Karuah River and Stroud Floodplain Risk Management Study

Level 17, 141 Walker St
North Sydney NSW 2060
Australia

Revision C

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Cover Photo: Floodwaters flowing across Cowper Street, Stroud, on the morning of 21st April 2015 (*Source: Gloucester Advocate*)

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Project: Karuah River & Stroud Floodplain Risk Management Study

Rev	Description	Author	Review	Advisian Approval	Date
0	Draft for Internal Review	LC L Collins			19/09/2019
A	Draft Report – Issued for Public Exhibition	LC L Collins	CRT C Thomas	Chris Thomas	23/10/2019
B	Final Draft Report	LC L Collins	CRT C Thomas	Chris Thomas	7/07/2020
C	Final Report	CRT C Thomas	LC L Collins	Chris Thomas	11/09/2020

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1 Introduction

The Karuah River Valley is located within the MidCoast Council Local Government Area (LGA) on the NSW mid-north coast. It drains a catchment area of approximately 1,460 km^2 from the Gloucester Tops in the north-west, to Port Stephens in the south (*refer* **Figure 1-1**). The catchment has a history of flooding, with flooding occurring along the Karuah River and smaller local tributaries. Most notably, significant flood damage was sustained across low lying areas at Stroud in April 2015 due to intense rainfall and flooding of Mill Creek, which is a tributary that joins the Karuah River just upstream of the village.

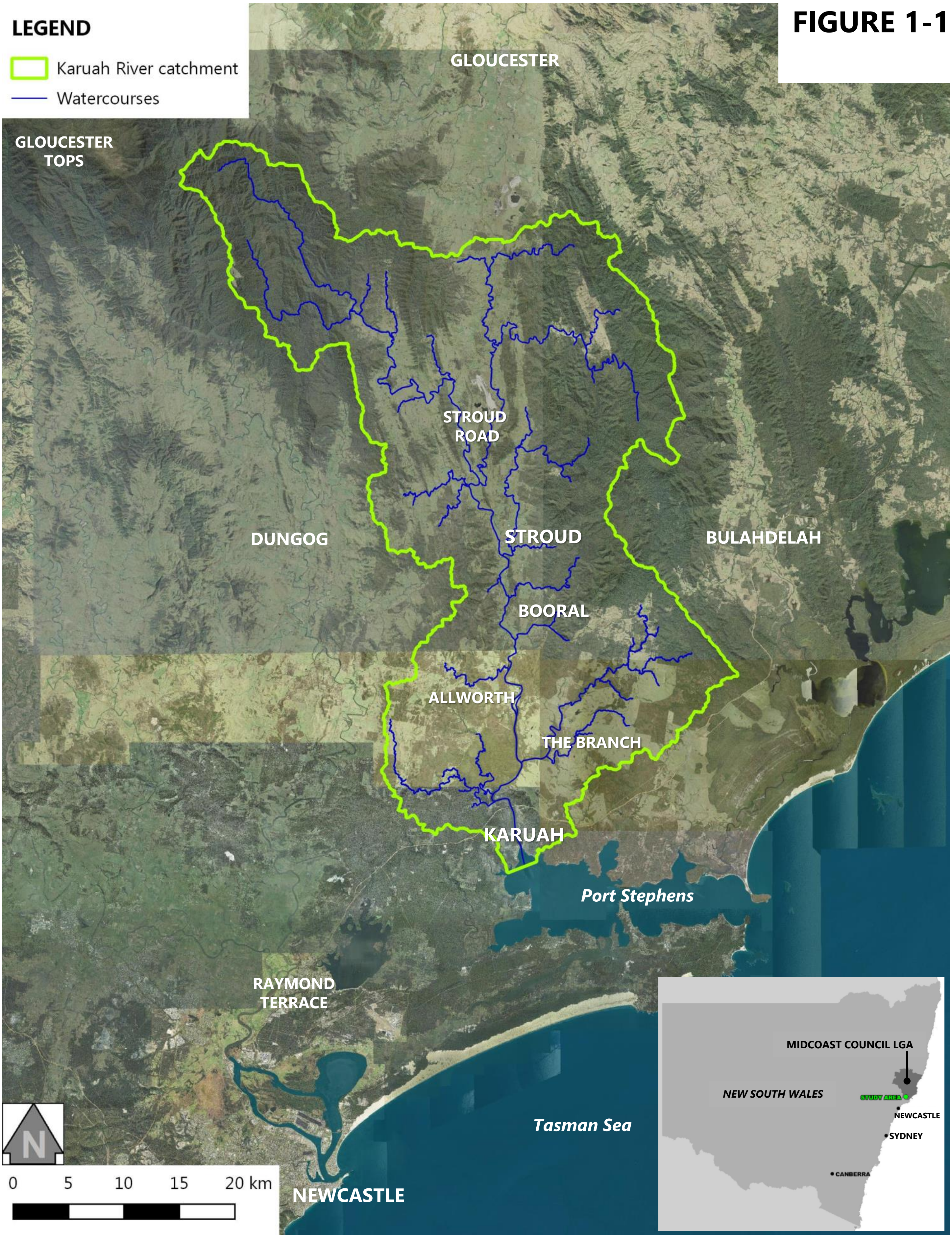
MidCoast Council (Council) is responsible for local planning and land management within its LGA, including the management of flood prone land. Council, with assistance from the NSW Office of Environment (OEH), engaged Advisian to prepare the *Karuah River and Stroud Floodplain Risk Management Study and Plan* (FRMS).

The *Karuah River and Stroud Flood Study Update* forms part of the FRMS but is presented as a separate report. Volume 1 of the Flood Study Update documents the work undertaken as part of the review of the existing flood study and the findings from that review. Volume 2 is a compendium of flood mapping developed from that review.

The FRMS will provide an improved understanding of the potential impacts of floods on the local communities of Stroud Road, Stroud, Booral, Allworth, The Branch and Karuah North. It also documents a range of measures and strategies that could potentially be implemented to better manage flood risk in accordance with the NSW Government's *Flood Prone Land Policy*, the primary objective of which is to reduce the impact of flooding on individual owners and occupiers of flood prone land, and to reduce private and public losses caused by flooding.

The findings of the study will direct the formulation of a Floodplain Risk Management Plan for the study area, detailing recommended works and management measures, and a program for their implementation by Council. Outputs from the study will help inform land use planning and decision-making for investing in the floodplain; improve management of flood risk through prevention, preparedness, response and recovery activities; and inform and educate the community on flood risk and response to floods.

FIGURE 1-1



STUDY LOCATION

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2 Background

2.1 The Need for Floodplain Risk Management

Floods are part of the Australian landscape. They occur in many parts of Australia, and their severity and causative mechanisms vary widely between locations.

While floods have positive impacts such as providing inflows to water supplies, sustaining flood-dependent ecosystems and improving soil moisture and fertility for farming, where humans have occupied the floodplain they pose significant risk to life and property. Negative impacts of flooding include human fatalities and injuries, as well as economic damage, disruption of individuals' lives and communities' function, and environmental damage (AEMI 2014).

Historically, flood damage in Australia is greater than that of any other natural hazard, and flood-related deaths are a continuing occurrence. There were reportedly 178 fatalities attributed to flooding in Australia between 2000 and 2015 (Haynes et al. 2016). One such event occurred in the early hours of 21 April 2015 when three people drowned in their dwellings in Dungog as floodwaters rose to record levels following sustained heavy rainfall. Less than 20 kilometres away, Stroud also suffered significant flood damage with at least 13 dwellings impacted by over floor flooding (SES 2017) but was fortunately spared from the severity of flooding experienced at Dungog.

Despite the hazard posed, flooding is the most manageable natural disaster, as its behaviour and potential extent can be estimated and considered in decision making.

In New South Wales, the management of flood liable land is governed by the NSW Government's *Flood Prone Land Policy*, the main objective of which is to reduce the impact of flooding and flood liability on owners and occupiers of flood-prone property and reduce public and private losses from flooding. The policy also recognises the benefits of the appropriate and sustainable use, occupation and development of flood-prone land.

Studies such as the *Karuah River and Stroud Floodplain Risk Management Study* are undertaken through the NSW Floodplain Management Program, which is administered by OEH in partnership with local government. These studies help local government make informed decisions about managing flood risk through the investigation of a range of property, flood and response modification measures. As well as the possible implementation of physical flood mitigation measures, this includes the provision of essential information to the State Emergency Service (SES) so that it can prepare and effectively implement local flood plans and emergency response, and the education of communities about the nature of local flood risk so that they can be better prepared for flooding, understand how to respond to flood threats and recover from the impacts of floods.

2.2 The Study Area

2.2.1 Catchment Description

The study area comprises the Karuah River valley from Stroud Road to Karuah including the townships of Stroud Road, Stroud, Booral, Allworth, The Branch and Karuah North. This also encompasses the major tributaries that pass through or border these townships, including Mammy Johnsons River, Mill Creek, Lamans Creek, The Branch River and Little Branch River (refer **Figure 2-1**).

The Karuah River is an open, semi-mature, tide-dominated drowned valley estuary (Roy et al. 2001). It rises on the south-eastern slopes of the Gloucester Tops, descending from an elevation of around 600 mAHD to discharge to Port Stephens approximately 80 kilometres to the south-southeast. The upper catchment is characterised by steep, narrow valleys, while in the lower reaches from about Allworth downstream the valley is wider with areas of saltmarsh and mangrove swamp. Tidal influence extends upstream to a gravel bar across the river located about 1 kilometre downstream of Booral.

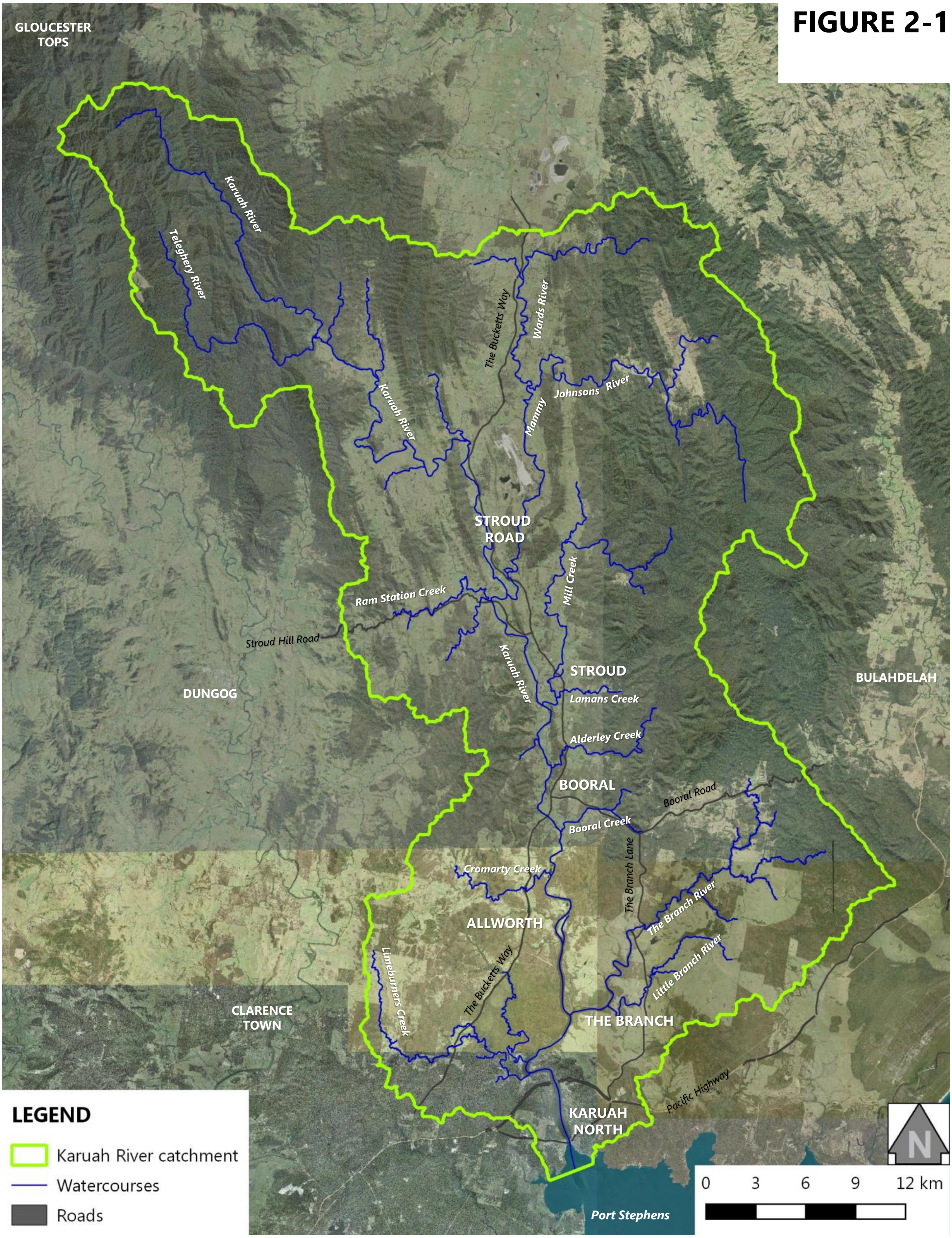
The topography of the Karuah River catchment is shown in **Figure 2-2**. Elevations of over 1,000 mAHD are reached in the upper Karuah and Teleghery River catchments, and elevations of over 600 mAHD in the upper Mammy Johnsons River catchment. Maximum elevations in the catchments of other tributaries range from about 200 to 500 mAHD. Downstream of Allworth, a significant portion of the catchment has elevations of less than 25 mAHD.

Land use within the catchment consists predominantly of natural bushland and rural areas which are mostly cleared for grazing. This includes Rural Landscape, Forestry, National Park and Nature Reserves zonings. Overall, development in the catchment is relatively sparse. The largest township of Karuah has a population of about 1,400, the majority of which is located outside of the study area and within the Port Stephens local government area (LGA). The next largest township at Stroud has a population of 938 (Australian Bureau of Statistics, 2016).

The main transport routes through the catchment include the Pacific Highway, Tarean Road, Booral Road, The Bucketts Way and Stroud Hill Road.

The study focuses on the townships and settlements of Stroud Road, Stroud, Booral, Allworth, The Branch and Karuah North, which are further described in the following.

FIGURE 2-1



STUDY AREA

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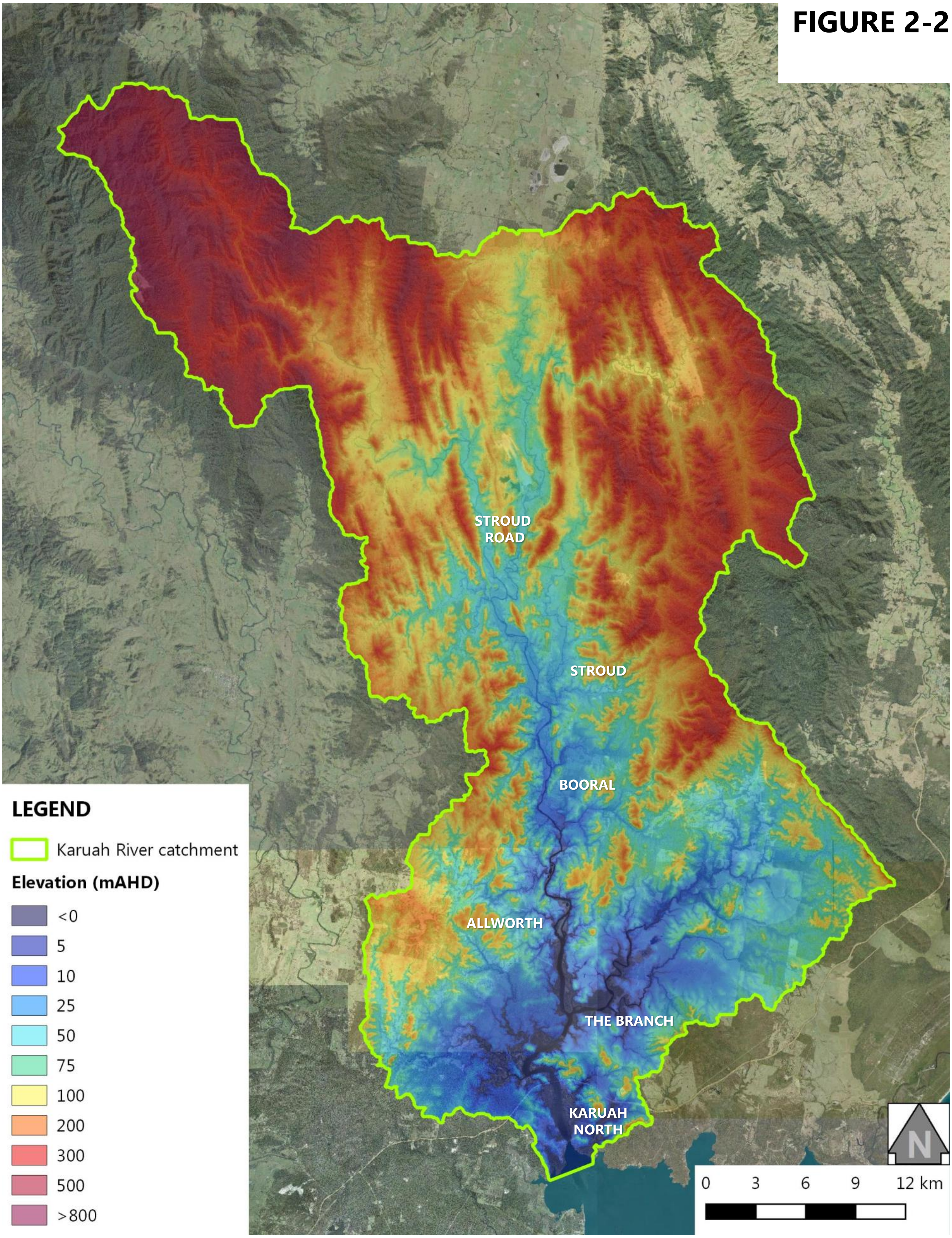
FIGURE 2-2



STUDY TOPOGRAPHY

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2.2.2 Karuah North

Karuah North is located on the eastern bank of the Karuah River, adjacent to the Karuah Bridge, near the river mouth at Port Stephens (refer **Figure 2-3**). Development is based along Tarean Road (the old Pacific Highway) and Alice Street, and comprises of around 40 residential lots, a number of boat sheds and a camping ground. With the exception of some boat and oyster sheds, development in Karuah North appears to be located above elevations of about 3.5 mAHD, with the majority above 5 mAHD.

2.2.3 The Branch

The Branch study area focuses on rural properties adjacent to the The Branch and Little Branch Rivers (refer **Figure 2-4**). The Branch River has a catchment area of about 210 km^2, including the catchment of the Little Branch River which covers approximately 57 km^2. The Branch River discharges to the Karuah River about 12.5 km upstream of the Karuah Bridge.

The main road passing through the area is The Branch Lane which follows a south to north alignment from the Pacific Highway to Booral Road. It has low level bridge crossings of The Branch and Little Branch Rivers.

2.2.4 Allworth

The township of Allworth is located on the western bank of the Karuah River about 19 km upstream of the Karuah Bridge, adjacent to Sketchleys Island (refer **Figure 2-5**). It has a population of about 200 people. Development is predominantly residential and appears to be located above elevations of about 7 mAHD.

There is a gravel quarry located approximately 2 km north of town, part of which is low lying (elevations less than 4 mAHD).

2.2.5 Booral

The township of Booral has a population of 407 (ABS, 2016) and is located on the eastern bank of the Karuah River about 31 km upstream of the Karuah Bridge (refer **Figure 2-6**). It comprises of rural, residential and a small number of commercial premises. Development is generally located above elevations of about 10 mAHD.

The Bucketts Way passes through the township in a north-south alignment, crossing the Karuah River at the Booral Bridge to the south. Booral Road leaves the township in an easterly direction and links Booral to Bulahdelah.

The Booral Creek and Alderley Creek tributaries discharge into the Karuah River about 1.5 km downstream and 4 km upstream of the Booral Bridge, respectively. Booral Creek has a catchment area of around 35 km^2 and Alderley Creek around 40 km^2.

2.2.6 Stroud

Stroud has a population of 938 (ABS, 2016) and is located near the confluence of Mill and Lamans Creeks (refer **Figure 2-7**). Mill Creek discharges into the Karuah River about 1.5 kilometres downstream of the township, and around 10 km upstream of the Booral Bridge.

The township of Stroud consists primarily of low density residential development with fringing rural properties. It has a greater number of commercial premises than the other townships, as well as a public school, aged care facility (Stroud Community Lodge), showground and associated camping area.

The Bucketts Way provides the main thoroughfare through town, within which it is known as Berkeley Street in the south and Cowper Street in the north. Lamans Creek, Mill Creek and Mill Brook (a flood runner off Mill Creek) all cross The Bucketts Way via bridges or large culverts.

Mill Creek has a catchment area of 120 km^2 and Lamans Creek an area of 20 km^2 at the Bucketts Way crossings (WMAwater 2012).

2.2.7 Stroud Road

The township of Stroud Road has a population of about 230 and is located just above the confluence of the Karuah and Mammy Johnson Rivers, about 10 km upstream of Stroud (refer **Figure 2-8**).

There are in the order of 70 low-density residential properties in the township, along with a small number of commercial premises and fringing rural properties. There is also a small public school. Development is generally located above elevations of 40 mAHD, with the majority above about 45 mAHD.

The Bucketts Way passes through the settlement and crosses the Mammy Johnsons River. Reisdale Road heads southwest out of town and crosses the Karuah River, as does the North Coast Railway.

FIGURE 2-3

KARUAH NORTH

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FIGURE 2-4

THE BRANCH

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ALLWORTH

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FIGURE 2-6

BOORAL

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FIGURE 2-7

STROUD

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FIGURE 2-8

STROUD ROAD

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2.3 Flood History

Flooding in the Karuah River catchment may be caused by differing mechanisms in different locations. Flooding of the Karuah River is characterised by slower rates of rise in response to widespread, persistent heavy rainfall, while flash flooding can occur on the creeks and tributaries in response to intense local storms.

In recent times, this shorter duration flooding of creeks and tributaries appears to have led to more extensive flood damages and disruption to residents – in particular at Stroud, which lies near the confluence of Mill and Lamans Creeks.

The available flood history of the Karuah River and Stroud is further discussed in the following.

2.3.1 Karuah River

The DPI Water stream gauge *Station 209003 – Karuah River at Booral* which was established in 1968 provides the best available record of past flooding of the Karuah River. Significant flood levels were recorded during events in March 1978 (9.03 mAHD), June 2007 (9.47 mAHD), February 1990 (9.65 mAHD), October 1985 (9.91 mAHD) and January 1971 (10.35 mAHD), with the highest recorded flood level of 10.37 mAHD occurring on 21st April 2015.

There is little evidence that these floods resulted in significant impacts along the Karuah River itself, and review of topographic information indicates that floodwaters would not break out of the river channel at Booral until flood levels at the gauge exceed about 10.8 mAHD. Volume 2 of the Mid Coast Local Flood Plan (SES 2017) does however state that "*farmers in various parts of the area have lost pumps, other machinery and livestock, and machinery at the gravel quarries near Allworth has been damaged by flood waters*".

A review of the National Library of Australia's historic newspaper database also reveals a long history of flood impacts on the Karuah River. **Table 2-1** shows the dates and impacts of flood events as indicated by the newspaper database. Much of the historic impacts relate to crop damage, however there have also been a number of flood deaths as well above floor flooding of dwellings and damage to bridges. A number of the more significant floods occurred during the 1800's.

Other sources site significant floods in 1850, 1894, 1913, 1927, 1946, 1956 and 1963 (SES 2017, Paterson Consultants 2010). The Roads and Traffic Authority (RTA, now Roads and Maritime Services) "general arrangement" drawing for Booral Bridge shows historical flood information that indicates that a peak flood level of 11.78 mAHD was reached at the bridge in 1944, although the source and reliability of this measurement cannot be confirmed (available newspaper articles suggest this may refer to the 1945 event).

Table 2-1 Historical flood events on the Karuah River compiled from the National Library of Australia newspaper database (TROVE)

Date	Description
January 1856	Heavy flood which cut off communication. A man attempted to cross the river at the crossing-place (Booral) on horse and perished. (*Sydney Morning Herald*)
20 August 1857	The Karuah River and all its tributaries reached a height hitherto unknown, covering all flats contiguous to the streams to a depth of 10 to 15 feet. Wheat crops were swept away or seriously damaged. Several families evacuated from their homes while others took refuge upon the ceilings and cross-beams until waters subsided. The flood broke into the stores at Booral and Pumpkin Point rising six feet above the floors and damaging goods. Upwards of 100 pigs were drowned. Two boys who were known to spend the night on a bend in the river to protect young crops from pademelons were drowned. Property of the boys was found in a tree downstream more than 20 feet above the level of the stream. (*Empire*)
3 June 1864	Levels in many places reached within one foot of 1957 levels. Great destruction was caused to maize crops, vegetables and fences, as well as removal of ploughed topsoil and causing great distress to farmers. Water rose several feet in receiving stores at Booral damaging maize. (*Sydney Morning Herald*)
29 February 1875	A distressing flood that did a great deal of damage to maize and tobacco crops and fences. In many places it was far higher than the great flood of 1857. Nearly all farms and crops were entirely under water. (*Maitland Mercury and Hunter River General Advertiser*)
March 1894	Reported as a disastrous flood – the highest ever known – that did an immense amount of damage. The river and creeks overflowed their banks, damaging crops, fencing, the telegraph line, numerous culverts and the approaches to the bridges at Booral and washpool. (*Canberra Times*)
March 1908	On the Karuah River flood waters did not rise high enough to do much damage, while levels on Johnson's Creek and Mill Creek were very high and damaged crops (*Maitland Weekly Mercury*)
May 1913	A man was rescued by boat from a tree on an island in the Karuah River near Booral. Damage was sustained to crops (*Raymond Terrace Examiner and Lower Hunter* and *Port Stephens Advertiser*)
April 1927	A horseman was washed away by floodwaters at Booral and drowned. Stroud Shire Council applied for a grant to repair flood damages to bridges and culverts which were washed away. The location of the damage is unclear, but includes Bulahdelah. (*Newcastle Sun* and *Port Stephens Advertiser*)
February 1929	The Karuah rose to great heights. Police sent out early warnings and stock losses were low, but crops suffered greatly (*Manning River Times*)

Date	Description
October 1942	Little damage done, the Pacific Highway was blocked by Johnson's Creek (*Dungog Chronicle*)
March 1945	Partial damage was sustained to the old Karuah River bridge at Booral (*Newcastle Sun*)
July 1950	An appeal was held in Stroud to raise funds for flood victims, though it was reported that flooding did not reach dangerous levels at Booral (*Dungog Chronicle*)
13 October 1985	A woman was rescued by the Westpac helicopter from a tree in the middle of flooding near Stroud (*Canberra Times*)

2.4 Stroud

While no official flood records exist, Mill and Lamans Creeks are known to have experienced several significant floods in the past century. Dates of known flood events include 15 April 1927, 25 March and 19 April 1946, 29 February 1956, 19 March 1978, 12 October 1985, 8 June 2007 (WMAwater 2012) and 21 April 2015.

The recent flood on 21 April 2015 appears to have been the most severe on record and, based on flood levels observed at the Stroud Showground, may have been as rare as a 0.2% Annual Exceedance Probability (AEP) event (analogous to a 1 in 500 year event). Floodwaters in Mill and Lamans Creeks rose quickly in response to heavy rainfall in the early hours of 21 April. The showground was inundated to depths of up to 1.8 m, while Lamans Creek Bridge, Berkley Street and Mill Creek Bridge were overtopped isolating the centre of Stroud. At least 13 properties were inundated to above floor level, with one home requiring demolition. The Stroud Community lodge was isolated and preparations were made for residents to be evacuated to higher ground (SES 2017). At Booral the highest flood level since gauging began in 1968 was reached, but floodwaters remained in-bank.

2.5 Social Profile

A general understanding of the makeup of the community potentially affected by flooding is an important factor in the development of floodplain management measures. For example, an area with a high proportion of senior citizens might need to give special attention to evacuation constraints, while the cultural diversity, internet usage and population turnover in an area will inform the design of flood education programs.

Accordingly, a basic social profile of the community in the Bulahdelah to Stroud statistical area was developed from Census data. Relevant findings are discussed in the following.

2.5.1 Age and Household Structure

Compared to the NSW average, the Bulahdelah to Stroud area has a similar proportion of children aged less than 14, a significantly lower proportion in age range of 14 to 44 (most markedly in the 25 to 34 age group), a higher proportion in the age range 45 to 84, and a similar proportion aged 85 or over.

Children may require assistance during a flood, while youth may be more prone to unsafe behaviours during flooding that could be targeted with educational messages. Some 21% of the resident population is aged 65 or over and may be particularly vulnerable to the impacts of flooding with communication and mobility challenges and find it difficult to recover after a flood. This would particularly be the case if they live alone as 25% of households do.

2.5.2 Language

Compared to the NSW average, the Bulahdelah to Stroud area has a low level of linguistic diversity, with over 98% of the resident population speaking only English at home. The 2011 Census also found that of migrants in the area only 1% indicated that they were not proficient in spoken English. This suggests that communications or educational material issued in English will be understood by the community.

2.5.3 Internet Access

The 2011 Census found that only 64% of residents in the Bulahdelah to Stroud area had access to the internet at home. More recent 2016 Census data found that 75% of households in the Stroud township had access to the internet, however this remains below the average for NSW. This suggests that the provision of flood education and warning messages by internet may not have a sufficiently broad reach in this area and that conventional methods of dissemination will continue to be required.

2.5.4 Motor Vehicle Ownership

Only 2.6% of dwellings in the Bulahdelah to Stroud area did not have a registered motor vehicle, which is well below the NSW average. In any case, people in dwellings without a motor vehicle may have trouble evacuating if required.

2.5.5 Home Ownership

Compared to the NSW average, a relatively high proportion of dwellings are owner occupied, and low proportion is rented. Home ownership could be relevant to willingness to participate in property modification options.

This may also indicate a low turnover of the population which is relevant to the level of flood awareness and readiness in the community.

2.6 Previous Studies

2.6.1 Stroud Flood Study, 1986

The first *Stroud Flood Study* (NSW Water Resources Commission 1986) assessed flood behaviour in the Stroud area through compilation and interpolation of historical flood height data obtained from debris marks. The purpose of the study was to identify flood liable areas to assist Council in planning decisions and evaluation of development.

No hydraulic modelling was undertaken as part of the study; rather, a limited number of flood levels from the 1956 and 1985 floods were used to infer information on flood characteristics. The 1956 flood was considered to be the largest flood of the century based on available records, and an extent of inundation, the delineation of floodways, and potential flood hazards were estimated based on this event. No estimate was made of the exceedance probability of the event.

The outcomes of this study involved significant uncertainty given the limited flood data and substantial interpolation used to derive them.

Notwithstanding, observed historic flood levels compiled in the 1986 Stroud Flood Study are of assistance in model calibration and validation.

2.6.2 Karuah River Flood Study, 2010

The *Karuah River Flood Study* (Paterson Consultants 2010) was undertaken to define flood behaviour and design flood levels along the Karuah River from about 1 km upstream of Stroud Road to the old Pacific Highway bridge at Karuah.

A RORB hydrologic model and a one-dimensional MIKE-11 hydraulic model were developed to simulate catchment runoff and flood hydraulics, respectively. The RORB model was calibrated to gauged flows at Booral for the 1977, 1978, 1990, 2001 and 2007 Karuah River floods. The MIKE-11 model was established using twenty-eight surveyed river cross-sections and calibrated to a limited number of flood levels from the Booral gauge, maximum water level indicators and anecdotal information for the 1976, 1977, 1978, 1990, 2001 and 2007 floods. Reasonable calibration results were achieved, particularly at the Booral gauge location which represented the most reliable available data set. Design flood levels were also validated against results of flood frequency analysis at the Booral gauge.

The study included a review of DPI Water's river level station 209003 – Karuah River at Booral. At such stations, water levels are recorded and converted to flow data via rating curves which are established by measuring flow (based on velocity and cross-sectional area of flow) at discrete times during site visits. The review indicated that the rating curve for the Booral gauge was based on regular flow gaugings, and also benefits from gaugings at high water levels and a reasonably geomorphically stable stream. Accordingly, the rating table was accepted as being of suitable quality for use in the flood study.

Information from the *Karuah River Flood Study* and associated models have helped to inform updated modelling of the Karuah River as part of the Updated Flood Study completed as part of this project. The available hydrographic survey was used to define the bathymetry of the Karuah River.

2.6.3 Stroud Flood Study, 2012

The *Stroud Flood Study* (WMAWater 2012) is the most recent flood study completed within the study area. It investigated flood behaviour around the township of Stroud, considering flooding from Mill and Lamans Creeks as well as backwater flooding from the Karuah River and flooding of smaller local catchments.

A WBNM hydrologic model and a two-dimensional TUFLOW hydraulic model were established to simulate catchment runoff and flood hydraulics, respectively. Comprehensive calibration of the models was not undertaken due to a lack of suitable pluviometer and streamflow records. Rather, typical recommended parameters were adopted and resulting design flood levels were compared to historical observed flood levels to provide a limited validation of the simulated flood behaviour.

Some key findings of the study include:

- From sensitivity analysis it was concluded that the principal factors influencing modelled flood behaviour were the magnitude and timing of runoff flows and the adopted Manning's 'n' roughness parameter.
- The potential impact of climate change as investigated by increasing the 100 year ARI design rainfall by 10%, 20% and 30% was found to be relatively significant, with each incremental 10% increase in flow generally resulting in a 0.15 to 0.2 m increase in peak flood levels along the Mill and Lamans Creeks floodplains.
- Lamans Creek exhibits a faster rate of rise than Mill Creek and is more significantly affected by backwater effects from the Karuah River in larger floods.
- Average Annual Damages (AAD) due to flooding of $20,000 were estimated from detailed floor level survey and flood model results. Two properties were estimated to be flooded above floor level in the 1% AEP design flood event, and 27 properties during the Probable Maximum Flood (PMF).

The models developed for the 2012 Stroud Flood Study were used to assist development of the updated flood models for the Stroud township as part of the FRMS. This included the use of the most recent LiDAR topographic data, calibration to the April 2015 flood event, and use of ARR2019 design flood parameters.

2.6.4 Flood Data Collection, Dungog and Stroud Flood Event 21 April 2015

A report titled, *Flood Data Collection, Dungog and Stroud Flood Event 21 April 2015* (Paterson Consultants 2015), was funded by OEH to gather information following the severe flooding at Dungog and Stroud on 21st April 2015.

The work comprised fieldwork over the week from 27 April to 1 May 2015 during which numerous flood marks were documented and conversations held with local residents. Flood extents at Dungog and Stroud were estimated from the flood marks.

Twenty flood marks in Stroud were photographed and documented in the report. Great Lakes Council (now MidCoast Council) also provided survey and photographs of 12 flood marks as presented in Appendix D of the report.

Information presented in the report has been used in this FRMS to assist in calibration of the updated flood models that have been generated for the Stroud township to the April 2015 flood.

2.7 Flood Planning Instruments

2.7.1 Environmental Planning and Assessment Act 1979

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

In NSW a formal development assessment and determination must be made of the proposed activity prior to taking place to ensure it complies with relevant planning controls and conforms with the principles of environmentally sustainable development.

Section 117 Directions – Direction No. 4.3 (Flood Prone Land)

Section 117 Direction No. 4.3 (Flood Prone Land) applies to councils that contain flood prone land within their Local Government Area and any draft LEP that creates, removes or alters a zone or provision that affects flood prone land.

The objectives of this direction are:

- To ensure that development of flood prone land is consistent with the NSW Government's *Flood Prone Land Policy* and the principles of the *Floodplain Development Manual 2005* (including the *Guideline on Development Controls on Low Risk Areas*), and
- To ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

The direction imposes various limitations on planning authorities including with regard to rezoning within flood planning areas, permitting development within floodways, permitting development that will result in significant flood impacts to other properties, permitting significant increase in development within flood planning areas, and imposing flood development controls on residential development above the residential flood planning level without justification to the satisfaction of the Director-General.

Section 149 Planning Certificates

Section 149 certificates are issued by councils under the *Environmental Planning and Assessment Regulations 2000* (Clause 279 and Schedule 4(7A)). The primary function of notations on the Section 149 certificate is as a planning tool for notification that the land is affected by a policy that restricts development due to the likelihood of a risk such as flood hazard.

2.7.2 State Environmental Planning Policies (SEPPs)

State Environmental Planning Policies (SEPPs) are the highest level of planning instrument and generally prevail over Local Environmental Plans.

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

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

Clause 4(6) and Schedule 1 indicate that the policy does not apply to land identified in another environmental planning instrument as being a floodway or area of high flood hazard.

SEPP (Infrastructure) 2007

State Environmental Planning Policy (Infrastructure) 2007 facilitates the delivery of infrastructure across the State by identifying development permissible without consent. Among its provisions, the policy allows local government to undertake stormwater and flood mitigation work without development consent.

SEPP (Exempt and Complying Development Codes) 2008

State Environmental Planning Policy (Exempt and Complying Development Codes) 2008, is an important policy which defines development exempt from obtaining development consent or which does not require development consent if it complies with certain criteria.

Clause 1.5 of the SEPP defines a 'flood control lot' as 'a lot to which flood related development controls apply in respect of development for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing)'. Development controls may be applied through an LEP or DCP. Exempt development is not permitted on flood control lots but some complying development is permitted.

Clause 3.36C states that complying development is permitted on flood control lots where a Council or professional engineer can certify that the part of the lot proposed for development is not a flood storage area, floodway area, flow path, high hazard area or high risk area. The SEPP specifies various controls in relation to floor levels, flood compatible materials, structural stability (up to the PMF if on-site refuge is proposed), flood affectation, safe evacuation, car parking and driveways.

2.7.3 Great Lakes Local Environmental Plan 2014

The *Great Lakes Local Environmental Plan 2014* (Great Lakes LEP 2014) is the statutory planning instrument that establishes the permissible and/or prohibited forms of development and land use within the former Great Lakes Local Government Area.

Flood planning is addressed in Clause 7.3, as reproduced below. The clause applies to land indicated on the associated Flood Planning Area maps.

7.3 Flood planning

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

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

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

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

(2) This clause applies to:

(a) land identified as "Flood Planning Area" on the Flood Planning Map, and

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

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

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

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

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

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

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

(4) In determining a development application for development on land to which this clause applies, the consent authority must have regard to the following matters:

(a) the intended design life and scale of the development,

(b) the sensitivity of the development in relation to future effective self-evacuation of the land, and if that is not possible, the low risk occupation in time of flood,

(c) the potential to modify, relocate or remove the development.

(5) A word or expression used in this clause has the same meaning as it has in the *Floodplain Development Manual* (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

(6) In this clause:

flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard and the projected 2100 sea level rise of 0.9 metres above the 1990 mean sea level.

2.7.4 Great Lakes Development Control Plan

The Great Lakes Development Control Plan (DCP) sets the standards, controls and regulations that apply when carrying out development within the former Great Lakes LGA. They support the Great Lakes LEP 2014, which regulates the uses that are permissible on the land.

Section 4.2 of the DCP relates to flooding, and has the following objectives:

- The risk of impacts from flooding on people and assets are avoided or otherwise minimised.
- Development is located in response to the identified flood hazard and designed to accommodate flood conveyance and storage.
- Environmental impacts of development on flood prone land are avoided or otherwise minimised.
- Development on flood prone land does not adversely impact neighbouring properties or visual amenity.
- The potential for financial loss or cost to the community as a result of development on flood prone land is limited.

The flood policy has differing controls for subdivisions, new buildings, alterations and additions, and fencing. Controls are applied according to three different flood planning areas / levels, those being:

- Current flood planning area: based on the current 1% AEP flood plus freeboard
- Projected 2060 flood planning area: based on the projected 2060 1% AEP flood + freeboard + sea level rise
- Projected 2100 flood planning area: based on the projected 2100 1% AEP flood + freeboard + sea level rise.

Definition of the floodway, the 2100 5% AEP flood level and 2100 1% AEP flood level are also used to guide the application of development controls.

It is noted that MidCoast Council has inherited planning documents from the former Great Lakes, Taree City and Gloucester Shire Councils. It is anticipated that at some stage in the future Council would look to develop a single, consistent DCP. This will be taken into consideration in preparing the FRMS when reviewing and making recommendations regarding flood-related development controls.

2.8 Great Lakes Local Flood Plan, 2017

Existing flood emergency response protocols for Stroud are outlined in the Great Lakes Local Flood Plan (2017), which is a sub-plan of the MidCoast Emergency Plan (MidCoast EMPLAN). The Local Flood Plan was reviewed in 2017 and sets out the known flood risks and consequences for flood affected areas of the former Great Lakes LGA and how NSW SES will respond in the event of a flood.

The document is divided in three parts:

- Volume 1 - Flood Emergency Sub Plan
- Volume 2 - Hazards and Risks
- Volume 3 – SES Response Arrangements for Great Lakes

Volume 1 - Flood Emergency Sub Plan, covers information on multi-agency arrangements and responsibilities for preparedness, response and recovery. Some of the key features of the flood emergency response arrangements are as follows.

- The Great Lakes SES Operations Centre is located at the Tuncurry SES Unit Headquarters at Lot 2 Grey Gum Road, Tuncurry. The local operations centre is Stroud SES Operations Centre located at 2756 Booral Road, Booral.
- Response operations will begin:
  - On receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for Flash Flooding, or;
  - When other evidence leads to an expectation of flooding within the council area.
- Contact with the Bureau of Meteorology to discuss the development of flood warnings will normally be through the Northern Zone Taree Incident Control Centre.
- Responsible persons and organisations will be advised of the start of response operations regardless of the location and severity of the flooding anticipated.
- The main response strategies for SES flood operations include Information Provision and Warning, Property Protection, Evacuation, Rescue, and Resupply.
- In most cases the decision to evacuate rests with the NSW SES Incident Controller who exercises his/her authority in accordance with Section 22(1) of The State Emergency Service Act 1989. However, the decision to evacuate will usually be made after consultation with the Local Emergency Operations Controller.
- During floods, evacuations will be controlled by the SES. Small-scale evacuations will be controlled by the NSW SES Incident Controller. Should the scale of evacuation operations be beyond the capabilities of local resources, control may be escalated to the Northern Zone Taree Incident Control Centre.
- The SES will advise the community of the requirements to evacuate. The SES will issue an Evacuation Warning when the intent of an SES Incident Controller is to warn the community of the need to prepare for a possible evacuation. The SES will issue an Evacuation Order when the intent of the SES Incident Controller is to instruct a community to immediately evacuate in response to an imminent threat.
- The NSW SES Incident Controller will distribute Evacuation Warnings/Orders to:
  - Sector Command Centres (where established)
  - Great Lakes Local Emergency Operations Centre
  - Great Lakes Council
  - Manning - Great Lakes Police Local Area Command
  - Great Lakes Rural Fire Service Control Centre
- The local flood evacuation centre is the School of Arts, Berkeley Street, Stroud
- When the immediate danger to life and property has passed the Northern Zone Taree Incident Control Centre or the NSW SES Incident Controller will issue an 'all clear' message signifying that response operations have been completed. The message will be distributed through the same media outlets as earlier evacuation messages. The relevant Controller will also advise details of recovery coordination arrangements, arrangements made for clean-up operations prior to evacuees being allowed to return to their homes, and stand-down instructions for agencies not required for recovery operations.

Volume 2 - Hazards and Risks sets out the risks and consequences of flooding on local communities. This includes a summary of roads that are liable to flooding, and facilities liable to flooding or isolation, as reproduced for the Karuah River catchment in **Table 2-2** and **Table 2-3** respectively.

Table 2-2 Roads in the Karuah River catchment liable to flooding as identified in the Local Flood Plan

Road	Closure location	Consequence of closure	Alternate Route
Laman Street, Stroud	Causeway over Mill Creek at western edge of town	Restricts access to and from Stroud from the west	Briton Court Road
Gortons Crossing, Stroud	Britton Court Road, 2 km west of Stroud at bridge over Karuah River	Restricts access between Stroud and Booral-Washpool Road residents	Via Booral or Stroud Road
Mill Creek Road (Stroud -Maybush), Stroud Road	At bridge over Mill Creek, at northern edge of Stroud	Restricts resident access/egress along Mill Creek Road, isolating residents	No
Mill Creek Road, Stroud Road	Saggers Crossing, Mill Creek	Restricts resident access/egress along Mill Creek Road, isolating residents	No
Gap Hill Road (Stroud Road -Mill Creek Road), Stroud Road	At bridge over Mill Creek	Restricts resident access/egress along Mill Creek Road, isolating residents	No
Stroud Road-Dungog (Dungog Road or Stroud Hill Road), Stroud Road	At bridge over Karuah River, at edge of Stroud Road; at bridge over Barnes Creek (Washpool vicinity); at bridge over Ramstation Creek.	Restricts access/egress between Dungog and Stroud	Via Clarence Town
Bucketts Way, Weismantels	At Groom Creek, between Stroud Road and Monkerai turnoff (major route between Stroud and Gloucester) and at corner of Bucketts Way and Forest Glenn Road.	Restricts access/egress between Gloucester (to the north) and Stroud	Via Bulahdelah
Monkerai Road (MR101), Monkerai	Andersons Creek bridge, 2km west of Bucketts Way	Restricts access between Mokerai and Gloucester or Stroud	Via Stroud Hill
Booral Road, Booral	Booral Creek Bridge	Restricts access between Booral and the Branch or Crawford River/Bulahdelah	Via Karuah
Booral - Washpool Road, Booral	Washpool Creek Bridge	Restricts access for Booral-Washpool Road residents	Via The Bucketts Way

Table 2-3 Facilities in the Karuah River catchment liable to flooding or isolation as identified in the Local Flood Plan

Facility Name	Street	Suburb	Comment
Schools			
Stroud Road Public School	Bucketts Way	Stroud Road	(risk unknown)
Stroud Public School	Erin Street	Stroud	(risk unknown)
Child Care Centres			
Stroud Pre-school	8 Berkeley Street	Stroud	
Facilities for the aged and/or infirm			
Stroud Community Lodge	Bucketts Way	Stroud	(risk unknown)
Camping Ground / Caravan Park			
Stroud Showground Caravan Park		Stroud	

Volume 3 of the flood plan includes details of the following:

- Flood Warning Systems (river gauges and warning dissemination options)
  - There are no warning systems in place for the primary drivers of flooding in Stroud, Mill and Lamans Creek.
  - River levels at the DPI Water gauges, *209002 – Mammy Johnson's River at Pikes Crossing*, *561106 – Karuah River at Dam Site*, and *561040 – Karuah River at Booral* are monitored for flooding however no levels are assigned relating to minor, moderate or major flooding.
  - Dissemination options include television stations (e.g. Prime and NBN, Newcastle), radio stations and newspapers (e.g. Stroud Community Web, as well as agencies such as NSW Ambulance, Police Force and Fire and Rescue. A door knock may be undertaken to highlight the potential risk of flash flooding and need to evacuate.
- NSW SES Locality Response Arrangements (plans for high risk areas)
  - Key triggers are Flood Watches for Myall and / or Karuah River catchments, and severe weather warning(s) for heavy rain.
  - High risk areas include Stroud Showground, Cowper Street (Bucketts Way between Stroud Lodge and Mill Creek Road), and the north-east section of Briton Court Road, and these are listed as priority evacuation locations.
  - Stroud can become isolated during flooding. The evacuation route is north along Buckets Way to the Stroud Country Club, with additional assembly areas also at Stroud School of Arts, and Stroud Central Pub.
  - It is noted that there is potential for a 10% population increase associated with tourism and camping during the Christmas holidays and Easter long weekend. In addition to this, the Stroud Show is held in April, Rodeo in September and Stroud Brick Throwing Festival in July each year, increasing the population by up to 1000.
- Special arrangements for Caravan Parks including the Stroud Showground camping area.

2.9 Relevant Manuals and Guidelines

2.9.1 Floodplain Development Manual, 2005

The *Floodplain Development Manual* 2005 (the Manual) incorporates the NSW *Flood Prone Land Policy* and guides its implementation in the floodplain risk management process. It aims to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods.

The Manual develops a merit-based framework to assist with floodplain risk management. It confirms that responsibility for management of flood risk remains with local government and assists councils in their management of the use and development of flood prone land by providing guidance in the development and implementation of local floodplain risk management plans.

2.9.2 Australian Emergency Management Handbook 7, 2014

AEM Handbook 7: Managing the floodplain: best practice in flood risk management in Australia (Australian Emergency Management (AEM) Institute 2014) provides guidance on best practice principles as presently understood in Australia. It provides information on the underlying principles that need to be considered when managing flood risk and formulating floodplain management plans and how to apply it, with the aim of promoting effective, equitable and sustainable land use across Australia's floodplains.

Other manuals in the handbook series that are used in conjunction include *Managing the Floodplain, Flood Preparedness, Flood Warning and Flood Response.*

2.9.3 Australian Rainfall and Runoff, 2019

Australian Rainfall and Runoff: A Guide to Flood Estimation 2019 (ARR 2019) was finalised in May 2019 and provides a national guideline document, data and software suite to be used for the estimation of design flood characteristics in Australia.

The guidelines update previous editions of ARR in light of many recent advances in knowledge regarding flood processes, the increased computational capacity available to engineering hydrologists and flood engineers, expanding knowledge and application of hydro-informatics, improved information about climate change and the use of stochastic inputs and Monte Carlo methods. The guidelines also incorporate new Intensity-Frequency-Duration (IFD) design rainfall estimates developed by the Bureau of Meteorology (BoM), using 30 years of additional observations from over 10,000 rainfall gauging stations and improved statistical analysis techniques.

ARR 2019 has been used in this FRMS to guide the determination of appropriate design rainfall and flood hydrographs for the Karuah River catchment.

A number of the ARR Revision Project reports that informed the update process for ARR 2019 contain information additional to that included in the final guidelines and remain valuable documents in their own right. Revision projects referenced in the preparation of this FRMS include:

- Project 15 – Two-dimensional Modelling of Urban and Rural Floodplains
- Project 6 – Loss Models for Catchment Simulation
- Project 11 – Blockage of Hydraulic Structures
- Project 18 – Coincidence of Fluvial Flooding Events and Coastal Water Levels in Estuarine Areas.

2.9.4 OEH Floodplain Risk Management Guidelines

OEH's floodplain risk management guidelines complement the *Floodplain Development Manual*, providing additional technical information to councils and consultants to support the preparation and implementation of floodplain risk management plans. Guidelines referenced in the preparation of this FRMS include:

- Guideline on modelling the interaction of catchment flooding and oceanic inundation in coastal waterways
- Floodway definition
- Practical consideration of climate change
- Residential flood damage
- Flood emergency response classification of communities
- SES requirements from the floodplain risk management process.

3 Data Collection and Review

3.1 Topographic Data

3.1.1 LiDAR

Topographic Digital Elevation Models (DEMs) as derived from triangulation of airborne Light Detection and Ranging (LiDAR) survey of the study area were provided by NSW Land and Property Information (LPI). The following data sets each partially cover the study area:

- LPI Dungog 1m DEM, captured 19 January to 24 February 2016
- LPI Raymond Terrace 1m DEM, captured 16 June to 21 September 2013
- LPI Bulahdelah 1m DEM, captured 9 June to 8 December 2013
- LPI Port Stephens 1m DEM, captured 15 December 2012 to 7 July 2013.

The combined extent of these data sets covers the Karuah River catchment from about 1 km upstream of Stroud Road, downstream to the confluence with Port Stephens. The majority of this area is covered by the Dungog and Port Stephens data. Where there is overlap between the data sets, the most recent data was adopted for use in this study. The accuracy of this data, as indicated by LPI, is 0.3 m in the vertical and 0.8 m in the horizontal.

For the purposes of delineating hydrologic sub-catchments across the remainder of the Karuah River catchment, the above LiDAR derived DEMs were supplemented by the 1 second Shuttle Radar Topography Mission (SRTM) DEM captured by NASA in February 2000.

3.1.2 Channel Cross-Section Data

Cross-sectional data for use in the hydraulic model update was obtained for the Karuah River from the *Karuah River Flood Study* (2010), and for Mill Creek and Lamans Creek from the *Stroud Flood Study* (2012).

The Karuah River data set comprises of 28 surveyed cross-sections along the Karuah River from downstream of the Karuah Bridge at Tarean Road to a location 1.6 km upstream of the North Coast Railway bridge at Stroud Road.

The Stroud data set comprises 6 cross-sections along Mill Creek plus survey of the Mill Creek Bridge, one (1) cross-section along Mill Brook plus survey of the Mill Brook Culvert, and two (2) cross-sections along Lamans Creek plus survey of Lamans Creek Bridge.

3.1.3 Floor Level Survey

Detailed floor level survey as used in the Stroud Flood Study (WMAwater 2012) was acquired for use in the current study. It is noted that two dwellings along Briton Court Road at Stroud appear to have had their floor levels raised in response to the April 2015 flood.

A review of the results from the *Karuah River Flood Study* (Paterson Consultants 2010), preliminary updated flood modelling, and site inspection, established that no additional properties require floor level survey and that floor level estimation by approximate techniques will be appropriate for damages analysis for the FRMS.

3.2 Hydrometric Data

In order to identify hydrometric data stations within or adjacent to the Karuah River catchment a thorough search of available databases was undertaken and discussions were held with relevant agencies including the Bureau of Meteorology (BoM), DPI Water and Manly Hydraulics Laboratory (MHL).

The search focused on currently operating stations and pluviometers (gauges that record continuous sub-daily rainfall) that would be appropriate for use in flood model calibration to the April 2015 flood event. Relevant stations are mapped in **Figure 3-1** and are discussed below.

It is noted that additional stations have been located within the catchment in the past but are no longer operational. Information on these gauges is documented in the *Karuah River Flood Study* (Paterson Consultants 2010).

3.2.1 River Level and Flow Data

The following current river level stations were identified within the Karuah River catchment:

- DPI Water gauges:
  - 209003 – Karuah River at Booral
  - 209018 – Karuah River at Dam Site
  - 209002 – Mammy Johnsons River at Pikes Crossing
- MHL gauges:
  - 209485 – Karuah River (at Karuah Motor Yacht Club).

MHL's Karuah River station is located about 110 m downstream of the Karuah Bridge (Tarean Road), close to where the Karuah River discharges to Port Stephens. Water levels at the gauge are only mildly influenced by catchment driven flooding.

Data from the DPI Water station includes flows that have been converted from recorded water levels using rating curves for each site. These rating curves are established by measuring flow (based on velocity and cross-sectional area of flow) at discrete times during site visits ('flow gaugings'). While numerous flow gaugings are completed to inform the rating curve at lower water levels, gaugings at higher water levels are infrequent and the rating curve must be extrapolated above the highest gauged water level. As a result, flow data at higher river levels is less reliable. The rating curve is also updated as new flow gaugings become available.

The dates and water levels of the highest flow gauging for each site are listed in **Table 3-1**.

Table 3-1 Details of highest gaugings at DPI Water stations

Station	Date of Highest Gauging	Maximum Gauged Level	
		Gauge Height (m)	RL (mAHD)
209003 – Karuah River at Booral	15 June 2011	6.175	7.225
209018 – Karuah River at Dam Site	2 February 2012	3.926	92.938
209002 – Mammy Johnsons River at Pikes Crossing	4 March 1977	5.844	79.134

The 10 highest water levels recorded at Booral since 1968 are presented in **Table 3-2** along with the associated flows both as determined using the discharge rating curve at the time of the event, and using the latest discharge rating curve that has been applied since 6 June 2016.

Table 3-2 Highest recorded flood levels at Karuah River at Booral gauge (since 1968)

Rank	Date	Peak Flood Level		Peak Flow (m^3/s)	
		Gauge Height (m)	RL (mAHD)	2016 Rating Curve	Rating Curve at Time of Event
1	21 April 2015	9.32	10.37	1209	1164
2	21 January 1971	9.30	10.35	1203	2423
3	13 October 1985	8.86	9.91	1105	2088
4	4 February 1990	8.60	9.65	1048	1890
5	8 June 2007	8.42	9.47	1008	1761
6	20 March 1978	7.98	9.03	916	1506
7	8 May 2001	7.87	8.92	894	1412
8	15 June 2011	7.67	8.72	853	810
9	12 November 1987	7.48	8.53	816	1219
10	4 March 1977	7.33	8.38	788	1173

Notable from **Table 3-2** is that there has been significant change in the rating curve over time, as most evident by comparing flows from the 21 April 2015 and 21 January 1971 events. While the peak flood levels for these events are very similar, the rating curve from 1971 estimated a flow of more than double that estimated using the 2016 rating curve. This is indicative of the significant uncertainty in the rating curves and resulting flow estimates at flood levels above the maximum gauged level.

3.2.2 Rainfall Data

Rainfall data was sought from current stations within and surrounding the Karuah River catchment. A particular focus was placed on data from pluviometers (gauges that record continuous sub-daily rainfall) in order to be able to resolve the temporal pattern of rainfall across the catchment.

The following current rainfall stations were identified for use in the study:

- BoM Flood Warning stations (pluviometers, not quality controlled)
  - 60099 – Crawford
  - 60096 – Cabbage Tree Mountain
  - 60042 – Craven (Longview)
  - 60155 – Waukivory
  - 61017 – Dungog Post Office
  - 60103 – Krambach (Tipperary)
  - 61415 – Upper Myall Creek
- BoM Climate Reference stations (pluviometers)
  - 61151 – Chichester Dam
  - 61250 – Paterson (Tocal AWS)
  - 61078 – Williamtown RAAF
  - 60112 – Gloucester (Hiawatha)
- BoM Daily Rainfall stations
  - 61071 – Stroud Post Office
  - 60159 – Warranulla (Myall Lodge)
  - 61010 – Clarence Town (Grey St)
  - 61017 – Dungog Post Office
  - 61364 – Dungog (Leawood)
  - 61106 – Monkerai Hill (Urimbirra)
  - 61170 – Dungog (Yeranda)
  - 60096 – Cabbage Tree Mountain
  - 61350 – Upper Chichester (Simmonds)
  - 61395 – Tanilba Bay WWTP
  - 61054 – Nelson Bay (Nelson Head)
  - 61031 – Raymond Terrace (Kinross)
- MHL stations (pluviometers)
  - 209460 – Myall River at Bulahdelah
  - 210462 – Williams River at Seaham
  - 210402 – Paterson River at Gostwyck.

The only rainfall station located within the Karuah River catchment is the daily rainfall station at Stroud Post Office. The Cabbage Tree Mountain pluviometer is located on the catchment boundary above Mammy Johnsons River, while pluviometer stations such as Crawford, Waukivory, Craven and Chichester Dam, are all located within a few kilometres of the catchment boundary.

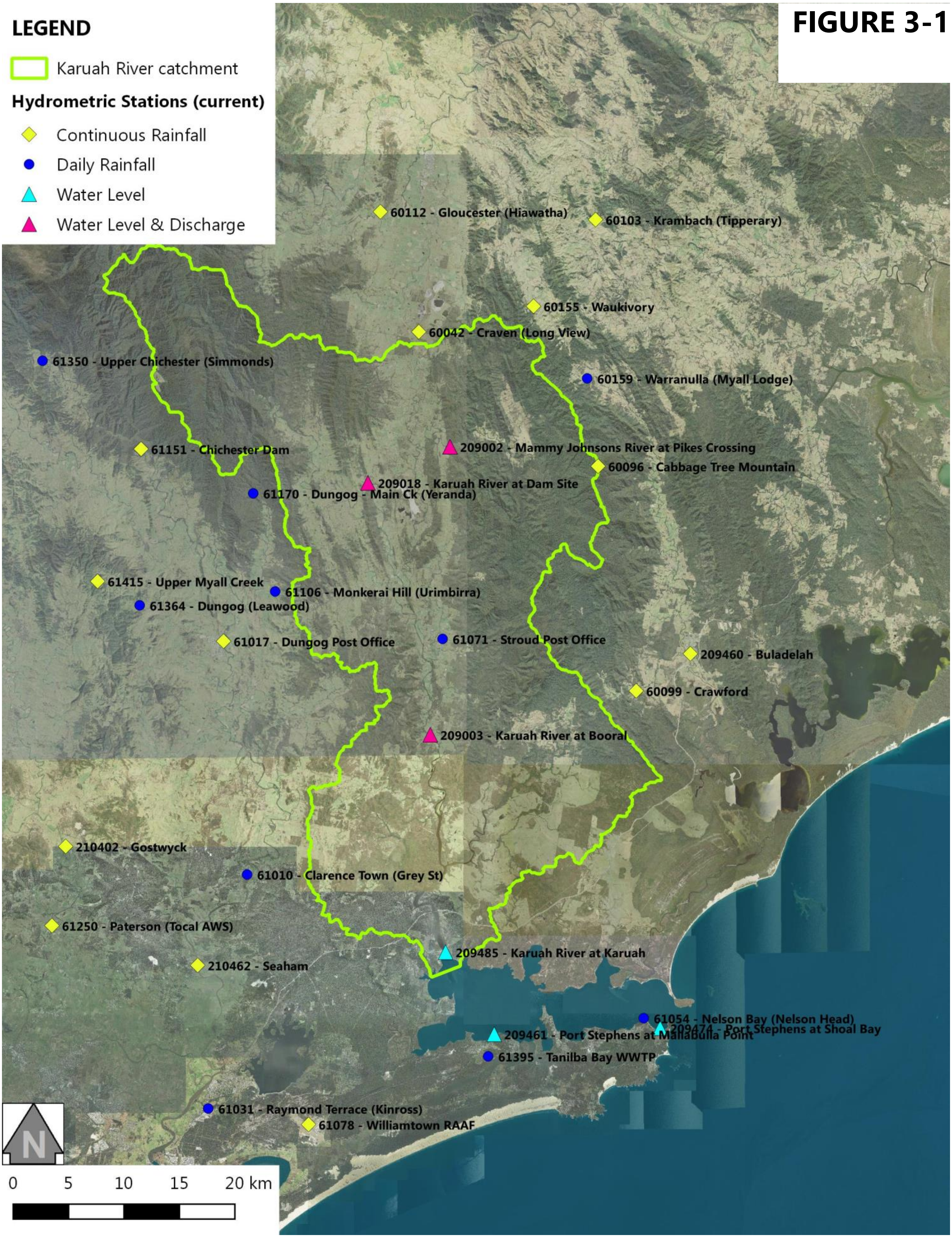
3.2.3 Port Stephens Estuary and Ocean Level Data

Data from the following water level stations was sought for use in the study:

- MHL estuary and ocean level stations:
  - 209461 – Port Stephens at Mallabulla point
  - 209474 – Port Stephens at Shoal Bay

The Shoal Bay station is located close to the mouth of Port Stephens and is representative of ocean conditions, while the Mallabulla Point gauge is located deeper in Port Stephens capturing any modification of the tidal signal as would be experienced at the mouth of the Karuah River.

FIGURE 3-1



HYDROMETRIC DATA STATIONS

Advisian
WorleyParsons Group

3.3 Historic Flood Data

Additional sources of historic flood levels are discussed in the following. Further detail on a number of these data sets in presented in *Karuah River Flood Study* (Paterson Consultants 2010).

3.3.1 Hunter District Water Board Peak Level Indicators

During investigations into drawing water from the Karuah River near Booral, the Hunter District Water Board (HDWB, now Hunter Water) produced flood reports for the January 1976, March 1977 and March 1978 floods. The reports tabulate a series of peak flood levels as derived from peak level recorders.

The 1977 and 1978 floods are ranked within the 10 highest levels recorded at the DPI Water gauge at Booral since 1968, peaking at 8.38 mAHD and 9.03 mAHD respectively. The peak levels recorded by the Hunter District Water Board for these events are reproduced in **Table 3-3**.

Table 3-3 Hunter District Water Board recorded flood levels, 1977 and 1978

HDWB ID	Location	Peak Flood Level (mAHD)	
		March 1977	March 1978
1	Karuah River, Washpool Bridge	33.86	37.75
2	Karuah River, Stroud (downstream of bridge)	24.04	25.10
3	Karuah River, Stroud to Booral (approx. 1.1 km upstream of Alderley Creek)	15.06	16.44
4	Karuah River, Booral (downstream of bridge)	8.43	9.26
5	Karuah River, Allworth Weir Site (approx. 3.6 km downstream of Booral Creek)	4.93	5.87

3.3.2 RMS Bridge Drawings

Some historical flood levels are indicated on the "general arrangement" drawings from NSW Roads and Maritime Services (RMS, formerly the Roads and Traffic Authority) for the Booral and Washpool bridges as follows.

- Karuah River at Washpool drawing dated 1980:
  - Deck level 39.56 mAHD
  - 1850 flood level 38.5 mAHD
  - 1946 flood level 37.1 mAHD
- Karuah River at Booral drawing dated 1944
  - Deck level 101 ft (14.28 mAHD)
  - 1894 flood level 92 ft (11.78 mAHD).

3.3.3 North Coast Railways Working Plans

The North Coast Railway, which crosses the Karuah River at Stroud Road, was constructed in the early 1900's. The "Working Plans" for the railway quote a recorded flood level of 230 feet (about 40.3 m AHD) for the Karuah River at Stroud Road. Given that the plans are dated 1909, the recorded level probably relates to a flood event in the 1800's, possibly the 1894 event.

3.3.4 Karuah River Flood Study Flood Mark Survey

The *Karuah River Flood Study* (Paterson Consultants 2010) included the survey of 13 flood marks identified through the community consultation process. The flood marks related to observed levels for the 2007, 1988, 1978, 1955 and "highest recorded" floods. The locations of the surveyed marks include Stroud Road, Washpool, Stroud, and Karuah.

3.3.5 Paterson Consultants April 2015 Flood Marks at Stroud

Flood Data Collection, Dungog and Stroud Flood Event 21 April 2015 (Paterson Consultants 2015) photographed and documented twenty flood marks in Stroud and measured their level relative to reference points which were to be surveyed subsequently.

The flood marks include locations within and adjacent to the Stroud Showground, Stroud Community Lodge, Erin Street, Millbrook Road, Briton Court Road, and Gortons Crossing Road at the Karuah River. The reference points have not yet been surveyed.

3.3.6 Council Survey of April 2015 Flood Marks at Stroud

Following the 21 April 2015 flood event, the then Great Lakes Council undertook photography and survey of 12 flood marks at Stroud in the vicinity of the Cowper Street crossings of Mill Creek and Mill Brook. These are presented in Appendix D of the report titled, *Flood Data Collection, Dungog and Stroud Flood Event 21 April 2015* (Paterson Consultants 2015).

3.3.7 SES Flood Intelligence Stroud Flash Flooding (April 2015)

Following the 21 April 2015 flood event, the NSW SES Mid North Coast Region undertook a door-knocking exercise to gather flood intelligence on the event. Information regarding the nature and timing of flooding was gathered from residents at 12 properties in Cowper Street and Briton Court Road.

3.4 Site Visit

A site visit attended by staff from Advisian, Council and OEH was undertaken on 7 September 2017. Sites of interest that were inspected during the visit are listed below.

- Karuah North
  - Properties along river front
- The Branch
  - The Branch Lane southern bridge crossing (Little Branch River)
  - The Branch Lane northern bridge crossing (The Branch River)
- Booral
  - Properties adjacent river and along Mulberry Lane
  - Booral Bridge
  - DPI Water gauge at Booral
  - Lowes Lane crossing of Booral Creek
- Stroud
  - Bucketts Way crossing of Mill Creek
  - Bucketts Way crossing of Mill Brook
  - Stroud Show Ground and adjacent properties (Briton Court Road, Cowper Street, Community Lodge, Pool, Erin Street)
  - Bucketts Way crossing of Lamans Creek and nearby properties
  - Gortons Crossing Road bridge
- Stroud Road
  - Properties and electrical substation at lower end of Karuah Street
  - Reisdale Road bridge
- Allworth
  - Properties along river front.

Discussions were held with a local resident at the corner of Cowper Street and Briton Court Road at Stroud, whose home was impacted by the April 2015 flood. The resident provided first-hand insight into the nature of the flood and experiences of the community. Also notable was that at least two properties on Britton Court Road appeared to have raised their floor levels in response to the flood.

The site visit enabled the study team to further familiarise themselves with the study area. The inspection also confirmed that the degree of flood risk posed to the community is expected to be greatest at Stroud, while homes at Karuah North, Allworth and Stroud Road are generally expected to be outside of the floodplain or only affected by extreme floods such as the Probable Maximum Flood (PMF).

4 Review of April 2015 Flood Event

4.1 Overview

In April 2015 an intense East Coast Low formed off the New South Wales coast, initially moving northward before until the evening of 19 April when it was centred approximately 250 km east of Port Macquarie. Over the period from Monday 20 to Tuesday 21 April, the system continued to intensify drawing more moist air inland while moving south-west towards Newcastle and the Hunter Valley.

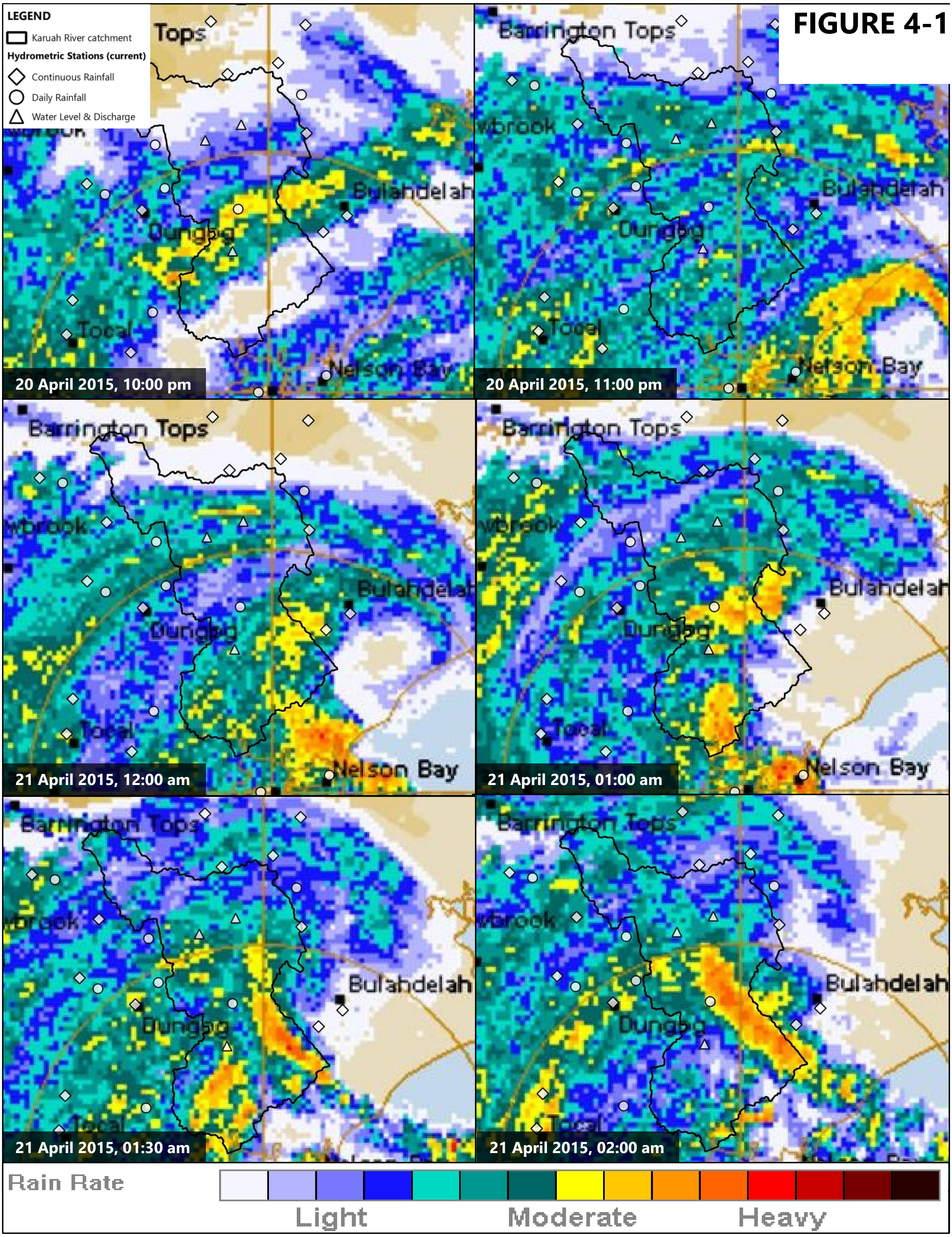
The system brought severe weather to the Lower Mid North Coast, Hunter, Central Coast and Sydney regions including intense rainfall, strong winds and large waves. In addition to the major flooding at Stroud, the rainfall caused widespread flooding in the Hunter region with devastating impacts suffered at Dungog including the loss of three lives and destruction of several houses.

An overview of the timing and intensity of rainfall in the Karuah River catchment as indicated by BoM rainfall radar imagery is presented in **Figure 4-1** and **Figure 4-2**. The imagery indicates that a band of moderate to heavy rainfall formed across the centre of the catchment in the vicinity of Stroud at around 10 pm on the evening of 20 April 2015. From there until about 12 am, rainfall in the catchment was generally of moderate intensity with heavier falls over The Branch River catchment.

From about 1 am on the morning of 21 April, heavy rainfall began to fall over Stroud, then forming a north-west to south-east aligned band of high intensity rainfall affecting the catchments of The Branch River, Mill and Lamans Creeks, and parts of the upper Mammy Johnsons River catchment through to about 3:30 am. By 4 am this zone of heavy rainfall had largely disbanded, with the lower Karuah River catchment experiencing little rainfall by 5 am and the storm cell having largely moved on to the Williams River catchment by 6 am with heavy rainfall centred around Dungog.

The location of hydrometric data stations is also indicated in **Figure 4-1** and **Figure 4-2**. It is evident that there was significant spatial and temporal variation in rainfall intensity across the Karuah River catchment throughout the event which could not be fully captured by the available rainfall stations.

FIGURE 4-1



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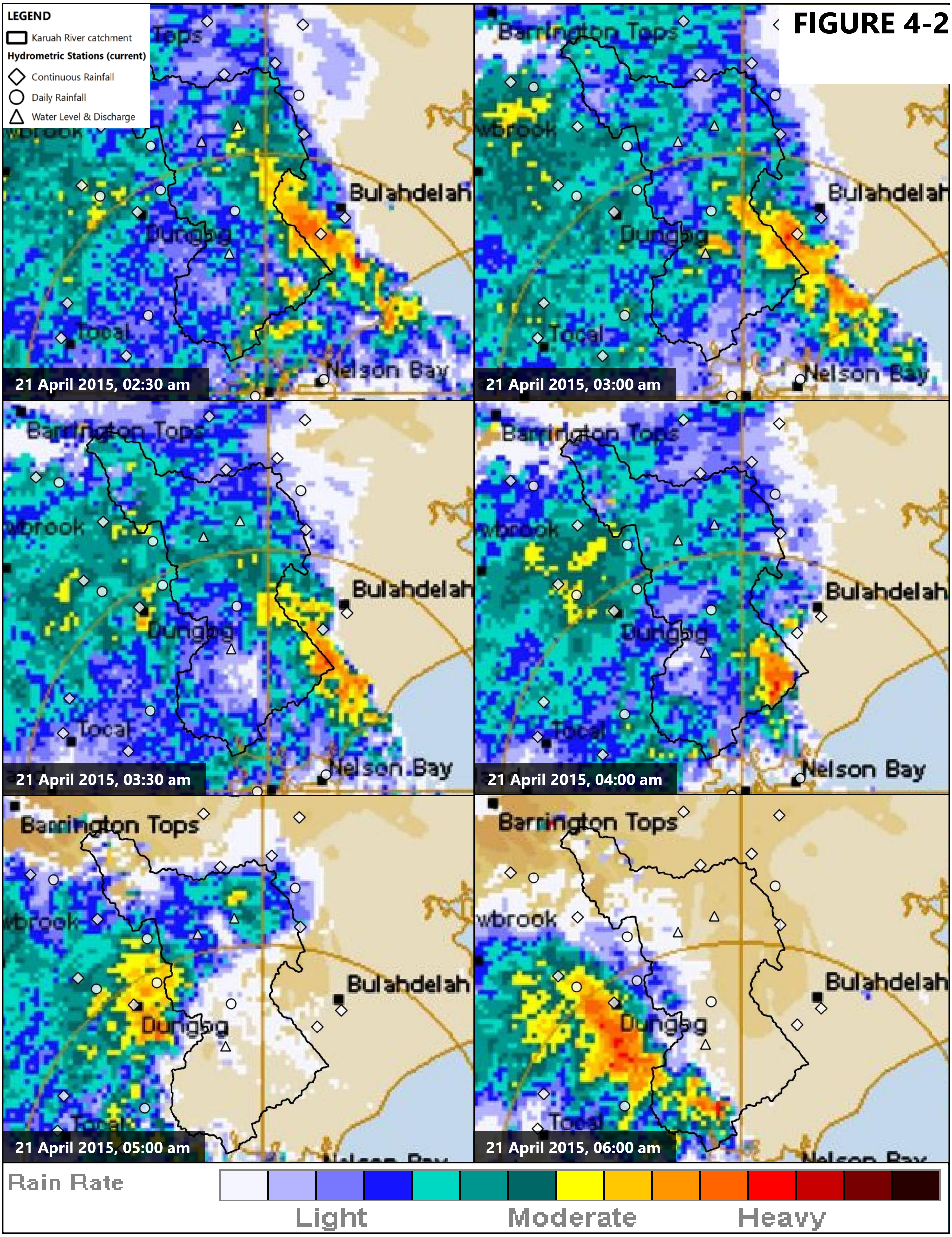
BOM RADAR RAINFALL RATE IMAGERY
21 APRIL 2015 EVENT

FIGURE 4-2



BOM RADAR RAINFALL RATE IMAGERY 21 APRIL 2015 EVENT

4.2 Rainfall Data

A cumulative rainfall plot for the period from 9 am 20 April to 9 am 21 April 2015 is presented in **Figure 4-3** including selected gauges most relevant to the Karuah River catchment. Rainfall totals for the same period at all stations from which data was acquired are presented spatially in **Figure 4-4**. It is noted that the rainfall contours shown, as determined by inverse-distance-weighting from available rainfall stations, may not accurately reflect the true distribution of rainfall, as evident by comparison with radar rainfall rate imagery.

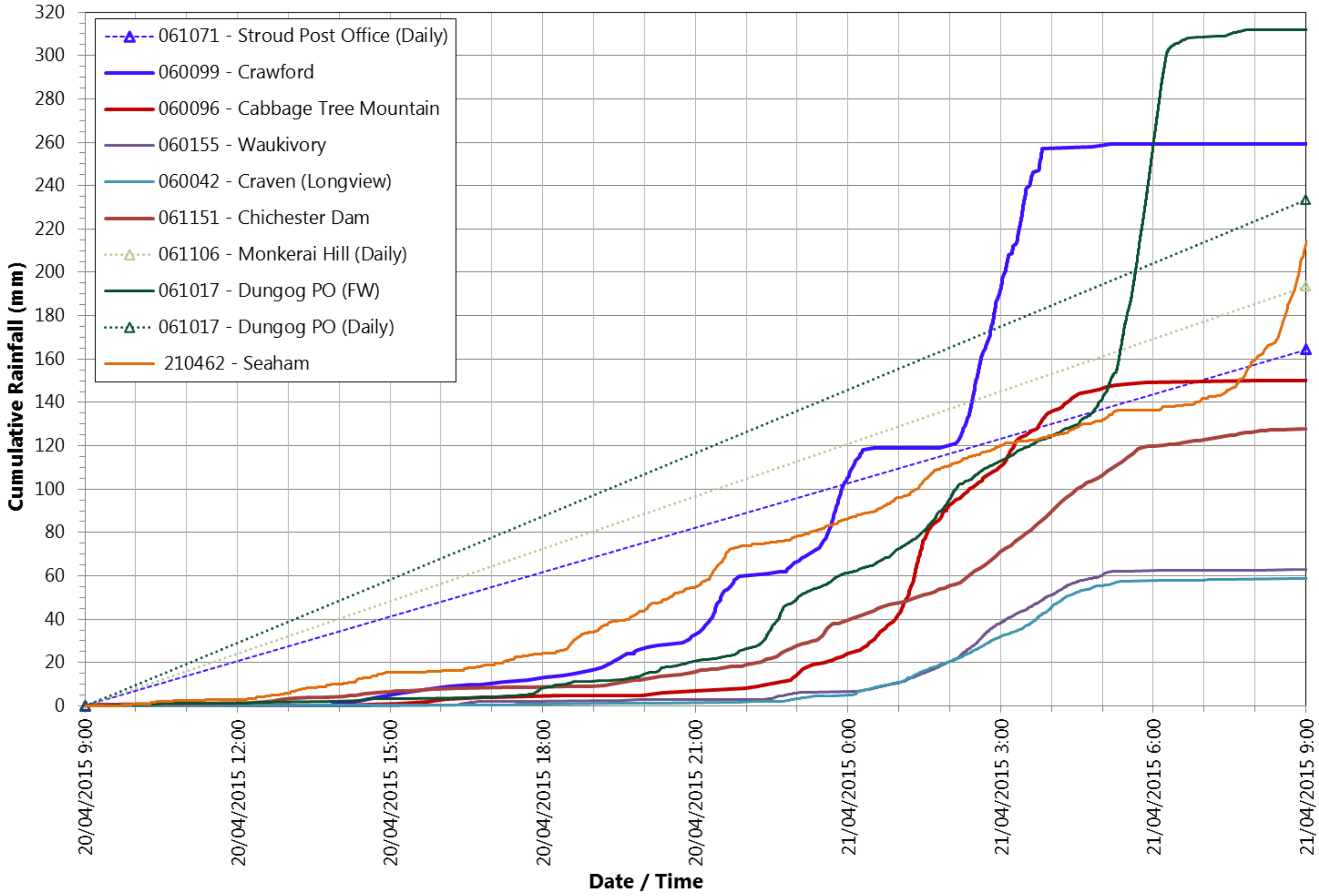
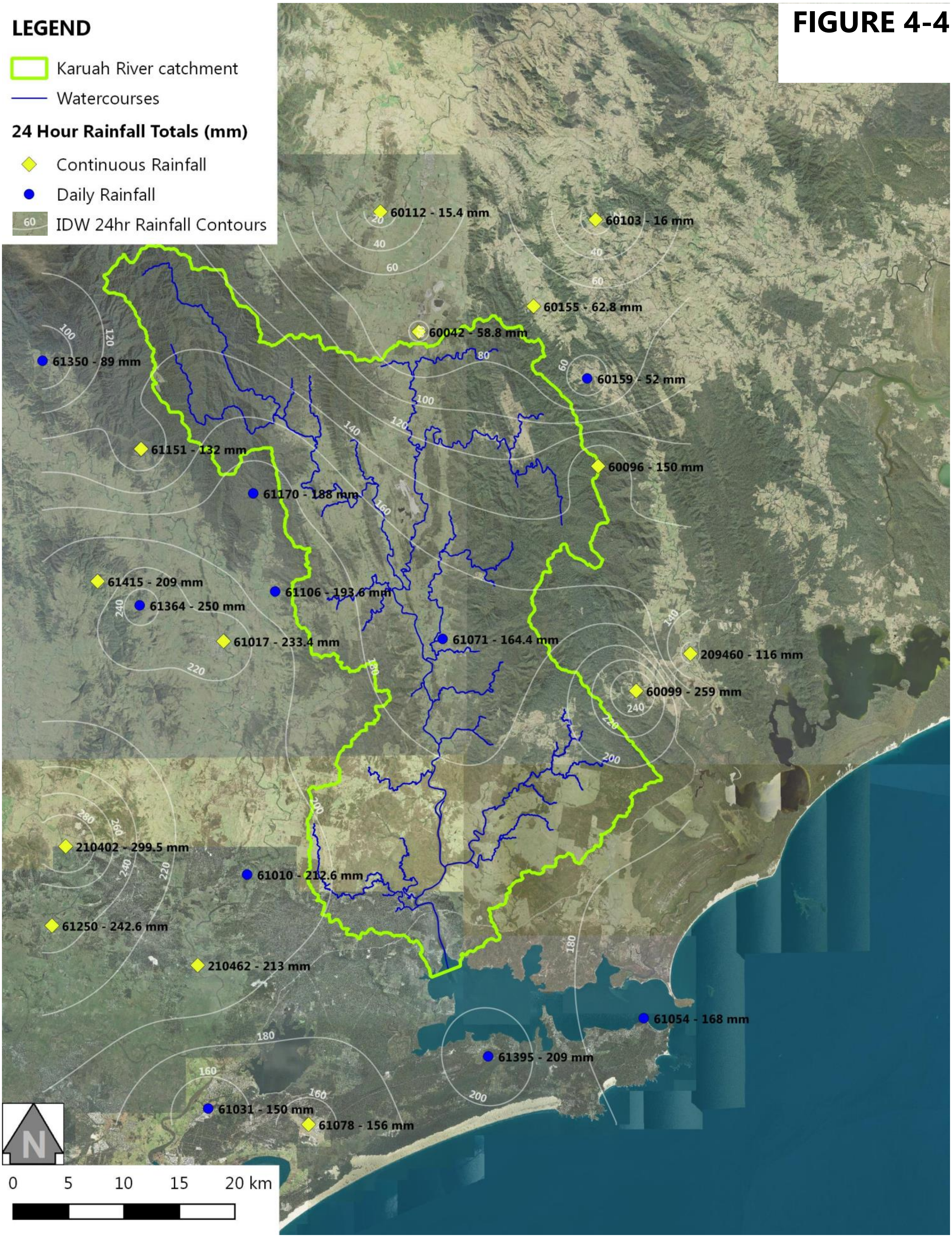


Figure 4-3 Cumulative rainfall plot for the period 9 am 20 April to 9 am 21 April 2015

The BoM daily rainfall station at Stroud is the only rainfall station located within the Karuah River catchment. It recorded a 24 hour rainfall total of 164.4 mm for the period to 9 am on 21st April 2015. The nearest pluviometer gauges at Cabbage Tree Mountain and Crawford recorded 24 hour totals of 158 mm and 259 mm respectively.

The Crawford gauge is most representative of the heavy rainfall band that formed over the south-east of the catchment. Rainfall over the upper catchment was generally lower with 24 hour totals of 62.8 mm, 58.8 mm and 127.6 mm recorded at the Waukivory, Craven and Chichester Dam stations respectively. Interestingly, the Dungog flood warning station located at Dungog Post Office recorded a 24 hour total of 311.8 mm while the daily rainfall station also located at Dungog Post Office recorded only 233.4 mm.

FIGURE 4-4



24 HOUR RAINFALL TOTALS
9 AM 20 APRIL TO 9 AM 21 APRIL 2015

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4.3 Assessment of Rainfall Return Period

In order to assess the relative intensity and return period of rainfall during the April 2015 event, maximum recorded rainfall depths over durations of one to 24 hours have been plotted against design Intensity-Frequency-Duration (IFD) curves for the catchment (refer **Figure 5-5**).

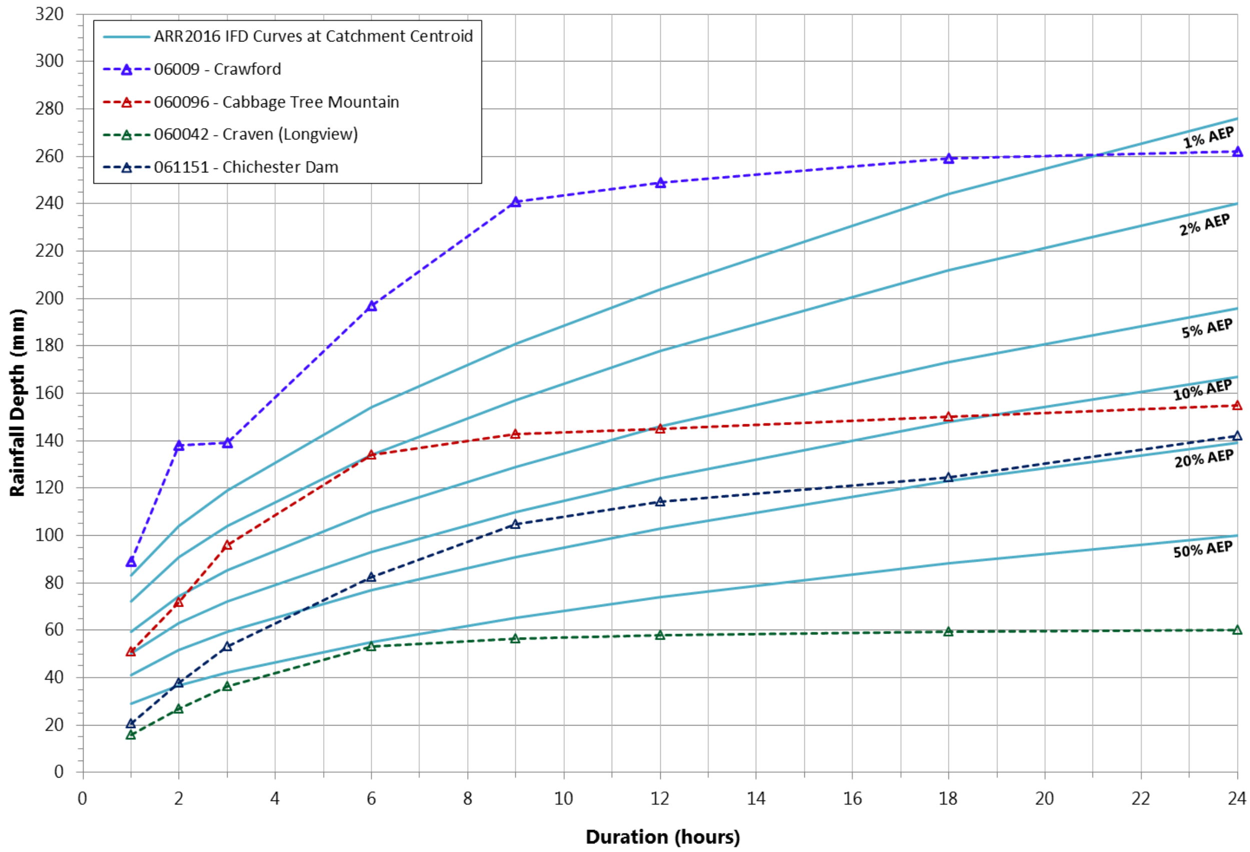


Figure 4-5 Comparison of recorded rainfall and design rainfall for 21 April 2015 event

It can be seen that rainfall at the Crawford gauge exceeded the 1% AEP design rainfall over durations from one hour to 18 hours, and by quite a significant margin for most of those durations.

Rainfall at Cabbage Tree Mountain exceeded a 10% AEP design event for all durations except 24 hours, exceeded a 5% AEP for durations from 3 to 9 hours, and was as high as a 2% AEP event over a duration of 6 hours.

Rainfall at Chichester Dam exceeded a 20% AEP design event for durations of 6 to 24 hours, while rainfall at Craven did not exceed a 50% AEP design event over any duration.

4.4 Stream Gauge Data

Stream flow data downloaded from the DPI Water website for the three gauges within the Karuah River catchment is presented in **Figure 4-6**.

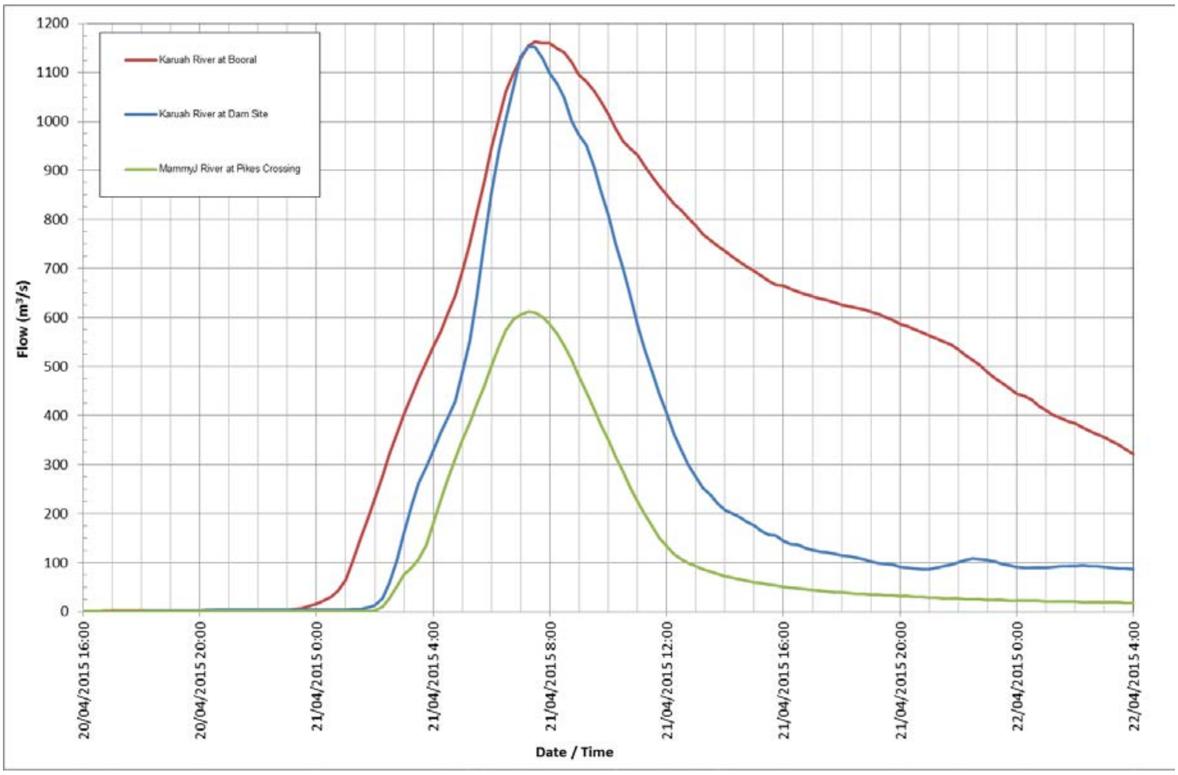


Figure 4-6 DPI Water streamflow data for 20 to 22 April 2015

Flows at the Karuah River at Dam Site and Mammy Johnson River at Pikes Crossing gauges peaked at 7:15 am, while flows at the Karuah River at Booral gauge peaked just 15 minutes later at 7:30 am.

Given the significant length of river between the Dam Site and Pikes Crossing gauges and the Booral gauge (greater than 30 kilometres), this – in conjunction with the intense rainfall observed in these areas – suggests that the flood peak at the Booral gauge was driven by flows from nearer catchments such as Alderley Creek, Lamans Creek, Mill Creek and perhaps Ram Station Creek. The secondary "hump" in the Booral hydrograph at around 6 pm would appear to relate to attenuated flows arriving from the upper Karuah and Mammy Johnsons River catchments.

It is notable that the peak rated flows at the Dam Site and Booral gauges are quite similar. Given the difference in catchment size at each of the gauges this may draw uncertainty toward the rating curves used to derive the flows, although temporal and spatial variation in rainfall is also likely to be a significant contributor to this observation.

A review of flow volumes at each of the sites over the duration of the flood event indicates that the flow volume at Dam Site and Pikes Crossing represents a higher than expected percentage of the flow volume at Booral relative to catchment area, a finding that is also at odds with the lower rainfall observed in the upper catchment.

4.5 Ocean and Port Stephens Estuary Water Levels

Data from MHL's three water level stations in Port Stephens and the lower Karuah River for the April 2015 event is shown in **Figure 4-7**.

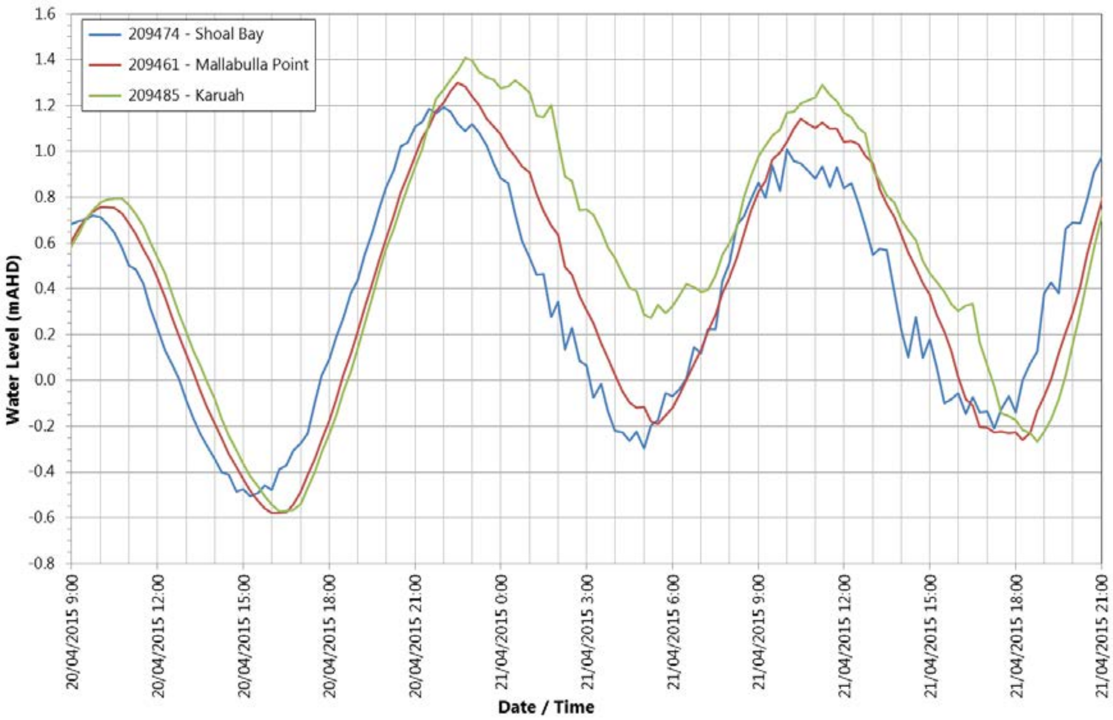


Figure 4-7 MHL ocean and estuary water level data for 20 and 21 April 2015

Given its similarity to the Karuah River gauge in terms of timing and peak tidal levels prior to the flood event, and its greater proximity to the downstream model boundary than the Shoal Bay gauge, data from the Mallabulla Point gauge would provide the most appropriate downstream boundary condition for use in the model calibration.

It is also evident from **Figure 4-7** that the Karuah River gauge is subject to influence from catchment flows, with levels in the order of 0.5 m higher at this gauge than at Mallabulla Point at low tide at around 5:30 am on 21 April. Data from the Karuah River gauge was therefore considered in the model calibration, albeit that it is downstream of the model boundary.

5 Existing Flood Behaviour

5.1 Flood Study Update

A *Flood Study Update* was undertaken as part of the *Karuah River and Stroud Floodplain Risk Management Study* and is presented as a separate report. Volume 1 documents the work undertaken as part of the review and updates the existing flood studies. Volume 2 is a compendium of updated flood mapping.

The objectives of the FRMS are to assess the potential impacts of flooding and to assess potential flood risk management measures and strategies. This requires a sound understanding of flood behaviour in the study area, which can readily be determined from reliable flood modelling outputs.

The following flood models had previously been developed covering parts of the study area.

- As part of the *Karuah River Flood Study* (Paterson Consultants 2010), a RORB hydrologic model and a one-dimensional (1D) MIKE-11 hydraulic model were developed to define flood behaviour and design flood levels along the Karuah River from around 1 km upstream of Stroud Road to the old Pacific Highway bridge at Karuah.
- As part of the *Stroud Flood Study* (WMAwater 2012), a WBNM hydrologic model and a two-dimensional TUFLOW hydraulic model were established to simulate flood behaviour around the township of Stroud, considering flooding from Mill and Lamans Creeks as well as backwater flooding from the Karuah River.

For the purposes of the FRMS, it was considered that there would be considerable benefit in developing updated flood models and mapping using the latest guidelines, catchment data and technology. Accordingly, Advisian developed a WBNM hydrologic model for the entire Karuah River catchment, and a two-dimensional (2D) TUFLOW hydraulic model for the study area from Stroud Road to Port Stephens. Benefits of the model update include the following.

- Use of a single model software and approach, providing model results that are directly comparable throughout the study area and which will allow assessment of flood impacts, emergency management and potential mitigation works to be undertaken on a consistent basis.
- Improved resolution of flooding patterns in overbank / floodplain areas in 2D compared to 1D.
- Provision of high resolution 2D temporal mapping outputs.
- Use of the latest topographic LiDAR data.
- Use of the April 2015 flood event to provide improved model calibration
- Use of *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Geoscience Australia 2016) (ARR2019) to define design flood conditions.

The flood modelling specifically investigated the following waterways:

- Karuah River from Stroud Road to Port Stephens
- Mammy Johnsons River at Stroud Road
- Mill Creek
- Lamans Creek
- The Branch River upstream to The Branch Lane
- Little Branch River upstream to The Branch Lane.

Flood modelling of any other tributaries did not investigate local catchment critical storm durations or incorporate bathymetric and structural data. Peak flood levels associated with backwater flooding from the specifically modelled waterways listed above are generally expected to be reliable but should be reviewed by the user for appropriateness prior to adoption. Local overland flow flooding was not investigated.

5.2 General Catchment Flood Behaviour

The following provides a general description of flood behaviour along the key study rivers and tributaries, and a discussion of the relative influence of flood magnitude (in terms of % AEP) on flood extent and peak flood levels.

The extents of all simulated design flood events are presented in **Figure 5-1** (Stroud Road to Booral) and **Figure 2-2** (Allworth to Karuah).

Karuah River

For the majority of its length, the floor of the Karuah River Valley is less than 1 km wide and is flanked by steep-sided ridges. The main river channel is also relatively narrow and well incised downstream to Allworth which is the tidal limit. From Allworth downstream the valley floor and river channel broaden, with significant areas of wetland present. These characteristics have a significant influence on the overall flood behaviour of the Karuah River.

Above Allworth, the extent of more frequent flood events such as the 20% AEP flood is largely confined to the main river channel, with limited overbank flow through narrow flood-runners. From Allworth downstream, the flood extent is greater with lower velocities owing to the inundation of the generally, lower, broader valley floor.

As the magnitude of flooding increases, the influence on flood behaviour varies throughout the catchment and can be described as follows.

- Upstream of Allworth:
  - In most areas, greater overbank flows begin to occur during the 5% AEP event, resulting in a significant increase in flood extent between the 20% AEP and 5% AEP events. In other areas, such increases in flood extent do not occur until the 2% or even the 1% AEP event.
  - In most areas, there is minimal increase in flood extent between the 1% AEP and 0.2% AEP events. The same can be said of the increase between the 0.2% AEP and PMF flood extents, with the exception of the eastern bank of the Karuah River near Ribbons Road (between Stroud and Booral), and in the vicinity of Booral.
  - While increases in flood extent with flood magnitude are relatively minor, associated increases in flood level are significant.
- From Allworth downstream, increases in flood extent with flood magnitude are even more limited, while associated increases in flood level remain significant as far downstream as the Pacific Highway Bridge crossing near Karuah.
- In general, it can be concluded that the increase in flood extent with increase in flood severity is relatively minor along the Karuah River. However, associated increases in flood level are significant. This is largely due to the generally narrow and steep-sided geometry of the Karuah River Valley and the relatively steep valley slope.

Stroud

Flooding in Stroud is dominated by local catchment flows from the Mill Creek and Lamans Creek catchments. Backwater flooding from the Karuah River can occur but only extends upstream to near the confluence of Mill Creek and Lamans Creek.

Along Mill Creek at Stroud, increase in flood extent with flood severity is generally limited except for a notable increase in flood extent between the 5% AEP and 2% AEP events. This is associated with increased inundation across Stroud Showground and overtopping of The Bucketts Way, which results in widespread inundation along Briton Court Road. There is also a significant increase in flood extent associated with the PMF, particularly near the intersection of The Bucketts Way and Mill Creek Road. Flood level increases with flood severity are less significant than along the Karuah River (*refer* **Table 5-1**), although may have a greater impact on floodplain development.

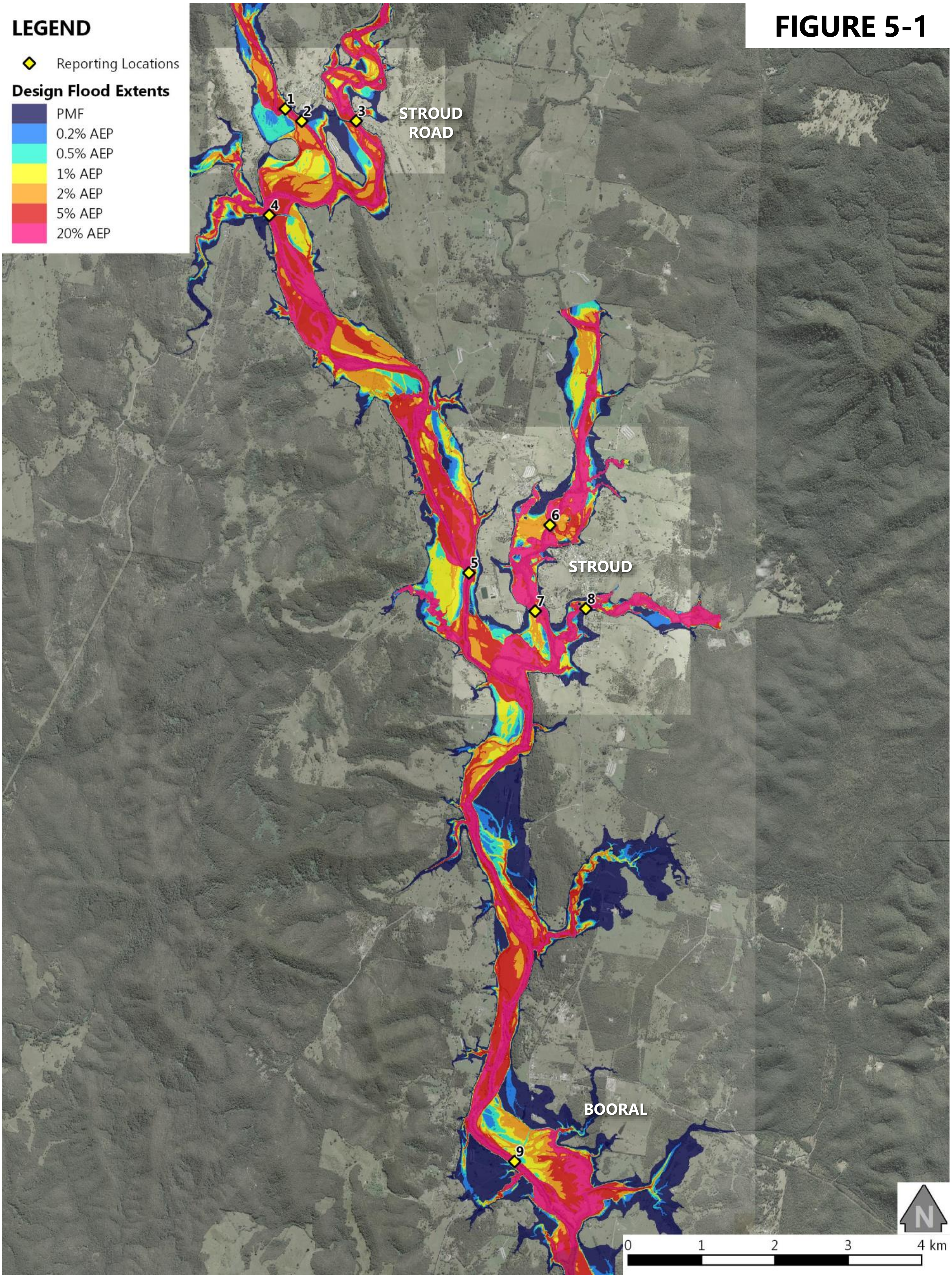
Along Lamans Creek at Stroud, increase in flood extent with flood severity is generally even less pronounced, with the exception of the PMF which results in the inundation of various additional properties between Laman and Hinton Streets. Flood modelling results indicate that The Bucketts Way would be overtopped to the north of the Lamans Creek bridge, near Laman Street, in a 2% AEP flood event.

The Branch

Similar to the lower Karuah River, the lower areas of the Branch River and the Little Branch River comprise a comparatively broad floodplain characterised by wetland areas that become inundated in events as frequent as the 20% AEP flood. Flooding in these areas is dominated by backwater flooding from the Karuah River. Increase in flood extent with increase in flood magnitude is generally quite minor, however associated increases in flood level are significant.

Further upstream, the river valleys become narrow and steep sided, again limiting increase in flood extent with flood magnitude but resulting in significant increases in floodwater depth. Local catchment rainfall is the dominant flood mechanism in these areas, with shorter critical durations than the Karuah River itself (12 hours for The Branch River and 6 hours for Little Branch River) and faster rates of rise.

FIGURE 5-1



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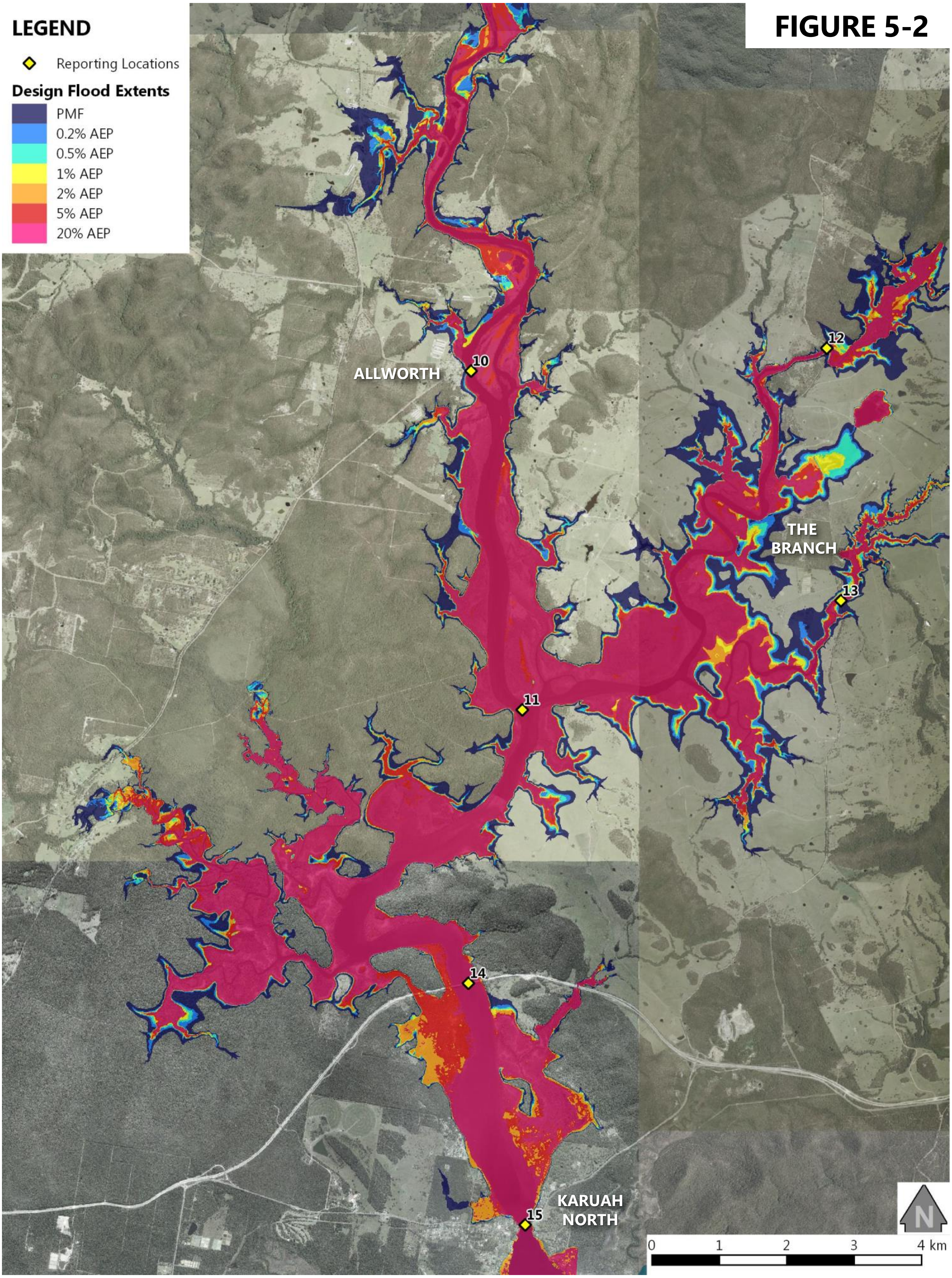
FLOOD EXTENTS FOR ALL DESIGN EVENTS
STROUD ROAD TO BOORAL

FIGURE 5-2



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FLOOD EXTENTS FOR ALL DESIGN EVENTS
ALLWORTH TO KARUAH

5.3 Peak Flood Levels

Simulated peak flood levels for the range of design flood events investigated are presented in **Table 5-1** for the locations shown in **Figure 5-1** and **Figure 5-2**. Flood profiles along the Karuah River are presented in **Figure 5-3** and **Figure 5-4**.

Table 5-1 Simulated peak design flood levels (mAHD) at selected locations

ID	Location	PMF	0.2% AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	20% AEP
1	Karuah River at Reisdale Rd Bridge	45.04	42.40	41.79	41.29	40.82	39.53	37.37
2	Karuah River at Railway Bridge	44.00	41.36	40.86	40.49	40.14	38.98	37.01
3	Mammy Johnsons River at The Bucketts Way	44.30	42.13	41.64	41.26	40.91	40.29	38.80
4	Karuah River at Washpool Bridge	41.56	38.42	37.70	37.09	36.44	35.57	34.13
5	Karuah River at Gorton's Crossing Rd Bridge	31.34	28.52	27.92	27.47	26.87	25.81	23.58
6	Mill Creek at The Bucketts Way	33.19	31.28	31.06	30.86	30.67	30.22	29.47
7	Mill Creek at Laman St Bridge	29.75	27.27	26.94	26.67	26.40	25.93	25.20
8	Lamans Creek at The Bucketts Way	29.59	26.76	26.54	26.37	26.11	25.92	25.32
9	Karuah River at Booral Gauge	18.47	13.23	12.27	11.73	11.09	10.10	8.39
10	Karuah River at Allworth (Karuah St)	10.09	6.46	5.54	4.88	4.21	3.29	2.17
11	Karuah River at The Branch	8.67	5.48	4.63	4.03	3.43	2.59	1.74
12	The Branch River at The Branch Lane	13.18	9.54	8.72	8.15	7.60	6.69	5.48
13	Little Branch River at The Branch Lane	8.79	7.06	6.66	6.34	6.04	5.46	4.66
14	Karuah River at Pacific Highway Bridge	4.03	2.68	2.35	2.14	1.91	1.44	1.22
15	Karuah River at Karuah Bridge	1.82	1.54	1.51	1.49	1.43	1.10	1.09

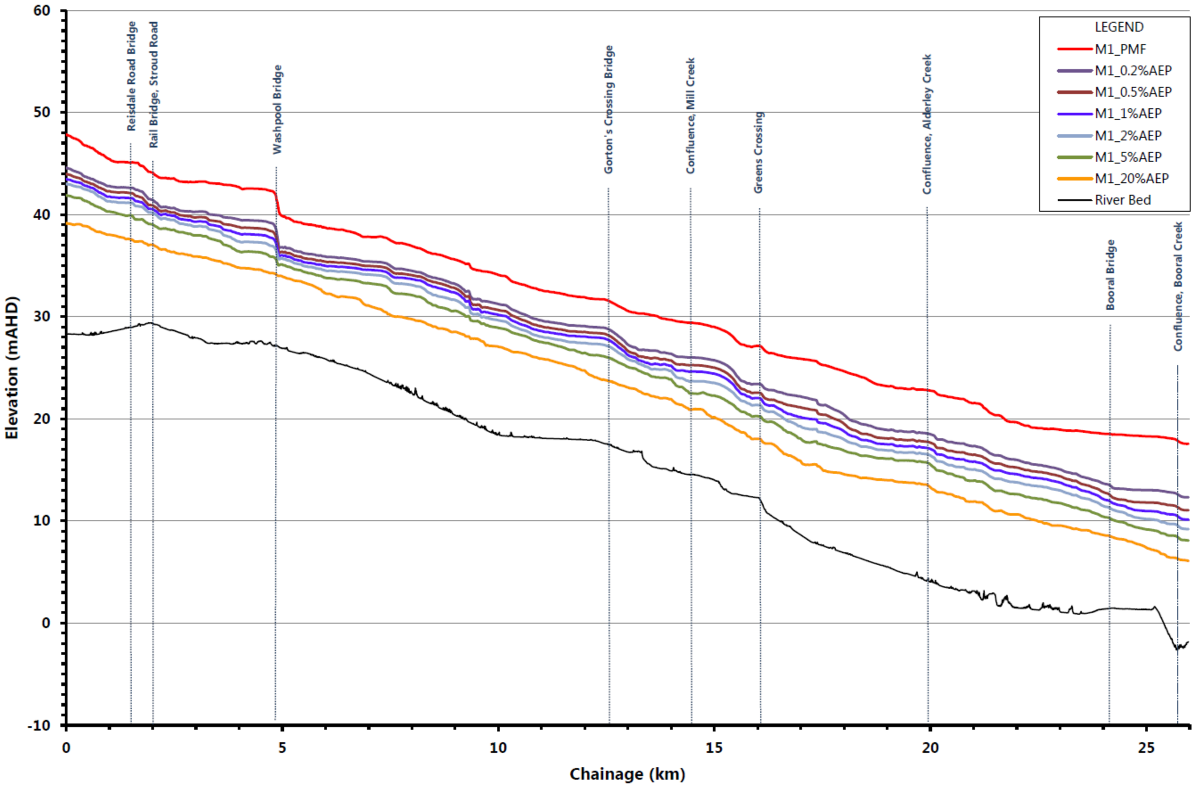


Figure 5-3 Flood profiles along the Karuah River from Stroud Road to Booral Creek

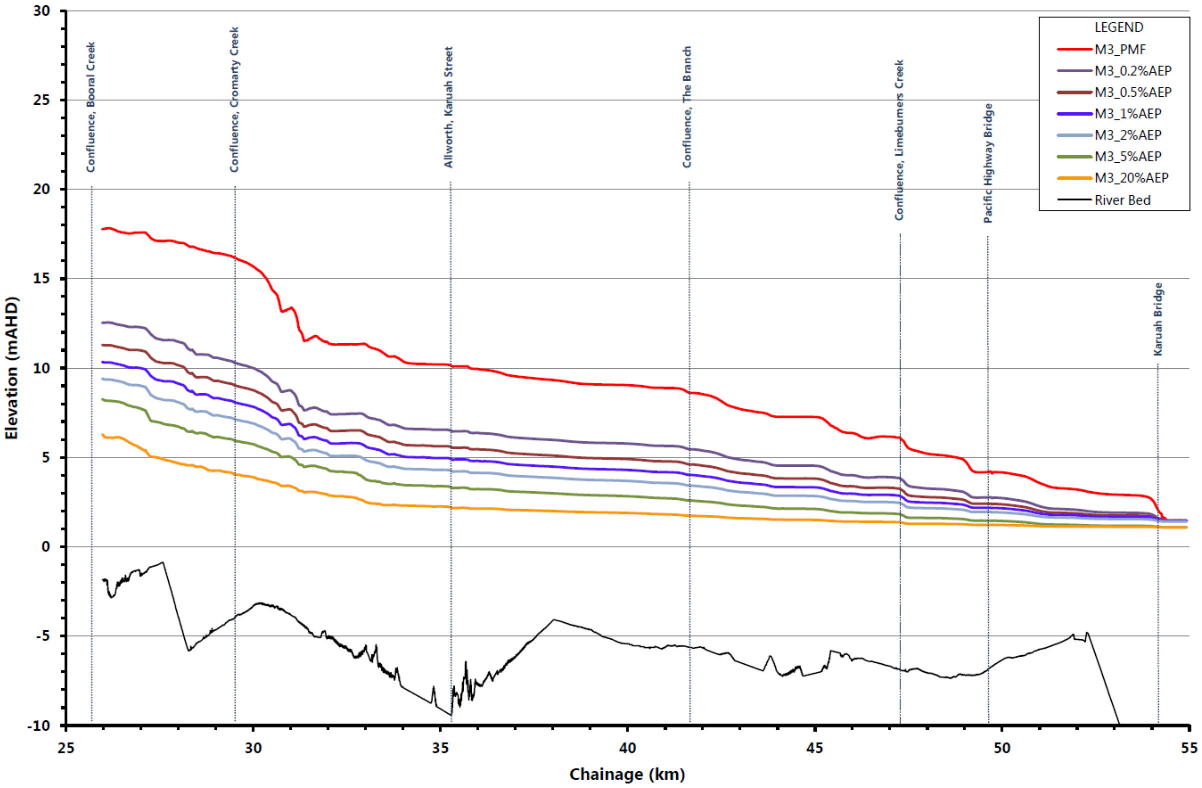


Figure 5-4 Flood profiles along the Karuah River from Booral Creek to Karuah

Interrogation of **Figure 5-3** and **Figure 5-4** indicates that there are numerous features along the Karuah River that have an influence on hydraulic behaviour and flood surface slope, with their impact generally becoming more pronounced with increasing flood magnitude. The features presenting the most significant hydraulic controls are as follows.

The Washpool Bridge

- In events larger than the 20% AEP flood, floodwaters begin to bank up behind the Stroud Hill Road embankment approaching the Washpool Bridge. This control does not appear to have any significant influence on property affectation, but model results indicate that Stroud Hill Road would overtop in events of a 2% AEP magnitude and larger.

Karuah River between Booral Creek confluence and Allworth

- Flood levels along this reach of the Karuah River decrease rapidly in the downstream direction due to a number of factors. During larger flood events, the flood surface near the confluence of the Karuah River and Booral Creek is relatively flat due to narrowing and bends in the channel and floodplain downstream. Flood levels drop rapidly moving through these flow constrictions, and as the waterway widens approaching Allworth.
- The constriction of the river channel and floodplain at the Karuah Bridge (Tarean Road) acts as a significant control during the PMF event.

5.4 Flood Function / Hydraulic Categories

The delineation of the floodplain into "hydraulic categories" based on its function during floods is used as a tool to help inform what impact development activity within the floodplain may have on flood behaviour.

The *NSW Floodplain Development Manual* (2005) defines three hydraulic categories based on flood functions as described below:

- **Floodway areas** are those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels, and even their partial blockage would cause a significant redistribution of flood flow or a significant increase in flood level.
- **Flood storage areas** are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
- **Flood fringe areas** are the remaining area of the floodplain after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

There is no specific procedure for defining the extent of the floodway and it has been well established that there is no uniform criteria that can be applied across the wide range of floodplain types and flood behaviour encountered (*e.g. Howells et al., 2004*). Traditionally, floodways have been viewed as areas of high flood velocity and depth, however the *Floodplain Risk Management Guideline: Floodway Definition* (OEH, 2005) emphasises that floodways are areas which convey a high *proportion* of flood flows and may include areas where velocity and depth are relatively low.

Typically the floodway is defined for the design planning level flood, in this case the 1% AEP design event, but may also take into consideration the variation in flood behaviour across a range of flood severities.

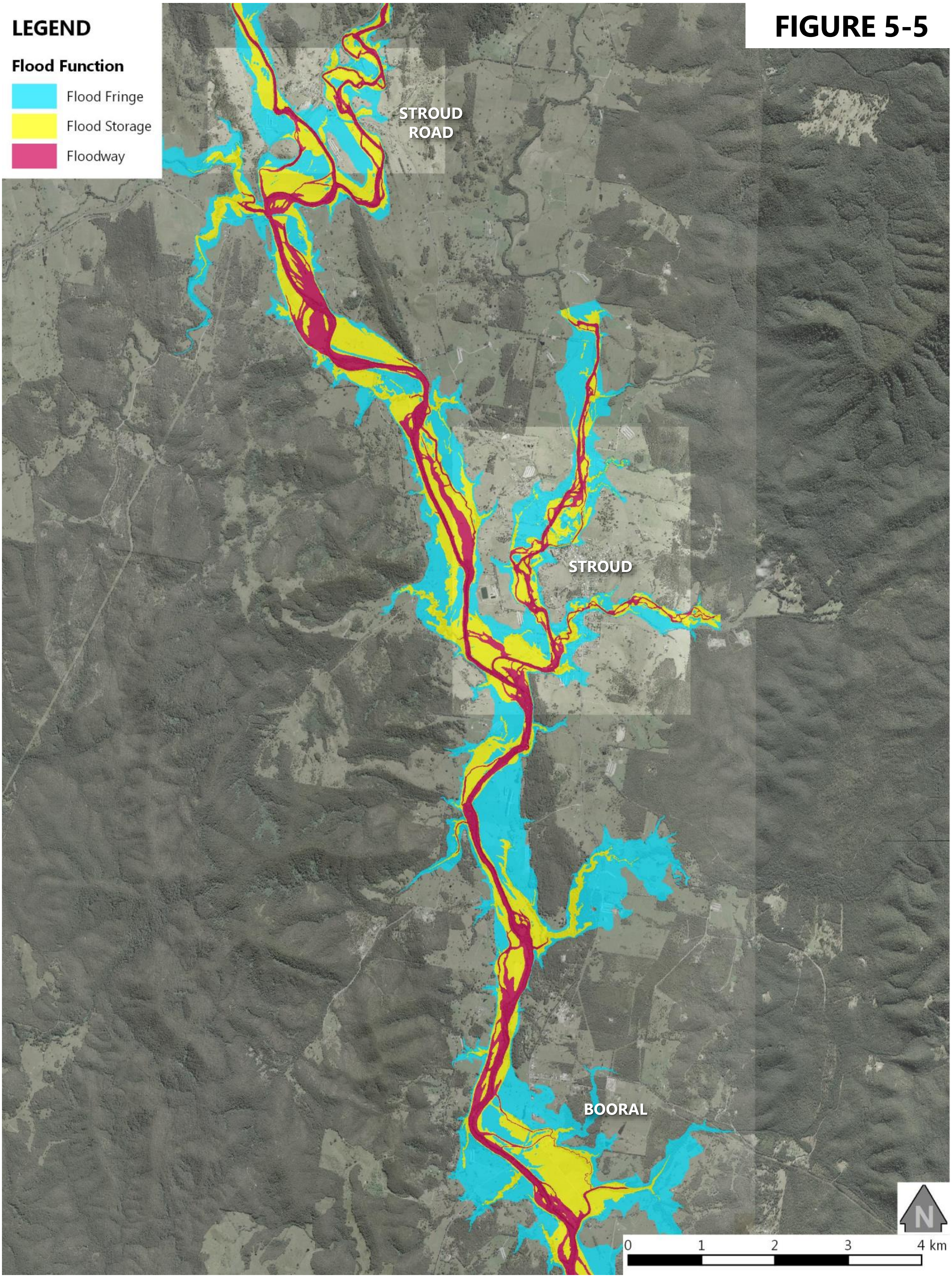
For the purposes of this study, the floodway extent has been derived following procedures similar to those outlined by Thomas et al (2012), as described in **Table 5-2**. The resulting flood function mapping is presented in **Figure 5-5** and **Figure 5-6**.

It can be seen that along significant reaches of the Karuah River and its major tributaries the extent of the floodway is largely limited to the main river channel. This is indicative of incised nature of the channels which allows them to convey the majority of flood flows even in the 1% AEP design event. Notwithstanding, there are also some significant areas of flood storage within well-defined floodplain areas, particularly in the lower reaches where extensive areas adjoin the main channel.

Table 5-2 Criteria for hydraulic categorisation of the floodplain

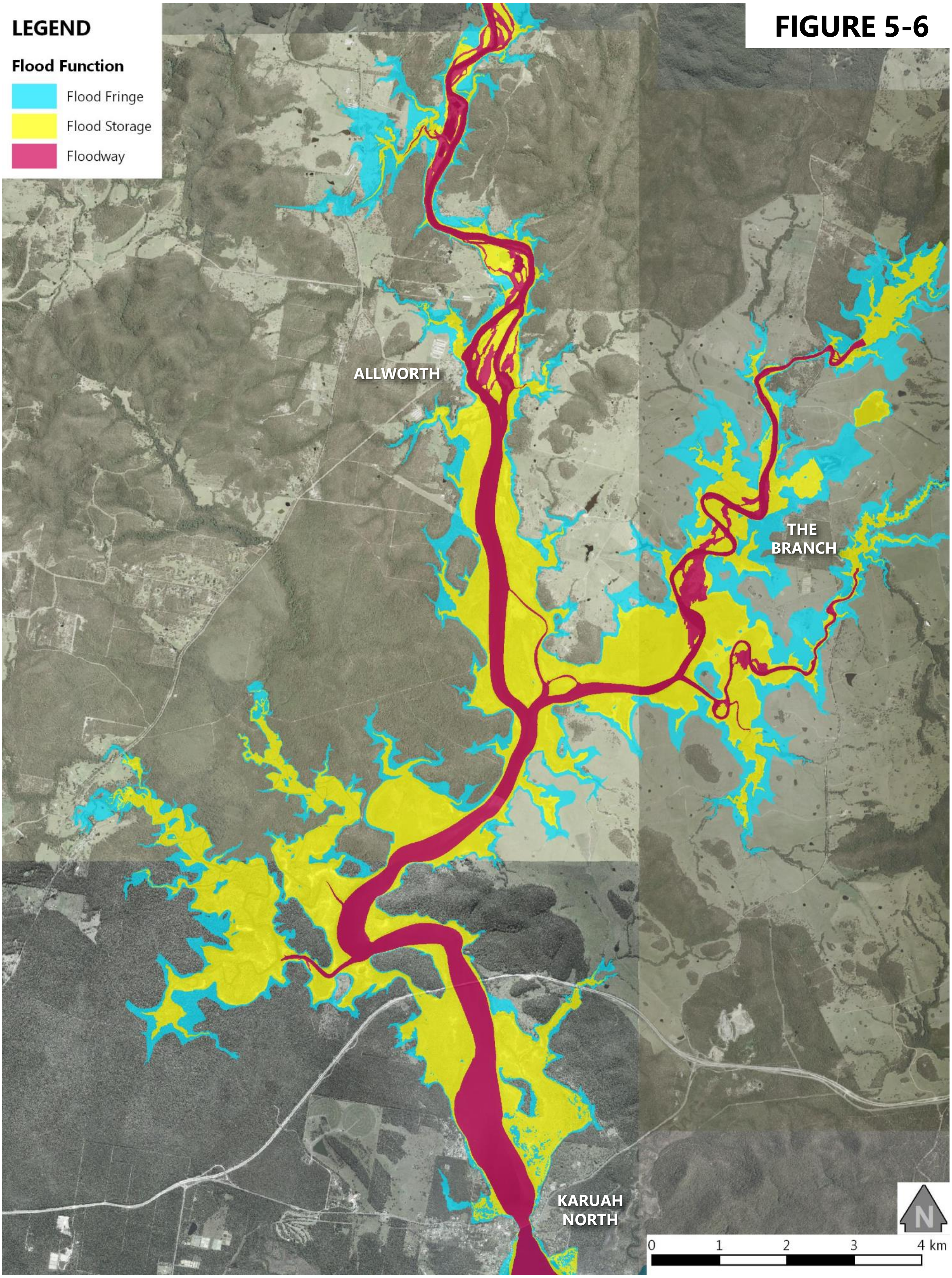
Hydraulic Category	Description of Criteria and Methodology
Floodway	▪ The floodway corridor was determined by using the waterRIDE software to examine the extent of the floodplain that conveys 80% of the peak flood flow during the 1% AEP design event. ▪ Velocity-depth product was used as guide to determine the section(s) across which this flow was measured and to provide a range of contours from which the floodway extent could be drawn. ▪ In incised channel areas, the primary floodway was well defined by high velocity-depth product during the 1% AEP event (typically great than 4 m^2/s). ▪ In areas with significant overbank flow conveyance, or presence of flood runners, lower 1% AEP velocity-depth products were considered (typically greater than 1.0 m^2/s but as low as 0.3 m^2/s) to ensure continuity of the floodway and satisfaction of the 80% flow conveyance criterion. ▪ In areas where the 1% AEP velocity-depth product was relatively uniform, the results from both smaller and larger flood events were considered to help delineate key flow paths (*i.e. by identifying those areas which convey flow in more frequent events, or which convey a higher proportion of flow in events larger than the 1% AEP design flood*).
Flood Storage	Non-floodway areas with an ARR2019 general hazard of H3 or greater in the 1% AEP event (*i.e. a depth greater than 0.5 m or velocity-depth product greater than 0.6 m^2/s*)
Flood Fringe	Those remaining areas of the floodplain (*i.e. the PMF extent*) not classified as floodway or flood storage

FIGURE 5-5



FLOOD FUNCTION
STROUD ROAD TO BOORAL

FIGURE 5-6



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FLOOD FUNCTION ALLWORTH TO KARUAH

5.5 Flood Hazard

Flood hazard provides a measure of the potential risk to life, well-being and property posed by a flood. There are two primary methods of categorising flood hazard that are employed in NSW:

- 'NSW provisional flood hazard' as defined in the *NSW Floodplain Development Manual* (*NSW Government, 2005*), and;
- 'ARR2019 general flood hazard' categories presented in Book 6, Chapter 7 of ARR 2019.

Mapping of both hazard categories is provided in the *Karuah River and Stroud Flood Study Update Volume 2* (Advisian, 2019). For the purposes of this FRMS, the ARR2019 general flood hazard curves have been adopted to aid analysis as they provide a more detailed delineation of hazard and the potential consequences of flooding.

The 'general flood hazard' curves presented in Book 6, Chapter 7 of ARR 2019 are reproduced in **Figure 5-7**, with the *NSW Floodplain Development Manual* hazard categories also indicated for comparison. The general flood curves, derived through laboratory testing by Smith et al. (2014), set six hazard thresholds relating to the vulnerability of people, vehicles and structures when interacting with floodwaters, based on relationships between flood depth and velocity.

For the 1% AEP flood event, much of the Karuah River floodplain is classified as H5 or H6. However, these high hazard areas generally do not coincide with current development. In developed areas that are affected by the 1% AEP flood, hazard categories are generally no higher than H3.

A significant area of H5 hazard occurs in the Mulberry Lane and Lowes Lane area of Booral, with structures at some properties located within areas of H4 hazard. At Stroud, the showground is subject to a H3 hazard while properties on The Bucketts Way and Briton Court Road are generally subject to a H1 to H2 hazard with very localised areas of H3. These hazard conditions may be unsafe for vehicles, and in some cases, people.

The hazard posed by flooding increases with flood magnitude, due both to increased depth of flooding and increase flow velocity. For the PMF, much of the development within the floodplain is subject to a H5 or H6 hazard presenting a major threat to life and property. The qualitative risk mapping presented in the following section provides a measure of the variation of flood hazard across the full range of design flood magnitudes.

Other factors contributing to flood hazard include:

- rate of rise of floodwaters;
- effective warning time;
- flood preparedness;
- duration of flooding;
- evacuation problems;
- effective flood access; and
- type of development.

These factors are discussed in the following sections of this report or are considered in the assessment of flood impacts on the community.

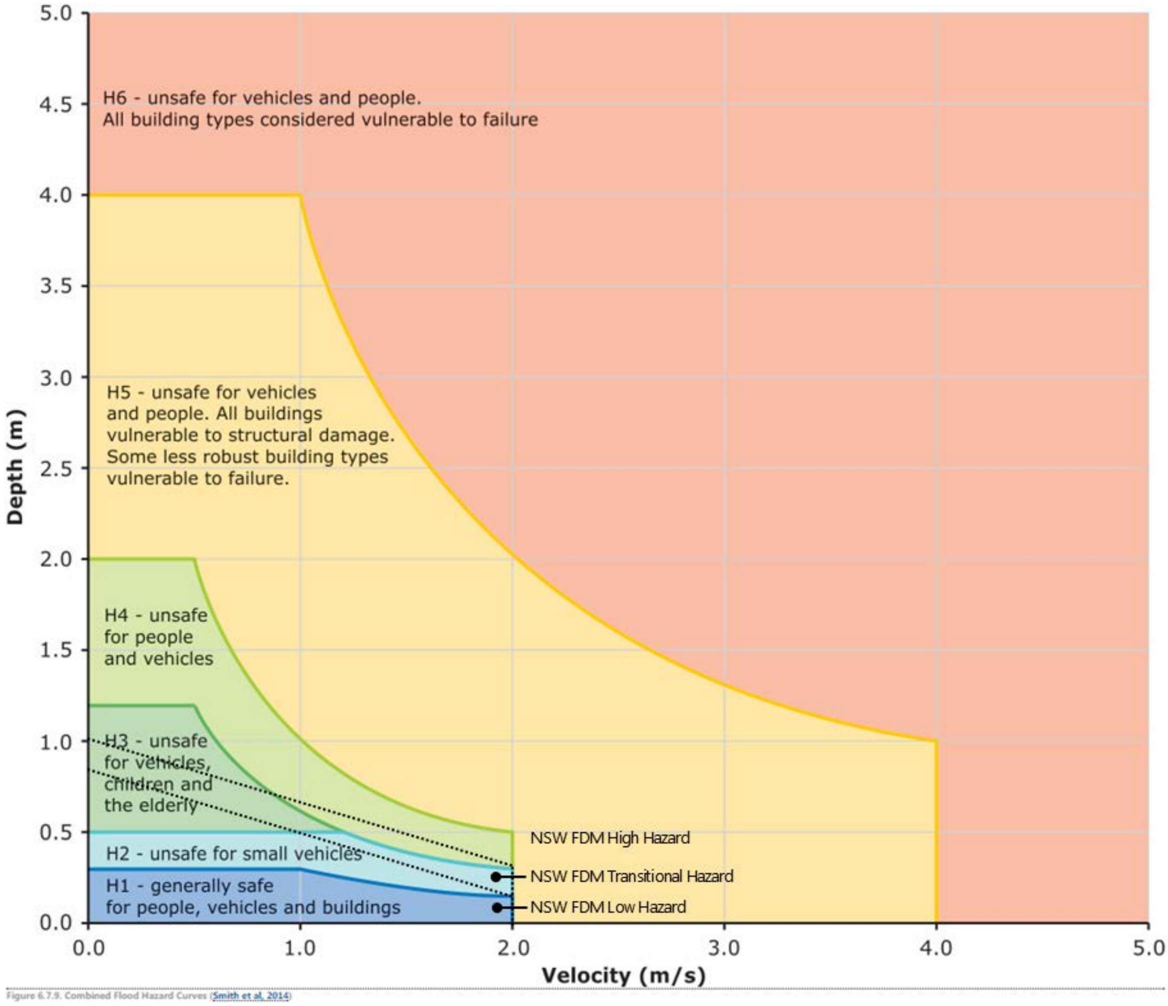


Figure 5-7 General Flood Hazard Curves (Source: ARR2019)

5.6 Flood Risk

Flood risk is a combination of the likelihood of occurrence of a flood event and the consequences of that event when it occurs.

As a result of the largely rural land use and generally incised channels and elevated floodplains within the study area, the consequences of a 1% AEP flood event would be relatively minor compared to some other river systems. However, larger flood events can occur and may have consequences that are considerably more severe. The April 2015 flood which impacted Stroud is one such example. The *Flood Study Update* found that the flood was similar in magnitude to a 0.2% AEP design flood event along Mill Creek and caused above floor flooding of several dwellings that would not be expected to occur in a 1% AEP flood. Identification of key flood risk areas in the study area therefore requires consideration of the full range of possible flood magnitudes and their potential impacts.

In order to provide additional understanding of the flood risk throughout the study area, a qualitative risk matrix was developed and is presented in **Table 5-3**. The matrix has been adapted from Table 6.1 of *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (Australian Institute for Disaster Resilience, 2017).

Table 5-3 Qualitative flood risk matrix

Likelihood of Consequence	Design Flood Event	Level of Consequence Insignificant (H1)	Minor (H2-H3)	Moderate (H4)	Major (H5)	Catastrophic (H6)
Likely	20% AEP	Low	Medium	High	Extreme	Extreme
Unlikely	1% AEP	Low	Low	Medium	High	Extreme
Rare	0.2% AEP	Very low	Low	Medium	High	High
Extremely Rare	PMF (~0.01% AEP)	Very low	Very low	Low	Low	Medium

Risk: Very low, Low, Medium, High, Extreme

Flood risk mapping showing the variation in flood risk across the floodplain is presented in **Figure 5-8** and **Figure 5-9**. Existing development located in 'High Risk' areas of the floodplain are indicated on the figures as follows:

1. **Stroud Road**
   (a) Poultry sheds off Reisdale Road to the north of railway line on the western bank of the Karuah River
   (b) Residential dwelling to the south-east of the railway line on the western bank of the Karuah River
2. Location of overtopping of Stroud Hill Road to the east of Washpool Bridge
3. **Stroud Hill Road** – low section of road from approximately 600 m to 1,300m west of intersection with The Bucketts Way
4. **Booral-Washpool Road** – land encircling a residential dwelling near Lowreys Creek (1444 Booral-Washpool Road)
5. **Gortons Crossing** – land encircling a residential dwelling including inundation of Gortons Crossing Road
6. **Stroud**
   (a) Land encroaching upon a dwelling at Millbrook Road (113 Millbrook Road)
   (b) Flows across Cowper Street into Briton Court Road including parts of residential properties near the roadway
   (c) Roadways within the Stroud Showground, flows across Cowper Street adjacent to the Showground, and a dwelling on Cowper Street adjacent to the Showground (49 Cowper Street)
   (d) Flows across Berkeley Street north of the Lamans Creek bridge, and into Laman Street
   (e) Residential dwelling at the end of Spencer Street adjacent Lamans Creek (8 Spencer Street)
   (f) Residential dwelling at the end of a long access track off Briton Court Road adjacent Mill Creek (220 Briton Court Road)
7. **Greens Crossing** – Poultry sheds at Greens Crossing on the western bank of the Karuah River downstream of the Mill Creek confluence

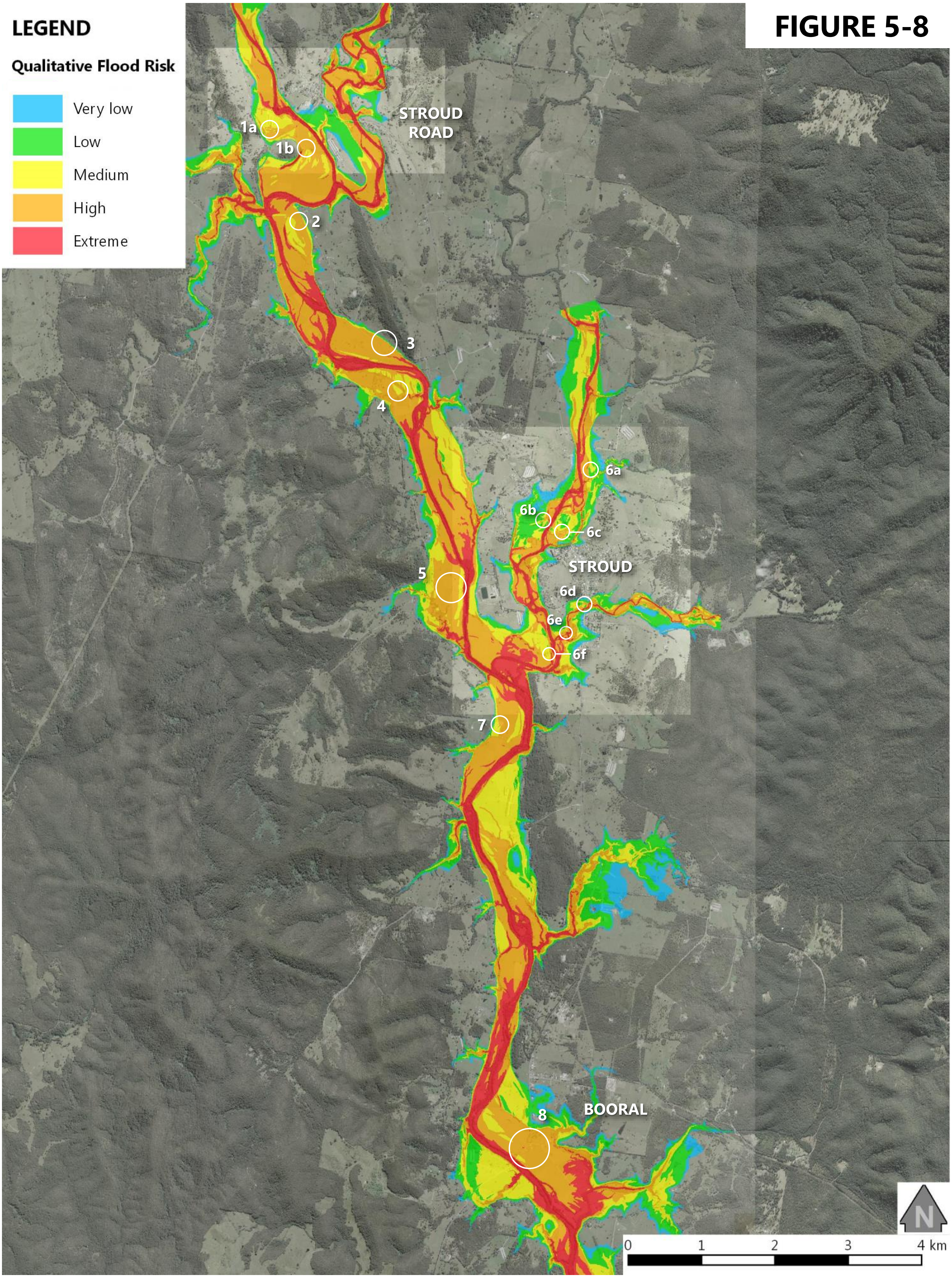
8. **Booral** – several residential dwellings on the northern bank of the Karuah River at The Bucketts Way, Mulberry Lane and Lowes Lane
9. **The Branch**
   (a) A building on the banks of The Branch River near Larpent Avenue
   (b) A section of The Branch Lane downstream of what appears to be a wetland area.

Those areas of Stroud which were subject to hazardous flood conditions in April 2015 generally register as a 'medium' to 'high' risk level.

Areas of 'extreme' risk are generally limited to watercourses, flood runners and immediately adjacent undeveloped land. The notable exceptions to this are the various low level crossings in the study area which are all subject to extreme risk and include the following (discussed further in **Section 6.2**):

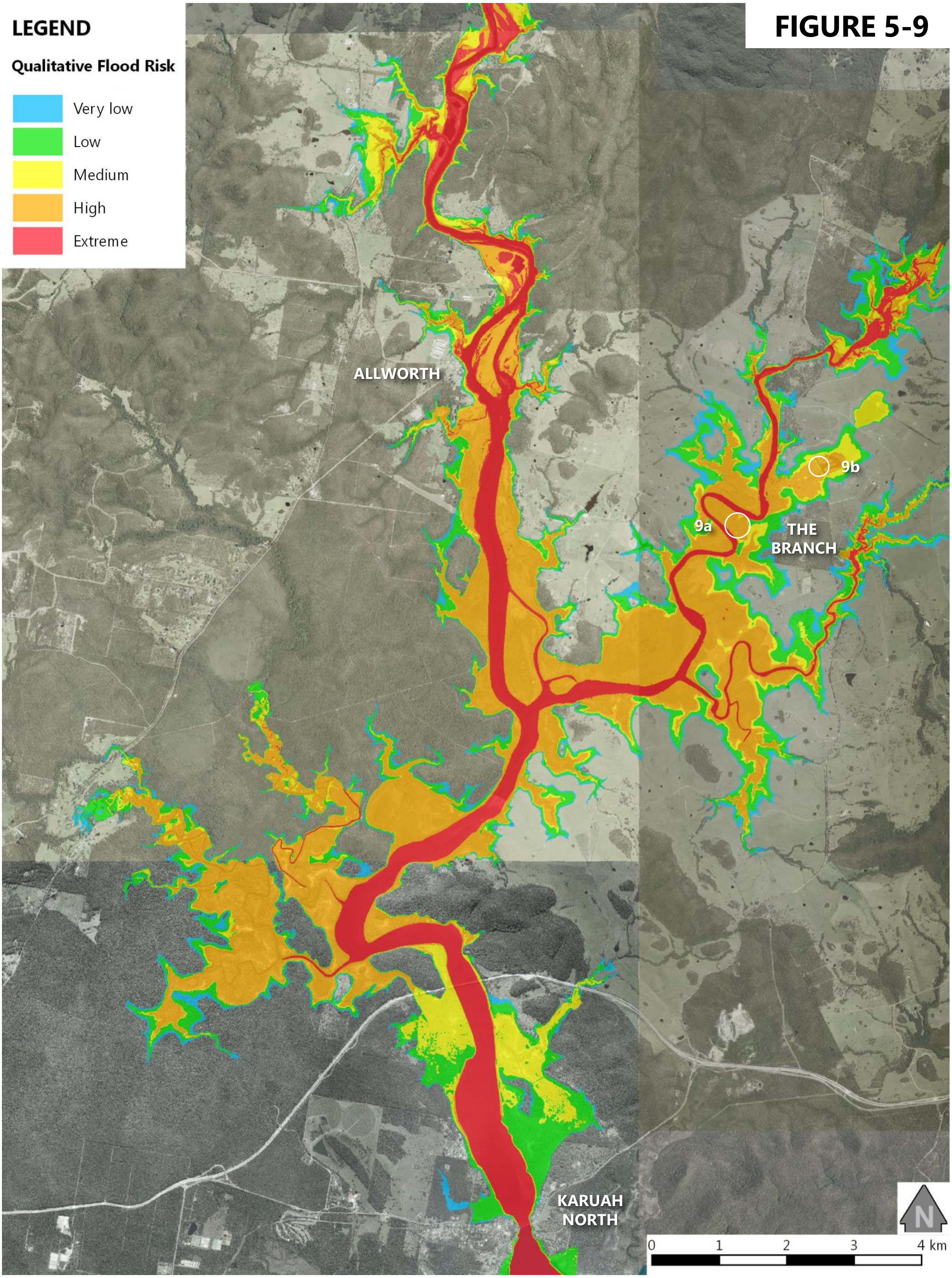
- Reisdale Road bridge, Stroud Road
- Reisdale Road at Barnes Creek
- Gortons Crossing Road bridge, Stroud
- Mill Creek at Laman Street, Stroud
- Mill Brook at Mill Brook Road, Stroud
- Booral Creek at Lowes Lane, Booral
- The Branch River at The Branch Lane
- Little Branch River at The Branch Lane.

FIGURE 5-8



QUALITATIVE FLOOD RISK
STROUD ROAD TO BOORAL

FIGURE 5-9



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QUALITATIVE FLOOD RISK
ALLWORTH TO KARUAH

5.7 Rate of Rise

Mapping of the indicative maximum rate of rise during the 1% AEP design flood is presented in **Figure 5-10** and **Figure 5-11**. The mapping is considered indicative only as the results are influenced by the TUFLOW hydraulic model output timestep (30 to 60 minutes depending on event duration), and higher rates of rise may occur throughout the catchment over different durations or intervals.

A statistical analysis of the mapping is presented in **Table 5-4** along with the implications that can be inferred from the general flood hazard curves (*refer* **Figure 5-7**).

Table 5-4 Analysis of rate of rise for the 1% AEP event

Max. Rate of Rise	Implications for affected land within one hour of initial inundation	Proportion of Flood Extent	
		1% AEP (Stroud Road to Booral)	1% AEP (Allworth to Karuah)
≥ 0.3 m/hour	Unsafe for small vehicles	85%	60%
≥ 0.5 m/hour	Unsafe for vehicles, children and the elderly	75%	20%
≥ 1.2 m/hour	Unsafe for vehicles and people	35%	5%
≥ 2.0 m/hour	Unsafe for vehicles, people and structures	15%	0.5%

While the results are skewed somewhat by the contribution of high rates of rise in waterway areas, it is notable from **Table 5-4** that the majority of the floodplain upstream of Allworth experiences a rate of rise of greater than 0.5 m/hour in the 1% AEP event. This is considered relatively rapid. From Allworth downstream the rate of rise is markedly lower (with the exception of the upper parts of The Branch and Little Branch Rivers), which can be attributed to the broadening of the floodplain and river channel. Rate of rise during the PMF is significantly higher than for the 1% AEP, with the vast majority of the floodplain having a maximum rate of rise of greater than 1.2 m/hour and generally greater than 2.0 m/hr.

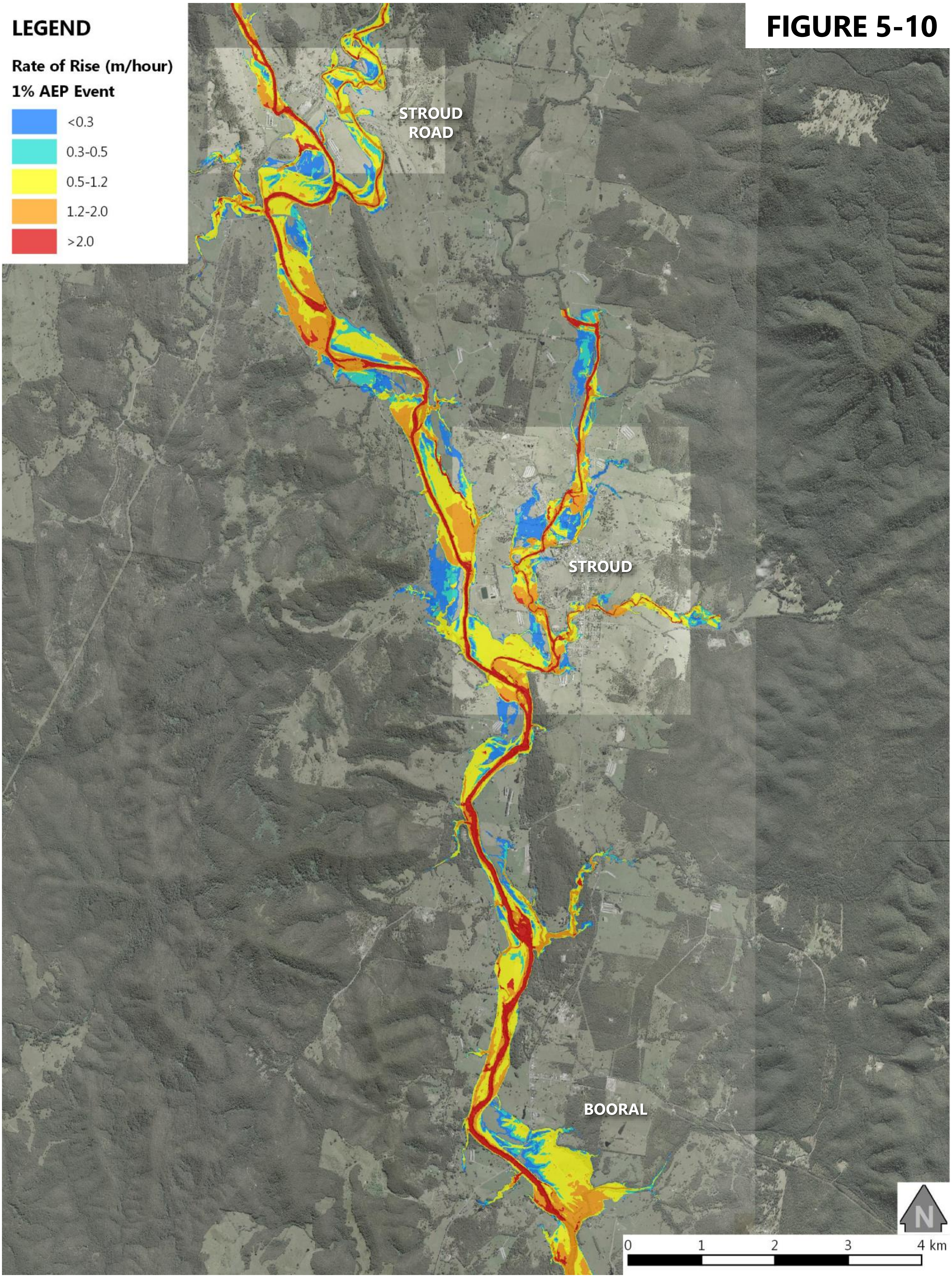
Rate of rise of floodwaters at some key locations during a 1% AEP flood event can be summarized as follows:

- All low level crossings: rate of rise exceeds about 1.5 m/hour
- Rural dwelling at Stroud Road on western bank of Karuah River: rate of rise along access road exceeds 2 m/hour in places, and exceeds 1 m/hour at the dwelling itself
- Stroud Hill Road to east of Washpool Bridge: less than 0.3 m/hour across roadway
- Stroud Hill Road low section 600 m west of The Bucketts Way: rate of rise exceeds 0.5 m/hr
- Gortons Crossing Road to west of bridge: rate of rise exceeds 0.3 m/hr
- Stroud Showground and adjacent Cowper Street property: rate of rise generally in 0.3-0.5 m/hr range or higher

- Briton Court Road, Stroud: rate of rise in the order of 0.3 m/hr
- Mulberry and Lowes Lanes, Booral: rate of rise exceeds 0.3 m/hr at one Lowes Lane dwelling, exceeds 0.3 m/hr across part of Mulberry Lane, and exceeds 0.5 m/hr along much of Lowes Lane, increasing in a southerly direction towards Booral Creek
- Larpent Avenue, The Branch: rate of rise along the western part of the roadway and at a building on the banks of The Branch River is in the order of 0.3 to 0.5 m/hour.

Flood model results suggest that the rate of rise of floodwaters at Stroud during the April 2015 event following breakout of floodwaters from Mill Creek was in the order of 0.5 m/hr over a duration of two hours (*refer* **Figure 5-12**). The maximum rate of rise at the Booral gauge was around 1.5 m/hour, however floodwaters remained in-bank and a lower rate of rise would be expected once breakout into the floodplain occurs.

FIGURE 5-10



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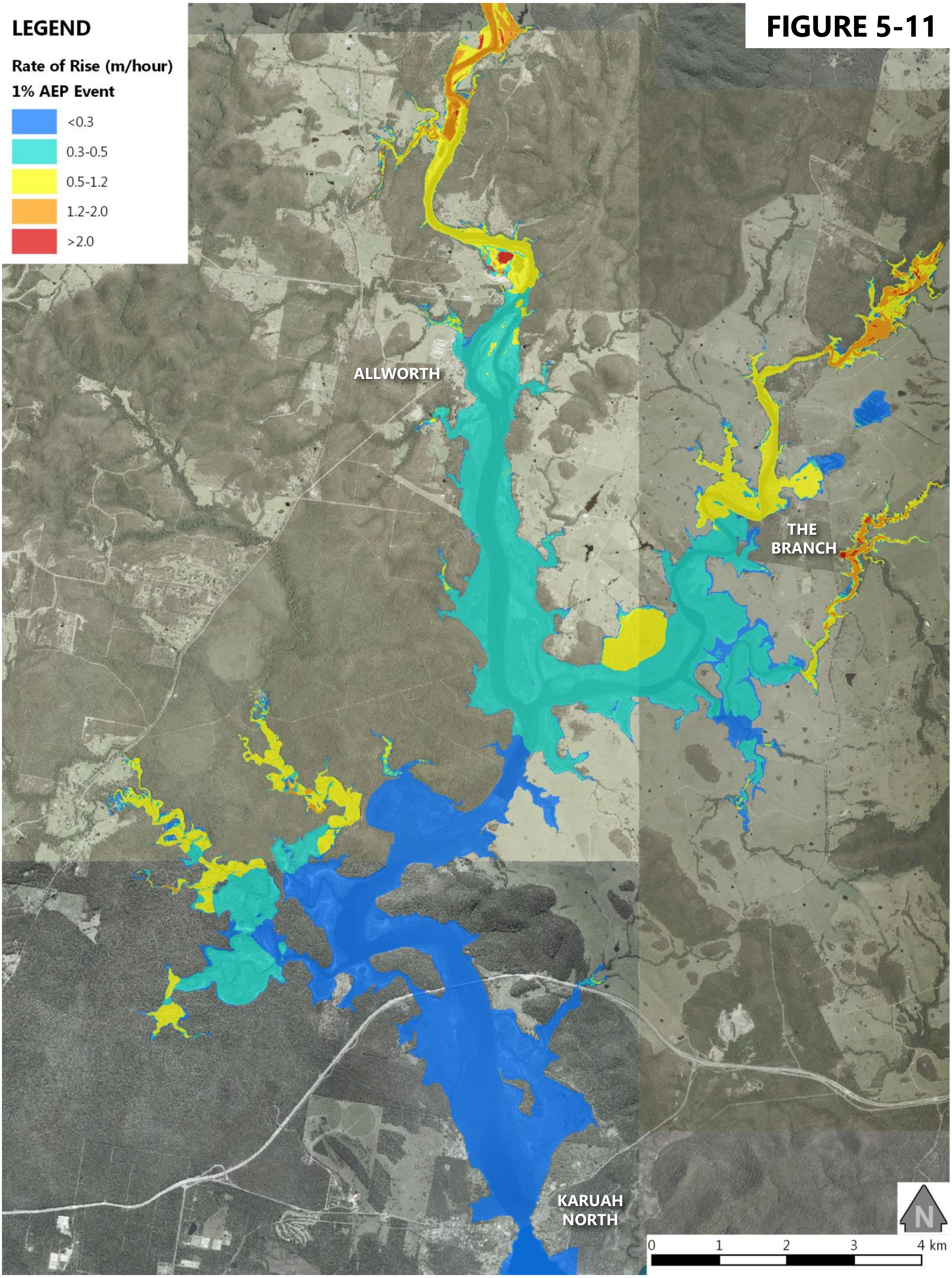
**INDICATIVE RATE OF RISE DURING 1% AEP FLOOD EVENT
STROUD ROAD TO BOORAL**

FIGURE 5-11



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INDICATIVE RATE OF RISE DURING 1% AEP FLOOD EVENT ALLWORTH TO KARUAH

5.8 Flood Warning Time

The amount of warning time available prior to an imminent flood can have a significant impact on the consequences of flooding. If adequate time is available and is well utilised, flood damages and risk to life may be reduced.

Total flood warning time is the time available to emergency services from the moment a flood warning is triggered until a certain flood threshold is reached (e.g. evacuation routes are cut).

Effective flood warning time is the time available for people to undertake appropriate actions (such as raise pumps, lift or transport belongings and/or evacuate) following receipt of a flood warning. It is less than the total warning time because of the time needed to alert people to the imminence of flooding, and to have them begin effective property protection and evacuation procedures.

Estimations of flood warning time depend on the criteria set for the issue of a flood warning. For example, if the DPI Water Karuah River at Dam Site gauge is to be used to provide flood warning at Stroud Road then total warning time is in the order of just 1 to 1.5 hours due to the proximity of the gauge to the settlement. If a set rainfall threshold is used, however, additional warning time could be provided but the nature of the warning may be less reliable.

Indicative total flood warning times at key reporting locations are presented in **Table 5-5**. The estimates are intended to provide an indication of the range of potential total warning times throughout the catchment. They required assumptions to be made regarding criteria for the issue of flood warnings, and the flood level at which any property protection or evacuation procedures would need to be completed. The adopted rainfall criteria were based on a preliminary review of simulated design rainfall events with an aim of triggering flood warning early during less frequent flood events, while not triggering flood warning during frequent events. They are not considered definitive or appropriate for adoption in flood warning procedures without further investigation.

- The indicative total flood warning times can be summarised as follows:
- In the PMF (180 minute duration design event) total flood warning throughout the catchment is generally 3 hours or less, and is typically less than 2 hours
- Little (less than two hours) or no time is available to warn of flooding of low level crossings at Reisdale Road, Laman Street, Gortons Crossing and The Branch Lane, or similar locations such as Lowes Lane at Booral Creek, which are overtopped in frequent events
- Total warning time throughout the remainder of the catchment is typically in the order of 4 to 6 hours, with slightly shorter warning times of 3 to 4 hours at Stroud.

The indicative total warning times of less than 6 hours are considered minimal, and limited coordination, assistance or direction from emergency services is likely to be possible.

Table 5-5 Indicative total flood warning times at reporting locations

ID	Location	Indicative Flood Warning Time (hrs) PMF	0.2% AEP	1% AEP	Basis of estimate*
1	Karuah River at Reisdale Rd Bridge	0	0	0	Low level bridge rapidly overtops in events more frequent than 20% AEP, no warning time available
2	Karuah River at Railway Bridge	2.0	4.5	5.0	Time from >70 mm rain in 2 hours until FL of 40 mAHD (2% AEP event peak FL, above which flood impacts are likely)
3	Mammy Johnsons River at The Bucketts Way	1.5	4.0	4.75	Time from >70 mm rain in 2 hours until FL of 38 mAHD (level at which property access roads may become inundated)
4	Karuah River at Washpool Bridge	1.5	4.25	5.0	Time from >70 mm rain in 2 hours until FL of 36 mAHD (level at which overtop of Stroud Hill Road is imminent)
5	Karuah River at Gorton's Crossing Rd Bridge	2.5	6.5	7.0	Time from >70 mm rain in 2 hours until FL of 26.5 mAHD at which western side of Gortons Crossing Rd may be cut imminently. The bridge itself overtops in events more frequent than 20% AEP, with warning time in 1% AEP of 1.5 hours
6	Mill Creek at The Bucketts Way	1.0	3.0	4.0	Time from >20 mm rain in 30 minutes until overtop of The Bucketts Way
7	Mill Creek at Laman St Bridge	0.5	1.0	1.0	Time from >20 mm rain in 30 minutes until overtop of Laman St bridge
8	Lamans Creek at The Bucketts Way	0.75	3.5	4.0	Time from >20 mm rain in 30 minutes until overtop of The Bucketts Way
9	Karuah River at Booral Gauge	2.5	5.0	6.25	Time from >70 mm rain in 2 hours until FL of 10.5 mAHD (level at which breakout occurs and Mulberyy and Lowes Lanes may be affected)
10	Karuah River at Allworth (Karuah St)	3.0	6.25	8.0	Time from >70 mm rain in 2 hours until FL of 4.0 mAHD at which boat ramp carpark depths >1.0 m
11	Karuah River at The Branch	2.75	6.0	9.0	Time from >70 mm rain in 2 hours until FL of 3.5 mAHD (potential impacts at Larpent Ave)
12	The Branch River at The Branch Lane	1.0	2.0	2.0	Time from >20 mm rain in 30 minutes until overtop of The Branch Lane
13	Little Branch River at The Branch Lane	0.5	1.75	1.75	Time from >20 mm rain in 30 minutes until overtop of The Branch Lane
14	Karuah River at Pacific Highway Bridge	3.0	6.75	8.75	Time from >70 mm rain in 2 hours until FL of 1.9 mAHD (likely flooding of downstream oyster sheds, tide dependent)
15	Karuah River at Karuah Bridge	6.0	13.5	13.5	Time from >70 mm rain in 2 hours until FL of 1.5 mAHD (likely flooding of oyster sheds) or flood peak, tide dependent

* Adopted rainfall criteria are based on a cursory review of simulated design rainfall events and are not considered definitive or appropriate for adoption in flood warning procedures without further investigation

The response of flood levels at Stroud and Booral to catchment rainfall during the April 2015 event is presented in **Figure 5-12**. While the flood levels for Stroud (Mill Creek at The Bucketts Way) are simulated, they compare well with anecdotal evidence from residents regarding the timing of flooding.

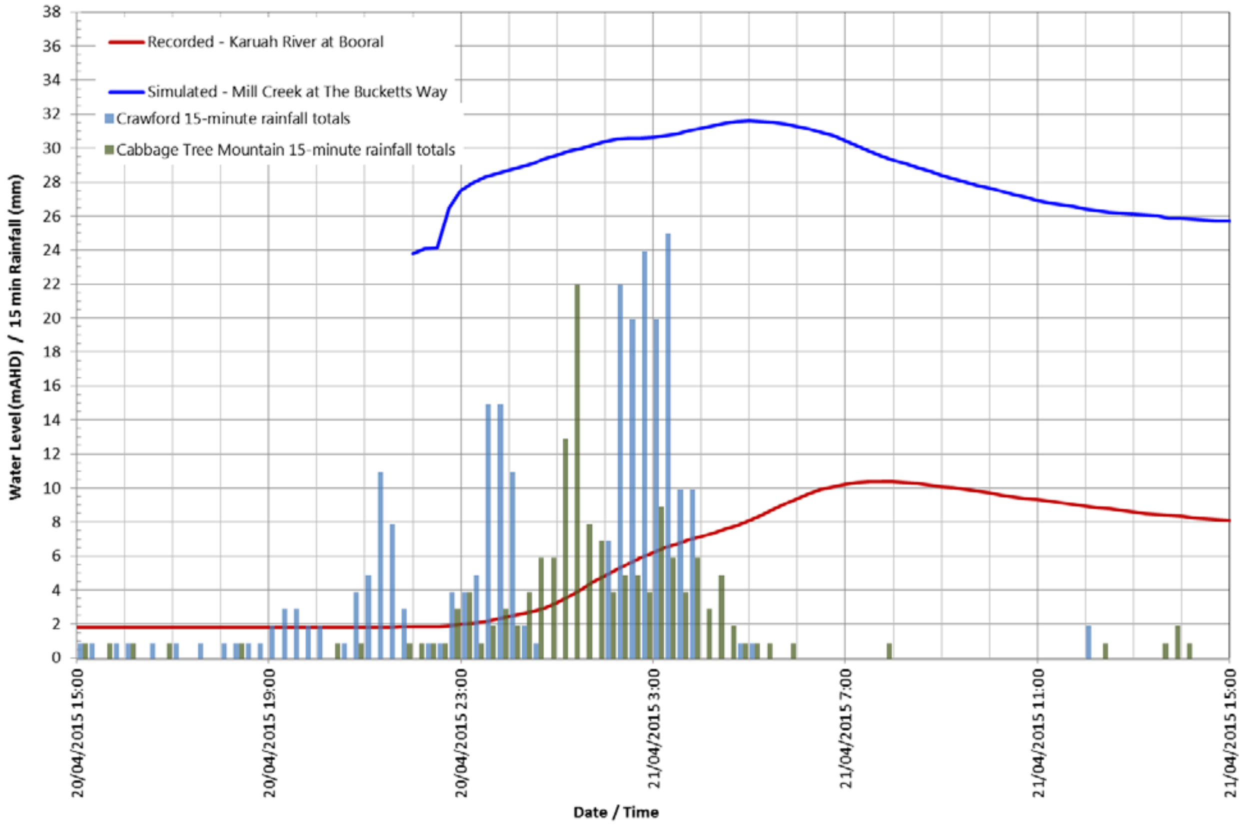


Figure 5-12 Recorded and simulated catchment response for the April 2015 event

Figure 5-12 indicates that during the April 2015 event, flooding of the Stroud Showground and overtopping of The Bucketts Way near 49 Cowper Street began within about 2.5 hours of an intense rainfall burst recorded at the Crawford gauge (30 mm in 30 minutes between 11:30 pm 20th April and midnight). Floodwaters at the Showground, Cowper Street and Briton Court Road continued to rise rapidly (on average 0.5 m/hr, though first-hand accounts suggest that floodwaters at the Showground initially rose significantly faster than this) until peaking at around 5 am on 21st April. This represents quite a rapid catchment response that would allow little time for effective flood warning and emergency response.

If considering rainfall at the Cabbage Tree Mountain gauge as a possible trigger for flood warning, even less time would have been available. The ability of residents to evacuate or prepare for the flood was further complicated by the time of day, very poor weather conditions, and the fact that rainfall at the town of Stroud itself was apparently far less intense than that experienced in the upper Mill Creek catchment.

The flood peak at Booral occurred around 7 hours after the second burst of rainfall recorded at the Crawford gauge (during which only 57 mm of rainfall was recorded over a duration of 2 hours), but remained largely in-bank.

Considering the rainfall thresholds adopted in the estimation of total flood warning times for Booral in **Table 5-5** (70 mm over 2 hours), rainfall at the Cabbage Tree Mountain gauge would have allowed about 5.25 hours total warning time prior to the flood peak while rainfall at Crawford would have allowed 4.5 hours.

It is notable that water levels at DPI Water's Karuah River at Dam Site and Mammy Johnsons River at Pikes Crossing gauges in the upper catchment peaked at a similar time to the Booral gauge during the April 2015 event (Advisian, 2018). This indicates that the flow contributing to the flood peak at Booral during the event came predominantly from nearer catchments including Mill Creek, Lamans Creek, Alderley Creek and perhaps Ram Station Creek.

5.9 Duration of Flooding

The longer the duration of flooding, the greater the disruption to the community and the potential for flood damages. The duration of flooding is largely related to the severity and duration of the rainfall event causing the flooding, and also varies with catchment size and location within the floodplain (i.e. flood function).

The duration of inundation throughout the study area was analysed for a range of events using waterRIDE™ and is summarised in the following:

- Overbank areas along the Karuah River from Stroud Road to Booral may remain flooded for in the order of 9 to 15 hours depending on event severity
- Flood duration could be as long as 6 to 9 hours in residential areas of Stroud, but would generally be expected to be shorter
- Floodwaters may take in the order of 24 hours to drain away from most waterways and adjacent storage areas, meaning that low level crossings may be cut for extended periods
- The majority of the floodplain from Allworth downstream may remain inundated for in the order of 32 hours.

Anecdotal information from residents suggests that flooding at Stroud in April 2015 rose and subsided quickly. Initial flooding of Briton Court Road was noted at about 2:30 am on the 21st, with the flood peaking at about 5 am and little water remaining on Cowper Street by 7:30 am. The simulated flood levels presented in **Figure 5-12** also suggest that the duration of flooding at the Stroud Showground and surrounding areas would have been around 5 hours.

5.10 Flood Preparedness

Flood readiness greatly influences the time taken by flood-affected people to respond in an effective fashion to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective (NSW Government, 2005). Flood readiness can refer to that of communities as a whole, organisations, businesses and individuals.

Based on available evidence it is expected that, while the community is highly conscious of flood risk following the April 2015 flood event that impacted Stroud, they may not understand the specific nature of the flood risk or how to effectively prepare for and respond to a major flood event. Additionally, available information on historical floods (*refer to Section 2.3 of the Stage 1 progress report*) suggests that significant overbank flooding along the Karuah River has not occurred since at least 1945, and knowledge of flood risk outside of Stroud is therefore likely to be very low.

It is therefore considered that the overall level of flood preparedness in the community is low. However, given the heightened flood awareness following the April 2015 flood, this FRMS presents an excellent opportunity to educate the community about flood risk throughout the study area. For example, the provision of information and templates to allow individuals and businesses to prepare personal flood emergency response plans that can be implemented effectively on receipt of a flood warning may help significantly improve flood preparedness in the community and reduce the potential consequences of flooding. Information from this study may also help the NSW SES improve emergency response planning for the area.

5.11 Potential Impacts of Climate Change

The Intergovernmental Panel on Climate Change's *Fifth Assessment Report* (IPCC, 2013) found that human influence on climate is clear and increasing, with impacts observed across all continents and oceans. While projections vary, there is a general consensus that climate change will alter the severity of flood impacts through sea level rise and an anticipated increase in the intensity of heavy rainfall events.

The potential impact of climate change on flood behaviour in the study area is discussed in the following.

5.11.1 Sea Level Rise

In the Great Lakes region, MidCoast Council has adopted Sea Level Rise (SLR) Benchmarks of 0.50m by 2060 and 0.90m by 2100 as policy. These benchmarks are derived from those recommended in Floodplain Risk Management Guideline *Practical Consideration of Climate Change* (DECC, 2007). The Great Lakes DCP 2014 also includes development controls which relate to 2060 and 2100 flood planning levels and areas which incorporate these SLR benchmarks.

Figure 5-13 and **Figure 5-14** present mapping of the simulated impacts of 0.5 m SLR and 0.9 m SLR scenarios on 1% AEP peak flood levels respectively.

The results can be summarised as follows:

- The influence of sea level rise on simulated peak 1% AEP flood levels diminishes with distance from Port Stephens.
  - Along the Karuah River the influence extends to a distance of about 6 km upstream of Allworth. It is possible that during smaller flood events the influence could extend as far as a gravel bar near Booral, about 1.5 km further upstream.
  - The influence extends a distance of approximately 9.5 km up The Branch River, where the channel becomes significantly narrower and gravel/rock bars are present. A similar situation occurs on the Little Branch River at a distance of approximately 4 km upstream.
- Associated increases in 1% AEP flood extent are quite limited. The greatest increase occurs at a wetland on the eastern side of The Branch Lane, which is associated with additional flows passing across the roadway in an easterly direction from The Branch River.
- The flood model results suggest that even 0.9 m SLR would result in limited additional impacts on existing development during the 1% AEP flood, as summarised below:
  - Increased flood depths at foreshore areas of Karuah affecting the Karuah Motor Yacht Club, oyster sheds (primarily within the Port Stephens LGA), Longworth Park (Port Stephens LGA), and one residential property at Bundabah Street (Port Stephens LGA)

- Increased flood depths along The Branch Lane and at Larpent Avenue, The Branch
- Increased flood depths at the boat ramp carpark at Allworth.

5.11.2 Increase in Rainfall Intensity

While climate models show significant uncertainty in quantifying the effect of climate change on rainfall intensity, the latest *Climate Change in Australia Technical Report* from CSIRO and BoM (2015) projects increased intensity of extreme rainfall events for the east coast with a high confidence. Work by Abbs and Rafter (2009) suggests that increases are likely to be more pronounced in areas with strong orographic enhancement, which may be relevant for parts of the Karuah River catchment.

Scenarios of between 10% and 30% increases as recommended in *Practical Consideration of Climate Change* (DECC, 2007) remain comparable to ranges projected by more recent research (e.g. CSIRO and BoM, 2015) and are appropriate for providing an assessment of the range of potential impacts.

For the purposes of this FRMS, the potential impacts of increases rainfall intensity associated with climate change have been assessed by comparing model results for the 1% AEP design flood with those for the 0.5% AEP (about a 15% increase in rainfall) and 0.2% AEP (about a 35% increase in rainfall) events.

Relevant model results are presented in the following:

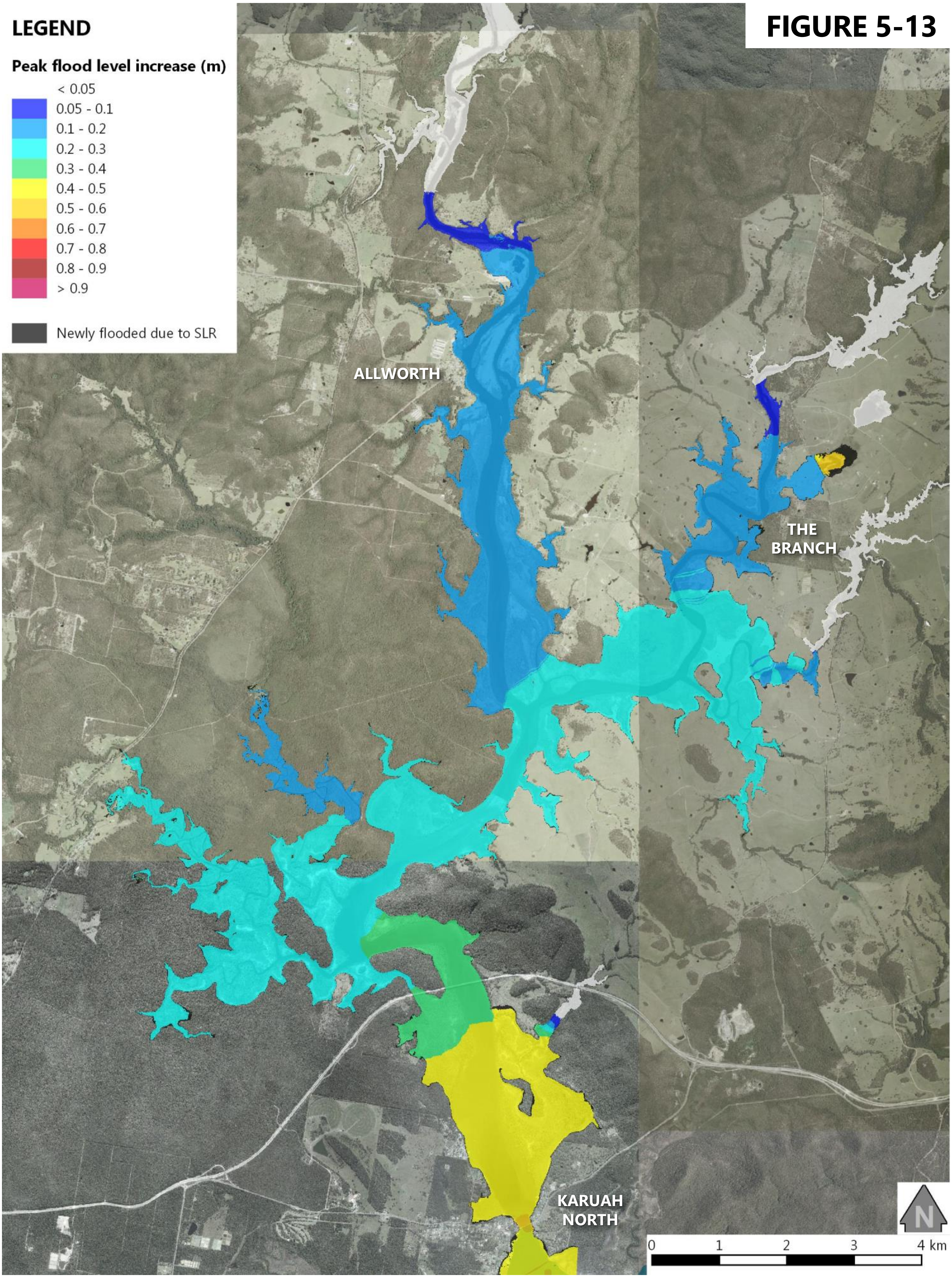
- **Figure 5-1** and **Figure 5-2** present relevant flood extents
- **Table 5-1** presents peak flood levels at selected locations, and,
- **Figure 5-3** and **Figure 5-4** present flood profiles along the Karuah River.

With reference to the above results, the impacts of the two rainfall increase scenarios can be summarised as follows:

- A 15% increase in rainfall intensity results in the following increases in peak flood level at locations of interest:
  - 0.4 to 0.6 m along the Karuah River, decreasing to 0.2 m at the Pacific Highway Bridge
  - 0.2 to 0.3 m along Mill and Lamans Creeks
  - Approximately 0.6 m at The Branch River crossing and 0.3 m at Little Branch River crossing
- A 35% increase in rainfall intensity results in the following increases in peak flood level at locations of interest:
  - 0.9 to 1.6 m along the Karuah River, decreasing to 0.5 m at the Pacific Highway Bridge
  - 0.4 to 0.6 m along Mill and Lamans Creeks
  - Approximately 1.4 m at The Branch River crossing and 0.7 m at Little Branch River crossing
- 15% increase in rainfall intensity generally results in increases in peak flood level at locations of interest in the order of 0.4 to 1.5 metres, decreasing approaching Karuah
- While there are exceptions, it could be said that increases in flood extent are fairly incremental. However, in some cases this results in significant increases in flood hazard.
- Areas of significant increase in flood hazard include:
  - Poultry sheds off Reisdale Road, Stroud Road to the north of railway line on the western bank of the Karuah River

- Property at Stroud Road to the south-east of the railway line on the western bank of the Karuah River
- Location of overtopping of Stroud Hill Road to the east of Washpool Bridge
- Property off Booral-Washpool Road near Lowreys Creek on the western bank of the Karuah River
- Gortons Crossing Road roadway and property
- Parts of Stroud near Mill Creek including the Showground, Cowper Street roadway and properties, Briton Court Road roadway and properties, the Stroud Community Lodge driveway and carpark, and sections of Mill Brook Road including one property
- The roadway of Berkeley Street and Laman Street near Lamans Creek, Stroud
- A number of properties in Stroud toward the confluence of Mill and Lamans Creeks including properties on Spencer Street, Berkeley Street and adjoining cross streets, as well as a property at the end of a long access track off Briton Court Road
- Poultry sheds at Greens Crossing on the western bank of the Karuah River downstream of the Mill Creek confluence
- Mulberry and Lowes Lanes, Booral
- The southern end of Stroud Street roadway, Allworth.

FIGURE 5-13



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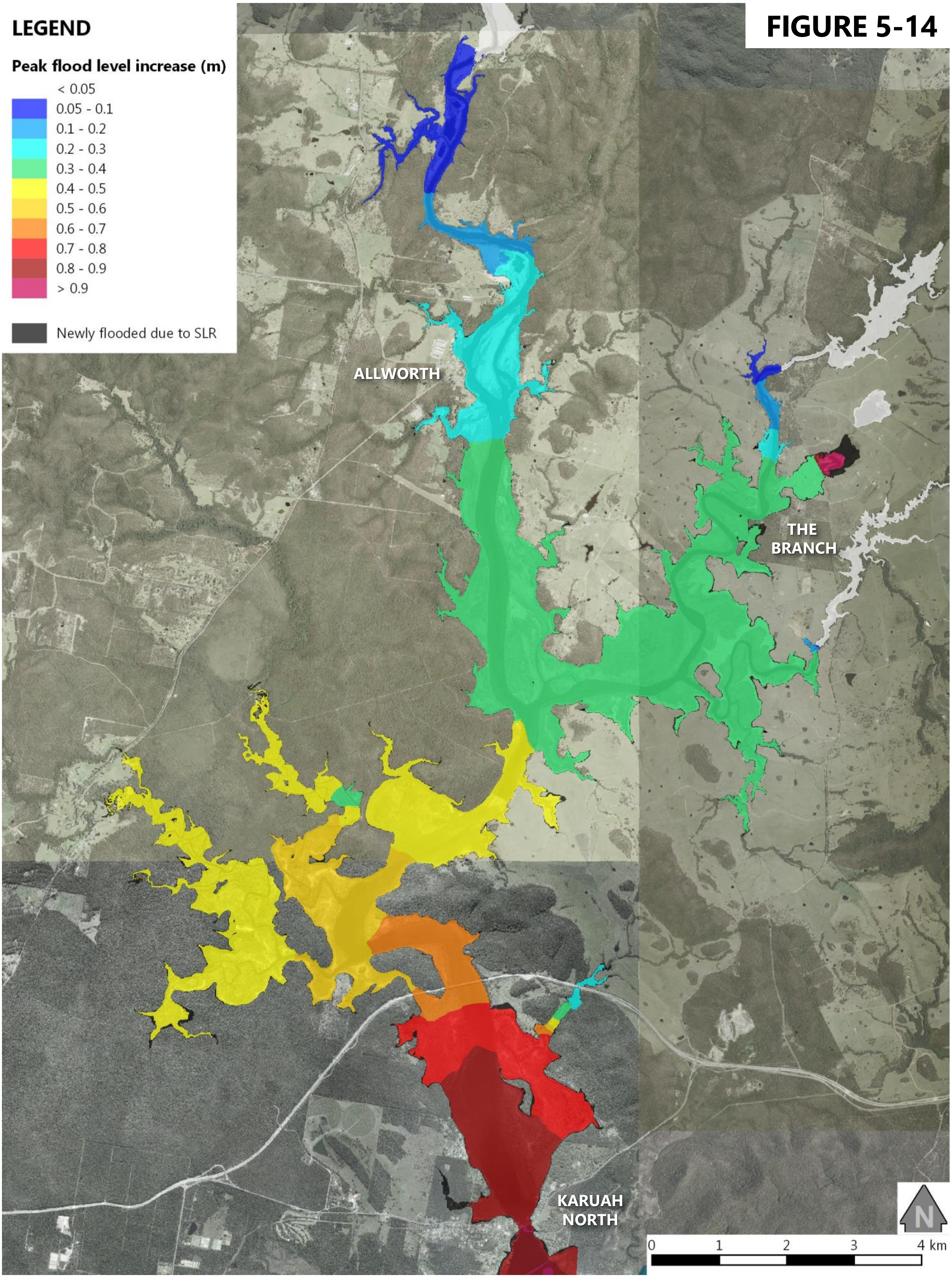
IMPACT OF 0.5 M SLR ON 1% AEP FLOOD EVENT
ALLWORTH TO KARUAH

FIGURE 5-14



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IMPACT OF 0.9 M SLR ON 1% AEP FLOOD EVENT ALLWORTH TO KARUAH

6 Consequences of Flooding on the Community

6.1 Property Affectation

6.1.1 Property Database

In order to allow assessment of the properties likely to be affected by above floor flooding, and to subsequently undertake estimation of flood damages, a database was prepared for properties within the floodplain.

The property database was compiled from the following data:

- Floor level survey of Stroud undertaken by PCB Surveyors in 2009
- Adjustments to surveyed levels for one dwelling which was raised after the April 2015 flood
- Estimates of floor levels from latest LiDAR data and observations of floor height above ground level from site photography or Google Street View where visible
- Estimates of remaining floor levels from latest LiDAR data and an averaged floor height above ground level of:
  - 0.4 m for residential properties
  - 0.1 m for non-residential properties.

Residential properties were characterised into three categories for the application of three different stage-damage curves per OEH's recommended method for assessing residential flood damages:

- Single story high set (applied where floor level > 1.5m higher than ground level, coded '1' in the property database)
- Single storey low set/slab-on-ground (coded '2')
- Two storeys (coded '3').

Non-residential properties were characterised into the following categories based on the relative value of damages expected:

- Non-residential high
- Non-residential medium
- Non-residential low.

Simulated flood surfaces for the PMF, 0.2% AEP, 0.5% AEP, 1% AEP, 2% AEP, 5% AEP and 20% AEP design events were used to extract flood levels at tag points for each building in the database. Results are discussed in the following and were used in the calculated of flood damages presented in **Section 6.4** of this report.

6.1.2 Above Floor Flood Affectation

Design flood levels were interrogated against the developed property database to provide an assessment of buildings expected to be flooded above floor. Results of the analysis are presented in **Figure 6-1** and **Figure 6-2**, and summarised in **Table 6-1**. The range of above floor flood depths expected at residential dwellings for each design event is presented in **Table 6-2**. It is noted that on rural properties there was some difficulty in differentiating between residential dwellings and other buildings, and that in some cases multiple non-residential buildings (e.g. poultry sheds) were included in the analysis.

Table 6-1 Number of buildings flooded above floor level by design event

	20% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Residential	0	0	3	4	11	20	104
Non-residential	0	2	8	8	11	20	55

Table 6-2 Depth of residential above floor flooding by design event

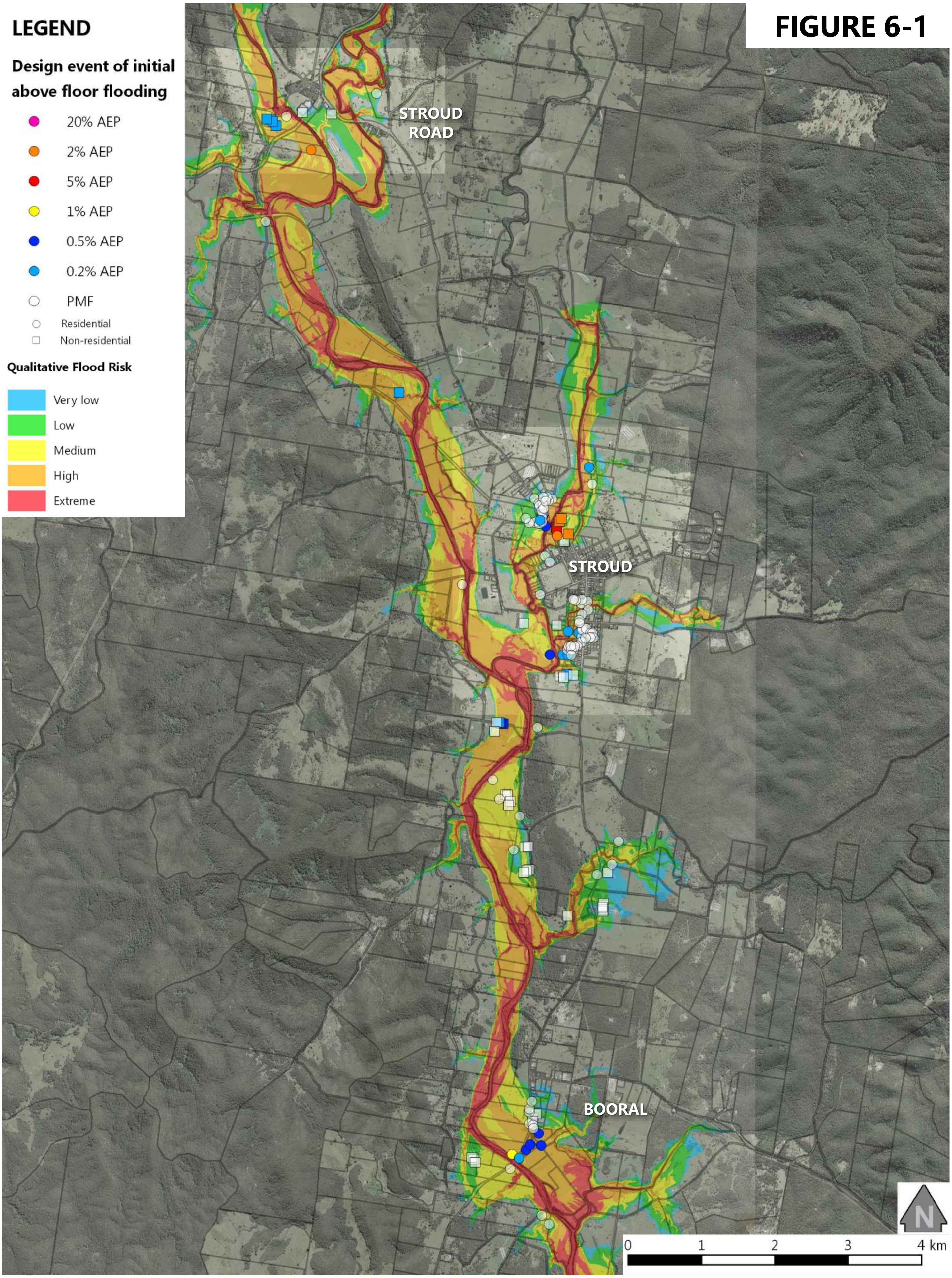
Depth above floor	20% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
0.0 to 0.5 m	0	0	3	3	4	10	24
0.5 to 1.0 m	0	0	0	1	7	2	18
1.0 to 2.0 m	0	0	0	0	0	6	25
>2.0 m	0	0	0	0	0	2	37

The following findings are notable:

- Of three dwellings affected in a 2% AEP event, one is located at Stroud Road, and two at Stroud.
- Of the 104 residential dwellings affected by above floor flooding in the PMF, 66 are located at Stroud. Twelve of these would be affected in a 0.2% AEP event and five in a 0.5% AEP event.
- 13 residential dwellings would be affected by above floor flooding at Booral in a PMF. Six of these would affected in the 0.2% AEP, 5 in the 0.5% AEP and one in the 1% AEP event.
- In the 0.2% AEP flood, depths of above floor flooding at a number of dwellings begin to exceed 1.0 m. During a PMF, depths of above floor flooding would exceed 2.0 m at some 37 dwellings, and exceed 1.0 m at a further 25.

In summary, the overall level of affectation could be described as low. However, affectation jumps in floods of greater than a 1% AEP magnitude, with the degree and severity of above floor flooding during a PMF posing a significant risk to property and the lives of occupants.

FIGURE 6-1



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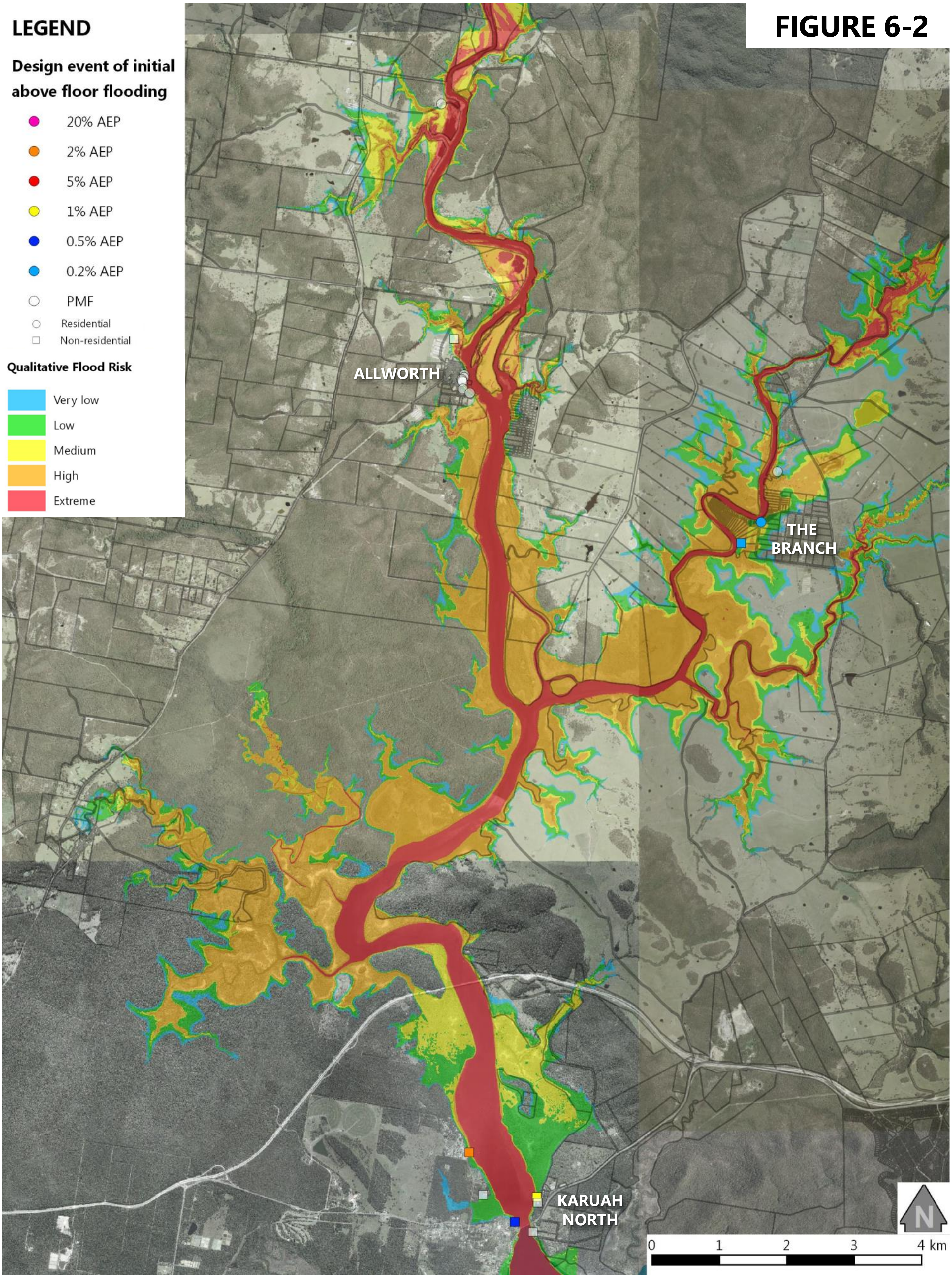
DISTRIBUTION OF ABOVE FLOOR FLOOD AFFECTATION
STROUD ROAD TO BOORAL

FIGURE 6-2



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DISTRIBUTION OF ABOVE FLOOR FLOOD AFFECTATION ALLWORTH TO KARUAH

6.2 Road Inundation

An assessment of road inundation has been undertaken in order to identify locations that are subject to flooding and may pose a risk to the lives of motorists and present constraints to evacuation and emergency response. This has been completed by assessing the frequency and hazard of inundation at 43 road low-points as presented in **Figure 6-3** and **Figure 6-4** ,and summarised in **Table 6-3**.

The general flood hazard curves presented in **Figure 5-7** have been used in the assessment. A 'H2' hazard represents flood conditions that are unsafe for small vehicles, while a hazard of 'H3' or higher (i.e. H4 to H6) represents conditions considered unsafe for all vehicles. It is noted that road inundation at minor tributaries considers only backwater flooding from the waterways specifically investigated by the *Karuah River and Stroud Flood Study Update* (Advisian, 2018), namely the Karuah River, Mammy Johnsons River, Mill Creek, Lamans Creek, The Branch River and Little Branch River.

The following is notable from the analysis with regard to the impact on evacuation and emergency response:

- There are several low level waterway crossings which become unsafe for all vehicles in a 20% AEP flood, and likely more frequent events. These crossings would become inundated quite rapidly and for a significant duration. This creates significant access issues even during relatively frequent flood events, for example:
  - During a 20% AEP event, the only available crossing from the eastern side of the Karuah River to the western side would be via the Booral Bridge. The Bucketts Way approaching the Booral Bridge becomes unsafe for vehicles in a 0.5% AEP event.
  - Land on the western side of the Karuah River at Stroud Road would become isolated in events more frequent than a 20% AEP
  - The Branch would become isolated in events more frequent than a 20% AEP
- Access to 55 Reisdale Road, Stroud Road becomes unsafe during a 5% AEP event as would access for small vehicles to 8 Spencer Street, Stroud
- Major roads that become unsafe for all vehicles during a 2% AEP event include:
  - Stroud Hill Road at a location about 700 m to the west of The Bucketts Way intersection
  - Cowper Street adjacent to the Stroud Showground
- Major roads that become unsafe for all vehicles during a 1% AEP event include:
  - Stroud Hill Road at Barnes Creek and the eastern approach to Washpool Bridge
  - Booral-Washpool Road near Lowreys Creek
  - Cowper Street, Stroud near Briton Court Road
  - Berkeley Street, Stroud near Laman Street
- The results show that a 1% AEP magnitude flood would result in isolation and access issues throughout much of the study area. It is noted, however, that the timing and magnitude of flooding may differ between tributaries during a real storm event.

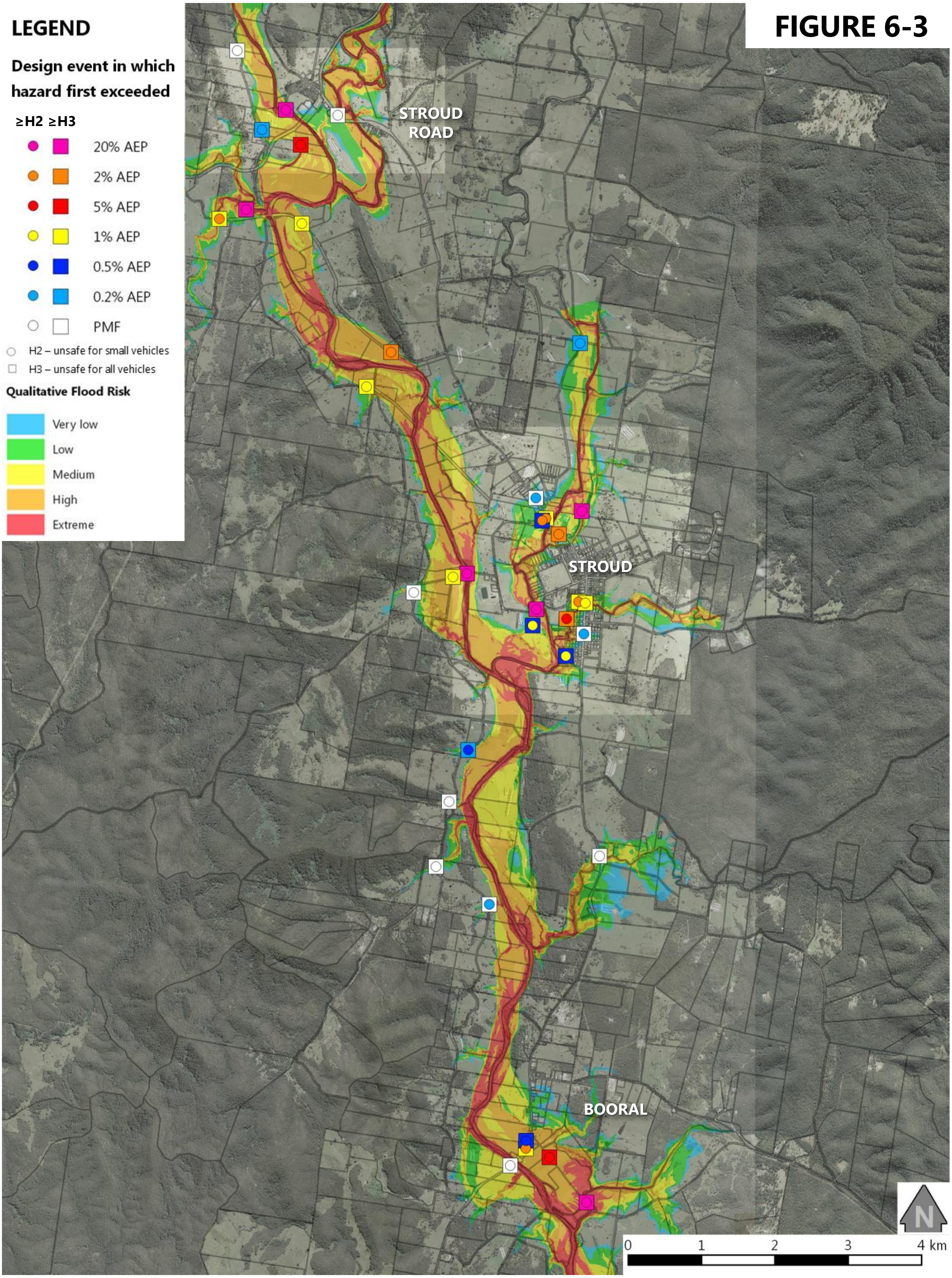
Isolation, evacuation constraints and emergency response classifications will be further investigated in the subsequent stages of the FRMS.

Table 6-3 Flood hazard at road low-points by design flood event

Location	20% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Williams Rd, Stroud Road	-	-	-	-	-	-	H3
Reisdale Rd bridge, Stroud Road	H6	H6	H6	H6	H6	H6	H6
The Buckets Way near Stroud Road Public School	-	-	-	-	-	-	H5
Reisdale Road, Stroud Road	-	-	-	-	-	H4	H6
Driveway to 55 Reisdale Rd, Stroud Road	-	H3	H5	H5	H5	H6	H6
Reisdale Rd at Barnes Creek	H5	H5	H6	H6	H6	H6	H6
Stroud Hill Rd at Barnes Creek	-	-	H2	H3	H4	H5	H6
Stroud Hill Rd near Washpool Bridge	-	-	H1	H5	H5	H5	H6
Mill Creek Road near Greenhams Lane	-	-	H1	H1	H1	H3	H5
Stroud Hill Rd 700m west of The Bucketts Way	-	-	H3	H5	H5	H6	H6
Booral-Washpool Rd near Lowreys Crk	-	-	H1	H3	H5	H5	H6
Cowper St near Mill Creek Rd, Stroud	-	-	H1	H1	H1	H2	H4
Mill Brook Road crossing	H3	H4	H5	H5	H5	H5	H6
Cowper St near Briton Court Rd, Stroud	-	-	H2	H3	H4	H5	H6
Briton Court Rd, Stroud	-	-	H2	H2	H4	H5	H6
Cowper St at Stroud Showground	-	-	H3	H5	H5	H5	H6
Gortons Crossing Rd Bridge	H5	H6	H6	H6	H6	H6	H6
Gortons Crossing Rd near #51	-	-	H1	H3	H5	H5	H6
Booral-Washpool Rd at Sawpit Creek	-	-	-	H1	H1	H1	H5
Laman St, Stroud	-	H1	H2	H3	H3	H4	H6
Berkeley St near Laman St, Stroud	-	-	H1	H3	H5	H5	H6
Laman St at Mill Creek, Stroud	H6	H6	H6	H6	H6	H6	H6
Driveway to 8 Spencer St, Stroud	H1	H2	H3	H4	H4	H5	H6
Driveway to 220 Briton Court Rd, Stroud	-	-	H1	H2	H3	H5	H6
Berkeley St near RFB, Stroud	-	-	-	-	-	H2	H5
Hinton St, Stroud	-	-	-	H2	H3	H4	H6
Booral-Washpool Rd	-	-	-	-	H2	H4	H6
Booral-Washpool Rd at Lillipilli Gully	-	-	-	-	-	-	H5
The Bucketts Way at Alderley Creek	-	-	-	-	-	-	H3
Booral-Washpool Rd at Washpool Creek	-	-	-	-	-	H1	H6
Booral-Washpool Rd near #483	-	-	-	-	-	H2	H6

Location	20% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
The Bucketts Way at Lowes Lane, Booral	-	-	-	-	H5	H6	H6
Mulberry Lane, Booral	-	-	H2	H5	H5	H6	H6
Lowes Lane, Booral	-	H3	H5	H5	H5	H6	H6
Booral Bridge	-	-	-	-	-	-	H6
Lowes Lane at Booral Creek	H5	H6	H6	H6	H6	H6	H6
Lemon Grove Rd	-	-	-	-	H2	H4	H6
The Bucketts Way near #1895	-	-	-	-	-	-	H6
Stroud St, Allworth	-	-	-	-	-	H2	H6
The Branch Lane at The Branch River	H4	H5	H6	H6	H6	H6	H6
The Branch Lane near #871	H1	H3	H4	H4	H5	H5	H6
Larpent Ave, The Branch	-	-	-	H1	H3	H4	H6
The Branch Lane at Little Branch River	H4	H5	H5	H5	H5	H5	H6

FIGURE 6-3



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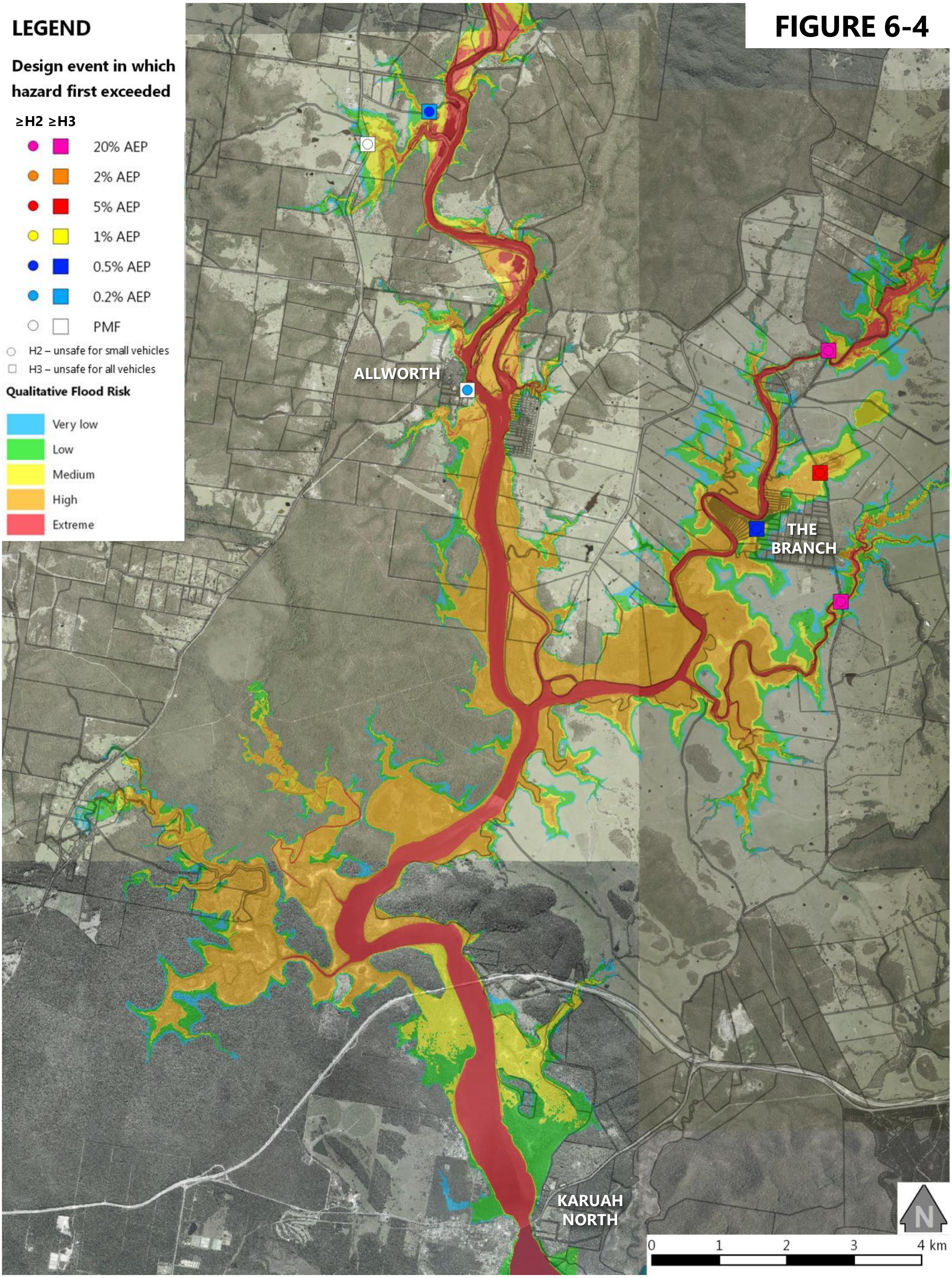
FLOOD HAZARD AT ROAD LOW-POINTS
STROUD ROAD TO BOORAL

FIGURE 6-4



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FLOOD HAZARD AT ROAD LOW-POINTS ALLWORTH TO KARUAH

6.3 Sensitive Land Uses and Public Infrastructure

Certain facilities, services, landuses, and infrastructure have a higher sensitivity to flooding or are critical to the community during or following flood events. The following provides a description of flood affectation for a number of critical or sensitive uses that have been identified within the study area.

6.3.1 Critical Use Facilities

Critical uses include community facilities which provide an important contribution to the notification, evacuation or well-being of the community during flood events. A brief summary of such facilities and their flood affectation is in provided in **Table 6-4**.

Table 6-4 Summary of critical use facilities for the study area

Facility / Service	Address	Comments on flood affectation and accessibility
SES Stroud Unit	Stroud	There are likely to be isolation issues that affect the ability of the SES to respond to flooding in both other areas of Stroud and throughout the study area.
Rural Fire Service	Booral Stroud Stroud Road Allworth Monkerai Ward's River Dungog	The RFS may assist SES in flood preparation, evacuation, rescue and recovery. While fire trucks may be able to pass through certain flood conditions that other vehicles cannot, during major floods there would be significant access issues due to inundation of roads and low level crossings (which is frequent). Careful consideration would be required to determine which brigade is best placed to assist a certain area, and the route to be taken. For example, due to difficulties in crossing the Karuah River, areas on the western bank of the Karuah River at Stroud Road, Greens Crossing and Gortons Crossing may be best accessed from Dungog or Booral depending on the severity of the flood. The Stroud brigade is located on Avon Street to the south of Lamans Creek and may become isolated from Stroud in major floods (the 0.5% AEP event and larger present conditions unsafe even for large vehicles). Additionally the site would be affected by depths of up to 0.5 m in a 0.2% AEP which may affect operations.
Police	6 Gidley Street, Stroud	The Police Station is located outside of the floodplain in Stroud. During major floods (2% AEP and larger) the town may become isolated, limiting the areas where Police assistance could be provided. Flood free access to the Stroud Community Lodge is maintained during very rare flood events (i.e. the 0.2% AEP event) but becomes cut during extreme floods (i.e. the PMF).
Ambulance	24 Berkeley Street, Stroud	Stroud Ambulance is located close to Lamans Creek. During an extreme flood (the PMF) parts of the site would be affected by depths of up to about 0.5 m, and greater depths on Berkeley Street may prevent vehicular access. Flood conditions on Berkeley Street and Lamans Street to the south of the site may become impassable during a 1% AEP flood (and larger events). Cowper Street and Briton Court Road may become impassable in a 2% AEP event. Depending on access and availability, assistance to certain areas could potentially be provided by alternative services such as Bulahdelah and Raymond Terrace.
Hospital	Dungog	The nearest hospital is located in Dungog. During major floods there would be significant access issues from much of the study area. Dungog may also experience its own flood access issues which have not been considered here.
Medical Centre	64 Cowper Street, Stroud	Located outside of floodplain in Stroud. Access would be limited in major floods due to isolation of Stroud.

6.3.2 Stroud Community Lodge Aged Care Facility

The Stroud Community Lodge is located at 51-55 Cowper Street, Stroud, opposite the Stroud Showground. It is a single storey facility with 30 permanent beds. Flood extents for the full range of simulated design events are presented in **Figure 6-5**. Flood conditions affecting the site are summarised as follows:

- In a 2% AEP flood event Cowper Street is overtopped to the north of the site but the site remains essentially unaffected
- In a 1% AEP event minor flooding of the driveway entry may occur
- In a 0.5% AEP event flooding of parts of the driveway entry and carpark would occur, but depths and velocities would remain fairly benign
- In a 0.2% AEP event flooding of the driveway entry and the majority of the carpark would occur, with depths and velocities that would be unsafe for small vehicles. A secondary driveway entrance near the south-eastern boundary of the site would remain unaffected and would provide a safer option for flood-free evacuation to the south across the Mill Brook bridge to the Stroud town centre. These conditions are comparable to those experienced during the April 2015 flood when floodwaters rose within the main driveway and carpark, and SES was on hand to monitor the need for evacuation to be carried out.
- In an extreme flood event (i.e. the PMF) the entire site would become inundated including both driveway entries, and would be subject to hazardous conditions that are unsafe for people and vehicles. Floor level survey (31.97 mAHD) from 2009 indicates that the building would be inundated above floor level by up to 1.4 metres. Evacuation would therefore need to occur quickly prior to inundation of the south-eastern driveway.

6.3.3 Schools

Stroud Road Public School

Flood modelling results indicate that Stroud Road Public School would be affected by flooding during an extreme flood event only (i.e. the PMF). Simulated flood conditions for the PMF are presented in **Figure 6-5** and are summarised below:

- Essentially the entire site would be inundated, with peak flood depths of 0.5 to 2.0 metres surrounding the buildings potentially resulting in flooding above floor level
- The Bucketts Way to the south of the site would be overtopped by high velocity, high hazard flows from the Mammy Johnsons River
- The Bucketts Way to the north of the site would remain unaffected, providing flood-free access to the Stroud Road town centre.

Stroud Public School

Flood modelling results indicate that Stroud Public School would remain essentially unaffected by flooding even during an extreme flood event (i.e. the PMF). Low lying parts of the site adjacent to Mill Brook and the southern corner of the site adjacent Erin Street do experience flooding, but flood extents do not enter the main school grounds (*refer* **Figure 6-6**). Flood modelling indicates that The Bucketts Way (Cowper Street) would be cut by floodwaters in a 2% AEP flood event (i.e. a 1 in 50 year event) at the Stroud Showground to the north of the site, and also at Laman Street to the south of the site.

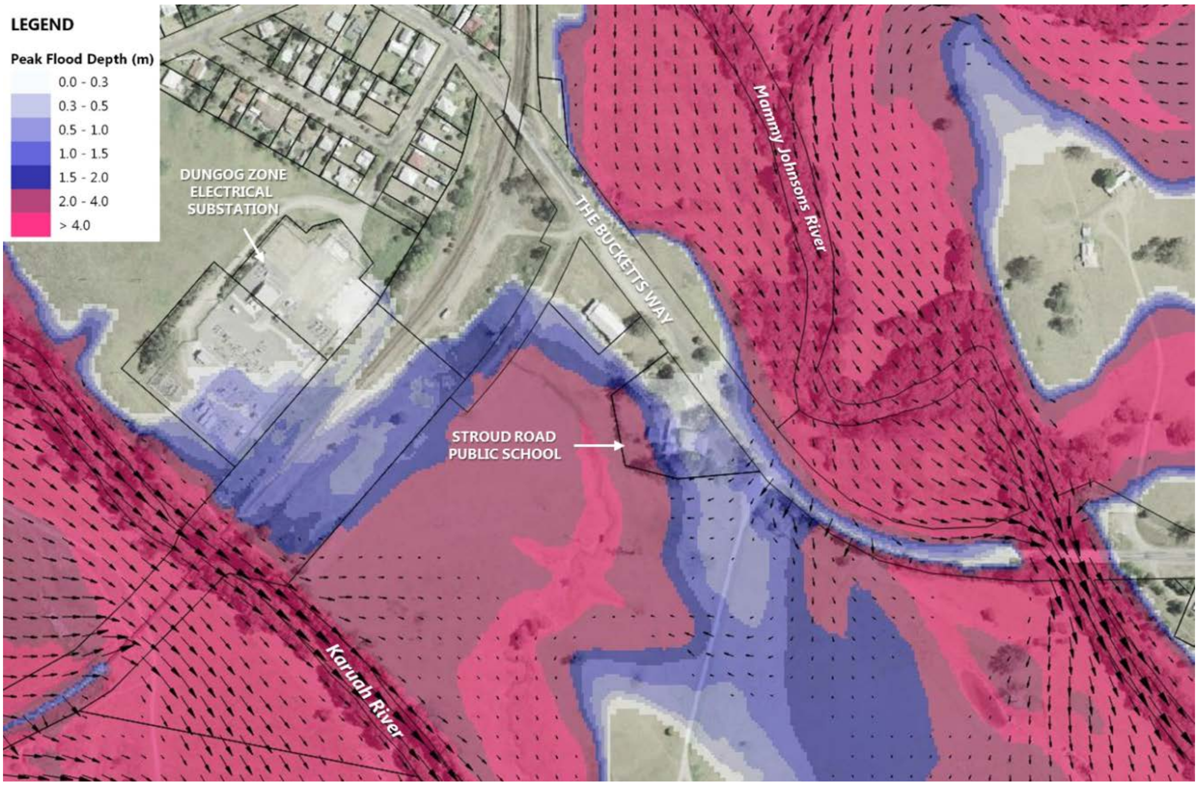


Figure 6-5 Flood conditions at Stroud Road Public School for the PMF (extreme flood event)

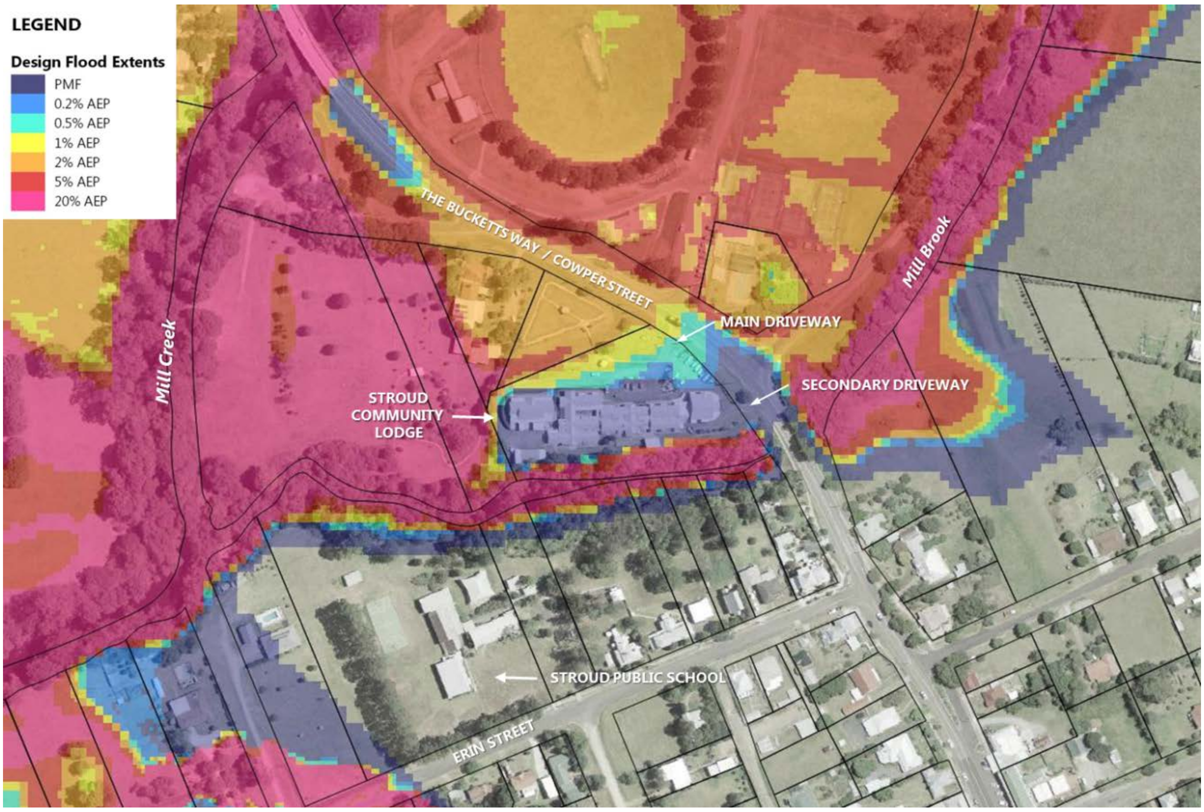


Figure 6-6 Flood extents at Stroud Community Lodge for all simulated design events

Stroud Pre-School

Stroud Pre-School is held at the School of Arts building at 8 Berkeley Street, Stroud. Flood modelling indicates that the site is not flood affected. As noted previously, The Bucketts Way can become cut by floodwaters in a 2% AEP flood event (i.e. a 1 in 50 year event) or larger, temporarily isolating the town centre.

Booral Public School

Flood modelling results indicate that Booral Public School would be affected by flooding during an extreme flood event only (i.e. the PMF). Simulated flood conditions for the PMF are presented in **Figure 6-7** and are summarised below:

- The sporting fields and buildings in the north-eastern half of the developed part of the site would be inundated to significant depths of up to about 2.5 m, with a flood hazard of up to H5 (unsafe for people and vehicles, buildings vulnerable to structural damage)
- The Bucketts Way would be inundated to the south and then north of the site prior to the inundation of school buildings, forming a 'high flood island' comprising the south-western portion of the school site and the Saint Barnabas' Anglican Church site to the south
- Buildings along the southern and western boundaries of the school site remain unaffected by flooding, as would the Saint Barnabas' Anglican Church building immediately to the south
- Local overland flows could potentially pass through the sporting fields during more frequent events along a flowpath running north-west to south-east across the site.

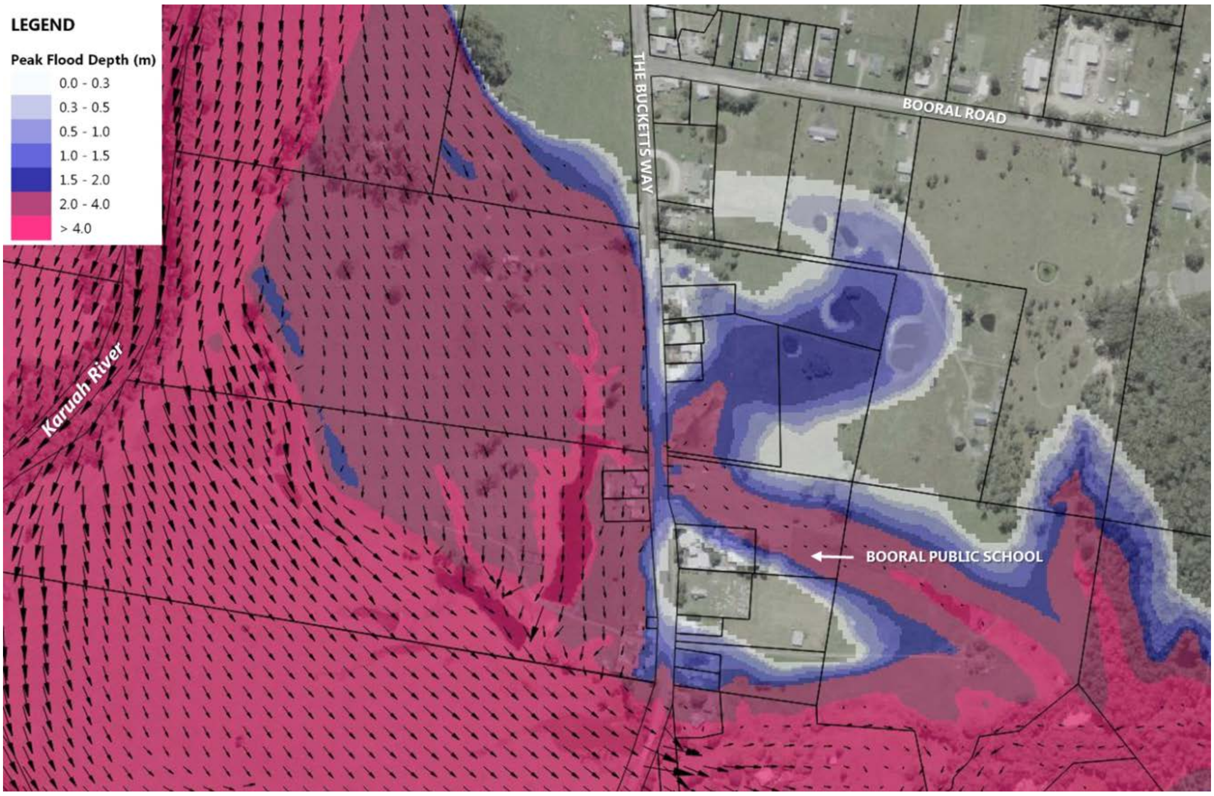


Figure 6-7 Flood conditions at Booral Public School for the PMF (extreme flood event)

6.3.4 Stroud Showground and Camping Area

The Stroud Showground is located on a piece of land bordered by Mill Brook to the east, Mill Creek to the north and west, and Cowper Street (The Bucketts Way) to the south. The Showground is also used as a camping ground and sees a spike of activity during the Christmas holidays, Easter long weekend, the Stroud Show in April, and the Stroud Brick Throwing Festival in July.

April 2015 Flood

During the 21 April 2015 flood, fast flowing floodwaters passed through the site in the early hours of the morning, reaching peak depths of up to 1.8 m. Several campers were asleep in their campervans and caravans as floodwaters began to rise and were lucky to be awoken by Mr. Michael Maytom who was returning home from work. A number of people were forced to take refuge in the grandstand, while one woman clung to the air vents of the amenities block for around two hours before being rescued by police officers in a boat at about 6.30 am as floodwaters receded (Yeo and Crompton, 2015). Given the rate of rise and severity of the flooding, and the time at which the flood occurred, it is very fortunate that there were no fatalities. One couple was hospitalised for hypothermia.

Figure 6-8 shows a caravan and vehicle which were swept away from the Showground and deposited about 150 metres downstream adjacent to Mill Creek, apparently after having been smashed against and passed beneath the Mill Creek Bridge.

Figure 6-8 A caravan and vehicle washed downstream by the floodwaters

A first-hand account of the experience of Steve and Alison Denman, who narrowly managed to escape to Cowper Street in their four-wheel-drive motorhome, can be read on the RV Pages website (https://www.rvpages.com.au/rv-owners-in-flood-nightmare-at-stroud-showground/). The Denmans are adamant that if it were not for the warning provided by Mr. Maytom five lives would have been lost at the Showground that day including their own.

Based on restoration funding received though the Natural Disaster Relief and Recovery Arrangements, damages at the Showground were in excess of $1 million. A wall of the heritage-listed grandstand was blown out, a poultry pavilion destroyed, roads damaged, and other buildings were moved off their footings including the luncheon building which was later demolished. Damages were also sustained to the adjacent tennis courts, swimming pool and playground.

Flood Hazard

The frequency and hazard of flooding at the Showground as indicated by flood model results can be summarised as follows (*refer* **Figure 6-9**):

- 20% AEP event: only very low lying areas in the north of the site are inundated, the entry road and Cowper Street remain flood-free.
- 5% AEP event: a significant portion of the site is inundated to shallow depths (generally less than 0.3 m). Greater depths (up to about 0.65 m) and hazard occur on the internal road behind the grandstand, with conditions that may be unsafe for vehicles and less mobile persons. Various internal roads are inundated including the entry road, however conditions are generally safe for people and vehicles. Cowper Street remains flood-free.
- 2% AEP event: the entire site is inundated except a raised mound east of the rodeo arena. Much of the south of the site including the grandstand area would be unsafe for less mobile persons to wade through. Conditions on the entry road are unsafe for vehicles, with depths of up to 0.7 m. Cowper Street is overtopped to the west of the entry road.
- 1% AEP event: flood hazard across the site continues to increase with depths generally in the 0.5 to 1.0 m range. While velocities across the site would be less than 1.0 m/s, the majority of the site would be unsafe for less mobile persons to wade through. The entry road becomes increasingly hazardous, and there would be minor inundation of Cowper Street at the entrance location.
- 0.5% AEP event: flood depth and hazard across the site continues to increase. The southern portion of the site would be unsafe for able-bodied adults to wade through, including the entry road and grandstand areas.
- 0.2% AEP event: flood depth and hazard across the site continues to increase. Much of the site would be unsafe for able-bodied adults to wade through. Depths of up to 1.4 m would be reached along the entry road, and conditions on Cowper Street at the site entrance may become unsafe. The raised mound east of the rodeo arena remains above surrounding flood levels.
- PMF: the entire site would be inundated including the raised mound east of the rodeo arena. Conditions across the entire site and Cowper Street would be unsafe for vehicles and people, and structures would be vulnerable to failure. Flood depths would be in the 2.5 to 3.5 m range.

In terms of emergency response and evacuation, the site would be classified as a low flood island – whereby the evacuation routes can be cut by flooding prior to inundation of the remainder of the site. This is a high risk situation where evacuation should occur prior to the evacuation route becoming unsafe. Simulated rates of rise indicate that the entry road could become unsafe for vehicles within less than 30 minutes of the first signs of flooding at the site.

As a last resort once evacuation routes become unsafe, the raised mound adjacent the rodeo arena may provide the safest place of refuge. Hazard surrounding the mound is low compared to rest of the site, and access would therefore remain safe for longer. In a PMF event however, the highest part of the mound would be overtopped by depths in the order of 0.3 m. The grandstand would provide greater protection from the elements, and likely some space above the PMF level, however it may be unsafe to access and would be vulnerable to failure in extreme floods.

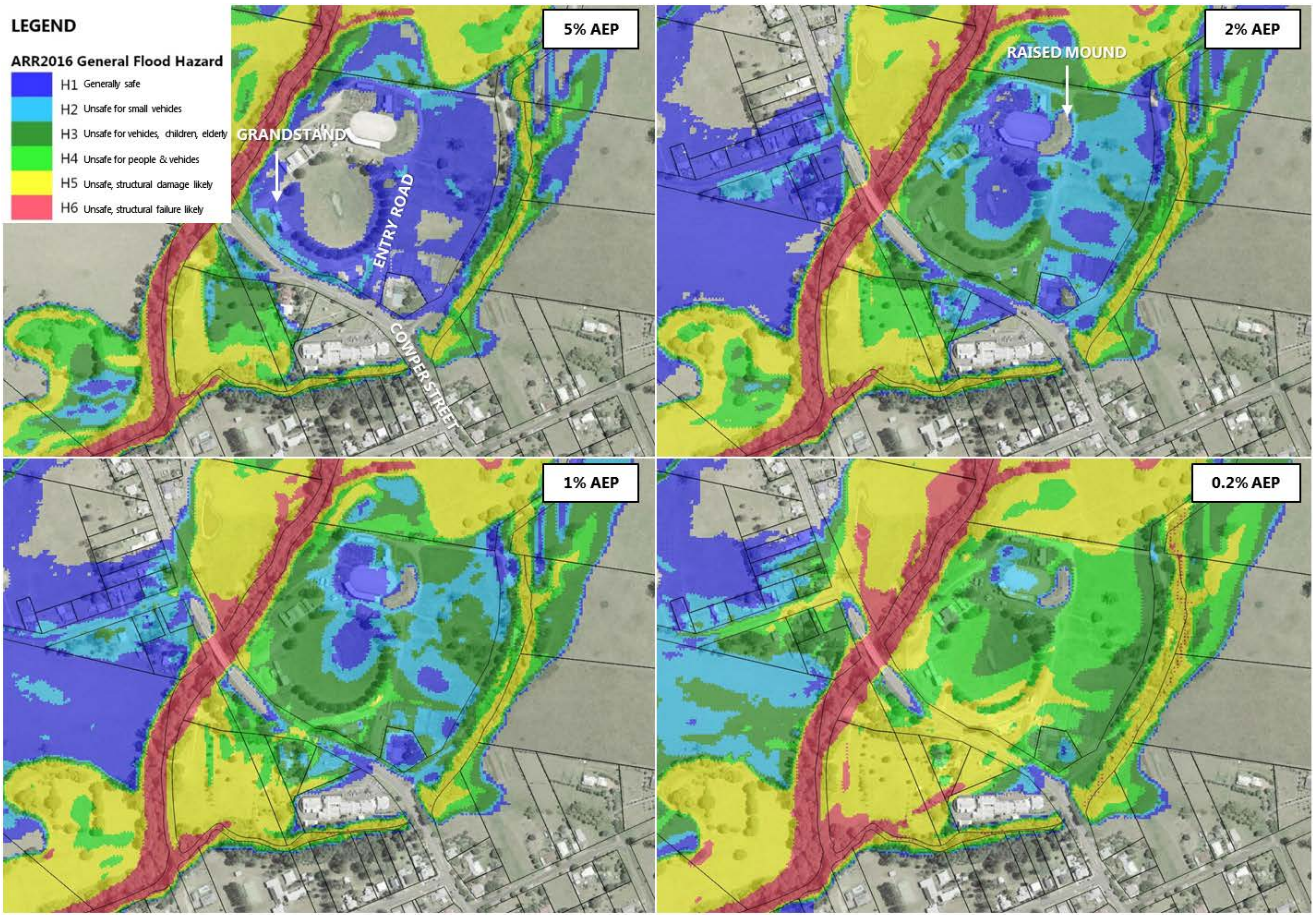


Figure 6-9 Flood hazard at Stroud Showground

Flood Risk Management Issues

Briefing Note 291: Camping Grounds and Flood Risk – Reflecting on the Stroud, NSW, Flood of 21 April 2015 (Yeo and Crompton, 2015), prepared for Risk Frontiers, provides an initial assessment of flood risk management issues relating to the camping ground. It states that as a "*primitive camping ground*" the operator is not required to notify occupants in writing of the location of flood liable land, as is usually required of caravan park and camping ground operators. Additionally, visitors may often set up camp after the Council officer has finished work for the day and therefore would not be made aware of the flood risk even if significant rainfall is expected.

Yeo and Crompton surmised that flood risk at the site could be better managed through the following strategies:

- Installation of signage to depict the flood liable nature of the land and to show a preferred evacuation route
- Temporary closure and monitoring of the site to ensure there are no late arrivals whenever a Flood Watch or Severe Weather Warning for torrential rain is issued
- Council could consider installing a flash flood warning system.

Other options that may warrant investigation include:

- Raising the main entry road to improve vehicular evacuation
- Augmenting the raised mound adjacent the rodeo arena to provide a refuge above the PMF.

6.3.5 North Coast Railway

The North Coast Railway passes through Stroud Road including a bridge across the Karuah River. Flood conditions that may affect the railway, as indicated by flood modelling, are summarised as follows:

- In a 0.5% AEP event and larger floods the railway bridge piers would be subject to a H6 flood hazard. Such conditions can cause damage to structures not specifically designed to withstand them.
- In a 0.2% AEP flood event the railway embankment on the western bank of the Karuah River is overtopped by shallow depths (<0.3 m) along a length of about 250 metres.
- In an extreme flood event (i.e. the PMF) the railway embankment is overtopped along a length of over 1 kilometre (including the railway bridge). Depths of overtopping are up to 3 metres in places and velocities in excess of 4 m/s. Significant damage would be expected under such conditions.

6.3.6 Dungog Zone Electrical Substation

The Dungog Zone Substation is located at the southern end of Karuah Street in Stroud Road, adjacent to the Karuah River (*refer* **Figure 6-6**). The substation serves a significant area including places as far afield as Pacific Palms, Hawks Nest, Gloucester, Dungog and Paterson.

Results of flood modelling indicate that the southern corner of the Stroud Road substation site would be inundated in an extreme flood event (i.e. the PMF) by depths of up to 0.9 m. Structures and electrical equipment are evident in this part of the site from aerial photography. The consequences of such inundation are not specifically known, however given the depths involved it is expected that interruption to service is possible.

6.3.7 Sewage Pumping Stations

One known pumping station (ST-SPS-02) is located near a picnic area adjacent to Mill Creek, around 100 m downstream of the Cowper Street bridge. The electrical kiosk for the pump station is on an elevated platform well above ground level at an elevation of 31.22 mAHD. Based on debris and markings, the April 2015 flood reportedly peaked at a level about 0.8 m below the platform (Yeo, 2015). Flood modelling results indicate that the kiosk would not be affected during a 0.2% AEP event, but would be inundated to a depth of about 1.0 m in a PMF event.

6.4 Assessment of Flood Damages

A flood damage assessment has been undertaken for the study area in order to quantify the impact of flooding in economic terms for existing 'base case' flood conditions and use this as a means for the assessment of the relative merit of potential entrance management options through cost-benefit analysis.

The general process for undertaking a flood damages assessment comprises:

- Identifying properties subject to flooding and attaining habitable floor levels
- Defining appropriate stage-damage relationships for various property types
- Determining depth of inundation above floor level for a range of design event magnitudes
- Estimating flood damages for each property and total flood damage for a range of design events
- Calculating Annual Average Damages (AAD), a measure of the cost of flood damage that could be expected each year by the community, on average
- Calculating the present value of flood damages (typically over a 50 year period at a 7% discount rate), which represents the sum of all future flood damages that can be expected over the calculation period expressed as a dollar value.

Flood damages have been estimated by applying one of three residential and three non-residential stage-damage curves to each property included in the database. These curves relate the amount of flood damage that would be expected at different flood depths for a particular property type.

6.4.1 Residential

The estimation of residential flood damages has followed the methodology presented in the *Floodplain Risk Management Guideline: Residential Flood Damages* (OEH, 2007) and associated spreadsheet. The stage-damage curves have been tailored to the study area using the inputs presented in **Table 6-5**.

6.4.2 Non-residential

No standard stage-damage curves have been issued for commercial and industrial damages. The relationships applied in this study are based on investigations by Water Studies (1992) as incorporated into WaterRIDE^{TM}.

A sanity check was undertaken on damage calculations at the Stroud Showground, which were known to be in the order of $1 million for the April 2015 flood (approximately equivalent to a 0.2% AEP design event). This suggested that the "commercial – high" stage-damage curves were appropriate for buildings at the Showground.

The majority of non-residential buildings in the study area are associated with agricultural land uses. Agricultural properties often suffer significant economic losses due to flooding associated with damage to fences, machinery and pastures, and loss of livestock. The "commercial – high" stage-damage curves were therefore considered appropriate throughout the study area, though losses during more frequent flood events are unlikely to be well represented as damages are assessed only once flooding impacts large buildings such as poultry sheds.

Table 6-5 Residential stage-damage curve input variables

Input	Value	Source
Regional Cost Variation Factor	1.08	Rawlinsons (value for Singleton)
Post late 2001 adjustments	1.65	Changes in NSW AWE from Nov 2001 to May 2017
Post Flood Inflation Factor	1.30	Regional town, medium scale impacts
Typical Duration of Immersion	4 hours	Typical scenario
Building Damage Repair Limitation Factor	0.90	Moderate duration
Typical House Size	240 m^2	Average of available house footprints for Stroud
Contents Damage Repair Limitation Factor	0.8	Moderate duration
Level of Flood Awareness	Low	Infrequent flood affectation
Effective Warning Time	0 hours	Rapid flooding scenario with no warning
Typical Table/Bench Height	0.90	Standard OEH recommendation
External Damage	$6,700	Standard OEH recommendation
Clean-up costs	$4,000	Standard OEH recommendation
Likely Time in Alternative Accommodation	3 weeks	Potentially significant flooding
Additional Accommodation Costs	$220 / week	Standard OEH recommendation

6.4.3 Indirect Damages

The OEH residential stage-damage curves make allowance for clean-up costs and the cost of time in alternative accommodation. Recent research for Hawkesbury-Nepean flood mitigation assessments suggests that an additional allowance of 5% is warranted for other indirect costs for the residential sector and has been applied in this study.

The indirect damages associated with commercial properties are typically higher and a value of 50% of the calculated direct damages has been adopted in this study.

6.4.4 Other

In previous floodplain risk management studies, OEH has advised that damages to infrastructure (roads, rail, recreational areas, utilities etc.) be estimated as 15% to 30% of total direct residential and non-residential damages. In the study area, the density of development and is low relative to the size of the floodplain and the infrastructure servicing it (particularly roads, bridges and rail). A higher infrastructure damage rate of 30% has therefore been adopted for this study.

Flooding can have various impacts on people's health, both physical and mental. These include stress-related ailments, viral infections and heart problems amongst others. Although it is difficult to quantify the cost of disruption, illness, injury and hospitalisation, social damages have been estimated as 25% of 'total damages' (interpreted as the sum of direct residential damages and direct non-residential damages) in line with previous advice from OEH.

6.4.5 Summary of Flood Damages

Flood damages estimated for the Karuah River and Stroud study area are summarised in **Table 6-6** and **Table 6-7**.

- Flood damages are very low for the more frequent events before a significant jump at the 2% AEP event, and similarly rapid increases with event magnitude from there on
- The largest contributions to AAD are associated with the PMF and 2% AEP events, resulting from the severity of damages in the PMF and the relative frequency of damages from the 2% AEP
- Direct flood damages for residential land use are higher than non-residential damages for all events except the 5% AEP
- The total
- It is noted that damages to rural properties that may occur during relatively frequent flood events (e.g. to fences and pastures) are not well represented as the damages are measured only once significant buildings (e.g. poultry sheds) become affected.

Table 6-6 Summary of direct flood damage by design flood event

Flood Event	Buildings Flooded Above Floor	Estimated Direct Damage by Flood Event ($2017)	Event Contribution to Direct AAD ($2017)	Direct Average Annual Damage ($2017)	Present Value of Direct Damage ($2017)*
20% AEP	0	$11,000	$2,000	**$66,000**	**$980,000**
5% AEP	2	$59,000	$5,000		
2% AEP	11	$617,000	$10,000		
1% AEP	12	$974,000	$8,000		
0.5% AEP	22	$1,896,000	$7,000		
0.2% AEP	40	$3,952,000	$9,000		
PMF	159	$21,441,000	$25,000		

*Calculated at a 7% discount rate over 50 years

Table 6-7 Components of total flood damage

	Damage Component	Method of Estimation	Contribution to AAD ($2017)	% of Total AAD
A.	Direct residential damage	OEH Guidelines (2007)	$36,900	31%
B.	Indirect residential damage	5% of A	$1,800	2%
C.	Direct non-residential damage	Water Studies (1992)	$29,300	25%
D.	Indirect non-residential damage	50% of C	$14,700	12%
E.	Infrastructure damage	30% of direct damage	$19,900	17%
F.	Social damage	25% of direct damage	$16,600	14%
	Total Annual Average Damages (AAD)		**$119,000**	
	Total Present Value of Damages*		**$1,761,000**	

*Calculated at a 7% discount rate over 50 years

An analysis of the spatial distribution of direct residential and non-residential damages was undertaken, with the findings presented in **Table 6-8**. By far the highest concentration of flood damages occurs in the vicinity of Mill Creek at Stroud, with significant contributions also at Booral, Stroud Road and Lamans Creek at Stroud. It is also evident that a significant portion of flood damages can be attributed to individual buildings, typically those that become affected during more frequent flood events.

Table 6-8 Summary of direct annual average flood damages by location

Location	Direct AAD ($2017)	AAD Per Property ($2017)		
		Buildings	Average	Maximum
Stroud Road	$5,700	10	$600	$3,100
Mill Creek at Stroud	$38,800	59	$700	$9,100
Lamans Creek at Stroud	$5,300	34	$200	$1,300
Booral	$8,200	21	$400	$1,500
Allworth	$900	13	$100	$200
The Branch	$800	3	$300	$400
Karuah (incl. Port Stephens LGA)	$1,200	6	$200	$500

7 Information to Support Flood Emergency Response Management

7.1 Introduction

The NSW State Emergency Service (SES) is the legislated Combat Agency for floods and is responsible for coordinating other agencies involved with flood emergency management. To assist SES in gathering flood intelligence to help inform and manage the emergency response to flood risk and undertake evacuation planning they, along OEH, have developed guideline documents which detail their desired outcomes from the Floodplain Risk Management process, those being:

- SES Requirements from the Floodplain Risk Management Process (2007); and,
- Flood Emergency Response Planning Classification of Communities (2007).

Existing flood emergency response protocols for Stroud are outlined in the MidCoast Emergency Plan (EMPLAN). The plan sets out the known flood risks and consequences for flood affected areas of the former Great Lakes LGA and how NSW SES will respond in the event of a flood.

More detailed information on flood behaviour and impacts in the Karuah River Valley has been made available as a result of this FRMS and should be considered by SES in their planning and incorporated into the Local Flood Plan as appropriate. Presented in the following is a summary of information relevant to flood emergency response planning and management. Where possible, this has been presented in formats similar to that of the existing Great Lakes Local Flood Plan.

7.1.1 Extent of the FRMS Study Area

It should be noted that this study has investigated flooding of the following areas and tributaries only:

- Karuah River from Stroud Road to Port Stephens
- Mammy Johnsons River at Stroud Road
- Mill Creek at Stroud (*including Mill Brook*)
- Lamans Creek at Stroud
- The Branch River from The Branch Lane downstream
- Little Branch River from The Branch Lane downstream.

This study has not investigated flooding in any area upstream of Stroud Road, nor local catchment flooding of any creek or tributary not listed above. Flood information associated with backwater flooding from the specifically modelled waterways listed above is generally expected to be reliable but should be reviewed by the user for appropriateness prior to adoption. Local overland flow flooding has not been investigated.

7.1.2 Coincident Flooding of Rivers and Tributaries

When considering likely flood impacts and evacuation constraints associated with an actual flood event, it should be noted that significant flooding of the Karuah River may or may not occur concurrently with significant flooding of any one or all of its tributaries. The magnitude or 'frequency' (i.e. in terms of AEP) of an actual flood event may vary throughout the various rivers and tributaries in the Karuah River Valley, as may the timing of the flood peak.

As such, not all of the flood impacts, road inundation and access/isolation issues described in this report may occur concurrently or during any one flood event – even if the flood is of a significant magnitude. The combination of impacts experienced during an actual flood event is dependent on the intensity, duration and spatial distribution of rainfall. As a general guide:

- Shorter more intense storms (e.g. 2 to 12 hours) may cause more severe flooding of creeks and tributaries (e.g. Lamans Creek, Mill Creek, Little Branch River)
- More widespread, longer duration rainfall events (e.g. 9 to 24 hours) may cause more severe flooding of major rivers (e.g. Karuah River, Mammy Johnsons River, The Branch River) though smaller tributaries may also experience significant flooding if rainfall intensity is high enough.

7.2 Flood Emergency Response Planning Classification

OEH, in collaboration with the NSW SES, developed the Flood Emergency Response Planning (FERP) classifications to provide a basis for the categorisation of floodplain communities according to the evacuation constraints they may face during flooding. The classifications provide SES with an indication of the type and scale of response required for different areas, assisting with the planning and implementation of response strategies.

The FERP classifications are determined through analysis of the sequence of inundation of roads, properties and overland evacuation routes for a range of design flood events. A description of the FERP categories and the likely response required for each is presented in **Table 7-4**.

Flood Emergency Response Planning classification mapping is presented in **Figure 7-1** and **Figure 7-2**. The mapping includes additional information such as design flood extents and the event in which various roads become unsafe for vehicles. FERP classification mapping is typically limited to a 'precinct' scale, however localised Low Flood Islands were discovered during the analysis and have been mapped so as to identify properties that may require particular attention during floods. Annotation on the mapping indicates the nature of access and evacuation constraints at key locations for a range of design flood magnitudes.

It should be noted that the FERP classifications are not inherently indicative of flood risk and may not, alone, be sufficient to determine an appropriate prioritisation for emergency response activities. For example, a Rising Road Access area that is rapidly inundated and subject to hazardous flood conditions during relatively frequent flood events may be subject to a higher flood risk and be a higher priority for emergency response than a Low Flood Island that only becomes isolated or inundated in very rare flood events.

Table 7-1 Description of Flood Emergency Response Planning (FERP) classifications and response required

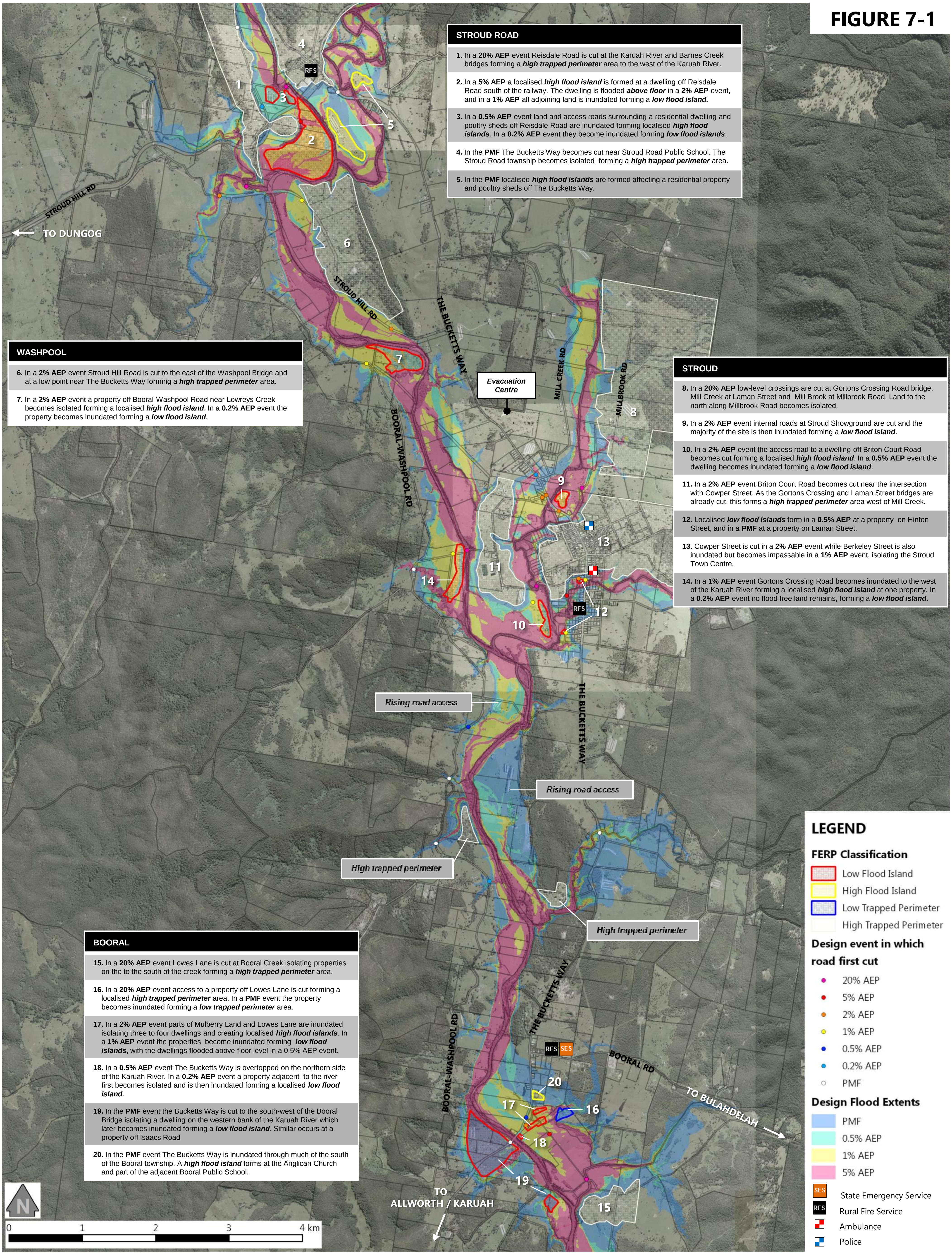
FERP Classification	Description	Response Required		
		Resupply	Rescue/Medivac	Evacuation
High Flood Island	Areas that are surrounded by floodwater during a flood, becoming isolated. The island includes sufficient flood-free land to accommodate the number of people in the area.	Yes*	Possibly	Possibly
Low Flood Island	Areas that are first surrounded by floodwater, becoming isolated, and are later completely inundated. Evacuation should take place before isolation occurs.	No	Yes	Yes
High Trapped Perimeter Area	Areas at the fringe of the floodplain where the only practical road or overland access becomes inundated and unavailable during a flood event. Sufficient flood-free land remains to accommodate the number of people in the area.	Yes*	Possibly	Possibly
Low Trapped Perimeter Area	Areas at the fringe of the flood where the only practical road or overland access first becomes inundated, and the area itself is later completely inundated. Evacuation should take place before isolation occurs.	No	Yes	Yes
Area with Rising Road Access	Flood liable areas where access roads rise uphill away from rising floodwaters. People should not be trapped unless they delay their evacuation from their homes.	No	Possibly	Yes
Area with Overland Escape Route	Flood liable areas where access roads become cut prior to flooding of the area itself. Escape from rising floodwater remains possible by walking overland to higher ground.	No	Possibly	Yes

*Duration of isolation in the Karuah River Valley is not expected to exceed about 36 hours. Resupply may not be required.

Key isolation and emergency response constraints can be summarised as follows:

- Stroud Road:
  - A high flood island can form on the western side of the Karuah River in flood events as frequent as the 20% AEP. Localised low flood islands can then form at some properties within this area during floods of a 2% AEP magnitude or greater.
  - The Stroud Road township can become isolated in an extreme flood (i.e. the PMF).
- Washpool
  - A high flood island can form on the eastern side of the Washpool Bridge along Stroud Hill Road in a 2% to 1% AEP event.
  - A low flood island can form at a property off Booral-Washpool Road near Lowreys Creek, first becoming isolated in a 2% AEP event then inundated in a 0.2% AEP event.
- Stroud
  - Land to the north of Stroud along Mill Brook Road can become isolated in flood events as frequent as the 20% AEP.
  - A low flood island forms at Stroud Showground during a 2% AEP event. Other localised low flood islands can form during floods of a 0.5% AEP magnitude or greater.
  - Cowper Street is cut in a 2% AEP event while Berkeley Street is also inundated but becomes impassable in a 1% AEP event, isolating the Stroud Town Centre.
  - Stroud Community Lodge is affected in an extreme flood (i.e. the PMF), with rising road access south to Stroud available via the secondary driveway at the south-east of the site.
- Booral
  - High trapped perimeter areas can be formed off Lowes Lane in flood events as frequent as the 20% AEP.
  - Localised low flood islands can form at properties at Mulberry Lane, Lowes Lane and The Bucketts Way during floods of a 1% AEP magnitude or greater.
  - The Bucketts Way becomes cut to the east of the bridge during a 0.5% AEP event, and to the west of the bridge in a PMF event.
  - A high flood island is formed at Booral Public School and St Barnabas' Anglican Church.
- Allworth
  - Affectation of residential properties occurs in an extreme flood only (i.e. the PMF), with rising road access available.
- The Branch
  - The Branch Lane becomes cut at The Branch River and Little Branch River crossings in a 20% AEP flood event, isolating The Branch (high flood island)
  - Localised low flood islands can form at two properties off Larpent Avenue/Myola Road during floods of a 0.5% AEP magnitude or greater.

FIGURE 7-1



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301015-037929 – Karuah River and Stroud FRMS

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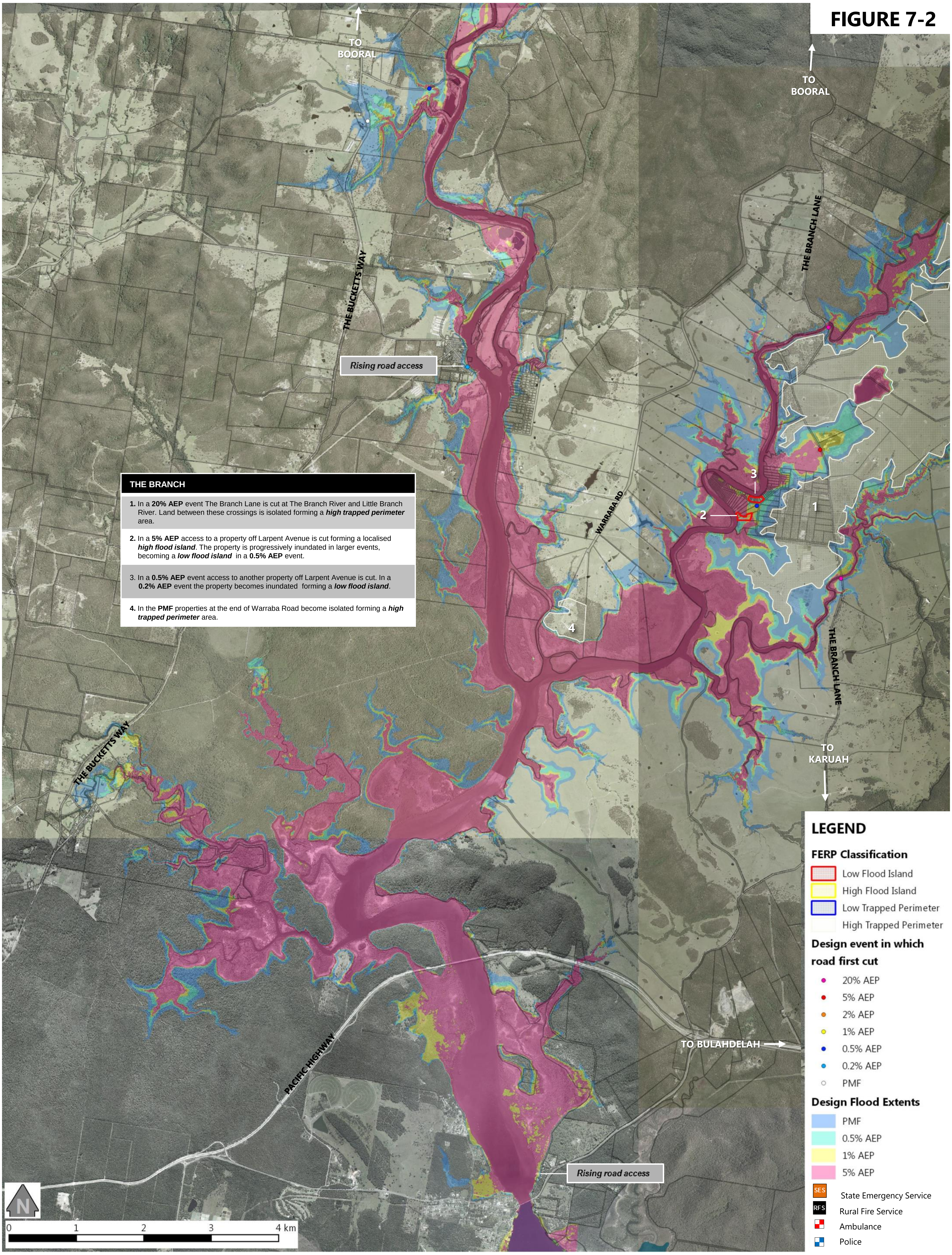
FLOOD EMERGENCY RESPONSE CLASSIFICATION
STROUD ROAD TO BOORAL



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FLOOD EMERGENCY RESPONSE CLASSIFICATION ALLWORTH TO KARUAH

7.3 Summary of Inundation and Flood Affectation

7.3.1 Summary of Property Affectation

An assessment of property affectation and above floor inundation was completed as part of the FRMS. The results are summarised in **Table 7-2** and **Table 7-3**.

Table 7-2 Estimated number of residential properties inundated above floor level from Stroud Road to Karuah

Design Flood	Maximum Over Floor Depths (m)	No. Properties with Over Floor Flooding	No. Properties with Flooding at Dwelling*
20% AEP	NA	0	1
5% AEP	NA	0	1
2% AEP	0.0 to 0.5 m	3	10
1% AEP	0.5 to 1.0 m	4	16
0.5% AEP	0.5 to 1.0 m	11	24
0.2% AEP	>2.0 m	20	32
Extreme (PMF)	>2.0 m	104	124

* Indicative number of residential dwellings with flooding encroaching upon the building footprint

Table 7-3 Estimated number of residential properties inundated above floor level by location

Design Flood	No. Properties with Over Floor Flooding				
	Stroud Road	Stroud	Booral	Allworth	The Branch
20% AEP	0	0	0	0	0
5% AEP	0	0	0	0	0
2% AEP	1	2	0	0	0
1% AEP	1	2	1	0	0
0.5% AEP	1	5	5	0	0
0.2% AEP	1	12	6	0	1
Extreme (PMF)	4	66	13	7	2

7.3.2 Areas of High Flood Risk

Flood risk is a combination of the likelihood of occurrence of a flood event and the consequences of that event when it occurs.

'Flood Risk' mapping was completed as part of the Stage 5 & 6 report for this FRMS. Existing development located in 'High Risk' areas of the floodplain (essentially areas that are more likely to experience significant consequences as a result of flooding) were identified as follows:

1. **Stroud Road**
   (a) Poultry sheds off Reisdale Road to the north of railway line on the western bank of the Karuah River
   (b) Residential dwelling to the south of railway line on the western bank of the Karuah River
2. Location of overtopping of Stroud Hill Road to the east of Washpool Bridge
3. **Stroud Hill Road** – low section of road from approximately 600 m to 1,300m west of intersection with The Bucketts Way
4. **Booral-Washpool Road** – land encircling a buildings near Lowreys Creek (1444 Booral-Washpool Road)
5. **Gortons Crossing** – land encircling a residential dwelling including inundation of Gortons Crossing Road
6. **Stroud**
   (a) Land encroaching upon a dwelling at Millbrook Road (113 Millbrook Road)
   (b) Flows across Cowper Street into Briton Court Road including parts of residential properties near the roadway
   (c) Roadways within the Stroud Showground, flows across Cowper Street adjacent to the Showground, and a dwelling on Cowper Street adjacent to the Showground (49 Cowper Street)
   (d) Flows across Berkeley Street north of the Lamans Creek bridge, and into Laman Street
   (e) Residential dwelling at the end of Spencer Street adjacent Lamans Creek (8 Spencer Street)
   (f) Residential dwelling at the end of a long access track off Briton Court Road adjacent Mill Creek (220 Briton Court Road)
7. **Greens Crossing** – Poultry sheds at Greens Crossing on the western bank of the Karuah River downstream of the Mill Creek confluence
8. **Booral** – several residential dwellings on the northern bank of the Karuah River at The Bucketts Way, Mulberry Lane and Lowes Lane
9. **The Branch**
   (a) A building on the banks of The Branch River near Larpent Avenue
   (b) A section of The Branch Lane downstream of a wetland area.

Areas of 'extreme' risk are generally limited to watercourses, flood runners and immediately adjacent undeveloped land. The notable exceptions to this are the various low level crossings in the study area which are all subject to extreme risk and include the following:

- Reisdale Road bridge at Karuah River, Stroud Road
- Reisdale Road at Barnes Creek, Stroud Road
- Gortons Crossing Road bridge, Stroud
- Mill Creek at Laman Street, Stroud
- Mill Brook at Mill Brook Road, Stroud
- Booral Creek at Lowes Lane, Booral
- The Branch River at The Branch Lane
- Little Branch River at The Branch Lane.

7.3.3 Rate of Rise

An assessment of the rate of rise of floodwaters was completed as part of the Stage 5 & 6 report for this FRMS. For a 1% AEP flood it was found that the rate of rise in affected areas was generally in the order of 0.5 m/hour or higher, indicating that flood conditions can become unsafe for vehicles and less mobile persons quite quickly following initial inundation. The rate of rise at all low level crossings exceeds about 1.5 m/hour.

Rate of rise during the PMF is significantly higher than for the 1% AEP, with the vast majority of the floodplain having a maximum rate of rise of greater than 1.2 m/hour and generally greater than 2.0 m/hr.

7.3.4 Flood Warning Time

An assessment of potential total flood warning time was completed as part of the Stage 5 & 6 report for this FRMS.

Estimations of flood warning time depend on the criteria set for the issue of a flood warning. For the purposes of the assessment, criteria for the issue of flood warnings based on recorded rainfall at nearby pluviometer gauges were assumed along with the flood level at which any property protection or evacuation procedures would need to be completed. The assessment indicated the following:

- Little (less than two hours) or no time is available to warn of flooding of low level crossings such as those at Reisdale Road, Laman Street, Gortons Crossing, Lowes Lane and The Branch Lane, which are overtopped in frequent events
- Total warning time throughout the remainder of the catchment is typically in the order of 4 to 6 hours, with slightly shorter warning times of 3 to 4 hours at Stroud
- In the PMF (180 minute duration design event) total flood warning throughout the catchment is generally 3 hours or less, and is typically less than 2 hours.

The indicative total warning times of less than 6 hours are considered minimal, and limited coordination, assistance or direction from emergency services is likely to be possible. As such, use of recorded rainfall triggers for the issue of flood warnings may not be appropriate.

Volume 3 of the Local Flood Plan states the following with regard to flood warning:

"In the event of a Flood Watch for moderate to major flooding on the Karuah or Myall Rivers and the issuance of associated severe weather warnings for heavy rain, the Stroud Unit may undertake a community liaison/"heads up" doorknock of residents in the following areas to highlight the potential risk of flash flooding and need to evacuate:

- Stroud Showground camping area
- The section of Cowper Street (Bucketts Way) from the Stroud Community Lodge (Aged Care Facility) through to Mill Creek Road
- The north east section of Briton Court Road."

While this approach may be appropriate and allow early evacuation to occur, additional high risk areas exist and should be added to the above list. It may also be possible to develop more specific flood warnings for the Karuah River and its tributaries (e.g. Mill Creek) from the BoM Australian Digital Forecast Database (ADFD) 3-hourly rainfall forecast grids.

7.4 Flooding of Key Transport and Evacuation Routes

Numerous roads within the study area can be cut by flooding causing substantial access, evacuation and isolation issues. Details of flooding of major transport routes and additional roads contributing to isolation issues are presented in **Table 7-4**.

Table 7-4 Summary of key transport and evacuation routes liable to flooding

Road	Closure location	Frequency of closure	Consequences of closure	Alternate route
Reisdale Rd bridge, Stroud Road	At bridge across Karuah River	Frequent (<20% AEP)	Prevents access between western side of Karuah River and Stroud Road centre. Road may also be cut at Barnes Creek, isolating residents to west of river.	Reisdale Rd via Stroud Hill Rd, however also likely to be inundated.
Reisdale Rd at Barnes Creek, Stroud Road	At bridge across Barnes Creek	Frequent (<20% AEP)	Prevents access between Reisdale Rd and Stroud Hill Rd. Road may also be cut at Karuah River, isolating residents to west of river.	Reisdale Rd from the Stroud Road township, however also likely to be inundated.
The Bucketts Way near Stroud Road Public School	Between bridge across Mammy Johnsons River and the Public School	Extreme flood (PMF)	Isolates the Stroud Road township.	None. Reisdale Rd inundated in this event.
Stroud Hill Rd at Barnes Creek	At bridge, about 150 m west of Black Camp Rd	Infrequent (2% AEP)	Prevents access along Stroud Hill Rd to/from the west (i.e. Dungog)	None.
Stroud Hill Rd near Washpool Bridge	About 400 m south-east of Washpool Bridge	Rare (1% AEP)	Stroud Hill Rd would also be cut west of The Bucketts Way, isolating properties.	None.
Stroud Hill Rd west of The Bucketts Way	About 600 m west of the intersection with The Bucketts Way	Infrequent (2% AEP)	Stroud Hill Rd may also be cut south-east of The Bucketts Way, isolating properties.	Potentially via Booral Bridge, Booral-Washpool Rd and Washpool bridge depending on flood behaviour (The Bucketts Way may be cut at Stroud)

Road	Closure location	Frequency of closure	Consequences of closure	Alternate route
Mill Creek Road near Greenhams Lane, Stroud	Around intersection of Mill Creek Rd and Greenhams Lane, north of Stroud	Very rare (0.2% AEP)	Prevents access along Mill Creek Rd isolating properties to the north, and to the west along Greenhams Lane.	None.
Booral-Washpool Rd near Lowreys Creek	3 km south of intersection with Stroud Hill Rd	Rare (1% AEP)	Prevents access to north along Booral-Washpool Rd, isolating properties.	None.
Mill Brook Road, Stroud	At crossing of Mill Brook north of Stroud Showground	Frequent (<20% AEP)	Prevents access to north along Mill Brook Rd, isolating properties.	None. Possibly Millbrook East Rd, though may also be unsafe.
Cowper St near Briton Court Rd, Stroud	Intersection of Cowper St and Briton Court Rd	Infrequent (2% AEP)	Prevents access between north Stroud and town centre, and isolates western portion of Briton Court Rd	None.
Cowper St at Stroud Showground	Cowper Street adjacent to the Stroud Showground	Infrequent (2% AEP)	Prevents access between north Stroud and town centre, isolates showground and adjacent property	None.
Gortons Crossing Road Bridge, Stroud	At bridge over Karuah River	Frequent (<20% AEP)	Prevents crossing of Karuah River via Gortons Crossing, limiting access to/from Stroud	Via Booral Bridge and Booral-Washpool Rd.
Gortons Crossing Rd, Stroud	Near #51 Gortons Crossing Rd, approximately 200 m west of bridge	Rare (1% AEP)	A property adjacent Karuah River becomes isolated	None.
Berkeley St near Laman St, Stroud	Immediately north of the Berkeley St crossing of Lamans Creek	Rare (1% AEP)	Prevents access between south Stroud and town centre. Minor inundation of Berkeley St begins in 2% AEP and of Laman St in 5% AEP.	None.
Laman St at Mill Creek, Stroud	At bridge across Mill Creek south-west of Stroud	Frequent (<20% AEP)	Prevents crossing of Mill Creek via Laman St, limiting access to/from Stroud	Depending on event, Briton Court Rd via Cowper St may provide access to western Stroud and Gorton's Crossing, however Gorton's Crossing bridge may also be cut.
The Bucketts Way near Lowes Lane, Booral	Overtopping of from about 400 m north of Booral Bridge	Rare (0.5% AEP)	Prevents crossing of Karuah River via Booral Bridge	Only crossing of Karuah River via Pacific Highway or Tarean Road, with The Branch Lane also likely to be cut.
Mulberry Lane, Booral	Various	Infrequent (2% AEP)	Isolates properties at Mulberry Lane and Lowes Lane	None.
Lowes Lane at Booral Creek, Booral	At or before crossing of Booral Creek	Frequent (<20% AEP)	Isolates properties at southern end of Lowes Lane	None.

Road	Closure location	Frequency of closure	Consequences of closure	Alternate route
The Branch Lane at The Branch River	At bridge across The Branch River	Frequent (<20% AEP)	Isolates The Branch and prevents passage between Karuah and Booral via The Branch Lane	None.
The Branch Lane at Little Branch River	At bridge across Little Branch River	Frequent (<20% AEP)	Isolates The Branch and prevents passage between Karuah and Booral via The Branch Lane	None.
Larpent Ave, The Branch	About 1 km from intersection with The Branch Lane	Rare (0.5% AEP)	Prevents access along Larpent Ave, isolating properties	None.

7.5 Facilities at Risk of Flooding or Isolation

Information regarding facilities that may be sensitive to flooding or important to the emergency response during after a flood, or recovery after a flood, is summarised in **Table 7-5**.

Table 7-5 Facilities at risk of flooding and/or isolation

Facility Name	Address	Comments on flood affectation and accessibility
Aged Care Facilities		
Stroud Community Lodge	51-55 Cowper St, Stroud	▪ In a 2% AEP flood event Cowper Street is overtopped to the north of the site but the site remains essentially unaffected ▪ Up to a 0.5% AEP event flooding of parts of the driveway entry and carpark would occur, but depths and velocities remain fairly benign ▪ In a 0.2% AEP event flooding of the driveway entry and the majority of the carpark would occur, with depths and velocities that would be unsafe for small vehicles. A secondary driveway entrance near the south-eastern boundary of the site would remain unaffected and would provide a safer option for flood-free evacuation to the south across the Mill Brook bridge to the Stroud town centre. These conditions are comparable to those experienced during the April 2015 flood. ▪ In an extreme flood event (i.e. the PMF) the entire site would become inundated including both driveway entries, and would be subject to hazardous conditions that are unsafe for people and vehicles. Floor level survey (31.97 mAHD) from 2009 indicates that the building would be inundated above floor level by up to 1.4 metres. Evacuation would therefore need to occur quickly prior to inundation of the south-eastern driveway.
Schools		
Stroud Road Public School	733 Bucketts Way, Stroud Road	▪ Up to a 0.2% AEP event the site remains essentially unaffected ▪ In an extreme flood event (i.e. the PMF) the majority of the site would be inundated, with peak depths of 0.5 to 2.0 m and potentially flooding above floor level. The Bucketts Way to the south of the site would be overtopped by high hazard flows from the Mammy Johnsons River. The Bucketts Way to the north of the site would remain unaffected, providing flood-free access to the Stroud Road town centre.

Facility Name	Address	Comments on flood affectation and accessibility
Stroud Public School	15-19 Erin Street, Stroud	Site remains unaffected even in an extreme flood event (i.e. the PMF). The Bucketts Way can become cut by floodwaters in a 2% AEP flood event or larger, temporarily isolating the town centre.
Stroud Pre-School	8 Berkeley St, Stroud (School of Arts)	Site remains essentially unaffected even in an extreme flood event (i.e. the PMF). The Bucketts Way can become cut by floodwaters in a 2% AEP flood event or larger, temporarily isolating the town centre.
Booral Public School	2300 Bucketts Way, Booral	In an extreme flood event (i.e. the PMF) the northern-eastern half of the site would be flooded to significant depth (up to 2.5 m) and hazard. The Bucketts Way would be cut either side of the site, but buildings along the southern-western boundaries of the school would remain unaffected by flooding, as would the Saint Barnabas' Anglican Church building immediately to the south.
Camping Areas		
Stroud Showground and Camping Area	Cowper Street, Stroud	▪ In a 5% AEP event a significant portion of the site is inundated to shallow depths including internal roads. Access/egress from the remains relatively safe and Cowper Street remains flood-free. ▪ In a 2% AEP event the entire site is inundated except a raised mound east of the rodeo arena. Much of the south of the site including the grandstand area would be unsafe for less mobile persons to wade through. Conditions on the entry road are unsafe for vehicles and Cowper Street is overtopped to the west of the entry road. ▪ In a 1% AEP event flood hazard across the site continues to increase, with depths generally in the 0.5 to 1.0 m range and the majority of the site unsafe for less mobile persons to wade through. The entry road becomes increasingly hazardous, and there would be minor inundation of Cowper Street at the entrance location. ▪ In a 0.5% AEP event flood depth and hazard across the site continues to increase. The southern portion of the site would be unsafe for able-bodied adults to wade through, including the entry road and grandstand areas. ▪ In a 0.2% AEP event much of the site would be unsafe for able-bodied adults to wade through. Depths of up to 1.4 m would be reached along the entry road, and conditions on Cowper Street at the site entrance may become unsafe. The raised mound east of the rodeo arena remains above surrounding flood levels. ▪ In an extreme flood event (i.e. the PMF) the entire site would be inundated including the raised mound east of the rodeo arena (to a depth of 0.3 m). Conditions across the entire site and Cowper Street would be unsafe for vehicles and people, and structures would be vulnerable to failure. Flood depths would be in the 2.5 to 3.5 m range. The Local Flood Plan 'caravan park arrangements' indicates that evacuation should occur via "*Cowper Street north to Stroud Country Club*". Once flooding has begun it may be preferable to evacuate to the south, to the Stroud Central Pub for example, due to potential inundation of Cowper Street to the north of the showground entrance.
Infrastructure		
North Coast Railway	Stroud Road	▪ In a 0.5% AEP and larger floods the railway bridge piers would be subject to conditions that can cause damage to structures not designed to withstand them. ▪ In a 0.2% AEP flood event the railway embankment on the western bank of the Karuah River is overtopped to shallow depths (<0.3 m). ▪ In an extreme flood event (i.e. the PMF) the railway embankment is

Facility Name	Address	Comments on flood affectation and accessibility
		overtopped along a length of over 1 km. Depths and velocities are significant and damage would be expected under such conditions.
Dungog Zone Electrical Substation	Karuah Street, Stroud Road	In an extreme flood event (i.e. the PMF) the southern corner of the site would be inundated by depths of up to 0.9 m. The consequences of such inundation are not specifically known, however interruption to service may be possible.
Sewage Pumping Stations	Adjacent Cowper Street, Stroud Avon Street, Stroud	The electrical kiosks for these pumping stations are on elevated platforms well above ground level. Flood model results indicate that the kiosks would not be affected during a 0.2% AEP event, but would be flooded to a significant depth in a PMF event.
Flood Assembly Areas		
Stroud and District Country Club	164 Bucketts Way, Stroud	The primary flood assembly area is located outside of the floodplain on the northern outskirts of Stroud. The site would be accessible from most areas up until a 5% AEP event, where access issues would begin to occur in the area.
Stroud School of Arts	8 Berkeley Street, Stroud	Sites remain unaffected even in an extreme flood event (i.e. the PMF). The Bucketts Way can become cut by floodwaters in a 2% AEP flood event or larger, preventing access from the north and south. It is noted that both sites lie within central Stroud, and no assembly area exists to the south of Lamans Creek.
Stroud Central Pub	52 Cowper Street, Stroud	
Critical Use Facilities		
SES Stroud Unit	2756 Booral Road, Booral	Isolation issues may affect the ability of the SES to respond to flooding both within Stroud and throughout the valley. Low level crossings become inundated in quite frequent flood events (<20% AEP event), but most areas would remain accessible by alternative routes under such conditions. Access and isolation issues become more significant in a 2% AEP event and continue to worsen with flood magnitude.
Rural Fire Service	Booral Stroud Stroud Road Allworth Monkerai Ward's River Dungog	While fire trucks may be able to pass through floodwaters under conditions that other vehicles cannot, during major floods there would be significant access issues due to inundation of roads and low level crossings. Careful consideration would be required to determine which brigade is best placed to assist a certain area, and the route to be taken. The Stroud brigade is located on Avon Street to the south of Lamans Creek and may become isolated from Stroud in major floods (the 0.5% AEP event and larger present conditions unsafe even for large vehicles). Additionally the site would be affected by depths of up to 0.5 m in a 0.2% AEP which may affect operations.
Police	6 Gidley Street, Stroud	The Police Station is located outside of the floodplain in Stroud. During major floods (2% AEP and larger) the town may become isolated, limiting the areas where Police assistance could be provided. Flood free access to the Stroud Community Lodge is maintained during very rare flood events (i.e. the 0.2% AEP event) but becomes cut during extreme floods (i.e. the PMF).
Ambulance	24 Berkeley Street, Stroud	Stroud Ambulance is located close to Lamans Creek. During an extreme flood (the PMF) parts of the site would be affected by depths of up to about 0.5 m, and greater depths on Berkeley Street may prevent vehicular access. Flood conditions on Berkeley Street and Lamans Street to the south of the site may become impassable during a 1% AEP flood (and larger events). Cowper Street and Briton Court Road may become impassable in a 2% AEP event. Depending on access and availability, assistance to certain areas could potentially be provided by alternative services such as Bulahdelah and Raymond Terrace.
Hospital	Dungog	The nearest hospital is located in Dungog. During major floods there would be significant access issues from much of the study area. Dungog may also experience its own local flood issues affecting access.
Medical Centre	64 Cowper Street, Stroud	Located outside of floodplain in Stroud. Access would be limited in major floods due to isolation of Stroud.

7.6 Relevant Gauge Levels

DPI Water operates three river level gauges in the Karuah Valley: 209003 Karuah River at Booral, 209018 Karuah River at Dam Site, and 209002 Mammy Johnsons River at Pikes Crossing.

Of these gauges, only levels from the Booral gauge can be directly related to any specific flood impacts, and even then only at the Booral township. A summary of relevant Booral gauge levels and impacts is presented in **Table 7-6**.

Table 7-6 Summary of key gauge levels and impacts at Booral

Flood Event / Impact	Level at Booral Gauge	
	Gauge Height (m)	Elevation (mAHD)
Lowes Lane cut at Booral Creek due to backwater flooding (*may occur earlier due to local creek flooding*)	3.05	4.10
20% AEP	7.34	8.39
20 March 1978	7.98	9.03
8 June 2007	8.42	9.47
4 February 1990	8.60	9.65
13 October 1985	8.86	9.91
5% AEP	9.05	10.10
21 January 1971	9.30	10.35
21 April 2015	9.32	10.37
Mulberry Lane and Lowes Lane inundated isolating properties	9.95	11.00
2% AEP	10.04	11.09
Property on Bucketts way adjacent river flooded above floor	10.65	11.70
1% AEP	10.68	11.73
Properties on Mulberry Lane and Lowes Lane flooded above floor	10.70	11.75
The Bucketts Way overtopped to east of Booral Bridge	11.05	12.10
0.5% AEP	11.22	12.27
Property on Mulberry Lane adjacent river flooded above floor	11.75	12.80
0.2% AEP	12.18	13.23
The Bucketts Way cut to west of Booral Bridge isolating property	13.05	14.10
Bucketts Way property to west of bridge flooded above floor	13.10	14.15
The Bucketts Way cut north of Booral Public School isolating the school and St Barnabas' church	15.75	16.80
Extreme flood (PMF)	17.42	18.47

The Karuah River at Dam Site gauge could potentially be used to indicate likely flooding and impacts at Stroud Road based on gauged flows. However, the effectiveness of this approach would hinge on the ability of the DPI Water rating table to reliably estimate flows and would need to assume rainfall across the remainder of the catchment upstream of Stroud Road was similar to that above the gauge. It is noted that little warning time (*in the order of just one hour*) would be provided.

7.7 Conclusions

The Study provides significantly improved flood information to assist SES and emergency services. The following additional activities are recommended for inclusion within the Plan:

- Raising of low level crossings
- Implementation of a flash flood warning system to educate and warn people at Stroud showground and camping area during the onset of major flooding of Mill Creek
- Provision of a template for residences and businesses to prepare their own specific flood plans

The Flood Warning System for the Stroud showground and camping area (Mill Creek) should include the following:

- Installation of signage to identify the flood liable nature of the land and to show a preferred evacuation route should flooding of Mill Creek be predicted or observed
- Temporary closure and monitoring of the site to ensure there are no late arrivals whenever a Flood Watch or Severe Weather Warning for torrential rain is issued
- Investigation of the feasibility of implementing a flash flood warning system for the site
- Raising the main entry road to improve vehicular evacuation
- Augmenting the raised mound adjacent the rodeo arena to provide a refuge above the predicted peak level of the PMF for Mill Creek

8 Community Consultation

The draft *Karuah River and Stroud Floodplain Risk Management Study* (*Revision A*) was placed on public exhibition for a four (4) week period from 28th February to 27th March 2020. It was accompanied by exhibition of the final draft of Volumes 1 and 2 of the *Updated Karuah River and Stroud Flood Study* (*Revision B*). Public exhibition of the documents was advertised in the local and regional media and on Council's web-site.

During the exhibition period, an information session was held at Stroud Public Library on 10th March from 3pm to 6pm. The information session was facilitated by Mr Evan Vale from MidCoast Council and Mr Chris Thomas from Advisian. Flood mapping and key findings from the studies were displayed on poster boards located in the central foyer of the library and those facilitating were on hand to provide clarification on the information displayed and respond to any questions.

Unfortunately, the information session was poorly attended with only two members of the community frequenting the session and inspecting the displays. One was a member of the Duralie Community Consultation Committee and the other a representative of the Stroud Road Community Hall & Progress Association. Both are members of the Board of the Stroud Community Lodge which is located at 51 – 55 Cowper Street, Stroud, which is located on the southern fringe of the floodplain of Mill Creek, south-east of the Stroud Showground. As noted in this report and the associated *Updated Karuah River and Stroud Flood Study* (*in draft, 2020*), the Stroud Community Lodge was threatened by floodwaters during the April 2015 event. Hence, the interest in the studies from the two Board representatives that attended the information session.

The only written submission that was received during the exhibition period was from NSW SES. The submission requested that some modifications be made to Section 7 of the report to bring it into line with the recent restructure of the NSW SES as well as the relocation of the Forster Pacific Palms SES Unit to Tuncurry. These amendments have been incorporated into the final report.

In summary, there is minimal interest in and concern about the consequences of the flooding of the Karuah River, albeit that inundation of a number of key crossings during major flooding will present issues for residents of rural areas of the valley. Flooding of Mill Creek is of greater concern to the residents of Stroud, particularly in the vicinity of the showground and for residential properties located either side of the Mill Creek Bridge.

9 Conclusions and Recommendations

9.1 Conclusions

Investigations completed for the *Karuah River and Stroud Floodplain Risk Management Study* considered a range of flood modification, property modification and response modification measures that could be implemented at the various villages within the study area to reduce flood damages and minimise the flood risk that the community could be exposed to.

Flood Modification Measures

The investigation of flood modification measures, which typically include structural works such as flood protection levees, diversions, culvert and bridge waterway augmentation and the like, established that no viable options exist for reducing flood damages or flood affectation at Stroud Road, Allworth and The Branch.

The greatest flood risk relates to flooding of Mill Creek at Stroud. However, flood affectation only begins in a 2% AEP event and really only manifest to be significant in events 0.5% AEP and greater. As a result, the economic viability of any flood modification measures for this location is low.

Flooding at Stroud also occur along Lamans Creek, which is a tributary of Mill Creek located at the southern extent of the village. However, flood affectation only begins in 0.5% AEP event and really only manfests to be of any significance in events of 0.2% AEP or greater. Hence, the economic viability of any flood modification measures for this location is very low.

At Booral, flood affectation occurs at a limited number of properties and only during rare events. The analysis completed for this investigation established that 13 residential dwellings would be affected by above floor flooding in a PMF. Six of these would affected in the 0.2% AEP, 5 in the 0.5% AEP and only one (1) in the 1% AEP event. Therefore, the economic viability of structural works such as a levee to improve the level of flood protection for properties at Booral is expected to be very low and not viable.

Response Modification Measures

Response modification measures, which typically include actions that will improve flood awareness and emergency response, present as the most effective flood management measures for areas where flood risk is greatest. The Study provides significantly improved flood information to assist SES and emergency services in delivering improved flood emergency response. In particular, the study has established that one of the greatest risks to the rural community relates to the number of low level river and creek crossings that are cut by floodwaters early in a flood.

Due to the relatively narrow valley and floodplain, the road network that services the rural community crosses the floodplain in a number of areas. Therefore, in circumstances where flooding occurs there can be many instances where residents would seek to cross the floodplain to get from their place of residence to a farm or property.

Hence, there is merit in considering opportunities for raising low level crossings on an opportunitistic basis in conjunction with programmed road upgrades. A typical example where this has occurred in recent times is the Gorton's Crossing upgrade along the Washpool Road crossing of the Karuah River in the area just to the west of Stroud.

Implementation of a flash flood warning system to educate and warn people at Stroud Showground and the associated camping area during the onset of major flooding of Mill Creek was also considered as a worthy flood response measure. A flood warning system for the camping area (Mill Creek) would need to include the following:

- Installation of signage to identify the flood liable nature of the land and to show a preferred evacuation route should flooding of Mill Creek be predicted or observed
- Temporary closure and monitoring of the site to ensure there are no late arrivals whenever a Flood Watch or Severe Weather Warning for torrential rain is issued
- Investigation of the feasibility of implementing a flash flood warning system for the site
- Raising the main entry road to improve vehicular evacuation
- Augmenting the raised mound adjacent the rodeo arena to provide a refuge above the predicted peak level of the PMF for Mill Creek

However, investigation of the logitistics and cost associated with implementing this measure established the the cost for a reliable system to be implemented would be very high for the current patronage of the camping ground. Hence, it is recommended that the installation of a flood warning system for the camping ground be investigated further and implemented should the demand for camp ground sites increase or there be any proposal to expand the use of the facility where the number of overnight stays increased; e.g., an increase in the number of dedicated caravan sites.

9.2 Recommendations

In summary, there is minimal interest in and concern about the consequences of the flooding of the Karuah River, albeit that inundation of a number of key crossings during major flooding will present issues for residents of rural areas of the valley. Flooding of Mill Creek is of greater concern to the residents of Stroud, particularly in the vicinity the showground and for residential properties located either side of the Mill Creek Bridge.

Specific recommendations arising from the investigation are as follows:

(i) Opportunities for road raising at low level crossings or in areas identified in this report where roads can be cut by floodwaters should be prioritised with reference to both hazard and traffic count. This could also be used for forward planning/indication of likely impact of road closures.

(ii) Flood Action Card/Flood Intelligence Cards relied upon by SES are to be reviewed and updated as required.

(iii) Although implementation of a flood warning system for the Stroud Showground / camping ground is not considered justifiable due to the short time of concentration from the Mill Creek catchment and the limited use of the facility for overnight stays, it is recommended that a flood warning sign be erected in the vicinity of the camping area and that markers recording the height of major historical events such as the April 2015 flood be placed on selected light or power poles situated around the showground.

(iv) Flood emergency response management plans (FERPs) should be developed for both the Stroud Lodge and the Stroud Showground.

(v) Further community education should be delivered jointly by SES and Council to ensure flood awareness is maintained and the lessons of the April 2015 event are not forgotton.

10 References

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