Geurie Flood Study

Final Report

Volume 1

October 2022

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Project Details	
Project Name	Geurie Flood Study
Client	Dubbo Regional Council
Author	Erika Taylor, Michael Wyk, Jamie Brooks
Job Number	18020
Document Stage	Final
Document Version	R07
Document Name	18020_Geurie_FS_Final_R07.docx

Document Version Control					
Version	Stage	Release	Author	Reviewer	Date
R01	Progress	Internal	Erika Taylor	Tim Morrison	11/03/2019
R02	Progress	Internal	Erika Taylor	Michael Wyk	15/07/2019
R03	Stage 3	Submission	Erika Taylor	Michael Wyk	17/10/2019
R04	Draft	Submission	Erika Taylor	Michael Wyk	03/12/2019
R05	Draft	Submission	Jamie Brooks	Erika Taylor	26/04/2021
R06	Draft	Submission	Jamie Brooks	Erika Taylor	28/03/2022
R07	Final	Submission	Jamie Brooks, Erika Taylor	Michael Wyk	10/10/2022

Document Approval	
Erika Taylor Director	Signature

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Table of Abbreviations

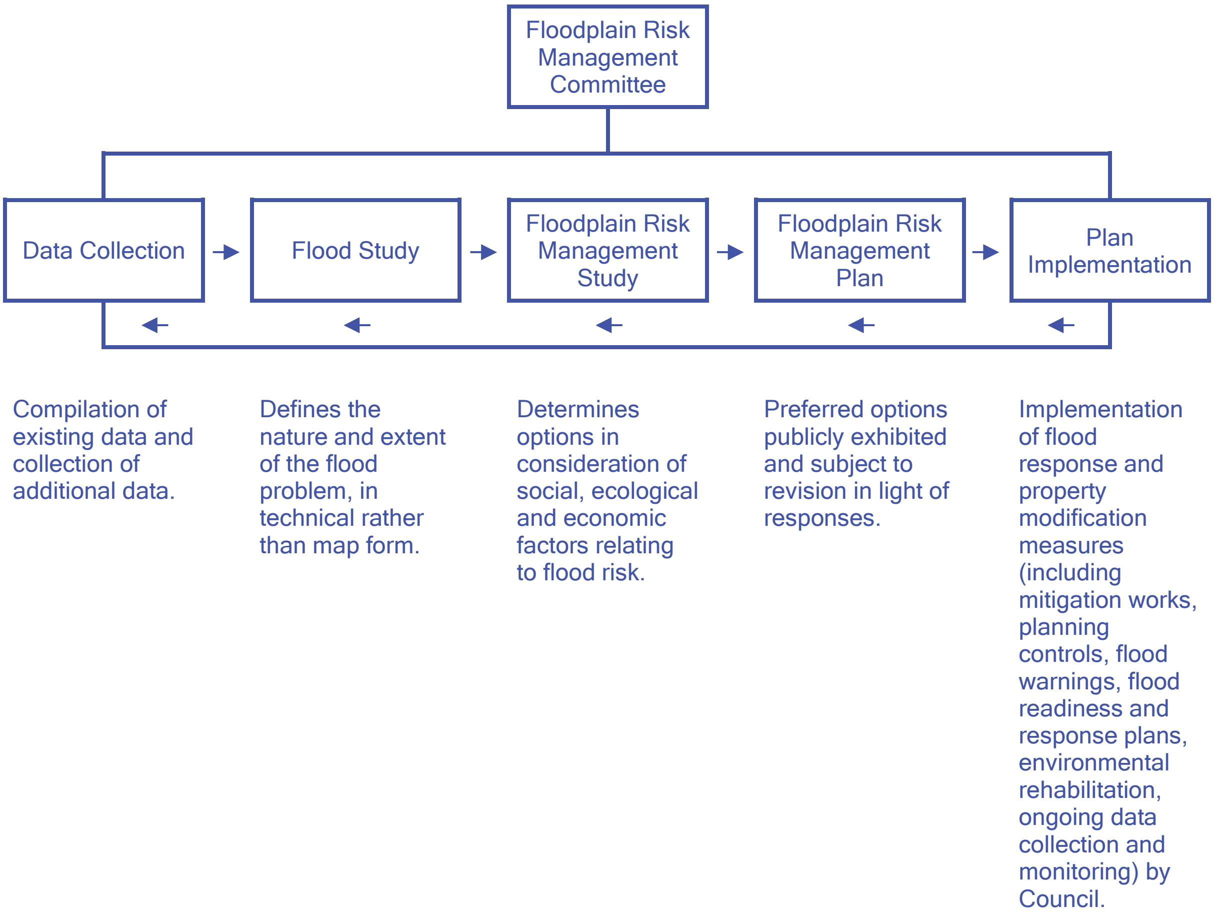
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AAD	Average Annual Damage
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
DEM	Digital Elevation Model
DPE	Department of Planning and Environment
EY	Exceedances per Year
FMC	Floodplain Management Committee
FPA	Flood Planning Area
FPL	Flood Planning Level
LGA	Local Government Area
LiDAR	Light Detection and Ranging
NSW	New South Wales
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Services

Forward

Flood-Related Legislation, Policies and Guidelines

The New South Wales (NSW) State Government's *Flood Prone Land Policy* places the primary responsibility for floodplain risk management with Councils and the *Local Government Act 1993 – Section 733* indemnifies Council from liability if the Council has acted in "good faith" in relation to floodplain risk management. Additionally, the State Government, through the Department of Planning and Environment (DPE) (formerly the Office of Environment and Heritage (OEH)), provides financial and technical support to Council in meeting its floodplain risk management obligations.

The NSW *Floodplain Development Manual* (2005) supports the NSW *Flood Prone Land Policy*. The manual provides direction on the floodplain risk management process, as detailed below.



There are a number of industry guidelines that provide technical guidance through the floodplain risk management process. This includes the *Australian Emergency Management Series* (particularly *Handbook 7: Managing the Floodplain Best Practice in Flood Risk Management in Australia*), and *Australia Rainfall and Runoff* (ARR). ARR has undergone several revisions since its inception; with the first publication in 1958, the second publication in 1977, the third publication in 1987 and the fourth (and latest) publication in 2019 (with an earlier draft version in 2016).

The current study has been undertaken in accordance with the aforementioned legislation, policies and guidelines.

Terminology

ARR 2019 has standardised the design flood terminology used in the industry. Very frequent events are expressed as Exceedances per Year (EY), frequent to very rare events are expressed as Annual Exceedance Probability (AEP) as a percentage, and very rare to extreme events are expressed as a 1 in x AEP. This is detailed in Table 0-1, which has been extracted from Section 2.2.5., Chapter 2, Book 1 of ARR 2019.

Table 0-1: Design Event Terminology

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			PMP	

Executive Summary

The NSW State Government, through the Department of Planning and Environment (DPE), oversee the Floodplain Management Program. The program provides support to local councils in the implementation of the NSW Government's Flood Prone Land Policy as outlined in the NSW Government's Floodplain Development Manual. The primary objective of the policy and manual is to reduce the impacts of flooding and flood liability on individual owners and occupiers. As part of this program Dubbo Regional Council, with the support of the NSW OEH, has commissioned HydroSpatial Pty Ltd to prepare the following Geurie Flood Study.

Geurie is located in the Dubbo Regional Council Local Government Area (LGA) in Central West NSW. The town is located on the Mitchell Highway and the Wellington - Dubbo railway line. Geurie Creek is located to the east of the town and is aligned north to south, discharging into the Macquarie River to the south. Boori Creek is a tributary to Geurie Creek and runs west to east through the town.

The following Flood Study consists of a data collection phase, hydrologic model development, hydraulic model development, historical flood simulations and design flood simulations. A data collection process was carried out to gather flood-related information that is used to inform the model development process. The hydrologic model development was carried out to calculate the runoff hydrographs as a function of the catchment conditions and the rainfall hyetographs. The hydrologic model developed for this study used the Watershed Bounded Network Model (WBNM) software. The hydraulic model development was undertaken to estimate the flood levels, depths, velocities and extents generated from the catchment conditions and the runoff hydrographs. The hydraulic model developed for this study used the TUFLOW software.

The hydrologic and hydraulic models were jointly calibrated against the 26 January 2020 flood event and an extensive sensitivity analysis was undertaken. Following this, the design flood simulations were carried out to determine the flood behaviour across the study area through a range of statistically-based rainfall events. These events ranged from the 20% AEP event to the 0.2% AEP event and the PMF event.

1 Introduction

1.1 Overview

Dubbo Regional Council, with the support of the NSW DPE, has commissioned HydroSpatial Pty Ltd to prepare the following Geurie Flood Study.

1.2 Study Objectives

The objectives of the Flood Study are to develop a hydrologic and hydraulic model to:

- Identify existing flood risks and consequences;
- Inform the community and key stakeholders of the flood risk;
- Provide input into relevant government information systems;
- Provide input into government and strategic decision making on flood risk;
- Provide information for land-use planning and infrastructure planning;
- Provide information to emergency management agencies;
- Prepare tools suitable for use in the Floodplain Risk Management Study and Plan (FRMS&P), in which practical, feasible and economic measures will be investigated for mitigating flood risk.

1.3 Study Area Description

Geurie is located in the Dubbo Regional Council Local Government Area (LGA) in Central West NSW. The town is located on the Mitchell Highway and the Wellington - Dubbo railway line. The town is a limited service town for the local area, with a post office, a primary school and some shopping facilities. The suburb of Geurie has a population of 755 people and the urban centre of Geurie has a population of 477 people, according to the 2016 Australian Bureau of Statistics Census.

Geurie Creek is located to the east of the town and is aligned north to south, discharging into the Macquarie River to the south. Boori Creek is a tributary to Geurie Creek and runs west to east through the town. A small portion of Boori Creek is concrete-lined between Douglas Street and Wellington Street. The remainder of the creek system is naturally channelised and grass-lined.

There is limited underground stormwater drainage in and around the town. As such, stormwater is primarily conveyed through table drains adjacent to the roadways and discharging into the creeks.

2 Study Methodology

The following tasks were undertaken as part the Geurie Flood Study Project:

- Stakeholder consultation;
- Data collection;
- Hydrologic analysis;
- Hydraulic model development;
- Historical flood simulation; and
- Design flood simulation.

Stakeholder consultation was undertaken to gather local information on historical flood levels and flood behaviour. Further details on the stakeholder consultation are discussed in Section 3.

A data collection process was carried out to gather flood-related information from a number of sources. This included collating topographic data, infrastructure data, field trips, historical flood level data, historical rainfall data, and design rainfall data etc. Further details on the data collection are discussed in Section 3 and 4.

The hydrologic model development was carried out to calculate the runoff hydrographs as a function of the catchment conditions and the rainfall hyetographs. Further details on the hydrologic model development are discussed in Section 5.

The hydraulic model development was undertaken to estimate the flood levels, depths, velocities and extents generated from the catchment conditions and the runoff hydrographs (the latter of which was calculated in the hydrologic model). Further details on the hydraulic model development are discussed in Section 6.

Historical flood simulations were carried out to calibrate and validate the models' performance in representing flood behaviour in historical flood events. Further details on the historic simulations are discussed in Section 7.

Design flood simulations were carried out to determine the flood behaviour across the study area through a range of statistically-based rainfall events. Further details on the design simulations are discussed in Section 8.

3 Consultation

As part of this study, consultation has been undertaken with a number of stakeholders, as discussed within the following.

3.1 Community Consultation

3.1.1 First Round

A community consultation process was undertaken during the data collection stage of the study through the October 2018 period. The purpose of this community consultation work was to gather data from the community on historical flood events in the study area. This was achieved by conducting a “drop-in” style community information desk.

The community information desk was held at the Geurie General Store on the 31 October 2018 between 9am to 5pm. The information desk was occupied by representatives from HydroSpatial, Council and DPE. Twelve community members attended the information desk throughout the day.

The key issues raised and data provided during this community consultation process were:

- The issues raised were predominantly related to local drainage, rather than mainstream flooding.
- Other residents who did not raise specific issues indicated that the town did not have a significant flooding issue and that no flooding had been observed in recent years.

3.1.2 Second Round

A community consultation process was undertaken during the public exhibition stage of the study through the February-March 2020 period. The purpose of this community consultation work was to inform the community of the Draft Flood Study Report and gain feedback, including to stimulate discussion on possible mitigation measures to be investigated at the next stage of the process. This was achieved by conducting a “drop-in” style community information desk.

The community information desk was held at the Geurie General Store on the 5 March 2020 between 9am to 5pm. The information desk was occupied by representatives from HydroSpatial, Council and DPE. Twenty-one community members attended the information desk throughout the day.

The key issues raised and data provided during this community consultation process were:

- Residents discussed and provided information on recent flooding, in particular the 26 January 2020 flood event.
- Several residents expressed frustrations regarding how they felt recent works located at or near Geurie Racecourse had significantly affected flooding in the area.
- Residents requested a newly built culvert located adjacent to the Geurie General Store be included in the model, as they felt it greatly impacted flood behaviour in the area.
- Several residents raised concerns regarding whether and how the Flood Hazard Category for their properties would be affected.
- Residents whose properties were located in the northern area of Geurie proper, described issues with overland flow sheeting off of roads and into properties.
- The community appears somewhat divided regarding the option to implement kerbs and guttering as a mitigation option.

4 Available Data

Data is an important component of every study. As such, the first stage within a flood study is to collect and review the available data.

The data available for the study area included:

- Previous studies;
- Aerial-based survey data;
- Ground-based survey data;
- Historic flood data;
- Historic rainfall data; and
- Design rainfall data.

The data available was found to be of sufficient quantity and quality to enable the establishment of the hydrologic and hydraulic models used in the study.

4.1 Previous Studies

4.1.1 Geurie Flood Study (Ref 11)

The Geurie Flood Study was undertaken by Webb, McKeown and Associates on behalf of the former Wellington Council. The study was completed in October 2006. The aim of the study was to define the design flood behaviour for the Boori, Geurie, Heatherbrae and Limestone Creek Catchments.

The data collected as part of and used within this study included:

- Topographic contours at 10m intervals across the broader catchment and 0.5m intervals across the township area;
- Ground-based survey of the creeks and structures;
- Anecdotal data provided by the community, via a questionnaire and face-to-face interviews;
- Historical rainfall data from the daily read rainfall gauge at Geurie Post Office (station number 065018); and the pluviometer rainfall gauges at Wellington Research Centre (station number 065035), Dubbo Airport (station number 65070), and Jaymark Road Dubbo (station number 65092);
- Design rainfall data from ARR 1987.

From the anecdotal data provided by the community, it was reported that:

- In April 1990, significant amounts of surface water flowed over Geurie and Wellington Street;
- In February 1955, Geurie Creek flooded when the Macquarie River flooded;
- In 1999 some flooding was experienced, however exact dates and/or flood levels were not able to be recalled.
    - The railway line was reportedly being upgraded when floodwaters reached the underside of the western culvert, however contacting the Rail Infrastructure Corporation did not yield any further information on the flood event and/or details of the upgrade works.
    - Floodwater ponded in low lying areas upstream of the railway line, over Comobella Road near Fitzroy Street.

Additionally, photographs of flooding in 1999 were provided by a resident and have been re-published here in Photo 4-1 and Photo 4-2.

Photo 4-1: Comobella Road near Fitzroy Street during flooding in 1999 (Extracted from the 2006 Geurie Flood Study)

Photo 4-2: Corner of Fitzroy Street on left and Comobella Road in background during flooding in 1999 (Extracted from the 2006 Geurie Flood Study)

The hydrologic model was established using the Watershed Bounded Network Model (WBNM) package and the hydraulic model was established using the 1D MIKE11 software package. However, analysis of the historic rainfall data undertaken as part of this study found there to be insufficient data to carry out historic flood modelling and calibration of the models. To compensate for the lack of calibration, the hydrologic model was validated against the Probabilistic Rational Method and the hydraulic model underwent a rigorous sensitivity analysis.

Although the study was fit-for-purpose and used the modelling approaches that were available at the time, the following advances have been made since this study:

- Collection of Aerial Laser Survey (ALS) provided greater detail on ground elevations compared to the cross-section survey previously available.
- Advances to two-dimensional (2D) hydraulic modelling packages (coupled with the availability of ALS) has resulted in this technique being more widely used than previously.
- Updated intensity-frequency-duration (IFD) data published by the Bureau of Meteorology (2016) includes an additional 30 years of rainfall record to determine the statistical probability of rainfall events.
- The publication of ARR 2019 has updated many of the techniques and data used to estimate rainfall runoff.

4.2 Field Trip

A field trip on the 27 July 2018 was undertaken to gain an understanding of the study area. The main areas inspected were structures over Geurie Creek and Boori Creek, the railway and roadway embankments, rural features to the south of Geurie, and the urban areas of Geurie. A selection of photographs from the field trip are presented in Photo 4-3 to Photo 4-16.

Photo 4-3: Rural creek beds to the south of Geurie

Photo 4-4: Rural levee to the south of Geurie

Photo 4-5: Detention basin to the south of Geurie

Photo 4-6: Indicative urban conditions, looking east along Hill St

Photo 4-7: Railway embankment, north-side looking west

Photo 4-8: Culvert under the railway near the intersection of Narragal St and Douglas Stre

Photo 4-9: Culvert under Narragal St near the intersection with Chambers St

Photo 4-10: Culvert under the railway near the intersection of Narragal St and Chambers St

Photo 4-11: Railway culverts over Geurie Creek, looking south from The Old Road

Photo 4-12: Mitchell Highway culverts over Geurie Creek, looking north

Photo 4-13: Jennings St Causeway over Boori Creek

Photo 4-14: Boori Creek between Jennings St and Wellington St, looking north

Photo 4-15: Mitchell St culvert over Boori Creek, looking south

Photo 4-16: Boori Creek to the east of Chambers St

4.3 Topographic Data

4.3.1 Aerial-based Survey Data

A range of aerial-based topographic datasets were available across the study area, known as Aerial Laser Survey (ALS) data. Council provided ALS data that was collected in 2015 with a 1 m resolution and covered the majority of the town. Additional ALS data was sourced from the NSW Government Spatial Services to cover the area surrounding the town, which was collected in 2013 and had a 5 m resolution. The aerial-based topographic data extents and levels across the study area are shown on Figure 2.

Aerial-based topographic data (such as ALS) is a very efficient way to collect ground level data across a large area. However, there are some limitations to this collection method such as the inability to penetrate heavy vegetation or water-bodies, and solid structures (such as bridges or culverts over open channels). As such, details of these local features were collected via ground-based surveying.

4.3.2 Ground-based Survey Data

Council provided ground-based survey data of the stormwater-related infrastructure within the study area. This included bridges and culverts along Geurie Creek and Boori Creek. The data was collected by Council staff in 2019. The location of this data is shown on Figure 3.

4.3.3 Verification of Aerial-based Survey Data with Ground-based Survey Data

The aerial-based survey data was verified against state survey marks within the study area. These survey marks were filtered to exclude those whose ground level height accuracy was unknown, resulting in a sample set of 16 survey marks. From this assessment, the average difference between the aerial-based survey data and the state survey mark data was found to be 0.09 m. As the average difference was within the range of the vertical accuracy of the given LiDAR data (i.e. 0.3 m), the data was deemed fit-for-use for this study.

4.4 Historic Flood Data

During the period that the earlier Geurie Flood Study Draft Report (HydroSpatial, 2019) was being advertised and displayed on public exhibition (discussed in Section 3.1.2) there was a flood event that occurred on the 26 January 2020. Data from this flood event was collected from online sources, the community, members of the FRMC and a field investigation during the public exhibition.

The ABC Western Plains Facebook post titled “Geurie: Five Days Between Photos” (ABC Western Plains, 27 January 2020) reported that a resident in Geurie described almost 50 mm of rainfall occurring in a one hour period on the 26 January 2020. This rainfall event was furthermore described as being fairly localised, with less than 1 mm of rainfall being recorded at Dubbo for this same period. Photo 4-17 shows the extent of flooding on Geurie Creek as published by the ABC Western Plains Facebook post.

Photo 4-17: Geurie Creek (upstream and north of The Old Road) on the 26 January 2020

Additionally, photographs were provided by members of the community, the SES and the FRMC showing flooding across roads as well as a car washed into Boori Creek (shown in Photo 4-18 to Photo 4-20).

Photo 4-18: Boori Creek (adjacent to Geurie Swimming Pool) on the 26 January 2020

Photo 4-19: Boori Creek culvert across Jennings Street

Photo 4-20: Corner of Douglas and Wellington Street

4.5 Historic Rainfall Data

4.5.1 Rainfall Gauges

Official rainfall gauges within a 100 km radius of the Geurie Town Centre that were active at any time between 1990 to date were sourced from the Bureau of Meteorology (BoM), shown in Table 4-1. The location of these rainfall gauges is shown on Figure 4.

Table 4-1: Rainfall Stations within 100 km of Geurie Town Centre

Distance	Station	Station name	First	Last	Type
0.92	65018	Geurie Post Office	1910 Jun	2015 Jan	Daily
4.59	65099	Geurie (Kurrabri)	2003 Jan	2018 Jun	Daily
13.93	65000	Arthurville (Cramond)	1888 Dec	2018 Jul	Daily
18.51	65035	Wellington Research Centre	1946 Jan	2005 Feb	Daily
18.51	65035	Wellington Research Centre	1961_Feb	2005_Feb	Continuous
18.92	65008	Dubbo (Jemaluang)	1999 Dec	2010 Dec	Daily
21.88	65092	Dubbo (Jaymark Road)	1984 Jan	1997 Jul	Daily
21.88	65092	Dubbo (Jaymark Road)	1986_Dec	1998_Aug	Continuous
22.32	65034	Wellington (D&j Rural)	1881 Nov	2018 Aug	Daily
22.32	65034	Wellington (D&j Rural)	2005_Mar	2015_Mar	Continuous
23.53	65082	Dubbo (Wilbertree)	1885 Feb	2014 May	Daily
26.43	65012	Dubbo (Darling Street)	1870 Sep	2009 Oct	Daily
27.7	65107	Dubbo (Muronbung (Bridgeview))	1995 Jan	2011 Nov	Daily
30.12	65070	Dubbo Airport Aws	1994 Jun	2018 Aug	Daily
30.12	65070	Dubbo Airport Aws	2000_Apr	2015_Apr	Continuous
30.58	51091	Dubbo Airport (Old Tower)	2010 Jan	2018 Jul	Daily
32.13	65030	Dubbo (Mentone)	1894 Sep	2018 Jul	Daily
32.44	62079	Dripstone (Gemarl)	1968 Sep	2003 Nov	Daily
33.45	65098	Neurea (Fernfield)	2000 Dec	2018 Aug	Daily
36.28	64010	Elong Elong (Bendeela St)	1926 Jan	2018 Jul	Daily
39.76	62003	Mumbil (Burrendong Dam)	1951 Mar	2018 Jul	Daily
42.39	65106	Dubbo (Mogriguy (Kyarra))	2003 Oct	2018 May	Daily
42.85	62028	Goolma (Brooklyn)	1919 Jan	2018 Jul	Daily
43.52	65036	Yeoval Post Office	1895 Mar	2017 Dec	Daily
47.96	65105	Wellington (Cundumbul (Mehruda))	1952 Jan	2017 Dec	Daily
49.64	50139	Tomingley (Gundongs)	1966 Jan	2018 Jul	Daily

4.5.2 Analysis of Daily Rainfall Data

Daily rainfall gauges typically collect data for the 24 hours prior to 9:00 am on the day the data is recorded. For instance, the data recorded on the 2nd January 2018 covers the period from 9:00 am on the 1st January 2018 to 9:00 am on the 2nd January 2018.

Table 4-2 details the highest daily rainfall values recorded at Geurie, Arthurville, Wellington and Dubbo. The gauge at Geurie Post Office was the closest gauge to the town centre and had the second longest period of record of the proximate gauges.

There were some dates that appeared to have relatively large rainfall values across multiple gauges, such as 24 February 1955, 9 February 1971, 20 April 1990, and 11 March 2000.

Table 4-2: Top 15 Daily Records at Geurie, Arthurville, Wellington and Dubbo

Geurie Post Office (65018) Jun 1910 - Jan 2015		
Rank	Date	Rainfall (mm)
1	24/02/1955	170.4
2	24/01/1930	116.3
3	10/02/1992 (3 days)	113.4
4	25/03/1926	102.9
5	9/02/1971	102.9
6	6/02/1950	100.3
7	11/02/1973	93.2
8	11/03/2000	92.0
9	20/04/1990	91.0
10	15/05/1915	90.7
11	20/01/1950	88.9
12	3/04/1989 (3 days)	87.0
13	5/03/1979	85.4
14	6/11/1969	84.3
15	1/03/2013	81.6

Arthurville (65000) Dec 1888 - To Date		
Rank	Date	Rainfall (mm)
1	24/02/1955	164.8
2	20/04/1894	125.2
3	26/12/2009	117.2
4	12/01/1898	97.5
5	15/05/1915	95.3
6	25/03/1926	95.0
7	12/01/1892	91.4
8	20/04/1990	91.2
9	24/01/1976	86.8
10	9/02/1971	85.1
11	7/12/1922	84.3
12	1/03/2013	84.0
13	8/02/1973	80.5
14	19/01/1950	79.2
15	11/03/2000	78.4

Dubbo (65008) Dec 1999 - Dec 2010		
Rank	Date	Rainfall (mm)
1	28/12/2009	82.4
2	6/02/2010	77.0
3	4/02/2002	73.0
4	2/12/2010	72.0
5	22/12/2007	67.0
6	24/08/2003	63.4
7	11/03/2000	60.2
8	19/11/2000	60.0
9	26/12/2009	58.0
10	28/12/2008	57.0
11	7/11/2001	53.4
12	31/01/2008	53.0
13	4/12/2010	52.2
14	2/04/2000	51.6
15	18/05/2007	49.6

Dubbo (65092) Jan 1984 - Jul 1997		
Rank	Date	Rainfall (mm)
1	20/04/1990	89.8
2	26/01/1993	78.4
3	25/10/1989	60.4
4	8/12/1986	58.0
5	17/12/1992	53.0
6	6/08/1984	51.4
7	12/02/1997	51.0
8	13/10/1985 (2 days)	48.6
9	7/02/1988	48.6
10	20/04/1984	48.2
11	4/10/1993	47.6
12	9/02/1992	46.8
13	24/01/1991 (2 days)	45.6
14	5/06/1988	45.2
15	25/07/1990	44.8

Wellington Research Centre (65035)		
Jan 1946 - Feb 2005		
Rank	Date	Rainfall (mm)
1	24/02/1955	179.8
2	20/04/1990	96.0
3	11/03/2000	95.0
4	19/01/1950	89.9
5	8/02/1971	73.7
6	24/02/1982	69.8
7	6/11/1969	67.1
8	20/01/1956	66.3
9	9/02/1971	66.0
10	10/02/1954	64.5
11	5/03/1979	63.0
12	25/07/1990	61.0
13	10/02/1969	60.5
14	13/01/1984	60.2
15	12/02/1997	59.8

4.5.3 Analysis of Pluviometer Rainfall Data

Pluviometer (or continuous) rainfall gauges typically collect data per increment of rainfall rather than per increment of time, thereby returning data at sub-daily intervals. In such a way, pluviometer gauges are ideal for analysing the short-duration, high-intensity storm bursts.

Table 4-3 details the highest hourly rainfall values for the pluviometer gauges located at Wellington and Dubbo; with Geurie roughly equidistant from these two locations.

Table 4-3: Top 15 Hourly Records at Wellington and Dubbo

Wellington Research Centre (65035)		
Feb 1961 - Feb 2005		
Rank	Date	Rainfall (mm)
1	23/02/1982 12:00	39.45
2	12/01/1984 18:00	34.09
3	13/05/1995 23:00	31.69
4	10/12/1983 16:00	31.28
5	22/01/1986 17:00	31.17
6	24/02/1976 19:00	30.1

Wellington D&J Rural (65034)		
Mar 2005 - Mar 2015		
Rank	Date	Rainfall (mm)
1	26/01/2013 23:00	32.8
2	28/02/2013 23:00	32
3	15/02/2006 18:00	27.4
4	5/02/2010 19:00	24.2
5	15/02/2006 17:00	22.8
6	21/12/2007 23:00	20.6

7	20/03/1968 22:00	29.79
8	7/02/1971 18:00	28.98
9	12/01/1964 20:00	27.13
10	7/02/1971 0:00	27.03
11	1/12/1965 21:00	26.39
12	16/12/1992 7:00	26.07
13	19/11/1989 16:00	25.63
14	28/01/1995 21:00	25.53
15	14/12/1961 18:00	23.9

7	14/03/2014 21:00	19.6
8	28/11/2012 18:00	18.6
9	26/01/2013 22:00	18.6
10	13/02/2010 19:00	18.4
11	8/11/2005 1:00	17.2
12	26/10/2007 16:00	17.2
13	16/07/2013 15:00	17.2
14	21/02/2007 21:00	16.4
15	6/02/2011 9:00	16.2

Dubbo Airport AWS (65070)		
Mar 2005 - Mar 2015		
Rank	Date	Rainfall (mm)
1	8/02/2012 17:00	55.8
2	16/12/2016 23:00	46.2
3	26/01/2013 21:00	39.6
4	14/01/2012 21:00	29.2
5	24/03/2017 2:00	28.6
6	20/03/2017 16:00	25.2
7	13/03/2017 12:00	20
8	28/09/2011 23:00	17.8
9	24/12/2016 1:00	17.6
10	16/07/2014 5:00	17.4
11	3/04/2014 22:00	17
12	28/02/2013 20:00	16.8
13	16/09/2013 18:00	16.8
14	27/01/2016 16:00	16.8
15	13/03/2017 13:00	16.6

From this it can be seen that the period from the year 2000 to 2015 (with more recent data not captured due to the closure of recording sites) has been characterised by relatively low intensity rainfall bursts compared to the period preceding the year 2000. This corresponds with the anecdotal data provided by Council and the community that no significant flood events had occurred in recent years prior to the commencement of the current Flood Study.

Since the commencement of the current Flood Study investigation, a number of flood events have occurred, and the community provided anecdotal data on these. However, due to the lack of gauges and recording sites, the frequency and magnitude of most of these recent rainfall and flood events were difficult to quantify (with the exception of the 26 January 2020 event, discussed in Section 7.2).

4.5.4 Analysis of Specific Events

The continuous rainfall data for a number of specific events are analysed below based upon dates of known flooding provided by Council and the community. However, as there is no continuous rainfall gauge within Geurie, this analysis was undertaken on the gauge located in Wellington. From this, the dates of known flooding within Geurie were found to have recorded relatively low rainfall depths at the Wellington gauge; all being less than a 1 Exceedence per Year (EY) event. This indicates that the rainfall events that have caused flooding in the past may have been highly localised to the Geurie area, and therefore the rainfall data may not have been sufficiently captured at the gauges outside the study area.

Table 4-4: Analysis of Specific Events – Wellington Research Centre (65035) Pluviometer

	Storm Burst Rainfall Totals Recorded (mm)	Rainfall IFD Estimation
1999 Event (4.5hrs preceding 02:00pm on the 01/03/1999)	14.2	12 EY - 6 EY
1999 Event (12hrs preceding 03:00pm on the 03/10/1999)	27	4 EY - 3 EY
1990 Event (14hrs preceding 12:00am on the 20/04/1990)	60.72	0.5 EY - 0.2 EY
1971 Event (5hrs preceding 09:00pm on the 07/02/1971)	40.1	0.5 EY - 0.2 EY

5 Hydrologic Model Development

5.1 Overview

The hydrologic model developed for this study used the Watershed Bounded Network Model (WBNM) software (Ref 5). WBNM requires minimal model parameter assumptions as the software uses established relationships between catchment geomorphology and hydrology to calculate the rainfall runoff hydrographs. The software has been updated to include built-in functionality to estimate design floods using the ARR 2019 design flood estimation procedures; whilst retaining the software's built-in functionality to use the ARR 1987 design flood estimation procedures, should comparison or backward compatibility be necessary. For these reasons, WBNM was considered suitable for use in this study; with the WBNM version used being 2017_V001.

5.2 Sub-catchment Delineation

The hydrologic catchment area covered a region of 46 km^2. This area was defined by the topographical ridges that form the upper bounds of the watershed area.

A total of 143 sub-catchments were delineated across the total hydrologic catchment area. The sub-catchments along creeks covered a larger individual area than those within the town, corresponding to the relative difference in size of the hydrologic features defining each area. All of the sub-catchment extents are shown in Figure 5.

5.3 Model Parameters

A range of model parameters are used in the hydrologic model calculations undertaken within WBNM. These include:

- Lag Parameter;
- Routing Parameter;
- Impervious Area; and
- Rainfall Losses.

The selection of these parameters are discussed within the following sections.

5.3.1 Lag Parameter

The time difference between the centroids of the rainfall hyetograph and the runoff hyetograph is a function of catchment characteristics (such as area, shape and slope) and a specified lag parameter within WBNM. A lag parameter value of 1.6 was used for this study and corresponds to the recommendations provided in the WBNM documentation.

5.3.2 Routing Parameter

Routing of flows from upstream to downstream through the sub-catchments can be calculated by a number of different methods within WBNM, including the nonlinear routing, time-delay routing and Muskingum routing methods. The nonlinear routing method with a parameter value of 1.0 was used for this study. This parameter value corresponds with the WBNM recommended value for natural channels.

5.3.3 Impervious Area

The proportion of pervious to impervious surface area across a region will influence the rate at which runoff will occur from the region. The percentage of impervious surface area within individual sub-catchments was based on the proportion and type of land uses within the sub-catchments (corresponding to the hydraulic roughness extents, discussed in Section 6.3). The impervious percentage per land use type is summarised in Table 5-1.

Table 5-1: Impervious Percentage per Land Use Type

Land Use Type	Impervious Percentage
Roads/Pavements	90%
Low Density Residential Properties	40%
Vegetation (Light, Medium, and Heavy)	0%

5.3.4 Rainfall Losses

Rainfall losses represent the amount of rainfall that does not contribute to runoff due to interception by vegetation, infiltration into the soil, retention on the surface (depression storage), and transmission loss through stream beds and banks. Rainfall losses can be calculated through empirical models, simple models or process models. Empirical models include the Initial Loss - Continuing Loss (IL/CL) Method; the Initial Loss - Proportional Loss Method; the Variable Continuing Loss Method; the SCS Curve Number Method; the Probability Distribution Storage Capacity Models; and the Soil Water Balance Model (SWMOD). Simple models include the Horton Model; the Green-Ampt Model; and the Australian Representative Basin Model (ARBM). Process models involve a complex method with "a large number of parameters that makes them difficult to apply to estimate design floods" (ARR 2019).

ARR 2019 cites a number of studies that show the IL/CL method is suitable for design flood estimation over a range of event probabilities (AEP). As such, the IL/CL method was adopted for this study.

In applying the IL/CL method, the ARR Data Hub provides values on storm continuing losses, storm initial losses, pre-burst depths (of varying probability) and probability neutral burst initial losses. Chart 5-1 shows the distinction between the storm, the pre-burst, the storm initial loss and the burst initial loss. Earlier versions of ARR 2019 (i.e. ARR 2016) recommended that the burst initial losses be determined by subtracting the pre-burst depths from the storm initial losses. However with the release of ARR 2019 and the accompanying release of the NSW OEH Floodplain Risk Management Guide: Incorporating 2016 Australian Rainfall and Runoff in Studies (Ref 10) (herein referred to as the NSW OEH ARR 2016 Guidelines), further guidance was provided for catchments in the NSW region including the provision of the probability neutral storm initial losses values.

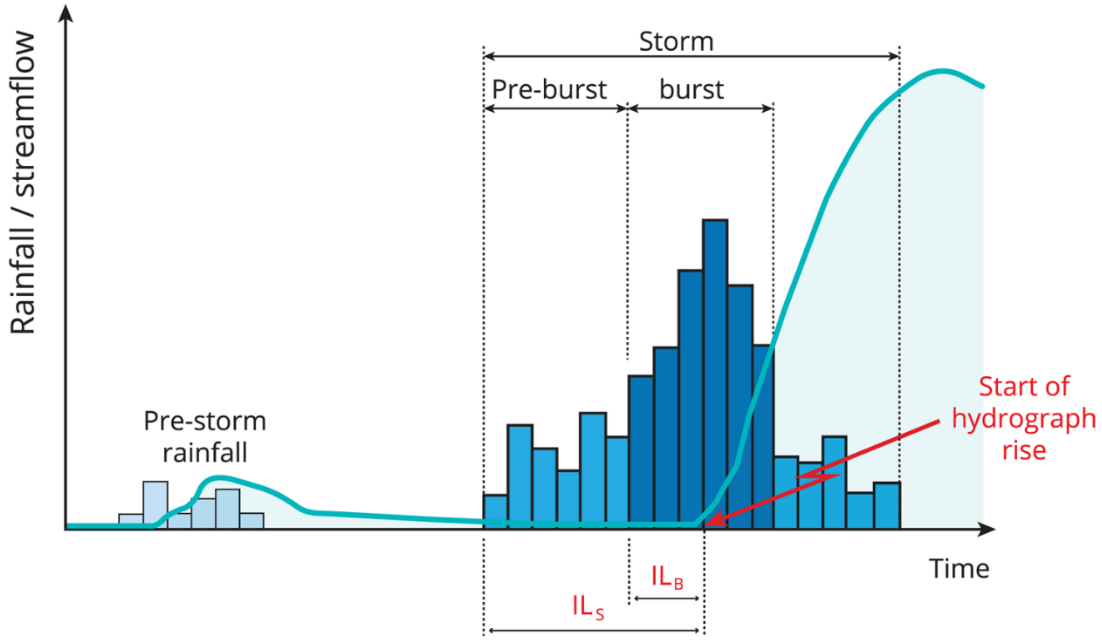


Chart 5-1: Distinction between storm and burst initial loss (Extracted from ARR 2019)

From the NSW OEH ARR 2016 Guidelines it is recommended that a hierarchical approach to loss estimation be used, provided below in order of preference (with 1 being the most preferred):

1. Use the average of calibration losses from the actual study on the catchment if available.
2. Use the average calibration losses from other studies in the catchment, if available and appropriate for the study.
3. Use the average calibration losses from other studies in similar adjacent catchments, if available and appropriate for the study.
4. Use the NSW FFA-reconciled losses available through the ARR Data Hub. These losses may be used within the catchment in which they were derived (available through the ARR Data Hub) or similar adjacent catchments with appropriate scrutiny. This is used with the unmodified ARR Data Hub initial losses which requires the application of additional scrutiny to the balance between initial loss and pre-burst to ensure it is reflective of flood history and observations for the catchment being investigated in the lead-up to events. This is particularly important in catchments of 100 km^2 or less.
5. Use default ARR data hub continuing losses for a location with a multiplication factor of 0.4. This is used with the unmodified ARR Data Hub initial losses which requires the application of additional scrutiny to the balance between initial loss and pre-burst to ensure it is reflective of flood history and observations for the catchment being investigated in the lead-up to events. This is particularly important in catchments of 100km^2 or less.

As calibration data was limited for the study area (discussed in Section 7), approach 1 could not be used. Previous studies undertaken for the study area (discussed in Section 4.1) were similarly restricted by lack of calibration data, therefore approach 2 and 3 could not be used. Furthermore, no stream gauge data was available for the study area, therefore an at-site Flood Frequency Analysis (FFA) could not be undertaken and approach 4 (which requires an at-site FFA to adjust the losses) could not be used. As such, approach 5 was adopted to calculate the initial and continuing losses for the study area (discussed in Section 8.2.1).

6 Hydraulic Model Development

6.1 Overview

The hydraulic model developed for this study used the TUFLOW software (Ref 4). The TUFLOW version used was 2018-03-AB with double precision.

6.2 Digital Elevation Model

The data used to generate the Digital Elevation Model (DEM) and the grid cell resolution are important components to the 2D domain definition used by TUFLOW.

The data used to generate the DEM is often dependent on:

- The degree of vertical accuracy;
- The horizontal resolution; and
- The date of collection (as older datasets may not entirely represent the current catchment conditions, if changes have occurred).

And the factors that influence the model grid cell resolution are:

- The purpose of the study;
- A balance between model resolution and model runtimes - with higher resolution models requiring longer computation runtimes; and
- The resolution of the available data - as very little is gained from modelling at a finer resolution than the input data.

Taking these factors into consideration, the LiDAR data (discussed in Section 4.3.1) was used to derive the DEM and establish a hydraulic model with a 3 m grid resolution across the study area.

6.3 Hydraulic Roughness

The hydraulic roughness (Manning's 'n') represents the hydraulic efficiency of the flow paths within the TUFLOW model. Various industry references provide guidelines for acceptable hydraulic roughness ranges for varying land use types including Chow (Ref 6), Henderson (Ref 7), and the ARR Revision Project 15. Field inspections were undertaken and the ARR Revision Project 15 guidelines were used to determine the Manning's 'n' values for varying land use types within the study area, detailed in Table 6-1.

Table 6-1: Roughness Values Adopted

Land Use Type	Adopted Manning's 'n' Value	Range of Acceptable Manning's 'n' Values
Roads	0.02	0.02 - 0.03
Concrete Open Channels	0.02	0.015 - 0.02
Urban	0.04	N/A *
Light Vegetation	0.03	0.03 - 0.05
Medium Vegetation	0.06	0.05 - 0.07

* Note: the Manning's 'n' values for residential and industrial/commercial areas within the guidelines are for use within the building extents not the urban area surrounding the building extents.

The aerial photography was used to delineate the spatial extents of the land use types (and thus the hydraulic roughness) throughout the study area, shown on Figure 6.

6.4 Hydraulic Structures

6.4.1 Bridges and Culverts

The bridges and culverts along Geurie Creek and Boori Creek were modelled as 1D features as the dimensions of the bridges and culverts were often smaller than the 2D grid cell size. The bridge and culvert details were obtained from the ground-based survey commissioned by Council (discussed in Section 4.3.2). The locations of the bridge and culvert structures modelled are shown in Figure 6.

6.4.2 Buildings

Buildings were simulated in the hydraulic model for the town as an absolute flow obstructions within the 2D domain. The building extents were determined from analysis of the aerial photography. This is shown in Figure 6.

6.5 Hydraulic Boundary Conditions

The hydraulic model requires inflow and boundary conditions to be specified. The runoff generated from upstream and outside of the study area was modelled as time-varying boundary conditions. The runoff generated from within the study area was modelled as time-varying local source-area inflows. These time-varying flows were derived from the routed hydrologic model. As the hydrologic model routes flow to the downstream end of the sub-catchments, the TUFLOW inflows were located at the downstream end of the sub-catchments so as not to duplicate routing calculations.

The downstream boundaries were modelled as water level versus flow boundary conditions, with the relationship between the two automatically calculated in TUFLOW using a specified slope. Within the study area, this slope was estimated to be 1.4 m over 100 m (i.e. 0.014 m/m).

7 Historical Flood Simulations

7.1 Overview

It is important to calibrate and validate the model's performance in representing flood behaviour in historical flood events prior to investigating design flood events. However, the degree of calibration is dependent upon the amount and type of calibration data available, such as:

- Rainfall records, in either daily or sub-daily (pluviograph) intervals;
- Stream flow gauges;
- Water level gauges;
- Historical catchment conditions (records of any changes to structures, land-forms, etc.);
- Photographs or videos recording historical flood events;
- Records of flood mark levels or extents from debris marks or watermarks etc.; and/or
- Anecdotal evidence

Where data is available, the models would ideally be calibrated to one historical event and validated to two historical events. Model calibration involves running the model with initial parameter estimates, then adjusting these parameter estimates (within the industry acceptable range) to produce model results that more closely correspond to the observed flood information. Model validation follows model calibration and involves running the models with other historical rainfall events and no additional refinement of the parameter values.

7.2 Historic Event Selection

7.2.1 2020 Event

During the public exhibition of the earlier Geurie Flood Study Draft Report (HydroSpatial, 2019) in February 2020, the community provided additional information regarding flooding that occurred on the 26 January 2020. Following the provision of this additional information, further investigation was undertaken on this flood event.

The rainfall data from the daily rainfall gauges in the area surrounding Geurie was analysed to determine the spatial distribution of the rainfall event. From this it was found that very little rainfall was recorded at Dubbo and Wellington (with 2.8mm at gauge 65070 and 0.6mm at gauge 65034). This indicated a localised event; however as there is no official daily rainfall gauge and no pluviometer rainfall gauge in Geurie, the magnitude of the event could not be discerned from the officially recorded data.

Following this, archived radar data from the BOM was assessed to confirm the spatial distribution of the rainfall event. Data from the 256km Namoi Radar Loop over the course of 26 January 2020 was collated and analysed (as shown in Figure 7); where a high reflectivity number corresponds to increased precipitation. This confirmed that a localised rainfall event occurred at Geurie, and that it did not significantly impact Dubbo or Wellington.

The ABC Western Plains Facebook post titled "Geurie: Five Days Between Photos" (ABC Western Plains, 27 January 2020) reported that a resident in Geurie described almost 50 mm of rainfall occurring in a one hour period on the 26 January 2020. This rainfall event was furthermore described as being fairly localised. This aligned with the daily rainfall records and the radar data collected for this event.

Comparing the anecdotal rainfall of 50mm over a 1 hour period to the IFD data (provided in Appendix B), the 26 January 2020 event was estimated to be of a rainfall magnitude between a 5% AEP event and a 2% AEP event. However, the short duration of the rainfall event was shorter than the critical duration for the 2% AEP flood event (which was 270 minutes; discussed in Section 8.2.6) and the 5% AEP flood event (which was 360 minutes). Due to this, the approximately 2% AEP rainfall event did not produce flooding equivalent to a 2% AEP flood event.

Considering all of the above, the 26 January 2020 event was deemed to be an event of sufficient magnitude with adequate data available for estimation. Therefore, this event was used for calibration of the hydrologic and hydraulic models.

7.2.2 1999 Event

The previous Geurie Flood Study (Webb, McKeown and Associates Pty Ltd, 2006) reported that a flood event occurred in 1999. However, there was not enough rainfall data available to undertake a comprehensive model calibration or validation process using this event.

7.3 Historic Parameters

7.3.1 2020 Event

Due to the lack of pluviometer data available at the time of the 2020 event, a design rainfall temporal pattern based on the approximate event magnitude and duration was used to determine incremental rainfall depths. The median temporal pattern for a 60 minute 2% AEP rare event was selected using the process discussed in Section 8.2.6. From this it was found that the temporal pattern 7 (Event ID 2183) was the median temporal pattern. A total rainfall depth of 50mm was then applied to the median temporal pattern to estimate the incremental rainfall depths applied within the hydrologic model.

7.4 Historic Flood Simulation Results

7.4.1 2020 Event

Figure 8A shows the hydraulic model's peak flood depth for the January 2020 event. Figure 8B and Figure 8C show the hydraulic model's peak flood depth compared to photographs of flooding for the January 2020 event. From this, the hydraulic model's peak flood extent was found to correspond with the photographic flood extent. Between Paxton Street and Geurie Creek, the hydraulic model showed significant depth of flooding along the back of residential properties, which corresponds to the photograph. At the intersection of Douglas Street and Wellington Street, the hydraulic model showed shallow depths of less than 0.15m on the roads, which corresponds to the photograph depicting shallow flood waters on the roads at that location. Additionally, the hydraulic model showed a shallow depth of flooding along Jennings Street between Mitchell Street and Severne Street, with moderate flood depths at the Boori Creek crossing of Jennings Street which corresponds to the photograph of the Boori Creek crossing.

In summary, the hydraulic model's peak flood extent was found to correspond relatively well to the photographs taken during the flood event.

8 Design Flood Simulations

8.1 Overview

A design event is a statistically-based estimate of the probability of a certain rainfall depth being recorded at a certain location over a defined duration. The various magnitudes of these statistically-based estimates are usually discussed in terms of the Annual Exceedance Probability (AEP); such as the 1% AEP event, which is an event that has a 1% chance of occurring in any given year. The terminology for design events is discussed in the Forward.

8.2 Design Parameters

8.2.1 Rainfall Losses

As discussed in Section 5.3.4, approach 5 of the NSW OEH ARR 2016 Guidelines were used to estimate the initial and continuing losses. From this, the continuing loss was estimated to be 0.6 mm/hr (from 1.5 mm/hr multiplied by 0.4). Whereas, the burst initial loss varied per event probability and event duration; as detailed in Appendix C for all probabilities and durations.

8.2.2 Areal Reduction Factors

Areal Reduction Factors (ARF) are a ratio between the design values of areal average rainfall and the point rainfall; to account for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms concurrently across the total catchment area. The ARR 2019 procedure for calculating the ARF for catchments between 10 and 1000 km^2 was applied to the 46 km^2 study area. The results of this calculation for all event probabilities and event durations are detailed in Appendix C.

8.2.3 Rainfall Depths

The design rainfall depths were extracted from the BoM’s 2016 Rainfall IFD Data System for the centroid of each of the sub-catchments. An example of this data is shown in Appendix B for the Geurie Post Office location.

8.2.4 Rainfall Spatial Patterns

The rainfall spatial patterns were derived using the methodology recommended in ARR 2019. This entailed:

1. Extracting the design rainfall depths for each of the sub-catchment centroids from the BoM website.
2. Multiplying the design rainfall depths by the sub-catchment area for each individual sub-catchment.
3. Calculating the weighted average design rainfall depth for the study area by summing the values calculated in Step 2 above and dividing by the total catchment area.
4. Calculating the catchment average design rainfall depth by multiplying the ARF values (discussed in Section 8.2.2) by the weighted average values (calculated in Step 3 above).
5. Calculating the design spatial pattern for each individual sub-catchment by taking the point rainfall values (calculated in Step 1 above), dividing by the weighted average values (calculated in Step 3 above) and multiplying by the catchment average values (calculated in Step 4 above).

The minimum and maximum range of the design rainfall spatial patterns calculated for all event probabilities and event durations are detailed in Appendix C.

8.2.5 Rainfall Temporal Patterns

As the study area is less than 75 km^2, the point temporal patterns were applied to design storm durations. The point temporal patterns for the Central Slopes region encompassed the total catchment area, and therefore these were exclusively applied.

8.2.6 Critical Temporal Pattern and Storm Duration

8.2.6.1 Hydrology

In areas of riverine flooding, the "ensemble" approach from ARR 2019 determines the critical duration and critical pattern as being that which produced the peak discharge one higher than the highest average and/or median peak discharge (via the hydrologic modelling).

To determine this, box and whisker plots were analysed for each design storm event for the four main external inflows upstream of Geurie; namely GEU_301, GEU_401, GEU_501, and GEU_601 (with these locations shown on Figure 5B). Appendix C presents the table and plots for each of these inflow locations for the 20% AEP, 5% AEP, and 1% AEP event.

For the 20% AEP event, three of the four inflow locations produced the same critical duration and temporal pattern; namely the 540 minute storm duration with temporal pattern 6 (Event ID 2413). In the one instance where the critical temporal pattern differed from this, the critical duration remained the 540 minute storm duration and temporal pattern 6 was ranked 4th highest (as in two higher than the average and median peak discharge). As such, for the 20% AEP event the 540 minute storm duration with temporal pattern 6 was adopted.

For the 10% AEP event, the four inflow locations produced the same critical duration and temporal pattern; namely the 360 minute storm duration with temporal pattern 7 (Event ID 2373).

For the 5% AEP event, the four inflow locations produced the same critical duration and temporal pattern; namely the 360 minute storm duration with temporal pattern 7 (Event ID 2373).

For the 2% AEP event, the four inflow locations produced the same critical duration and temporal pattern; namely the 270 minute storm duration with temporal pattern 9 (Event ID 2333).

For the 1% AEP event, two of the inflow locations produced a critical duration of 180 minutes and the remaining two inflow locations produced a critical duration of 270 minutes. For the inflow locations that produced a critical duration of 180 minutes, temporal pattern 7 (Event ID 2279) was critical for both. For the inflow locations that produced a critical duration of 270 minutes, temporal pattern 9 (Event ID 2282) was critical. As such, both the 180 minute and 270 minute storm durations (with their respective critical temporal patterns) were adopted for the 1% AEP event.

For the 0.5% AEP event, three of the inflow locations produced a critical duration of 180 minutes and the remaining inflow location produced a critical duration of 270 minutes. For the inflow locations that produced a critical duration of 180 minutes, temporal pattern 7 (Event ID 2279) was critical for two locations. Where the critical duration was the 180 minute but temporal pattern 7 was not critical, temporal pattern 7 was ranked 6th highest (as in one lower than the median peak discharge) with a peak discharge of 0.08 m^3/s below the median peak discharge. Therefore, the 180 minute storm duration with temporal pattern 7 was adopted for the 0.5% AEP event.

For the 0.2% AEP event, three of the inflow locations produced a critical duration of 180 minutes and the remaining inflow location produced a critical duration of 270 minutes. For the inflow locations that produced a critical duration of 180 minutes, temporal pattern 7 (Event ID 2279) was critical for two locations. Where the critical duration was the 180 minute but temporal pattern 7 was not critical, temporal pattern 7 was ranked 7th highest (as in two lower than the median peak discharge) with a peak discharge of 0.61 m^3/s below the median peak discharge. Therefore, the 180 minute storm duration with temporal pattern 7 was adopted for the 0.2% AEP event.

8.2.6.2 Hydraulics

In urban overland flow areas where flooding is less directionally constrained, the “ensemble” approach from ARR 2019 determines the critical duration and critical pattern as being that which produced the peak flood level one higher than the highest average peak flood level (via the hydraulic modelling).

To determine this, box and whisker plots were analysed for the 20% AEP, 5% AEP and the 1% AEP peak flood levels; so as to represent each of the temporal pattern ranges i.e. the frequent temporal pattern range (events that are more frequent than the 14.4% AEP event), the intermediate temporal pattern range (events that are between a 3.2% AEP event and a 14.4% AEP event), and the rare temporal pattern range (events that are rarer than a 3.2% AEP event). This analysis focused on specific locations within the study area, as shown on Figure 9.

For the 20% AEP event, two of the locations produced a critical duration of 540 minutes and the remaining two inflow locations produced a critical duration of 360 minutes. The locations on Geurie Creek (with Location ID H03 and H16) had a critical duration of 540 minute with temporal pattern 6 (Event ID 2413), which corresponded with the critical duration and temporal pattern of the inflows, discussed in Section 8.2.6.1. The locations on Boori Creek (with Location ID H030 and H033) had a critical duration of 360 minutes with temporal pattern 3 (Event ID 2380). As such, both the 360 minute and 540 minute storm durations (with their respective critical temporal patterns) were adopted for the frequent temporal pattern range.

For the 5% AEP event, the four locations produced the three critical duration and temporal patterns. The locations on Geurie Creek (with Location ID H03 and H16) had a critical duration of 360 minute with temporal pattern 2 (Event ID 2379). However, the 360 minute storm duration with temporal pattern 7 (which corresponded with the critical duration and temporal pattern of the inflows, discussed in Section 8.2.6.1) was found to be ranked 3rd highest at these locations; hence this latter duration and temporal pattern were adopted. The locations on Boori Creek (with Location ID H030 and H033) had a critical duration of 120 minutes, with temporal pattern 7 (Event ID 2274) and temporal pattern 1 (Event ID 2268) respectively. However, where temporal pattern 7 was critical the next highest ranked temporal pattern was temporal pattern 1 (ranked 4th). And where temporal pattern 1 was critical the 3rd ranked temporal pattern was temporal pattern 7. The difference in flood level between these two temporal patterns was 0.006 m at each of the two locations where the 120 minute storm duration was critical. Therefore, the 120 minute storm duration with temporal pattern 1 and the 360 minute storm duration with temporal pattern 7 were adopted for the intermediate temporal pattern range.

For the 1% AEP event, two of the locations produced a critical duration of 270 minutes and the remaining two inflow locations produced a critical duration of 90 minutes. The locations on Geurie Creek (with Location ID H03 and H16) had a critical duration of 270 minute with temporal pattern 9 (Event ID 2282), which corresponded with the critical duration and temporal pattern of the inflows, discussed in Section 8.2.6.1. The locations on Boori Creek (with Location ID H030 and H033) had a critical duration of 90 minutes with temporal pattern 8 (Event ID 2222). As such, both the 270 minute and 90 minute storm durations (with their respective critical temporal patterns) were adopted for the rare temporal pattern range.

8.2.6.3 Summary

Table 8-1 summarises the critical storm duration and temporal pattern adopted for each event probability based upon both the hydrologic and hydraulic model analysis (discussed in Section 8.2.6.1 and 8.2.6.2, respectively).

Table 8-1: Critical duration and temporal pattern for each event probability

Event Probability	Critical Duration and Temporal Pattern
20% AEP	360 minute TP03 540 minute TP06
10% AEP	120 minute TP01 360 minute TP07
5% AEP	120 minute TP01 360 minute TP07
2% AEP	90 minute TP08 270 minute TP09
1% AEP	90 minute TP08 180 minute TP07 270 minute TP09
0.5% AEP	90 minute TP08 180 minute TP07
0.2% AEP	90 minute TP08 180 minute TP07
PMF	60 minute 120 minute

8.3 Design Parameter Sensitivity Analysis

A sensitivity analysis process was undertaken on the parameters selected for the design events to estimate the variation in peak flood levels possible under an alternate parameter scenario. The following sections detail the methodology and results from this process.

8.3.1 Rainfall Temporal Patterns

As discussed in Section 8.2.6.1, the temporal pattern selected for the design events were the ones that produced the peak discharge one higher than the highest average peak discharge. To assess the sensitivity of peak flood levels to the temporal pattern selected, the temporal patterns that produced the highest and lowest peak discharge for the selected critical storm duration was analysed. The results of this analysis are provided in Appendix D (Section D.1.)

From this it was found that the models were highly sensitivity to variations in rainfall temporal patterns. The temporal pattern that produced the lowest discharge produced lower peak flood levels and vice versa.

8.3.2 Rainfall Losses

The sensitivity of the models to variations in rainfall losses (either continuing loss or initial loss) was analysed. The sensitivity to continuing losses were assessed by modelling the unadjusted ARR Data Hub values and by modelling the 60% adjusted ARR Data Hub values; and comparing to the results to the adopted 40% adjusted ARR Data Hub values (discussed in Section 5.3.4 and 8.2.1). The sensitivity to initial losses were assessed by modelling the ARR 2016 method of calculating the burst initial losses (by subtracting the pre-burst depths from the storm initial losses) using the median, the 75% and the 90% pre-burst depths. The results of this analysis are provided in Appendix D (Section D.2.)

From this it was found that the peak flow and peak flood level was relatively insensitivity to variations in continuing rainfall losses. Generally, the peak flood level difference was less than 0.05 m across the town; however slightly higher differences were seen in the downstream portion of Geurie Creek.

By comparison, the models were found to be highly sensitivity to variations in initial rainfall losses. The results detailed in Appendix D show a large variation in peak flow and peak flood level when the rainfall initial loss is varied for the selected storm duration and temporal pattern. However, it was also found that varying the initial rainfall losses resulted in a variation in critical storm duration and temporal pattern; with the median pre-burst depths producing longer critical durations compared to the base case, and the 90% pre-burst depths producing slightly shorter critical durations compared to the base case.

8.3.3 Hydrologic Lag and Routing

The sensitivity of the models to variations in hydrologic lag and hydrologic routing was analysed. This was undertaken by varying the lag parameter by ± 6% of the adopted values and decreasing the routing parameter to correspond with excavated earth instead of the base case of natural channels. The results of this analysis are provided in Appendix D (Section D.3.).

From this it was found that Geurie Creek was more sensitivity to variations in hydrologic lag and routing, whereas Boori Creek through town was less sensitivity. Generally, increasing the hydrologic lag values resulted in a decrease in peak flood levels and vice versa.

8.3.4 Hydraulic Roughness

The sensitivity of the peak flood levels to the hydraulic roughness parameters selected was analysed by varying the hydraulic roughness parameters by ± 20% of the adopted values. The results of this analysis are provided in Appendix D (Section D.4.).

From this it was found that Geurie Creek was more sensitivity to variations in hydraulic roughness, whereas Boori Creek through town was less sensitivity. Generally, increasing the hydraulic roughness values resulted in a decrease in peak flood levels and vice versa.

8.3.5 Blockage of Hydraulic Structures

The sensitivity of the peak flood levels to blockage of bridges and culvers was analysed by comparing the peak flood levels from the base case to a 25% blockage scenario and a 50% blockage scenario. The results of this analysis are provided in Appendix D (Section D.5.).

Generally, this scenario resulted in increased flood levels upstream of the blocked structure and decreased flood levels downstream of the structure. However, where structures were located in close proximity, these structures were found to be influenced by the cumulative effects of multiple upstream blockages as well.

8.3.6 Interim Climate Change Factors

The sensitivity of the peak flood levels to interim climate change factors was analysed by comparing the peak flood levels from the base case to a 2090 scenario with Representative Concentration Pathway (RCP) values of 4.5 and 8.5. The results of this analysis are provided in Appendix D (Section D.6.).

From this it was found that there were relatively small increases in the total area subjected in flooding in both the RCP 4.5 and RCP 8.5 scenarios. However, both scenarios resulted in low to moderate increases in peak flood levels across most of the flood extent, with the high increases in peak flood level mainly occurring along Boori Creek and Geurie Creek. In both scenarios, the largest area of high increases in peak flood level was in the area directly north of the intersection of Geurie Creek and the Mitchell Highway.

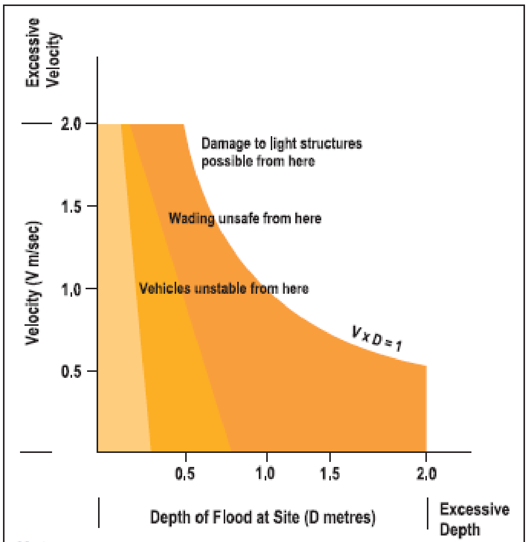
8.4 Design Flood Simulation Results

8.4.1 Post Processing Methodology

Hydraulic modelling defines flood behaviour in terms of peak flood levels, peak flood depths and flood velocities. Flood categories are further defined as functions of these flood metrics, as discussed in the following.

8.4.1.1 Hazard Categories

There are two standard industry methods for determining flood hazard categories as defined by the Floodplain Development Manual (2005) and Australian Rainfall and Runoff (2019). Both methods use the depth and velocity product, however they differ in the thresholds applied and the categories denoted.

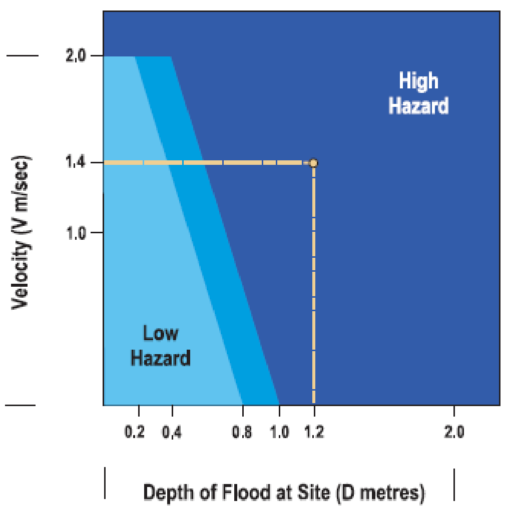


Notes

1. At velocities in excess of 2.0 m/s, the stability of foundations and poles can be affected by scour. Also, grass and earth surfaces begin to scour and can become rough and unstable
2. The velocity of floodwaters passing between buildings can produce a hazard, which may not be apparent if only the average velocity is considered. For instance, the velocity of floodwaters in a model test has risen from an average of 1 m/sec to 3 m/sec between houses.
3. Vehicle instability is initially by buoyancy.
4. At floodwater depths in excess of 2.0 meters and even at low velocities, there can be damage to light-framed buildings from water pressure, flotation and debris impact.

Derived from laboratory testing and flood conditions which caused damage.

FIGURE L1 - Velocity & Depth Relationships



Notes

The degree of hazard may be either -

- reduced by establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

In the transition zone highlight by the median colour, the degree of hazard is dependant on site conditions and the nature of the proposed development.

Example:

If the depth of flood water is **1.2 m**
and the velocity of floodwater is **1.4 m/sec**
then the provisional hazard is **high**

FIGURE L2 - Provisional Hydraulic Hazard Categories

Chart 8-1: Flood Hazard Thresholds (FDM, 2005)

The FDM (2005) method denotes hazard categories as low hazard or high hazard based upon the thresholds, shown in Chart 8-1. The high hazard category is particularly significant as it is a criterion in regulating complying development as per the State Environmental Planning Policy (SEPP) (Exempt and Complying Development Codes) 2008. Until such a time as the SEPP Codes are updated to correspond to ARR (2019) method it remains important to define flood hazard as per the FDM (2005) method.

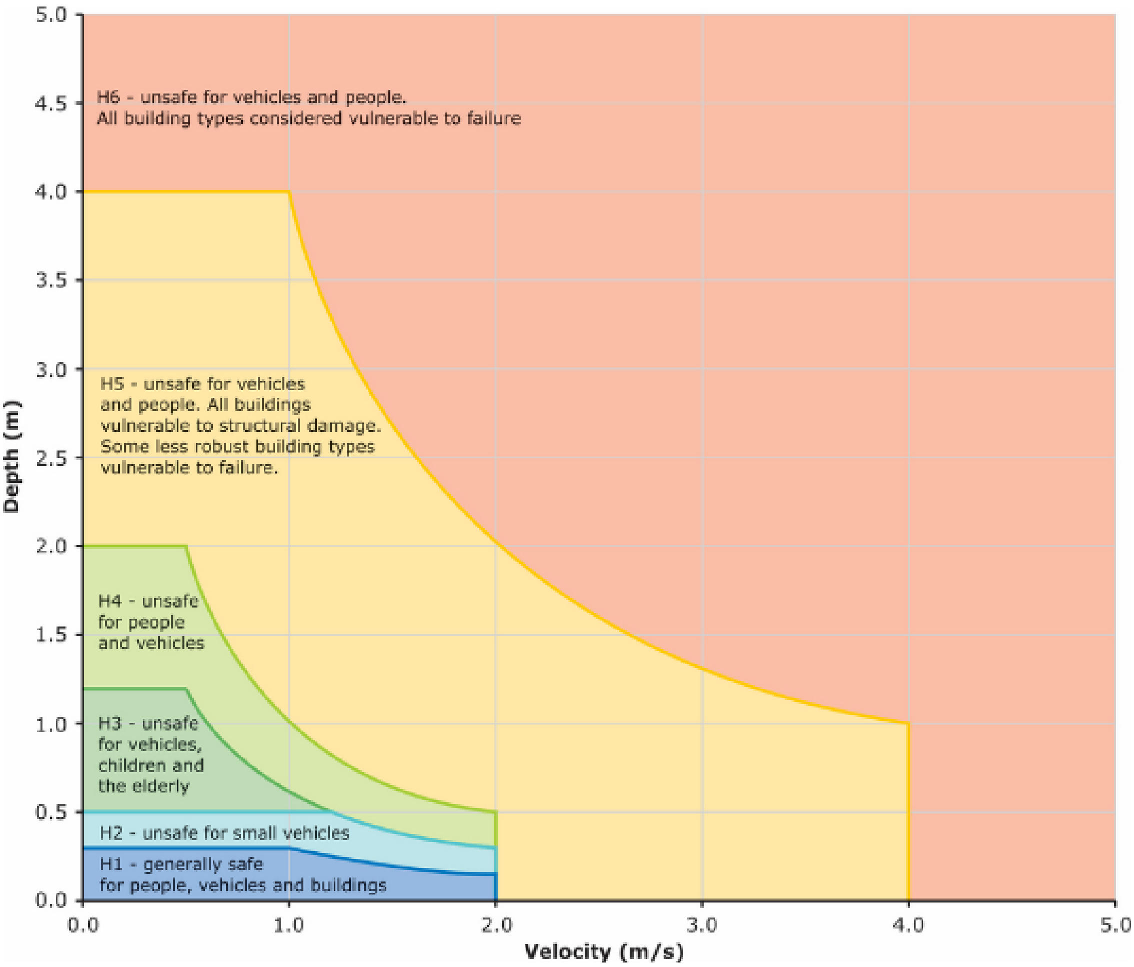


Chart 8-2: Flood Hazard Curves (ARR, 2019)

The ARR (2019) method is defined in both the Australian Rainfall and Runoff Guidelines (Ref 3) and also in the AEMI Handbook 7 Guidelines (Ref 2). This method denotes hazard categories as H1, H2, H3, H4, H5 and H6; with the greater risk attributed to the highest category (i.e. H6), shown in Chart 8-2. These hazard categories are described as follows:

- H1 - Generally safe for vehicles, people and buildings.
- 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 results of this process are discussed in Section 8.4.2.

8.4.1.2 Flood Function (formerly Flood Hydraulic Categories)

The Floodplain Development Manual (2005) identifies three hydraulic categories: floodways, flood storage, and flood fringe. Floodway is described as those areas where a significant portion of the flood flow is conveyed and where partial blockage will negatively affect flood behaviour to a substantial extent. Flood storage is described as those areas where the temporary storage of floodwaters during the passage of a flood is important. Flood fringe is described as the remaining area affected by flooding, excluding the floodway and flood storage areas.

Although a description is given for each, a technical method to define these hydraulic categories is not provided by the Manual. A number of different methods are available for use, including the Howells et al (2003) method, the Thomas et al (2012) method, and the 5% AEP extent coupled with the encroachment method. The latter two methods are best suited to estimating hydraulic categories where mainstream flood behaviour is being investigated, however the methods are less suited to overland flood behaviour. As such, the Howells et al (2003) method was used as it is well suited to both the mainstream and the overland flood behaviour being investigated in the study area.

From the Howells et al (2003) method, the hydraulic categories were defined as follows:

- Floodway where:
    - the peak velocity-depth product (V x D) > 0.25 m^2/s AND the peak velocity > 0.25 m/s; OR
    - the peak velocity > 1.0 m/s AND the peak depth > 0.15 m.
- Flood Storage where:
    - the area is outside of the Floodway; AND
    - the peak flood depth > 0.5 m.
- Flood Fringe where:
    - the area is outside the Floodway; AND
    - the peak flood depth < 0.5 m.

The results of this process are discussed in Section 8.4.2.

8.4.1.3 Emergency Response Classification of Communities

The AEMI Handbook 7 Guidelines (Ref 2) provides national guidance on flood emergency response and presents six classifications that are described in Table 8-2, with the flow chart to determine these classifications shown in Chart 8-3.

The results of this process are discussed in Section 8.4.2.

Table 8-2: Flood Emergency Response Classification Table (Extracted from the AEM Handbook 7 Guidelines 2017)

Primary Category	Primary Description	Secondary Category	Secondary Description	Tertiary Category	Tertiary Description	Category
Flooded (F)	The area is flooded in the PMF	Isolated (I)	Areas that are isolated from community evacuation facilities (located on flood-free land) by floodwater and/or impossible terrain as waters rise during a flood event up to and including the PMF. These areas are likely to lose electricity, gas, water, sewerage and telecommunications during a flood.	Submerged (S)	Were all the land in the isolated area will be fully submerged in a PMF after becoming isolated.	FIS
				Elevated (E)	Where there is a substantial amount of land in isolated areas elevated above the PMF.	FIE
		Exit Route (E)	Areas that are not isolated in the PMF and have an exit route to community evacuation facilities (located on flood-free land).	Overland Escape (O)	Evacuation from the area relies upon overland escape routes that rise out of the floodplain.	FEO
				Rising Road (R)	Evacuation routes from the area follow roads that rise out of the floodplain.	FER

Not Flooded (N)	The area is not flooded in the PMF.			Indirect Consequences (IC)	Areas that are not flooded but may lose electricity, gas, water, sewerage, telecommunications and transport links due to flooding.	NIC
				Flood Free	Areas that are not flood affected and are not affected by indirect consequences of flooding.	

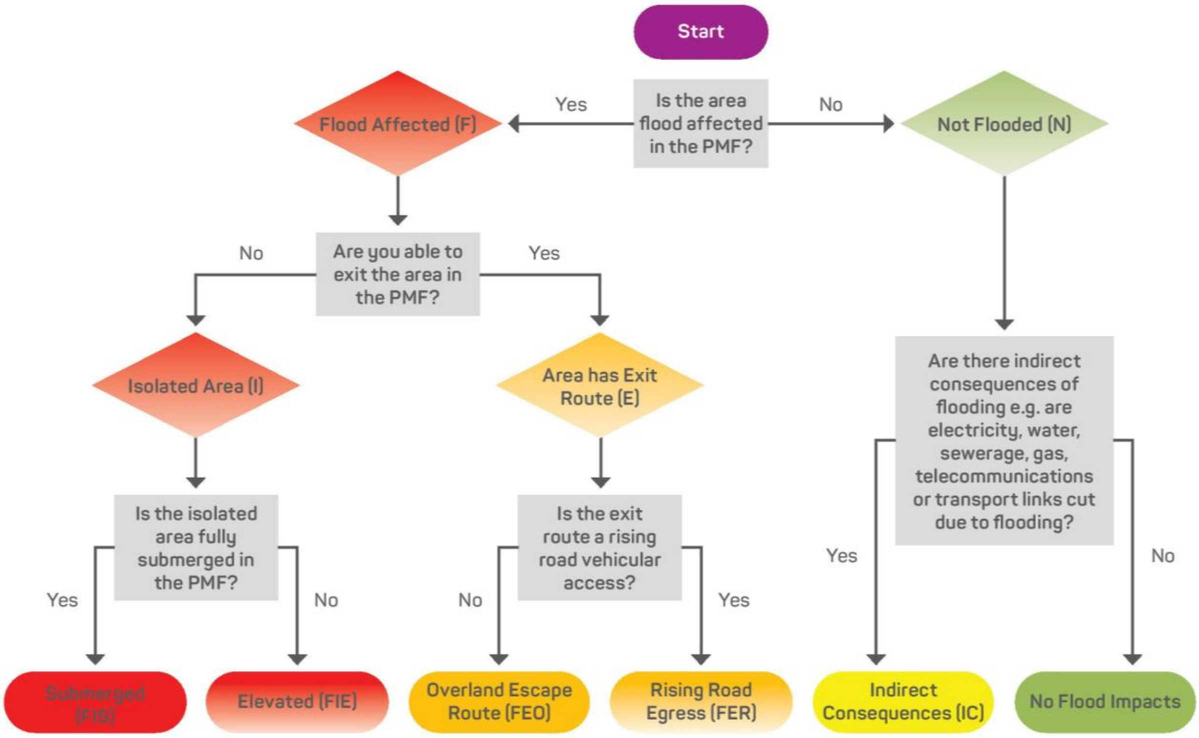


Chart 8-3: Flood Emergency Response Classification Flow Chart (Extracted from the AEMI Handbook 7 Guidelines, 2017)

8.4.2 Results Summary

Figure 9 shows the placement of key locations used within the following to discuss the results of various flooding metrics.

Figure 10 to Figure 17 shows the peak flood depth across the study area for events ranging from the 20% AEP event to the PMF event. The peak flood depths for these same events at key locations is provided in Table 8-3.

Table 8-3: Peak Flood Depth (m) for Key Locations

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	2.33	2.56	2.87	3.06	3.26	3.48	3.77	8.55
H02	Geurie Ck - Upstream of Mitchell Hwy	0.98	1.12	1.21	1.23	1.29	1.39	1.48	2.81
H03	Geurie Ck - Upstream of Railway Tracks (east)	1.38	1.65	1.95	2.08	2.24	2.40	2.49	3.82
H04	Geurie Ck - Upstream of Railway Tracks (west)	1.59	1.91	2.22	2.35	2.50	2.63	2.71	3.96
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.65	0.76	0.85	0.89	0.97	1.04	1.14	2.74
H06	Jennings St (south-east of Mitchell St)	0.49	0.53	0.56	0.60	0.69	0.79	0.89	2.38
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.52	0.57	0.60	0.62	0.65	0.69	0.71	1.37
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.36	0.53	0.67	0.71	0.74	0.79	0.82	1.21
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.90	1.04	1.12	1.15	1.17	1.15	1.18	1.98
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.34	0.39	0.42	0.47	0.51	0.55	0.58	1.24
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.54	0.56	0.58	0.60	0.61	0.63	0.64	1.30
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	1.08	1.14	1.24	1.35	1.40	1.44	1.49	2.16
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.59	0.63	0.66	0.69	0.71	0.74	0.77	1.37
H14	Boori Ck (north of Railway Tracks)	0.31	0.38	0.43	0.47	0.51	0.57	0.62	1.18

Figure 18 to Figure 25 shows the peak flood velocity across the study area for events ranging from the 20% AEP event to the PMF event. In events of a smaller magnitude (such as the 5% AEP event), the high velocity flows greater than 1.5 m/s were predominantly confined to the concrete-lined open channels through the town, along Geurie Creek and the upstream tributaries. However, in events of a larger magnitude (such as the 1% AEP event), the high velocity flows also encroached upon the roadways (particularly the Mitchell Highway) and the railway embankment.

Figure 26 to Figure 33 shows the flood hazard categories across the study area for events ranging from the 20% AEP event to the PMF event. In events of a smaller magnitude (such as the 5% AEP event), the H1 category covered the majority of the town, however the hazard categories were more severe along Geurie Creek (up to the H5-H6 category). In events of a larger magnitude (such as the 1% AEP event), slightly more severe hazard categories occurred through some properties between Arthurville Road and the Mitchell Highway.

Figure 34 to Figure 41 shows the flood function categories across the study area for events ranging from the 20% AEP event to the PMF event. Generally, floodways corresponded to Geurie Creek and Boori Creek; however in larger magnitude events (such as the 1% AEP event) the floodway extents encroached upon some properties between Arthurville Road and the Mitchell Highway. Across all events investigated, the flood storage areas were confined to areas upstream of the Mitchell Highway embankment and the railway embankment.

Figure 42 shows the flood emergency response classification of communities as per the methodology discussed in Section 8.4.1.3. The predominant classifications across the study area were Flood - Isolated - Submerged (FIS) and Flood - Isolated - Elevated (FIE). In the areas classified as FIS, the area is isolated and then fully inundated in the PMF event. Whereas in areas classified as FIE, the area is isolated but not inundated in the PMF event. The remainder of the study area either had an exit route or was indirectly affected by flooding.

9 References

Ref 1: ABC Western Plains (2020), *Geurie: Five Days Between Photos*, ABC Western Plains Facebook

Ref 2: Australian Emergency Management Institute (2017), *Australian Emergency Management Handbook 7: Managing the Floodplain Best Practice in Flood Risk Management in Australia*, AEMI, Canberra

Ref 3: 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

Ref 4: BMT WBM (2016), *TUFLOW User Manual*

Ref 5: Boyd, M., Rigby, E., VanDrie, R. (2017), *Watershed Bounded Network Model (WBNM) User Guide*

Ref 6: Chow, V.T. (1959), *Open Channel Hydraulics*, McGraw-Hill, New York

Ref 7: Henderson, F.M. (1966), *Open Channel Flow*, MacMillan, New York

Ref 8: Institute of Engineers, Australia (1987), *Australian Rainfall and Runoff: A Guide to Flood Estimation, Vol. 1*, Editor-in-chief D.H. Pilgrim, Revised Edition 1987 (Reprinted 1998), Barton, ACT

Ref 9: NSW Government (2005), *Floodplain Development Manual: The management of flood liable land*, Department of Infrastructure, Planning and Natural Resources, NSW Government, Sydney

Ref 10: NSW Office of Environment and Heritage (2019), *Floodplain Risk Management Guide: Incorporating 2016 Australian Rainfall and Runoff in Studies*, NSW Government

Ref 11: Webb, McKeown and Associates Pty Ltd (2006), *Geurie Flood Study*, Wellington Council

APPENDIX A
GLOSSARY

The following glossary has been extracted from the Australian Emergency Management Handbook 7 (Ref 2).

Annual Exceedance Probability (AEP)	The likelihood of the occurrence of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood flow of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (that is, a one-in-20 chance) of a flow of 500 m3/s or larger occurring in any one year (see also average recurrence interval, flood risk, likelihood of occurrence, probability).
Astronomical tide	The variation in sea level caused by the gravitational effects of (principally) the moon and sun. It includes highest and lowest astronomical tides (HAT and LAT) occur when relative alignment and distance of the sun and moon from the earth are 'optimal'. Water levels approach to within 20 cm of HAT and LAT twice per year around mid-summer and mid-winter 'king tides'.
Australian Height Datum (AHD)	A common national survey height datum as a reference level for defining reduced levels; 0.0 m AHD corresponds approximately to sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood-prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time. If the damage associated with various annual events is plotted against their probability of occurrence, the AAD is equal to the area under the consequence-probability curve. AAD provides a basis for comparing the economic effectiveness of different management measures (i.e. their ability to reduce the AAD).
Average Recurrence Interval (ARI)	A statistical estimate of the average number of years between the occurrence of a flood of a given size or larger than the selected event. For example, floods with a flow as great as or greater than the 20-year ARI (5% AEP) flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (see also annual exceedance probability).
Catchment	The area of land draining to a particular site. It is related to a specific location, and includes the catchment of the main waterway as well as any tributary streams.
Catchment flooding	Flooding due to prolonged or intense rainfall (e.g. severe thunderstorms, monsoonal rains in the tropics, tropical cyclones). Types of catchment flooding include riverine, local overland and groundwater flooding.
Chance	The likelihood of something happening that will have beneficial consequences (e.g. the chance of a win in a lottery). Chance is often thought of as the 'upside of a gamble' (Rowe 1990) (see also risk).
Coastal flooding	Flooding due to tidal or storm-driven coastal events, including storm surges in lower coastal waterways. This can

	be exacerbated by wind-wave generation from storm events.
Consent authority	The authority or agency with the legislative power to determine the outcome of development and building applications.
Consequence	The outcome of an event or situation affecting objectives, expressed qualitatively or quantitatively. Consequences can be adverse (e.g. death or injury to people, damage to property and disruption of the community) or beneficial.
Defined Flood Event (DFE)	The flood event selected for the management of flood hazard to new development. This is generally determined in floodplain management studies and incorporated in floodplain management plans. Selection of DFEs should be based on an understanding of flood behaviour, and the associated likelihood and consequences of flooding. It should also take into account the social, economic, environmental and cultural consequences associated with floods of different severities. Different DFEs may be chosen for the basis for reducing flood risk to different types of development. DFEs do not define the extent of the floodplain, which is defined by the PMF (see also design flood, floodplain and probable maximum flood).
Design flood	The flood event selected for the treatment of existing risk through the implementation of structural mitigation works such as levees. It is the flood event for which the impacts on the community are designed to be limited by the mitigation work. For example, a levee may be designed to exclude a 2% AEP flood, which means that floods rarer than this may breech the structure and impact upon the protected area. In this case, the 2% AEP flood would not equate to the crest level of the levee, because this generally has a freeboard allowance, but it may be the level of the spillway to allow for controlled levee overtopping (see also annual exceedance probability, defined flood event, floodplain, freeboard and probable maximum flood).
Development	Development may be defined in jurisdictional legislation or regulation. This may include erecting a building or carrying out of work, including the placement of fill; the use of land, or a building or work; or the subdivision of land. Infill development refers to the development of vacant blocks of land within an existing subdivision that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. New development is intensification of use with development of a completely different nature to that associated with the former land use or zoning (e.g. the urban subdivision of an area previously used for rural purposes). New developments generally involve rezoning, and associated consents and approvals. It may require major extensions of existing urban

	services, such as roads, water supply, sewerage and electric power. Redevelopment refers to rebuilding in an existing developed area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
Ecologically sustainable development	Using, conserving and improving natural resources so that ecological processes on which life depends are maintained, and the total quality of life - now and in the future - can be maintained or increased.
Effective warning time	The effective warning time available to a floodprone community is equal to the time between the delivery of an official warning to prepare for imminent flooding and the loss of evacuation routes due to flooding. The effective warning time is typically used for people to self-evacuate, to move farm equipment, move stock, raise furniture, and transport their possessions.
Existing flood risk	The risk a community is exposed to as a result of its location on the floodplain.
Flash flood	Flood that is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. It is generally not possible to issue detailed flood warnings for flash flooding. However, generalised warnings may be possible. It is often defined as flooding that peaks within six hours of the causative rain.
Flood	Flooding is a natural phenomenon that occurs when water covers land that is normally dry. It may result from coastal or catchment flooding, or a combination of both (see also catchment flooding and coastal flooding).
Flood awareness	An appreciation of the likely effects of flooding, and a knowledge of the relevant flood warning, response and evacuation procedures. In communities with a high degree of flood awareness, the response to flood warnings is prompt and effective. In communities with a low degree of flood awareness, flood warnings are liable to be ignored or misunderstood, and residents are often confused about what they should do, when to evacuate, what to take with them and where it should be taken.
Flood damage	The tangible (direct and indirect) and intangible costs (financial, opportunity costs, clean-up) of flooding. Tangible costs are quantified in monetary terms (e.g. damage to goods and possessions, loss of income or services in the flood aftermath). Intangible damages are difficult to quantify in monetary terms and include the increased levels of physical, emotional and psychological health problems suffered by flood-affected people that are attributed to a flooding episode.

Flood education	Education that raises awareness of the flood problem, to help individuals understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
Flood emergency response plan	A step-by-step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations. The objective is to ensure a coordinated response by all agencies having responsibilities and functions in emergencies.
Flood emergency management	Emergency management is a range of measures to manage risks to communities and the environment. In the flood context, it may include measures to prevent, prepare for, respond to and recover from flooding.
Flood fringe areas	The part of the floodplain where development could be permitted, provided the development is compatible with flood hazard and appropriate building measures to provide an adequate level of flood protection to the development. This is the remaining area affected by flooding after flow conveyance paths and flood storage areas have been defined for a particular event (see also flow conveyance areas and flood storage areas).
Flood hazard	Potential loss of life, injury and economic loss caused by future flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolation, rate of rise of floodwaters, duration), topography and emergency management.
Floodplain	An area of land that is subject to inundation by floods up to and including the probable maximum flood event - that is, flood-prone land.
Floodplain management entity (FME)	The authority or agency with the primary responsibility for directly managing flood risk at a local level.
Floodplain management plan	A management plan developed in accordance with the principles and guidelines in this handbook, usually includes both written and diagrammatic information describing how particular areas of flood-prone land are to be used and managed to achieve defined objectives. It outlines the recommended ways to manage the flood risk associated with the use of the floodplain for various purposes. It represents the considered opinion of the local community and the floodplain management entity on how best to manage the floodplain, including consideration of flood risk in strategic land-use planning to facilitate development of the community. It fosters flood warning, response, evacuation, clean-up and recovery in the onset and aftermath of a flood, and suggests an organisational structure for the integrated management for existing, future and residual flood risks. Plans need to be reviewed regularly to assess progress and to consider the

	consequences of any changed circumstances that have arisen since the last review.
Flood Planning Area (FPA)	The area of land below the flood planning level, and is thus subject to flood-related development controls.
Flood Planning Level (FPL)	The FPL is a combination of the defined flood levels (derived from significant historical flood events or floods of specific annual exceedance probabilities) and freeboards selected for floodplain management purposes, as determined in management studies and incorporated in management plans.
Flood-prone land	Land susceptible to flooding by the probably maximum flood event. Flood-prone land is synonymous with the floodplain. Floodplain management plans should encompass all flood-prone land rather than being restricted to areas affected by defined flood events.
Flood proofing of buildings	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures that are subject to flooding, to reduce structural damage and potentially, in some cases, reduce contents damage.
Flood readiness	An ability to react within the effective warning time (see also flood awareness and flood education).
Flood risk	The potential risk of flooding to people, their social setting, and their built and natural environment. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into three types - existing, future and residual.
Flood severity	A qualitative indication of the 'size' of a flood and its hazard potential. Severity varies inversely with likelihood of occurrence (i.e. the greater the likelihood of occurrence, the more frequently an event will occur, but the less severe it will be). Reference is often made to major, moderate and minor flooding (see also minor, moderate and major flooding).
Flood storage areas	The parts of the floodplain that are important for temporary storage of floodwaters during a flood passage. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas (see also flow conveyance areas and flood fringe areas).
Flood study	A comprehensive technical investigation of flood behaviour. It defines the nature of flood hazard across the floodplain by providing information on the extent, level and velocity of floodwaters, and on the distribution of flood flows. The flood study forms the basis for subsequent management studies and needs to take into account a full range of flood events up to and including the probable maximum flood.
Flow	The rate of flow of water measured in volume per unit time - for example, cubic metres per second (m3/s). Flow is

	different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
Flow conveyance areas	Those areas of the floodplain where a significant flow of water occurs during floods. They are often aligned with naturally defined channels. Flow conveyance paths are areas that, even if only partially blocked, would cause a significant redistribution of flood flow or a significant increase in flood levels. They are often, but not necessarily, areas of deeper flow or areas where higher velocities occur, and can also include areas where significant storage of floodwater occurs. Each flood has a flow conveyance area, and the extent and flood behaviour within flow conveyance areas may change with flood severity. This is because areas that are benign for small floods may experience much greater and more hazardous flows during larger floods (see also flood fringe areas and flood storage areas).
Freeboard	The height above the DFE or design flood used, in consideration of local and design factors, to provide reasonable certainty that the risk exposure selected in deciding on a particular DFE or design flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels and so on. Freeboard compensates for a range of factors, including wave action, localised hydraulic behaviour and levee settlement, all of which increase water levels or reduce the level of protection provided by levees. Freeboard should not be relied upon to provide protection for flood events larger than the relevant defined flood event of a design flood. Freeboard is included in the flood planning level and therefore used in the derivation of the flood planning area (see also defined flood event, design flood, flood planning area and flood planning level).
Frequency	The measure of likelihood expressed as the number of occurrences of a specified event in a given time. For example, the frequency of occurrence of a 20% annual exceedance probability or five-year average recurrence interval flood event is once every five years on average (see also annual exceedance probability, annual recurrence interval, likelihood and probability).
Future flood risk	The risk that new development within a community is exposed to as a result of developing on the floodplain.
Gauge height	The height of a flood level at a particular gauge site related to a specified datum. The datum may or may not be the AHD (see also Australian height datum).
Habitable room	In a residential situation, a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. In an industrial or commercial situation, it refers to an area used for offices or to store valuable

	possessions susceptible to flood damage in the event of a flood.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this handbook, the hazard is flooding, which has the potential to cause damage to the community.
Hydraulics	The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level, extent and velocity.
Hydrograph	A graph that shows how the flow or stage (flood level) at any particular location varies with time during a flood.
Hydrologic analysis	The study of the rainfall and runoff process, including the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Intolerable risk	A risk that, following understanding of the likelihood and consequences of flooding, is so high that it requires consideration of implementation of treatments or actions to improve understanding, avoid, transfer or reduce the risk.
Life-cycle costing	All of the costs associated with the project from the cradle to the grave. This usually includes investigation, design, construction, monitoring, maintenance, asset and performance management and, in some cases, decommissioning of a management measure.
Likelihood	A qualitative description of probability and frequency (see also frequency and probability).
Likelihood of occurrence	The likelihood that a specified event will occur. (With respect to flooding, see also annual exceedance probability and average recurrence interval).
Local overland flooding	Inundation by local runoff on its way to a waterway, rather than overbank flow from a stream, river, estuary, lake or dam. Can be considered synonymous with stormwater flooding.
Loss	Any negative consequence or adverse effect, financial or otherwise.
Mathematical and computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land-use options for different flood-prone areas, together with flood damage, hazard and behaviour implications, and environmental protection and wellbeing of rivers and floodplains. This approach operates at two levels. At the strategic level, it allows for the consideration of flood hazard and associated social, economic, ecological and cultural issues in formulating statutory planning instruments, and development control plans and policies. At a site specific level, it involves consideration of the best way of

	developing land in consideration of the zonings in a statutory planning instruments, and development control plans and policies.
Minor, moderate and major flooding	These terms are often used in flood warnings to give a general indication of the types of problems expected with a flood.
Probability	A statistical measure of the expected chance of flooding. It is the likelihood of a specific outcome, as measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between zero and unity, zero indicating an impossible outcome and unity indicating an outcome that is certain. Probabilities are commonly expressed in terms of percentage. For example, the probability of 'throwing a six' on a single roll of a die is one in six, or 0.167 or 16.7% (see also annual exceedance probability).
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from PMP and, where applicable, snow melt, coupled with the worst flood-producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood-prone land - that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event, should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (WMO 1986). It is the primary input to probable maximum flood estimation.
Rainfall intensity	The rate at which rain falls, typically measured in millimetres per hour (mm/h). Rainfall intensity varies throughout a storm in accordance with the temporal pattern of the storm (see also temporal pattern).
Residual flood risk	The risk a community is exposed to that is not being remedied through established risk treatment processes. In simple terms, for a community, it is the total risk to that community, less any measure in place to reduce that risk. The risk a community is exposed to after treatment measures have been implemented. For a town protected by a levee, the residual flood risk is the consequences of the levee being overtopped by floods larger than the design flood. For an area where flood risk is managed by land-use planning controls, the residual flood risk is the risk associated with the consequences of floods larger than the DFE on the community.

Risk	'The effect of uncertainty on objectives' (ISO31000:2009). NOTE 4 of the definition in ISO31000:2009 also states that 'risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence'. Risk is based upon the consideration of the consequences of the full range of flood behaviour on communities and their social settings, and the natural and built environment (see also likelihood and consequence).
Risk analysis	The systematic use of available information to determine how often specified (flood) events occur and the magnitude of their likely consequences. Flood risk analysis is normally undertaken as part of a floodplain management study, and involves an assessment of flood levels and hazard associated with a range of flood events (see also flood study).
Risk management	The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring flood risk. Flood risk management is undertaken as part of a floodplain management plan. The floodplain management plan reflects the adopted means of managing flood risk (see also floodplain management plan).
Riverine flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam. Riverine flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Runoff	The amount of rainfall that drains into the surface drainage network to become stream flow; also known as rainfall excess.
Stage	Equivalent to water level. Both stage and water level are measured with reference to a specified datum (e.g. the Australian height datum).
Storm surge	The increases in coastal water levels above predicted astronomical tide level (i.e. tidal anomaly) resulting from a range of location dependent factors including the inverted barometer effect, wind and wave setup and astronomical tidal waves, together with any other factors that increase tidal water level (see also astronomical tide, wind set-up and wave set-up).
Stormwater flooding	Is inundation by local runoff caused by heavier than usual rainfall. It can be caused by local runoff exceeding the capacity of an urban stormwater drainage systems, flow overland on the way to waterways or by the backwater effects of mainstream flooding causing urban stormwater drainage systems to overflow (see also local overland flooding).
Temporal pattern	The variation of rainfall intensity with time during a rainfall event.

Tidal anomaly	The difference between recorded storm surge levels and predicted astronomical tide level.
Treatment options	The measures that might be feasible for the treatment of existing, future and residual flood risk at particular locations within the floodplain. Preparation of a treatment plan requires a detailed evaluation of floodplain management options (see also floodplain management plan).
Velocity of floodwater	The speed of floodwaters, measured in metres per second (m/s).
Vulnerability	The degree of susceptibility and resilience of a community, its social setting, and the natural and built environments to flood hazards. Vulnerability is assessed in terms of ability of the community and environment to anticipate, cope and recover from flood events. Flood awareness is an important indicator of vulnerability (see also flood awareness).
Wave set-up	The increase in water levels in coastal waters (within the breaker zone) caused by waves transporting water shorewards. The zone of wave set-up against the shore is balanced by a zone of wave 'set-down' (i.e. reduced water levels) seawards of the breaker zone. Wave setups of 2-4 m could occur during tropical cyclones.
Wind set-up	The increase in water levels in coastal waters caused by the wind driving the water shorewards and 'piling it up' against the shore. Wind set-up can be as high as 10 m in an extreme case, and often exceeds 2-3 m in typical tropical cyclones.

APPENDIX B
ARR DATA HUB

ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	148.857
Latitude	-32.383
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show
Baseflow Factors	show

Leaflet (http://leafletjs.com) | Map data © OpenStreetMap (http://openstreetmap.org) contributors, CC-BY-SA (http://creativecommons.org/licenses/by-sa/2.0/), Imagery © Mapbox (http://mapbox.com)

Data

River Region

Division	Murray-Darling Basin
River Number	22
River Name	Macquarie-Bogan Rivers
Shape Intersection (%)	100.0

Layer Info

Time Accessed	20 May 2019 10:21AM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i	Shape Intersection (%)
Central NSW	0.265	0.241	0.505	0.321	0.00056	0.414	-0.021	0.015	-0.00033	100.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration\quad 180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	20 May 2019 10:21AM

Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

Storm Initial Losses (mm)	39.0
Storm Continuing Losses (mm/h)	1.5

Layer Info

Time Accessed	20 May 2019 10:21AM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/CS.zip)

code	CS
Label	Central Slopes
Shape Intersection (%)	100.0

Layer Info

Time Accessed	20 May 2019 10:21AM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal /Areal_CS.zip)

code	CS
arealabel	Central Slopes
Shape Intersection (%)	100.0

Layer Info

Time Accessed	20 May 2019 10:21AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-32.3826713754&longitude=148.856953501&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	20 May 2019 10:21AM

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)	1.4 (0.061)	1.1 (0.035)	0.9 (0.024)	0.7 (0.016)	0.6 (0.011)	0.5 (0.008)
90 (1.5)	0.7 (0.025)	1.2 (0.034)	1.6 (0.037)	1.9 (0.039)	0.9 (0.016)	0.1 (0.002)
120 (2.0)	0.8 (0.026)	0.9 (0.024)	1.1 (0.023)	1.2 (0.023)	1.0 (0.016)	0.9 (0.013)
180 (3.0)	0.7 (0.022)	0.7 (0.016)	0.7 (0.014)	0.7 (0.012)	1.3 (0.018)	1.7 (0.021)
360 (6.0)	1.1 (0.029)	2.1 (0.040)	2.8 (0.045)	3.5 (0.049)	5.5 (0.065)	7.0 (0.075)
720 (12.0)	0.0 (0.000)	2.5 (0.038)	4.1 (0.054)	5.6 (0.065)	8.4 (0.082)	10.5 (0.091)
1080 (18.0)	0.0 (0.000)	0.7 (0.010)	1.2 (0.014)	1.7 (0.017)	4.7 (0.040)	7.0 (0.053)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	3.1 (0.024)	5.4 (0.037)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.5 (0.003)	0.8 (0.005)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
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	20 May 2019 10:21AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
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	20 May 2019 10:21AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
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	20 May 2019 10:21AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	12.6 (0.541)	9.1 (0.289)	6.8 (0.183)	4.6 (0.108)	7.1 (0.139)	8.9 (0.156)
90 (1.5)	11.7 (0.444)	12.7 (0.356)	13.4 (0.318)	14.1 (0.289)	13.1 (0.229)	12.3 (0.193)
120 (2.0)	13.9 (0.486)	15.1 (0.388)	15.8 (0.345)	16.6 (0.314)	16.5 (0.267)	16.5 (0.239)
180 (3.0)	10.6 (0.330)	11.9 (0.274)	12.8 (0.249)	13.6 (0.231)	18.3 (0.265)	21.8 (0.284)
360 (6.0)	12.2 (0.311)	19.8 (0.375)	24.8 (0.399)	29.7 (0.415)	37.9 (0.452)	44.2 (0.472)
720 (12.0)	6.1 (0.128)	15.9 (0.247)	22.4 (0.295)	28.6 (0.328)	37.1 (0.360)	43.5 (0.376)
1080 (18.0)	3.5 (0.064)	10.4 (0.144)	15.0 (0.176)	19.4 (0.198)	27.4 (0.234)	33.3 (0.252)
1440 (24.0)	0.4 (0.007)	3.4 (0.043)	5.3 (0.058)	7.2 (0.067)	17.2 (0.135)	24.8 (0.171)
2160 (36.0)	0.0 (0.000)	2.8 (0.032)	4.6 (0.045)	6.3 (0.053)	10.2 (0.071)	13.1 (0.080)
2880 (48.0)	0.0 (0.000)	1.6 (0.017)	2.6 (0.024)	3.7 (0.028)	8.3 (0.053)	11.8 (0.066)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	1.4 (0.008)	2.4 (0.012)

Layer Info

Time Accessed	20 May 2019 10:21AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	34.3 (1.473)	27.8 (0.879)	23.5 (0.627)	19.3 (0.448)	28.9 (0.568)	36.1 (0.635)
90 (1.5)	27.5 (1.045)	40.6 (1.136)	49.3 (1.167)	57.6 (1.184)	48.5 (0.848)	41.7 (0.654)
120 (2.0)	30.0 (1.049)	39.1 (1.008)	45.1 (0.985)	50.9 (0.965)	57.9 (0.935)	63.1 (0.915)
180 (3.0)	42.9 (1.335)	40.5 (0.932)	39.0 (0.760)	37.5 (0.636)	49.9 (0.722)	59.1 (0.769)
360 (6.0)	24.9 (0.633)	40.9 (0.774)	51.6 (0.829)	61.8 (0.865)	71.8 (0.855)	79.2 (0.846)
720 (12.0)	22.0 (0.457)	43.6 (0.676)	57.9 (0.764)	71.6 (0.822)	73.9 (0.716)	75.6 (0.652)
1080 (18.0)	16.0 (0.296)	30.6 (0.423)	40.3 (0.473)	49.5 (0.505)	59.8 (0.512)	67.4 (0.511)
1440 (24.0)	5.3 (0.091)	13.9 (0.177)	19.5 (0.212)	25.0 (0.234)	51.6 (0.405)	71.6 (0.494)
2160 (36.0)	6.0 (0.093)	13.7 (0.157)	18.8 (0.182)	23.6 (0.198)	36.4 (0.253)	46.0 (0.280)
2880 (48.0)	3.4 (0.050)	10.9 (0.117)	15.9 (0.144)	20.7 (0.161)	36.5 (0.234)	48.3 (0.270)
4320 (72.0)	0.1 (0.001)	4.3 (0.043)	7.2 (0.059)	9.9 (0.069)	17.3 (0.100)	22.9 (0.115)

Layer Info

Time Accessed	20 May 2019 10:21AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.972 (4.9%)**	0.847 (4.2%)	**1.052 (5.3%)**
2040	**1.225 (6.2%)**	1.127 (5.7%)	**1.495 (7.6%)**
2050	**1.452 (7.3%)**	1.406 (7.1%)	**1.971 (10.1%)**
2060	**1.653 (8.4%)**	1.685 (8.6%)	**2.480 (12.9%)**
2070	**1.827 (9.3%)**	1.963 (10.1%)	**3.023 (15.9%)**
2080	**1.974 (10.1%)**	2.241 (11.6%)	**3.599 (19.2%)**
2090	**2.095 (10.8%)**	2.518 (13.1%)	**4.208 (22.8%)**

Layer Info

Time Accessed	20 May 2019 10:21AM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	23.4	18.3	16.6	16.9	17.1	16.1
90 (1.5)	26.4	18.9	15.9	15.3	14.6	13.7
120 (2.0)	28.7	18.9	16.3	15.8	14.7	12.2
180 (3.0)	32.2	18.7	17.5	17.9	15.9	13.1
360 (6.0)	32.7	20.7	17.1	15.6	13.5	8.8
720 (12.0)	34.3	23.2	18.8	17.5	14.8	9.1
1080 (18.0)	36.2	26.2	23.4	21.9	19.5	13.2
1440 (24.0)	39.3	30.7	29.3	28.7	23.0	15.0
2160 (36.0)	39.6	31.4	30.7	31.1	28.2	19.0
2880 (48.0)	40.5	33.0	32.5	33.2	30.3	19.6
4320 (72.0)	41.6	34.8	35.7	36.7	34.4	28.2

Layer Info

Time Accessed	20 May 2019 10:21AM

Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Baseflow Factors

Downstream	9659
Area (km2)	16172.463224
Catchment Number	9665
Volume Factor	0.201522
Peak Factor	0.034916
Shape Intersection (%)	99.3

Layer Info

Time Accessed	20 May 2019 10:21AM
Version	2016_v1

Download TXT (downloads/9a27428d-144b-4c49-a2bf-02e58f8ade79.txt)

Download JSON (downloads/ee8d05d7-a824-4688-8202-cc31a78f30f0.json)

Generating PDF... (downloads/4612122c-d828-48a4-adb8-7ee11b6d7287.pdf)

Australian Government
Bureau of Meteorology

Location

Label: Geurie Post Office (Gauge 65018)

Latitude: -32.3987 [Nearest grid cell: 32.3875 (S)]

Longitude:148.8281 [Nearest grid cell: 148.8375 (E)]

IFD Design Rainfall Depth (mm)

Issued: 24 April 2019

Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	1.86	2.09	2.84	3.35	3.87	4.58	5.13
2 min	3.15	3.56	4.85	5.74	6.62	7.74	8.59
3 min	4.35	4.91	6.68	7.90	9.11	10.7	11.9
4 min	5.42	6.11	8.29	9.80	11.3	13.3	14.8
5 min	6.37	7.17	9.72	11.5	13.3	15.6	17.4
10 min	9.89	11.1	15.0	17.8	20.5	24.3	27.3
15 min	12.2	13.7	18.6	22.0	25.4	30.1	33.9
20 min	13.9	15.7	21.2	25.1	29.0	34.4	38.7
25 min	15.3	17.2	23.3	27.6	31.9	37.8	42.4
30 min	16.4	18.4	25.0	29.6	34.2	40.5	45.5
45 min	18.9	21.3	28.9	34.2	39.5	46.6	52.2
1 hour	20.7	23.3	31.7	37.5	43.3	51.0	57.0
1.5 hour	23.4	26.3	35.8	42.3	48.7	57.3	63.9
2 hour	25.4	28.6	38.8	45.8	52.8	61.9	69.0
3 hour	28.5	32.0	43.4	51.2	58.9	69.0	76.8
4.5 hour	32.0	35.9	48.5	57.1	65.6	77.0	85.8
6 hour	34.7	39.0	52.5	61.8	70.9	83.4	93.0
9 hour	39.1	43.8	58.8	69.2	79.4	93.6	105
12 hour	42.5	47.6	63.8	75.0	86.1	102	115
18 hour	47.8	53.4	71.4	84.0	96.6	115	130
24 hour	51.7	57.7	77.2	91.0	105	126	143
30 hour	54.9	61.2	81.9	96.6	112	134	153
36 hour	57.4	64.0	85.8	101	117	142	162
48 hour	61.4	68.5	92.0	109	127	154	176
72 hour	66.6	74.5	101	120	140	171	196
96 hour	70.0	78.5	107	128	150	182	209
120 hour	72.5	81.4	111	134	157	191	219

144 hour	74.4	83.8	115	138	162	197	225
168 hour	75.9	85.7	118	142	166	202	230

Note:
The 50% AEP IFD **does not** correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.
* The 20% AEP IFD **does not** correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

This page was created at **14:11 on Wednesday 24 April 2019 (AEST)**

Location

Label: Geurie Post Office (Gauge 65018)

Latitude: -32.3987 [Nearest grid cell: 32.3875 (S)]

Longitude: 148.8281 [Nearest grid cell: 148.8375 (E)]

Rare Design Rainfall Depth (mm)

Issued: 24 April 2019

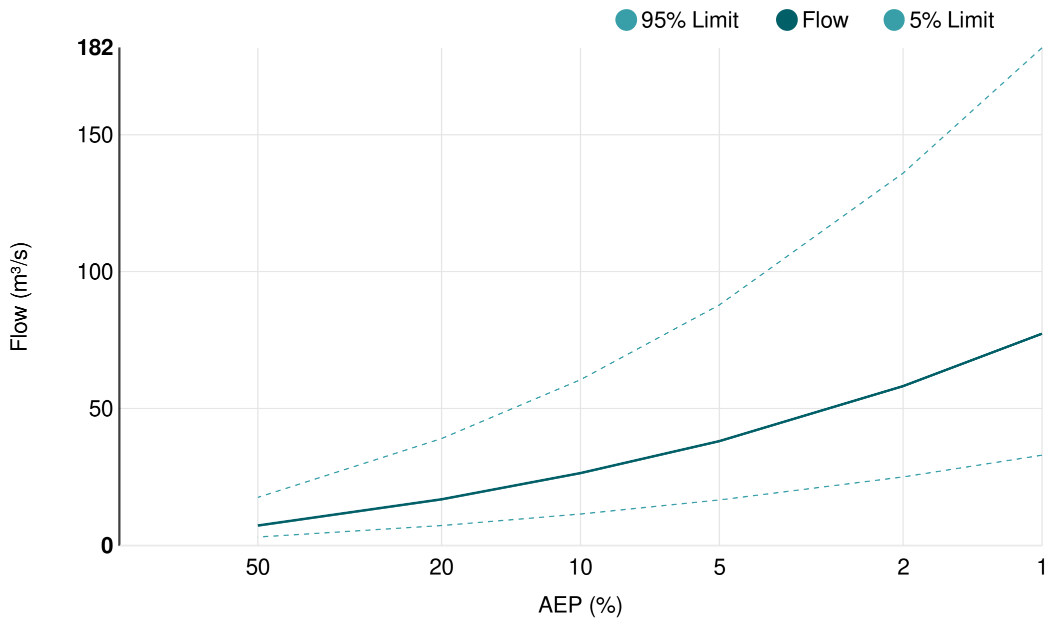
Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

	Annual Exceedance Probability (1 in x)				
Duration	**1 in 100**	**1 in 200**	**1 in 500**	**1 in 1000**	**1 in 2000**
1 min	5.13	5.94	7.00	7.89	8.86
2 min	8.59	9.87	11.6	13.1	14.8
3 min	11.9	13.7	16.1	18.2	20.4
4 min	14.8	17.1	20.2	22.7	25.5
5 min	17.4	20.2	23.8	26.8	30.1
10 min	27.3	31.7	37.3	42.0	47.2
15 min	33.9	39.3	46.3	52.1	58.5
20 min	38.7	44.8	52.8	59.5	66.8
25 min	42.4	49.1	57.9	65.2	73.3
30 min	45.5	52.7	62.0	69.9	78.5
45 min	52.2	60.4	71.2	80.2	90.1
1 hour	57.0	65.9	77.7	87.5	98.4
1.5 hour	63.9	73.8	87.0	98.1	110
2 hour	69.0	79.8	94.0	106	119
3 hour	76.8	89.0	105	118	133
4.5 hour	85.8	99.6	117	132	148
6 hour	93.0	108	127	143	161
9 hour	105	122	144	162	182
12 hour	115	133	157	177	198
18 hour	130	151	178	201	225
24 hour	143	165	195	219	246
30 hour	153	176	208	234	264
36 hour	162	186	219	247	278
48 hour	176	201	237	268	302
72 hour	196	223	263	296	333
96 hour	209	237	280	315	354

120 hour	219	248	292	328	368
144 hour	225	256	301	338	378
168 hour	230	262	308	345	385

This page was created at **04:24 on Wednesday 24 April 2019 (UTC)**

Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	7.32	3.02	17.6
20	16.9	7.28	39.0
10	26.4	11.5	60.6
5	38.2	16.6	88.0
2	58.3	25.1	136
1	77.4	33.0	182

Statistics

Variable	Value	Standard Dev
Mean	2.013	0.526
Standard Dev	0.984	0.111
Skew	0.071	0.026

Note: These statistics come from the nearest gauged catchment. Details.

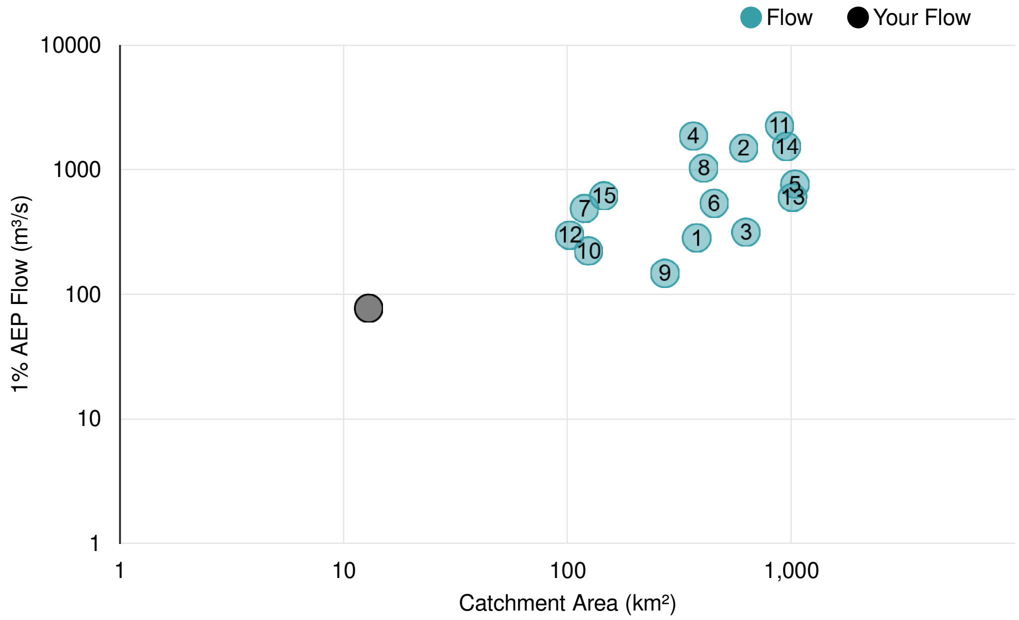
Correlation

1.000	

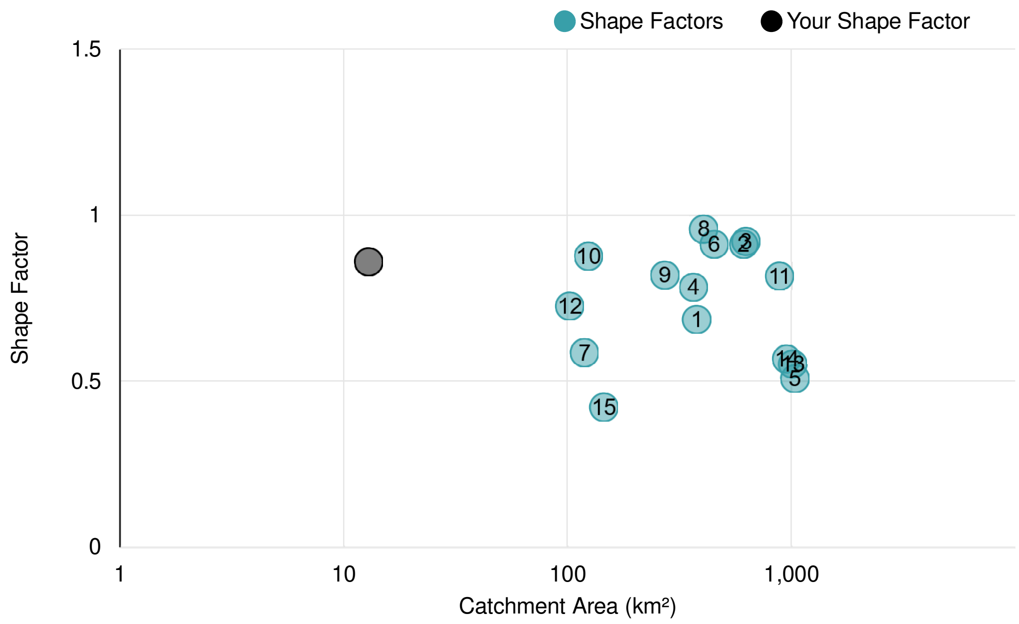
Correlation		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

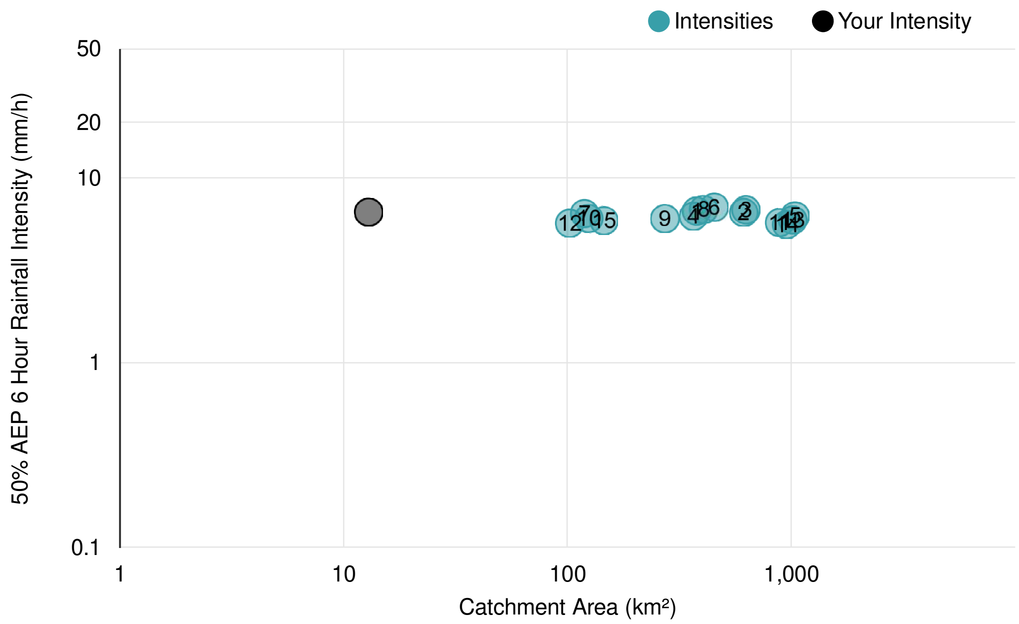
1% AEP Flow vs Catchment Area



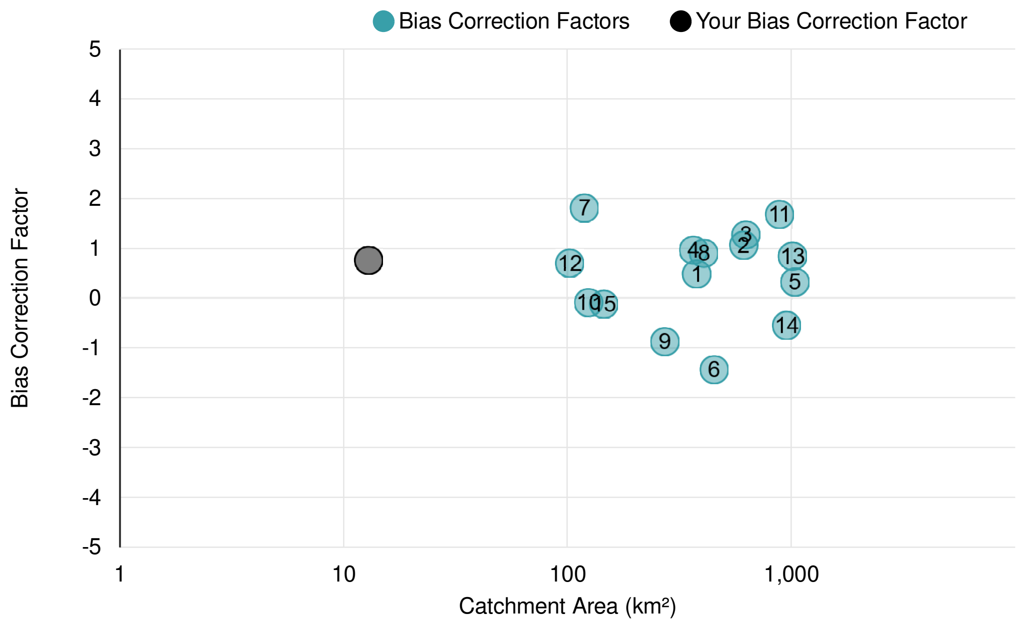
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



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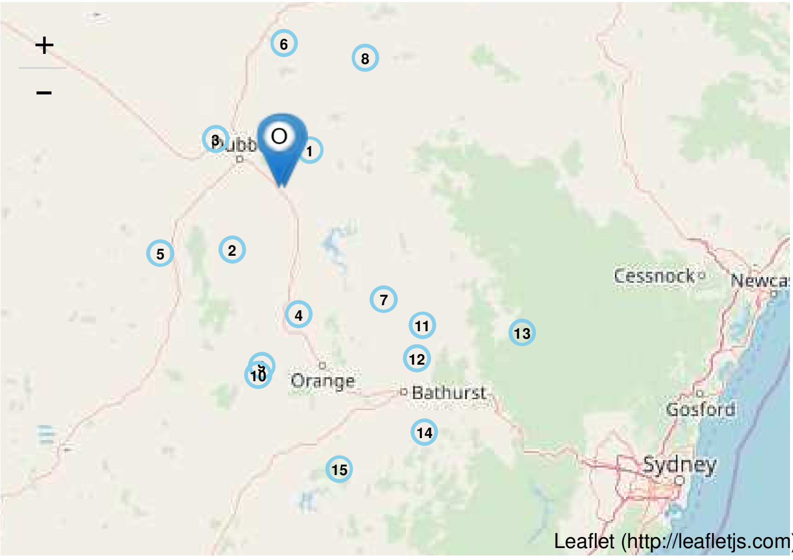
TXT Nearby JSON

Input Data

Date/Time	2019-04-27 15:47
Catchment Name	GEU_300
Latitude (Outlet)	-32.3966089821
Longitude (Outlet)	148.848219177
Latitude (Centroid)	-32.39481
Longitude (Centroid)	148.88119
Catchment Area (km^2)	12.91013
Distance to Nearest Gauged Catchment (km)	26.99
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.549942
2% AEP 6 Hour Rainfall Intensity (mm/h)	13.947526
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1

Input Data

Region Source (User/Auto)	Auto
Shape Factor	0.86
Interpolation Method	Natural Neighbour
Bias Correction Value	0.761



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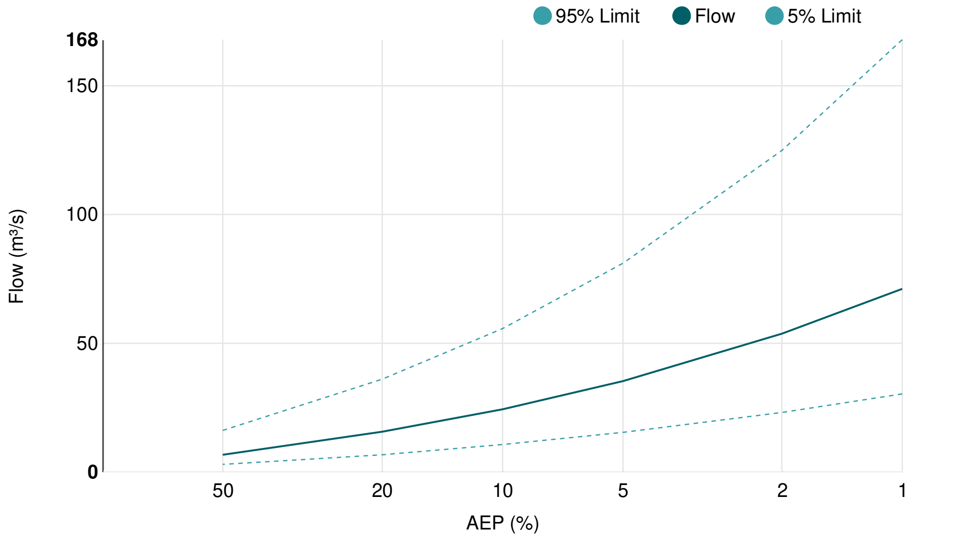


AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	6.73	2.78	16.1
20	15.6	6.71	35.9
10	24.3	10.6	55.8
5	35.2	15.3	81.0
2	53.6	23.1	125
1	71.2	30.4	168

Statistics

Variable	Value	Standard Dev
Mean	1.930	0.526
Standard Dev	0.984	0.111
Skew	0.071	0.026

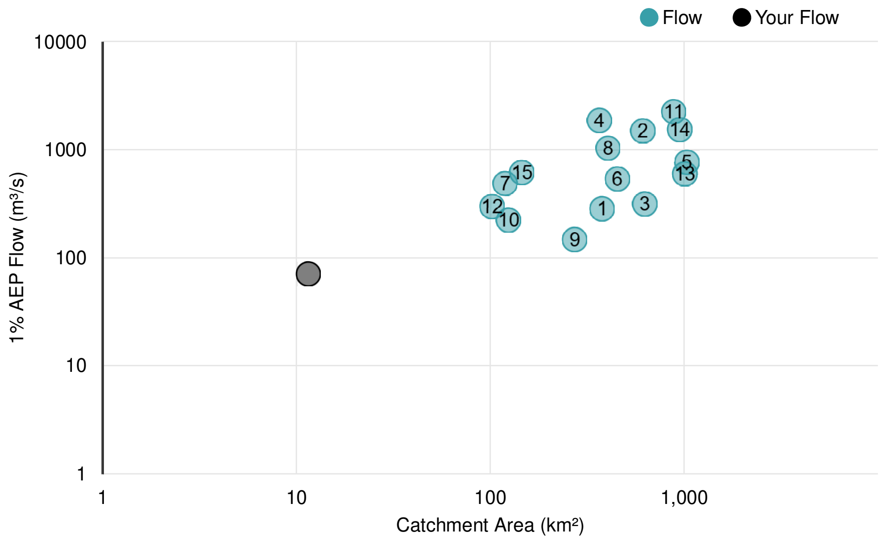
Note: These statistics come from the nearest gauged catchment. Details.

Correlation

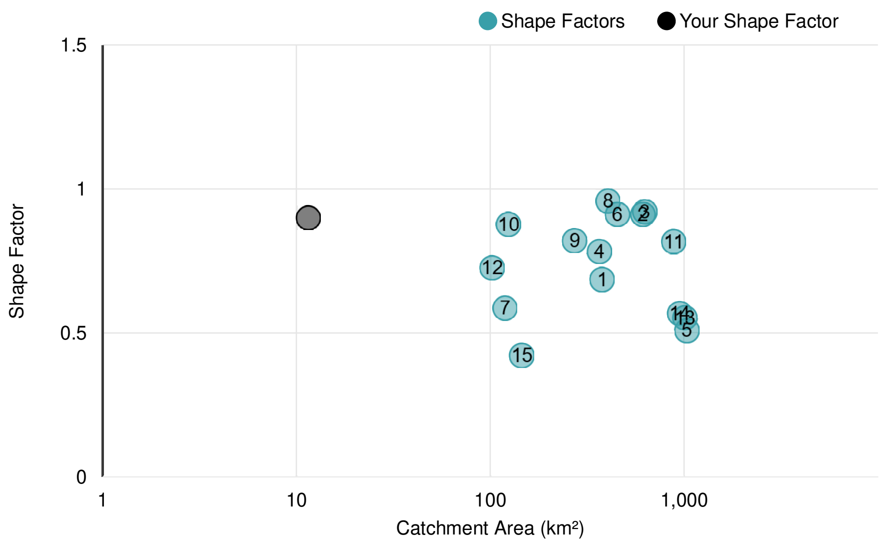
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

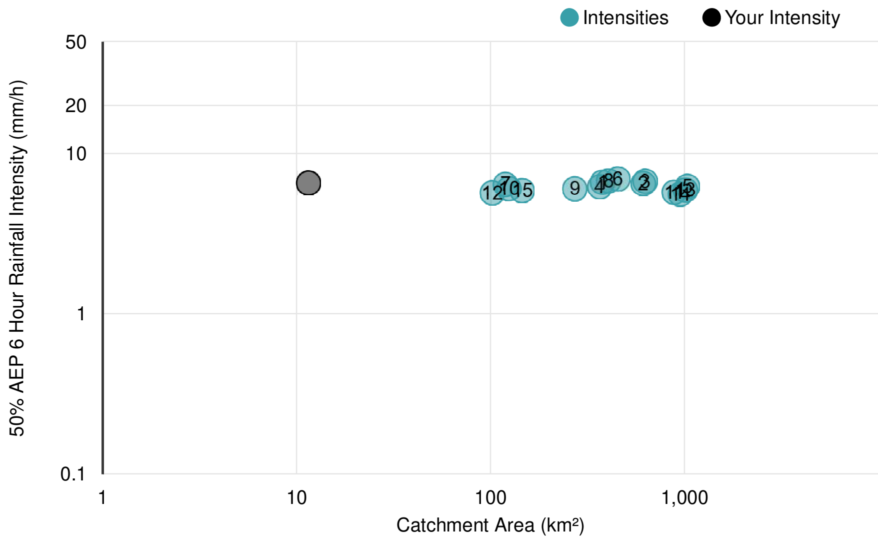
1% AEP Flow vs Catchment Area



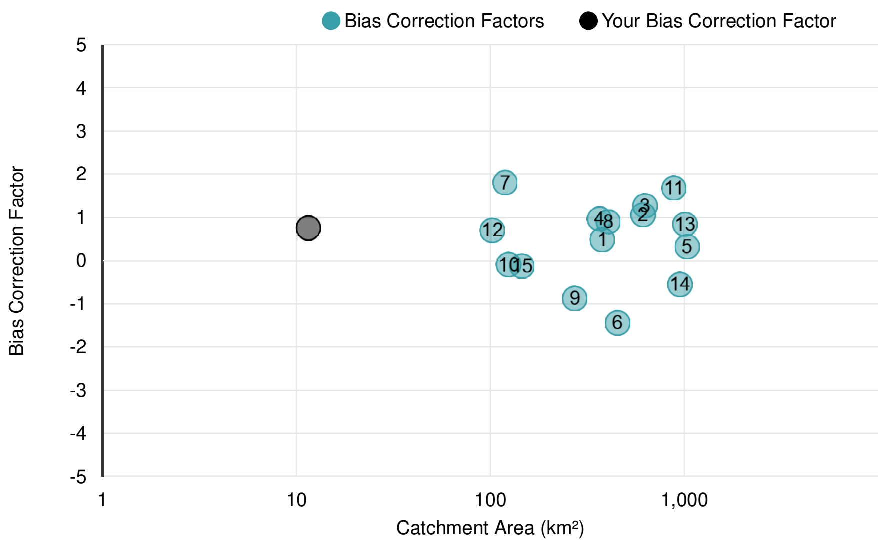
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



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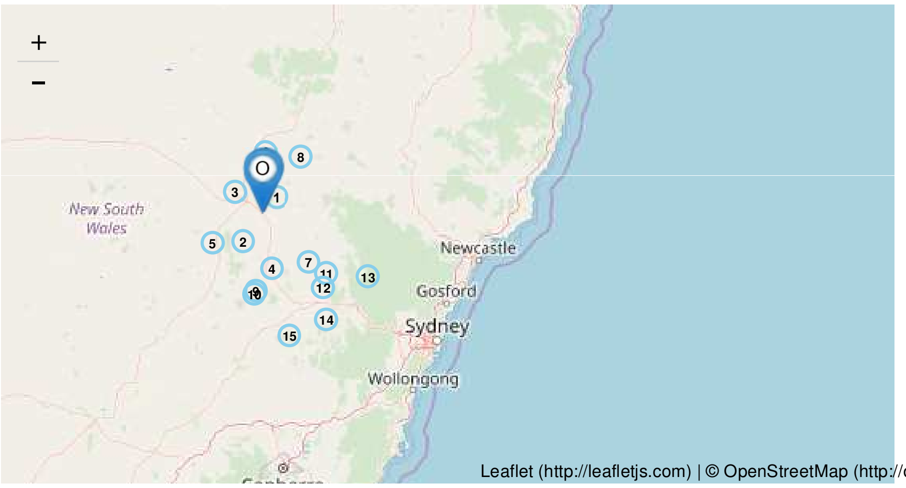
TXT Nearby JSON

Input Data

Date/Time	2019-04-27 15:54
Catchment Name	GEU_400
Latitude (Outlet)	-32.3937994992
Longitude (Outlet)	148.848576421

Input Data	
Latitude (Centroid)	-32.37355
Longitude (Centroid)	148.87066
Catchment Area (km^2)	11.49222
Distance to Nearest Gauged Catchment (km)	26.72
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.56314
2% AEP 6 Hour Rainfall Intensity (mm/h)	13.988516
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.9
Interpolation Method	Natural Neighbour
Bias Correction Value	0.759



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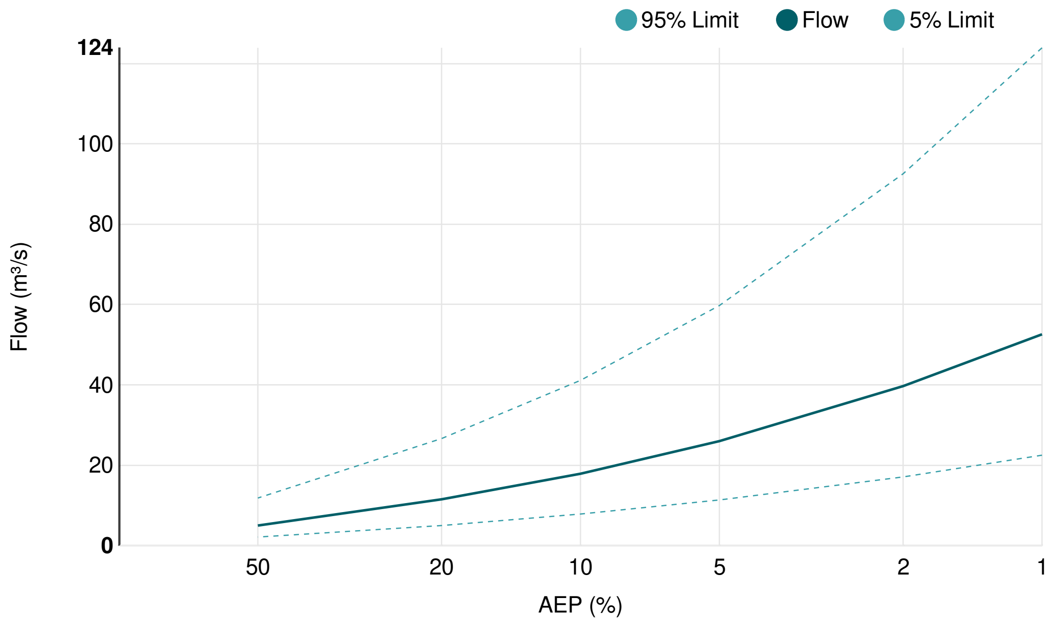


AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	4.98	2.05	11.9
20	11.5	4.96	26.6
10	17.9	7.81	41.2
5	26.0	11.3	59.8
2	39.7	17.1	92.5
1	52.6	22.5	124

Statistics

Variable	Value	Standard Dev
Mean	1.631	0.526
Standard Dev	0.984	0.111
Skew	0.071	0.026

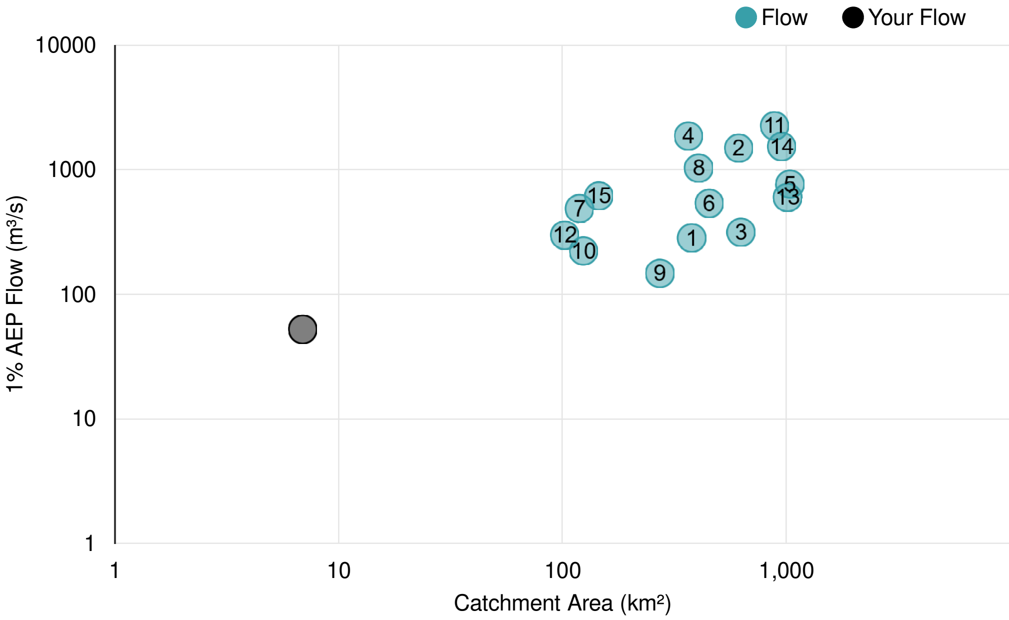
Note: These statistics come from the nearest gauged catchment. Details.

Correlation
1.000

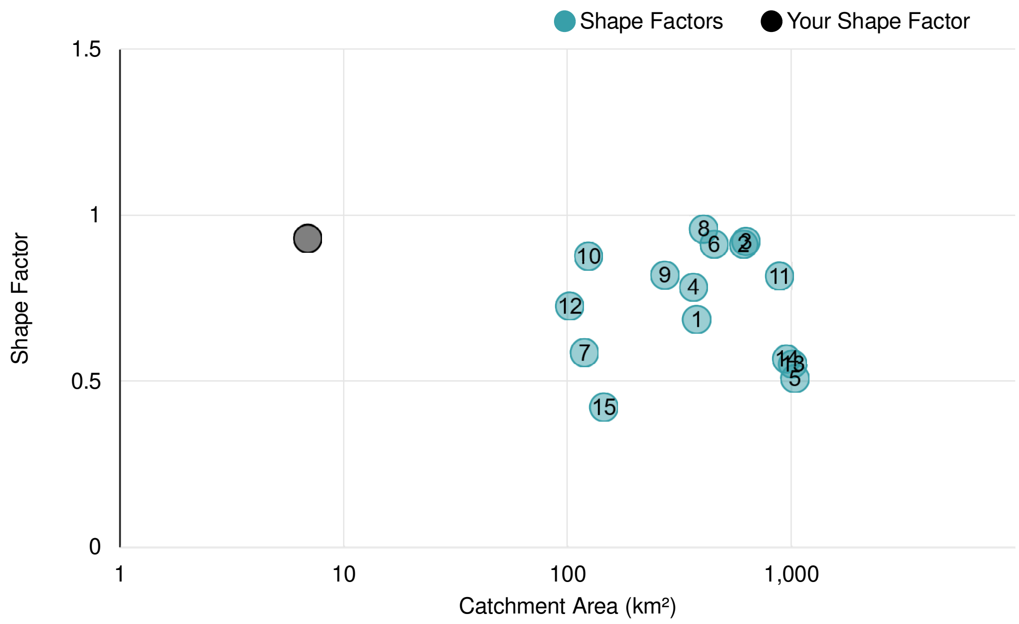
	Correlation	
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

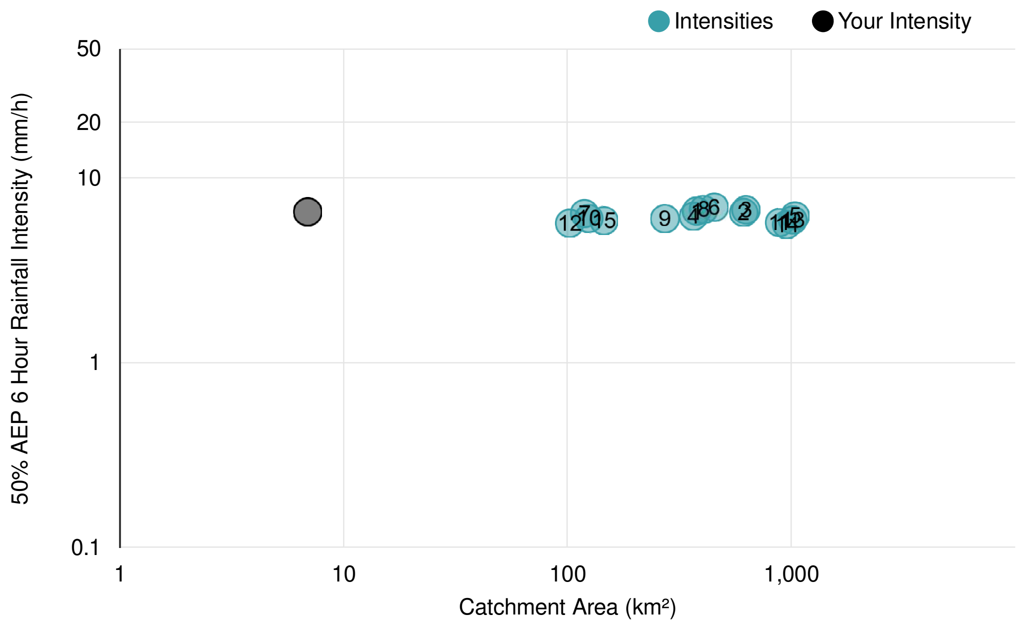
1% AEP Flow vs Catchment Area



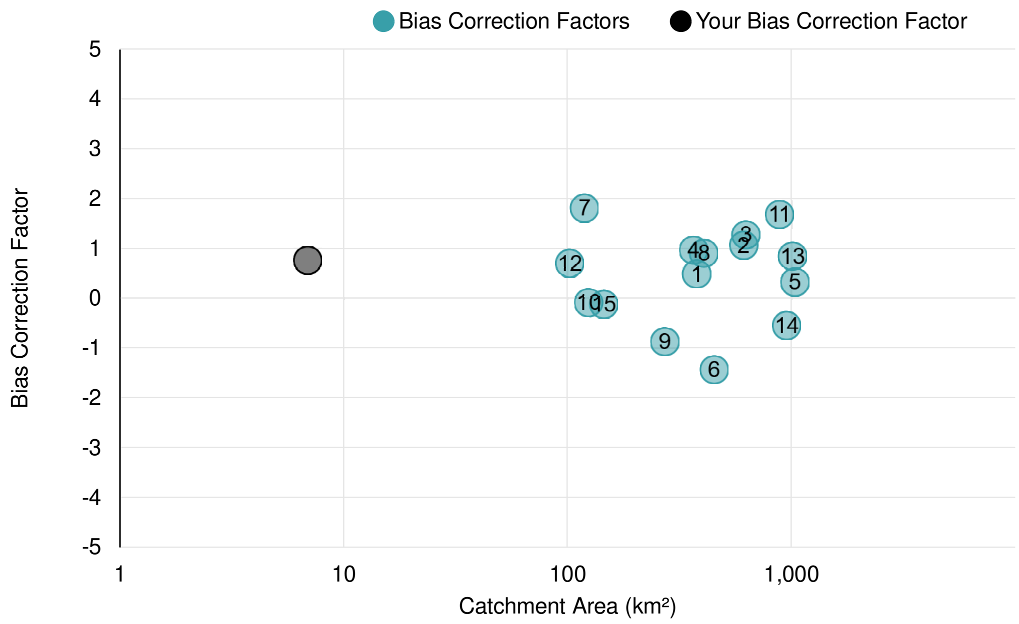
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



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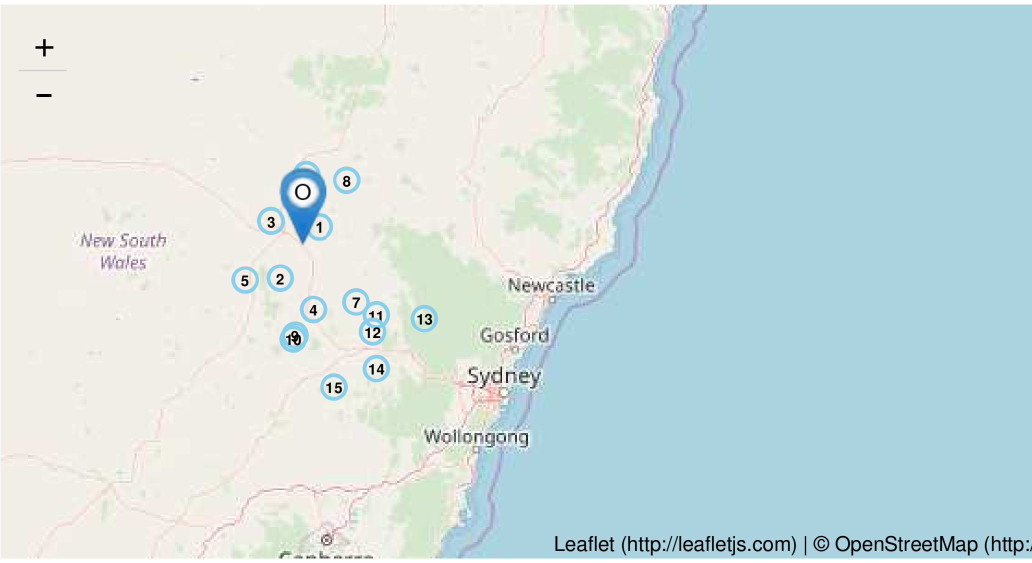
TXT Nearby JSON

Input Data

Date/Time	2019-04-27 15:59
Catchment Name	GEU_500
Latitude (Outlet)	-32.3877903698
Longitude (Outlet)	148.840290334
Latitude (Centroid)	-32.36703
Longitude (Centroid)	148.84846
Catchment Area (km^2)	6.90848
Distance to Nearest Gauged Catchment (km)	26.66
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.566995
2% AEP 6 Hour Rainfall Intensity (mm/h)	14.003894
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1

Input Data	
Region Source (User/Auto)	Auto
Shape Factor	0.93
Interpolation Method	Natural Neighbour
Bias Correction Value	0.762



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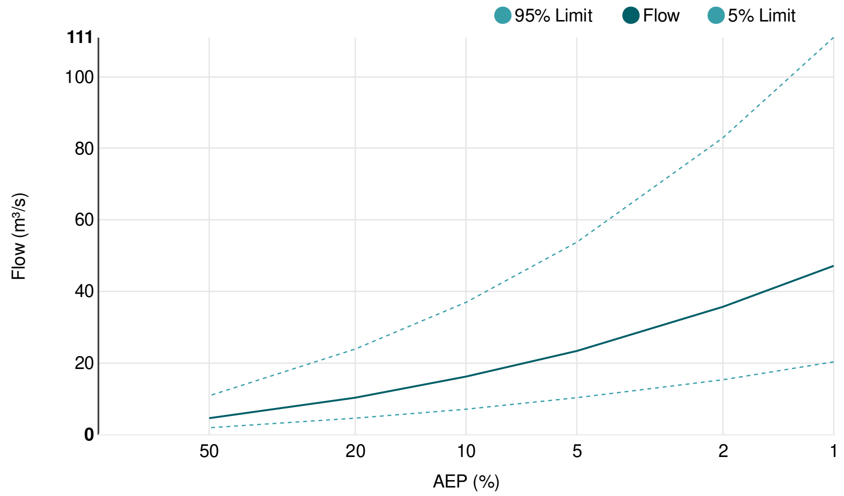


AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	4.47	1.84	10.7
20	10.3	4.45	23.8
10	16.1	7.01	37.0
5	23.4	10.2	53.7
2	35.6	15.3	83.0
1	47.2	20.2	111

Statistics

Variable	Value	Standard Dev
Mean	1.525	0.526
Standard Dev	0.984	0.111
Skew	0.071	0.026

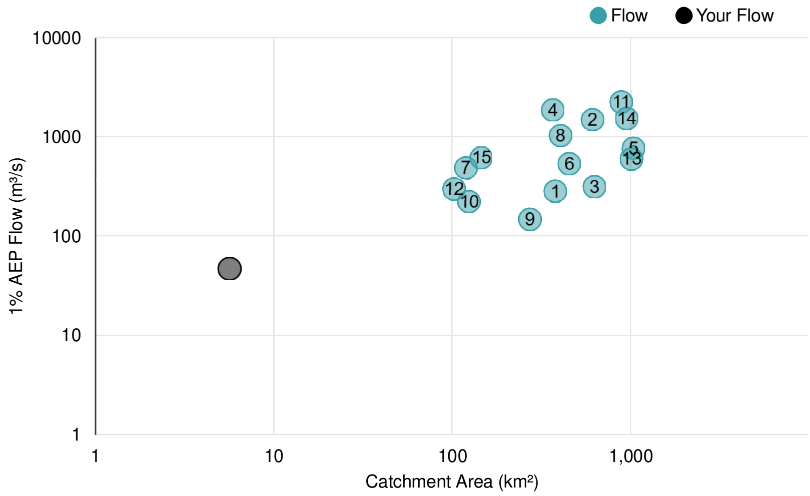
Note: These statistics come from the nearest gauged catchment. Details.

Correlation

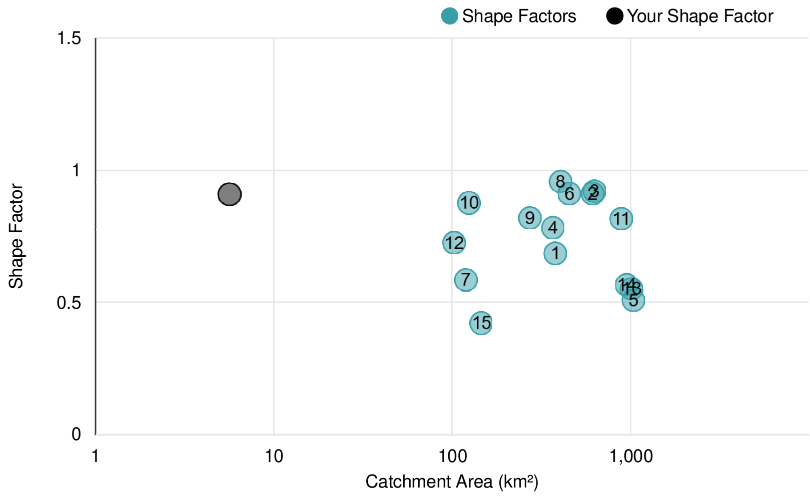
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

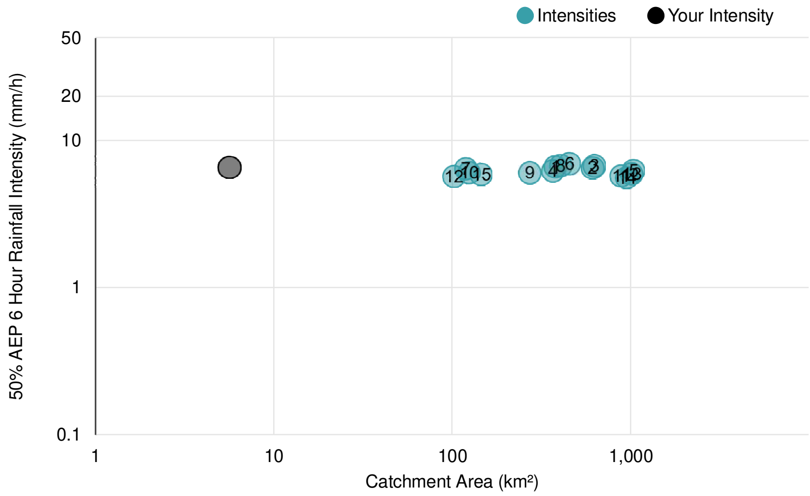
1% AEP Flow vs Catchment Area



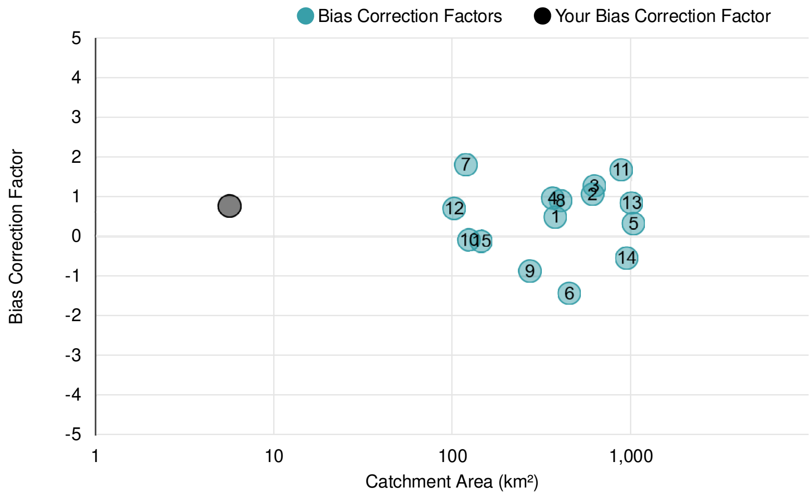
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



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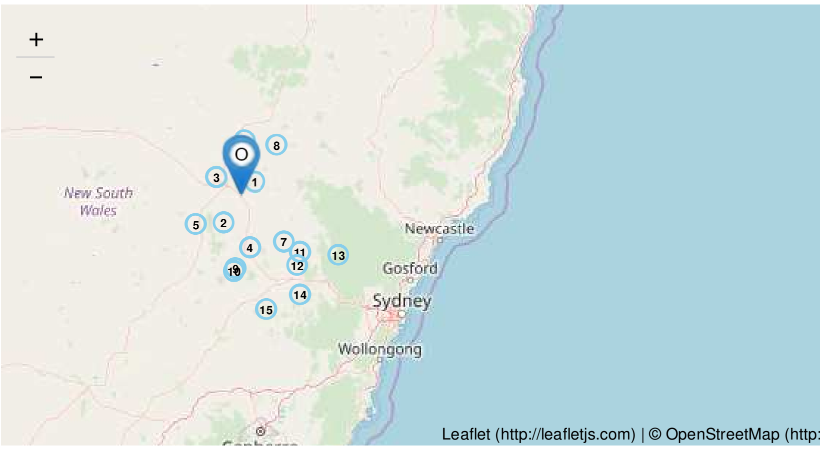
TXT Nearby JSON

Input Data

Date/Time	2019-04-27 16:02
Catchment Name	GEU_600
Latitude (Outlet)	-32.3858463791
Longitude (Outlet)	148.833572421
Latitude (Centroid)	-32.36658
Longitude (Centroid)	148.83118
Catchment Area (km^2)	5.63101

Input Data

Distance to Nearest Gauged Catchment (km)	26.9
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.566995
2% AEP 6 Hour Rainfall Intensity (mm/h)	14.003894
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.91
Interpolation Method	Natural Neighbour
Bias Correction Value	0.766



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APPENDIX C
DESIGN PARAMETER CALCULATIONS

The design parameter calculations for all event probabilities and durations are provided below.

C.1 Rainfall Losses

The rainfall burst initial losses calculated for the full range of event probabilities and durations are detailed in Table 9-1.

Table 9-1: All Event Probabilities and Durations - Design Rainfall Burst Initial Loss

Storm Duration (minutes)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
15 *	18.3	16.6	16.9	17.1	16.1
20 *	18.3	16.6	16.9	17.1	16.1
25 *	18.3	16.6	16.9	17.1	16.1
30 *	18.3	16.6	16.9	17.1	16.1
45 *	18.3	16.6	16.9	17.1	16.1
60	18.3	16.6	16.9	17.1	16.1
90	18.9	15.9	15.3	14.6	13.7
120	18.9	16.3	15.8	14.7	12.2
180	18.7	17.5	17.9	15.9	13.1
270 #	19.7	17.3	16.75	14.7	10.95
360	20.7	17.1	15.6	13.5	8.8
540 #	21.95	17.95	16.55	14.15	8.95
720	23.2	18.8	17.5	14.8	9.1
1440	30.7	29.3	28.7	23	15
2880	33	32.5	33.2	30.3	19.6
4320	34.8	35.7	36.7	34.4	28.2

Note:

* ARR 2019 does not provide probability neutral burst initial losses for durations less than the 60 minute storm duration. Therefore, the probability neutral burst initial losses for the 60 minute storm duration were applied to all shorter storm durations.

ARR 2019 does not provide probability neutral burst initial losses for the 270 and 540 minute storm duration. Therefore, the probability neutral burst initial losses were linearly interpolated from the values given for the two nearest storm durations.

C.2 Areal Reduction Factors

The Areal Reduction Factors (ARF) calculated for the full range of event probabilities and durations are detailed in Table 9-2.

Table 9-2: All Event Probabilities and Durations - Design Storm ARF

Duration	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
15 min	0.748	0.742	0.736	0.727	0.721	0.715	0.707
20 min	0.777	0.770	0.764	0.755	0.749	0.743	0.734
25 min	0.797	0.790	0.783	0.774	0.768	0.761	0.752
30 min	0.812	0.805	0.798	0.788	0.781	0.774	0.765
45 min	0.841	0.833	0.825	0.815	0.807	0.799	0.789
1 hour	0.858	0.849	0.840	0.829	0.820	0.812	0.800
1.5 hour	0.878	0.868	0.858	0.844	0.834	0.824	0.810
2 hour	0.890	0.878	0.867	0.852	0.840	0.829	0.813
3 hour	0.904	0.892	0.879	0.862	0.849	0.837	0.820
4.5 hour	0.921	0.910	0.900	0.886	0.875	0.864	0.850
6 hour	0.934	0.928	0.921	0.912	0.906	0.899	0.890
9 hour	0.948	0.945	0.941	0.936	0.932	0.929	0.924
12 hour	0.954	0.951	0.947	0.942	0.938	0.935	0.930
24 hour	0.969	0.964	0.959	0.953	0.947	0.942	0.936
30 hour	0.972	0.967	0.962	0.956	0.951	0.946	0.939
36 hour	0.974	0.969	0.964	0.958	0.953	0.948	0.941
48 hour	0.977	0.973	0.968	0.961	0.956	0.951	0.945
72 hour	0.981	0.976	0.972	0.965	0.961	0.956	0.950
96 hour	0.984	0.979	0.974	0.968	0.964	0.959	0.953
120 hour	0.985	0.981	0.976	0.970	0.966	0.961	0.956
144 hour	0.986	0.982	0.978	0.972	0.968	0.963	0.958
168 hour	0.987	0.983	0.979	0.974	0.969	0.965	0.960

C.3 Rainfall Spatial Patterns

The minimum and maximum range of the design rainfall spatial patterns calculated for the full range of event probabilities and durations are detailed in Table 9-3.

Table 9-3: All Event Probabilities and Durations - Design Rainfall Spatial Pattern Range

Event Probability	Event Duration (minutes)	Design Rainfall (mm) - Minimum	Design Rainfall (mm) - Maximum
20% AEP	15	13.84	13.98
20% AEP	20	16.39	16.55
20% AEP	25	18.41	18.65
20% AEP	30	20.13	20.37
20% AEP	45	24.04	24.38

20% AEP	60	26.93	27.28
20% AEP	90	31.16	31.60
20% AEP	120	34.34	34.79
20% AEP	180	39.16	39.61
20% AEP	270	44.66	45.21
20% AEP	360	49.06	49.80
20% AEP	540	55.67	56.90
20% AEP	720	60.70	62.42
20% AEP	1440	74.64	77.36
20% AEP	2880	89.73	92.96
20% AEP	4320	99.11	102.05
20% AEP	5760	105.24	108.19
20% AEP	7200	109.36	113.30
10% AEP	15	16.17	16.39
10% AEP	20	19.18	19.49
10% AEP	25	21.57	21.89
10% AEP	30	23.58	23.98
10% AEP	45	28.15	28.65
10% AEP	60	31.50	32.01
10% AEP	90	36.36	36.96
10% AEP	120	40.04	40.57
10% AEP	180	45.47	46.10
10% AEP	270	51.88	52.70
10% AEP	360	57.24	58.26
10% AEP	540	65.18	66.69
10% AEP	720	71.11	73.11
10% AEP	1440	87.46	90.84
10% AEP	2880	106.01	109.90
10% AEP	4320	117.18	121.09
10% AEP	5760	124.33	129.22
10% AEP	7200	130.44	135.34
5% AEP	15	18.54	18.83
5% AEP	20	22.00	22.31
5% AEP	25	24.75	25.15
5% AEP	30	27.04	27.44
5% AEP	45	32.25	32.75

5% AEP	60	35.97	36.65
5% AEP	90	41.42	42.10
5% AEP	120	45.41	46.11
5% AEP	180	51.50	52.29
5% AEP	270	58.92	59.82
5% AEP	360	65.22	66.41
5% AEP	540	74.52	76.31
5% AEP	720	81.35	83.81
5% AEP	1440	100.72	104.56
5% AEP	2880	121.93	127.73
5% AEP	4320	136.04	141.87
5% AEP	5760	145.18	151.03
5% AEP	7200	152.30	158.16
2% AEP	15	21.75	22.11
2% AEP	20	25.76	26.21
2% AEP	25	28.97	29.43
2% AEP	30	31.62	32.17
2% AEP	45	37.55	38.28
2% AEP	60	41.78	42.61
2% AEP	90	47.86	48.79
2% AEP	120	52.37	53.22
2% AEP	180	59.22	60.17
2% AEP	270	68.10	69.17
2% AEP	360	75.91	77.28
2% AEP	540	87.43	89.49
2% AEP	720	96.10	98.92
2% AEP	1440	119.07	123.83
2% AEP	2880	147.06	153.79
2% AEP	4320	164.13	170.89
2% AEP	5760	175.26	183.00
2% AEP	7200	184.37	191.17
1% AEP	15	24.24	24.67
1% AEP	20	28.69	29.21
1% AEP	25	32.25	32.86
1% AEP	30	35.17	35.79
1% AEP	45	41.63	42.43

1% AEP	60	46.27	47.17
1% AEP	90	52.78	53.79
1% AEP	120	57.54	58.55
1% AEP	180	64.97	66.08
1% AEP	270	74.90	76.21
1% AEP	360	84.14	85.68
1% AEP	540	97.90	99.76
1% AEP	720	106.98	110.73
1% AEP	1440	134.54	140.23
1% AEP	2880	167.35	175.00
1% AEP	4320	187.34	195.02
1% AEP	5760	200.44	209.12
1% AEP	7200	210.57	218.30
0.5% AEP	15	27.68	28.39
0.5% AEP	20	32.75	33.64
0.5% AEP	25	36.76	37.75
0.5% AEP	30	40.04	41.12
0.5% AEP	45	47.37	48.73
0.5% AEP	60	52.52	53.98
0.5% AEP	90	59.80	61.45
0.5% AEP	120	65.21	66.86
0.5% AEP	180	73.70	75.46
0.5% AEP	270	85.49	87.30
0.5% AEP	360	97.10	98.90
0.5% AEP	540	113.30	116.09
0.5% AEP	720	124.32	127.12
0.5% AEP	1440	154.55	160.21
0.5% AEP	2880	190.28	197.89
0.5% AEP	4320	211.27	220.82
0.5% AEP	5760	226.34	235.93
0.5% AEP	7200	237.48	247.09
0.2% AEP	15	32.10	33.02
0.2% AEP	20	37.95	39.13
0.2% AEP	25	42.65	44.00
0.2% AEP	30	46.45	47.90
0.2% AEP	45	54.88	56.70

0.2% AEP	60	60.75	62.75
0.2% AEP	90	69.03	71.30
0.2% AEP	120	75.07	77.43
0.2% AEP	180	84.43	86.89
0.2% AEP	270	98.65	101.20
0.2% AEP	360	112.18	115.74
0.2% AEP	540	132.11	135.80
0.2% AEP	720	145.06	149.70
0.2% AEP	1440	180.59	186.21
0.2% AEP	2880	222.99	232.44
0.2% AEP	4320	247.86	258.31
0.2% AEP	5760	264.92	275.41
0.2% AEP	7200	277.11	288.57

C.4 Critical Temporal Pattern and Storm Duration

C.4.1 Hydrology

Table 9-4: Design Storm Critical Duration and Pattern for Key Locations in the Hydrologic Model

Event Probability	Duration and Temporal Pattern (TP) with the peak discharge one higher than the average/median peak discharge				Critical Duration and Temporal Pattern
	Inflow GEU_301	Inflow GEU_401	Inflow GEU_501	Inflow GEU_601	
20% AEP	540 minute TP06	540 minute TP06	540 minute TP03	540 minute TP06	540 minute TP06
10% AEP	360 minute TP07	360 minute TP07	360 minute TP07	360 minute TP07	360 minute TP07
5% AEP	360 minute TP07	360 minute TP07	360 minute TP07	360 minute TP07	360 minute TP07
2% AEP	270 minute TP09	270 minute TP09	270 minute TP09	270 minute TP09	270 minute TP09
1% AEP	180 minute TP07	270 minute TP09	270 minute TP09	180 minute TP07	180 minute TP07 270 minute TP09
0.5% AEP	180 minute TP07	180 minute TP07	270 minute TP09	180 minute TP04	180 minute TP07
0.2% AEP	180 minute TP07	180 minute TP07	270 minute TP08	180 minute TP05	180 minute TP07

C.4.1.1 20% AEP Event

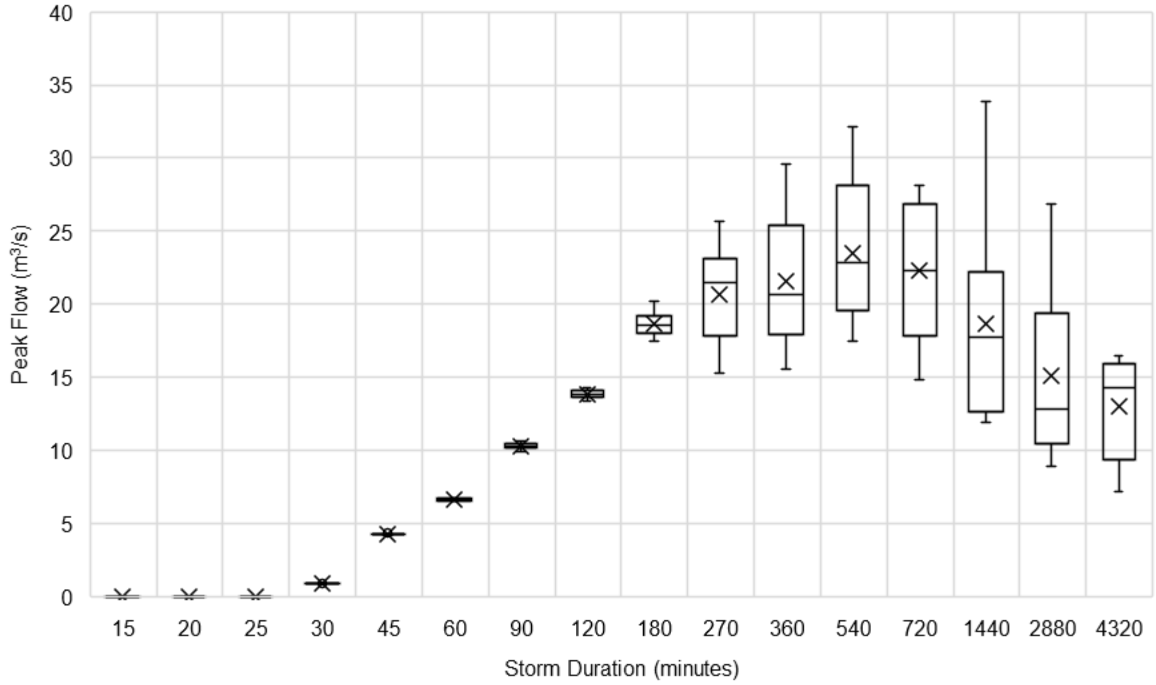

Chart 9-1: Box and Whisker Plot - 20% AEP Event - Inflow GEU_301

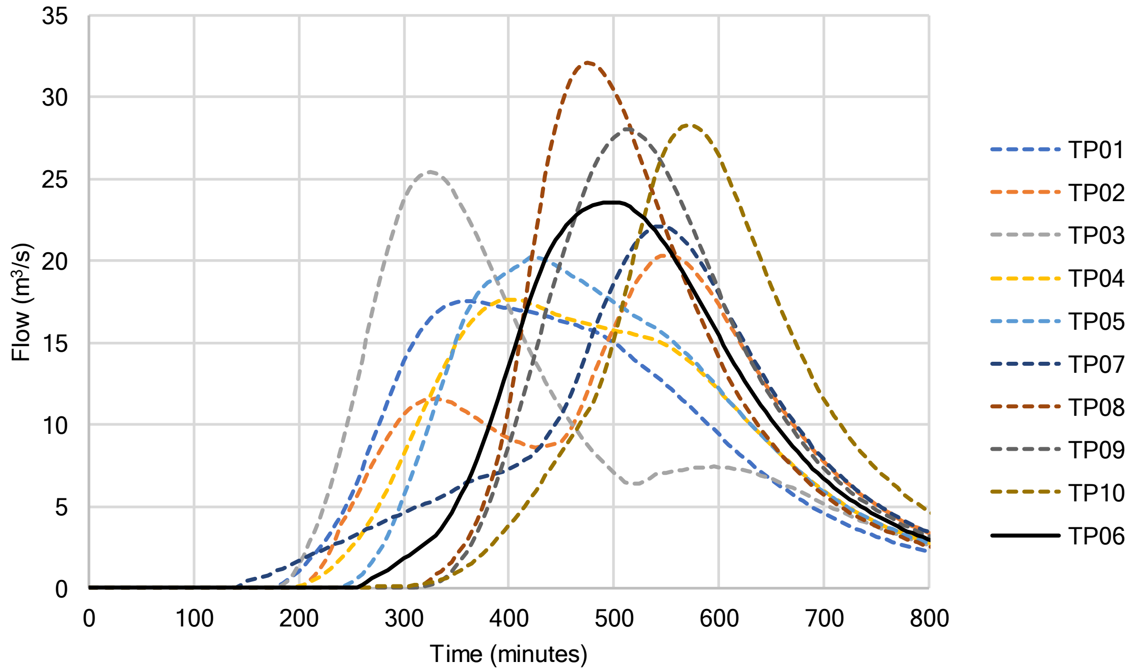

Chart 9-2: Hydrographs - 20% AEP 540 minute storm duration - Inflow GEU_301

C.4.1.2 5% AEP Event

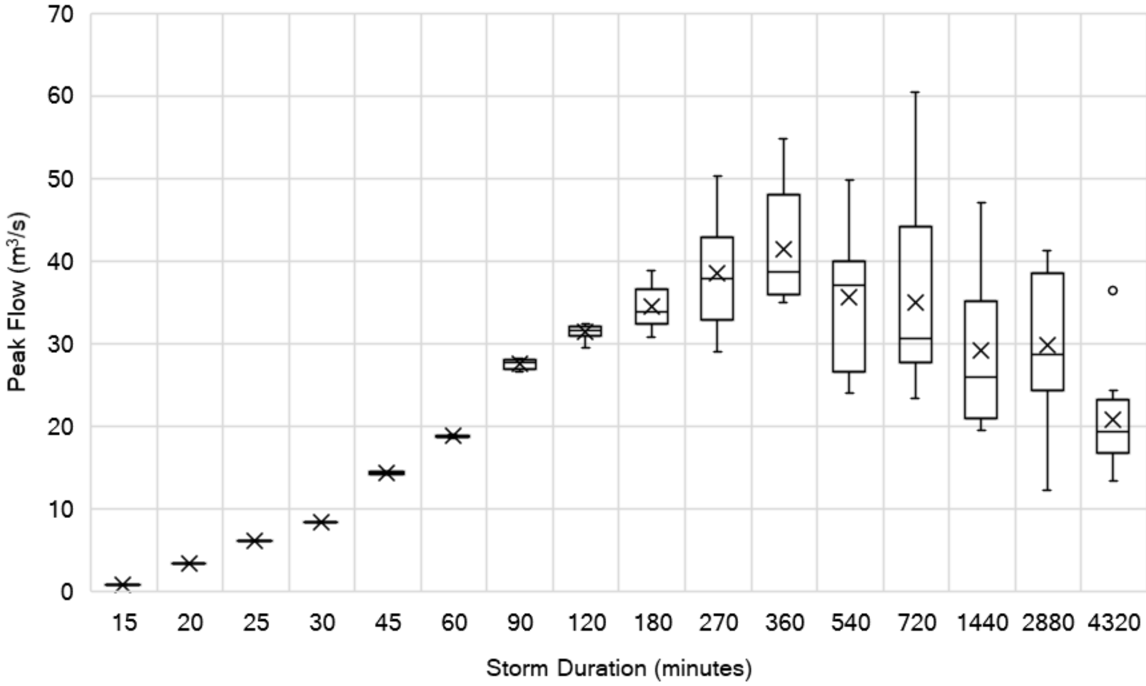

Chart 9-3: Box and Whisker Plot - 5% AEP Event - Inflow GEU_301

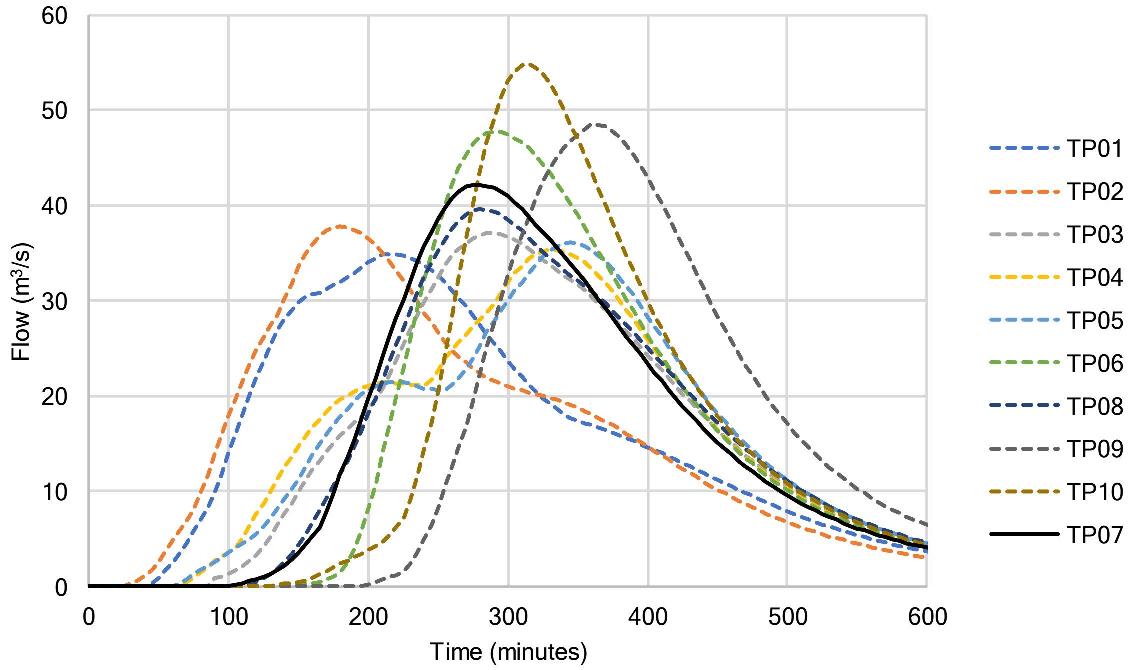

Chart 9-4: Hydrograph - 5% AEP 360 minute storm duration - Inflow GEU_301

C.4.1.3 1% AEP Event

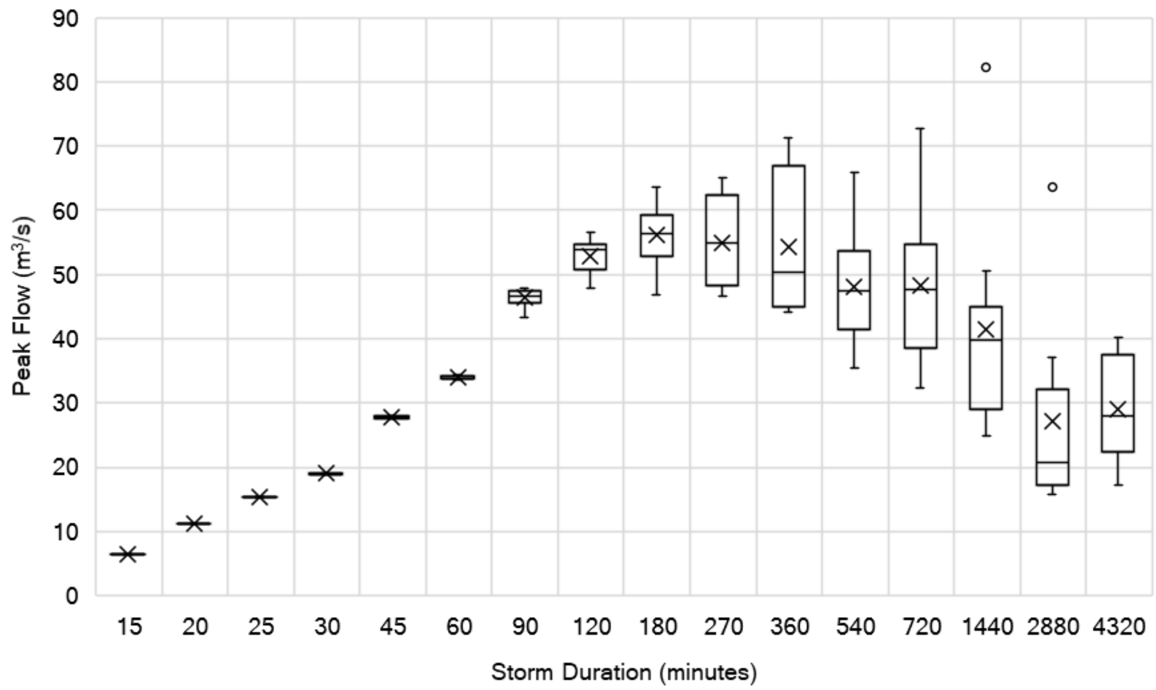

Chart 9-5: Box and Whisker Plot - 1% AEP Event - Inflow GEU_301

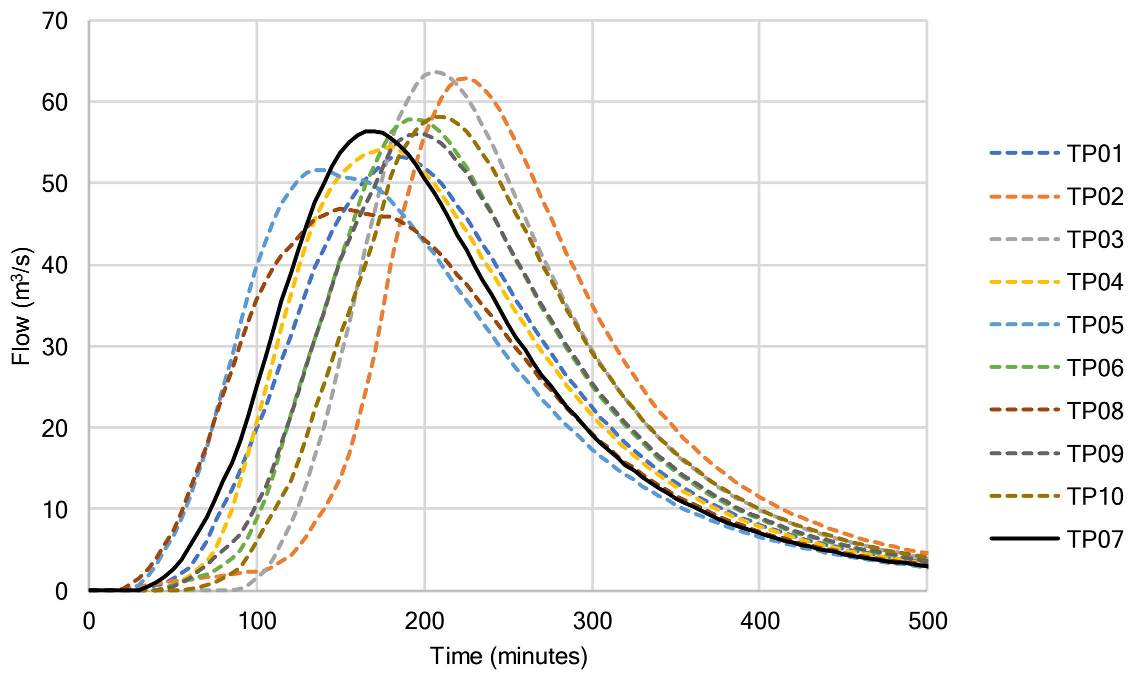

Chart 9-6: Hydrograph - 1% AEP 180 minute storm event - Inflow GEU_301

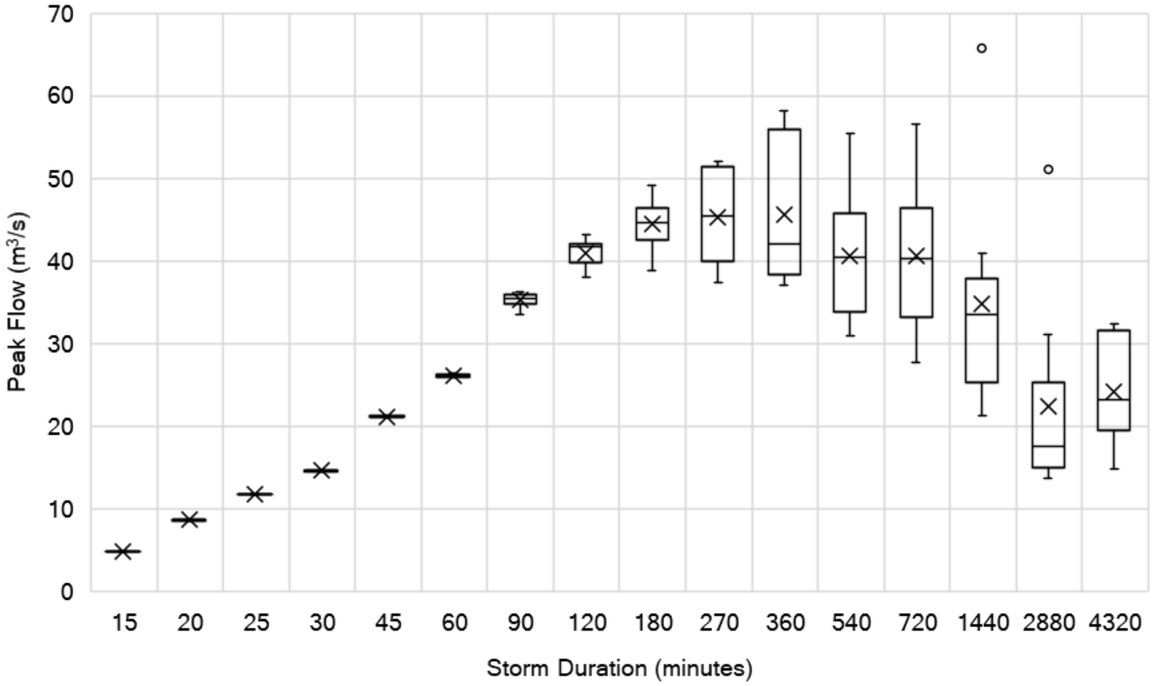

Chart 9-7: Box and Whisker Plot - 1% AEP Event - Inflow GEU_401

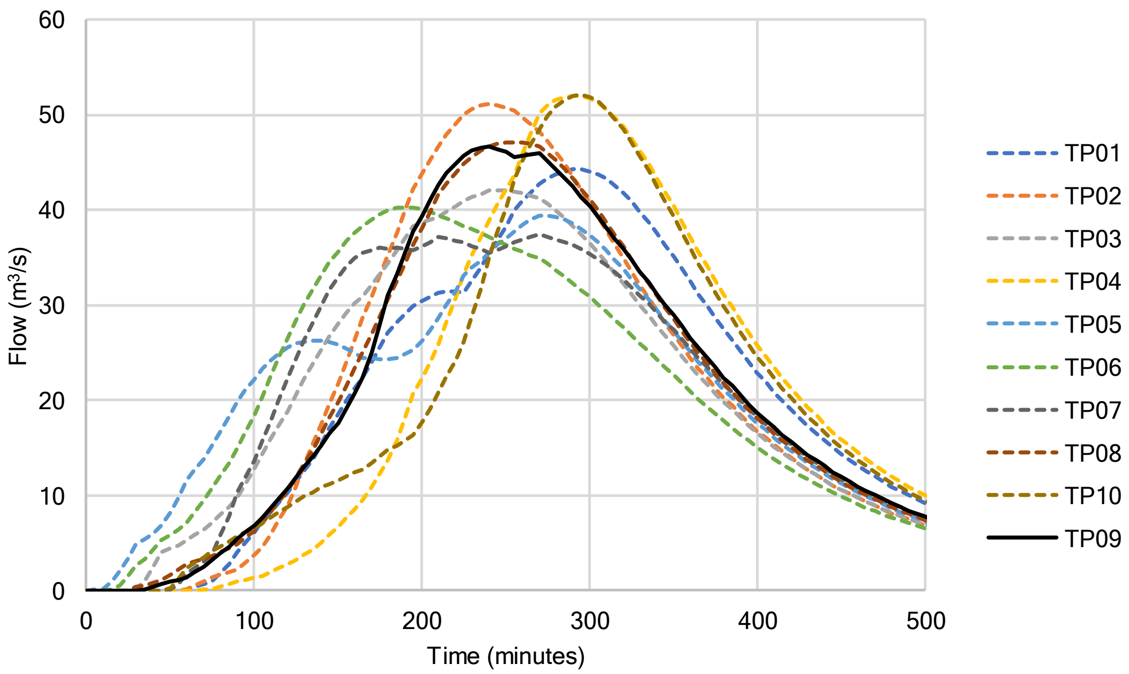

Chart 9-8: Hydrology - 1% AEP 270 minute storm event - Inflow GEU_401

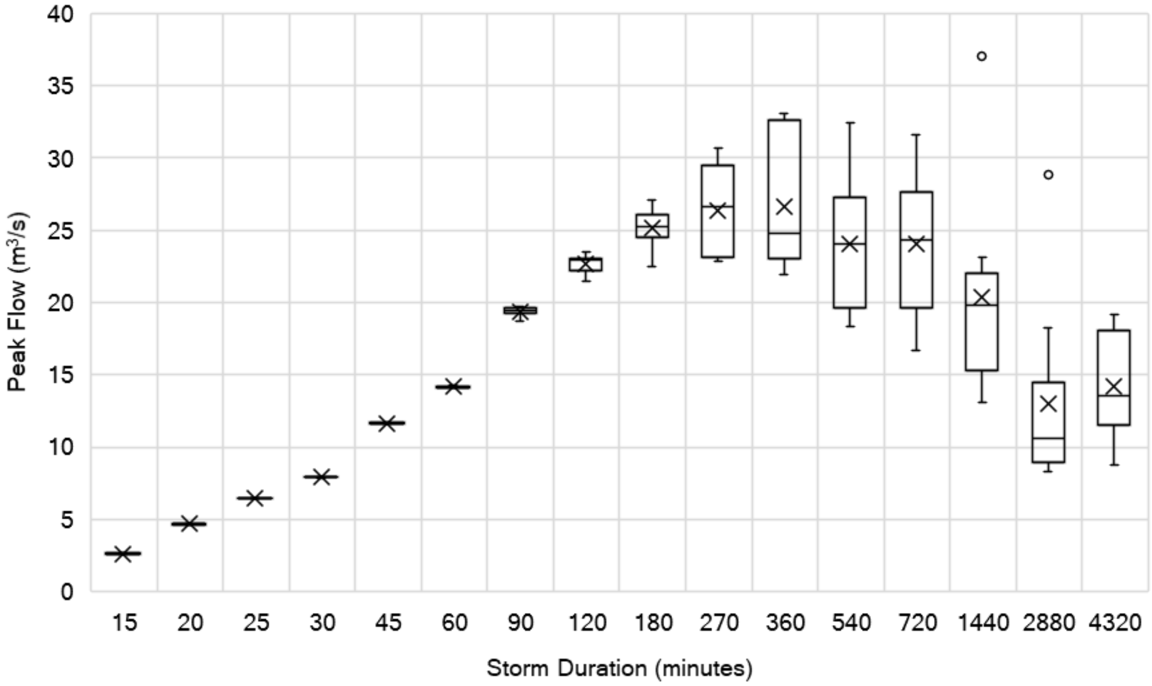

Chart 9-9: Box and Whisker Plot - 1% AEP Event - Inflow GEU_501

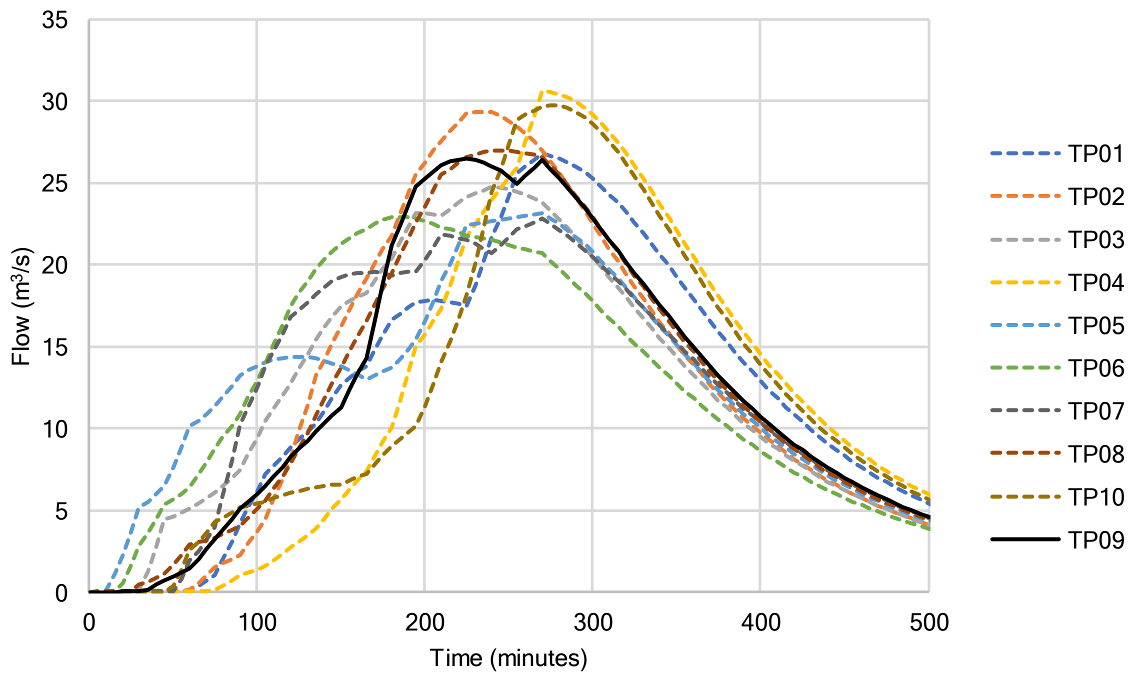

Chart 9-10: Hydrograph - 1% AEP 270 minute storm event - Inflow GEU_501

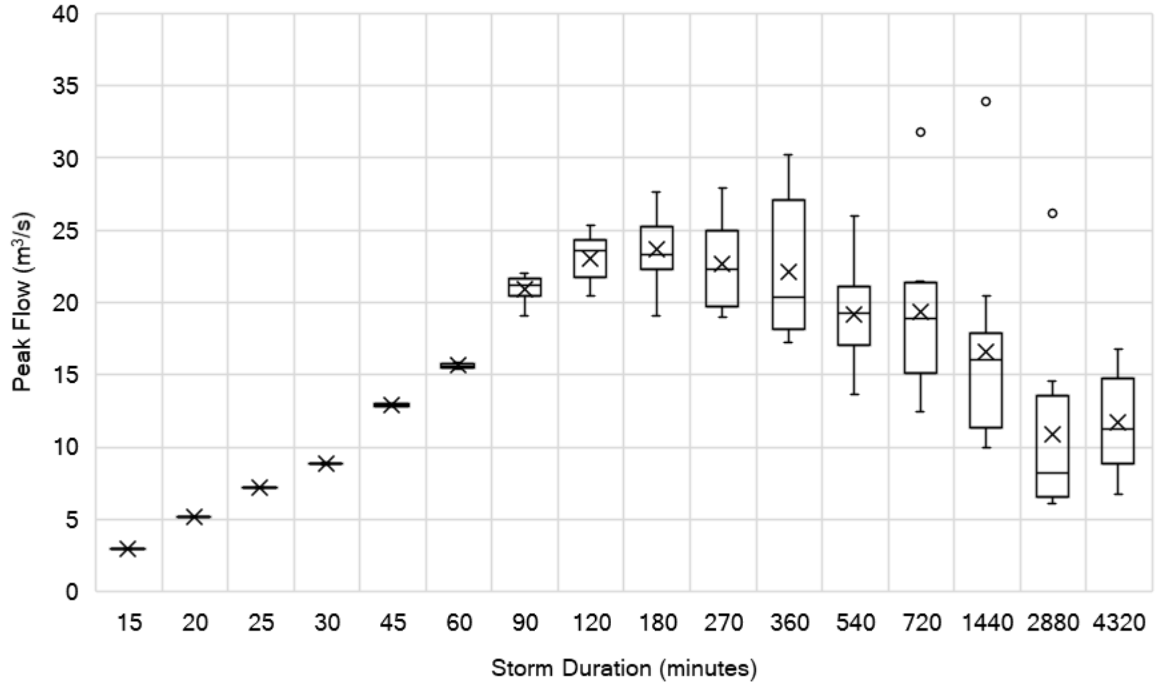

Chart 9-11: Box and Whisker Plot - 1% AEP Event - Inflow GEU_601

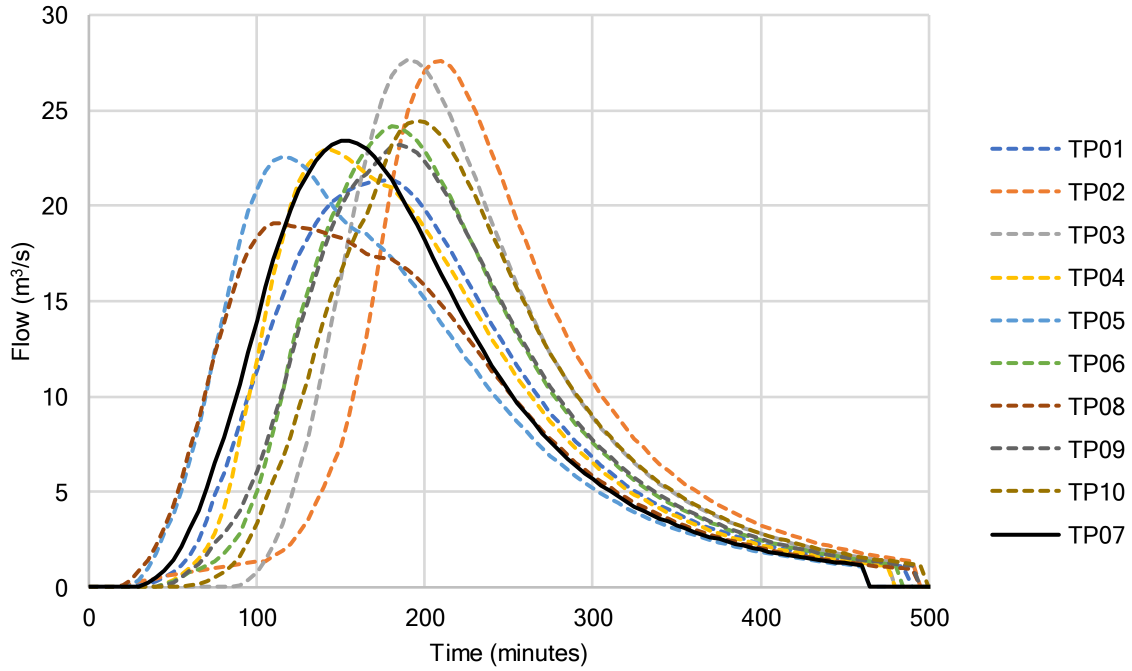

Chart 9-12: Hydrograph - 1% AEP 180 minute storm event - Inflow GEU_601

C.4.2 Hydraulics

Table 9-5: Design Storm Critical Duration and Pattern for Key Locations in the Hydraulic Model

Event Probability	Duration and Temporal Pattern (TP) with the peak flood level one higher than the average peak flood level				Critical Duration and Temporal Pattern
	H03	H16	H30	H33	
20% AEP	540 minute TP06	540 minute TP06	360 minute TP03	360 minute TP03	360 minute TP03 540 minute TP06
5% AEP	360 minute TP02	360 minute TP02	120 minute TP07	120 minute TP01	120 minute TP01 360 minute TP07
1% AEP	270 minute TP09	270 minute TP09	90 minute TP08	90 minute TP08	90 minute TP08 270 minute TP09

C.4.2.1 20% AEP Event

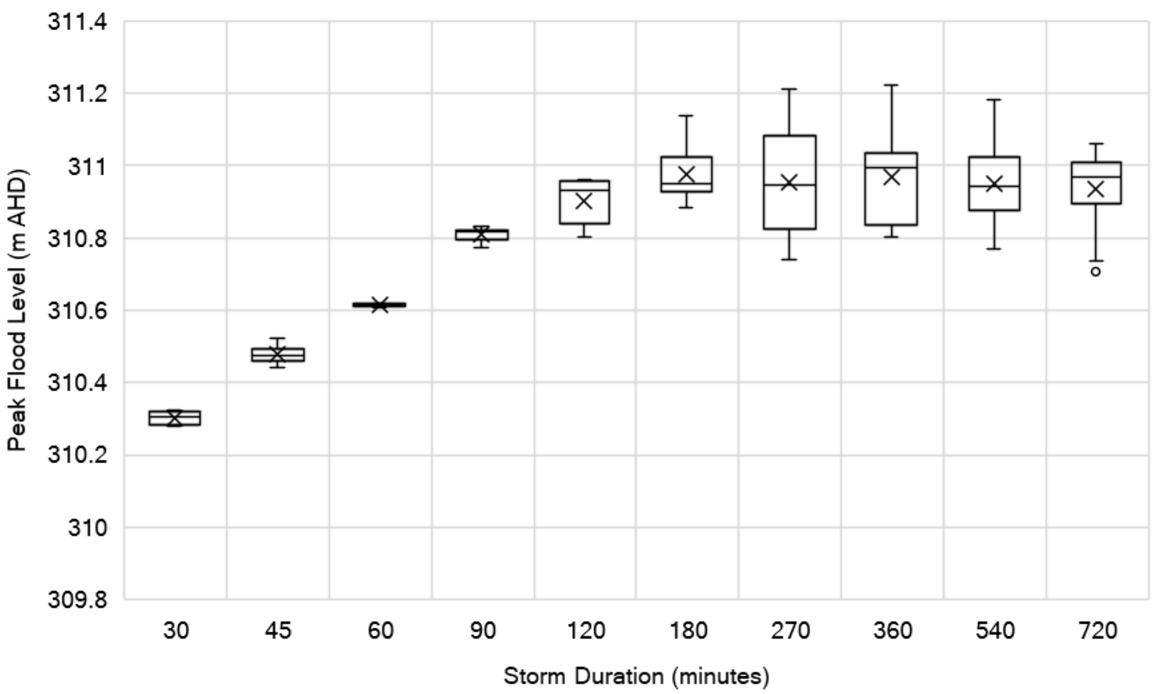

Chart 9-13: Box and Whisker Plot - 20% AEP Event - Boori Creek (Chambers Street between Mitchell Highway and Wellington Street)

C.4.2.2 5% AEP Event

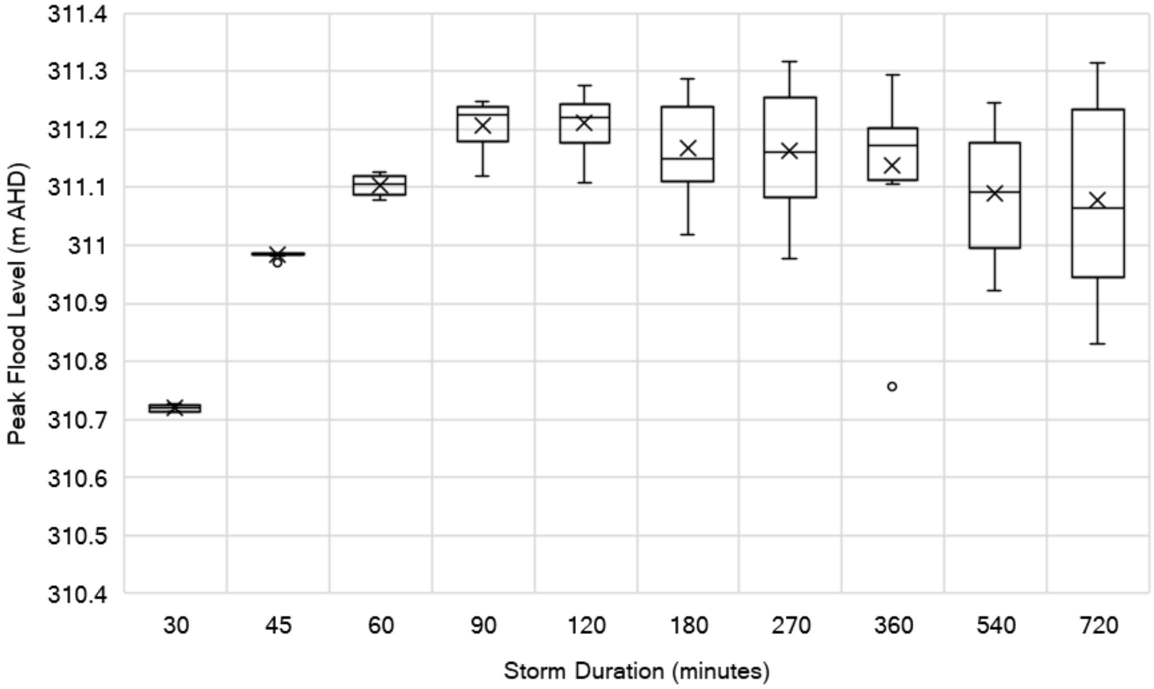

Chart 9-14: Box and Whisker Plot - 5% AEP Event - Boori Creek (Chambers Street between Mitchell Highway and Wellington Street)

C.4.2.3 1% AEP Event

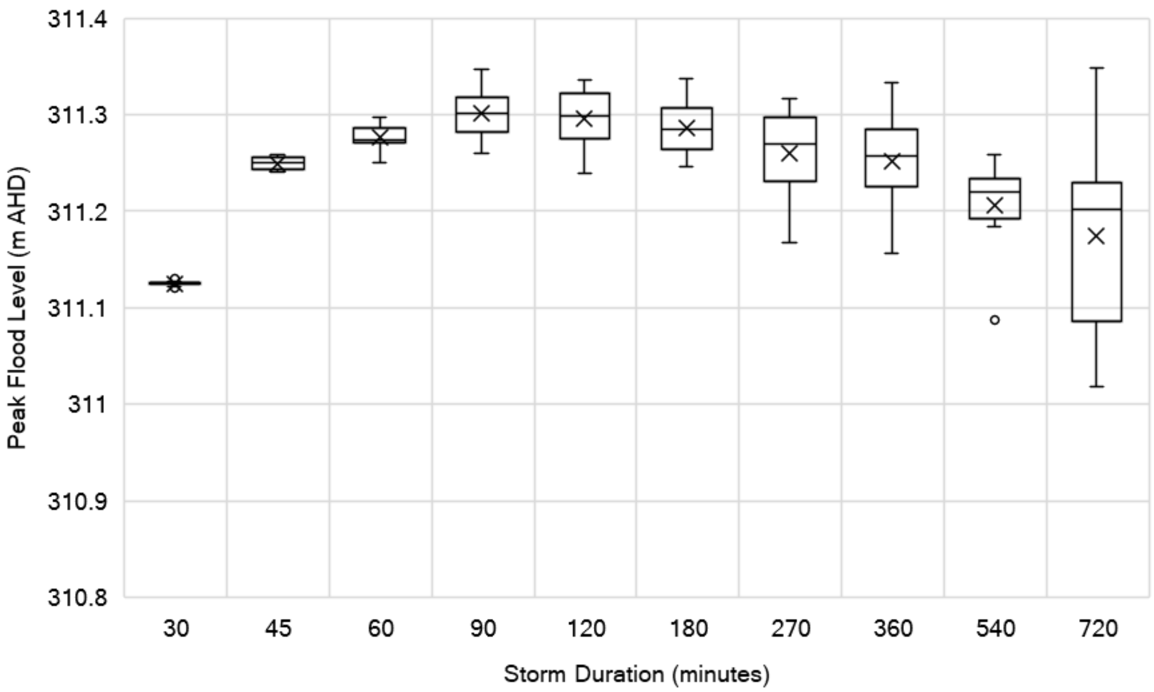

Chart 9-15: Box and Whisker Plot - 1% AEP Event - Boori Creek (Chambers Street between Mitchell Highway and Wellington Street)

APPENDIX D
DESIGN PARAMETER SENSITIVITY

D.1 Rainfall Temporal Patterns

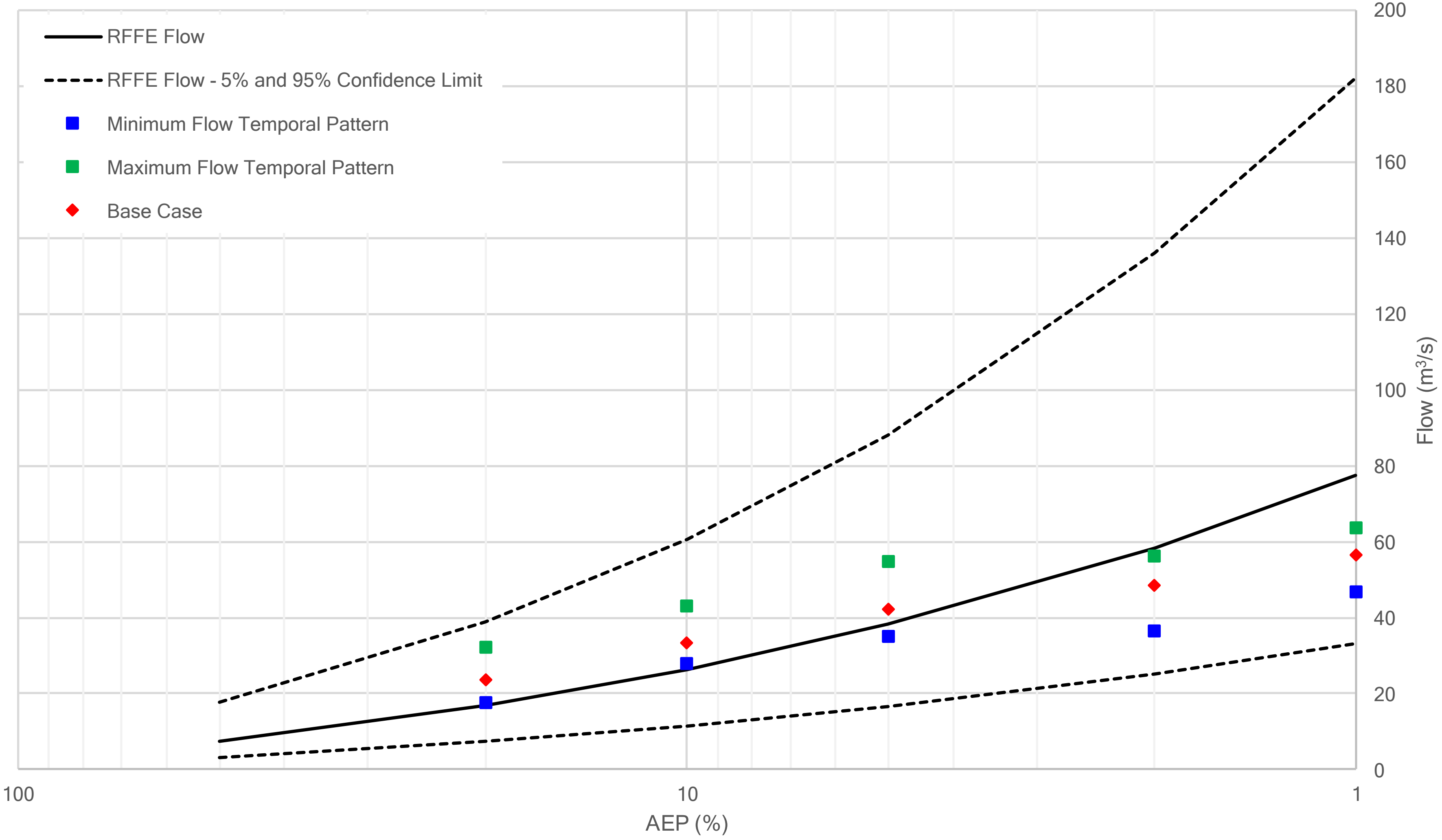

Chart 9-16: RFFE Comparison - Inflow GEU_301 - Temporal Patterns

Table 9-6: Peak Flood Level Difference (m) - Minimum Flow Temporal Pattern

ID	Location	20% AEP	5% AEP	1% AEP
H01	Confluence of Geurie Ck and Boori Ck	-0.24	-0.12	-0.21
H02	Geurie Ck - Upstream of Mitchell Hwy	-0.07	-0.06	-0.06
H03	Geurie Ck - Upstream of Railway Tracks (east)	-0.21	-0.22	-0.16
H04	Geurie Ck - Upstream of Railway Tracks (west)	-0.24	-0.22	-0.15
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	-0.08	-0.06	-0.09
H06	Jennings St (south-east of Mitchell St)	-0.04	-0.02	-0.09
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	-0.03	-0.02	-0.03
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	-0.04	-0.10	-0.03
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	-0.05	-0.05	-0.07
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	-0.10	-0.02	-0.04
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	-0.04	-0.01	-0.01
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	-0.20	-0.09	-0.05
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	-0.06	-0.02	-0.02
H14	Boori Ck (north of Railway Tracks)	-0.07	-0.03	-0.04

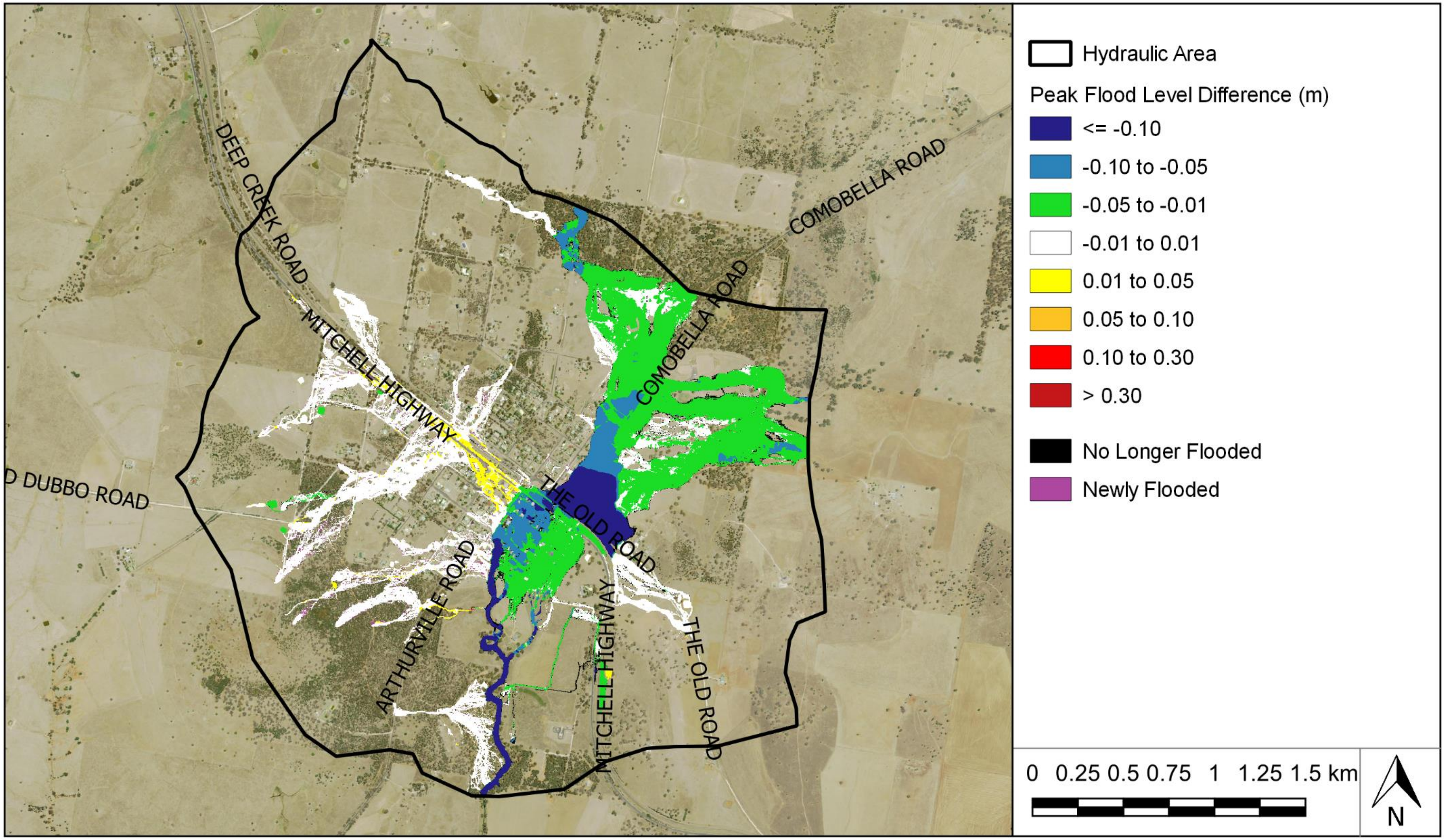

Image 9-1: 1% AEP Peak Flood Level Difference (m) - Minimum Flow Temporal Pattern

Table 9-7: Peak Flood Level Difference (m) - Maximum Flow Temporal Pattern

ID	Location	20% AEP	5% AEP	1% AEP
H01	Confluence of Geurie Ck and Boori Ck	0.17	0.29	0.04
H02	Geurie Ck - Upstream of Mitchell Hwy	0.11	0.06	0.07
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.21	0.23	0.09
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.26	0.22	0.06
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.09	0.09	0.03
H06	Jennings St (south-east of Mitchell St)	0.06	0.08	0.03
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.06	0.04	0.00
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.22	0.09	0.00
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.08	0.15	0.00
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.06	0.09	0.00
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.02	0.03	0.00
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.09	0.17	0.00
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.05	0.05	0.00
H14	Boori Ck (north of Railway Tracks)	0.09	0.09	0.01

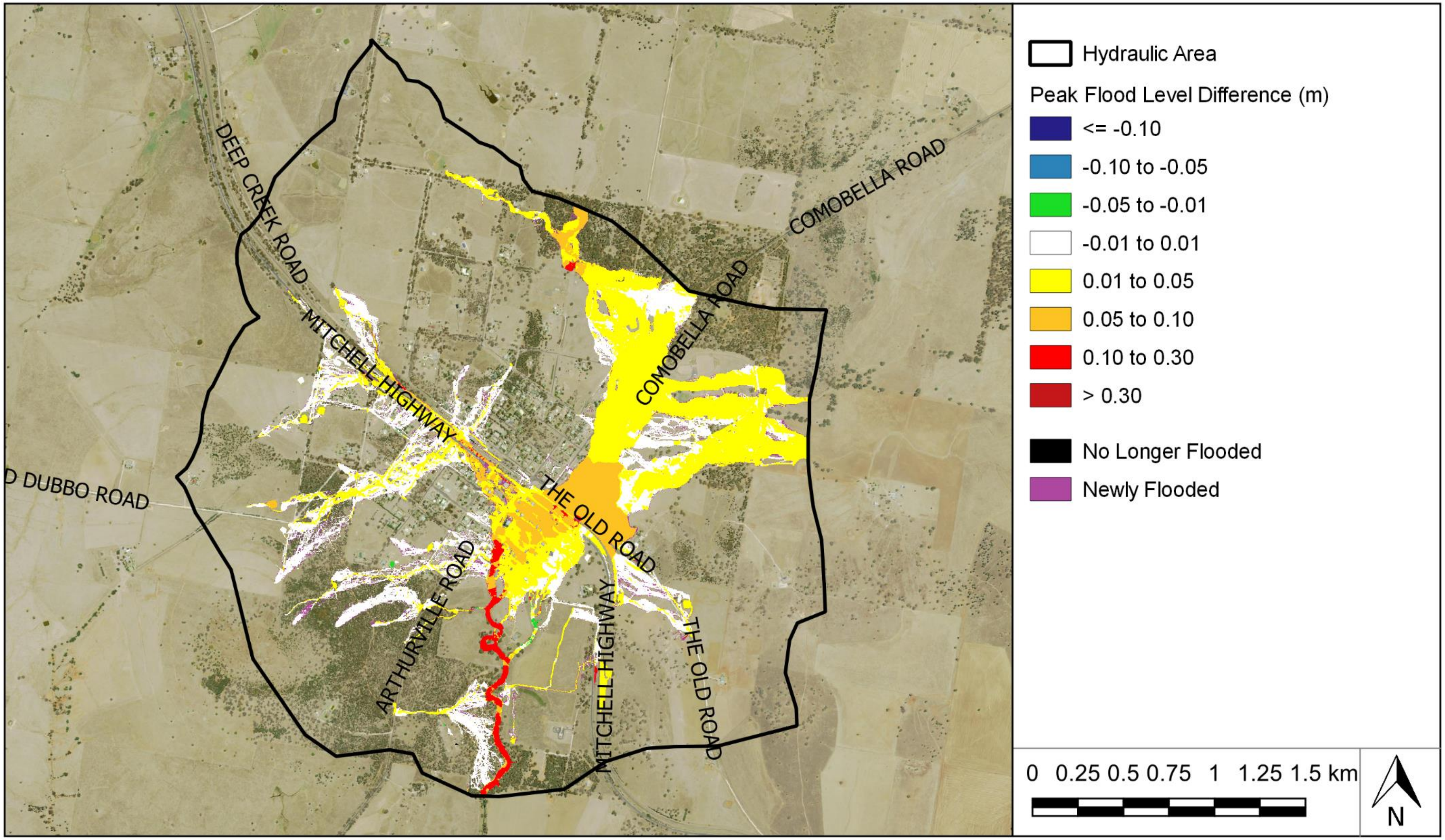

Image 9-2: 1% AEP Peak Flood Level Difference (m) - Maximum Flow Temporal Pattern

D.2 Rainfall Losses

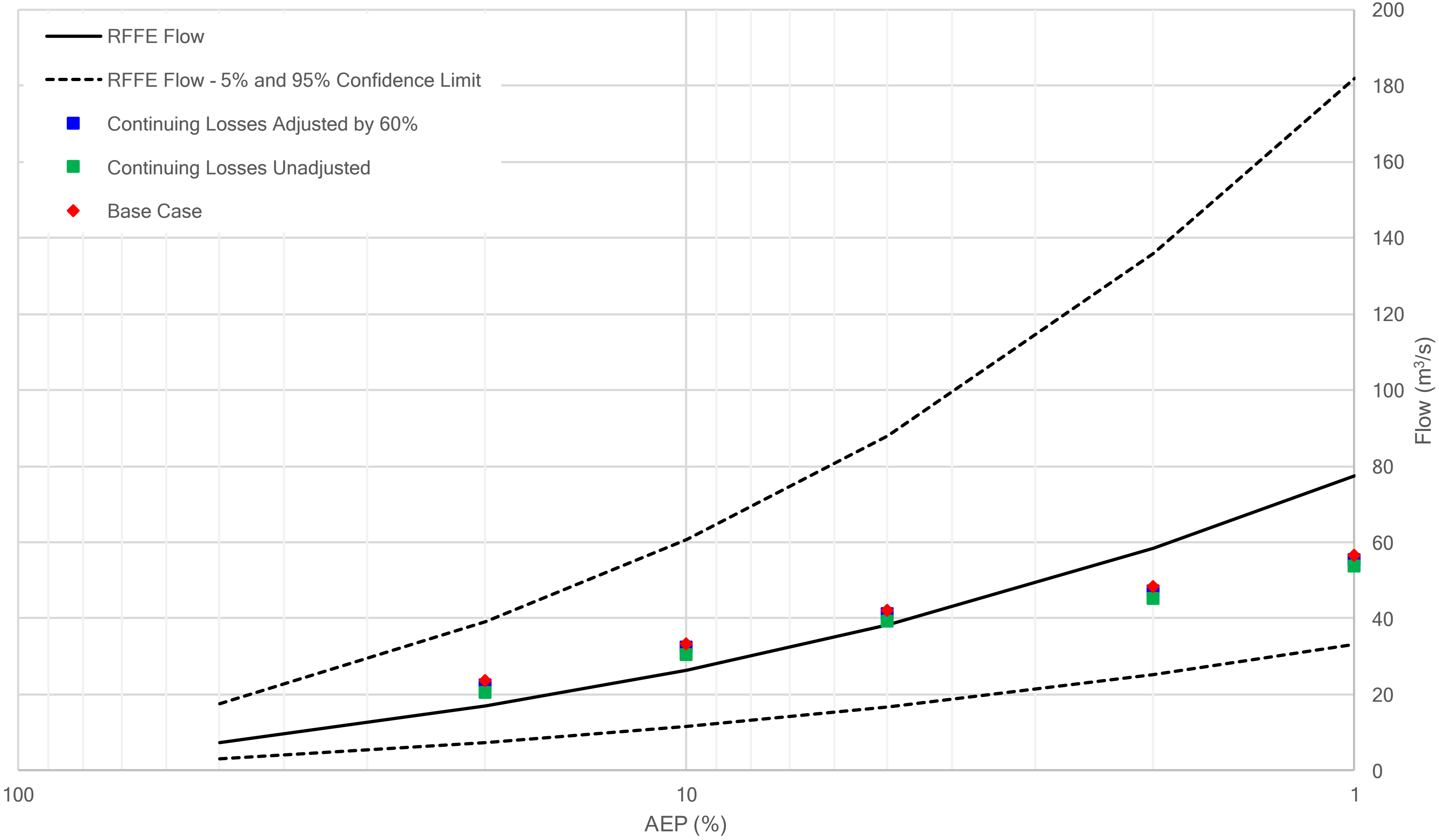

Chart 9-17: RFFE Comparison - Inflow GEU_301 - Continuing Losses

Table 9-8: Peak Flood Level Difference (m) - Rainfall Continuing Losses Adjusted by 60%

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	-0.02	-0.02	-0.03	-0.01	-0.02	-0.02	-0.03	0.00
H02	Geurie Ck - Upstream of Mitchell Hwy	-0.02	-0.01	-0.01	-0.01	-0.01	0.00	-0.01	0.02
H03	Geurie Ck - Upstream of Railway Tracks (east)	-0.04	-0.03	-0.03	-0.02	-0.01	-0.01	-0.01	0.02
H04	Geurie Ck - Upstream of Railway Tracks (west)	-0.06	-0.03	-0.03	-0.02	-0.01	-0.01	-0.01	0.01
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00
H06	Jennings St (south-east of Mitchell St)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	0.00
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	-0.01	-0.01	0.00	0.00	0.01	0.00	0.00	0.02
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.01
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H14	Boori Ck (north of Railway Tracks)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

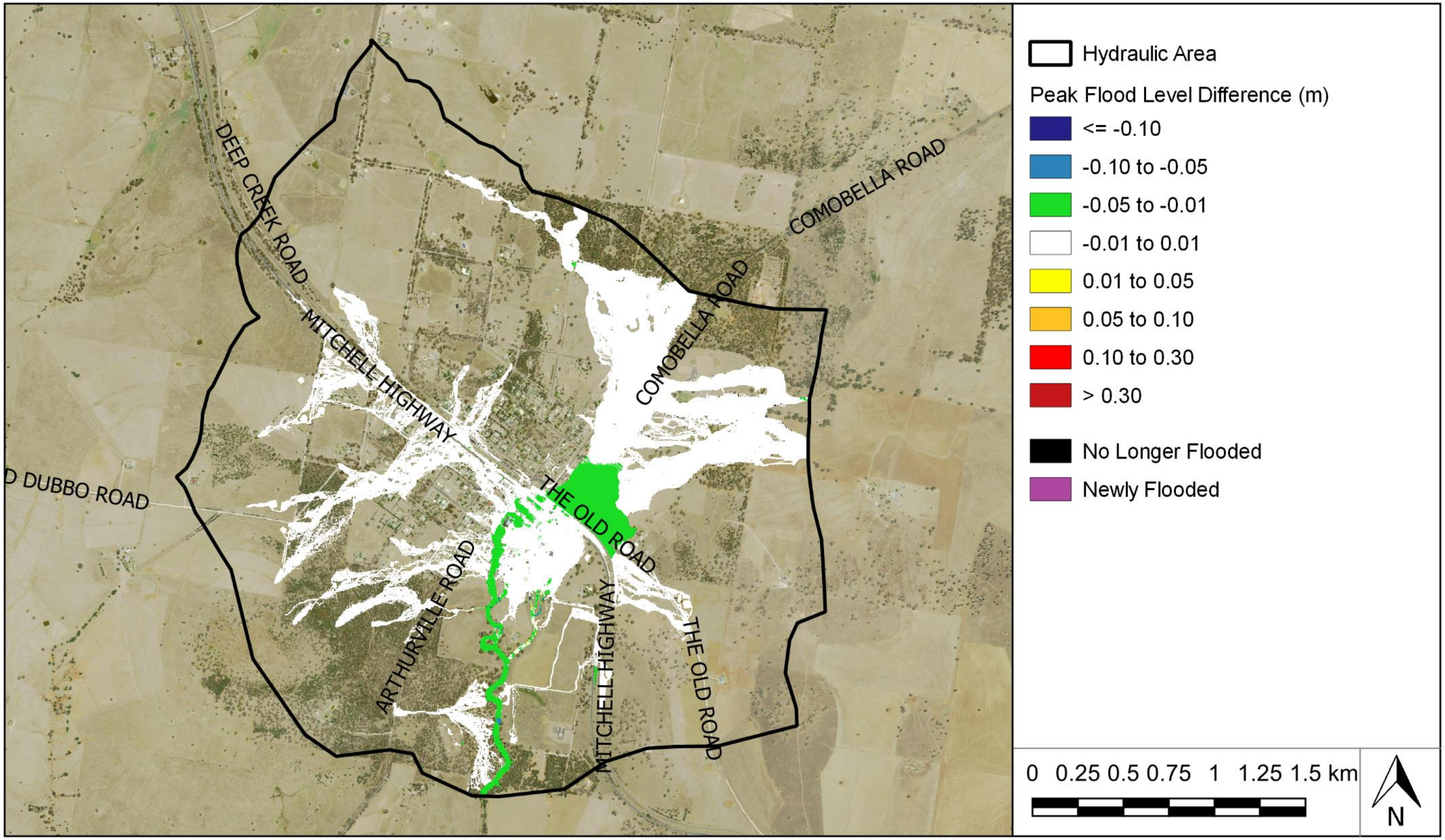

Image 9-3: 1% AEP Peak Flood Level Difference (m) - Rainfall Continuing Losses Adjusted by 60%

Table 9-9: Peak Flood Level Difference (m) - Rainfall Continuing Losses Unadjusted

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	-0.32	-0.10	-0.08	-0.06	-0.07	-0.07	-0.06	-0.01
H02	Geurie Ck - Upstream of Mitchell Hwy	-0.15	-0.04	-0.03	-0.02	-0.01	-0.01	-0.02	0.02
H03	Geurie Ck - Upstream of Railway Tracks (east)	-0.36	-0.09	-0.10	-0.08	-0.05	-0.02	-0.02	0.01
H04	Geurie Ck - Upstream of Railway Tracks (west)	-0.41	-0.10	-0.11	-0.08	-0.04	-0.02	-0.02	0.01
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	-0.12	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.01
H06	Jennings St (south-east of Mitchell St)	-0.01	-0.01	0.00	-0.01	-0.03	-0.02	-0.02	0.00
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	-0.01	0.00	0.00	0.00	-0.01	-0.01	-0.01	0.00
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	-0.01	-0.02	0.01	-0.01	-0.01	0.00	0.00	-0.01
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	-0.02	-0.01	-0.01	-0.01	0.01	0.01	0.00	0.01
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	-0.02	0.00	-0.02	0.01	0.00	-0.01	0.00	0.01
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
H14	Boori Ck (north of Railway Tracks)	-0.01	-0.02	-0.01	-0.01	-0.01	0.01	0.00	0.01

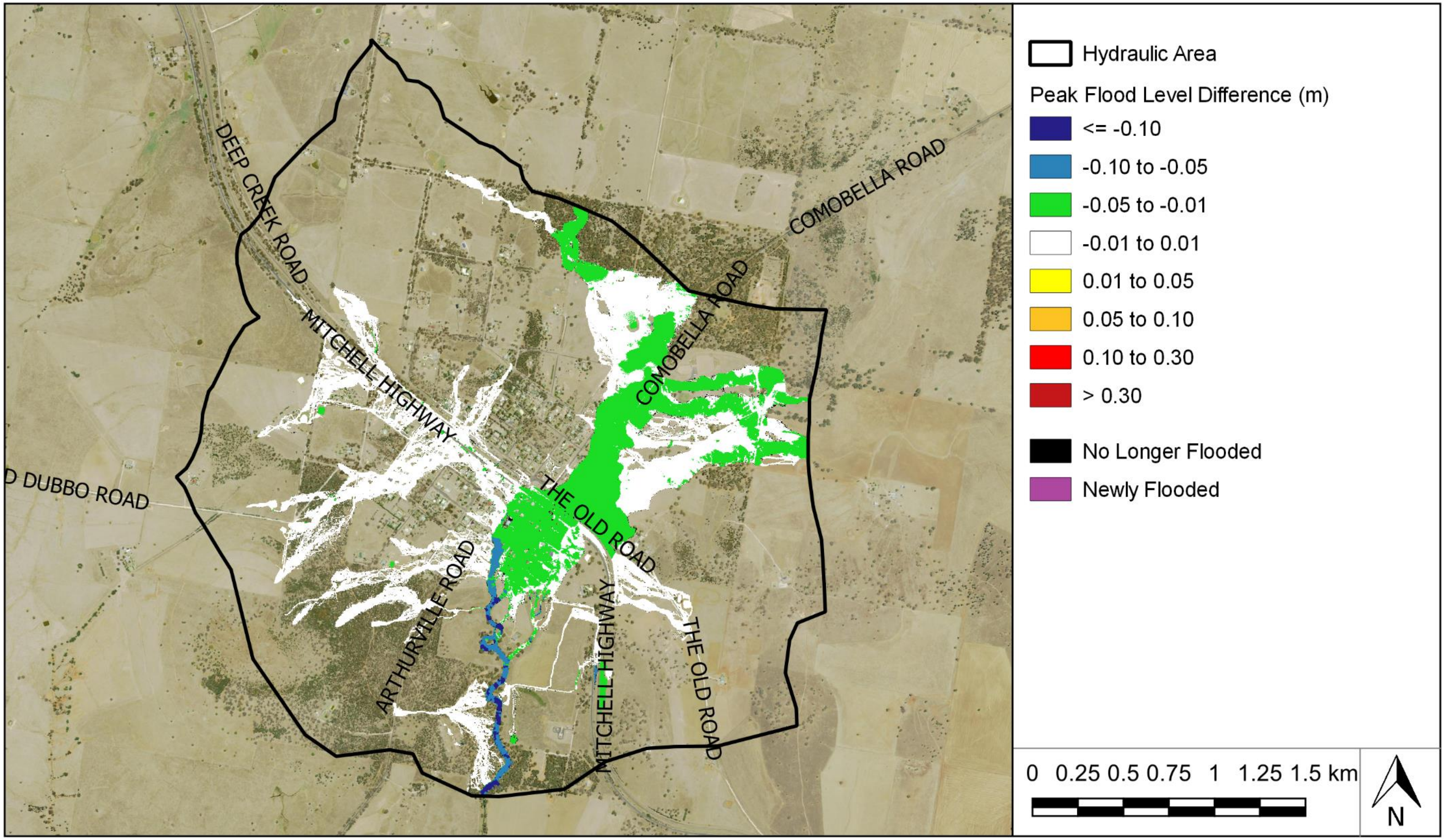

Image 9-4: 1% AEP Peak Flood Level Difference (m) - Rainfall Continuing Losses Unadjusted

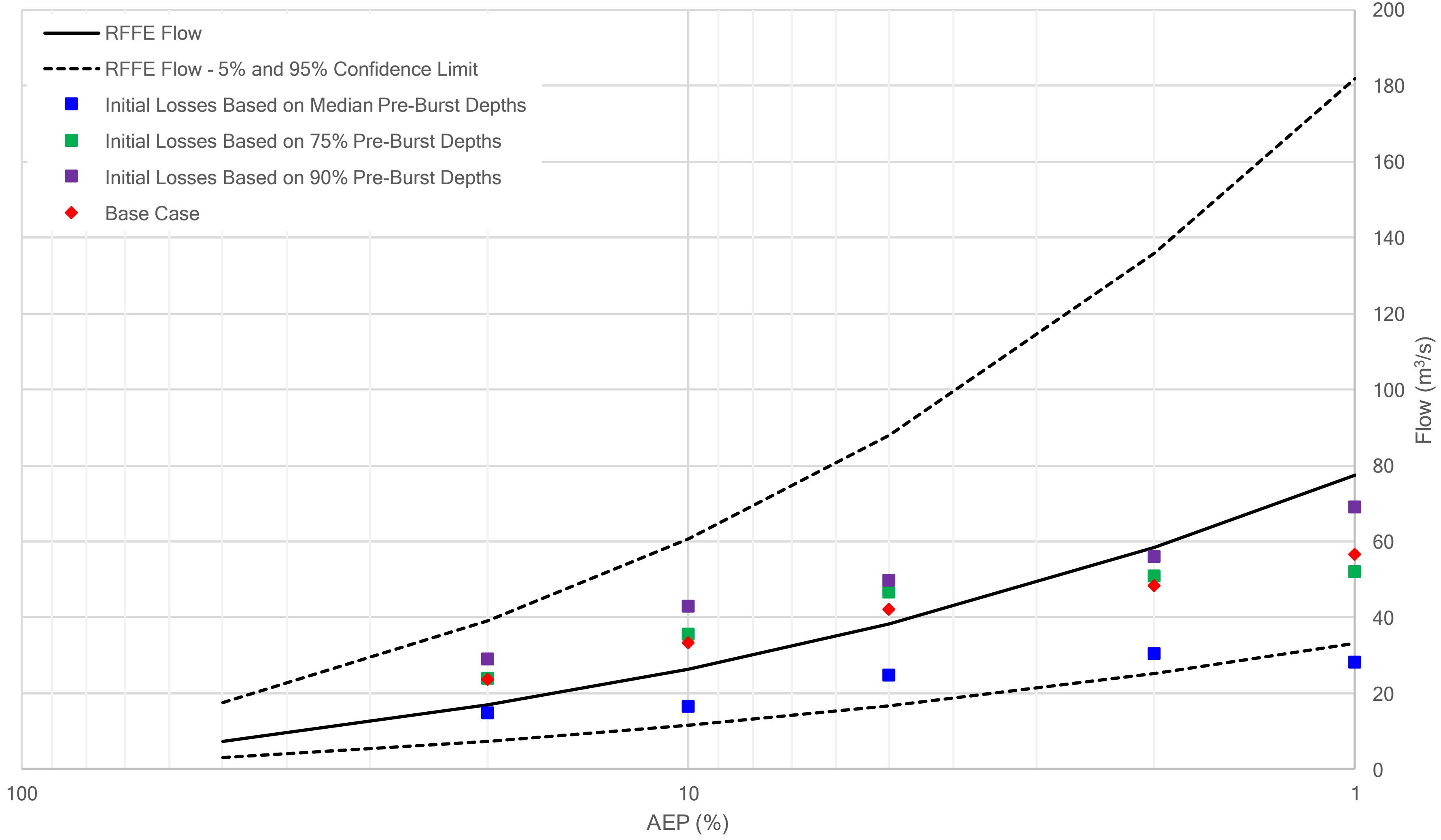

Chart 9-18: RFFE Comparison - Inflow GEU_301 - Initial Losses

Table 9-10: Peak Flood Level Difference (m) - Rainfall Initial Losses Based on Median Pre-Burst Depths

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	-0.32	-0.53	-0.54	-0.57	-0.48	-0.76	-0.59	-0.10
H02	Geurie Ck - Upstream of Mitchell Hwy	-0.15	-0.24	-0.22	-0.15	-0.12	-0.19	-0.19	-0.05
H03	Geurie Ck - Upstream of Railway Tracks (east)	-0.36	-0.54	-0.55	-0.52	-0.43	-0.51	-0.27	-0.05
H04	Geurie Ck - Upstream of Railway Tracks (west)	-0.41	-0.62	-0.61	-0.54	-0.41	-0.47	-0.23	-0.05
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	-0.12	-0.20	-0.19	-0.17	-0.16	-0.23	-0.20	-0.08
H06	Jennings St (south-east of Mitchell St)	-0.06	-0.07	-0.07	-0.05	-0.10	-0.23	-0.23	-0.07
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	-0.03	-0.08	-0.07	-0.03	-0.03	-0.09	-0.08	-0.05
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	-0.04	-0.20	-0.29	-0.11	-0.04	-0.12	-0.09	-0.03
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	-0.10	-0.11	-0.12	-0.11	-0.08	-0.23	-0.14	-0.01
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	-0.12	-0.15	-0.08	-0.06	-0.04	-0.13	-0.09	-0.03
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	-0.03	-0.04	-0.05	-0.02	-0.01	-0.04	-0.03	-0.03
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	-0.27	-0.22	-0.16	-0.14	-0.05	-0.21	-0.10	-0.02
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	-0.08	-0.08	-0.07	-0.03	-0.02	-0.08	-0.07	-0.02
H14	Boori Ck (north of Railway Tracks)	-0.10	-0.12	-0.11	-0.06	-0.05	-0.13	-0.11	-0.01

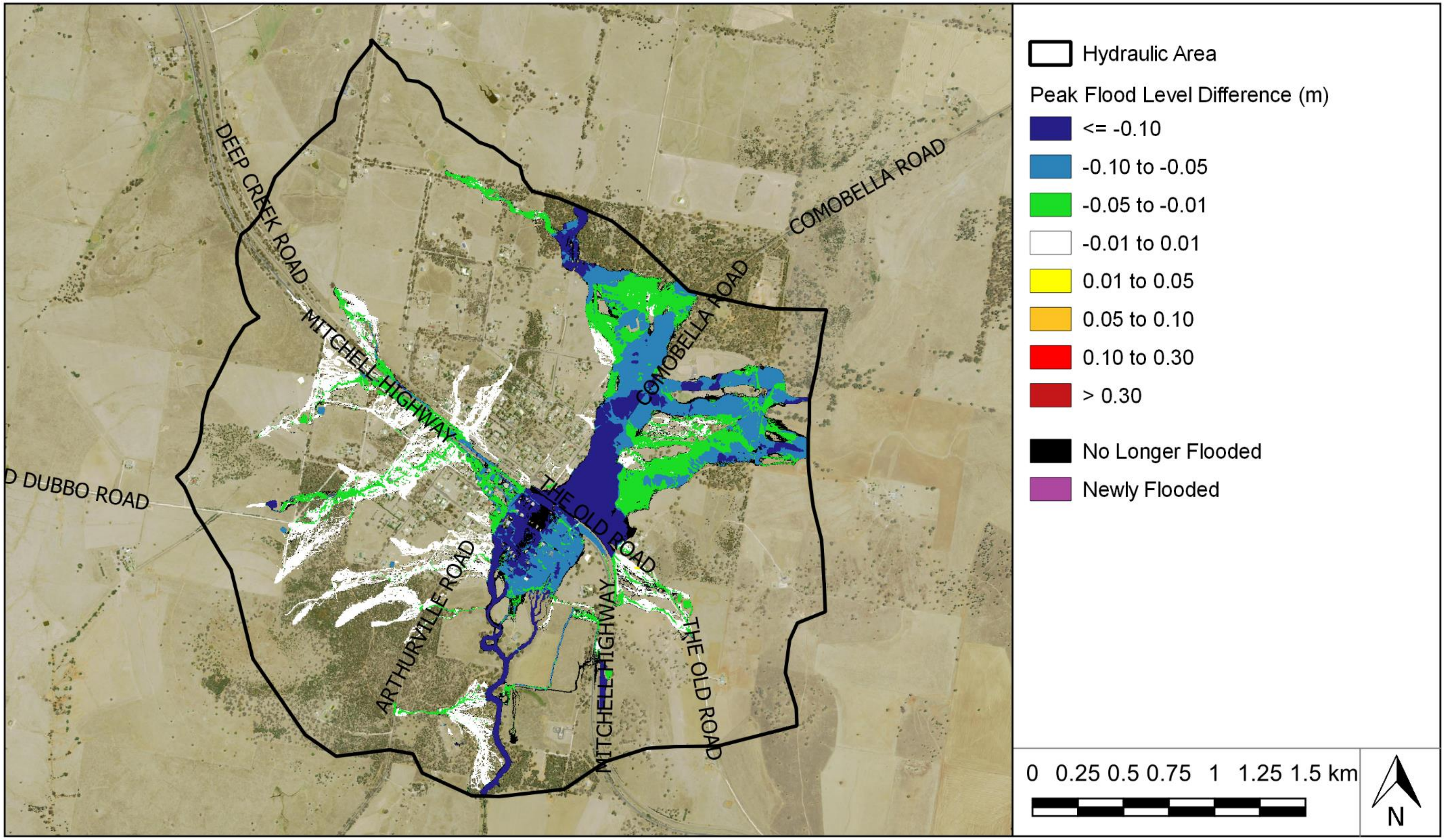

Image 9-5: 1% AEP Peak Flood Level Difference (m) - Rainfall Initial Losses Based on Median Pre-Burst Depths

Table 9-11: Peak Flood Level Difference (m) - Rainfall Initial Losses Based on 75% Pre-Burst Depths

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	0.01	0.14	0.18	0.10	0.06	-0.10	-0.09	-0.04
H02	Geurie Ck - Upstream of Mitchell Hwy	0.01	0.03	0.02	0.02	0.07	-0.01	-0.03	0.00
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.01	0.07	0.12	0.06	0.09	-0.03	-0.03	-0.01
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.01	0.07	0.12	0.05	0.06	-0.03	-0.02	-0.01
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.00	0.03	0.04	0.02	0.02	-0.03	-0.03	-0.03
H06	Jennings St (south-east of Mitchell St)	0.01	-0.01	0.01	0.01	0.04	-0.03	-0.03	-0.02
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.02	-0.01	0.00	0.00	0.01	-0.01	-0.01	-0.01
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.03	-0.03	-0.07	0.00	-0.01	-0.05	-0.03	-0.02
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.02	-0.02	-0.03	0.00	-0.02	-0.08	-0.03	0.00
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.01	-0.01	-0.01	0.00	-0.01	-0.05	-0.03	-0.02
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.01	0.00	-0.01	0.00	0.00	-0.02	-0.01	-0.02
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.02	-0.01	-0.03	0.00	0.00	-0.05	-0.04	-0.01
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.01	-0.01	-0.01	0.00	-0.01	-0.04	-0.03	-0.01
H14	Boori Ck (north of Railway Tracks)	0.02	-0.03	-0.02	0.00	-0.01	-0.05	-0.06	-0.01

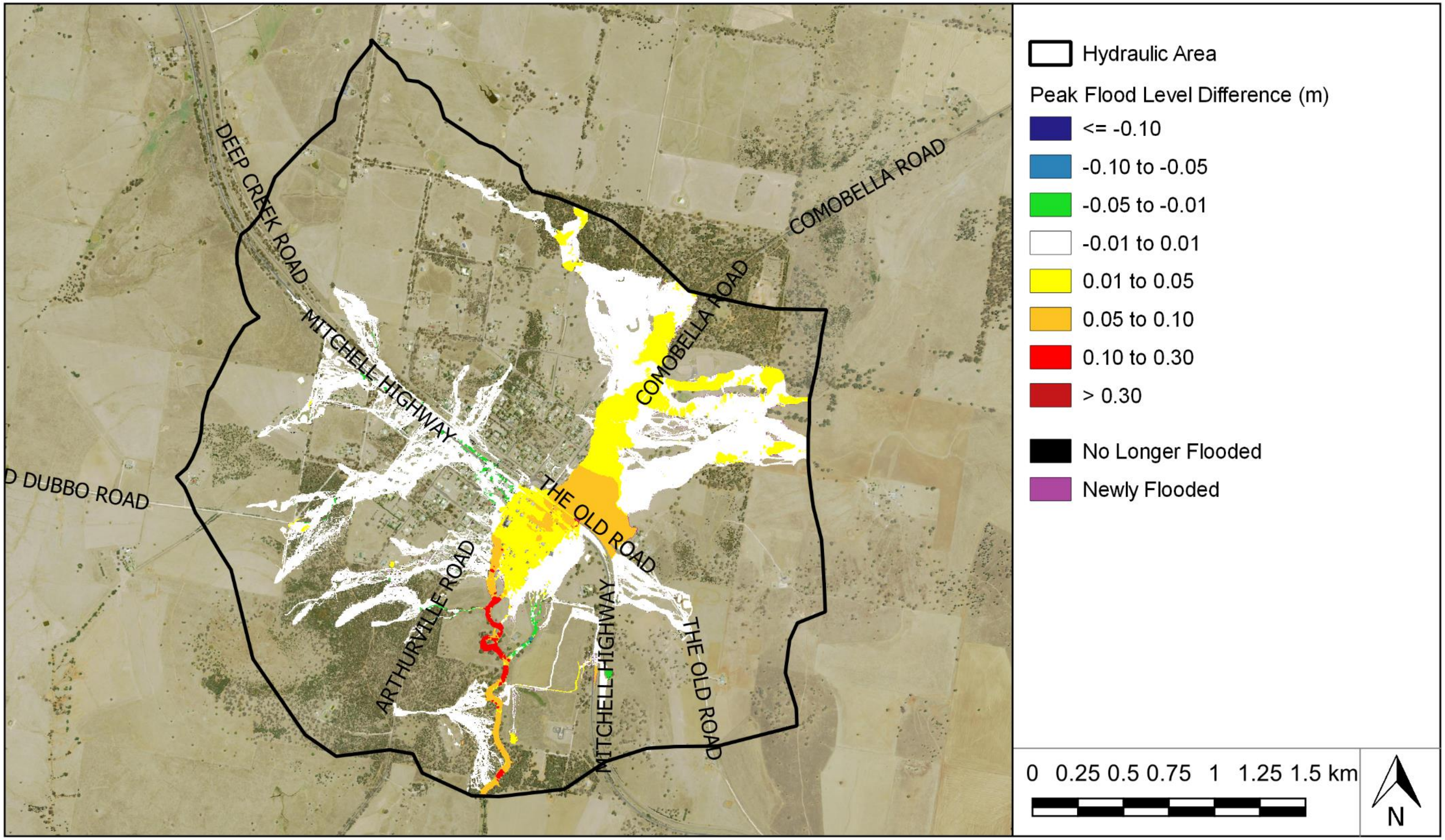

Image 9-6: 1% AEP Peak Flood Level Difference (m) - Rainfall Initial Losses Based on 75% Pre-Burst Depths

Table 9-12: Peak Flood Level Difference (m) - Rainfall Initial Losses Based on 90% Pre-Burst Depths

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	0.44	0.41	0.30	0.21	0.23	0.26	0.23	0.04
H02	Geurie Ck - Upstream of Mitchell Hwy	0.19	0.09	0.05	0.05	0.08	0.08	0.09	0.05
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.41	0.35	0.21	0.15	0.16	0.08	0.07	0.05
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.47	0.35	0.20	0.14	0.12	0.08	0.06	0.04
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.16	0.10	0.08	0.08	0.08	0.09	0.07	0.04
H06	Jennings St (south-east of Mitchell St)	0.06	0.06	0.07	0.09	0.11	0.09	0.08	0.03
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.06	0.04	0.03	0.03	0.04	0.03	0.02	0.03
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.21	0.16	0.05	0.04	0.04	0.02	0.01	0.01
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.08	0.12	0.11	0.07	0.07	0.04	0.03	0.03
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.06	0.07	0.06	0.04	0.03	0.03	0.02	0.02
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.02	0.03	0.02	0.01	0.01	0.00	0.00	0.02
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.07	0.20	0.15	0.05	0.03	0.04	0.03	0.03
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.05	0.05	0.04	0.03	0.02	0.02	0.01	0.01
H14	Boori Ck (north of Railway Tracks)	0.09	0.08	0.06	0.05	0.04	0.04	0.02	0.01

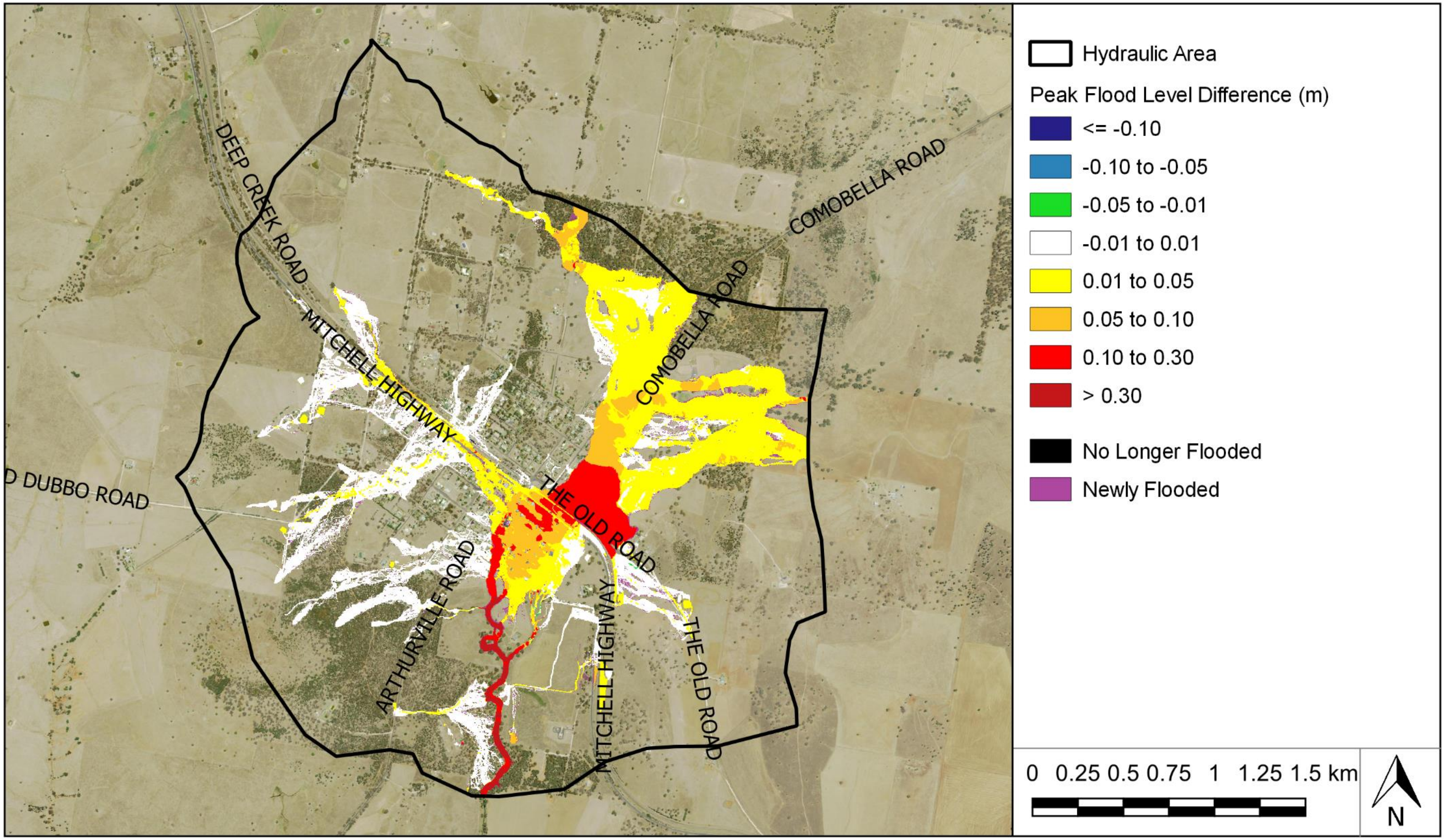

Image 9-7: 1% AEP Peak Flood Level Difference (m) - Rainfall Initial Losses Based on 90% Pre-Burst Depths

D.3 Hydrologic Lag and Routing

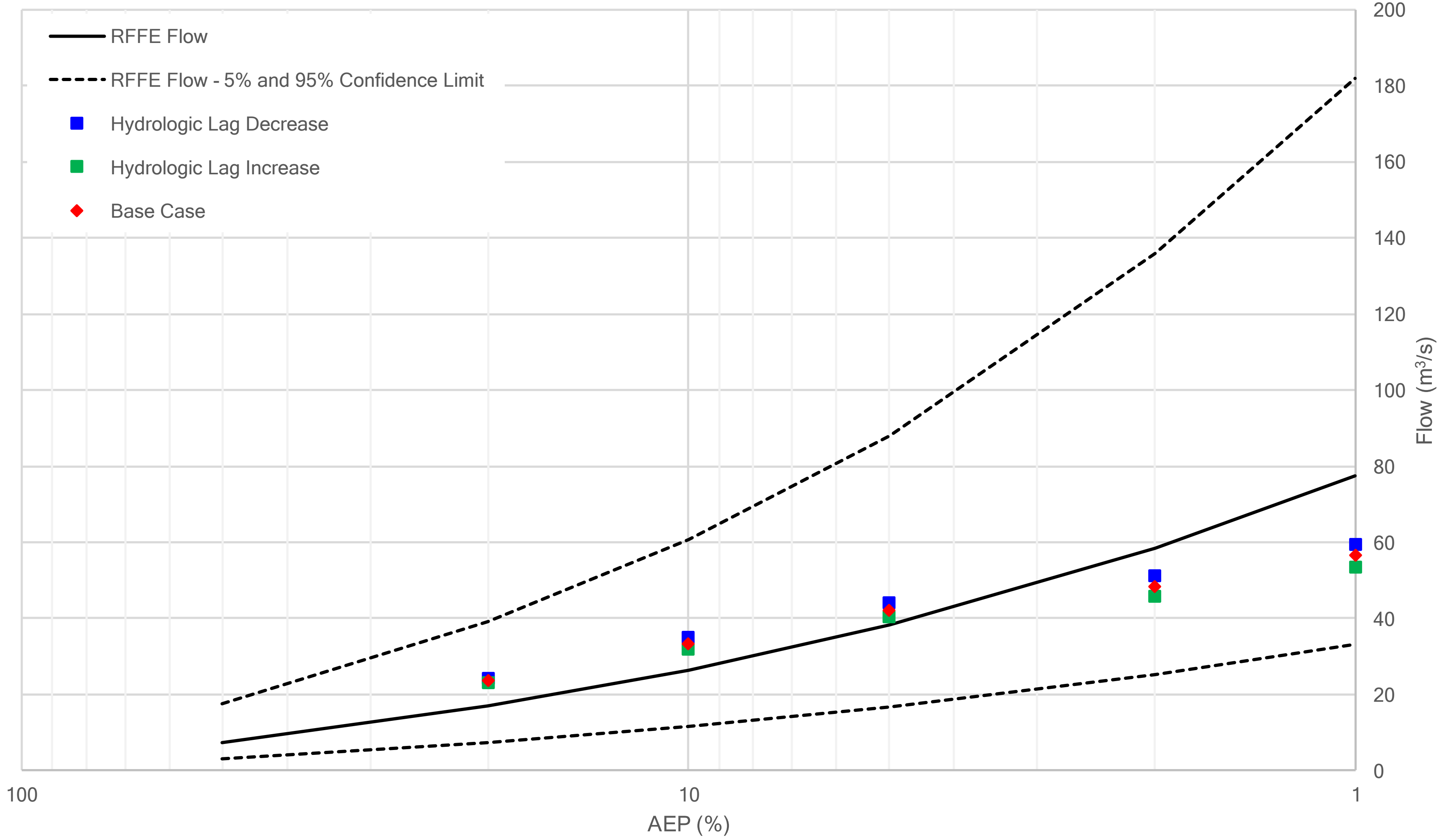

Chart 9-19: RFFE Comparison - Inflow GEU_301 - Hydrologic Lag

Table 9-13: Peak Flood Level Difference (m) - Hydrologic Lag Decrease

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	0.02	0.10	0.12	0.10	0.04	0.09	0.07	0.07
H02	Geurie Ck - Upstream of Mitchell Hwy	0.01	0.02	0.00	0.02	0.07	0.02	0.03	0.06
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.02	0.05	0.05	0.05	0.08	0.02	0.02	0.06
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.03	0.05	0.05	0.05	0.06	0.02	0.03	0.06
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.05
H06	Jennings St (south-east of Mitchell St)	0.00	0.00	0.00	0.02	0.03	0.02	0.03	0.05
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.04
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.02	0.02	0.00	0.00	0.01	0.01	0.00	0.00
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.01	0.00	0.01	0.00	0.00	0.02	0.00	0.03
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.01	0.00	0.07	0.00	0.01	0.01	0.01	0.02
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
H14	Boori Ck (north of Railway Tracks)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00

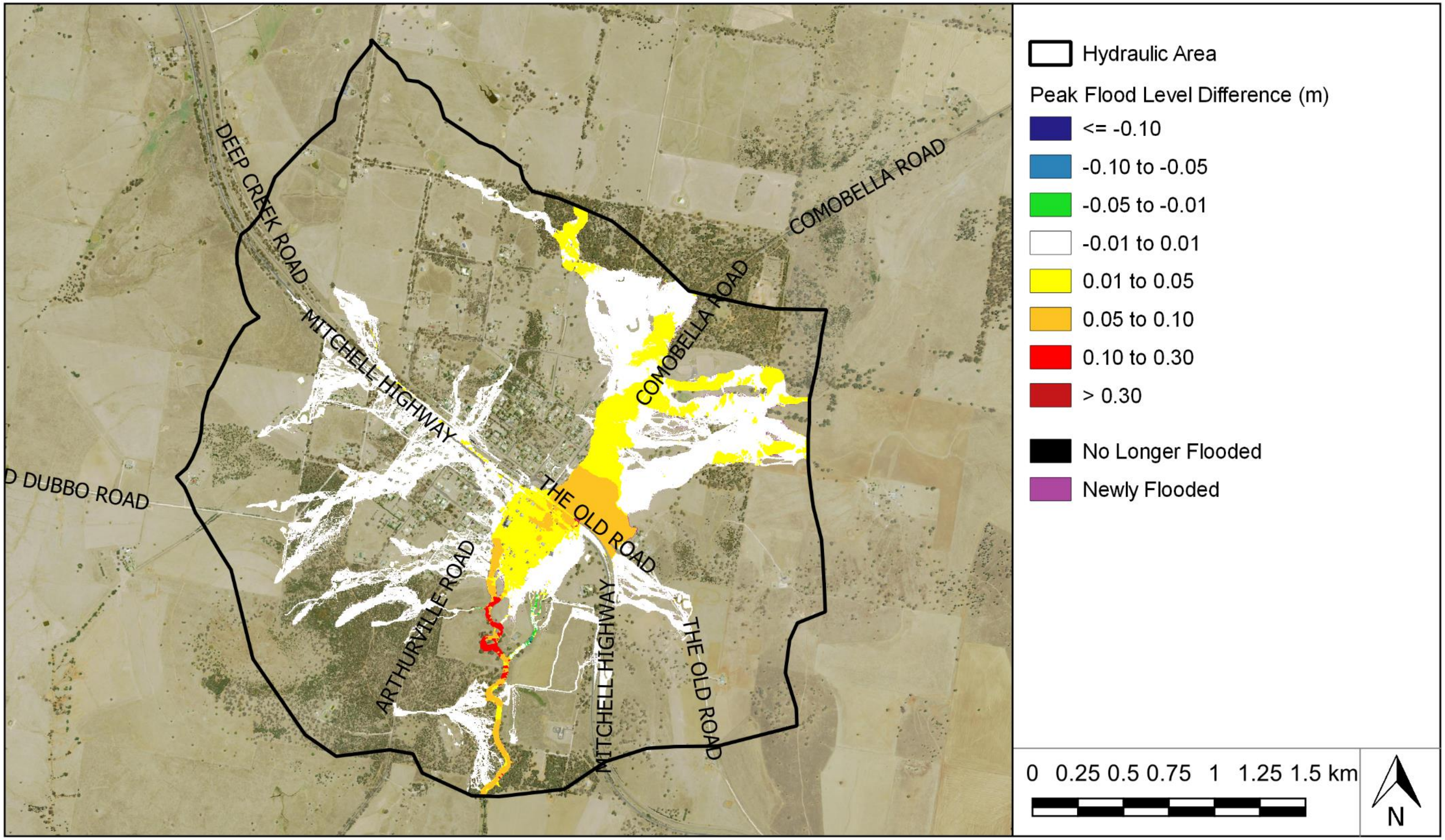

Image 9-8: 1% AEP Peak Flood Level Difference (m) - Hydrologic Lag Decrease

Table 9-14: Peak Flood Level Difference (m) - Hydrologic Lag Increase

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	-0.02	-0.05	-0.06	-0.04	-0.05	-0.08	-0.07	-0.06
H02	Geurie Ck - Upstream of Mitchell Hwy	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01	-0.03	-0.02
H03	Geurie Ck - Upstream of Railway Tracks (east)	-0.03	-0.05	-0.06	-0.04	-0.04	-0.03	-0.02	-0.03
H04	Geurie Ck - Upstream of Railway Tracks (west)	-0.04	-0.05	-0.06	-0.04	-0.03	-0.02	-0.02	-0.03
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.05
H06	Jennings St (south-east of Mitchell St)	0.00	0.00	0.00	-0.01	-0.03	-0.02	-0.03	-0.04
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.03
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	-0.01	-0.01	0.00	-0.01	-0.01	0.00	0.00	-0.01
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	-0.01	-0.01	-0.01	-0.01	0.02	-0.01	0.00	-0.01
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	-0.01	0.00	-0.01	0.01	-0.01	-0.01	-0.01	-0.01
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	-0.01	0.00	-0.02	0.00	0.00	-0.01	-0.01	0.00
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	-0.01	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01
H14	Boori Ck (north of Railway Tracks)	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	0.00

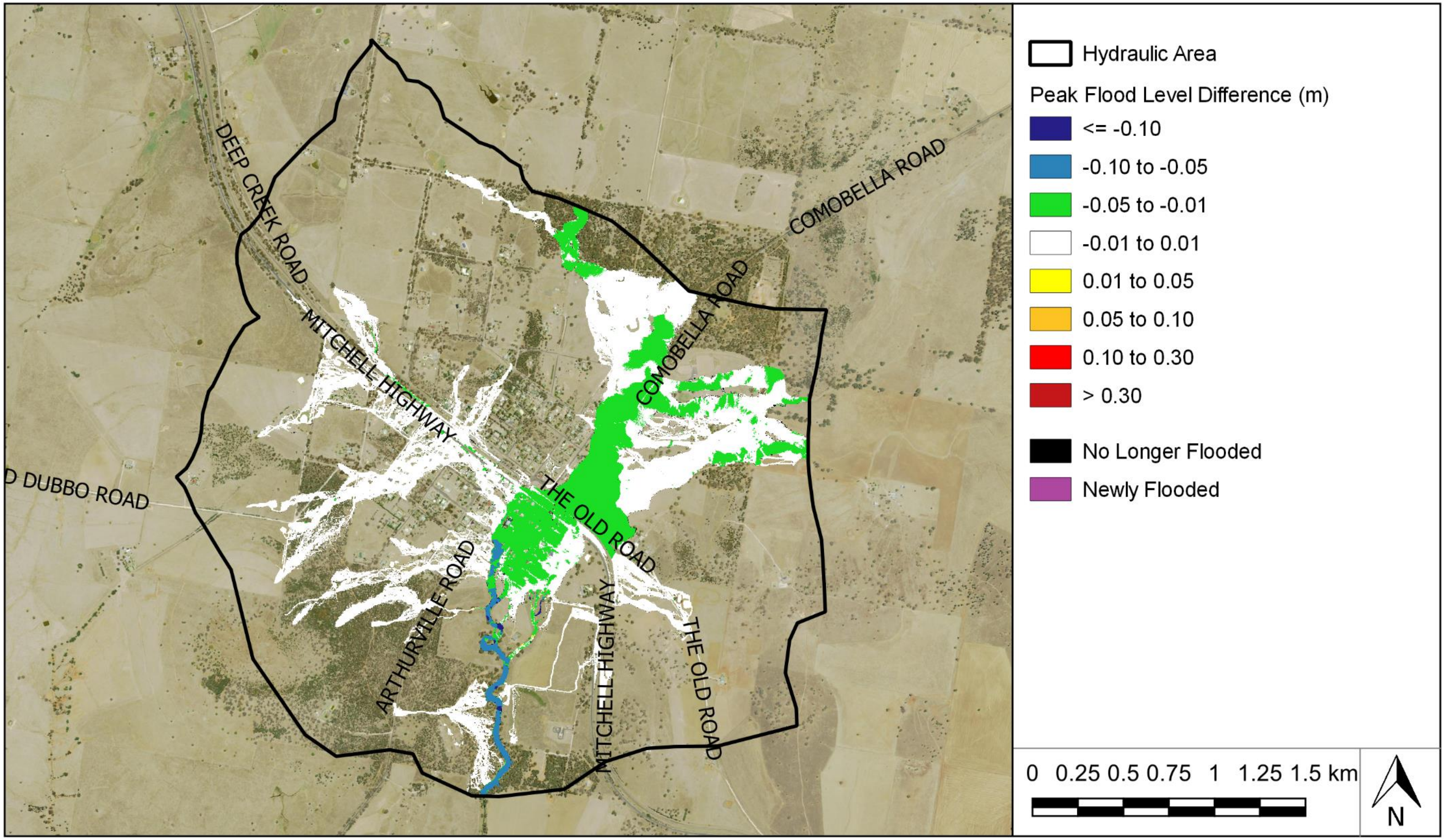

Image 9-9: 1% AEP Peak Flood Level Difference (m) - Hydrologic Lag Increase

Table 9-15: Peak Flood Level Difference (m) - Hydrologic Routing Decrease

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	0.09	0.26	0.30	0.26	0.32	0.30	0.36	0.31
H02	Geurie Ck - Upstream of Mitchell Hwy	0.07	0.07	0.04	0.13	0.10	0.09	0.14	0.20
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.11	0.25	0.18	0.25	0.18	0.09	0.10	0.25
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.14	0.25	0.18	0.21	0.14	0.09	0.09	0.23
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.05	0.07	0.07	0.12	0.11	0.10	0.11	0.28
H06	Jennings St (south-east of Mitchell St)	0.00	0.00	0.06	0.13	0.13	0.11	0.13	0.25
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.00	0.00	0.02	0.04	0.04	0.03	0.03	0.23
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H14	Boori Ck (north of Railway Tracks)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01

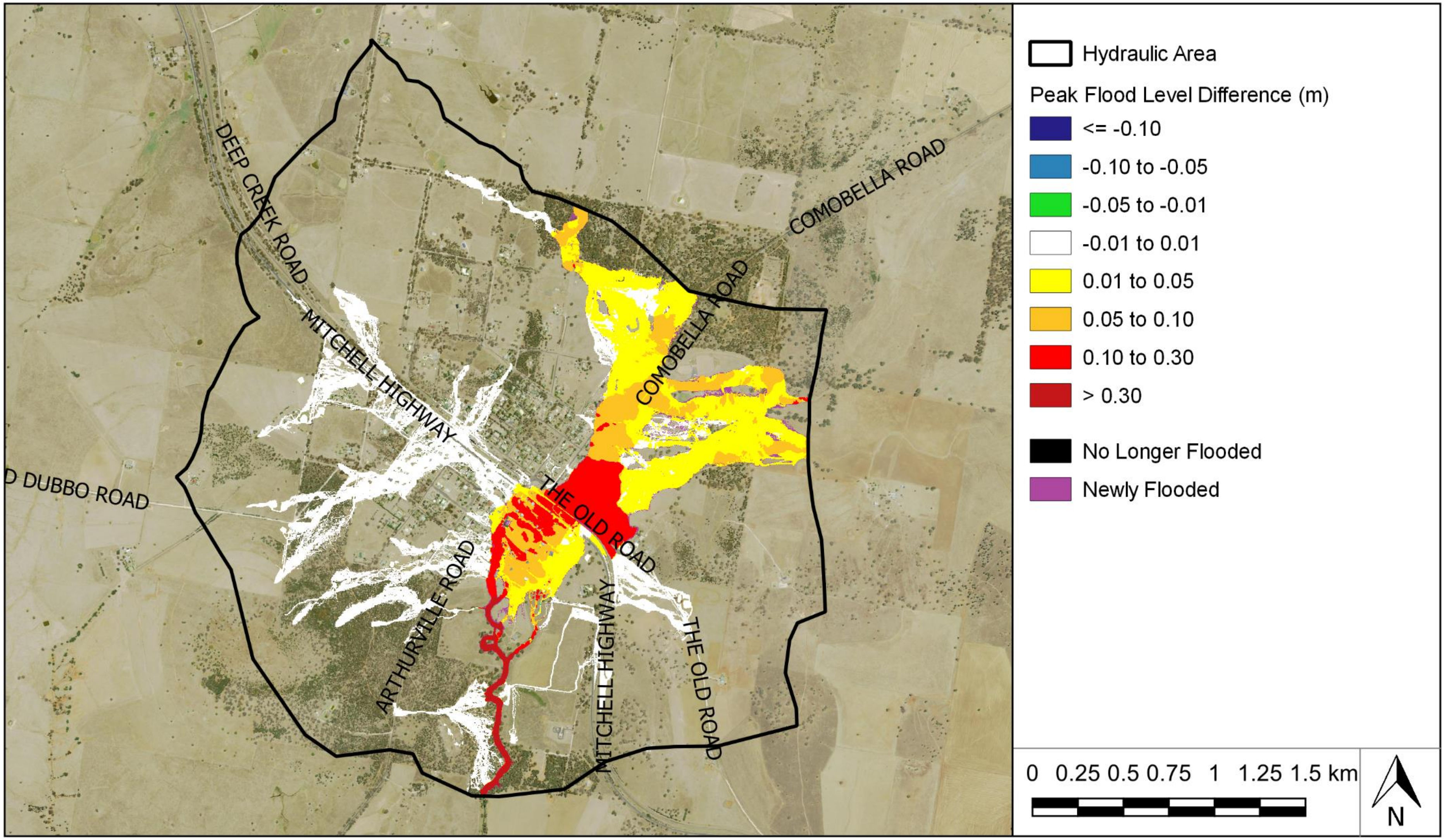

Image 9-10: 1% AEP Peak Flood Level Difference (m) - Hydrologic Routing Decrease

D.4 Hydraulic Roughness

Table 9-16: Peak Flood Level Difference (m) - Hydraulic Roughness Decrease

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	0.04	0.13	0.12	0.11	0.10	0.08	-0.01	-0.18
H02	Geurie Ck - Upstream of Mitchell Hwy	-0.02	-0.04	-0.03	-0.04	-0.03	-0.02	-0.03	-0.01
H03	Geurie Ck - Upstream of Railway Tracks (east)	-0.01	-0.03	-0.03	-0.02	-0.02	-0.01	-0.01	0.04
H04	Geurie Ck - Upstream of Railway Tracks (west)	-0.04	-0.03	-0.03	-0.02	-0.01	-0.01	0.00	-0.00
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	-0.05	-0.06	-0.06	-0.06	-0.06	-0.07	-0.07	-0.08
H06	Jennings St (south-east of Mitchell St)	-0.01	-0.02	-0.01	-0.01	-0.03	-0.03	-0.05	-0.13
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.01
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.00	-0.01
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.02	-0.04
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.03
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.00	-0.01	0.07	0.02	0.00	0.00	0.00	-0.01
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02
H14	Boori Ck (north of Railway Tracks)	-0.01	-0.02	-0.01	-0.01	-0.02	-0.02	-0.01	-0.04

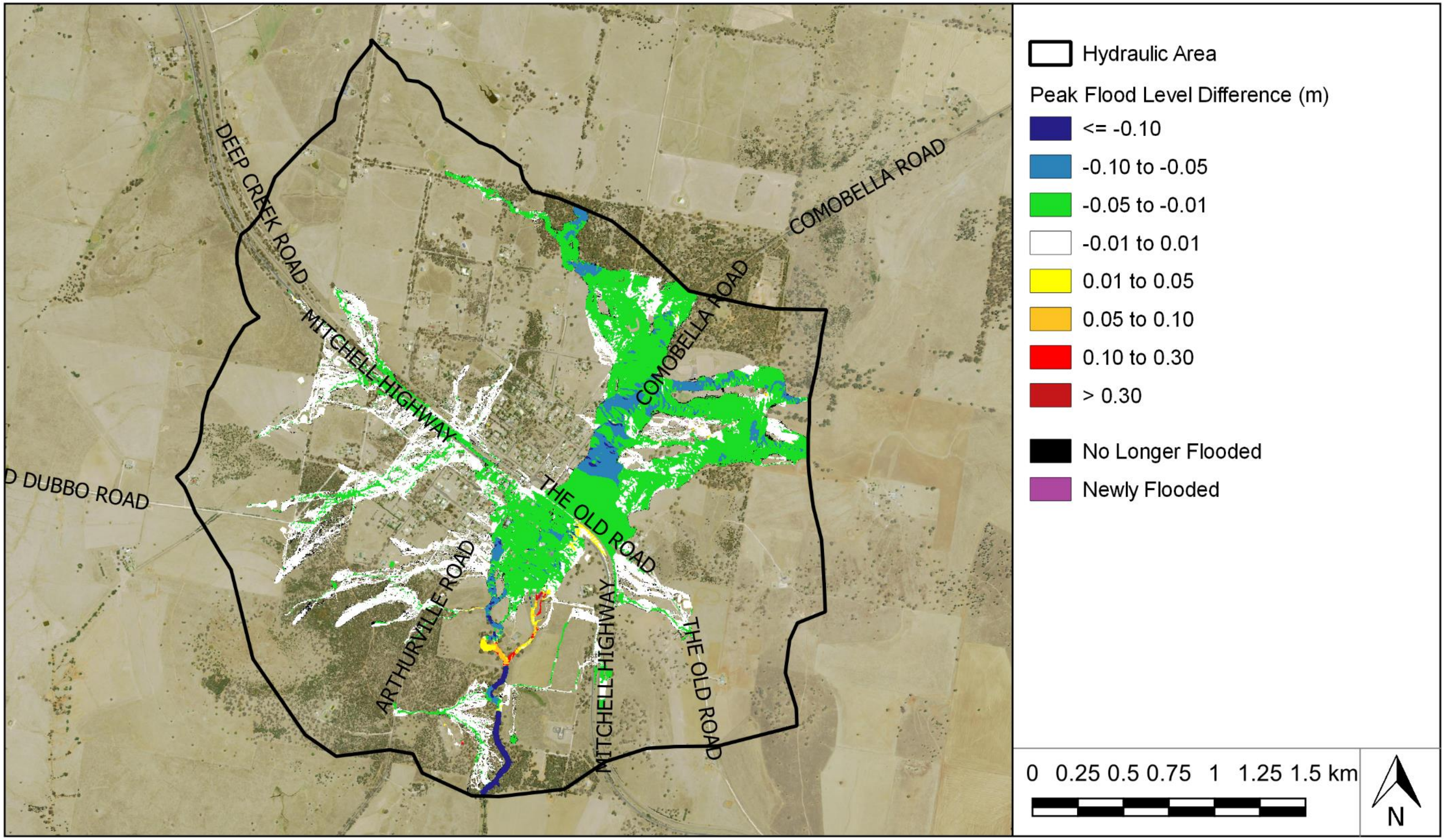

Image 9-11: 1% AEP Peak Flood Level Difference (m) - Hydraulic Roughness Decrease

Table 9-17: Peak Flood Level Difference (m) - Hydraulic Roughness Increase

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	0.00	0.03	0.07	0.01	0.07	0.11	0.19	0.17
H02	Geurie Ck - Upstream of Mitchell Hwy	0.03	0.02	0.02	0.03	0.08	0.02	0.03	0.04
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.02	0.03	0.02	0.02	0.06	0.01	0.01	0.02
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.04	0.03	0.02	0.02	0.03	0.01	0.01	0.01
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.10
H06	Jennings St (south-east of Mitchell St)	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.12
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	0.01
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.02	0.02	0.00	0.01	0.00	0.00	-0.01	0.00
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.00	0.00	0.00	0.00	-0.01	0.02	0.00	0.04
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
H14	Boori Ck (north of Railway Tracks)	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.07

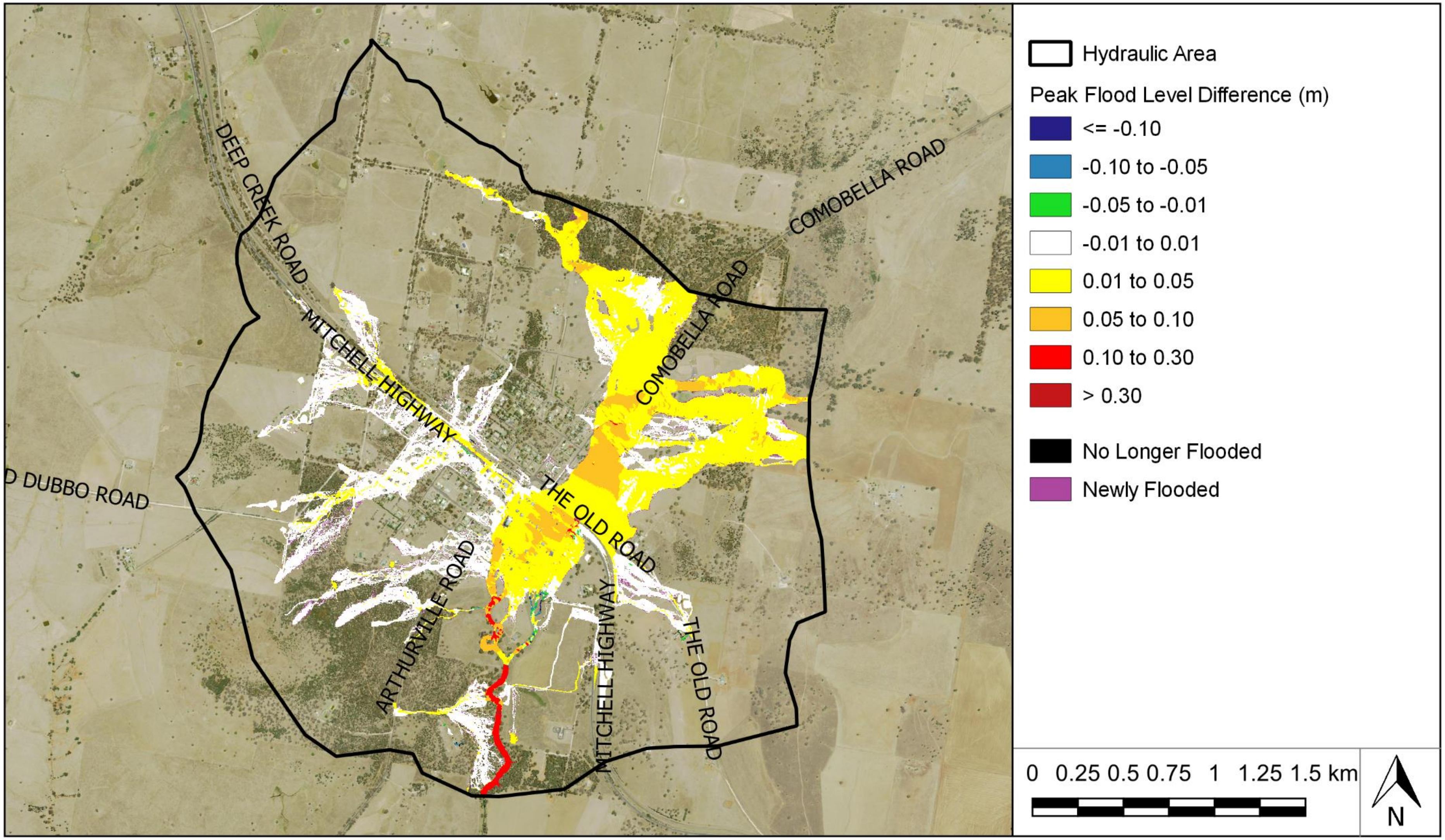

Image 9-12: 1% AEP Peak Flood Level Difference (m) - Hydraulic Roughness Increase

D.5 Blockage of Hydraulic Structures

Table 9-18: Peak Flood Level Difference (m) - Blockage of Hydraulic Structures by 25%

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	0.00	-0.02	0.01	0.00	0.00	-0.02	0.00	0.00
H02	Geurie Ck - Upstream of Mitchell Hwy	0.12	0.11	0.09	0.08	0.14	0.08	0.09	0.04
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.10	0.21	0.20	0.15	0.13	0.04	0.04	0.05
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.13	0.19	0.17	0.13	0.10	0.04	0.03	0.04
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H06	Jennings St (south-east of Mitchell St)	0.00	-0.01	0.02	0.04	0.06	0.02	0.02	0.00
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.01	0.03	0.01	0.01	0.01	0.01	0.00	-0.01
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.04	-0.06	0.08	0.09	0.07	0.05	0.03	0.04
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.00	-0.01	-0.01	0.00	0.00	-0.01	0.00	0.00
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	-0.01	-0.01	0.00	0.00	0.00	0.00	0.01	0.03
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
H14	Boori Ck (north of Railway Tracks)	0.03	0.04	0.04	0.04	0.04	0.03	0.02	0.03

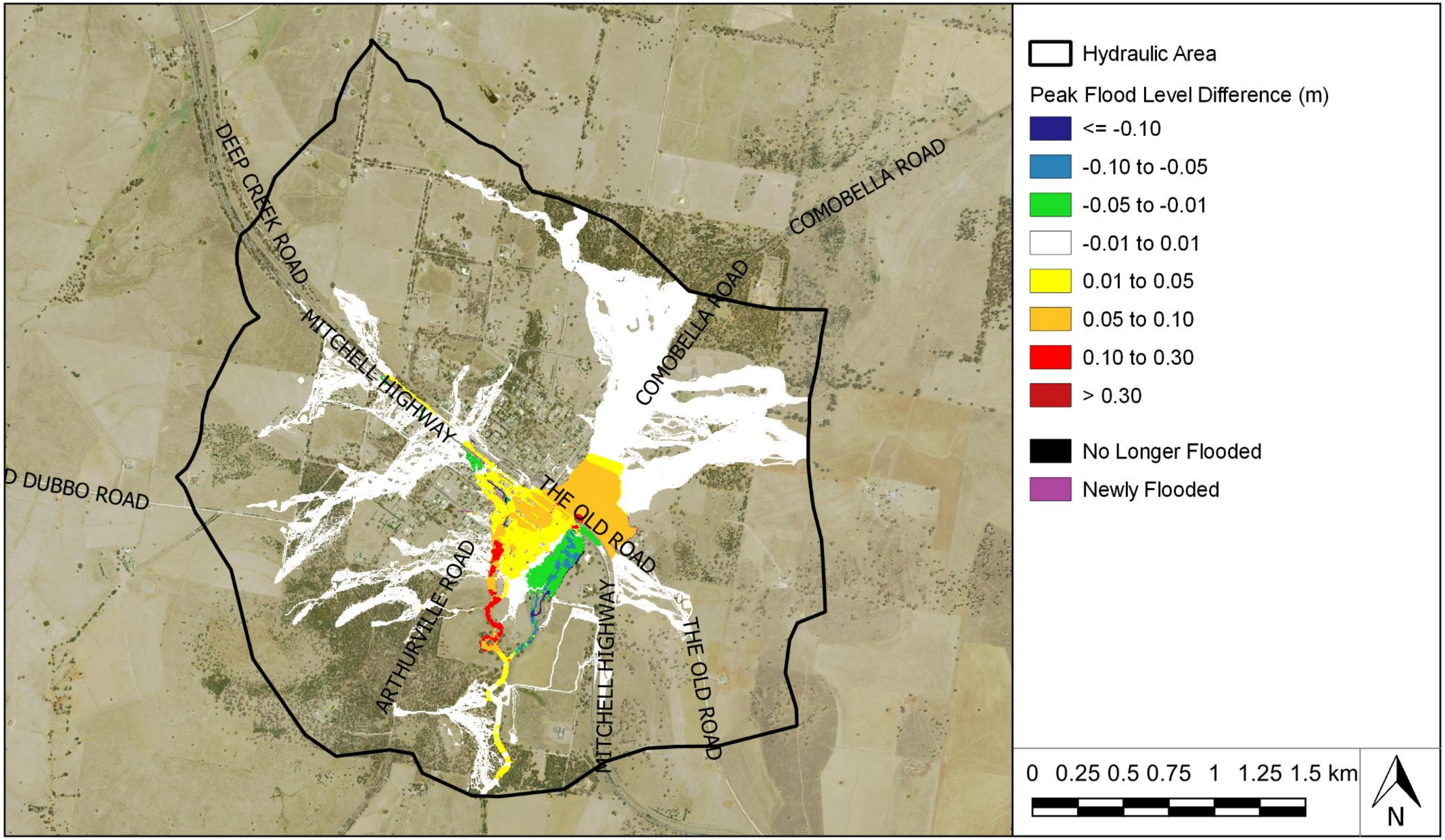

Image 9-13: 1% AEP Peak Flood Level Difference (m) - Blockage of Hydraulic Structures by 25%

Table 9-19: Peak Flood Level Difference (m) - Blockage of Hydraulic Structures by 50%

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
H01	Confluence of Geurie Ck and Boori Ck	-0.02	0.04	0.02	0.02	0.02	0.01	0.01	0.00
H02	Geurie Ck - Upstream of Mitchell Hwy	0.32	0.24	0.25	0.26	0.27	0.23	0.23	0.06
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.48	0.56	0.39	0.31	0.22	0.12	0.11	0.11
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.51	0.52	0.33	0.25	0.18	0.11	0.09	0.09
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H06	Jennings St (south-east of Mitchell St)	-0.01	0.04	0.12	0.12	0.11	0.06	0.06	0.01
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.05	0.04	0.05	0.05	0.05	0.03	0.02	0.03
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.13	0.13	0.03	0.02	0.02	0.02	0.01	-0.02
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.16	0.18	0.19	0.16	0.15	0.09	0.07	0.08
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	-0.01	-0.02	-0.01	-0.01	0.00	0.00	0.00	0.00
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.00	0.15	0.12	0.06	0.03	0.03	0.03	0.05
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00
H14	Boori Ck (north of Railway Tracks)	0.09	0.10	0.09	0.09	0.09	0.08	0.08	0.06

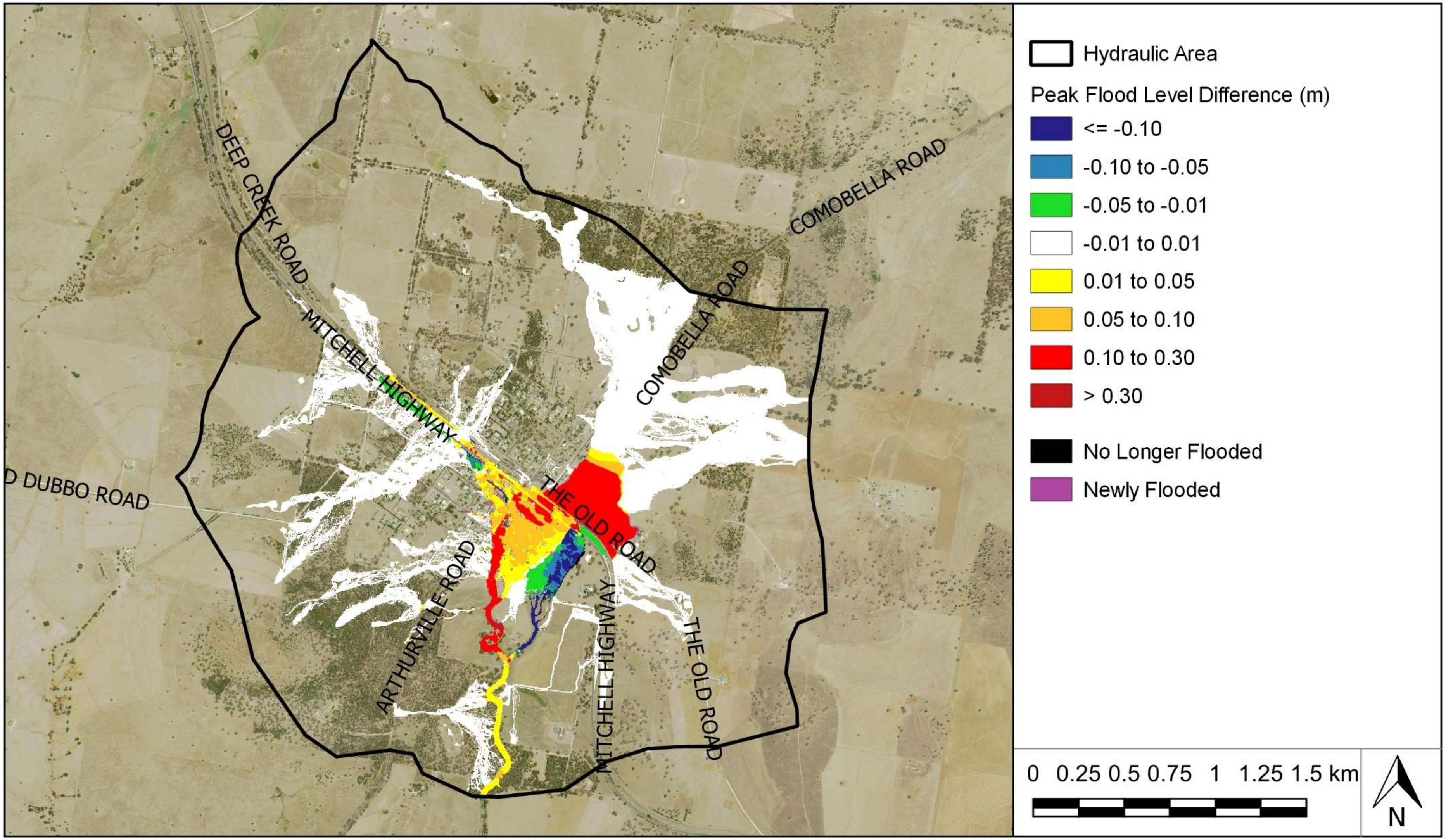

Image 9-14: 1% AEP Peak Flood Level Difference (m) - Blockage of Hydraulic Structures by 50%

D.6 Interim Climate Change Factors

Table 9-20: Peak Flood Level Difference (m) - RCP of 4.5 at 2090

ID	Location	1% AEP
H01	Confluence of Geurie Ck and Boori Ck	0.18
H02	Geurie Ck - Upstream of Mitchell Hwy	0.08
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.13
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.11
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.06
H06	Jennings St (south-east of Mitchell St)	0.09
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.03
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.03
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.02
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.03
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.01
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.03
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.02
H14	Boori Ck (north of Railway Tracks)	0.03

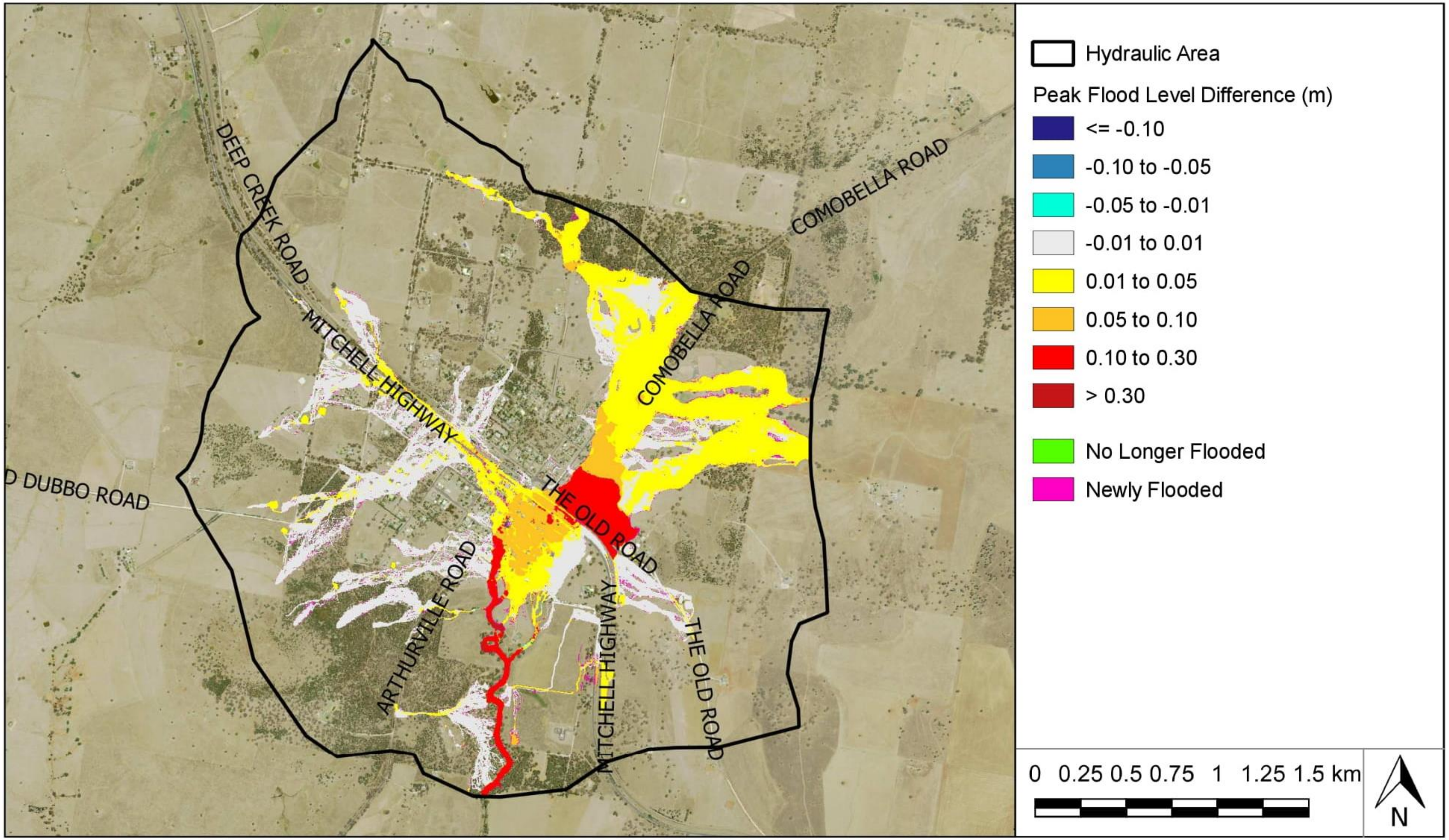

Image 9-155: 1% AEP Peak Flood Level Difference (m) - RCP of 4.5 at 2090

Table 9-211: Peak Flood Level Difference (m) - RCP of 8.5 at 2090

ID	Location	1% AEP
H01	Confluence of Geurie Ck and Boori Ck	0.39
H02	Geurie Ck - Upstream of Mitchell Hwy	0.10
H03	Geurie Ck - Upstream of Railway Tracks (east)	0.19
H04	Geurie Ck - Upstream of Railway Tracks (west)	0.16
H05	Geurie Ck - Upstream of Paxton St (north of Fitzroy St)	0.12
H06	Jennings St (south-east of Mitchell St)	0.17
H07	Swale along northern edge of Mitchell Hwy (north of Mitchell St)	0.06
H08	Swale along northern edge of Mitchell Hwy (north of Chambers St)	0.06
H09	Swale along northern edge of Mitchell Hwy (north of Douglas St)	0.04
H10	Swale along northern edge of Mitchell Hwy (north of Geurie St)	0.06
H11	Swale along northern edge of Railway Tracks (south of Douglas St)	0.02
H12	Boori Ck (west of the intersection of Mitchell Hwy and Douglas St)	0.07
H13	Boori Ck (west of the intersection of Mitchell Hwy and Geurie St)	0.04
H14	Boori Ck (north of Railway Tracks)	0.07

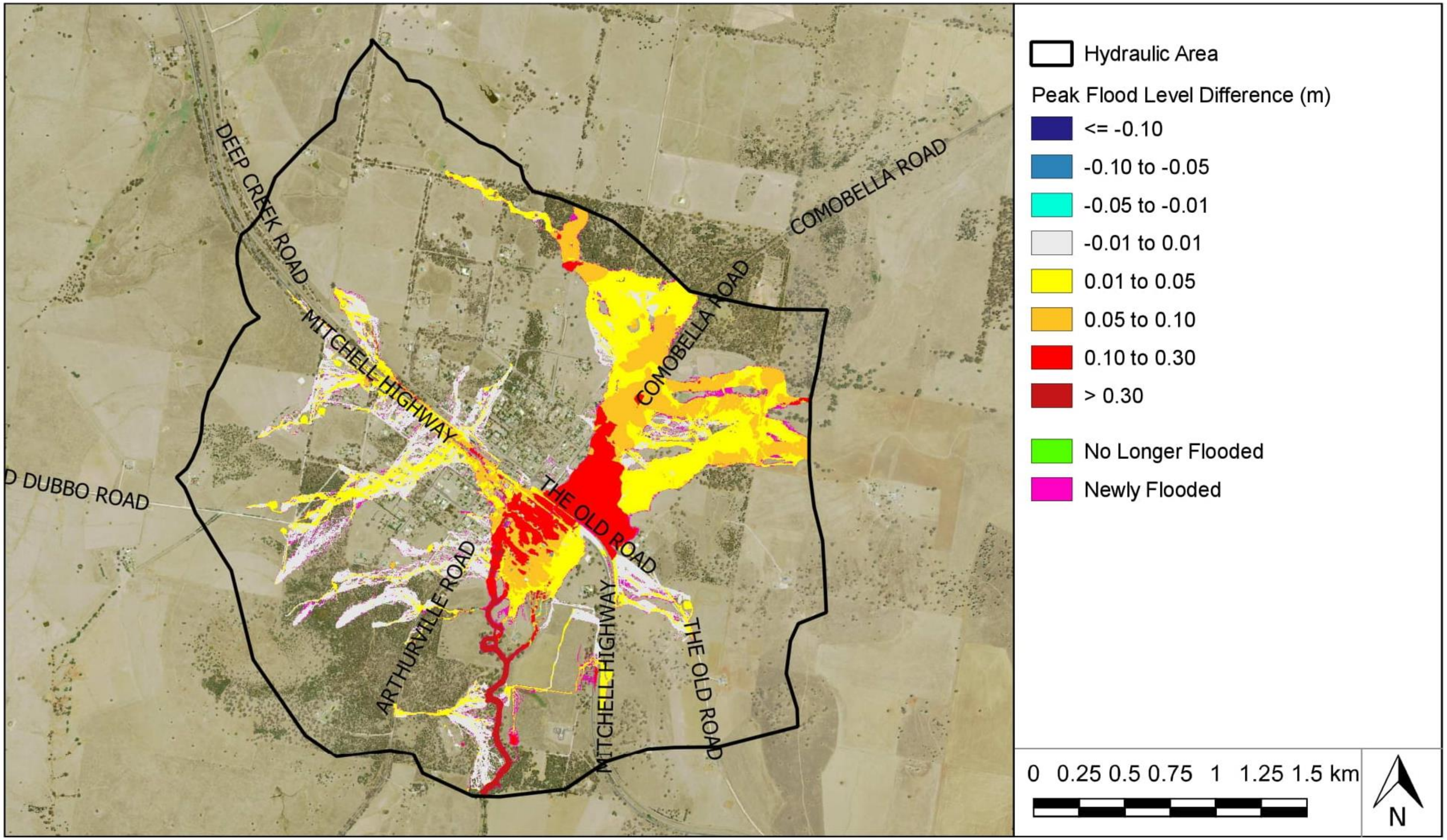

Image 9-166: 1% AEP Peak Flood Level Difference (m) - RCP of 8.5 at 2090