Bimbi Flood Study

Final Report
Volume 1

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Prepared for
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Table of Abbreviations

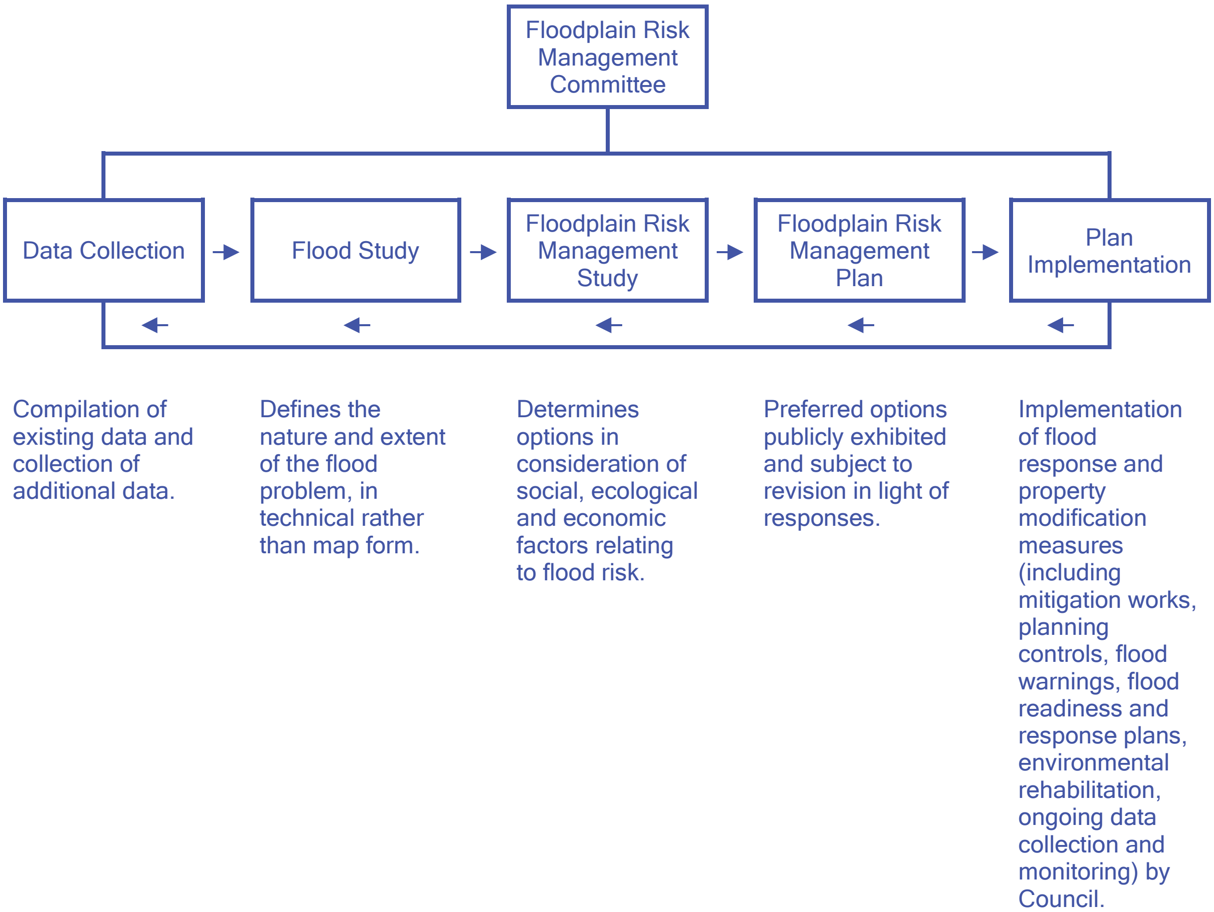
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AAD	Average Annual Damage
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
DEM	Digital Elevation Model
DPE	Department of Planning and Environment
EY	Exceedances per Year
FMC	Floodplain Management Committee
FPA	Flood Planning 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.

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 Weddin Shire Council, with the support of the NSW DPE, has commissioned HydroSpatial Pty Ltd to prepare the following Bimbi Flood Study.

Bimbi is located in the Weddin Shire Council Local Government Area (LGA) in Central West NSW. It predominately consists of rural residential properties, with the exception of the Rural Fire Service (RFS) building on the corner of Caldwell Street and Young Street. The closest service town to Bimbi is Grenfell, located approximately 30 km north-east via Mary Gilmore Way. Burrangong Creek runs through Bimbi in an east-to-west direction. It is located to the south of (and runs approximately parallel to) Mary Gilmore Way. This creek system extends as far upstream as the town of Young, approximately 50 km to the south-east of Bimbi.

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 September-October 2016 flood event. 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

Weddin Shire Council, with the support of the NSW DPE, has commissioned HydroSpatial Pty Ltd to prepare the following Bimbi 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

Bimbi is located in the Weddin Shire Council Local Government Area (LGA) in Central West NSW. According to the 2016 Australian Bureau of Statistics Census, the suburb of Bimbi has a population of 114 people. It predominately consists of rural residential properties, with the exception of the Rural Fire Service (RFS) building on the corner of Caldwell Street and Young Street. The closest service town to Bimbi is Grenfell, located approximately 30 km north-east via Mary Gilmore Way.

Burrangong Creek runs through Bimbi in an east-to-west direction. It is located to the south of (and runs approximately parallel to) Mary Gilmore Way. This creek system extends as far upstream as the town of Young, approximately 50 km to the south-east of Bimbi.

2 Study Methodology

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

- Stakeholder consultation;
- Data collection;
- Hydrologic model development;
- 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 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 Consult

3.1.1 First Round

A community consultation process was undertaken during the data collection stage of the study through the August 2020 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 mail-out, which included a newsletter and questionnaire. The newsletter contained information about the flood study process and where it fits into the wider floodplain risk management process. The questionnaire was provided in paper form as well as online and asked questions about the community's experience of flooding in the past.

There were 5 responses to the community consultation questionnaire. Of the respondents that listed how long they had been living in the area, most had been at their current addresses for an average of 10 years. All respondents expressed that they had been affected by the September-October 2016 flood event, and 2 respondents mentioned themselves or family members being affected by other historical flood events. Over 40 photographs have been submitted displaying the affects of historical flooding in Bimbi.

3.1.2 Second Round

A community information session was held at the Bimbi RFS Shed on the 16 March 2021 between 4pm and 7pm. The information session was attended by representatives from HydroSpatial, the SES, Council, and two Councillors. Approximately a dozen community members attended the information session.

At the information session, a discussion was held regarding the results of computational modelling of historical events, as well as possible mitigation measures to be investigated at the next stage of the process.

The key notes from the community meeting were:

- Community members generally felt that the results of computational modelling of historical events presented were largely accurate to their recollection of the events.
- Several community members felt strongly that the Burrangong Creek Travelling Stock Reserve (TSR) fence erected by Local Land Services (LLS) in 2014 has significantly impacted flood behaviours in the town, and requested that its impact be investigated.
- One resident noted that shortly after the flood events in 2016, a private aerial photography company captured images of the receding flood waters in the area. The resident has provided the images he purchased from the aerial photography company to HydroSpatial.
- One resident brought up concerns that any mitigation measures that would aim to divert flood waters away from the town may negatively impact the efficacy of the aquifer recharge areas near town.
- One resident mentioned that they requested assistance to evacuate a mobility impaired family member during the 2016 flood event and that this was not provided.

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:

- 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 Field Trip

A field trip on the 7-8 May 2020 was undertaken to gain an understanding of the study area. A selection of photographs from the field trip are presented in Photo 4-1 to Photo 4-8.

Photo 4-1: Mary Gilmore Way Bridge over Burrangong Creek

Photo 4-2: Burrangong Creek upstream of Mary Gilmore Way Bridge

Photo 4-3: Burrangong Creek downstream of Mary Gilmore Way Bridge

Photo 4-4: Culverts under Grenfell Street, north of Caldwell Street

Photo 4-5: RFS building on the corner of Caldwell Street and Young Street

Photo 4-6: Information board on RFS building showing photos of the 1990 flood

Photo 4-7: Young Street looking towards Caldwell Street intersection

Photo 4-8: Mary Gilmore Way, south of Young Street

4.2 Topographic Data

4.2.1 Aerial-based Survey Data

A range of aerial-based topographic datasets were available across the study area, known as Aerial Laser Survey (ALS) data. This data was sourced from the NSW Government Spatial Services. The metadata for the ALS showed that the 1 m resolution data was collected between 2014 and 2017. 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 solid structures (such as bridges or culverts over open channels). As such, details of these local features were collected via ground-based surveying.

4.2.2 Ground-based Survey Data

Council provided ground-based survey data of the Mary Gilmore Way Bridge at Bimbi, including some of the surrounding area. The data was collected by Council staff in October 2007. The location of this data is shown on Figure 3.

4.3 Orthophotography

Council provided an orthomosaic of the Burrangong Creek TSR fence at Bimbi, including some of the surrounding area. The orthomosaic was produced by Council staff in May of 2021.

4.4 Historic Flood Data

4.4.1 Community

During the first round of community consultation (as discussed in Section 3.1.1) over 40 photographs were submitted displaying the effects of historical flooding in Bimbi. A majority of the photographs were of the October 2016 flood event; however, some were of flooding as early as 1911. A selection of these photographs from the community consultation are presented in Photo 4-9 to Photo 4-14.

Photo 4-9: 1916 flooding in Bimbi

Photo 4-10: 1930's flooding on the corner of Mary Gilmore Way and Grenfell Street

Photo 4-11: 1955 flooding, looking towards Quandialla

Photo 4-12: 1990 flooding on Wah Way Creek at Wentworth Station

Photo 4-13: 2016 flooding on Caldwell Street looking towards Grenfell Street

Photo 4-14: 2016 flooding on Bimbi-Quandialla Road, corner of Nowlans Road

During the second round of community consultation (as discussed in Section 3.1.2) 12 aerial photographs were submitted displaying the effects of the September 2016 flooding on a property in Bimbi. A selection of these photographs from the community consultation are presented in Photo 4-15 and Photo 4-16.

Photo 4-15: 2016 flooding at the corner of Bimbi-Quandialla Road and Nowlans Road, facing Bimbi-Caragabal Road

Photo 4-16: 2016 flooding at the corner of Bimbi-Quandialla Road and Nowlans Road, facing Wah Way Creek

4.4.2 Landsat

The United States Geological Survey (USGS) and National Aeronautics and Space Administration (NASA) developed Landsat 8. The Landsat 8 satellite consists of two scientific instruments; the Operational Land Imager (OLI) and the Thermal Infrared Sensors (TIRS). Landsat 8 is the most recent satellite launched as part of the Landsat Program which provides repetitive high resolution multispectral data of the surface of the Earth. From this, the study was able to acquire imagery of the September-October 2016 flood extent (as shown in Figure 4).

4.5 Historic Stream Data

Official stream gauges in the vicinity of and upstream of Bimbi were sourced from Water NSW, shown in Table 4-1.

Table 4-1: Stream Gauges

Station number	Station name	First Record	Last Record
412170	Burrangong Creek at Bimbi	18/06/1998	7/04/2004
412186	Tyagong Creek D/S Emu Creek	12/02/2002	7/04/2004
412103	Bland Creek at Morangarell	16/11/1976	8/04/2004
412171	Bland Creek at Marsden	24/06/1998	22/01/2007

4.6 Historic Rainfall Data

4.6.1 Rainfall Stations

Official rainfall gauges within a 75 km radius of Bimbi were sourced from the Bureau of Meteorology (BoM), shown in Table 4-2. The location of these rainfall gauges is shown on Figure 5.

Table 4-2: Rainfall Stations within 75 km of Bimbi

Distance	Station	Station name	First	Last	Type
3.19	73061	Bimbi	1901 Apr	1931 Dec	Daily
9.23	73048	Wattle Vale	1906 Jan	1951 Mar	Daily
12.89	73032	Quandialla Post Office	1925 Mar	2020 Apr	Daily
14.41	73062	Bland	1901 Aug	1918 Jul	Daily
16.93	73070	Cucumgilliga	1888 Dec	1926 Nov	Daily
17.04	73110	Grenfell (Corowood)	1968 May	2020 Feb	Daily
18.81	73113	Tubbul (Keiraville)	1968 Jun	2020 Feb	Daily
18.82	73084	Kokkedahl	1891 Jun	1927 Oct	Daily
25.07	73040	Tubbul Post Office	1908 Jan	1976 Dec	Daily
25.61	73026	Moorilla	1934 Jun	1961 Aug	Daily
26.05	73014	Grenfell (Manganese Rd)	1885 Nov	2020 Apr	Daily
27.41	73144	Grenfell (Hiview)	1998 Jan	1998 Oct	Daily
27.75	73008	Caragabal Post Office	1916 Jan	2013 Jul	Daily
29.12	73145	Quandialla (Bland (Sunnyside))	2003 Jul	2020 Apr	Daily
32.77	73101	Melyra	1895 Nov	1921 Sep	Daily
33.04	65074	Pinnacle	1883 Jan	1915 May	Daily

Distance	Station	Station name	First	Last	Type
35.87	73143	Temora (Narraburra (Attunga))	2003 Jul	2004 Oct	Daily
36.31	65027	Pinaroo	1932 Jan	1965 Dec	Daily
36.35	65093	Grenfell (Bald Hills)	1887 Apr	1911 May	Daily
37.15	73138	Young Airport	2011 Dec	2020 Apr	Continuous
37.15	73138	Young Airport	1994 Jun	2020 Apr	Daily
37.23	73121	Brundah	1884 Nov	1919 Dec	Daily
37.3	65044	Bogo Bogolog	1886 Feb	1920 Nov	Daily
37.3	73134	Mogongong (North Brundah)	1895 Sep	1907 Aug	Daily
38.37	73035	Young (Kooringa)	1933 Jan	2019 Jan	Daily
38.54	73089	Narraburra Post Office	1896 Dec	1920 Nov	Daily
39.35	73090	Narraburra Station 1	1887 Jan	1909 Dec	Daily
40.13	73017	Greenethorpe (Iandra)	1890 Jul	2020 Apr	Daily
40.71	65048	Ooma	1887 Jun	1937 Feb	Daily
41.21	73093	Trungley	1901 Apr	1916 Aug	Daily
41.48	65109	Grenfell (Warraderry (Mascot))	1999 Mar	2013 Feb	Daily
41.69	73067	Burlington Flat (Narraburra)	1887 Feb	1932 Feb	Daily
42.37	73091	Oakhurst (Wyalong)	1907 Jun	1994 May	Daily
43.62	65060	Summer House Creek	1892 May	1914 Mar	Daily
44.41	73098	Young Railway Station	1888 Jan	1919 Mar	Daily
44.69	73059	Back Creek	1901 Jan	1916 Dec	Daily
45.37	73087	Lintondale	1903 Nov	1913 Apr	Daily
45.41	73056	Young Post Office	1871 Sep	1991 Oct	Daily
46.5	73041	Wombat (Tumbleton)	1888 Jun	2014 Dec	Daily
46.52	73002	Bendick	1929 Sep	1950 Sep	Daily
46.94	73060	Bandangan	1902 Apr	1917 May	Daily
47.32	73024	Marsden (Merungle)	1881 Nov	1973 Apr	Daily
48.52	73139	Young (Kiah)	1992 Feb	2010 Aug	Daily
48.72	73100	Bumbaldry (Bushview)	1897 Apr	2020 Feb	Daily
50.04	73052	Wombat (Tenah Merah)	1948 Jan	1969 May	Daily
50.1	50068	Moobong	1885 Nov	1922 Dec	Daily
50.18	73075	Fair View	1901 Feb	1909 Sep	Daily
50.41	73149	Wyalong (Marsden (Minoru))	1997 Jan	2020 Apr	Daily
50.64	65021	Marrumba Station	1939 May	1950 Jul	Daily
51.04	73036	Stockinbingal Post Office	1903 Jun	2020 Apr	Daily
51.13	73000	Barmedman Post Office	1887 Jan	2020 Apr	Daily
51.48	65072	Garema (Forest Lodge)	1971 Jan	2020 Feb	Daily
52.43	73047	Warrangong	1882 May	1956 Jan	Daily
53.1	73043	Wallendbeen (Corang)	1914 Jan	2020 Feb	Daily
53.19	73042	Wallandoon	1911 Feb	1952 May	Daily
53.19	73011	Dunollie	1936 Oct	1953 Sep	Daily
53.19	73003	Berthong	1886 Feb	1952 Dec	Daily
53.88	65017	Garema	1933 May	1996 Jul	Daily
54.62	73092	Stockinbingal 1	1896 Nov	1938 May	Daily

Distance	Station	Station name	First	Last	Type
54.83	73150	Stockinbingal (Sunnydale)	1949 Jan	2020 Apr	Daily
54.88	73038	Temora Research Station	1934 Aug	2011 Mar	Daily
55.64	50065	Lake Cowal West	1887 Sep	1915 Jun	Daily
56.57	73069	Cooyong	1904 Jul	1920 Dec	Daily
56.82	73133	Koorawatha Railway	1897 Jul	1913 May	Daily
57.24	73021	Koorawatha (Boorowa Street)	1903 Jan	2020 Feb	Daily
57.33	65057	Kywong	1913 Jan	1937 Aug	Daily
57.42	73130	Koorawatha (The Glen)	1890 Nov	1900 Feb	Daily
57.45	73151	Temora Airport	2011 Nov	2020 Apr	Continuous
57.45	73151	Temora Airport	2005 Feb	2020 Apr	Daily
57.56	73037	Temora Ambulance Station	1880 Jan	2020 Feb	Daily
57.98	65076	Broula	1884 Jun	1928 Jul	Daily
58.09	73088	Mandamar	1880 Nov	1926 Jun	Daily
58.09	74189	Mandamah West	1895 Jan	1927 Feb	Daily
58.37	73071	Devlins Forest	1905 Apr	1918 Nov	Daily
59.92	73051	Murringo (Windermere)	1888 Apr	2020 Mar	Daily
60.89	73028	Murringo Post Office	1886 Jul	1969 May	Daily
61.5	50064	Lake Cowal 2	1888 Jan	1925 May	Daily
61.5	50022	Lake Cowal	1881 Jan	1950 May	Daily
62.26	73053	Woodburn 3	1897 Mar	1970 Dec	Daily
62.67	50042	Wilga Vale	1936 Jun	1949 Jun	Daily
64.35	73054	Wyalong Post Office	1895 Jun	2020 Feb	Daily
65.59	73105	Rothsay	1913 Jan	1918 Aug	Daily
65.86	73072	Dudauman	1899 Nov	1925 Nov	Daily
65.95	73142	Cootamundra Airport	1995 Oct	2020 Apr	Daily
66.03	73126	Koorawatha (Illunie)	1974 Oct	1983 Feb	Daily
66.07	65019	Gooloogong Post Office	1889 Jul	2020 Feb	Daily
66.52	73118	Cootamundra Aero	1940 Nov	1943 Nov	Daily
66.52	73085	Cootamundra 1	1885 Jan	1911 Jan	Daily
66.75	65065	Forbes 3	1892 May	1916 Aug	Daily
67.02	73009	Cootamundra Post Office	1889 Jan	2000 Dec	Daily
67.52	65085	Eugowra (Pilgrim Hill)	1978 Mar	2001 Sep	Daily
67.71	73030	Narra Allen	1885 Jan	1950 Aug	Daily
67.73	50044	West Wyalong Post Office	1895 Feb	2002 Dec	Daily
68.22	50017	West Wyalong Airport Aws	2012 Jan	2020 Apr	Continuous
68.22	50017	West Wyalong Airport Aws	1999 Apr	2020 Apr	Daily
68.26	73029	Murrumburrah (Historical Society)	1884 Oct	2020 Apr	Daily
68.55	65097	Forbes (Bethany Park)	1991 Jul	1993 Mar	Daily
68.56	50060	Corran	1896 Sep	1913 Dec	Daily
68.69	73111	Bellarwi (Glen Avon)	1968 Apr	1971 Jan	Daily
68.72	50123	Wyalong Upper 3 Run	1882 Jan	1923 Feb	Daily
68.72	65049	Springthorpe	1897 May	1928 Sep	Daily
68.77	74222	Quandary (Happy Corner)	1886 Dec	1922 Jul	Daily

Distance	Station	Station name	First	Last	Type
68.77	50103	West Wyalong Airport	1978 Aug	2016 Jul	Daily
68.81	65112	Paytens Bridge (Yandilla)	2005 Jul	2020 Feb	Daily
69.78	65091	Cowra Airport Comparison	1966 Oct	2011 Jul	Daily
69.87	73033	Bethungra (Retreat)	1896 Nov	2004 Nov	Daily
69.98	73016	Harden (East St)	1886 Aug	2006 Jun	Daily
70.07	65111	Cowra Airport Aws	2011 Oct	2020 Apr	Continuous
70.07	65111	Cowra Airport Aws	2004 Jul	2020 Apr	Daily
70.22	73109	Murringo (Yallambee)	1968 Jan	2020 Feb	Daily
70.29	73099	Junee Reefs (Clear Hills)	1898 Mar	2017 Nov	Daily
70.39	73129	Godfreys Creek (Taroona)	1978 Mar	2020 Feb	Daily
70.44	73022	Cootamundra (Landgrove)	1891 Feb	2020 Feb	Daily
70.62	65009	Cucumgillica Public School	1947 Jan	1957 Nov	Daily
71.22	65088	Forbes Iron Bridge (Lachlan River)	1993 Jan	1993 Mar	Daily
71.53	65113	Forbes (Bimbimbi)	2004 Jul	2020 Jan	Daily
72.05	65104	Forbes Council Depot	1998 Jul	2011 Dec	Daily
72.2	50135	Forbes (Jemalong Weir)	1988 Sep	2012 Mar	Daily
72.29	63021	Cowra Post Office	1885 Jan	1965 Dec	Daily
72.33	65016	Forbes (Camp Street)	1875 Jul	1998 Jul	Daily
72.48	65031	Wandary	1891 Feb	1945 Oct	Daily
73.26	74002	Ariah Park Post Office	1905 Nov	2020 Feb	Daily
73.87	50079	Warroo	1886 Jan	1925 Dec	Daily
73.88	73031	Junee Reefs (Noorla)	1889 Mar	1976 Jul	Daily
74.27	65114	Forbes (Bedgerabong Rd)	2012 Jan	2020 Feb	Daily
74.33	63229	Cowra (Billimari (Pine View))	1968 Apr	2020 Feb	Daily
74.9	65103	Forbes Airport Aws	2012 Jan	2020 Apr	Continuous
74.9	65103	Forbes Airport Aws	1995 Dec	2020 Apr	Daily

4.6.2 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 4-3 details the highest daily rainfall values recorded at Quandialla, Grenfell, Tubbul and Young. The gauge at Quandialla Post Office was the closest gauge to Bimbi and had the longest period of record of the proximate gauges.

The Quandialla gauge recorded a number of large rainfall events in the 1950's and 1960's, with only two of the top 15 records occurring more recently than that (specifically, in 1982 and 1993). The other proximate gauges, having been installed after the 1950's and 1960's period, recorded more recent events in the top 15 records. From these, some dates that appeared to have relatively large daily rainfall values across multiple gauges were the November-December 2010 period, the February 2012 period, and November 2015 period.

Table 4-3: Top 15 Daily Rainfall Records at Quandialla, Grenfell, Tubbul and Young

Quandialla Post Office (73032) Mar 1925 - To Date		
Rank	Date	Rainfall (mm)
1	19/01/1962	112.3
2	25/03/1963	95.5
3	22/04/1964	95.5
4	24/03/1982	92.4
5	18/01/1962	91.4
6	25/07/1993	89.8
7	8/03/1956	88.6
8	19/03/1950	88.1
9	25/02/1955	87.9
10	16/04/1969	84.3
11	20/01/1928	82.6
12	5/12/1962	77.5
13	2/03/1956	71.6
14	13/05/1963	71.6
15	19/01/1950	71.1

Grenfell (73110) May 1968 - To Date		
Rank	Date	Rainfall (mm)
1	8/12/1971	110
2	29/11/2010	100.8
3	22/01/1976	98.8
4	22/02/2003	98
5	19/03/1969	87.6
6	21/01/1995	84.2
7	29/02/2012	79
8	20/02/1974	78.6
9	24/03/1982	75.4
10	25/07/1993	73
11	3/05/1995	66.4
12	3/02/2012	66.2
13	8/03/2010	65.6
14	11/01/1974	63.2
15	11/05/1968	61

Tubbul (73113) Jun 1968 - To Date		
Rank	Date	Rainfall (mm)
1	6/08/1992	150
2	28/12/1999	114.4
3	7/08/1992	94
4	1/03/2012	91.8
5	25/07/1993	86.4
6	9/12/2010	80.3
7	5/04/1999	76
8	22/01/1976	68
9	26/01/1984	64
10	24/03/1982	63.2
11	14/04/1990	62
12	20/02/1974	61.8
13	10/02/1969	61
14	14/11/2015	59.6
15	13/06/2001	59.4

Young Airport (73138) Jun 1994 - To Date		
Rank	Date	Rainfall (mm)
1	29/11/2010	118.6
2	9/12/2010	81
3	6/02/2019	80
4	1/03/2012	79.6
5	3/05/1995	77
6	21/01/1995	72
7	27/12/1999	71
8	13/06/2001	69
9	21/07/1998	61
10	26/12/2009	60.2
11	3/12/2003	59.6
12	3/02/2012	58.8
13	2/06/2013	55.8
14	15/11/2015	55.4
15	7/11/2001	53

4.6.3 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 4-4 details the highest hourly rainfall values for the pluviometer gauges located at Young, Temora, West Wyalong and Cowra. However, none of these pluviometer gauges pre-dated 2011 and none were located within Bimbi.

Table 4-4: Top 15 Hourly Records at Young, Temora, West Wyalong and Cowra

Young Airport (73138) Dec 2011 - To Date		
Rank	Date	Rainfall (mm)
1	5/02/2019 18:00	41
2	14/11/2015 15:00	37.4
3	5/02/2019 17:00	35.8
4	21/01/2016 17:00	33
5	29/02/2012 12:00	20.6
6	25/02/2018 8:00	20.4
7	16/12/2016 19:00	18.4
8	14/11/2015 16:00	18
9	22/03/2019 13:00	17.8
10	29/02/2012 11:00	17.4
11	24/12/2012 1:00	16
12	28/02/2013 9:00	15.6
13	7/01/2015 16:00	15
14	7/11/2018 3:00	14.8
15	5/11/2015 17:00	14.6

Temora Airport (73151) Nov 2011 - To Date		
Rank	Date	Rainfall (mm)
1	30/03/2020 18:00	19.2
2	10/02/2020 20:00	17.8
3	1/11/2015 20:00	17.6
4	8/05/2012 16:00	16.8
5	7/01/2019 18:00	15.4
6	31/10/2015 14:00	14.8
7	8/01/2019 15:00	14.6
8	19/02/2012 19:00	14.2
9	25/12/2011 18:00	13.6
10	27/01/2018 11:00	12.6
11	28/12/2014 17:00	12.4
12	6/04/2015 17:00	12.4
13	20/01/2012 19:00	12.4
14	1/11/2015 21:00	12.4
15	7/01/2019 22:00	11.8

West Wyalong Airport (50017) Jan 2012 - To Date		
Rank	Date	Rainfall (mm)
1	28/03/2014 18:00	27.8

Cowra Airport (65111) Oct 2011 - To Date		
Rank	Date	Rainfall (mm)
1	22/12/2011 20:00	31.2

2	2/12/2017 10:00	27.4
3	1/11/2015 20:00	19.2
4	22/02/2012 16:00	16.2
5	4/04/2020 3:00	15.2
6	7/01/2015 19:00	14.8
7	28/02/2013 8:00	14
8	12/02/2020 19:00	12.8
9	14/09/2016 10:00	12.6
10	7/01/2019 21:00	12.6
11	12/11/2013 0:00	12.4
12	5/03/2020 4:00	12.4
13	29/03/2019 20:00	12.4
14	1/06/2014 0:00	12.4
15	8/02/2019 19:00	12.2

2	22/07/2016 20:00	22.2
3	16/01/2020 17:00	20.4
4	21/10/2016 21:00	19.8
5	2/12/2017 6:00	19.6
6	11/01/2019 17:00	18.6
7	29/03/2020 23:00	18
8	20/11/2017 11:00	16.8
9	28/02/2012 20:00	15.8
10	19/02/2014 13:00	15
11	26/12/2015 14:00	15
12	20/02/2012 22:00	14.8
13	10/11/2011 6:00	14.8
14	16/03/2012 16:00	14.6
15	20/05/2017 0:00	14.4

5 Hydrologic Model Development

5.1 Overview

The hydrologic model developed for this study used the Watershed Bounded Network Model (WBNM) software (Ref 4). 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 2020 version of WBNM being used.

5.2 Sub-catchment Delineation

The hydrologic catchment area covers a region of 1595 km^2. This area was defined by the hydrographical ridges that form the upper bounds of the watershed area.

A total of 127 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 6.

5.3 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.

5.4 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.

5.5 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 zonings within the sub-catchments (corresponding to the hydraulic roughness extents, discussed in Section 6.3). The land zonings were determined using zoning maps from the Weddin Local Environmental Plan (LEP) 2011, the Young LEP 2010, and the Harden LEP 2011. The impervious percentage per land use type is summarised in Table 5-1.

Table 5-1: Impervious Percentage per Land Zoning Type

Land Zoning Type	Impervious Percentage
B2 - Local Centre	70%
B4 - Mixed Use	70%
B6 - Enterprise Corridor	20%
B7 -Business Park	40%

E1 - National Parks and Nature Reserve	10%
E3 - Environmental Management	10%
IN1 - General Industrial	40%
R1 - General Residential	50%
R5 - Large Lot Residential	20%
RE1 - Public Recreation	20%
RE2 - Private Recreation	20%
RU1 - Primary Production	10%
RU3 - Forestry	10%
RU4 - Primary Production Small Lots	20%
RU5 - Village	40%
SP1 - Special Infrastructure	40%
SP2 - Infrastructure	40%
DM - Deferred Matter	40%

5.6 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 9) (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.

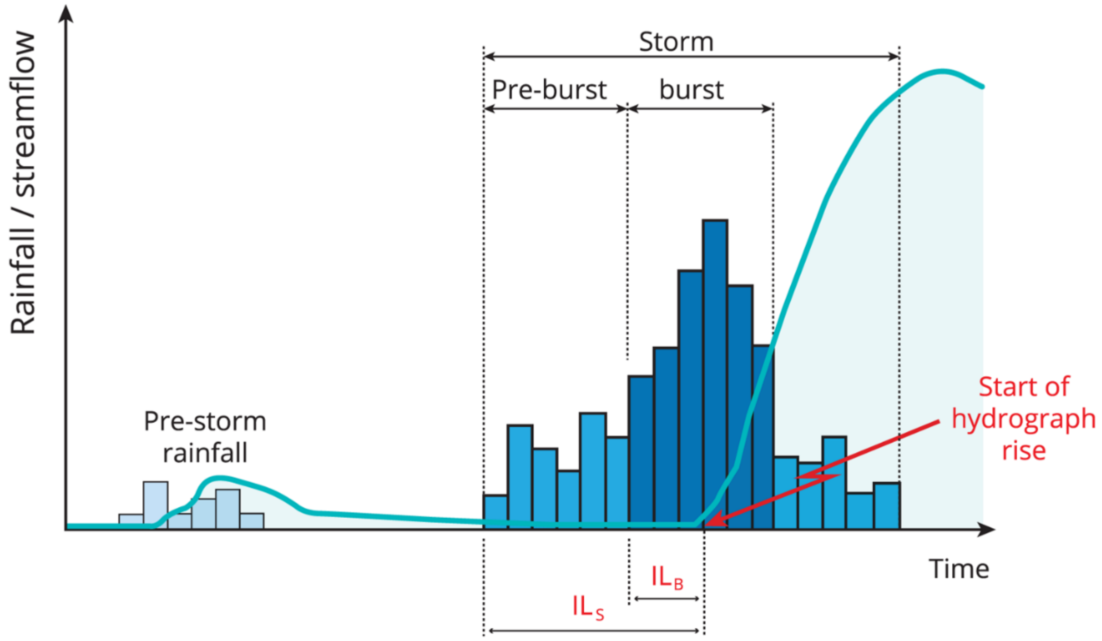


Chart 5-1: Distinction between storm and burst initial loss (Extracted from ARR 2019)

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.

During the calibration process, the ARR Data Hub initial and continuing losses were used as a starting point. This resulted in a relatively good correlation between the recorded flood levels/extents and the modelled flood levels/extents (discussed in Section 7). Therefore, the ARR Data Hub values were adopted for this study.

6 Hydraulic Model Development

6.1 Overview

The hydraulic model developed for this study used the TUFLOW software (Ref 3). The TUFLOW version used was HPC 2020-10-AA with single 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 an 8 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 5), Henderson (Ref 6), 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
Light Vegetation	0.03	0.03 - 0.05
Medium Vegetation	0.05	0.05 - 0.07
Heavy Vegetation	0.08	0.07 - 0.12
Minimally Vegetated Channel	0.04	0.02 - 0.04
Vegetated Channel	0.05	0.04 - 0.1
Water Storages	0.03	0.015 - 0.35

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 Creeks and Tributaries

There are a number of creeks and tributaries through the study area. These have been modelled in the 2D domain, with the centrelines based upon the aerial photography and the inverts carved into the 2D domain based upon the LiDAR data (discussed in Section 4.2). The location of the 2D creeks and tributaries are shown on Figure 7.

6.4.2 Bridges and Culverts

The culverts throughout the hydraulic model area were modelled as 1D features as the dimensions of the culverts were often smaller than the 2D grid cell size. The culvert details were obtained from the culvert inspections undertaken by Council in 2018 and 2019. The locations of the culvert structures modelled are shown on Figure 7.

The Mary Gilmore Way bridge that crosses Burrangong Creek to the south of town was modelled in the 2D domain given its width relative to the 2D grid cell size. The bridge details were obtained from the ground-based survey undertaken by Council in 2007 (discussed in Section 4.2.2).

The locations of the bridge and culvert structures modelled are shown on Figure 7.

6.4.3 Burrangong Creek Fence

The Burrangong Creek Travelling Stock Reserve (TSR) fence erected by LLS to the south of town was modelled in the 2D domain as a partial flow blockage. The fence details were approximated from verbal discussions with LLS, as well as aerial based imaging conducted by Council in 2021.

The location of the fence is shown on Figure 7.

6.4.4 Buildings

Buildings were simulated in the hydraulic model for the town as absolute flow obstructions within the 2D domain. The building extents were determined from analysis of the aerial photography. This is shown in Figure 7.

6.5 Hydraulic Boundary Conditions

The hydraulic model requires inflow and boundary conditions to be specified. The runoff generated from upstream and outside 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 to not duplicate routing calculations.

7 Historic 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 2016 Event

From discussions with Council and the community, a flood event is known to have taken place in 2016. Therefore, an analysis of available records was carried out for this period; utilising the LandSat data (discussed in Section 4.4) and the daily/continuous rainfall data (discussed in Section 4.6). However, unfortunately the stream gauge records did not extend across this period (discussed in Section 4.5).

As the LandSat data is collected at roughly weekly intervals and can at times be obscured by cloud cover, the records available were as follows:

- 21 and 28 August 2016 – little to no flood water observed.
- 24 September 2016 – flood water observed to the west of Bimbi, however no data was available for the east of Bimbi.
- 2 October 2016 – flood water observed to the west of Bimbi, however no data was available for the east of Bimbi.
- 18 and 20 October 2016 – little to no flood water observed.

The continuous rainfall data was analysed for the September-October period to coincide with the LandSat data, and it was found that there were a number of storm events that occurred in this period, shown on Figure 8A. As no LandSat data is available for the early September 2016 period, it is unknown to what extent these earlier rainfall events may have resulted in flooding. However, regardless of if these earlier rainfall events resulted in a direct flood event, they would have contributed indirectly to the flood events from the later rainfall events by "pre-wetting" the catchment.

For the LandSat data on the 24 September 2016 the rainfall event that would have directly contributed to that flood event occurred across a 24 hour period on the 21 September, shown on Figure 8B. Comparing the cumulative rainfall across this 24 hour period to the IFD data for Bimbi places this rainfall event at around a 50% AEP rainfall event, shown on Figure 8C.

The rainfall data from the daily rainfall gauges in the area surrounding Bimbi was analysed to determine the spatial distribution of rainfall during the 21 September event, shown on Figure

8D. It was found that rainfall depths were higher to the south of Bimbi at Young and Stockinbingal, and lower to the north and north-east at Forbes and Canowindra.

For the LandSat data on the 2 October 2016 the rainfall event that would have directly contributed to that flood event occurred across an approximately 60 hour period from the 29 September through to the 1 October, shown on Figure 8E. Comparing the cumulative rainfall across this 60 hour period to the IFD data for Bimbi places this rainfall event at around a 50% AEP rainfall event, shown on Figure 8F. This is a similar magnitude as the 24 hour rainfall event on the 21 September, however the 24 hour rainfall event reached this magnitude earlier in the rainfall period.

The rainfall data from the daily rainfall gauges in the area surrounding Bimbi was analysed to determine the spatial distribution of rainfall during the 29 September event, shown on Figure 8G. It was found that rainfall depths were higher to the south of Bimbi at Young and Stockinbingal, and lower to the north and north-west at Forbes and Lake Cowal. This was again similar to the event on the 21 September.

Based upon this analysis, both of these 2016 storm bursts were used to calibrate the models.

7.2.2 1999 Event

Analysis of the Bimbi stream gauge was undertaken to determine the historical events that produced the largest flow during the relatively short period of record for the gauge. From this, it was found that the largest flow recorded at this gauge occurred in August 1998. However, the only continuous rainfall gauge that was operating during this period (namely the Boorowa River at Prossers Crossing Gauge (gauge number 412029)) was found to have recorded an insignificant amount of rainfall for the corresponding period.

Following on from this, the second largest flow recorded at the Bimbi stream gauge occurred in October 1999. The continuous rainfall gauge at Boorowa River (412029) was again the only continuous rainfall gauge operating during this period and it did record a moderate amount of rainfall for the corresponding period. This is shown on Figure 10A.

Based upon this analysis, the 1999 event was used to verify the models.

7.2.3 1990 Event

From discussions with Council and the community, a flood event is known to have taken place in 1990. However, unfortunately no rainfall gauge data, stream gauge data or LandSat data is available for that period. Therefore, this flood event could not be used for calibration or validation of the models.

7.3 Historic Flood Simulation Results

7.3.1 2016 Event

Figure 9A and Figure 9B shows the flood depth results for the storm event that occurred on the 21 September 2016. The former shows the peak flood depth results; whereas the latter shows the flood depth results for midday on the day that the LandSat data was captured for (i.e. the 24 September 2016). From this it was found that the modelled flood extents correspond relatively well with the LandSat flood extents; however the LandSat data did not correspond with the peak flood depths and extents.

Figure 9C and Figure 9D shows the flood depth results for the storm event that occurred from the 29 September to the 1 October 2016. The former shows the peak flood depth results; whereas the latter shows the flood depth results for midday on the day that the LandSat data was captured for (i.e. the 2 October 2016). Similarly, it was found that the modelled flood extents correspond relatively well with the LandSat flood extents; however the LandSat data did not correspond with the peak flood depths and extents.

7.3.2 1999 Event

Figure 11A shows the peak flood depth results for the 1999 event. From this it was found that the 1999 event was mostly confined to within the creek bank. However, the limited extent of flood affectation corresponds with the data showing that the 1999 event was of a relatively small magnitude.

Figure 11B shows the modelled flood level over the duration of the event compared to the Bimbi stream gauge data. This showed that the modelled peak flood level was relatively similar to the recorded peak flood level. However on the ascending and descending limb, the model does not appear to have replicated the two smaller flood level crests that occurred on either side of the peak. This could be attributed to the data from the continuous rainfall gauge not being entirely representative of the conditions over the catchment (as the rainfall gauge was located some distance outside of the Bimbi catchment, however it was the only continuous rainfall gauge proximate to the catchment during this storm 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 5.6, unaltered ARR Data Hub loss values were used to estimate the initial and continuing losses. From this, the continuing loss was estimated to be 1.7 mm/hr. 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 1000 and 30,000 km^2 was applied to the 1,595 km^2 study area. It should be noted that the generalised equations for calculating ARF are not applicable for event durations of less than 12 hours in catchments between 1000 and 30,000 km^2. 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 Burrangong Creek at Bimbi stream gauge 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 between 700 and 1,600 km^2, the 1000 km^2 areal temporal patterns were applied to design storm durations. The 1000 km^2 areal temporal patterns for the Murray Basin region encompassed the total catchment area, and therefore these were exclusively applied.

8.2.6 Critical Temporal Pattern and Storm Duration

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 BIM_100, BIM_200, BIM_400, and BIM_500. 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 with varying temporal patterns, namely the 540 minute storm duration. The inflow location with the largest upstream catchment produced temporal pattern 9 (Event ID 4077), with the other two inflow locations ranking temporal pattern 9 as 3rd or 4th highest (as in three or two higher than the average and median peak discharge respectively). In the one instance where the critical storm duration differed from this, the 540 minute storm duration was the second most critical, with temporal pattern 9 ranked as the third highest. It should also be noted that this fourth inflow location represented a significantly smaller upstream catchment. As such, for the 20% AEP event the 540 minute storm duration with temporal pattern 9 was adopted.

For the 10% 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 7 (Event ID 4064). In the one instance where the critical temporal pattern differed from this, the critical duration remained the 540 minute storm duration and temporal pattern 7 was ranked 4th highest (as in two higher than the average peak discharge). As such, for the 10% AEP event the 540 minute storm duration with temporal pattern 7 was adopted.

For the 5% AEP event, each of the four inflow locations produced the same critical duration with varying temporal patterns, namely the 540 minute storm duration. The inflow location with the largest upstream catchment produced temporal pattern 7 (Event ID 4054), with the other three inflow locations ranking temporal pattern 7 as 3rd highest (as in three higher than the average and median peak discharge). As such, for the 5% AEP event the 540 minute storm duration with temporal pattern 7 was adopted.

For the 2% AEP event, each of the four inflow locations produced the same critical duration with varying temporal patterns, namely the 540 minute storm duration. The inflow location with the largest upstream catchment produced temporal pattern 7 (Event ID 4054), with the other three inflow locations ranking temporal pattern 7 as 3rd highest (as in three higher than the average and median peak discharge). As such, for the 2% AEP event the 540 minute storm duration with temporal pattern 7 was adopted.

For the 1% 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 4053). In the one instance where the critical storm duration differed from this, the 540 minute storm duration was the third most critical, with temporal pattern 6 ranked as the third lowest. It should also be noted that this fourth inflow location represented a significantly smaller upstream catchment. As such, for the 1% AEP event the 540 minute storm duration with temporal pattern 6 was adopted.

For the 0.5% 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 4053). In the one instance where the critical storm duration differed from this, the 540 minute storm duration was the third most critical, with temporal pattern 6 ranked as the lowest. It should also be noted that this fourth inflow location represented a significantly smaller upstream catchment. As such, for the 0.5% AEP event the 540 minute storm duration with temporal pattern 6 was adopted.

For the 0.2% 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 4053). In the one instance where the critical storm duration differed from this, the 540 minute storm duration was the third most critical, with temporal pattern 6 ranked as the third lowest. It should also be noted that this fourth inflow location represented a significantly smaller upstream catchment. As such, for the 0.5% AEP event the 540 minute storm duration with temporal pattern 6 was adopted.

Table 8-1 summarises the critical storm duration and temporal pattern adopted for each event probability based upon both the hydrologic model analysis.

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

Event Probability	Critical Duration and Temporal Pattern
20% AEP	540 minute TP09
10% AEP	540 minute TP07
5% AEP	540 minute TP07
2% AEP	540 minute TP07
1% AEP	540 minute TP06
0.5% AEP	540 minute TP06
0.2% AEP	540 minute TP06
PMF	1440 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, 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 sensitive 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 60% adjusted ARR Data Hub values; and comparing to the results to the adopted unadjusted ARR Data Hub values (discussed in Section 5.6 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 moderately 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 upstream portion of Burrangong Creek, as well as along Red 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, particularly along Burrangong Creek and Red Creek.

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 Red Creek was more sensitivity to variations in hydrologic lag and routing compared to both Wah Way Creek and Burrangong Creek. However, Burrangong Creek was more sensitive to variations in routing compared to Wah Way Creek. 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 Re Creek was more sensitivity to variations in hydraulic roughness than Burrangong Creek and Wah Way Creek. However, Burrangong Creek was more sensitive to variations in roughness compared to Wah Way Creek. 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, culverts and fences 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, it was found that variations in the blockages of structures had little to no effect on flood levels outside of highly localised differences at the location of structures.

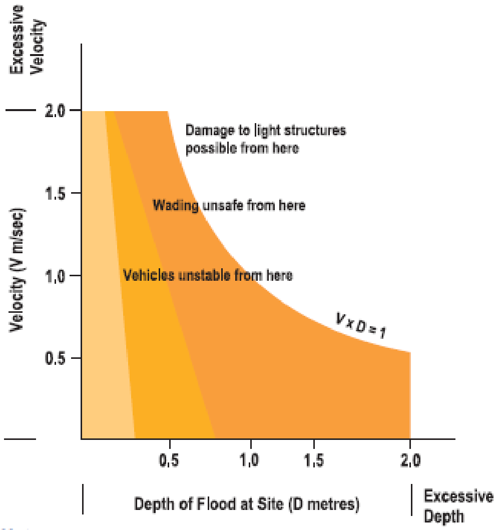
8.4 Design Flood Simulation Results

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.

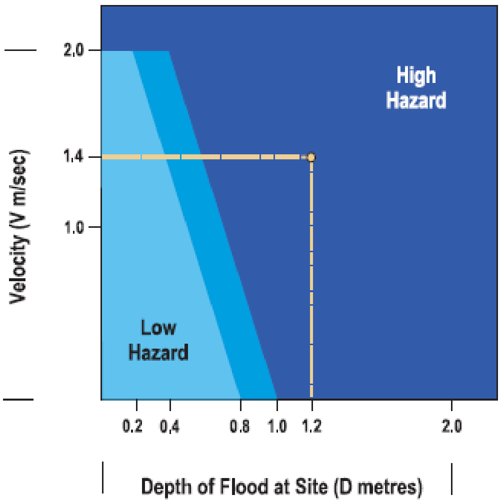


Notes

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.

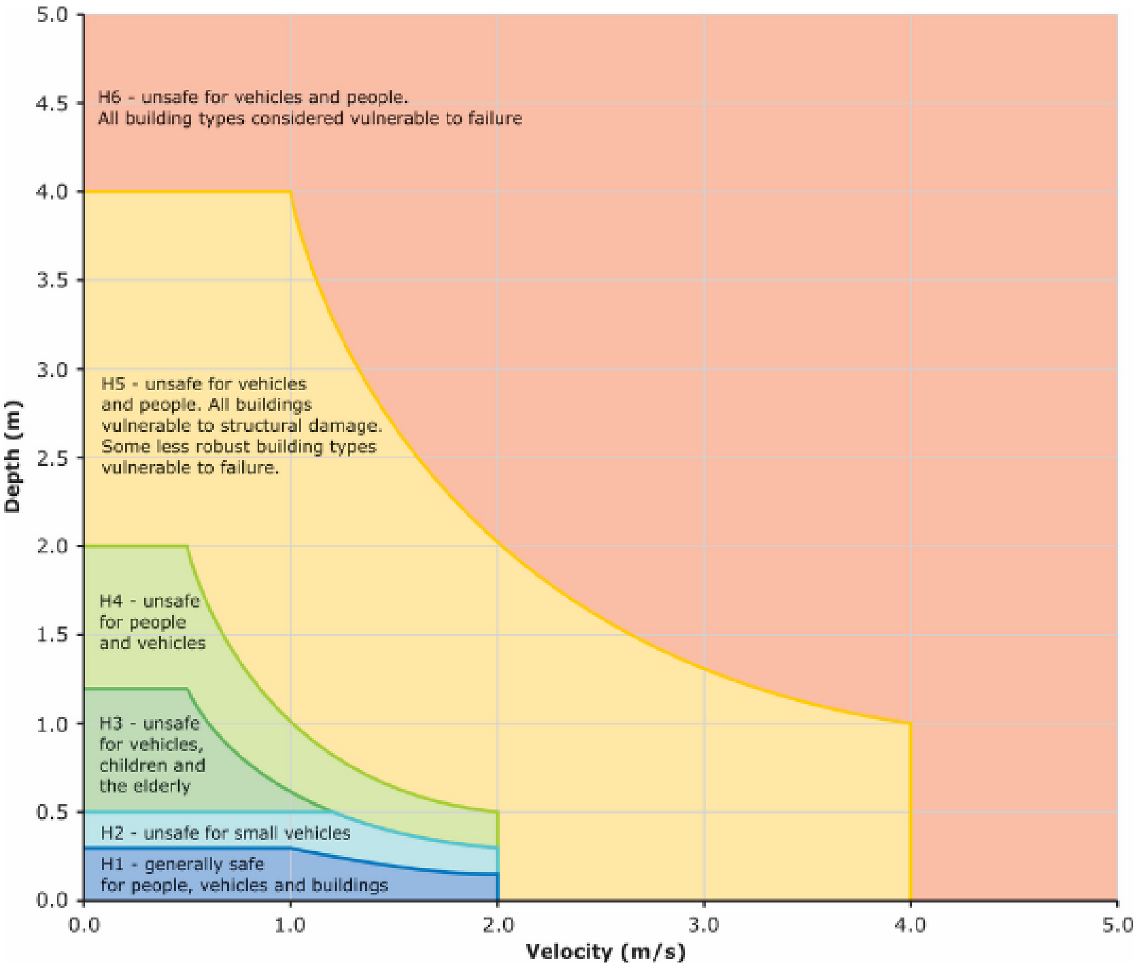


Chart 8-2: Flood Hazard Curves (ARR, 2019)

The ARR (2019) method is defined in both the Australian Rainfall and Runoff Guidelines (Ref 2) and also in the AEMI Handbook 7 Guidelines (Ref 1). 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 1) 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.

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.	

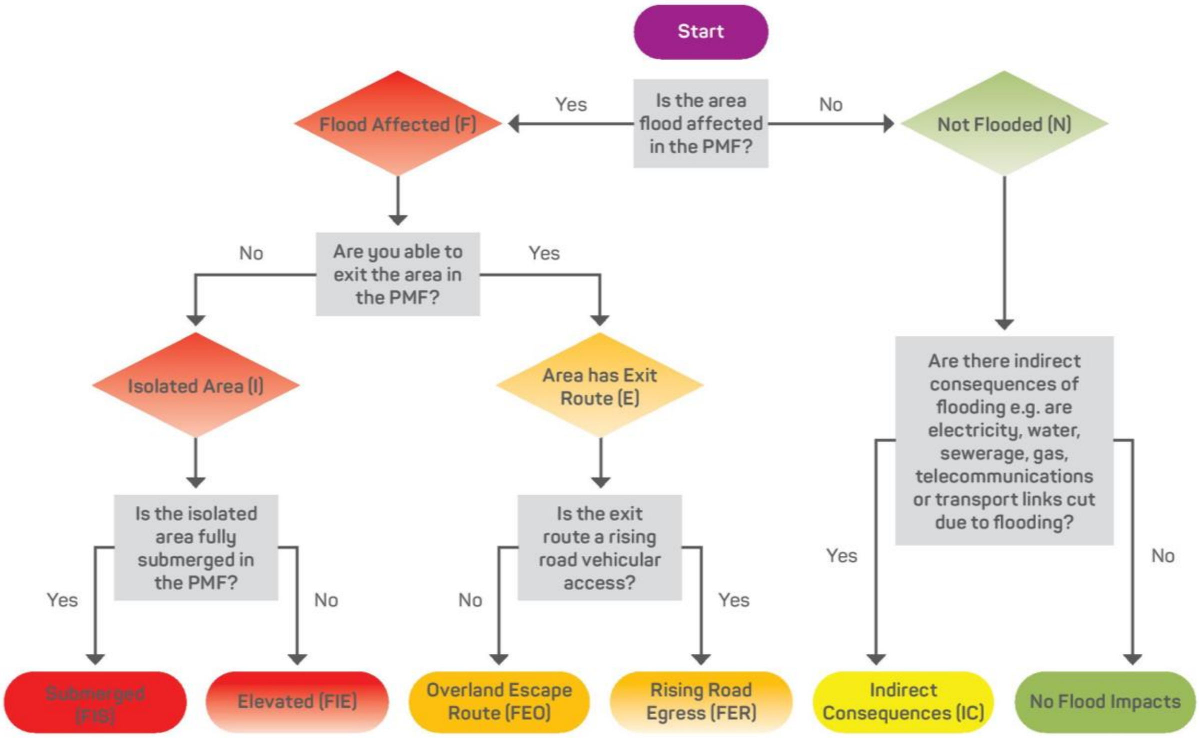


Chart 8-3: Flood Emergency Response Classification Flow Chart (Extracted from the AEMI Handbook 7 Guidelines, 2017)

8.4.2 Results Summary

Figure 12 shows the placement of key locations used within the following to discuss the results of various flooding metrics.

Figure 13 to Figure 20 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	Burrangong Ck - Stream Gauge 412170	2.52	2.54	2.59	2.67	2.73	2.82	2.94	3.50
H02	Burrangong Ck - Stream Gauge 412186	6.11	6.45	6.72	7.04	7.27	7.65	8.09	9.20
H03	Flow Crossing of Mary Gilmore Way	0.74	0.91	1.02	1.16	1.26	1.39	1.54	2.06
H04	Burrangong Ck - Upstream of LLS Fence	3.70	3.72	3.75	3.80	3.85	3.95	4.10	4.76
H05	Mary Gilmore Way - Grenfell St Intersection	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
H06	Young St - Nowlan St Intersection	0.22	0.25	0.31	0.42	0.52	0.65	0.80	1.35
H07	Mary Gilmore Way - Young St Intersection	0.00	0.00	0.02	0.12	0.19	0.30	0.42	0.97
H08	Arramagong St - Bland St Intersection	0.25	0.28	0.34	0.42	0.51	0.65	0.81	1.37
H09	Grenfell St - Caldwell St Intersection	0.08	0.10	0.11	0.22	0.30	0.40	0.51	1.00

Figure 21 to Figure 24 shows the peak flood velocity across the study area for select events ranging from the 5% 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 m/s were predominately experienced in and along the open channels around town with some distributed high velocity flows to the north-east of Bimbi, following Wah Way Creek. However, in events of a larger magnitude (such as the 1% AEP event), the distribution of high velocity flows increased significantly to the north-east of Bimbi along Wah Way Creek and to the east of town along Burrangong Creek. Bimbi proper also began to experience larger areas of moderate to high velocity (0.5 m/s to 1.0 m/s) flows in these larger magnitude events.

Figure 25 to Figure 28 shows the flood hazard categories across the study area for select events ranging from the 5% AEP event to the PMF event. In events of a smaller magnitude (such as the 5% AEP event), the H1 and H2 categories covered the majority of the town, however the hazard categories were more severe in and around Burrangong Creek and Wah Way Creek (up to the H5 and H6 categories). In events of a larger magnitude (such as the 1% AEP event), a portion of the town experienced the H3 category, and a larger area around Wah Way Creek and Burrangong Creek the more sever H4 and H5 categories.

Figure 29 to Figure 32 shows the flood function categories across the study area for select events ranging from the 5% AEP event to the PMF event. Generally, floodways to the south of Bimbi corresponded to Red Creek and Burrangong Creek. However, to the north and east of the town, floodways encroached onto areas surrounding Wah Way Creek and Burrangong Creek in events as small at the 20% AEP. In larger events, these floodways to the north and east of Bimbi expanded to cover a significant area surrounding the creeks. In these events of larger magnitudes (such as the 1% AEP event), floodways and flood storage areas were also identified within Bimbi proper.

9 References

Ref 1: Australian Emergency Management Institute (2017), *Australian Emergency Management Handbook 7: Managing the Floodplain Best Practice in Flood Risk Management in Australia*, AEMI, Canberra

Ref 2: Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019), *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia

Ref 3: BMT WBM (2016), *TUFLOW User Manual*

Ref 4: Boyd, M., Rigby, E., VanDrie, R. (2017), *Watershed Bounded Network Model (WBNM) User Guide*

Ref 5: Chow, V.T. (1959), *Open Channel Hydraulics*, McGraw-Hill, New York

Ref 6: Henderson, F.M. (1966), *Open Channel Flow*, MacMillan, New York

Ref 7: 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 8: NSW Government (2005), *Floodplain Development Manual: The management of flood liable land*, Department of Infrastructure, Planning and Natural Resources, NSW Government, Sydney

Ref 9: NSW Office of Environment and Heritage (2019), *Floodplain Risk Management Guide: Incorporating 2016 Australian Rainfall and Runoff in Studies*, NSW Government

APPENDIX A
GLOSSARY

The following glossary has been extracted from the Australian Emergency Management Handbook 7 (Ref 1).

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.

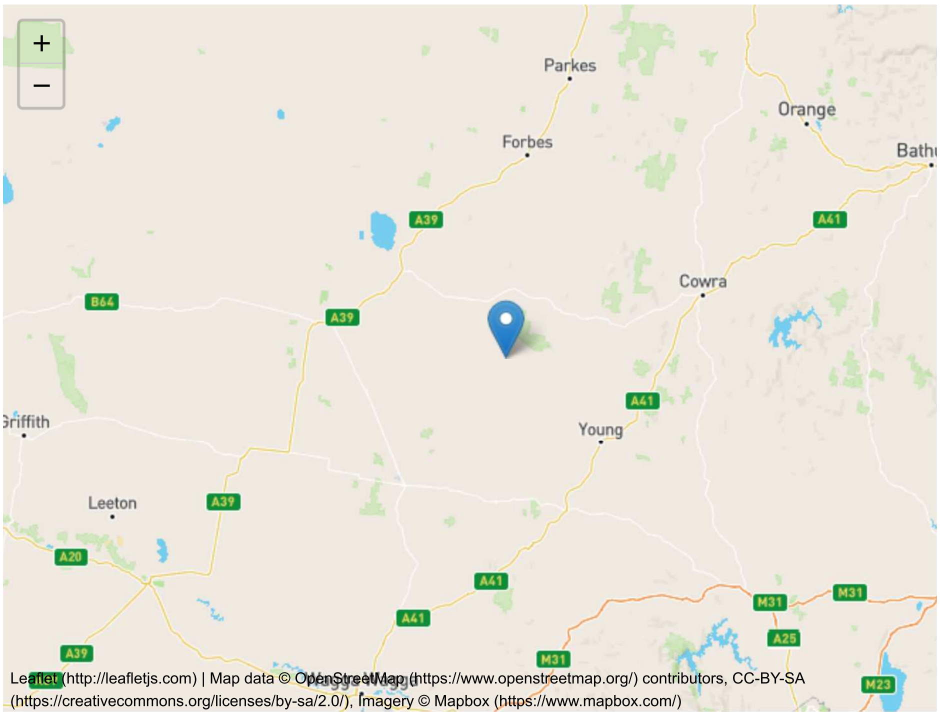
Tidal anomaly	The difference between recorded storm surge levels and predicted astronomical tide level.
Treatment options	The measures that might be feasible for the treatment of existing, future and residual flood risk at particular locations within the floodplain. Preparation of a treatment plan requires 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

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	147.927
Latitude	-34.04
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



Data

River Region

Division	Murray-Darling Basin
River Number	13
River Name	Lachlan River

Layer Info

Time Accessed	16 February 2021 12:55PM
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
Central NSW	0.265	0.241	0.505	0.321	0.00056	0.414	-0.021	0.015	-0.00033

Short Duration ARF

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

Layer Info

Time Accessed	16 February 2021 12:55PM
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.

ID	2722.0
Storm Initial Losses (mm)	30.0
Storm Continuing Losses (mm/h)	1.7

Layer Info

Time Accessed	16 February 2021 12:55PM
Version	2016_v1

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

code	MB
Label	Murray Basin

Layer Info

Time Accessed	16 February 2021 12:55PM
Version	2016_v2

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

code	MB
arealabel	Murray Basin

Layer Info

Time Accessed	16 February 2021 12:55PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.0404&longitude=147.9268&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	16 February 2021 12:55PM

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)	3.5 (0.183)	2.6 (0.099)	2.1 (0.065)	1.5 (0.041)	1.1 (0.026)	0.8 (0.017)
90 (1.5)	2.2 (0.101)	1.6 (0.052)	1.1 (0.032)	0.8 (0.018)	0.7 (0.014)	0.6 (0.011)
120 (2.0)	2.8 (0.116)	1.8 (0.056)	1.2 (0.031)	0.7 (0.014)	0.4 (0.008)	0.3 (0.004)
180 (3.0)	1.8 (0.068)	1.5 (0.041)	1.3 (0.030)	1.1 (0.021)	0.6 (0.010)	0.3 (0.004)
360 (6.0)	2.2 (0.064)	1.2 (0.027)	0.6 (0.012)	0.1 (0.001)	0.9 (0.011)	1.5 (0.017)
720 (12.0)	0.1 (0.002)	1.0 (0.017)	1.6 (0.023)	2.1 (0.027)	5.8 (0.062)	8.5 (0.082)
1080 (18.0)	0.0 (0.000)	0.5 (0.007)	0.8 (0.010)	1.1 (0.012)	3.6 (0.034)	5.4 (0.046)
1440 (24.0)	0.0 (0.000)	0.2 (0.002)	0.3 (0.003)	0.4 (0.004)	1.0 (0.009)	1.5 (0.011)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.001)
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	16 February 2021 12:55PM
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	16 February 2021 12:55PM
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)	0.1 (0.007)	0.1 (0.003)	0.1 (0.002)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.001)	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	16 February 2021 12:55PM
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)	13.7 (0.725)	13.0 (0.491)	12.5 (0.394)	12.0 (0.324)	12.4 (0.280)	12.7 (0.253)
90 (1.5)	14.3 (0.662)	11.7 (0.389)	10.0 (0.277)	8.3 (0.198)	9.2 (0.182)	9.8 (0.172)
120 (2.0)	13.6 (0.577)	11.3 (0.344)	9.8 (0.249)	8.3 (0.181)	7.3 (0.133)	6.6 (0.106)
180 (3.0)	10.0 (0.370)	12.5 (0.334)	14.2 (0.317)	15.8 (0.304)	15.3 (0.247)	14.9 (0.214)
360 (6.0)	13.3 (0.392)	12.1 (0.261)	11.4 (0.206)	10.6 (0.167)	20.0 (0.265)	27.1 (0.319)
720 (12.0)	5.2 (0.122)	9.0 (0.155)	11.5 (0.168)	13.9 (0.176)	25.5 (0.275)	34.3 (0.330)
1080 (18.0)	2.3 (0.049)	6.5 (0.099)	9.2 (0.119)	11.9 (0.133)	17.8 (0.170)	22.3 (0.191)
1440 (24.0)	0.6 (0.011)	3.6 (0.050)	5.6 (0.066)	7.5 (0.077)	11.3 (0.099)	14.2 (0.111)
2160 (36.0)	0.0 (0.000)	1.7 (0.022)	2.9 (0.030)	4.0 (0.036)	5.6 (0.044)	6.8 (0.048)
2880 (48.0)	0.0 (0.000)	1.3 (0.015)	2.1 (0.021)	2.9 (0.025)	4.1 (0.030)	5.0 (0.032)
4320 (72.0)	0.0 (0.000)	0.1 (0.001)	0.1 (0.001)	0.2 (0.001)	0.3 (0.002)	0.3 (0.002)

Layer Info

Time Accessed	16 February 2021 12:55PM
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)	31.9 (1.692)	27.6 (1.049)	24.8 (0.783)	22.1 (0.596)	28.2 (0.634)	32.7 (0.651)
90 (1.5)	33.7 (1.566)	30.0 (0.998)	27.5 (0.763)	25.2 (0.597)	27.3 (0.542)	29.0 (0.509)
120 (2.0)	32.4 (1.372)	30.1 (0.915)	28.6 (0.724)	27.1 (0.589)	29.1 (0.531)	30.7 (0.495)
180 (3.0)	19.5 (0.724)	25.5 (0.683)	29.5 (0.661)	33.3 (0.642)	34.6 (0.559)	35.5 (0.510)
360 (6.0)	25.9 (0.765)	29.2 (0.628)	31.4 (0.568)	33.5 (0.524)	51.5 (0.682)	65.0 (0.768)
720 (12.0)	17.6 (0.416)	29.0 (0.501)	36.5 (0.534)	43.8 (0.555)	62.0 (0.667)	75.6 (0.728)
1080 (18.0)	14.7 (0.306)	21.1 (0.322)	25.3 (0.327)	29.4 (0.329)	45.5 (0.434)	57.6 (0.492)
1440 (24.0)	9.3 (0.178)	14.9 (0.209)	18.6 (0.221)	22.2 (0.228)	29.8 (0.261)	35.5 (0.279)
2160 (36.0)	2.8 (0.048)	8.4 (0.106)	12.1 (0.128)	15.6 (0.143)	18.0 (0.141)	19.8 (0.139)
2880 (48.0)	0.8 (0.012)	8.2 (0.097)	13.1 (0.130)	17.8 (0.152)	21.4 (0.156)	24.2 (0.157)
4320 (72.0)	0.2 (0.003)	5.7 (0.062)	9.3 (0.084)	12.7 (0.099)	12.3 (0.081)	11.9 (0.071)

Layer Info

Time Accessed	16 February 2021 12:55PM
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	**0.816 (4.1%)**	0.726 (3.6%)	**0.934 (4.7%)**
2040	**1.046 (5.2%)**	1.015 (5.1%)	**1.305 (6.6%)**
2050	**1.260 (6.3%)**	1.277 (6.4%)	**1.737 (8.8%)**
2060	**1.450 (7.3%)**	1.520 (7.7%)	**2.214 (11.4%)**
2070	**1.609 (8.2%)**	1.753 (8.9%)	**2.722 (14.2%)**
2080	**1.728 (8.8%)**	1.985 (10.2%)	**3.246 (17.2%)**
2090	**1.798 (9.2%)**	2.226 (11.5%)	**3.772 (20.2%)**

Layer Info

Time Accessed	16 February 2021 12:55PM
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(%)	50.0	20.0	10.0	5.0	2.0	1.0
60 (1.0)	17.9	10.3	10.3	11.0	10.8	9.6
90 (1.5)	18.0	11.3	11.2	12.2	12.0	9.9
120 (2.0)	18.0	11.8	11.6	12.7	12.5	10.4
180 (3.0)	19.6	13.7	11.9	12.4	10.8	8.6
360 (6.0)	18.4	13.9	13.4	14.0	12.1	6.5
720 (12.0)	21.4	15.9	14.7	13.9	10.9	5.1
1080 (18.0)	22.5	18.0	16.6	16.7	13.5	8.6
1440 (24.0)	24.1	19.7	19.6	19.7	16.2	10.5
2160 (36.0)	25.8	21.6	21.6	22.4	20.4	13.6
2880 (48.0)	26.4	22.0	22.0	23.0	20.9	14.0
4320 (72.0)	26.8	23.1	24.0	25.5	22.7	18.6

Layer Info

Time Accessed	16 February 2021 12:55PM
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.

Download TXT (downloads/345fa5a7-d3bd-4393-aee2-51bfa8cced45.txt)

Download JSON (downloads/aad2d7bc-e8ad-44c9-b7b6-3135cb2bf5c9.json)

Generating PDF... (downloads/98ad8265-9f67-4a33-9a35-b954901e3b71.pdf)

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 *	10.3	10.3	11.0	10.8	9.6
20 *	10.3	10.3	11.0	10.8	9.6
25 *	10.3	10.3	11.0	10.8	9.6
30 *	10.3	10.3	11.0	10.8	9.6
45 *	10.3	10.3	11.0	10.8	9.6
60	10.3	10.3	11.0	10.8	9.6
90	11.3	11.2	12.2	12.0	9.9
120	11.8	11.6	12.7	12.5	10.4
180	13.7	11.9	12.4	10.8	8.6
270 #	13.8	12.7	13.2	11.5	7.6
360	13.9	13.4	14.0	12.1	6.5
540 #	14.9	14.1	14.0	11.5	5.8
720	15.9	14.7	13.9	10.9	5.1
1440	19.7	19.6	19.7	16.2	10.5
2880	22.0	22.0	23.0	20.9	14.0
4320	23.1	24.0	25.5	22.7	18.6

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	1.000	1.000	1.000	1.000	1.000	1.000	1.000
20 min	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25 min	1.000	1.000	1.000	1.000	1.000	1.000	1.000
30 min	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45 min	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1 hour	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.5 hour	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2 hour	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3 hour	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4.5 hour	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6 hour	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9 hour	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12 hour	0.833	0.825	0.817	0.806	0.798	0.790	0.779
24 hour	0.883	0.879	0.874	0.869	0.864	0.860	0.854
30 hour	0.893	0.889	0.885	0.879	0.875	0.871	0.866
36 hour	0.900	0.896	0.892	0.887	0.833	0.880	0.875
48 hour	0.910	0.906	0.903	0.898	0.895	0.892	0.887
72 hour	0.922	0.919	0.916	0.912	0.909	0.906	0.902
96 hour	0.930	0.927	0.924	0.920	0.917	0.914	0.910
120 hour	0.935	0.932	0.929	0.925	0.922	0.920	0.916
144 hour	0.939	0.936	0.933	0.930	0.927	0.924	0.920
168 hour	0.943	0.940	0.937	0.933	0.930	0.927	0.923

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 9-3Table 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	14.60	16.00
20% AEP	20	16.60	18.20
20% AEP	25	18.20	20.00
20% AEP	30	19.60	21.40
20% AEP	45	22.70	24.70

20% AEP	60	25.10	27.20
20% AEP	90	28.80	31.00
20% AEP	120	31.70	34.10
20% AEP	180	36.40	39.10
20% AEP	270	41.70	45.10
20% AEP	360	45.90	50.00
20% AEP	540	52.30	57.90
20% AEP	720	47.82	53.41
20% AEP	1440	62.45	71.11
20% AEP	2880	76.61	87.89
20% AEP	4320	84.21	96.84
20% AEP	5760	89.00	102.30
20% AEP	7200	92.32	106.63
10% AEP	15	17.50	19.10
10% AEP	20	19.90	21.70
10% AEP	25	21.80	23.80
10% AEP	30	23.40	25.50
10% AEP	45	27.20	29.50
10% AEP	60	30.00	32.50
10% AEP	90	34.40	36.90
10% AEP	120	37.80	40.40
10% AEP	180	43.30	46.20
10% AEP	270	49.40	53.00
10% AEP	360	54.20	58.60
10% AEP	540	61.50	67.60
10% AEP	720	55.52	61.71
10% AEP	1440	72.68	82.53
10% AEP	2880	89.65	102.43
10% AEP	4320	99.27	113.06
10% AEP	5760	104.75	120.50
10% AEP	7200	109.09	125.87
5% AEP	15	20.40	22.20
5% AEP	20	23.20	25.30
5% AEP	25	25.40	27.70
5% AEP	30	27.30	29.70
5% AEP	45	31.70	34.40

5% AEP	60	35.00	37.80
5% AEP	90	40.00	42.90
5% AEP	120	44.00	46.90
5% AEP	180	50.20	53.30
5% AEP	270	57.10	60.90
5% AEP	360	62.40	67.10
5% AEP	540	70.50	77.10
5% AEP	720	62.81	69.51
5% AEP	1440	82.46	93.57
5% AEP	2880	102.04	117.39
5% AEP	4320	112.68	131.00
5% AEP	5760	119.19	139.52
5% AEP	7200	124.54	144.98
2% AEP	15	24.30	26.50
2% AEP	20	27.70	30.20
2% AEP	25	30.40	33.10
2% AEP	30	32.70	35.50
2% AEP	45	37.90	41.10
2% AEP	60	41.80	45.10
2% AEP	90	47.80	51.10
2% AEP	120	52.40	55.70
2% AEP	180	59.60	63.00
2% AEP	270	67.50	71.60
2% AEP	360	73.40	78.60
2% AEP	540	82.50	89.80
2% AEP	720	72.29	79.63
2% AEP	1440	94.68	107.71
2% AEP	2880	117.70	135.67
2% AEP	4320	130.41	152.30
2% AEP	5760	138.91	161.91
2% AEP	7200	145.30	169.36
1% AEP	15	27.40	29.90
1% AEP	20	31.30	34.10
1% AEP	25	34.30	37.40
1% AEP	30	36.90	40.20
1% AEP	45	42.80	46.40

1% AEP	60	47.20	51.00
1% AEP	90	53.90	57.70
1% AEP	120	59.00	62.80
1% AEP	180	67.00	70.50
1% AEP	270	75.60	79.90
1% AEP	360	81.90	87.40
1% AEP	540	91.70	99.50
1% AEP	720	79.30	86.95
1% AEP	1440	104.57	118.40
1% AEP	2880	129.78	150.37
1% AEP	4320	143.60	168.14
1% AEP	5760	154.05	179.72
1% AEP	7200	161.43	187.26
0.5% AEP	15	30.20	32.90
0.5% AEP	20	34.40	37.50
0.5% AEP	25	37.80	41.20
0.5% AEP	30	40.60	44.20
0.5% AEP	45	47.10	51.10
0.5% AEP	60	51.90	56.10
0.5% AEP	90	59.30	63.50
0.5% AEP	120	65.00	69.00
0.5% AEP	180	73.80	77.70
0.5% AEP	270	83.10	88.10
0.5% AEP	360	90.10	96.50
0.5% AEP	540	101.00	110.00
0.5% AEP	720	86.06	95.53
0.5% AEP	1440	114.36	129.83
0.5% AEP	2880	140.88	164.06
0.5% AEP	4320	156.69	183.86
0.5% AEP	5760	169.08	196.50
0.5% AEP	7200	178.38	205.97
0.2% AEP	15	33.80	36.90
0.2% AEP	20	38.50	42.10
0.2% AEP	25	42.20	46.20
0.2% AEP	30	45.30	49.60
0.2% AEP	45	52.60	57.40

0.2% AEP	60	58.00	63.20
0.2% AEP	90	66.20	71.60
0.2% AEP	120	72.50	78.00
0.2% AEP	180	82.40	87.80
0.2% AEP	270	92.60	98.80
0.2% AEP	360	100.00	108.00
0.2% AEP	540	112.00	123.00
0.2% AEP	720	95.00	105.90
0.2% AEP	1440	126.39	145.18
0.2% AEP	2880	155.25	182.75
0.2% AEP	4320	174.91	204.67
0.2% AEP	5760	189.27	219.30
0.2% AEP	7200	200.51	230.73

C.4 Critical Temporal Pattern and Storm Duration

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 BIM_100	Inflow BIM_200	Inflow BIM_400	Inflow BIM_500	
20% AEP	540 minute TP07	540 minute TP03	360 minute TP05	540 minute TP09	540 minute TP09
10% AEP	540 minute TP07	540 minute TP09	540 minute TP07	540 minute TP07	540 minute TP07
5% AEP	540 minute TP04	540 minute TP09	540 minute TP09	540 minute TP07	540 minute TP07
2% AEP	540 minute TP04	540 minute TP09	540 minute TP09	540 minute TP07	540 minute TP07
1% AEP	540 minute TP06	540 minute TP06	360 minute TP02	540 minute TP06	540 minute TP06
0.5% AEP	540 minute TP06	540 minute TP06	360 minute TP03	540 minute TP06	540 minute TP06
0.2% AEP	540 minute TP06	540 minute TP06	360 minute TP03	540 minute TP06	540 minute TP06

C.4.1 20% AEP Event

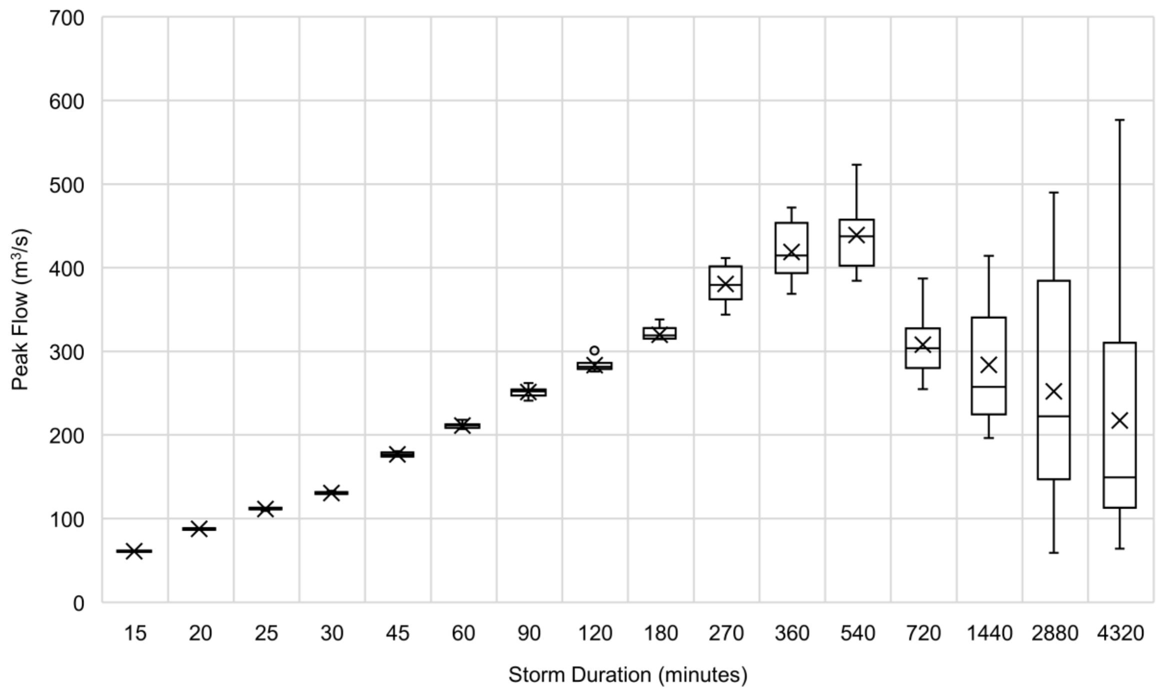


Chart 9-1: Box and Whisker Plot - 20% AEP Event - Inflow BIM_200

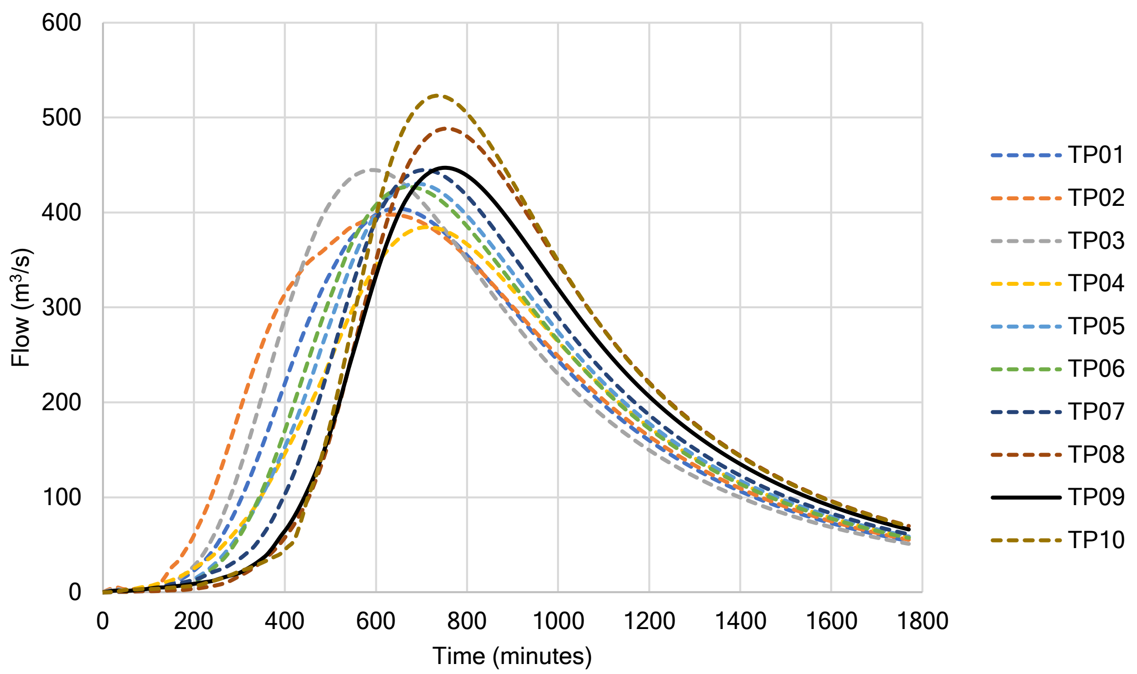


Chart 9-2: Hydrographs - 20% AEP 540 minute storm duration - Inflow BIM_200

C.4.2 5% AEP Event

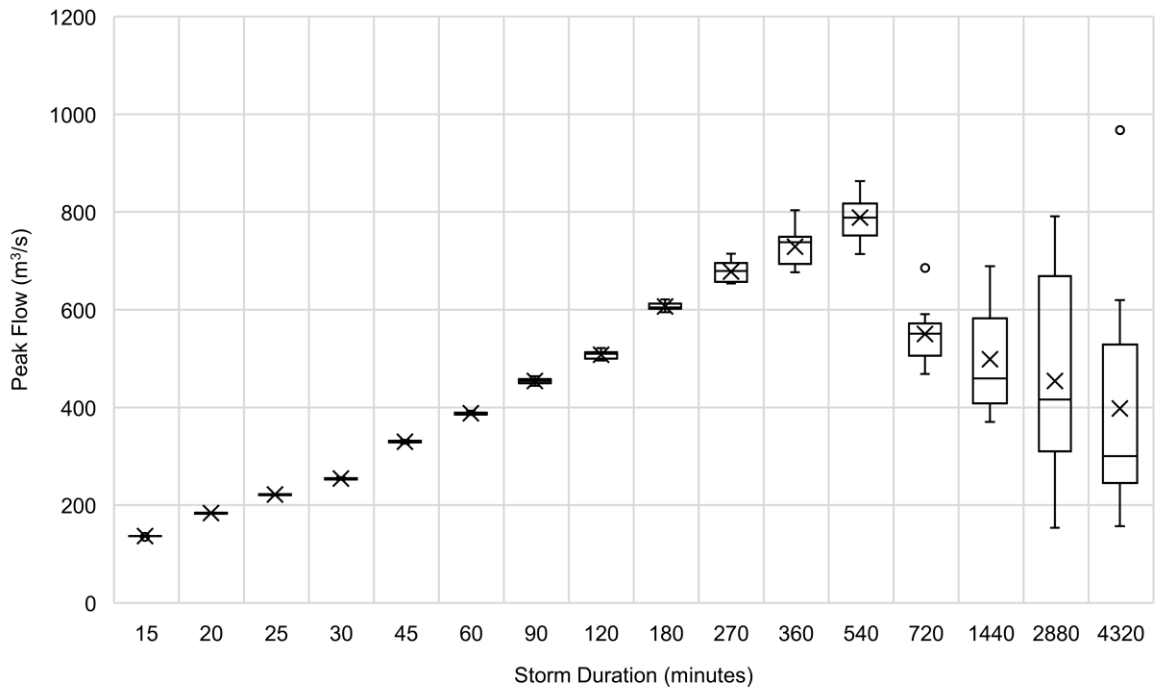


Chart 9-3 : Box and Whisker Plot - 5% AEP Event - Inflow BIM_200

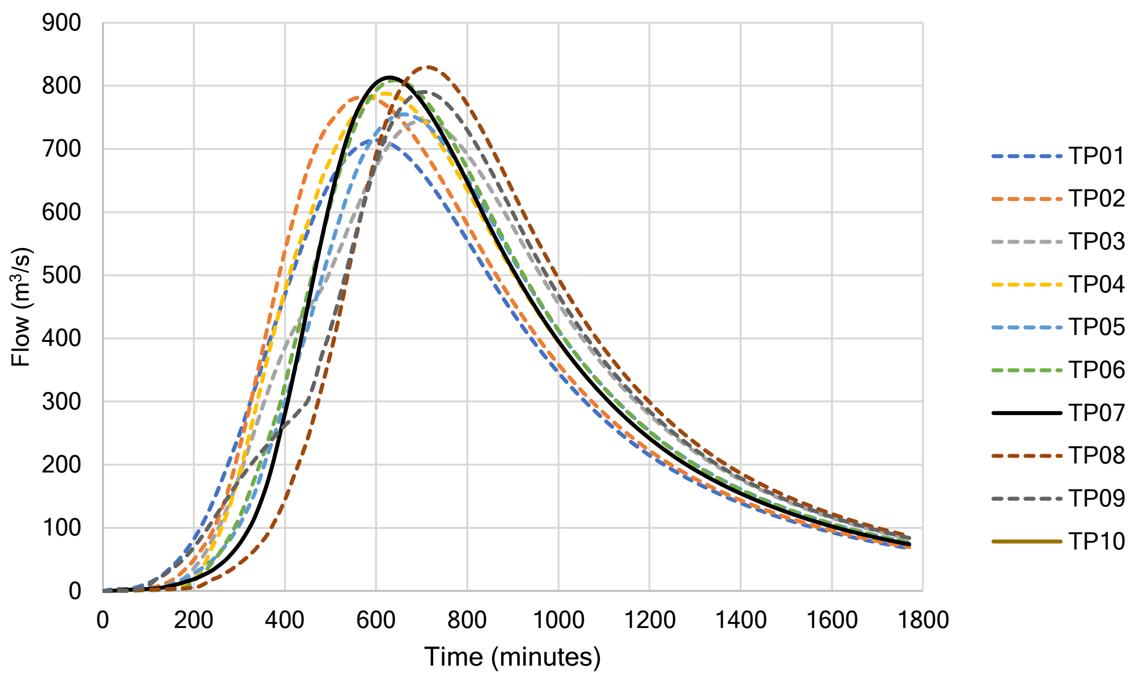


Chart 9-4: Hydrographs - 5% AEP 540 minute storm duration - Inflow BIM_200

C.4.3 1% AEP Event

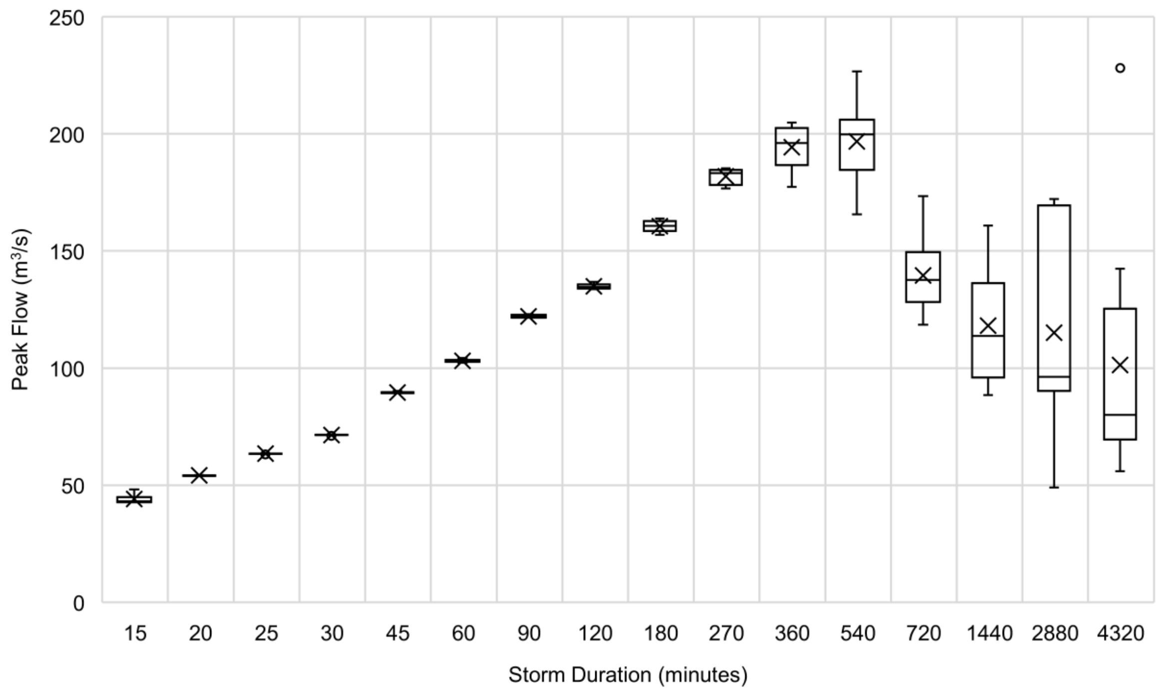


Chart 9-5: Box and Whisker Plot - 1% AEP Event - Inflow BIM_100

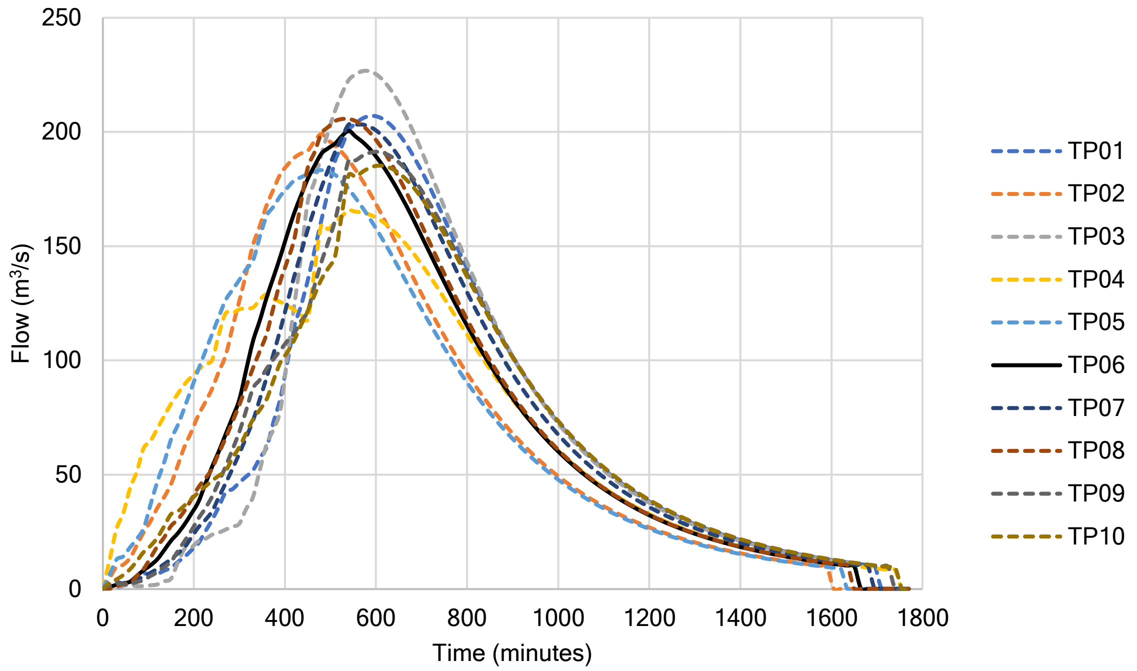


Chart 9-6: Hydrographs - 1% AEP 540 minute storm duration - Inflow BIM_100

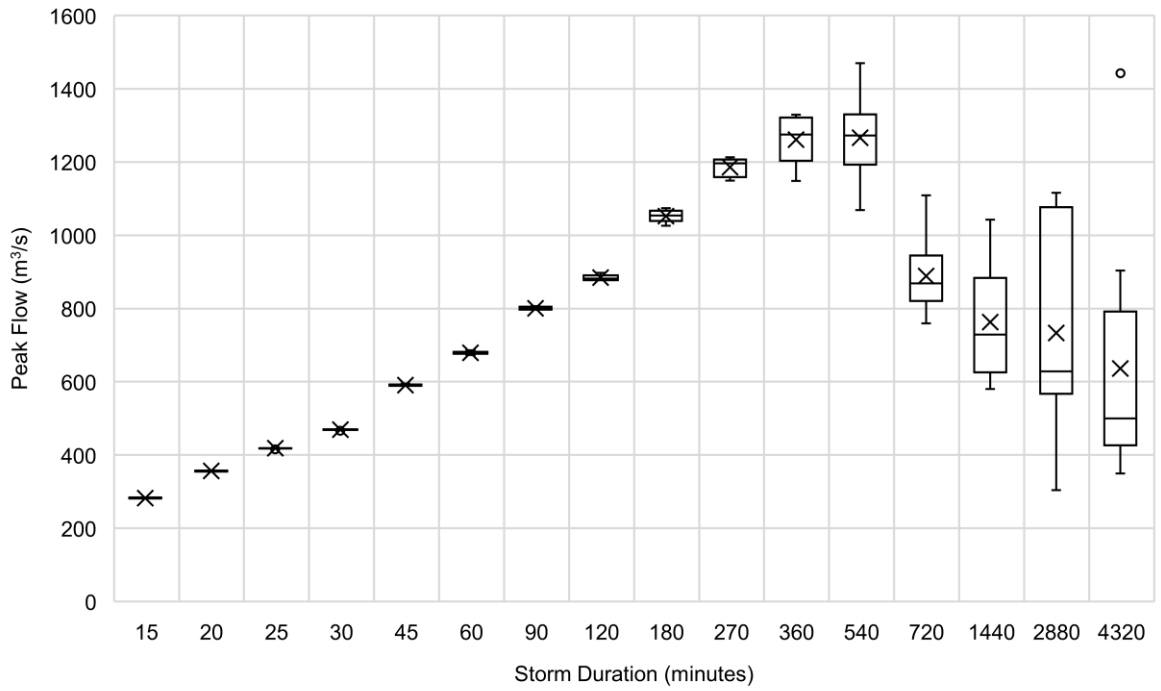


Chart 9-7: Box and Whisker Plot - 1% AEP Event - Inflow BIM_200

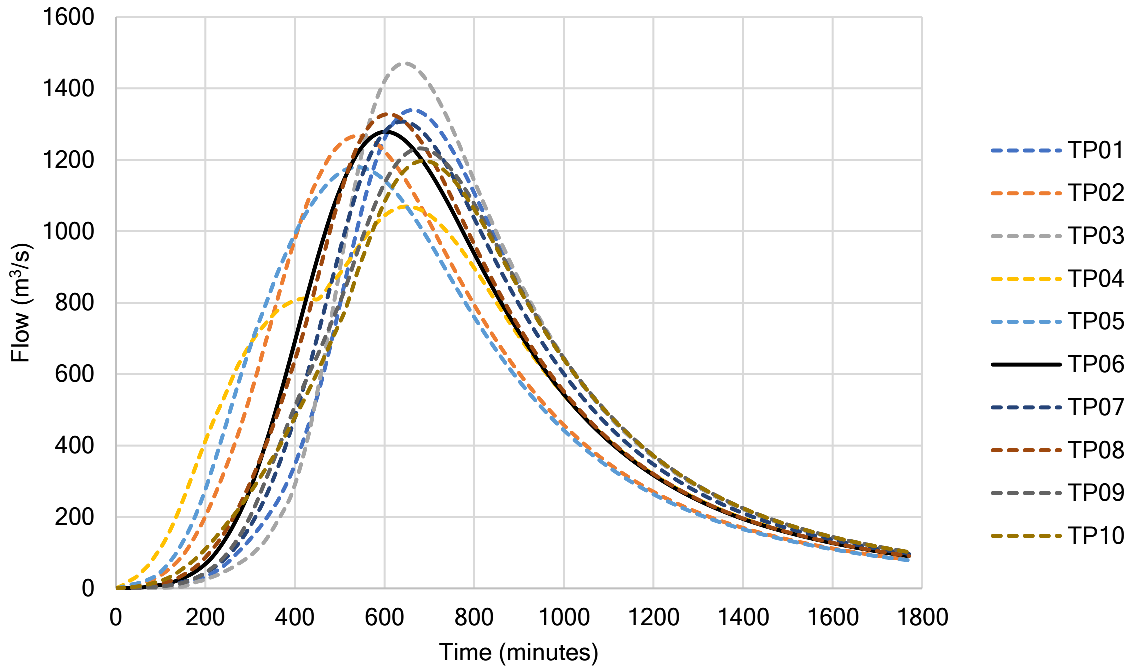


Chart 9-8: Hydrographs - 1% AEP 540 minute storm duration - Inflow BIM_200

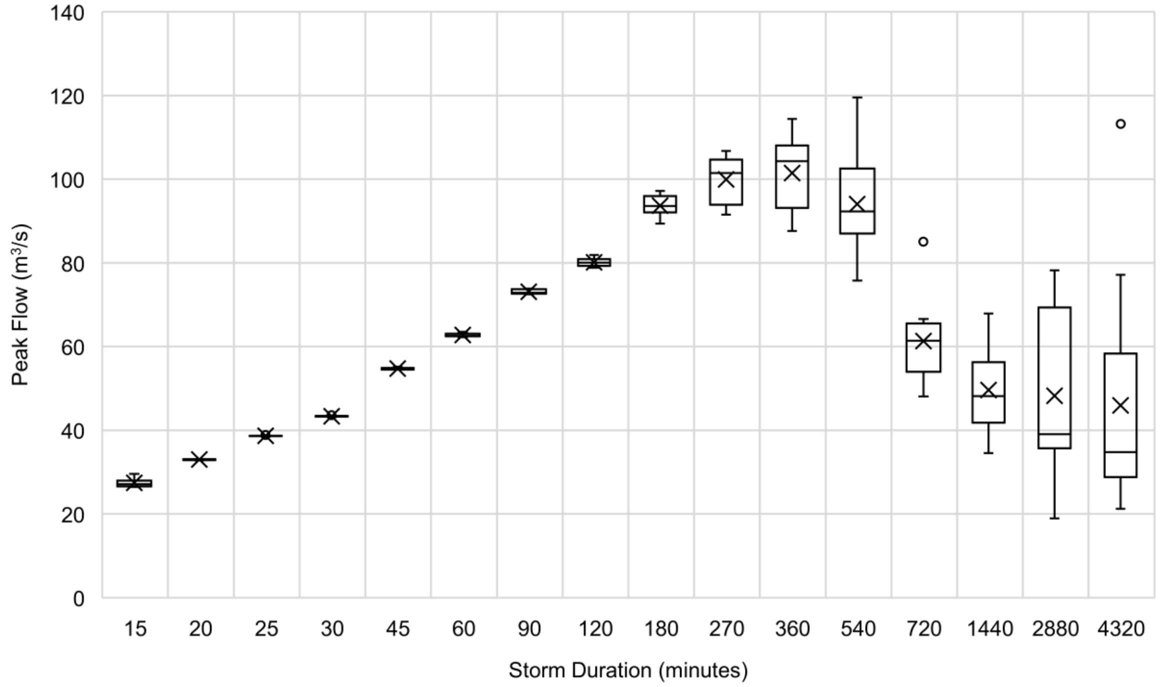


Chart 9-9: Box and Whisker Plot - 1% AEP Event - Inflow BIM_400

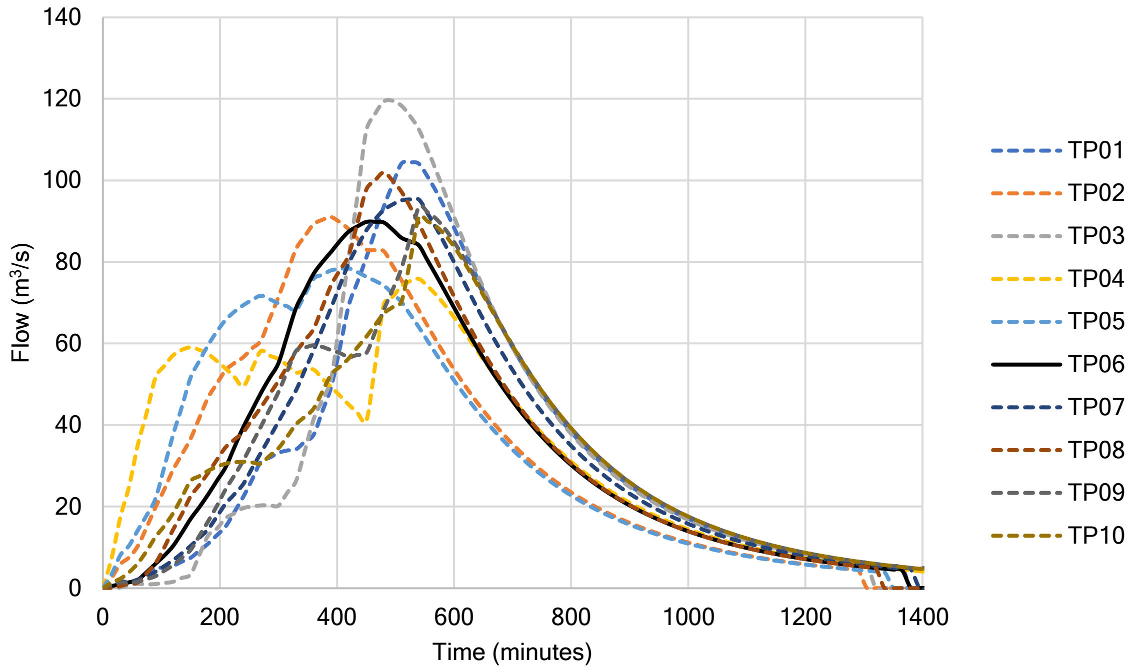


Chart 9-10: Hydrographs - 1% AEP 540 minute storm duration - Inflow BIM_400

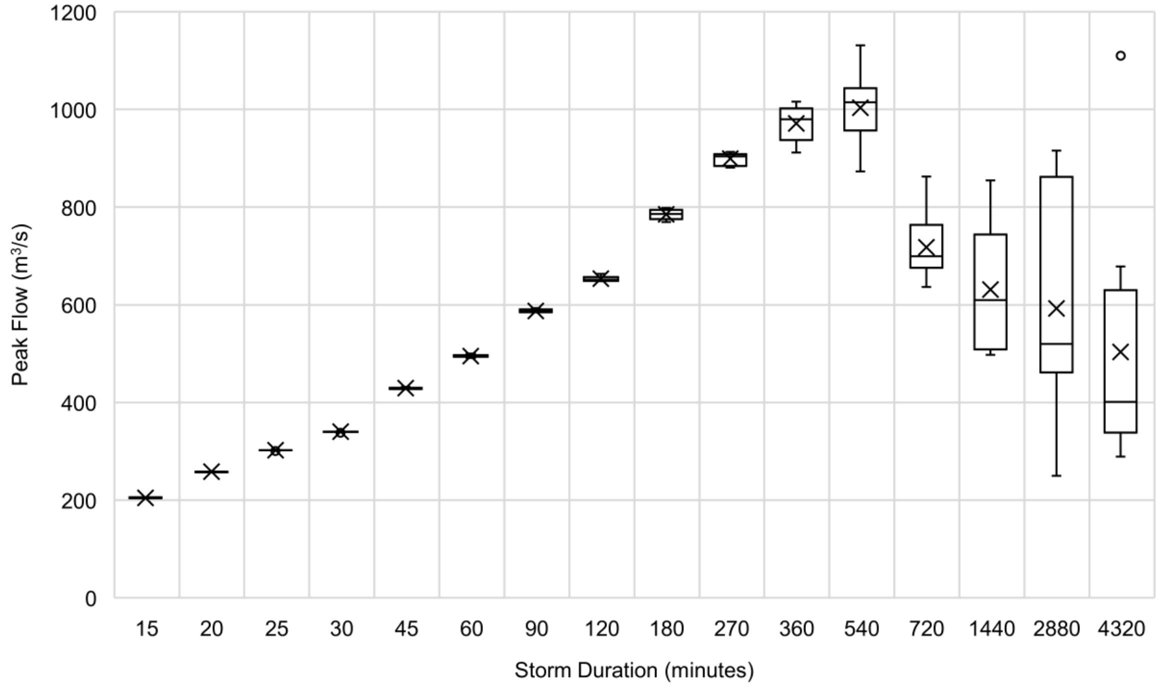


Chart 9-11: Box and Whisker Plot - 1% AEP Event - Inflow BIM_500

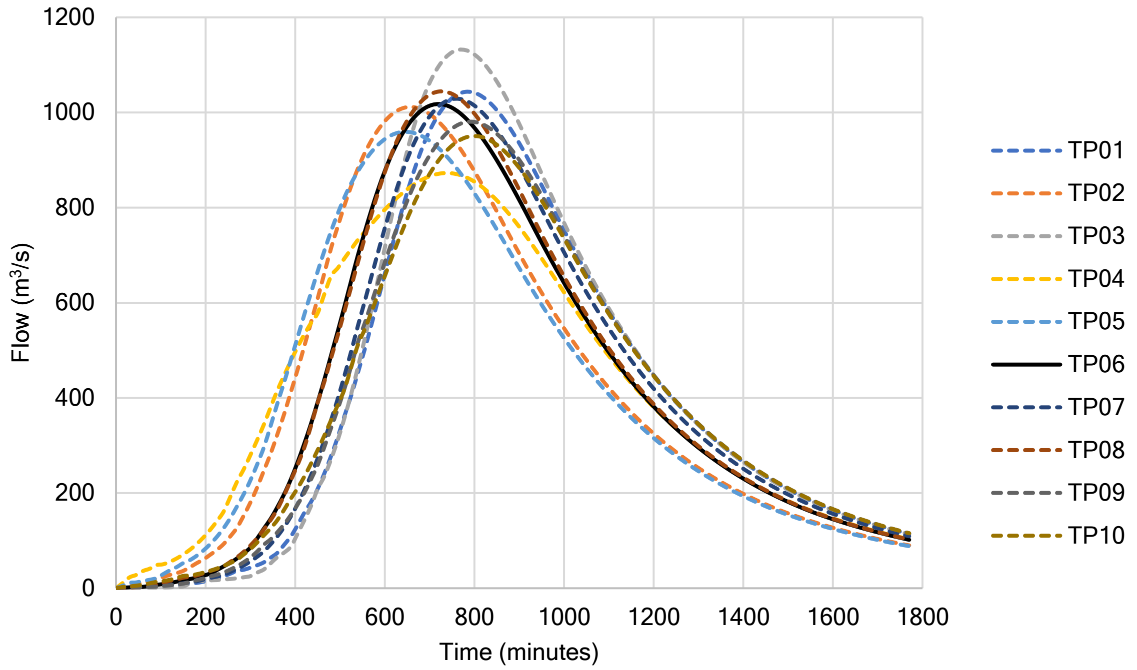


Chart 9-12: Hydrographs - 1% AEP 540 minute storm duration - Inflow BIM_500

APPENDIX D
DESIGN PARAMETER SENSITIVITY

D.1 Rainfall Temporal Patterns

Table 9-5: Peak Flood Level Difference (m) - Minimum Flow Temporal Pattern

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	0.001	-0.021	-0.042
H02	Burrangong Ck - Stream Gauge 412186	-0.135	-0.129	-0.219
H03	Flow Crossing of Mary Gilmore Way	-0.056	-0.044	-0.067
H04	Burrangong Ck - Upstream of LLS Fence	0.000	-0.014	-0.031
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	0.001	-0.028	-0.061
H07	Mary Gilmore Way - Young St Intersection	0.000	0.000	-0.050
H08	Arramagong St - Bland St Intersection	0.000	-0.027	-0.053
H09	Grenfell St - Caldwell St Intersection	-0.012	-0.021	-0.052

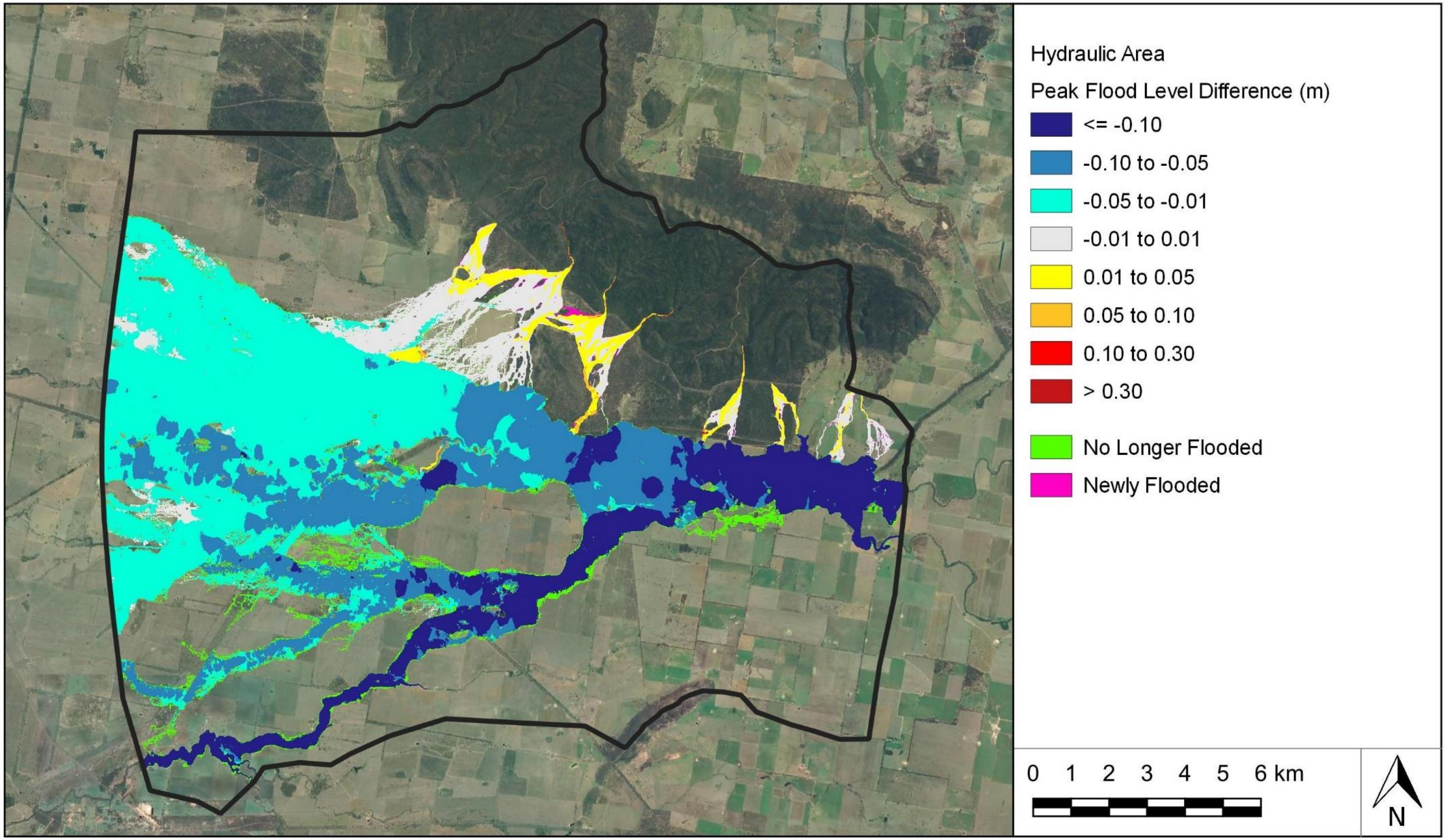


Image 9-1: 1% AEP Peak Flood Level Difference (m) - Minimum Flow Temporal Pattern

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

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	0.001	0.012	0.030
H02	Burrangong Ck - Stream Gauge 412186	0.144	0.064	0.172
H03	Flow Crossing of Mary Gilmore Way	0.067	0.025	0.047
H04	Burrangong Ck - Upstream of LLS Fence	0.000	0.009	0.030
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	0.004	0.018	0.044
H07	Mary Gilmore Way - Young St Intersection	0.000	0.015	0.035
H08	Arramagong St - Bland St Intersection	0.004	0.016	0.045
H09	Grenfell St - Caldwell St Intersection	0.040	0.004	0.033

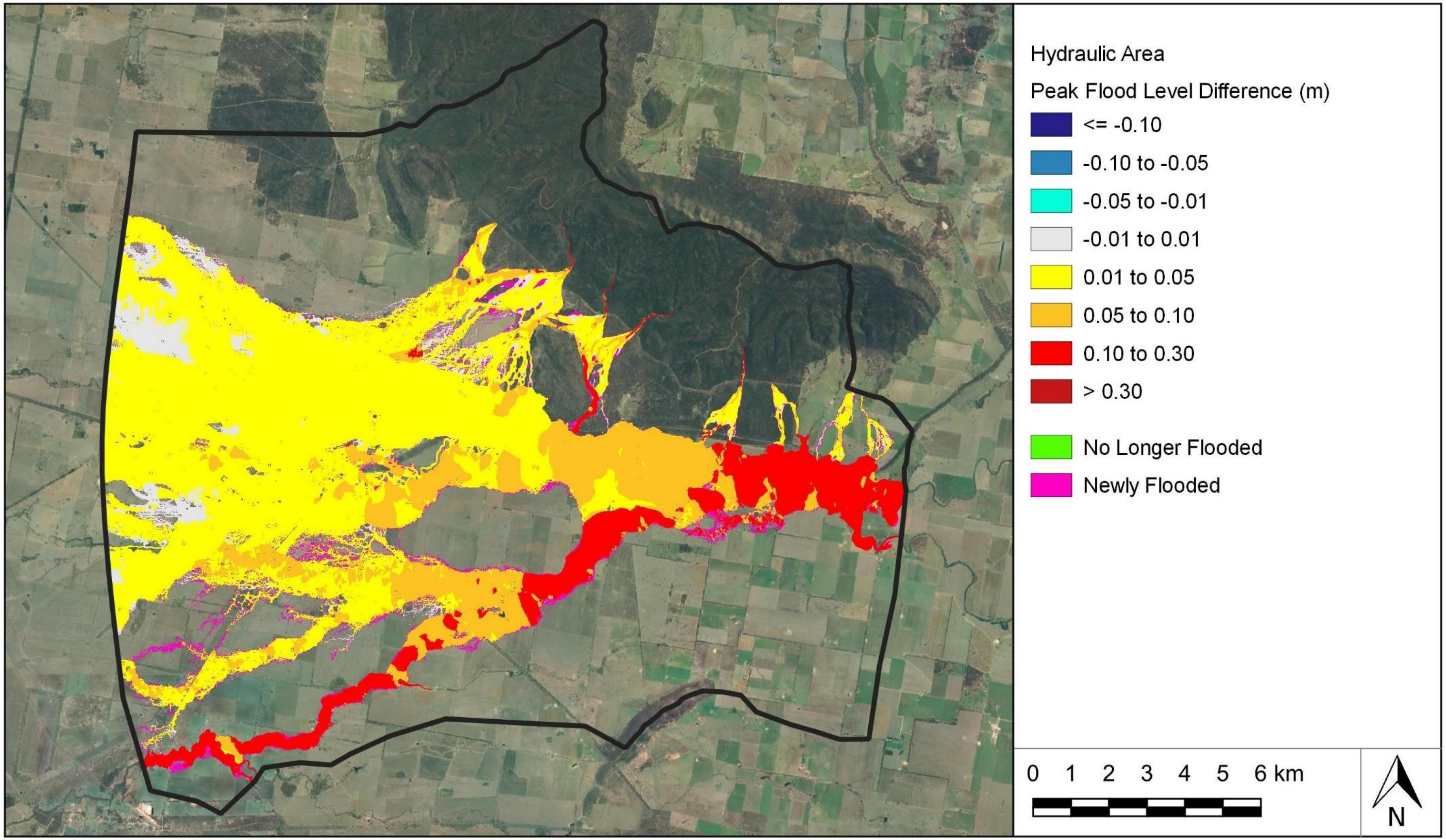


Image 9-2: 1% AEP Peak Flood Level Difference (m) - Maximum Flow Temporal Pattern

D.2 Rainfall Losses

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

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	0.002	0.026	0.023
H02	Burrangong Ck - Stream Gauge 412186	0.124	0.107	0.096
H03	Flow Crossing of Mary Gilmore Way	0.062	0.047	0.035
H04	Burrangong Ck - Upstream of LLS Fence	0.002	0.019	0.023
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	0.004	0.037	0.035
H07	Mary Gilmore Way - Young St Intersection	0.000	0.031	0.027
H08	Arramagong St - Bland St Intersection	0.003	0.032	0.036
H09	Grenfell St - Caldwell St Intersection	0.002	0.016	0.026

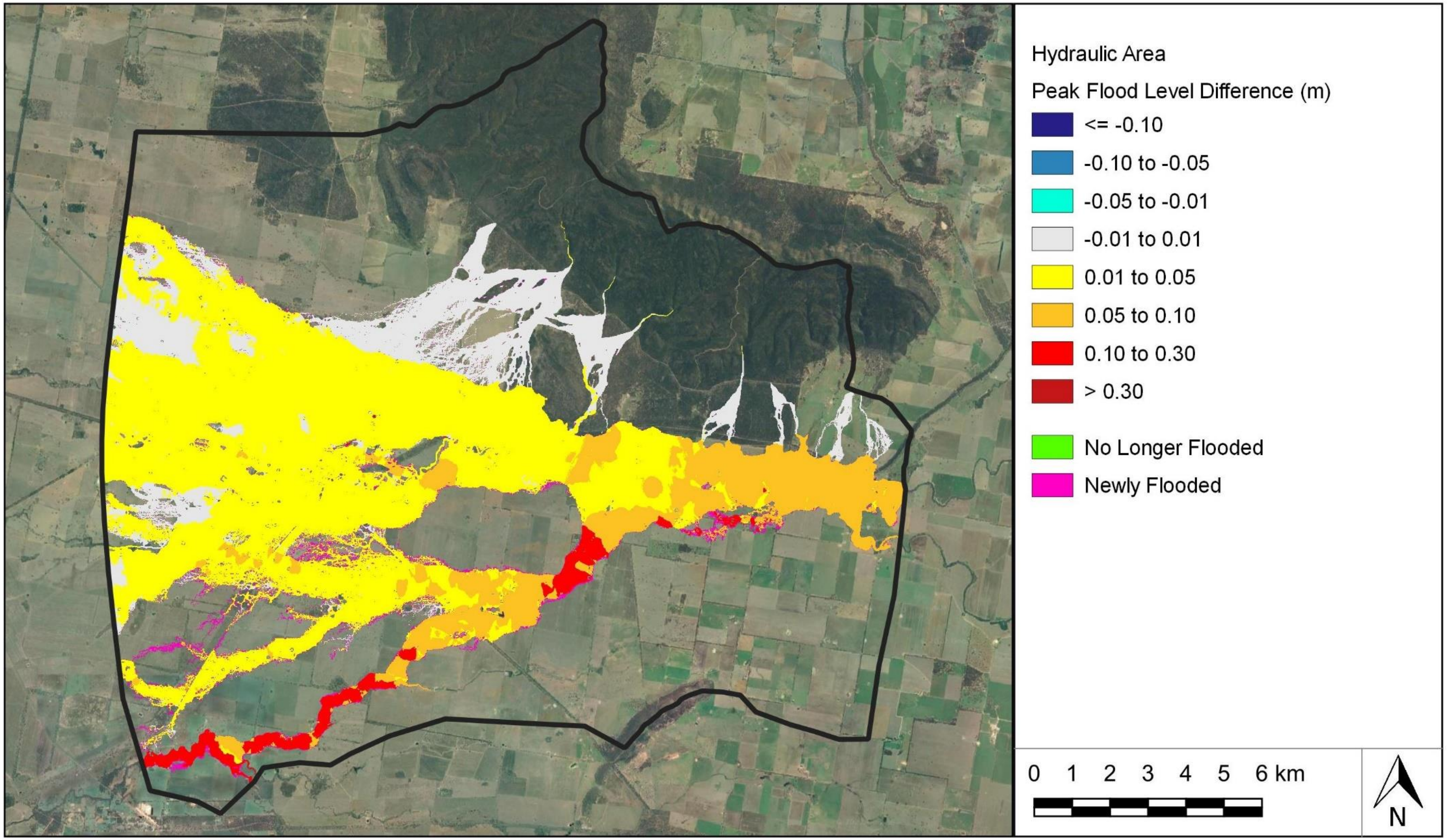


Image 9-2: 1% AEP Peak Flood Level Difference (m) - Rainfall Continuing Losses Adjusted by 60%

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

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	-0.053	-0.003	-0.069
H02	Burrangong Ck - Stream Gauge 412186	-0.286	-0.328	-0.271
H03	Flow Crossing of Mary Gilmore Way	-0.130	-0.147	-0.108
H04	Burrangong Ck - Upstream of LLS Fence	-0.037	-0.005	-0.049
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	-0.063	-0.006	-0.105
H07	Mary Gilmore Way - Young St Intersection	0.000	0.000	-0.083
H08	Arramagong St - Bland St Intersection	-0.065	-0.006	-0.089
H09	Grenfell St - Caldwell St Intersection	-0.001	-0.005	-0.091

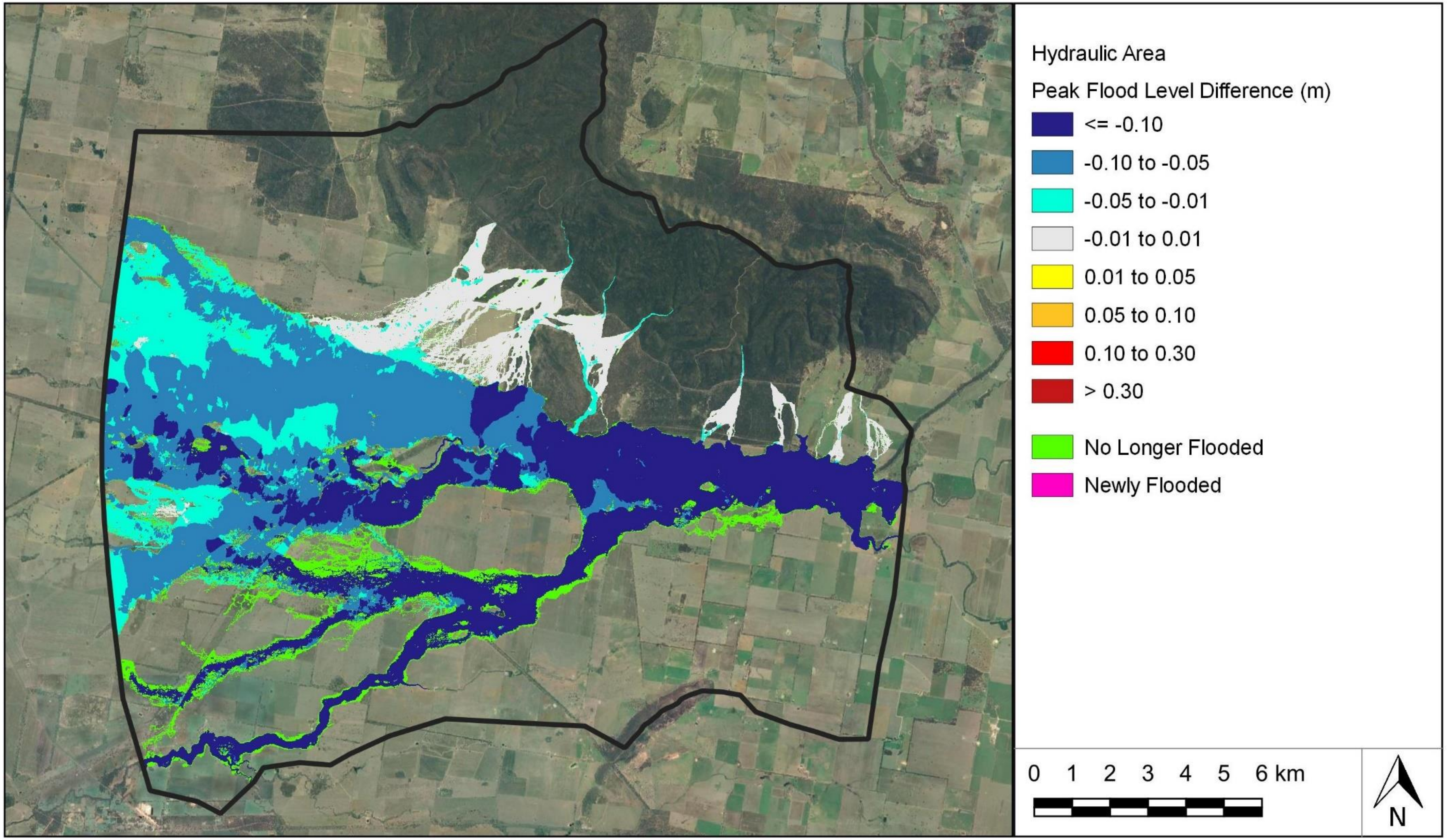


Image 9-4: 1% AEP Peak Flood Level Difference (m) - Rainfall Initial Losses Based on Median Pre-Burst Depths

Table 9-10: Peak Flood Level Difference (m) - Rainfall Initial Losses Based on 75% Pre-Burst Depths

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	-0.016	-0.001	0.016
H02	Burrangong Ck - Stream Gauge 412186	-0.067	-0.057	0.061
H03	Flow Crossing of Mary Gilmore Way	-0.030	-0.027	0.024
H04	Burrangong Ck - Upstream of LLS Fence	-0.011	-0.001	0.016
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	-0.022	-0.001	0.024
H07	Mary Gilmore Way - Young St Intersection	-0.017	0.000	0.018
H08	Arramagong St - Bland St Intersection	-0.020	-0.002	0.025
H09	Grenfell St - Caldwell St Intersection	0.000	-0.001	0.018

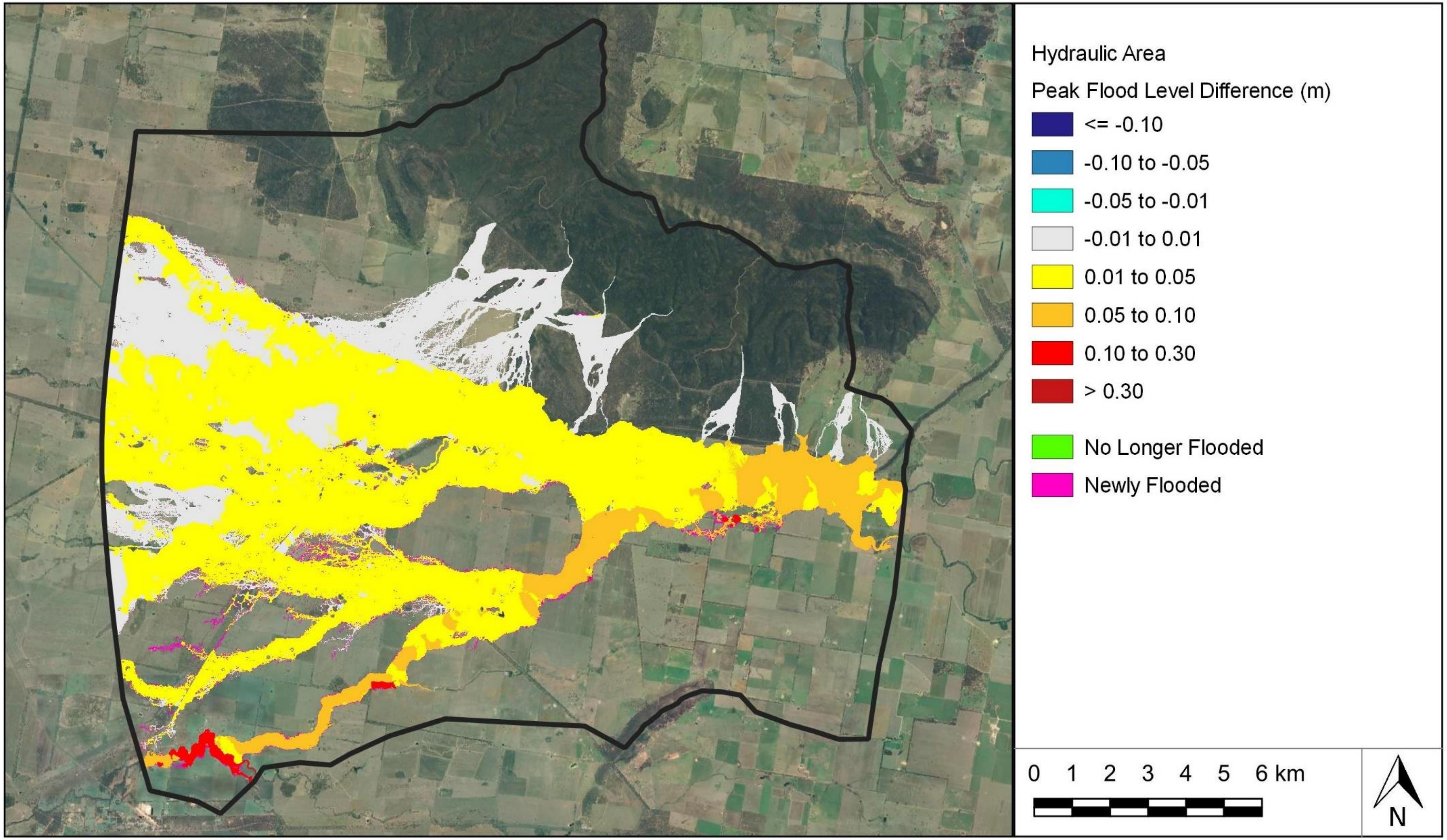


Image 9-5: 1% AEP Peak Flood Level Difference (m) - Rainfall Initial Losses Based on 75% Pre-Burst Depths

Table 9-11: Peak Flood Level Difference (m) - Rainfall Initial Losses Based on 90% Pre-Burst Depths

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	0.051	0.011	0.016
H02	Burrangong Ck - Stream Gauge 412186	0.202	0.255	0.061
H03	Flow Crossing of Mary Gilmore Way	0.090	0.132	0.024
H04	Burrangong Ck - Upstream of LLS Fence	0.035	0.012	0.016
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	0.074	0.018	0.024
H07	Mary Gilmore Way - Young St Intersection	0.062	0.000	0.018
H08	Arramagong St - Bland St Intersection	0.060	0.020	0.025
H09	Grenfell St - Caldwell St Intersection	0.065	0.000	0.018

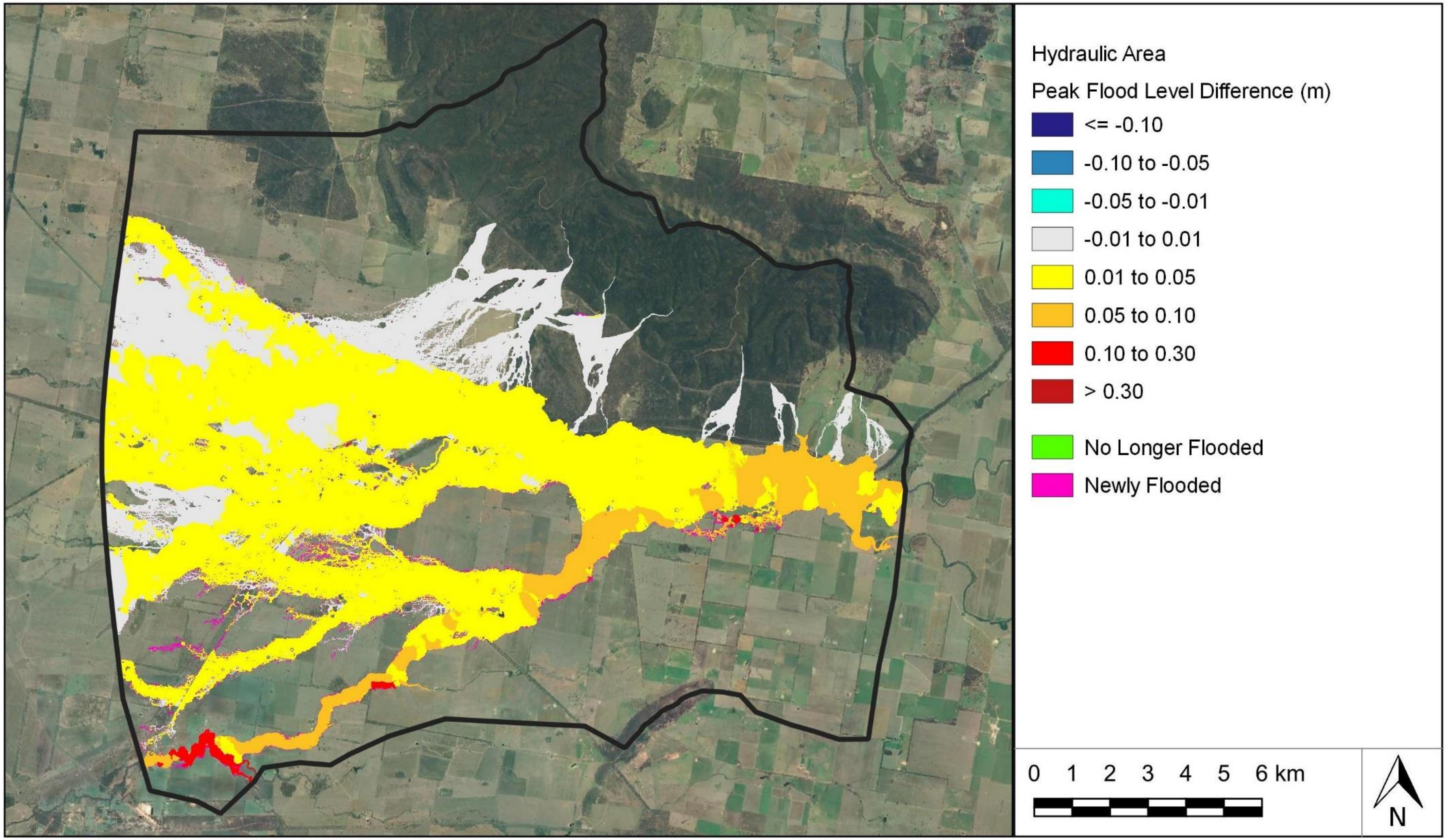


Image 9-6: 1% AEP Peak Flood Level Difference (m) - Rainfall Initial Losses Based on 90% Pre-Burst Depths

D.3 Hydrologic Lag and Routing

Table 9-12: Peak Flood Level Difference (m) - Hydrologic Lag Decrease

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	0.000	0.018	0.019
H02	Burrangong Ck - Stream Gauge 412186	0.067	0.078	0.073
H03	Flow Crossing of Mary Gilmore Way	0.034	0.035	0.029
H04	Burrangong Ck - Upstream of LLS Fence	0.000	0.013	0.018
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	0.001	0.026	0.028
H07	Mary Gilmore Way - Young St Intersection	0.000	0.022	0.022
H08	Arramagong St - Bland St Intersection	0.000	0.022	0.028
H09	Grenfell St - Caldwell St Intersection	0.000	0.001	0.021

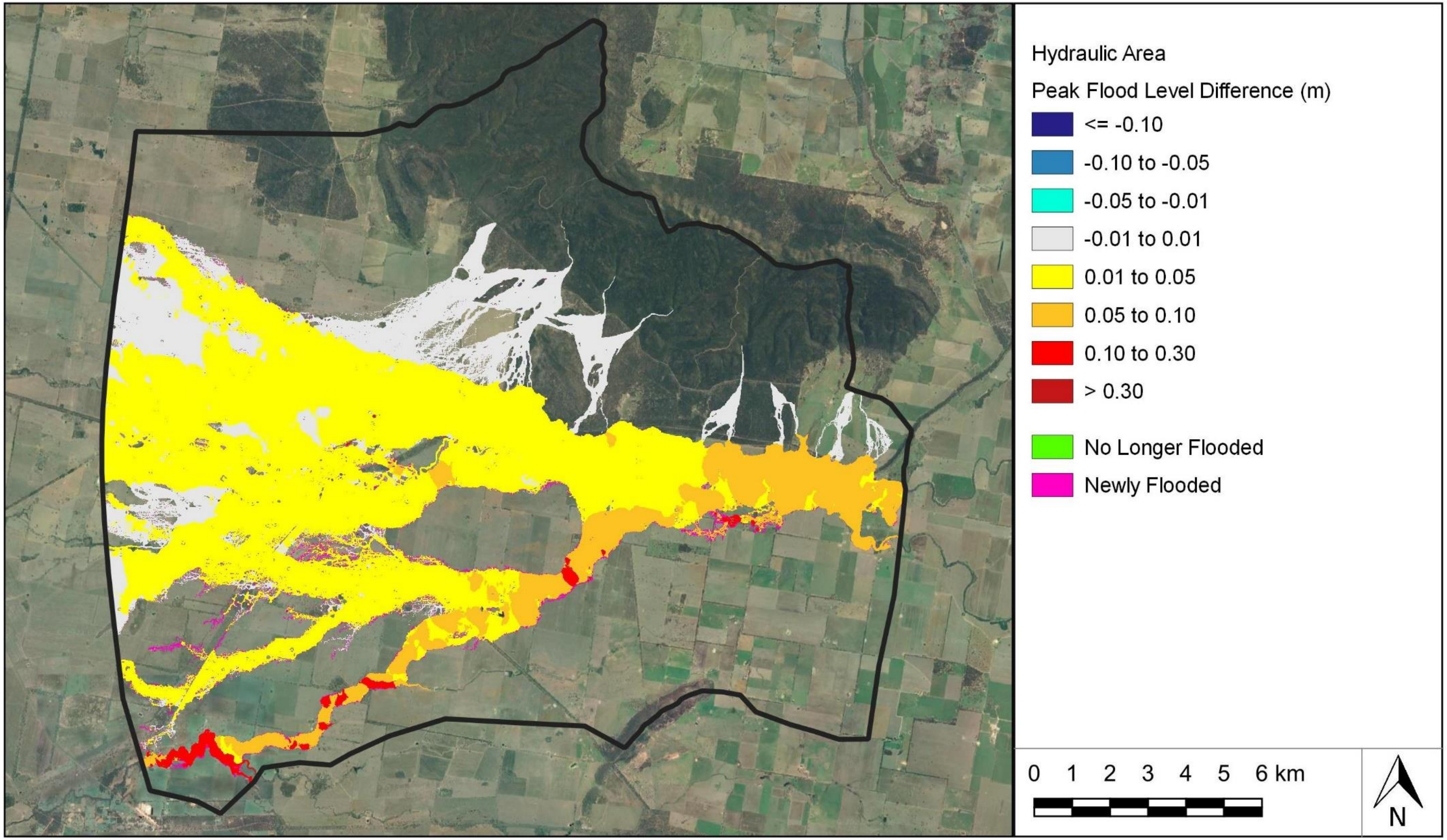


Image 9-7: 1% AEP Peak Flood Level Difference (m) - Hydrologic Lag Decrease

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

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	0.000	-0.016	-0.018
H02	Burrangong Ck - Stream Gauge 412186	-0.064	-0.073	-0.072
H03	Flow Crossing of Mary Gilmore Way	-0.031	-0.033	-0.028
H04	Burrangong Ck - Upstream of LLS Fence	-0.001	-0.011	-0.014
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	0.000	-0.022	-0.026
H07	Mary Gilmore Way - Young St Intersection	0.000	-0.017	-0.022
H08	Arramagong St - Bland St Intersection	-0.001	-0.020	-0.024
H09	Grenfell St - Caldwell St Intersection	-0.001	-0.001	-0.022

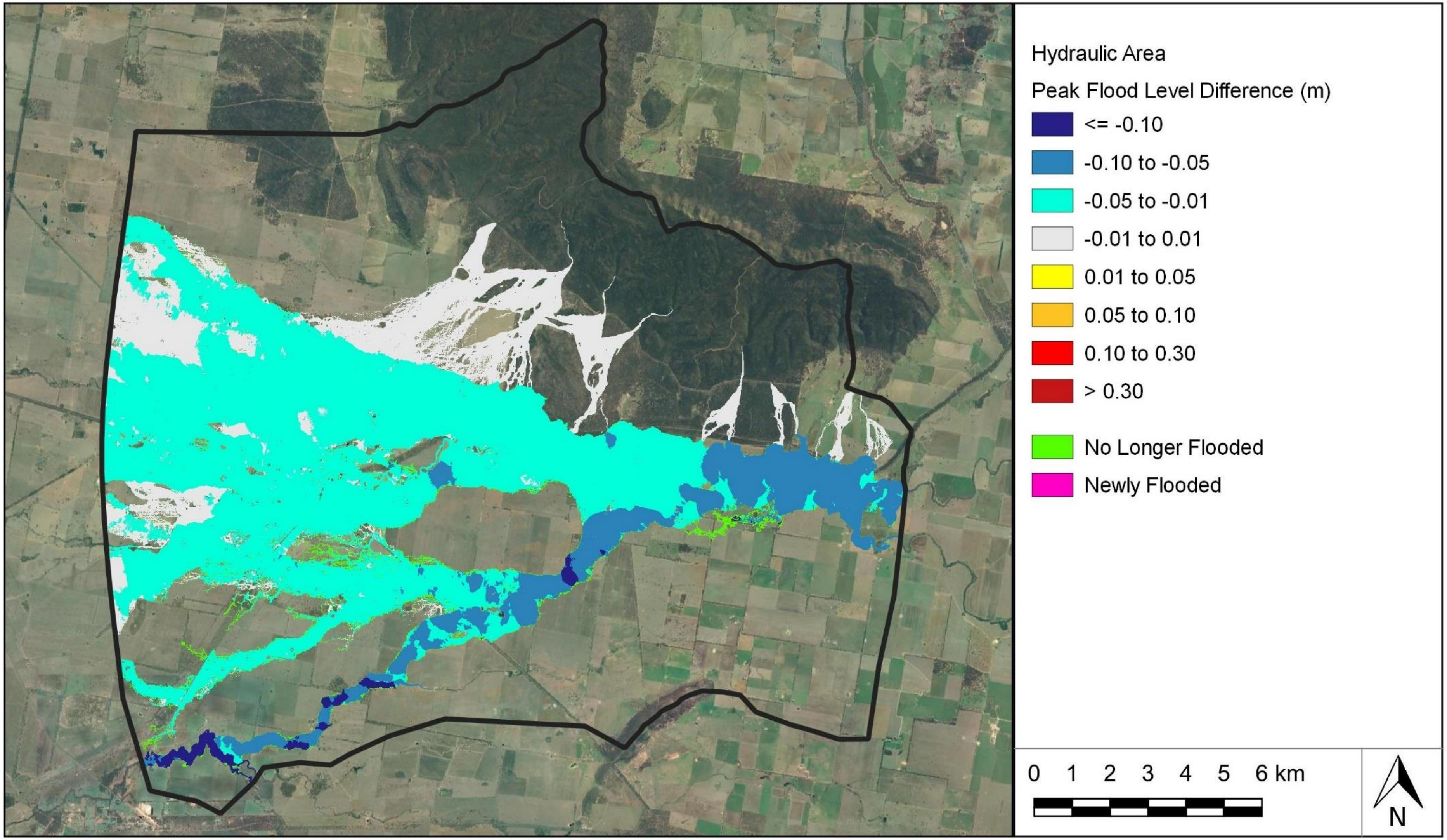


Image 9-8: 1% AEP Peak Flood Level Difference (m) - Hydrologic Lag Increase

Table 9-14: Peak Flood Level Difference (m) - Hydrologic Routing Decrease

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	0.021	0.109	0.098
H02	Burrangong Ck - Stream Gauge 412186	0.356	0.425	0.313
H03	Flow Crossing of Mary Gilmore Way	0.186	0.196	0.137
H04	Burrangong Ck - Upstream of LLS Fence	0.016	0.071	0.102
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	0.028	0.157	0.138
H07	Mary Gilmore Way - Young St Intersection	0.000	0.134	0.107
H08	Arramagong St - Bland St Intersection	0.030	0.122	0.144
H09	Grenfell St - Caldwell St Intersection	0.000	0.154	0.100

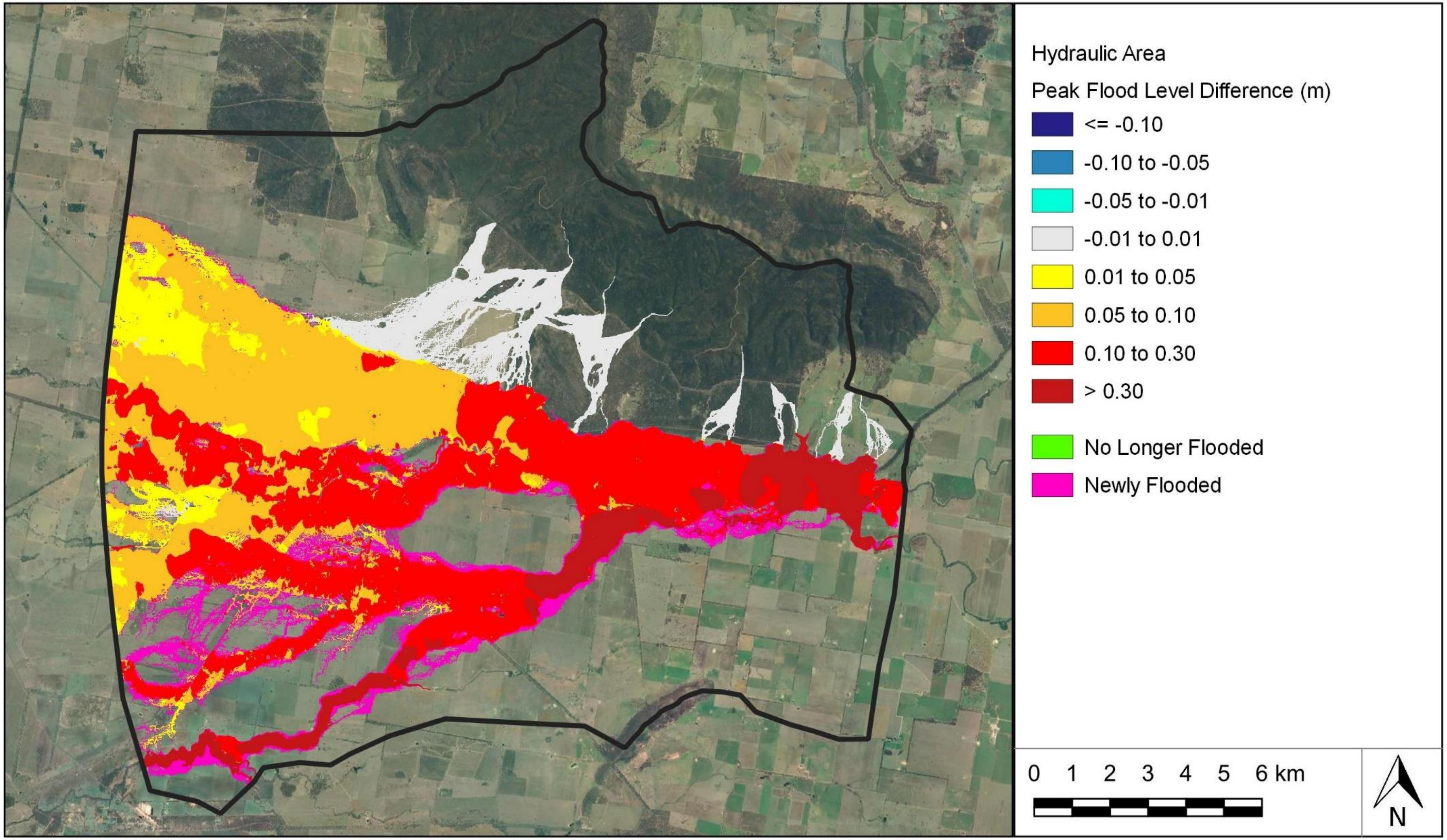


Image 9-9: 1% AEP Peak Flood Level Difference (m) - Hydrologic Routing Decrease

D.4 Hydraulic Roughness

Table 9-15: Peak Flood Level Difference (m) - Hydraulic Roughness Decrease

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	-0.011	-0.050	-0.070
H02	Burrangong Ck - Stream Gauge 412186	-0.170	-0.163	-0.161
H03	Flow Crossing of Mary Gilmore Way	-0.091	-0.095	-0.094
H04	Burrangong Ck - Upstream of LLS Fence	-0.002	-0.029	-0.045
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	0.005	-0.044	-0.088
H07	Mary Gilmore Way - Young St Intersection	0.000	0.000	-0.070
H08	Arramagong St - Bland St Intersection	0.002	-0.048	-0.078
H09	Grenfell St - Caldwell St Intersection	-0.007	-0.008	-0.073

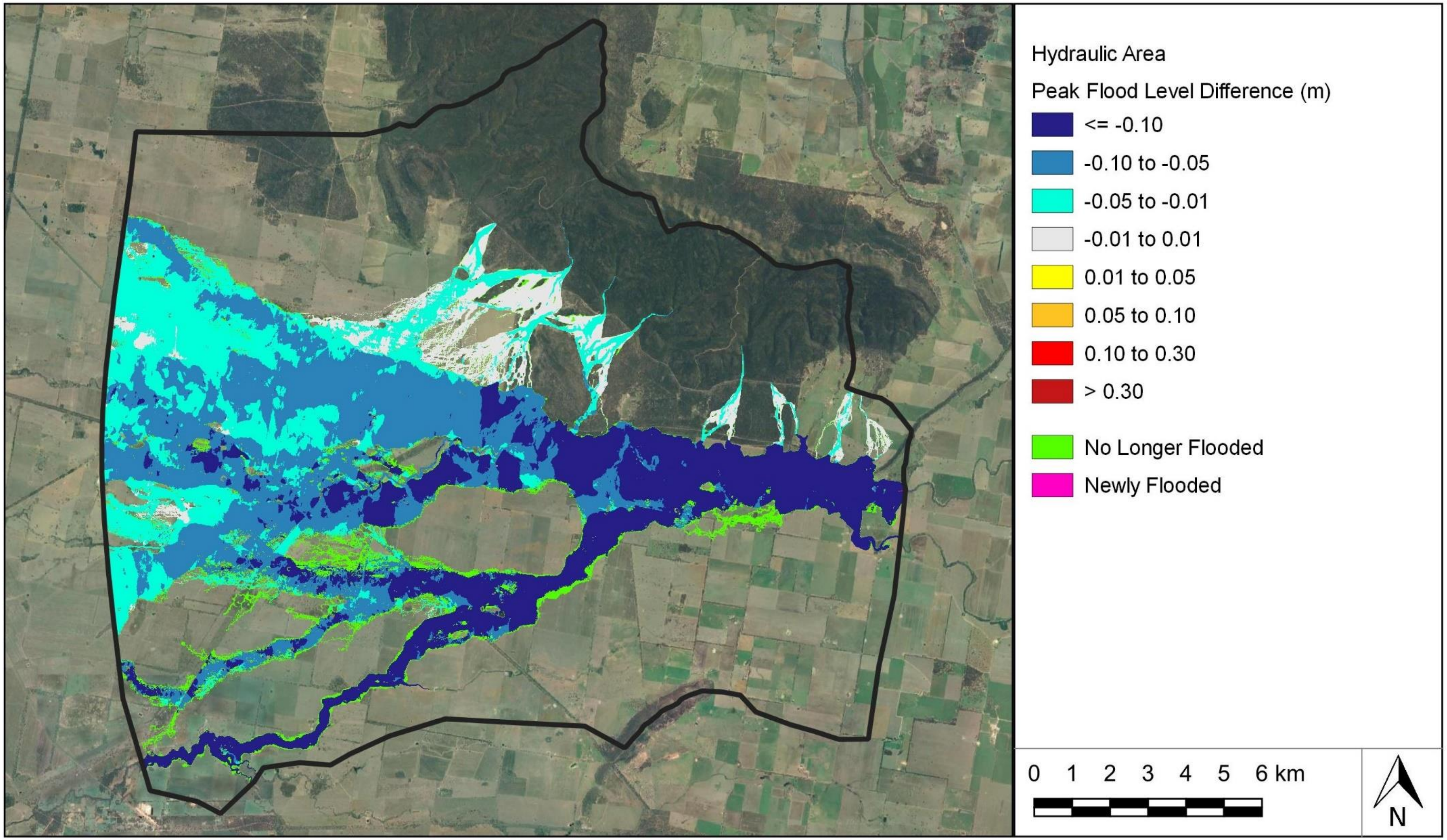


Image 9-10: 1% AEP Peak Flood Level Difference (m) - Hydraulic Roughness Decrease

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

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	0.023	0.091	0.109
H02	Burrangong Ck - Stream Gauge 412186	0.165	0.187	0.204
H03	Flow Crossing of Mary Gilmore Way	0.133	0.146	0.144
H04	Burrangong Ck - Upstream of LLS Fence	0.018	0.067	0.117
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	0.024	0.127	0.157
H07	Mary Gilmore Way - Young St Intersection	0.000	0.089	0.090
H08	Arramagong St - Bland St Intersection	0.009	0.075	0.126
H09	Grenfell St - Caldwell St Intersection	0.008	0.107	0.093

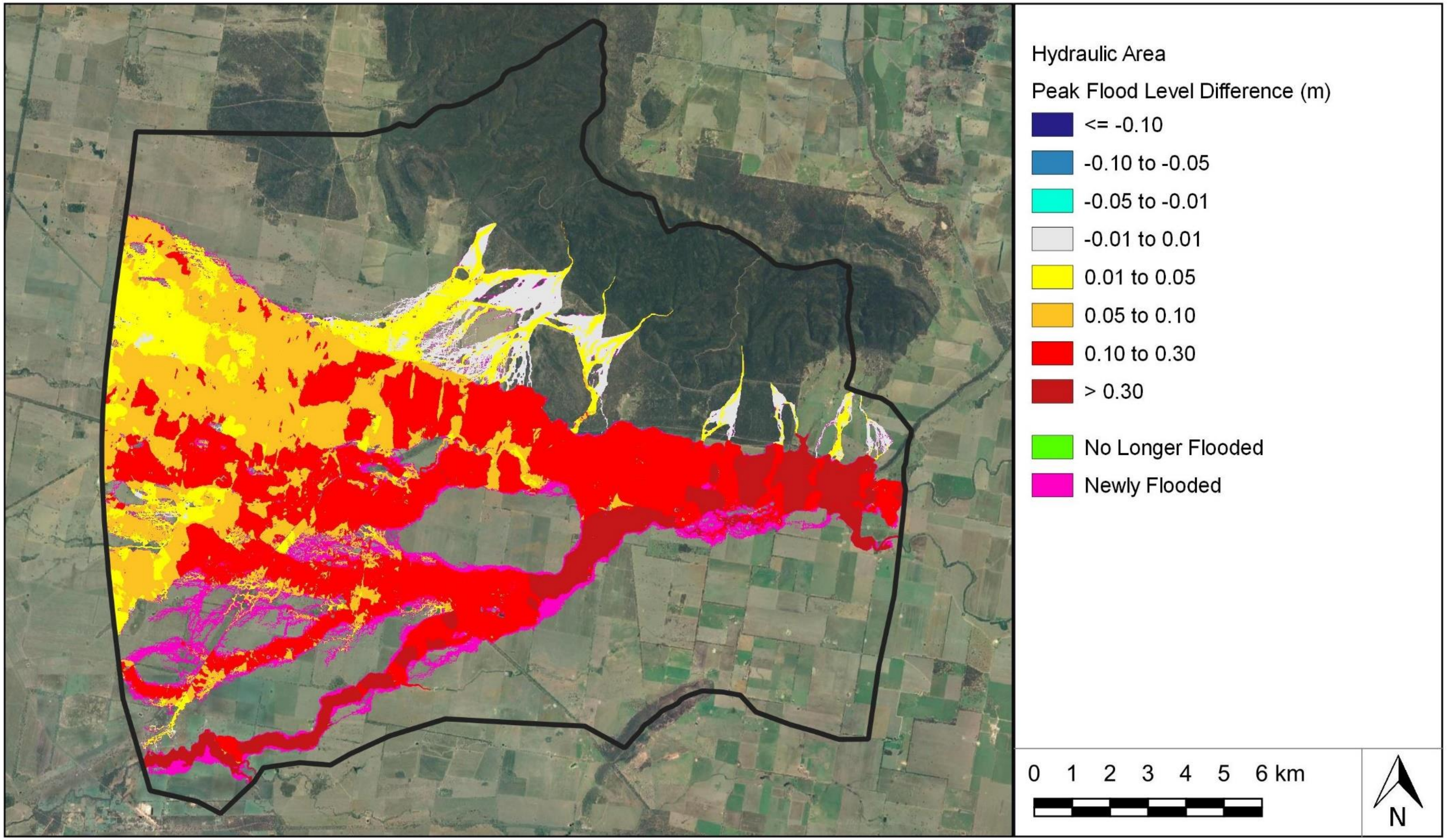


Image 9-10: 1% AEP Peak Flood Level Difference (m) - Hydraulic Roughness Increase

D.5 Blockage of Hydraulic Structures

Table 9-17: Peak Flood Level Difference (m) - Blockage of Hydraulic Structures by 25%

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	0.002	0.000	-0.004
H02	Burrangong Ck - Stream Gauge 412186	0.000	0.000	0.000
H03	Flow Crossing of Mary Gilmore Way	0.000	0.000	0.000
H04	Burrangong Ck - Upstream of LLS Fence	-0.019	-0.018	-0.015
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	-0.018	-0.007	0.005
H07	Mary Gilmore Way - Young St Intersection	0.000	0.010	0.012
H08	Arramagong St - Bland St Intersection	-0.018	-0.010	0.001
H09	Grenfell St - Caldwell St Intersection	0.000	0.000	0.013

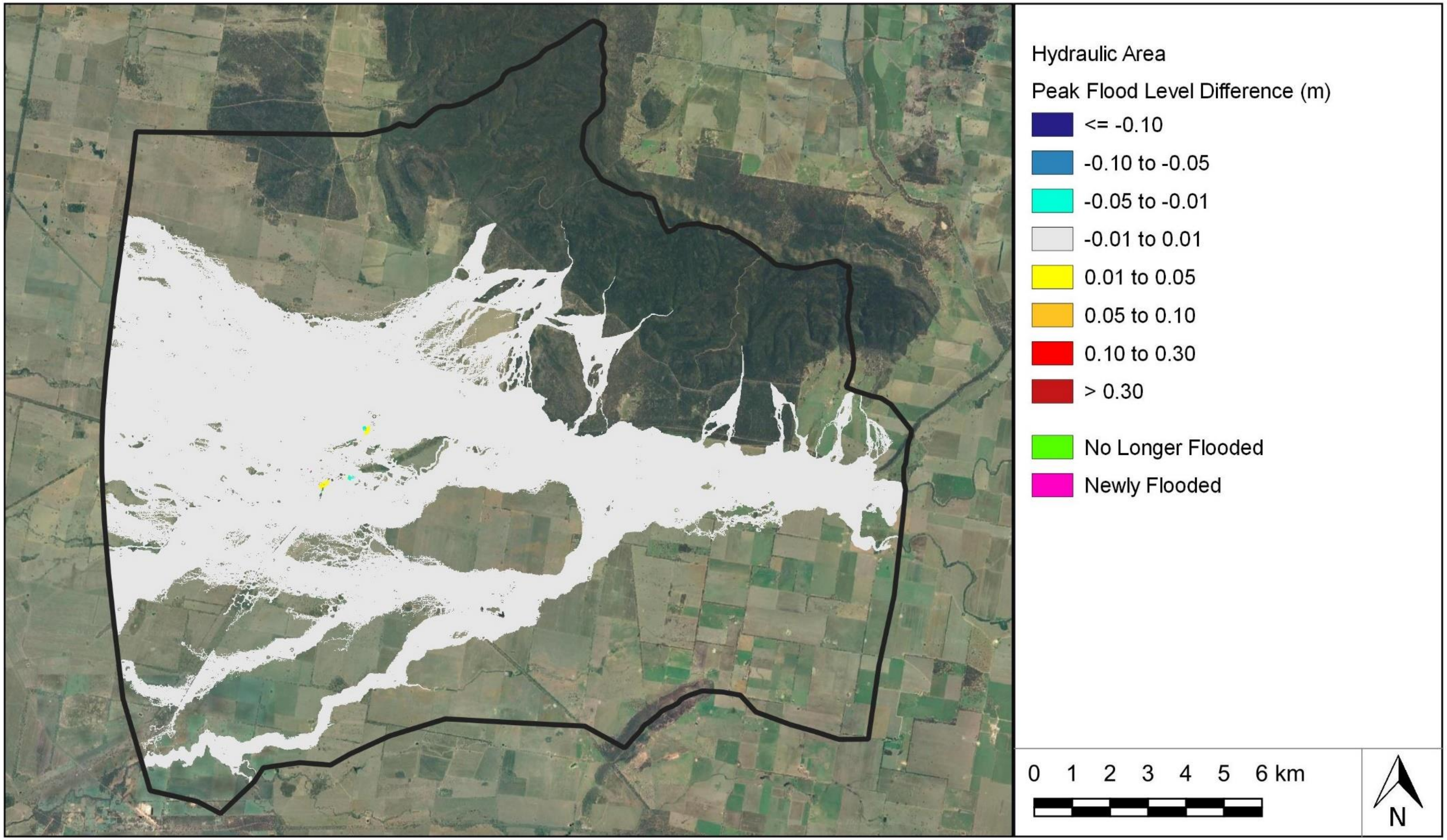


Image 9-11: 1% AEP Peak Flood Level Difference (m) - Blockage of Hydraulic Structures by 25%

Table 9-18: Peak Flood Level Difference (m) - Blockage of Hydraulic Structures by 50%

ID	Location	20% AEP	5% AEP	1% AEP
H01	Burrangong Ck - Stream Gauge 412170	-0.005	-0.009	-0.019
H02	Burrangong Ck - Stream Gauge 412186	0.000	0.000	0.000
H03	Flow Crossing of Mary Gilmore Way	0.000	0.000	0.000
H04	Burrangong Ck - Upstream of LLS Fence	-0.024	-0.022	-0.019
H05	Mary Gilmore Way - Grenfell St Intersection	0.000	0.000	0.000
H06	Young St - Nowlan St Intersection	-0.025	-0.005	0.013
H07	Mary Gilmore Way - Young St Intersection	0.000	0.025	0.026
H08	Arramagong St - Bland St Intersection	-0.024	-0.014	0.004
H09	Grenfell St - Caldwell St Intersection	0.000	0.010	0.030

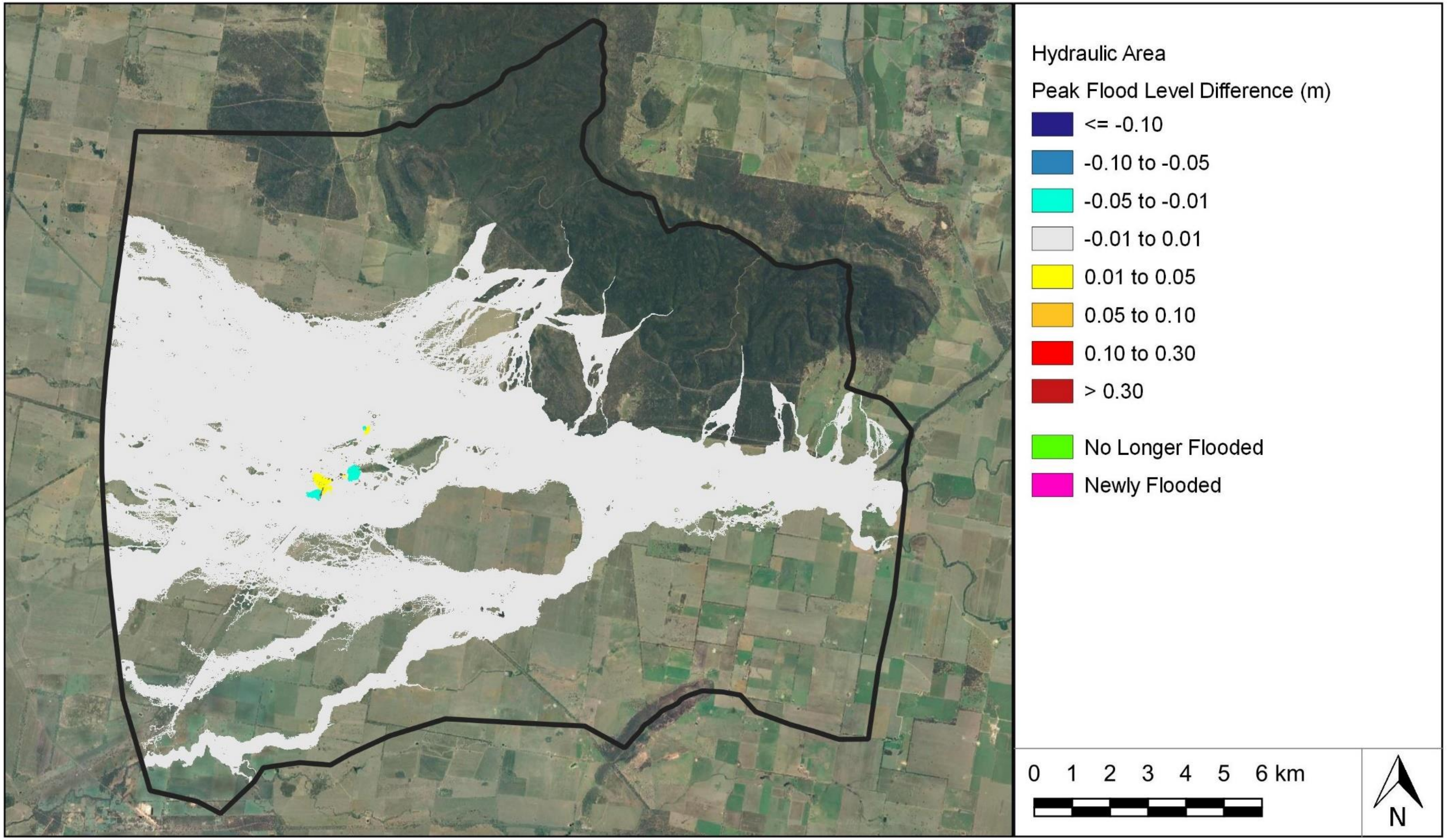


Image 9-12: 1% AEP Peak Flood Level Difference (m) - Blockage of Hydraulic Structures by 50%