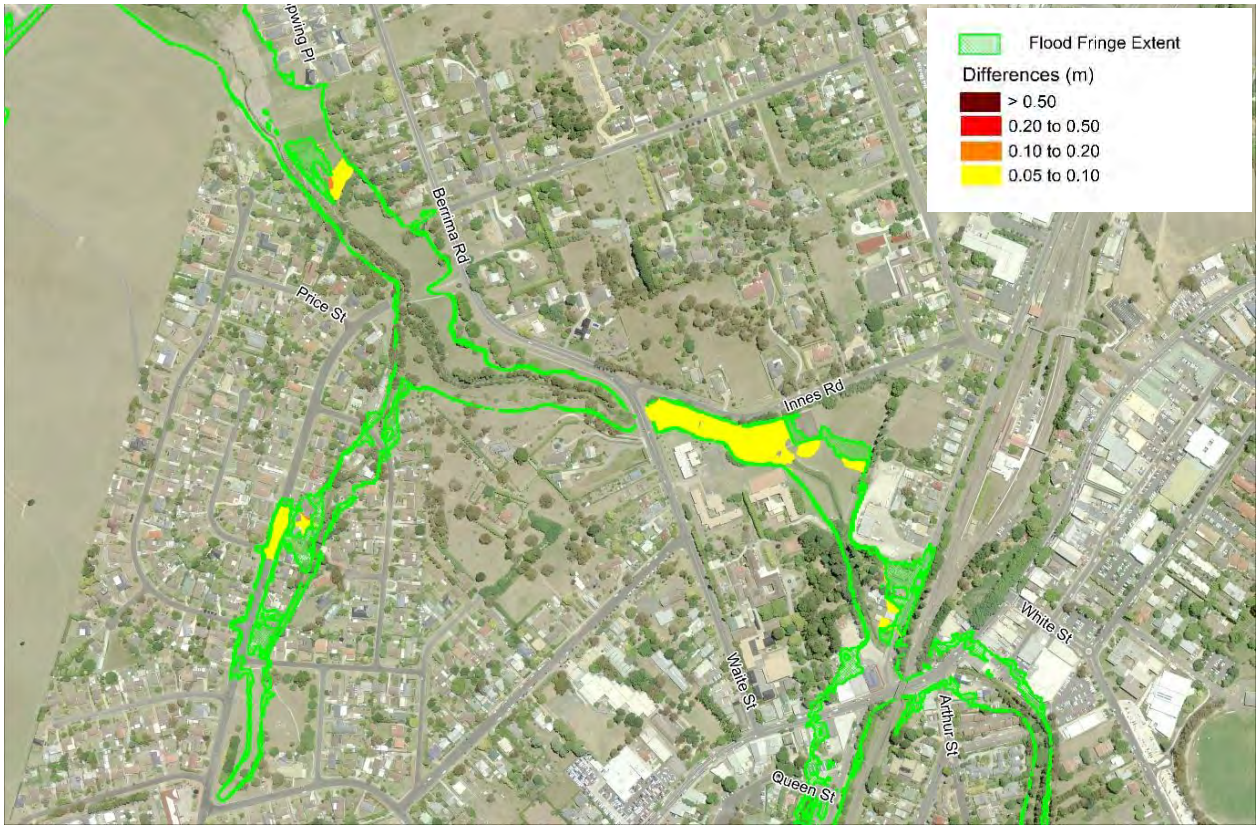


Plate M7 1% AEP flood level differences associated with filling of Flood Fringe Areas near the downstream end of Catchment



Plate M8 1% AEP flood level differences associated with filling of Flood Fringe Areas near the upstream end of Catchment

APPENDIX N

COST ESTIMATES

Notes on Cost Estimates

Catchment Simulation Solutions (CSS) has prepared the preliminary cost estimate set out in this appendix using information reasonably available to the CSS employees who prepared this report and based on assumptions and judgements made by CSS.

The Cost Estimates have been prepared for the purpose of preliminary information and must not be used for any other purpose.

The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless, as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. CSS does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence, there remains a chance that the cost will be greater. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM1 - Modify the Proposed Chelsea Gardens / Coomangie Detention Basins

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03
Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$0**
	A1.1	Assume no additional costs associated with scaling the project		1	0	0	$0
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	Compensational costs for the use of previously residential lottable lands					NA
					SUBTOTAL		**$0**
B)		**CONSTRUCTION COSTS**					
	B1	**EARTHWORKS**					**$935,150**
	B1.1	Extra cut	m3	35500	23.25	26.34	$935,150
					SUBTOTAL		**$935,150**
				TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)			**$935,150**
C)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	C1	**CONTINGENCIES**					**$233,787**
	C1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$233,787.47
				ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**			**$1,170,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM2 - New Detention Basin within Broulee Park

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$4,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	1,000	1,000	$1,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
	A1.4	Environmental Management Plans	lump sum	1	1,000	1,000	$1,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$4,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$3,000**
	B1.1	Site Establishment	lump sum	1	1,000	1,000	$1,000
	B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
	B1.3	Traffic Management	lump sum	1	1,000	1,000	$1,000
	B2	**SITE PREPARATION**					**$1,088**
	B2.1	Demolish existing footpaths	m2	80	12.00	13.60	$1,088
	B3	**EARTHWORKS**					**$20,685**
	B3.1	Fill from sourced material offsite	m3	340	18.86	21.37	$7,265
	B3.2	Stabilise embankment with cellular maps allowing vegetation growth	m2	450	11.00	12.46	$5,608
	B3.3	Paved footpath	m	90	76.60	86.79	$7,811
					SUBTOTAL		**$24,772**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$1,439**
	C1.1	Investigation and preparation of engineering design plans	%	1	5		$1,439
	C2	**PROJECT MANAGEMENT**					**$4,316**
	C2.1	Construction management/supervision/consultant fees	%	1	10		$2,877
	C2.2	Project Management	%	1	5		$1,439
					SUBTOTAL		**$5,754**
		TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$34,527**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$13,801**
	D1.1	Structural engineer inspection annually (NPV @ 7%)					$13,801
					SUBTOTAL		**$13,801**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$8,632**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$8,632
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$60,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM3 - Upgrade Stormwater System along Railway Street (near Argyle Street)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$8,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
A1.4	Environmental Management Plans	lump sum	1	1,000	1,000	$1,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$8,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$33,500**
B1.1	Site Establishment	lump sum	1	7,500	7,500	$7,500
B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
B1.3	Traffic Management	lump sum	1	25,000	25,000	$25,000
B2	**EARTHWORKS**					**$209,917**
B2.1	Excavate trenches in clay soils	m3	1440	70.00	79.31	$114,206
B2.2	Remove roadways	m2	910	32.73	37.08	$33,746
B2.3	Laying roadways	m2	910	60.10	68.09	$61,965
B3	**DRAINAGE - PIPES**					**$571,451**
B3.1	2.1m wide by 1.2m high precast conrete pipe	m	77	2,000.00	2,266.00	$174,482
B3.2	1.87m wide by 1.1m high precast concrete pipe	m	17	1,760.00	1,994.08	$33,899
B3.3	1.83m wide by 1.13m high precast concrete pipe	m	10	1,765.00	1,999.75	$19,997
B3.4	1.35m diameter precast concrete pipe	m	157	900.00	1,019.70	$160,093
B3.5	1.05m diameter precast concrete pipe	m	197	630.00	713.79	$140,617
B3.6	0.525m diameter precast concrete pipe	m	70	225.00	254.93	$17,845
B3.7	0.45m diameter precast concrete pipe	m	113	191.50	216.97	$24,518
B3.8	In situ concrete pit including lintel	each	26	2,000.00	2,266.00	$58,916
B3.9	Fitted galvanised steel access grates. Class C cover and frame	each	17	771.00	873.54	$14,850
				SUBTOTAL		**$814,868**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$41,143**
C1.1	Investigation and preparation of engineering design plans	%	1	5		$41,143
C2	**PROJECT MANAGEMENT**					**$123,430**
C2.1	Construction management/supervision/consultant fees	%	1	10		$82,287
C2.2	Project Management	%	1	5		$41,143
				SUBTOTAL		**$164,574**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$987,441**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$246,860**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$246,860
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$1,230,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM4 - Upgrade Stormwater System along Argyle Street near Railway Street and Arthur Street

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03
Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$8,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
A1.4	Environmental Management Plans	lump sum	1	1,000	1,000	$1,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$8,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$31,000**
B1.1	Site Establishment	lump sum	1	5,000	5,000	$5,000
B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
B1.3	Traffic Management	lump sum	1	25,000	25,000	$25,000
B2	**EARTHWORKS**					**$54,785**
B2.1	Excavate trenches in clay soils	m3	342	70.00	79.31	$27,124
B2.2	Remove roadways	m2	263	32.73	37.08	$9,753
B2.3	Laying roadways	m2	263	60.10	68.09	$17,909
B3	**DRAINAGE - PIPES**					**$112,526**
B3.1	1.05m diameter precast concrete pipe	m	75	630.00	713.79	$53,534
B3.2	0.9m diameter precast concrete pipe	m	25	490.00	555.17	$13,879
B3.3	0.75m diameter precast concrete pipe	m	34	386.00	437.34	$14,869
B3.4	0.6m diameter precast concrete pipe	m	66	231.00	261.72	$17,274
B3.5	0.525m diameter precast concrete pipe	m	33	225.00	254.93	$8,413
B3.6	0.45m diameter precast concrete pipe	m	21	191.50	216.97	$4,556
B3.7	In situ concrete pit including lintel	each	18	2,000.00	2,266.00	$40,788
B3.8	Fitted galvanised steel access grates. Class C cover and frame	each	16	771.00	873.54	$13,977
				SUBTOTAL		**$198,311**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$20,631**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$20,631.10
C2	**PROJECT MANAGEMENT**					**$41,262**
C2.1	Construction management/supervision/consultant fees	%	1	15		$30,946.65
C2.2	Project Management	%	1	5		$10,316
				SUBTOTAL		**$61,893**
				TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$268,204**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$67,051**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$67,051
				ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$340,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM5 - Upgrade Culverts along Whites Creek at Argyle Street and the Railway

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03
Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$10,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
A1.4	Environmental Management Plans	lump sum	1	3,000	3,000	$3,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$10,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$39,000**
B1.1	Site Establishment	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation	lump sum	1	4,000	4,000	$4,000
B1.3	Traffic Management	lump sum	1	25,000	25,000	$25,000
B2	**EARTHWORKS**					**$48,794**
B2.1	Excavate trenches in clay soils	m3	350	70.00	79.31	$27,759
B2.2	Remove roadways	m2	200	32.73	37.08	$7,417
B2.3	Laying roadways	m2	200	60.10	68.09	$13,619
B3	**DRAINAGE - PIPES**					**$248,392**
B3.1	2.4m diameter precast concrete pipe	m	25	2,945.00	3,336.69	$83,417
B3.2	1.7m wide by 2.05m high concrete box culvert	m	30	2,500.00	2,832.50	$84,975
B3.3	Pipe culvert jacking	lump sum	1	80,000.00	80,000.00	$80,000
				SUBTOTAL		**$336,186**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$34,619**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$34,619
C2	**PROJECT MANAGEMENT**					**$69,237**
C2.1	Construction management/supervision/consultant fees	%	1	15		$51,928
C2.2	Project Management	%	1	5		$17,309
				SUBTOTAL		**$103,856**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$450,042**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$24,368**
D1.1	Regular cleaning schedule (over 50 years with total at 7% NPV)					$24,368
				SUBTOTAL		**$24,368**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$180,017**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	40		$180,017
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$650,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM6 - Upgrade Stormwater System on Willow Drive and Dangar Street

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$5,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	2,000	2,000	$2,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
A1.4	Environmental Management Plans	lump sum	1	1,000	1,000	$1,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$5,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$13,000**
B1.1	Site Establishment	lump sum	1	2,000	2,000	$2,000
B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
B1.3	Traffic Management	lump sum	1	10,000	10,000	$10,000
B2	**EARTHWORKS**					**$114,347**
B2.1	Excavate trenches in soft rock	m3	343	219.00	248.13	$85,108
B2.2	Remove roadways	m2	278	32.73	37.08	$10,309
B2.3	Laying roadways	m2	278	60.10	68.09	$18,930
B3	**DRAINAGE - PIPES**					**$109,755**
B3.1	1.2m diameter precast concrete pipe	m	25	807.00	914.33	$22,858
B3.2	0.75m diameter precast concrete pipe	m	122	386.00	437.34	$53,355
B3.3	0.6m diameter precast concrete pipe	m	59	231.00	261.72	$15,442
B3.4	0.525m diameter precast concrete pipe	m	71	225.00	254.93	$18,100
B3.5	In situ concrete pit including lintel	each	5	2,000.00	2,266.00	$11,330
B3.6	Fitted galvanised steel access grates. Class C cover and frame	each	1	771.00	873.54	$874
				SUBTOTAL		**$237,101**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$24,210**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$24,210
C2	**PROJECT MANAGEMENT**					**$48,420**
C2.1	Construction management/supervision/consultant fees	%	1	15		$36,315
C2.2	Project Management	%	1	5		$12,105
				SUBTOTAL		**$72,630**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$314,732**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$78,683**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$78,683
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$390,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM7 - Channel Reshaping of Whites Creek upstream of Argyle Street

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
	Not Calculated					

- Due to the negative flooding effects due to the implementation of this concept, further investigation into the cost effectiveness wasn't warranted

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM8 - Lower Northern Floodplain Elevations of Whites Creek between 6-12 Berrima Road

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
	Not Calculated					

- Due to the minimal benefits due to the implementation of this concept, further investigation into the cost effectiveness wasn't warranted

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM9 - Elevate Pedestrian Walkway in Walton Park between Railway and Throsby Street to Direct Flows into Downstream Channel

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03
Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$6,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	3,000	3,000	$3,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
A1.4	Environmental Management Plans	lump sum	1	1,000	1,000	$1,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$6,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$24,000**
B1.1	Site Establishment	lump sum	1	2,000	2,000	$2,000
B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
B1.3	Traffic Management	lump sum	1	1,000	1,000	$1,000
B1.4	Railway Management	lump sum	1	20,000	20,000	$20,000
B2	**SITE PREPARATION**					**$408**
B2.1	Demolish existing footpaths	m2	30	12.00	13.60	$408
B3	**EARTHWORKS**					**$9,588**
B3.1	Fill from sourced material offsite	m3	170	18.86	21.37	$3,633
B3.2	Stabilise embankment with cellular maps allowing vegetation growth	m2	60	11.00	12.46	$748
B3.3	Paved footpath	m	60	76.60	86.79	$5,207
B4	**DRAINAGE**					**$8,899**
B4.1	0.6m diameter precast concrete pipe	m	34	231.00	261.72	$8,899
				SUBTOTAL		**$42,894**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$4,889**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$4,889
C2	**PROJECT MANAGEMENT**					**$9,779**
C2.1	Construction management/supervision/consultant fees	%	1	15		$7,334
C2.2	Project Management	%	1	5		$2,445
				SUBTOTAL		**$14,668**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$63,562**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$15,231**
D1.1	Regular cleaning and maintenance schedule (over 50 years with total at 7% NPV)					$15,231
				SUBTOTAL		**$15,231**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$19,069**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	30		$19,069
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$100,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM10 - Construct Bund Wall/Levee on Eastern Bank of Whites Creek near 201-207 Lackey Road

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$5,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	1,000	1,000	$1,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
A1.4	Environmental Management Plans	lump sum	1	2,000	2,000	$2,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$100,000**
A3.1	No Property Acquisitions (see note)		1	100000	100000	$100,000
				SUBTOTAL		**$105,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$7,000**
B1.1	Site Establishment	lump sum	1	4,000	4,000	$4,000
B1.2	Environmental Mitigation	lump sum	1	2,000	2,000	$2,000
B1.3	Traffic Management	lump sum	1	1,000	1,000	$1,000
B2	**SITE PREPARATION**					**$612**
B2.1	Take down and remove existing fencing	m	90	6.00	6.80	$612
B3	**EARTHWORKS**					**$43,890**
B3.1	Fill from sourced material offsite	m3	300	18.86	21.37	$6,411
B3.2	Reinforce earthern embankment creekside. Includes appropriate footing and excavation	m2	50	640.00	725.12	$36,256
B3.3	Reprofiling top road layer	m2	24	45.00	50.99	$1,224
B4	**REMEDIATION**					**$7,240**
B4.1	Replace fencing	m	90	71.00	80.44	$7,240
				SUBTOTAL		**$58,742**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$16,374**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$16,374
C2	**PROJECT MANAGEMENT**					**$32,748**
C2.1	Construction management/supervision/consultant fees	%	1	15		$24,561
C2.2	Project Management	%	1	5		$8,187
				SUBTOTAL		**$49,123**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$212,864**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$53,216**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$53,216
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$270,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM11 - Modify Existing Overland Flowpath and/or Existing Levee at rear of 71-77 Throsby Street

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$2,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	500	500	$500
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	500	500	$500
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	500	500	$500
	A1.4	Environmental Management Plans	lump sum	1	500	500	$500
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$2,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$2,000**
	B1.1	Site Establishment	lump sum	1	1,000	1,000	$1,000
	B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
	B1.3	Traffic Management	lump sum	1	0	0	$0
	B2	**EARTHWORKS**					**$427**
	B2.1	Fill from sourced material offsite	m3	20	18.86	21.37	$427
					SUBTOTAL		**$2,427**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$443**
	C1.1	Investigation and preparation of engineering design plans	%	1	10		$443
	C2	**PROJECT MANAGEMENT**					**$885**
	C2.1	Construction management/supervision/consultant fees	%	1	15		$664
	C2.2	Project Management	%	1	5		$221
					SUBTOTAL		**$1,328**
		TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$5,756**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$0**
	D1.1	Assume existing asset O&M management plan is sufficient					$0
					SUBTOTAL		**$0**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$1,439**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$1,439
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$10,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM12 - Construct Bund Wall/Levee on Bank of Railway Swale at Rear of 51-55 Thorsby Street

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03
Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$3,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	0	0	$0
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
	A1.4	Environmental Management Plans	lump sum	1	1,000	1,000	$1,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$3,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$2,000**
	B1.1	Site Establishment	lump sum	1	1,000	1,000	$1,000
	B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
	B1.3	Traffic Management	lump sum	1	0	0	$0
	B2	**SITE PREPARATION**					**$816**
	B2.1	Take down and remove existing fencing	m	120	6.00	6.80	$816
	B3	**EARTHWORKS**					**$3,205**
	B3.1	Fill from sourced material offsite	m3	150	18.86	21.37	$3,205
	B4	**REMEDIATION**					**$9,653**
	B4.1	Replace fencing	m	120	71.00	80.44	$9,653
					SUBTOTAL		**$15,674**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$1,867**
	C1.1	Investigation and preparation of engineering design plans	%	1	10		$1,867
	C2	**PROJECT MANAGEMENT**					**$5,602**
	C2.1	Construction management/supervision/consultant fees	%	1	15		$2,801
	C2.2	Project Management	%	1	15		$2,801
					SUBTOTAL		**$7,470**
				TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)			**$26,144**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$0**
	D1.1	Assume existing asset O&M management plan is sufficient					$0
					SUBTOTAL		**$0**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$6,536**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$6,536
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$30,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

RM6 - Regrading of Lackey Road from Argyle Street to Whites Creek

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$8,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
	A1.4	Environmental Management Plans	lump sum	1	1,000	1,000	$1,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$160,000**
	A3.1	Land acquisition for easement through private property		1	160000	160000	$160,000
					SUBTOTAL		**$168,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$36,000**
	B1.1	Site Establishment	lump sum	1	10,000	10,000	$10,000
	B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
	B1.3	Traffic Management	lump sum	1	25,000	25,000	$25,000
	B2	**EARTHWORKS**					**$70,193**
	B2.1	Remove roadways	m2	450	32.73	37.08	$16,687
	B2.2	Excavate	m3	130	30.80	34.90	$4,537
	B2.3	Laying roadways	m2	450	60.10	68.09	$30,642
	B2.4	Layinng and grading carpark area	m2	480	33.70	38.18	$18,327
	B3	**LANDSCAPING AND REMEDIATION**					**$2,493**
	B3.1	Wire safety barrier	m	20	110.00	124.63	$2,493
					SUBTOTAL		**$108,686**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$27,669**
	C1.1	Investigation and preparation of engineering design plans	%	1	10		$27,669
	C2	**PROJECT MANAGEMENT**					**$55,337**
	C2.1	Construction management/supervision/consultant fees	%	1	15		$41,503
	C2.2	Project Management	%	1	5		$13,834
					SUBTOTAL		**$83,006**
					TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$359,692**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$0**
	D1.1	Assume existing asset O&M management plan is sufficient					$0
					SUBTOTAL		**$0**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$89,923**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$89,923
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$450,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

RM7 - Regrading/raising of Argyle Street and Railway Street

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03
Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$8,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
A1.4	Environmental Management Plans	lump sum	1	1,000	1,000	$1,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$8,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$36,000**
B1.1	Site Establishment	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
B1.3	Traffic Management	lump sum	1	25,000	25,000	$25,000
B2	**EARTHWORKS**					**$19,728**
B2.1	Remove roadways	m2	100	50.82	57.58	$5,758
B2.2	Fill from sourced material offsite	m3	175	18.86	21.37	$3,739
B2.3	Laying roadways	m2	100	90.30	102.31	$10,231
B3	**DRAINAGE**					**$2,266**
B3.1	Pit adjustments	each	4	500.00	566.50	$2,266
				SUBTOTAL		**$57,994**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$6,599**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$6,599
C2	**PROJECT MANAGEMENT**					**$19,798**
C2.1	Construction management/supervision/consultant fees	%	1	20		$13,199
C2.2	Project Management	%	1	10		$6,599
				SUBTOTAL		**$26,398**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$92,392**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$23,098**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$23,098
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$120,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

RM8 - Creation of an emergency railway level crossing between Vale Road and Lytton/Lackey Road

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.03
Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$8,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	1,000	1,000	$1,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	1,000	1,000	$1,000
	A1.4	Environmental Management Plans	lump sum	1	1,000	1,000	$1,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$8,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$6,000**
	B1.1	Site Establishment	lump sum	1	2,000	2,000	$2,000
	B1.2	Environmental Mitigation	lump sum	1	1,000	1,000	$1,000
	B1.3	Traffic Management	lump sum	1	3,000	3,000	$3,000
	B2	**EARTHWORKS**					**$21,187**
	B2.1	Remove roadways	m2	150	33.70	38.18	$5,727
	B2.2	Cut and fill from sourced material offsite	m3	100	18.86	21.37	$2,137
	B2.3	Laying roadways	m2	650	18.09	20.50	$13,322
	B3	**REHABILITATION**					**$12,000**
	B3.1	Signage including installation	each	2	1,000.00	1,000.00	$2,000
	B3.2	Gates including installation	each	2	5,000.00	5,000.00	$10,000
					SUBTOTAL		**$39,187**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$2,359**
	C1.1	Investigation and preparation of engineering design plans	%	1	5		$2,359
	C2	**PROJECT MANAGEMENT**					**$7,078**
	C2.1	Construction management/supervision/consultant fees	%	1	10		$4,719
	C2.2	Project Management	%	1	5		$2,359
					SUBTOTAL		**$9,437**
				TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)			**$56,624**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$0**
	D1.1	Assume existing asset O&M management plan is sufficient					$0
					SUBTOTAL		**$0**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$14,156**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$14,156
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$70,000**

APPENDIX O

PUBLIC EXHIBITION COMMENTS & RESPONSES

SUBMISSION	SUBMISSION COMMENTS	RESPONSE TO SUBMISSION
1	Notes that footbridge between Berrima Road and Willow Dr can be overtopped leading to dangerous conditions for pedestrians. Suggests foot bridge could be raised and/or "access closed" signs be placed during floods to prevent pedestrians trying to cross.	These observations are confirmed by the flood mapping in Volume 2. Unfortunately, providing an elevated footbridge/culverts will likely increase upstream flood levels/extents and this option is unlikely to perform well from a financial standpoint. The suggestion regarding signage is likely to be a more cost effective option.
	Northern most section of Whites Ck is choked by willows and exacerbates flooding. Efforts to reduce/remove blockages by vegetation should be explored	As outlined in Section 7.4.2 of the report, vegetation removal in this area was explored, but it was shown to produce only minor reductions in flood levels so was not recommended for implementation.
	Suggests Yarrawa Rd to Railway St could be used as an alternate access across railway line	Implementation of this option is likely to involve more substantial work rela5tive to the Lackey Road crossing documented in Section 9.3.2. As noted in the report, the Moss Vale bypass would also provide an alternate access across the railway when complete. Nevertheless, this alternate option will be mentioned as a "backup".
	Recommends rain garden and detention basins for all new developments that are appropriately landscaped.	As discussed in Section 10.1.1, detention is recommended for all future development. However, text will be updated to recommend that suitably landscaped detention options be explored where practical.
	Suggests a detention basin could be places near corner of Argyle St and Willow Dr to alleviate flooding in Willow Dr/Mann Cres	This option was explored and is documented in Section 7.2.3.
2	Has concerns that enlarging the railway culverts will direct more water downstream of the railway, thereby increasing flooding. Asks if this has been considered.	The hydraulic impacts of any works are always considered as part of the evaluation of potential flood risk management options. This includes the railway culvert upgrade option, which is documented in Section 7.3.3 of the report. The flood level difference mapping included in this section shows that this option is predicted to reduce water levels downstream of the railway during small floods as water is more efficiently directed into the downstream channel (rather than "building up" and travelling along roads and into the channel). During larger floods, some localised

SUBMISSION	SUBMISSION COMMENTS	RESPONSE TO SUBMISSION
		increases are predicted downstream of the railway. However, they do not extend across existing residential properties.
3	States that Council is failing to maintain vegetation along Whites Creek and this must be cleared to reduce flooding problems	Vegetation clearing was explored but was found to provide only relatively minor reductions in flood levels. In addition, gaining the support of other permitting agencies (e.g., EPA) would be very difficult to achieve. Therefore, wide-scale clearing was not recommended as part of the report. It is acknowledged that vegetation in the vicinity of bridges and culverts can have a more significant impact. In this regard, Council already employs a maintenance program for all key culverts and bridges in the LGA. For example, the images below show a photo of the railway culvert that was included with the original submission dated 2018 and a photo of the same area that was captured in 2019. It shows a significant reduction in vegetation density in this area. 

SUBMISSION	SUBMISSION COMMENTS	RESPONSE TO SUBMISSION
		