BELLINGEN SHIRE COUNCIL

LOWER BELLINGER AND KALANG RIVERS FLOODPLAIN RISK MANAGEMENT STUDY

FINAL REPORT

NOVEMBER 2021

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Project Lower Bellinger and Kalang Rivers Floodplain Risk Management Study	**Project Number** 111036-13
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LOWER BELLINGER AND KALANG RIVERS FLOODPLAIN RISK MANAGEMENT STUDY

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

MAIN REPORT FIGURES

APPENDIX D.

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2016) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2016/2019 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore the term Exceedances per Year (EY) is recommended. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR 2016/2019 and uses % AEP for all events rarer than the 50 % AEP. As the intensity frequency duration data used for the study developed a 5 year ARI rainfall, this terminology has been retained for this event only.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
Extreme	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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

The Policy provides for technical and financial support by the Government through four sequential stages:

1. Flood Study

- Determine the nature and extent of the flood problem.

2. Floodplain Risk Management

- Evaluates management options for the floodplain in respect of both existing and proposed development.

3. Floodplain Risk Management Plan

- Involves formal adoption by Council of a plan of management for the floodplain.

4. Implementation of the Plan

- Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Lower Bellinger and Kalang Rivers Floodplain Risk Management Study constitutes the second stage of the management process. This study has been prepared by WMAwater for Bellingen Shire Council and provides the basis for the future management of flood prone lands in the Lower Bellinger and Kalang Rivers.

Funding for this study was provided by Bellingen Shire Council and the Department of Planning, Industry and Environment. This document does not necessarily represent the opinions of the NSW Government or the Department of Planning, Industry and Environment.

EXECUTIVE SUMMARY

STUDY AREA

The study area (refer to Figure 1) includes the Bellinger River and Kalang River catchments. The Bellinger and Kalang Rivers are located within Bellingen Shire Council on the Mid North Coast of NSW. The Bellinger and Kalang Rivers join and discharge into the Pacific Ocean near Urunga. The total catchment area of both rivers is 1110 km^2. The catchment area of the Kalang River upstream of its junction with the Bellinger River is approximately 340 km^2.

FLOOD STUDY

A flood study was undertaken for the Lower Bellinger and Kalang Rivers in 2016 (Reference 31) to define the existing flood behaviour.

FLOODPLAIN RISK MANAGEMENT STUDY

The specific aims of this study were:

- Assessment of hazard and hydraulic classifications,
- Flood damages assessment,
- Make recommendations to adopt Flood Planning Levels (FPL) appropriate for the catchment,
- Investigate available floodplain risk management measures along with prioritisation, staging of works and preliminary costings,
- Examination of emergency management arrangements and
- Review of Council's flood policy.

The subsequent Floodplain Risk Management Plan will document the recommended strategies.

FLOODPLAIN RISK MANAGEMENT MEASURES

A list of all possible floodplain risk management measures which could be applied in the study area were initially developed for consideration. The measures were then assessed in terms of their suitability and effectiveness for reducing social, ecological, environmental, cultural and economic impacts. As part of this process a number of measures were identified as not being worthy of further consideration. Table 23 provides a summary of the measures considered within the study.

1. INTRODUCTION

1.1. Study Area

The study area (refer to Figure 1) includes the Lower Bellinger River and Kalang River catchments. The Bellinger and Kalang Rivers are located within Bellingen Shire Council on the Mid North Coast of NSW. The Bellinger and Kalang Rivers join and discharge into the Pacific Ocean near Urunga. The total catchment area of both rivers is 1110 km^2. The catchment area of the Kalang River upstream of its junction with the Bellinger River is approximately 340 km^2.

The headwaters of the catchments are located in the Dorrigo Plateau escarpment and are characterised by steep topography. The lower reaches are characterised by broad floodplains and farmland. Residential development within the catchments generally consists of small settlements. Major centres exist at Bellingen and Urunga.

The Study area is defined as (Figure 1):

- 3.5 km upstream of Lavenders Bridge on the Bellinger River,
- 2.5 km upstream of Brierfield Bridge on the Kalang River, and
- Downstream to the Pacific Ocean.

A flood study was undertaken for the Lower Bellinger and Kalang Rivers in 2016 (Reference 31) to define the existing flood behaviour. This study forms the basis and extent for the current floodplain risk management study and plan.

1.2. Objectives

WMAwater was engaged by Bellingen Shire Council (BSC) to develop a floodplain risk management study and plan for the Lower Bellinger and Kalang Rivers. The previous management plan which covered a larger area was published in 2002. The current study and plan takes into consideration:

- Updates to hydraulic modelling technology,
- Australian Rainfall and Runoff updates to methodology and design flood inputs,
- NSW Government’s Floodplain Development Manual,
- Climate change projections for sea level rise and rainfall intensity increases, and
- Additional data.

The objectives of the present Study are to identify and compare various management options, including an assessment of their social, economic and environmental impacts, together with opportunities to enhance the floodplain environments. It also seeks to ensure future development is controlled in a manner consistent with the flood hazard and risk at this time, and in the future as a result of predicted climate change.

Key drivers for undertaking the present study and plan include:

- The need for an updated understanding of flood risk and flood behaviour, incorporating the recently adopted updated national flood guidelines (ARR, 2016/9).
- The need for an updated decision-making process for land use planning and development controls.
- The need for development and appraisal of floodplain management measures appropriate to the location and acceptable to the local community economically, socially and environmentally.

2. BACKGROUND

2.1. Catchment Description

The study area (refer to Figure 1) is the lower reaches of the Bellinger River and Kalang River catchments. The Bellinger and Kalang Rivers are located within Bellingen Shire Council. The Bellinger and Kalang Rivers join and discharge into the Pacific Ocean near Urunga. The total catchment area of both rivers is 1110 km^2. The catchment area of the Kalang River upstream of its junction with the Bellinger River is approximately 340 km^2 and therefore contributes about 30% of the total catchment area.

The headwaters of the catchments are located in the Dorrigo Plateau escarpment and are characterised by steep topography. Annual rainfall averages within the catchment are among some of the highest in New South Wales. The steep terrain results in an orographic effect that enhances rainfall.

The lower reaches are characterised by broad floodplains and farmland. Flooding in the lower reaches of the estuary is influenced by elevated ocean levels. Residential development within the catchments generally consists of small settlements. Major centres exist at Bellingen and Urunga. Small settlements include Rayleigh, Newry Island, Repton, Mylestom, Fernmount, and Yellow Rock.

2.2. Previous Studies

A number of flood studies and assessments have previously been undertaken within the Bellinger and Kalang River catchments. These studies range from lot sized flood assessments to large scale studies encompassing both the Bellinger and Kalang Rivers. A brief overview of the more significant studies is provided below.

Lower Bellinger and Kalang Rivers Flood Study (WMAwater 2016)
This report (Reference 31) adopted the hydrologic and hydraulic models used in the Warrell Creek to Urunga Pacific Highway Modelling report, with a review of the previous model and assessment of suitability for the flood study. A review of the “Lower Bellinger and Kalang Rivers Hydraulic Modelling Report” (Reference 26) is not contained here as the contents of that report largely form this report.

Additional assessment undertaken in the flood study included the calculation of hydraulic hazard, flood function, duration of inundation and flood damages. The Lower Bellinger and Kalang Rivers Flood Study will be henceforth referred to as the flood study. The models used in the study form the basis of the current floodplain risk management study.

Council has also recently completed an Estuary Inundation Mapping report (BMT, 2015) which uses the model and boundary conditions from Lower Bellinger Kalang River Flood Study.

Warrell Creek to Urunga: Pacific Highway Upgrade Modelling (WMAwater, 2012)

This report (Reference 24) contains a detailed assessment of the impacts of the Pacific Highway upgrade on flood levels in the Bellinger/Kalang River system. The hydraulic model used in this study is used as a basis for the current study.

Kalang River – 2009 Flood Event (WMAwater, 2011)

This study (Reference 19) modelled the March/April 2009 flood event using the hydraulic model established as part of the Newry Island Flood Study (Reference 18) using inflows developed by Reference 3. Overall a good calibration to the observed flood levels during 2009 event was achieved.

Review of Bellinger, Kalang and Nambucca Rivers Catchment Hydrology (WMAwater, 2011)

The *Review of Bellinger, Kalang and Nambucca Rivers Catchment Hydrology* (Reference 3) investigates known hydrologic issues in the Bellinger, Kalang and Nambucca River catchments. This area of the NSW north coast has presented a range of challenges for a number of studies, where problems have been encountered matching rainfall runoff modelling with flood frequency results. As part of the study, WBNM models were developed for each catchment and calibrated to historical events. The hydrologic model developed as part of the study has been used for the current study.

Bellinger and Kalang Rivers Flood Event of 31 March 2009 Collection and Collation of Flood Data (Enginuity Design, 2010)

This report (Reference 20) contains the results of an extensive data collection exercise undertaken following the 2009 event. The report contains rainfall data and observed flood level marks for the March 2009 event. This data has been used in the current study to inform the calibration of the hydraulic model.

Warrell Creek to Urunga Upgrade Environmental Assessment (RTA, 2010)

The *Warrell Creek to Urunga Upgrade Environmental Assessment (2010)* (Reference 5) assessed the impact of the proposed Pacific Highway upgrade crossing on the Kalang River on flood levels. A RORB model of the catchment was developed. In order to fit the flood frequency analysis results the study adopted the Australian Rainfall and Runoff (ARR) temporal patterns for zone 3 rather than zone 1.

Newry Island Flood Study Draft (WMAwater, 2008)

The *Newry Island Flood Study* (Reference 18) developed a TUFLOW model of the Lower Bellinger and Kalang Rivers. Inflows for the TUFLOW model were derived from the *Lower Bellinger Flood Study* RORB and CELLS models. Model calibration and validation was conducted using the 1974, 1977 and 2001 events. Information on the 2001 event derived as part of the Newry Island study was used to inform the current flood study.

Upper Kalang River Flood Assessment, (Bellingen Shire Council, December 2006)

This report (Reference 15) modelled 26.5 km of the Upper Kalang River to Pickett Creek using a one dimensional MIKE 11 model. Boundary conditions were drawn from the *Lower Bellinger River Flood Study*. The *Lower Bellinger River Flood Study* RORB model was adopted for the upper

Kalang River. An areal reduction factor of 0.6 was adopted to be consistent with the *Lower Bellinger River Flood Study* and the *Upper Bellinger River Flood Assessment*. Filtering of the temporal patterns was undertaken. A critical storm duration of 12 hours was adopted in comparison to 36 hours, which was adopted in the 1991 flood study. Flood frequency analysis undertaken for this study used heights. This approach is not ideal as the variance in the cross section is not taken into account. A combined record of the three Kooroowi –Scotchman gauges was derived. Peak height correlations between the stations were derived using a MIKE 11 model.

The intent of the study is to provide indicative flood levels, and therefore the model was not calibrated. The flood levels should be used for general purposes only and do not have the same reliability as flood levels derived in a detailed flood study. Cross section survey undertaken for this study was used in the current study.

Upper Bellinger River Flood Assessment (Bellingen Shire Council, 2006)

The *Lower Bellinger Flood Study* (Reference 10) RORB model was adopted for the *Upper Bellinger River Flood Assessment* (Reference 17). Areal reduction factors of 0.6 above Thora and 1.0 for all other catchments were required in order to fit the flood frequency analysis. Filtering of the temporal patterns resulted in the 12 hour event being critical rather than the 36 hour event, which was found to be critical in the *Lower Bellinger Flood Study*. The RORB model was refined in the Never Never River catchment to provide inflows to the hydraulic model. On the Never Never River, a larger than standard practice continuing loss (7.5mm/hr) was adopted, with an initial loss of 0mm. A rating curve extrapolation was undertaken for 900m downstream of Bellingen using the CELLS model developed as part of the *Lower Bellinger Flood Study*. This flood assessment provided flood levels for design events in the Upper Bellinger area. A detailed calibration of the hydraulic model was not undertaken as part of the study. Cross section survey undertaken for this study was used in the current study.

Bellinger and Kalang Rivers Floods of February and March 2001 (Bruce Fidge and Associates, 2003)

Rainfall and flood level information for the February and March 2001 floods is summarized in this report. Survey of peak flood debris levels was undertaken by Council following the March 2001 event. Based on the design flood behaviour defined in the 1991 Flood Study and Flood History Report (Reference 13) the recurrence intervals for the events at various locations within the catchments were estimated. The February 2001 event was estimated to have a 5 year Average Recurrence Interval (ARI) for Repton, 6 year ARI for Newry Island and 10 year ARI for Urunga. The March 2001 event was estimated to have a 12 year ARI for Repton, 6 year ARI for Newry Island and 10 year ARI for Urunga. Compared to the February flood, the March 2001 event was bigger on the Bellinger River. However, the February and March events were of similar magnitude on the Kalang River and in the vicinity of Newry Island. The 2001 event was used in the current flood study for model verification.

Floodplain Risk Management Study Stage 2- An Assessment of Floodplain Management Options and Strategies (Bellingen Shire Council, April 2002)

The report (Reference 14) was commissioned by Bellingen Shire Council to investigate management strategies for flood prone land in the Bellinger and Kalang River catchments.

Floodplain risk management options are considered and prioritised. The report recommended additional rainfall and water level gauges be installed on the Kalang River and Lower Bellinger River, to improve flood prediction and supplement the existing system. Flood management recommendations for Newry Island included increasing the level of Newry Island Drive so that rural residents have access during 5% and 10% AEP floods, and the expansion of Newry Island bridge to improve evacuation. The main study area of this study is updated by the current study.

South Arm Road Flood Study (Final) (DeGroot and Benson Pty Ltd, June 2000)

The report (Reference 16) details the hydrologic and hydraulic modelling of the existing conditions in the vicinity of South Arm Road and the unnamed creek that drains into Boggy Creek. South Arm Road is subject to flooding from the Kalang River (via backwater flooding from Boggy Creek), local runoff and a combination of both. The road is subject to frequent inundation between Short Cut Road and the Riverside Drive subdivision, cutting off the main access to the area. The hydraulic modelling for this study was undertaken using a water balance model originally developed for the Central Urunga Flood Study. The report investigates the effect of raising the road to 2.5, 3.0, 3.5 and 4.0 mAHD. Raising the road was found to have minimal effect on the flood level at Urunga (<15mm), due to the conveyance capacity of the wetland area at that level. Details of the culverts under South Arm Road are described in this report. The report recommends raising South Arm Road to no greater than 3.30 mAHD if the existing culvert arrangement was to remain.

Lower Bellinger River Flood Study, Location of Flood Marks Engineering Survey Brief (Cameron McNamara, 1991)

As part of the 1991 Lower Bellinger River Flood Study, a survey of local residents was conducted of the area downstream of Bellingen (on the Bellinger River) and Picket Hill Creek (on the Kalang River). The survey identified 46 flood reference points and information on the flood behaviour. The report (Reference 11) shows the location and photos of the survey reference points.

Lower Bellinger River Flood Study Compendium of Data (PWD, 1991)

This report (Reference 12) provides a review of available data for the Lower Bellingen River Flood Study. Total rainfall isohyets were drawn for selected events. A summary of results from the resident survey for the 1950, 1962 and 1974 flood events is presented.

Lower Bellinger River Flood Study (PWD, 1991)

The Lower Bellinger River Flood Study (1991, Reference 10) investigated flooding in the Bellinger River below Bellingen and the Kalang River downstream of Picket Hill Creek. A CELLS hydraulic model was developed to determine flood levels for the 1%, 2%, and 5% Annual Exceedance Probability (AEP) and extreme design flood events. The 1962, 1974 and 1977 historical events were used for model calibration and verification. The effects of ocean levels and bed scour were incorporated into the model. A RORB hydrological model of the Bellinger and Kalang River catchments was developed to convert rainfall to flow hydrographs. Model data and results from the hydraulic model developed for this study were used to provide boundary conditions and topographic information for the Newry Island Flood Study. This report was used as a comparison with new model results. The hydrologic model sub-catchment layout formed a basis for the hydrologic model layout for the current study.

Proposed Industrial Area, Urunga NSW (Outline Planning Consultants, May 1984)
The report (Reference 7) covers a proposed industrial area situated adjacent to the Pacific Highway and the North Coast Railway line, on the northern fringe of Urunga. The site characteristics and its suitability for the proposed development were assessed. Flooding on the site was assessed based on available flood maps. The Pacific Highway is noted to act as a levee and protect some low lying areas in the middle of the site. The majority of the site was found to be flood free based on the available data. The northern end of the site was found to be flood affected from backwater flooding by an intermittent creek.

Bellinger River May 1980 Flood Report (PWD, 1981)
This report (Reference 8) details data collected for the May 1980 flood in the Bellinger Valley and presents rainfall, flood heights and stage hydrographs for the event. Insufficient information was available to include this event in the model calibration.

Bellinger River Flood History 1843-1979 (PWD, 1980)
This study (Reference 9) was undertaken to document flood data in the tidal section of the Bellinger River (up to Bellingen) to be used in preparing flood maps for Bellingen. A flood frequency analysis was conducted using recorded data for the Lavenders Bridge. Floods with peak heights greater than 8.3m were included. Due to a lack of data downstream of Bellingen flood heights determined for the 1%, 2% and 5% AEP events at Bellingen were combined with estimated flood gradients to determine flood levels and flood maps for downstream towns. The report details personal recollections of residents about significant historical events. Flood reference points for significant flood events including the 1962, 1974 and 1977 events are reported, and were used for model calibration.

New South Wales Coastal Rivers Floodplain Management Studies Bellinger Valley (Cameron McNamara, December 1980)
As one of a series of reports on NSW coastal rivers, this report (Reference 6) details floodplain management measures within the Bellinger Valley and makes recommendations on policy. The report contains recorded water levels and selected aerial photographs of historical floods.

2.3. Environmental Summary

The upper reaches of the catchment are steep and forested. Due to its steep nature it has remained forested. The lower reaches of the catchment have been subject to agriculture, clearing and development.

The Lower Bellinger and Kalang Rivers have been subject to significant floodplain erosion. Bank erosion has been noted by a number of studies including Reference 41. Reference 41 notes that the Bellinger river is still a geomorphologically active river. Locations of erosion include Back Creek and the southern arm of the Kalang river around Newry Island. The Morphology Study (Reference 41) noted that erosion was accelerated between 1946 and 1985 which was a wetter period. Maps of erosion hazard were produced. Protection works have been undertaken in a number of locations.

The entrance is prone to siltation during dry periods. The entrance of the river is heavily entrained. Two periods of dredging have occurred historically (Reference 41):

- 1903-1929 – river entrance confluence of the rivers to maintain a port
- After 1976 –
    - for landfill and gravel - around Newry Island 1976
    - Upstream of Fernmount -gravel -1980
    - Urunga highway bridge -landfill – 1981
    - Newry Island - 1984

Extraction has occurred within the river under license in the vicinity of Rayleigh. Hydrosurvey of the river was undertaken in early 2009 and resulted in survey before and after. A large amount of sediment was washed out of the entrance during the flood.

The study area contains areas of environmental significance including SEPP 14 wetlands. Paperbark swamps occur in some low lying areas.

Acid sulphate soils occur in the lower reaches of the floodplain.

2.4. Legislation and Policies

2.4.1. Land Use

Bellingen Local Environmental Plan 2010 outlines the acceptable land uses for the Bellingen Shire Council area. The land use zoning for the study area is presented in Figure 6. The catchment is mixed use with areas of general residential, general industrial, recreation and other non-developed uses in flood affected areas. The majority of flood affected land is zoned residential, industrial or primary production.

2.4.2. Floodplain Management Policy

It is important to understand the state legislation that overarches all local planning so as to enable appropriate floodplain risk management measures to be proposed that meet both state and local statutory requirements. This section discusses the state legislation that influences planning in relation to flood risk at the local government level.

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development.

Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. Specifically, Direction 4.3 states:

Objectives

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, 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.*

Clause (3) of Direction 4.3 states:

- *This direction applies when a relevant planning authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.*

Clauses (4)-(9) of Direction 4.3 state:

- *A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).*

- *A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.*

- *A planning proposal must not contain provisions that apply to the flood planning areas which:*

    - *permit development in floodway areas,*

    - *permit development that will result in significant flood impacts to other properties,*

    - *permit a significant increase in the development of that land,*

    - *are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or*

    - *permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.*

- *A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).*

- *For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).*

- *A planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that:*

    - *the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or*

    - *the provisions of the planning proposal that are inconsistent are of minor significance.*

2.4.2.1. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

- to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and

- to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual 2005 (the Manual), relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

The Manual outlines a merits approach based on floodplain management. At the strategic level, this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk.

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both.

2.4.2.2. Section 733 – Local Government Act 1993

Section 733 of the Local Government Act relates to Exemption from liability – flood liable land, land subject to risk of bush fire and land in coastal zone. It states:

(1) A Council does not incur any liability in respect of:

(a) any advice furnished in good faith by the council relating to the likelihood of any land being flooded or the nature or extent of any such flooding, or

(b) anything done or omitted to be done in good faith by the council in so far as it relates to the likelihood of land being flooded or the nature or extent of any such flooding.

And;

(3) Without limiting subsections (1), (2) and (2A), those subsections apply to:

(a) the preparation or making of an environmental planning instrument, including a planning proposal for the proposed environmental planning instrument, or a development control plan, or the granting or refusal of consent to a development application, or the determination

of an application for complying development certificate, under the Environmental Planning and Assessment Act 1979, and

(b) the preparation or making of a coastal zone management plan, or the giving of an order, under the Coastal Protection Act 1979, and

(c) the imposition of any condition in relation to an application referred to in paragraph (a), and

(d) advice furnished in a certificate under section 149 of the Environmental Planning and Assessment Act 1979, and

(e) the carrying out of flood mitigation works, and

(f) the carrying out of coastal management works, and

(f1) the carrying out of bush fire hazard reduction works, and

(f2) anything done or omitted to be done regarding beach erosion or shoreline recession on Crown land, land within a reserve as defined in Part 5 of the Crown Lands Act 1989 or land owned or controlled by a council or a public authority, and

(f3) the failure to upgrade flood mitigation works or coastal management works in a response to projected or actual impacts of climate change, and

(f4) the failure to undertake action to enforce the removal of illegal or unauthorised structures that results in erosion of a beach or land adjacent to a beach, and

(f5) the provision of information relating to climate change or sea level rise, and

(f6) anything done or omitted to be done regarding the negligent placement or maintenance by a landowner of temporary coastal protection works, and

(g) any other thing done or omitted to be done in the exercise of a council's functions under this or any other Act.

(4) Without limiting any other circumstances in which a council may have acted in good faith, a council is, unless the contrary is proved, taken to have acted in good faith for the purposes of this section if the advice was furnished, or the thing was done or omitted to be done, substantially in accordance with the principles contained in the relevant manual most recently notified under subsection (5) at that time.

2.4.2.3. Section 10.7 Planning Certificates

In accordance with Section 10.7 (formerly Section 149) of the EP&A Act, Councils can issue planning certificates which describe planning and development matters relating to a piece of land. The two planning certificates are available under the EP&A Act are Section 10.7 (2) and 10.7 (5) planning certificates. Obtaining a Section 10.7 certificate is required under the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 when land is bought or sold.

Specifically, Section 10.7 of the EP&A Act states:

(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a ***planning certificate****) with respect to any land within the area of the council.*

(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected

with this or any other Act or otherwise).

(3) (Repealed)

(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.

(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.

(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.

(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

2.4.2.4. Schedule 4 Planning Certificates

Schedule 4 Planning certificates of the Environmental Planning and Assessment Regulation (EP&A Regulation), 2000, sets out which matters are to be included in a planning certificate under Section 10.7 (2) of the EP&A Act and includes but is not limited to information such as planning instruments that apply to development, zoning and land use under relevant Local Environmental Plans (LEPs) and State Environmental Planning Policy (SEPP) and complying development.

Specific to flood related development controls information, Schedule 4, 7A of the EP&A regulation states:

7A Flood related development controls information

(1) Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.

(2) Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.

(3) Words and expressions in this clause have the same meanings as in the Standard Instrument.

Section 10.7 (2) and 10.7 (5) certificates are more detailed certificates and includes all information specified in Schedule 4 and any additional information Council may choose to provide. Types of flood related information that could be provided in a Section 10.7 (2) and 10.7 (5) planning certificate include design flood depths, percentage of the lot flood affected or evacuation information (note that this is not an exhaustive list).

2.4.2.5. State Environmental Planning Policy (Exempt and Complying Development Codes (2008))

The aims of State Environmental Planning Policy (Exempt and Complying Development) 2008 (SEPP) are:

This Policy aims to provide streamlined assessment processes for development that complies with specified development standards by:

- *providing exempt and complying development codes that have State-wide application, and*
- *identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and*
- *identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and*
- *enabling the progressive extension of the types of development in this Policy, and*
- *providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.*

2.4.2.6. General Housing Code

Division 1 of Part 3 of the SEPP, which comprises clauses 3.1-3.3 of the SEPP, relates to ***Requirements for complying development under this code***. Clauses 3.1 (1) states:

3.1 Development that is complying development under this code

(1) The following development is complying development under this code –
a. the erection of new 1 or 2 storey dwelling house and any attached development,
b. the alteration of, or an addition to, a 1 or 2 storey dwelling house (including any addition that results in a 2 storey dwelling house) and any attached development,
c. the erection of detached development and the alteration of, or an addition to, any detached development.

and

(3) Lot requirements
Complying development specified for this code may only be carried out on a lot that meets the following requirements –

a. *the lot must be in Zone R1, R2, R3, R4 or RU5,*
b. *the area of the lost must not be less than 200m^2,*
c. *the width of the lot must be at least 6m measured at the building line,*
d. *there must only be 1 dwelling house on the lot at the completion of the development,*
e. *the lot must have lawful access to a public road at the completion of the development,*
f. *if the development is on a battle-axe lot – the lot must be at least 12m by 12m (not including the access laneway) and must have an access laneway that is at least 3m wide.*
g. *If the development is on a corner lot – the width of the primary road boundary of the lot must be at least 6,.*
h.
i. *the erection of new 1 or 2 storey dwelling house and any attached development,*

Division 2 of Part 3 of the SEPP "***General standards relating to land type***" contains Clause 3.5 *"Complying development on flood control lots"*

A *"flood control lot"* is defined in the SEPP as:

flood control lot *means a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).*

Note. *This information is a prescribed matter for the purpose of a certificate under section 10.7 (2) of the Act.*

As such, a *"flood control lot"* is a lot where the Council has provided for flood related development controls, which are all lots with notation on a 10.7 Planning Certificate that flood related development controls apply. This is generally land which falls within the *"Flood Planning Area"*.

Clause 3.5 states

3.5 Complying development on flood control lots

(1) Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the relevant complying development certificate, as not being any of the following –
(a) a flood storage area,
(b) a floodway area,
(c) a flow path,
(d) a high hazard area,
(e) a high risk area.

(2) If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards –

(a) if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,

(b) any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,

(c) any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris, and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),

(d) the development must not result in increased flooding elsewhere in the floodplain,

(e) the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,

(f) vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,

(g) the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.

(3) The requirements under subclause (2) (c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual, unless it is otherwise defined in this Policy.

(5) In this clause -

flood compatible material *means building materials and surface finishes capable of withstanding prolonged immersion in water.*

flood planning level *means –*

(a) the flood planning level adopted by a local environmental plan applying to the lot, or

(b) if a flood planning level is not adopted by a local environmental plan applying to the lot, the flood planning level adopted in a development control plan by the relevant council for the lot.

Floodplain Development Manual *means the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.*

flow path *means a flow path identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

high hazard area *means a high hazard area identified in the council's flood study or flood risk management study carried out in accordance with the Floodplain Development Manual.*

high risk area *means a high risk area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

Note 1. ***Council, flood control lot, habitable room*** *and* ***professional engineer*** *are defined in clause 1.5*
Note 2. A section 10.7 certificate from a Council will state whether or not a lot is a flood control lot.

2.4.2.7. Rural Housing Code

Part 3A of the SEPP contains the *"Rural Housing Code"*, which applies to development that is specified in clauses 3A.2–3A.5 on lots in Zones RU1, RU2, RU3, RU4, RU6 and R5. Section 3A.38 contains "Complying development on flood control lots". The standards contained in this section are the same as those in Clause 3.5 provided in Section 2.4.2.7, with the exception of Clause 2 (c) which states:

> *2 (c) any part of the dwelling house or any ancillary development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level)*

2.4.2.8. Summary of State Legislative and Planning Polices

From the above discussion of the Housing Code, it is clear that, unless a lot affected by flooding is included as a *"flood control lot"*, a s.10.7 notification is not applied and, as a result, planning controls relating to flooding do not apply and Exempt Development can be undertaken. This highlights the importance of Council undertaking Flood Studies (such as this FRMS) to ensure appropriate properties are tagged and planning controls applied to reduce the risk and impact of flooding for current and future occupants.

2.4.2.9. Flood Prone Land Package

The Department of Planning, Industry and Environment (DPIE) have proposed updates to the Flood Prone Land Package. The purpose of the package is to increase flood resilience in New South Wales, reduce loss of life and property damage. The package provides Councils additional land use planning tools to manage flood risk beyond the 1% AEP flood event and strengthen evacuation consideration in land use planning. The updates to this package were on exhibition until 25 June 2020. The package is now under consideration and has not yet been adopted.

The proposed changes include:

- *Amendments to Schedule 4, Section 7A of the Environmental Planning and Assessment Regulation 2000,*
- *A revised planning circular,*
- *A revised Ministerial Direction 4.3 regarding flooding issued under Section 9.1 of the Environmental Planning and Assessment Act 1979,*
- *Revised Local Environmental Plan flood clauses,*
- *A new guideline: Considering Flooding in Land Use Planning (2020).*

The current drafting is clear that these documents are proposal only and not yet government policy. The key changes and implications are outlined below:

- Amendments to Schedule 4 of EP&A Regulation including changes to Clause 7A(1), Clause 7A(2) and the addition of the Clause 7A(3). These amendments now require Councils to note on Section 10.7 certificates if any flood related development controls apply to the land relating to either the Flood Planning Area, hazardous materials / industry, sensitive, vulnerable or critical uses or if there is need to consider evacuation constraints under a regional evacuation strategy.

- The Ministerial Direction 4.3 has been amended to remove the requirement for Councils to seek exceptional circumstances to apply residential development controls to land outside the 1% AEP flood event (currently included in Clause 7 of Direction 4.3).

- Three proposed LEP clauses relating to the Flood Planning Area, Regional Evacuation Consideration Area and Special Flood Consideration.

    - The Flood Planning Area clause allows Council to extend the FPA to include more extreme flood events where the flood risk requires land use planning tools.

    - The clause relating to Special Flood Consideration provides Councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry.

    - Regional Evacuation Consideration Area applies to land that is included in a regional evacuation strategy or a flood related state emergency sub-plan that has been developed by the NSW SES. This can include land both within or outside the floodplain.

2.4.3. Local Council Policy

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding. Plans and Policies have been discussed below and later have been reviewed in regards to flood risk management to identify where improvements might be made (see Section 10.4.1 and Section 10.4.4).

A LEP guides land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and Development Planning Controls (DCPs). LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to. Bellingen Shire Council's LEP was gazetted in August 2010 and was prepared under the Standard Instrument LEP program.

2.4.3.1. Bellingen Local Environment Plan 2010 (LEP2010)

Clause 7.3 of LEP 2010 relates to flood planning and states:

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

(5) In this clause—
flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus freeboard.
Flood Planning Map means the Bellingen Local Environmental Plan 2010 Flood Planning Map.

2.4.3.2. Development Control Plan 2017 (amended 2019)

Chapter 8 of the Bellingen DCP 2017 addresses flood and riverine processes. The DCP outlines flood planning levels for different building purposes. The current free board is specified as 0.5m for the lower catchment covered in this study however a free board of 0.75m is adopted in the DCP for the Fitzroy Street catchment in Urunga. In this report, the freeboard has been adopted as 0.5m across the entire lower catchment, including the Fitzroy Street catchment, as the model has been refined to include short duration events and local runoff.

Section A8.1 of the Bellingen DCP 2017 addresses flood prone land and is written so that it will automatically stay current with updates in flood risk management such as this study.

Specific building and development controls are provided in Appendix 8.5 of the DCP, as well as Flood Proofing Guidelines.

The current DCP was amended in 2019 to provide additional guidance on below ground garages and carparks. In addition to this the current DCP 2019 was amended to allow for the voluntary house raising applications (See DCP 2019 Section 8.10.1 New Development and Redevelopment).

3. AVAILABLE DATA

3.1. Rainfall Information

3.1.1. Historic Rainfall Data

Historical rainfall data was obtained at a number of locations within the study area and surrounds. Daily rainfall and pluviograph data was obtained for a number of gauges within the region from sources including the Bureau of Meteorology (BoM) and Manly Hydraulics Laboratory (MHL).

Historic rainfall data available for the 1974, 1977, 2001 and 2009 events on the Bellinger and Kalang Rivers is documented in Reference 3 and Reference 19. For the 1974 and 1977 events no pluviograph information was available within the catchment though several pluviometers were located in adjacent catchments. A limited set of pluviometer records was available for the historical events examined in the *1991 Flood Study* (Reference 10). The largest set of pluviometer data used in the *1991 Flood Study* was for the 1977 event (though none were located within the catchment). More pluviometer records were available for the more recent events. Resident rainfall totals collected as part of the post flood data collection for the 2009 event (Reference 20) were included in the vicinity of Urunga where the official gauges were considered to have under recorded.

3.1.2. Design Rainfall Data

Design rainfall data available for the Bellinger and Kalang River is documented in Reference 3. All of the BoM long term daily and pluviograph gauges within and near the catchment were analysed on a 24hr 9am restricted basis to produce new IFD estimates. This was supplemented by at site analysis of other gauges, which was incorporated into the surface mapping.

3.2. Water Level Data

3.2.1. Time Series Water Level Data

Manly Hydraulics Laboratory (MHL) operates the following water level recorders in the Bellinger and Kalang Rivers catchments:

- Newry Island,
- Urunga,
- Repton, and
- Bellingen (Lavenders) Bridge.

Stage hydrograph data was obtained from the MHL operated water level stations. The recorded time-series of water levels was used for model calibration purposes. It should be noted that these water level recorders are located within the tidal limit. The opportunity for the water level record to be translated into a corresponding flow hydrograph is therefore limited except for Bellingen, which is at the very upper limit of the tidal limit and for which rating curves exist. However, the recorders do provide a valuable record of flood level behaviour during an actual flood.

A number of temporary gauges operated by OEH and MHL were located on the Bellinger and Kalang rivers during 2009 as part of a water quality study (Reference 26). Many of the gauges were damaged during the event or did not record the peak. Where possible these gauges were used as a comparison to model results, for example for timing of the rising limb.

3.2.2. Peak Flood Heights

The Bellinger and Kalang River valleys have a long history of flooding. Flood records for Bellingen date back to the 1840s (Reference 9). In comparison to the Bellinger River, there is less observed peak flood height data available for historical events on the Kalang River. However, most large floods on the Bellinger River occur at the same time as a large event on the Kalang River. A summary of significant events that have occurred in the area is presented in Table 1. The more recent events for which significant data is available for calibration and validation purposes occurred in 1974, 1977, 2001 and 2009.

The 1962 event, though used in previous studies for calibration, was not included in this study for the following reasons:

- No pluviographs were operating within the catchment at the time of the event,
- Limited observed data was available, including water level recorders,
- The more recent 2009 event was larger and had significantly more data available.

Table 1: Significant Peak Flood Levels at Bellinger Bridge

Year	Gauge Height (mAHD)	Comment
1870	11.5	Bellingen Flood History 1843 to 1979
1875	10.9	Bellingen Flood History 1843 to 1979
1950	10.4	Bellingen Flood History 1843 to 1979
1946	9.8	Bellingen Flood History 1843 to 1979
1954	9.8	Bellingen Flood History 1843 to 1979
1876	9.6	Bellingen Flood History 1843 to 1979
1974	9.5	Bellingen Flood History 1843 to 1979
1887	9.2	Bellingen Flood History 1843 to 1979
1959	9.1	Bellingen Flood History 1843 to 1979
1890	9	Bellingen Flood History 1843 to 1979
2013	8.96	SES readings
1921	8.9	Bellingen Flood History 1843 to 1979
1967	8.8	Bellingen Flood History 1843 to 1979
2009	8.8	MHL readings
2001	8.77	MHL readings
1894	8.7	Bellingen Flood History 1843 to 1979
1989	8.6	SES readings
1962	8.5	Bellingen Flood History 1843 to 1979
1977	8.5	Bellingen Flood History 1843 to 1979

1890	8.4	Bellingen Flood History 1843 to 1979
1938	8.4	Bellingen Flood History 1843 to 1979
1887	8.2	Bellingen Flood History 1843 to 1979
1893	8.2	Bellingen Flood History 1843 to 1979
1933	8.2	Bellingen Flood History 1843 to 1979
1963	8.2	Bellingen Flood History 1843 to 1979
1973	8.2	Bellingen Flood History 1843 to 1979
1956	8.1	Bellingen Flood History 1843 to 1979

A review of previous studies and available data found some observed peak flood heights at a number of locations within or near the study area. The most significant flood events within the catchment for which suitable calibration data is available occurred in 1974, 1977, 2001 and April/March 2009. Data for the 1974 and 1977 events is presented in Reference 10. References 13 and 20 contain data for the 2001 and 2009 event respectively. Several data collection exercises have been undertaken to collect peak flood levels and anecdotal evidence of significant floods in the area (Refer Section 2.2). The flood study calibrated to 1974, 1977, 2001 and April/March 2009 events.

Following the model update, it was confirmed that the calibration was similar for these events. The only significant changes were found for the 2009 event, where observed peak flood levels were available in Bellingen and Urunga. Therefore calibration results are presented herein only for the 2009 event.

3.3. Topographic Information

There is a considerable amount of topographic data available for the study area. However, the accuracy and suitability of these existing datasets for use in the present study varies. This includes contours, hydrosurvey, cross sections and Airbourne Laser Scanning.

Topographic survey was adopted from the Bellinger Kalang Flood Study. This data included topographic contours of the study area in GIS format provided by council (at 10 m intervals over the majority of the catchment and at 2 m intervals over a limited area including Newry Island).

Hydrosurvey of the estuary was available from OEH (Refer Reference 27). The hydrosurvey was collected between September and November 2008. It provides waterway cross sections for the estuarine reaches of the Bellinger River, Kalang River and Pickets Creek. The hydrosurvey shows a significant amount of sediment at the entrance, which OEH staff advised was eroded during the 2009 event. A significant amount of erosion also occurred on the Kalang River.

Aerial photography collected by the Lands and Property Management Authority was also available within the catchment boundary. This was used in assigning Manning's n values and identifying catchment changes.

Cross sections from the MIKE 11 models used as part of the Upper Bellinger and Upper Kalang Flood Assessments (Reference 17 and 15) were also available in the areas where hydrosurvey was not available.

Airbourne Laser Scanning (ALS) ground levels were provided for the study area. The ALS collection was part of the Coastal Capture Program undertaken by the Lands and Property Management Authority. It includes the area from the coast to the 10m contour interval. Spatial accuracy of the ALS in the horizontal and vertical directions was reported as 0.8m and 0.3m respectively.

Due to issues with the data processing used to produce the original grids provided, the raw ALS files were obtained. The non-ground strikes were filtered from this data set. Within a 60m buffer of the waterway, the ground strikes and hydrosurvey were tinned and a DEM produced. This DEM and the ALS grid (outside of the 60m buffer) were combined to create a DEM for use in the 2D model.

A DEM (Digital Elevation Model) at a 1m grid resolution was used in order to:

- confirm sub-catchment and catchment watershed boundaries; and
- inform the 2D model used in the study.

3.4. Culvert and Structure Data

Details of culverts and structures along the existing highway and Waterfall Way were obtained from Roads and Maritime Services works as executed plans and culvert database. For local roads, details of culverts and bridge structures were collected on a site visit and based on council records. Where culvert details were not available, a reasonable estimate was made based on upstream culverts. Some details on culverts and structures under the North Coast Railway were available from the *Newry Island Flood Study* (Reference 18).

The Nambucca Heads to Urunga Pacific Highway upgrade was included based on the final construction design plans (option PHU 049 as at 8/10/2014).

3.5. Additional Data Obtained for FRMS Model Update

Additional data was required as part of the floodplain risk management study in order to provide more detailed flood information in the urban areas of Bellingen and Urunga.

Council provided GIS layers of their stormwater drainage systems in Bellingen and Urunga. These were filtered to include only pipes of size greater than or equal to 0.45m diameter. The Council data did not include pipe inverts or slopes. For the purposes of this model, pipe slopes have been calculated based surface ground levels and a minimum cover of 1m. Pipes that flowed the wrong way in the GIS layers were rectified as far as possible, based on inspection of the ALS and existing watercourses. A number of pits did not have the invert assigned, and inverts were modelled based on an assumption of 2m cover typically (min 0.5m).

Additional ground survey was captured, including the creek inverts along the Cemetery Creek and Central Drainage line in North Bellingen, and culverts and bridge structures along Hungry Head

Road. The survey was provided to WMAwater on the 9th January 2019. The following survey was undertaken:

1. Survey of peak flood (debris) level at 8 locations in Bellingen and Urunga,
2. Survey of 7 hydraulic structures, and
3. Creek in-bank and floodplain cross section survey perpendicular to flow direction at 7 locations along the Lower Bellinger and Kalang River floodplain.

4. COMMUNITY CONSULTATION

One of the central objectives of the FRMS process is to actively liaise with the community throughout the process, to keep them informed about the current study, identify community concerns and gather information from the community on potential management options for the floodplain. The consultation programme consists of:

- The Coastal, Estuary and Floodplain Advisory Committee,
- Bellingen Shire Council's website, and
- Public meetings.

Details of the study were made available on Council's website.

4.1. Coastal, Estuary and Floodplain Advisory Committee Meetings

The Coastal, Estuary and Floodplain Advisory Committee oversees and assists with the floodplain risk management process being carried out within the Council LGA. The committee is comprised of representatives from various stakeholder groups and includes:

- planners,
- farmers,
- SES, and
- local residents.

A number of mitigation options were workshopped with the committee, which formed the basis for the options assessment and draft management study. Outcomes of the committee meetings include support for investigating:

- Increasing immunity along Waterfall Way
- Increasing the riparian zone along the river
- Promotion of flood awareness
- Possible Basin in Urunga Upstream of Railway
- Further drainage options for Urunga CBD under Morgo Street
- Duplication of culverts under the railway
- Increasing immunity for key areas of North Bank Road near Frenchman's Creek and
- Increasing the immunity of Lavenders Bridge.

4.2. Public Exhibition

Following approval by the Committee, this Floodplain Risk Management Study and draft Plan was put on public exhibition. This is the opportunity for the community to examine the report and the study outcomes and make any comments or suggestions.

Three written submissions were received. The submissions mainly contained comments on drainage and maintenance around Urunga. It was also noted that there is some community support for the Basin in Urunga despite significant challenges (Section 10.3.2.1) and making the flood layers generated in this study publicly available in an interactive online format or mapping tool (Section 10.5.2). Formal submissions from the community were considered by Council and the Committee in finalisation of the report.

5. HYDROLOGICAL ANALYSIS

5.1. Hydrological Model Review and Update

The *Review of Bellinger, Kalang and Nambucca Rivers Catchment Hydrology* (referred to as Regional study WMAwater, 2011) investigates known hydrologic issues in the Bellinger, Kalang and Nambucca River catchments. This area of the NSW north coast has presented a range of challenges for a number of studies where problems have been encountered matching rainfall runoff modelling with flood frequency results (including adopting a 0.4 reduction factor to ARR 1987 rainfalls). As part of the Regional study WBNM models were developed for each catchment and calibrated to historical events.

Due to concerns over the ARR 1987 design rainfall estimates (and prior to the release of the BoM 2013/6 IFDs), revised intensity frequency duration (IFD) estimates were produced for a range of design events in an approach consistent with that being proposed for the new version of ARR.

As part of the current study an update to ARR 2016/2019 methodology was undertaken.

The hydrologic model was reviewed as part of the flood study update and a higher level of detail added in the townships of Bellingen and Urunga to allow modelling of overland flow.

5.2. Methodology

A review of the hydrology of the Bellinger and Kalang Rivers, to update the hydrological model to meet ARR 2016/2019 approaches has been undertaken.

The updated consisted of the following:

- Update of the FFA at each gauge to incorporate the last 10 years of data
- Update of the WBNM model to enable the development and assessment of ARR 2016/2019 approaches
- Rerunning of the WBNM model with ARR 2016/2019 approaches to determine the revised design flows at each area of interest.

5.3. Flood Frequency Analysis Update

Table 2 provides the updated Flood Frequency Analysis (FFA) estimates for the Bellingen, on the Bellinger River and Kooroowi, on the Kalang River gauges. Note that during the previous FFA assessment for Thora, due to significant differences in the timescales present at the Bellingen and Thora gauges there was a large discrepancy. This was resolved utilising a regionalisation factor on the Thora gauge. This is not completed as part of the current study however it is anticipated that limited variation between previous and the current flow values will be present. Both the Log Pearson 3 (LP) and Generalized Extreme Value (GEV) fits were trialed (refer to Diagram 1 and Diagram 2).

Table 2: Comparison of FFA analysis

AEP	Bellingen			Kooroowi		
	2011 FFA (m^3/s)	2019 FFA (m^3/s)	Difference (%)	2011 FFA (m^3/s)	2019 FFA (m^3/s)	Difference (%)
20%	1170	1220	4.1%	270	310	12.9%
10%	1620	1670	3.0%	480	540	11.1%
5%	2220	2230	0.4%	680	760	10.5%
2%	3370	3250	-3.7%	820	990	17.2%
1%	4590	4300	-6.7%	1060	1120	5.4%

At the Bellingen gauge peak flow estimates have slightly reduced for rare events. This is due to no significant flood events (rarer than 7% AEP) occurring in the last 10 years. At the Kooroowi gauge there is a slight increase however this is generally minor and due to the increased record length.

In general, the flood frequency update has resulted in the expected minor changes.

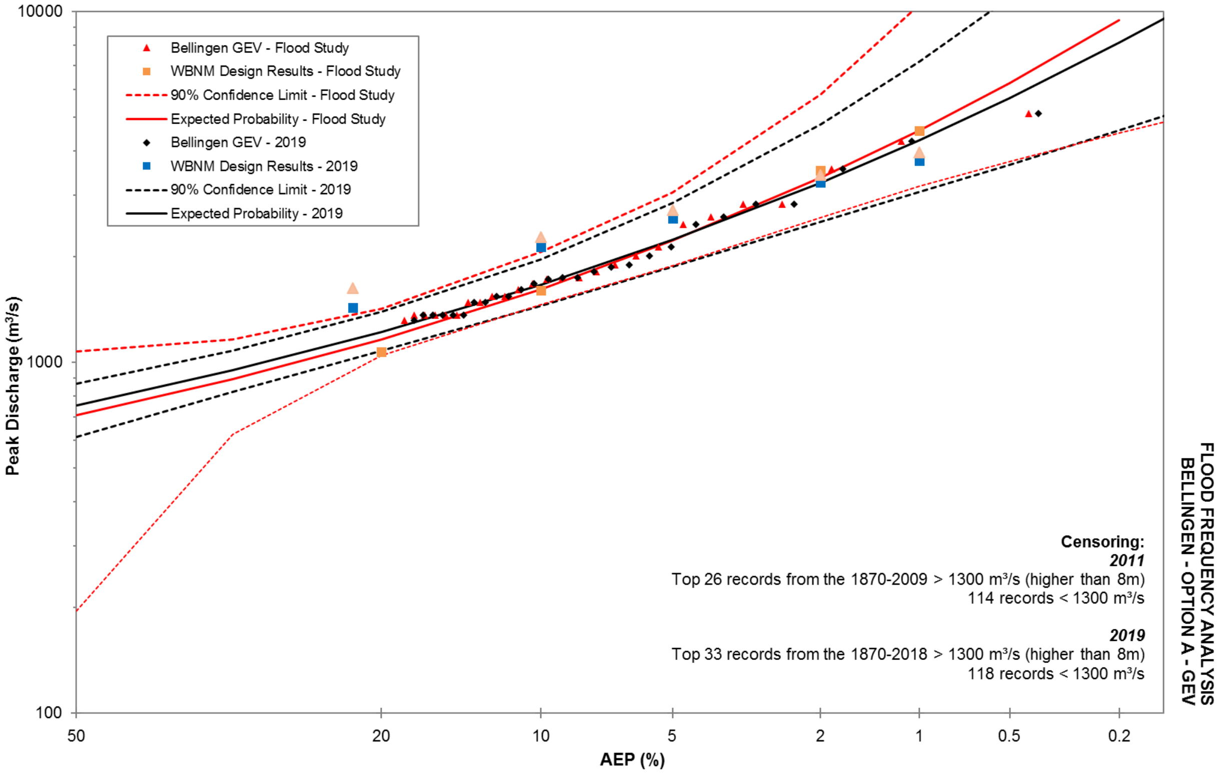


Diagram 1: FFA Bellingen

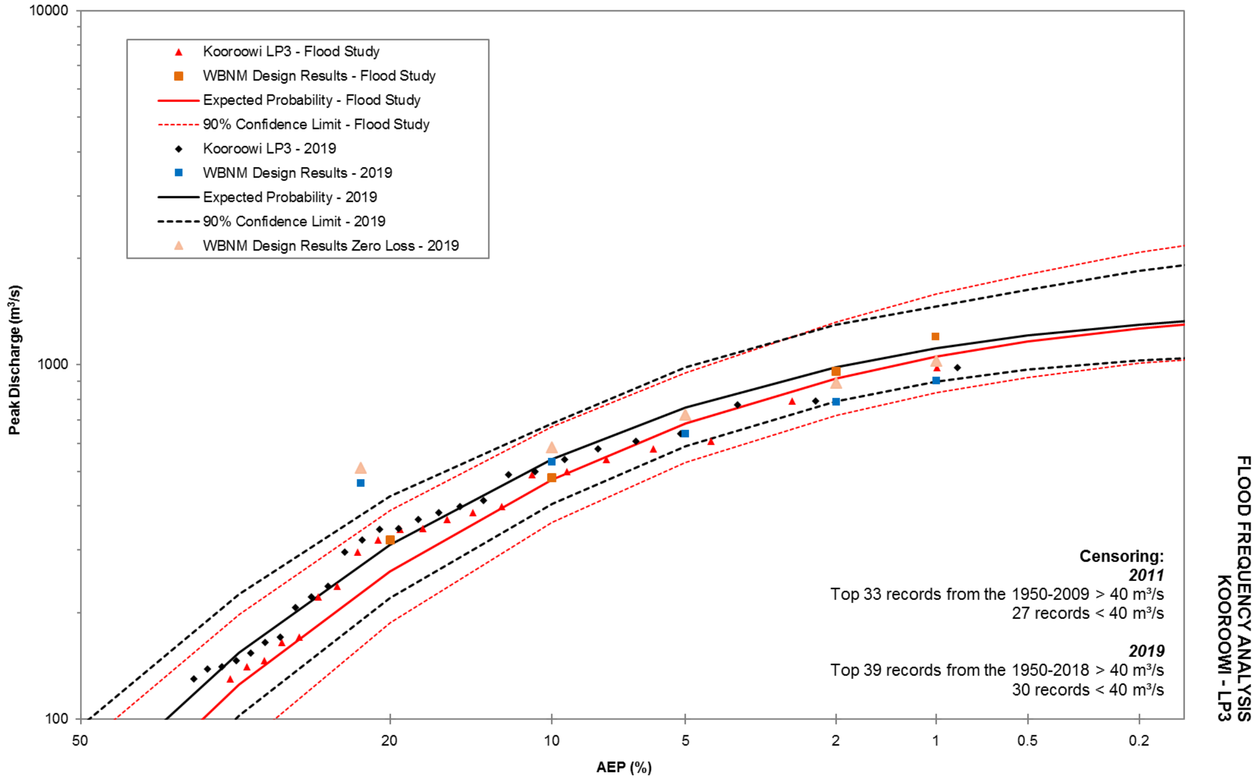


Diagram 2: FFA Koorowi

5.4. Overview of Issues

In several locations the rainfall depths present in the 2016 IFDs are lower than the previous estimates. This has been noted in several locations across the country. The reduction in IFD depths in critical events in some locations results in lower flood estimates.

The ensemble temporal patterns utilised in conjunction with both the revised IFD depths and the 2011 IFD depths result in peak flow estimates lower than the estimate provided in the FFA. This peak flow estimate is based on the mean peak flow generated by the ensemble events.

5.5. Design Rainfall Update

The IFD information relies on the time period that is present at the rainfall gauges in the area. As the Bellingen FFA utilizes information dating back into the 1800's the streamflow record is significantly longer. At Bellingen, the two highest recorded flood events occurred prior to the availability of rainfall data in the area. As a result, it is likely that the 2016 IFD, with its limited data record, is under predicting rainfall depths.

During the previous regional hydrology assessment, it was identified that the ARR 1987 rainfall depths for the area significantly over predicted rainfall for the region. During the regional hydrology analysis undertaken in 2011 (WMAwater), updated IFD parameters for the area were derived. During the flood study undertaken in 2015-16, a review of these IFDs against the BoM 2013 interim IFD update was undertaken which indicated similar rainfall depths. As shown in Table 1, both the 2013 IFD and the regional study IFD parameters using filtered ARR 1987 temporal patterns resulted in a closer alignment to the estimated FFA flows for the 1% AEP, both IFD scenarios events slightly under estimating flow in general. As part of the update to provided rare design rainfalls the BoM reissued the IFDs in 2016.

The updated assessment has utilized the revised NSW advice with regards to loss application which recommends the initial and continuing loss rates are based upon an average of the calibrated model initial and continuing losses. Diagram 3 compares the four IFDs available for the catchment:

- ARR 1987
- Regional study 2011
- 2013 IFD
- 2016 IFD

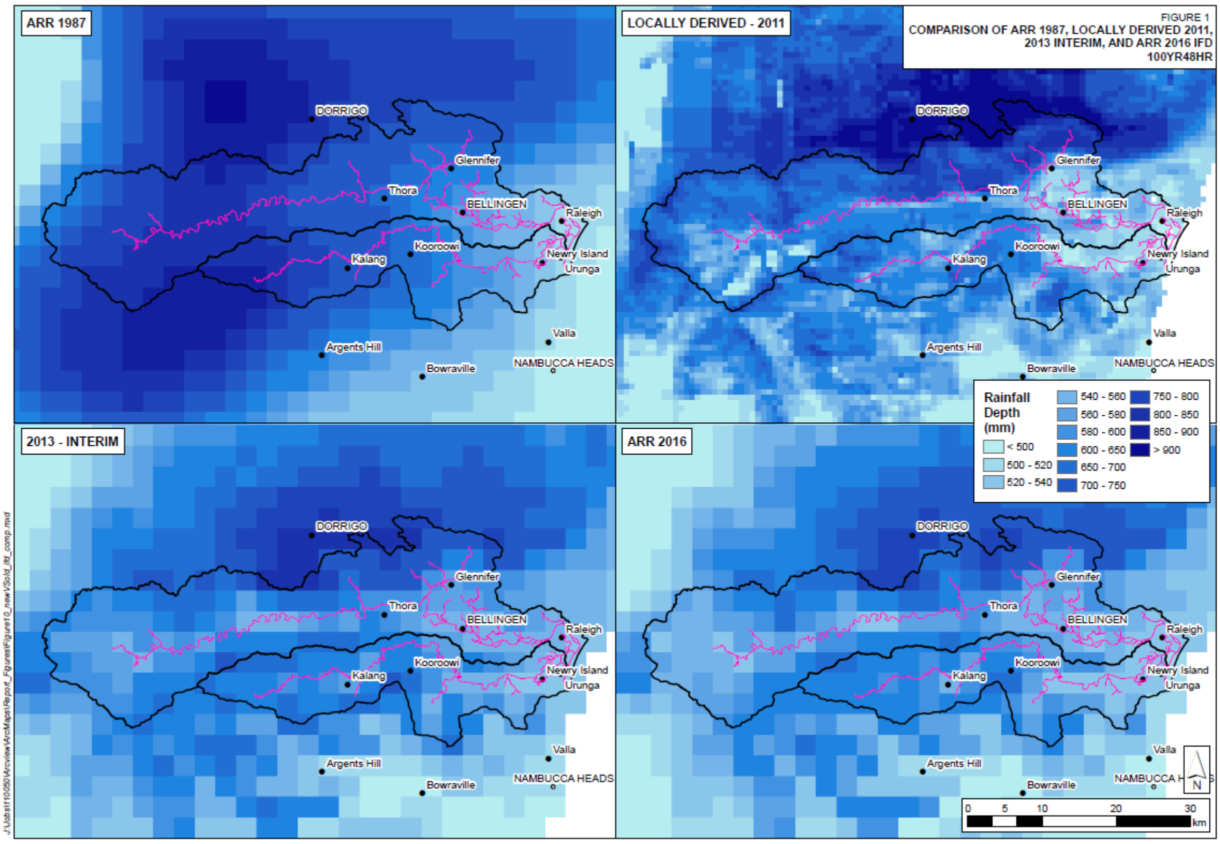


Diagram 3: Comparison of ARR 1987 IFDs, Locally Derived IFDs, 2013 ARR Interim IFDs and ARR 2016 IFDs.

For this it can be seen that the 2013 and 2016 IFDs are lower than the 2011 IFDs particularly in the upper catchment. Diagram 4 shows the difference between the 2016 and 2013 IFDs (2016 minus 2013- therefore a negative number indicates the 2016 IFDs are less than the 2013). For the entire catchment the IFDs in 2016 are lower than 2013 by up to 50mm.

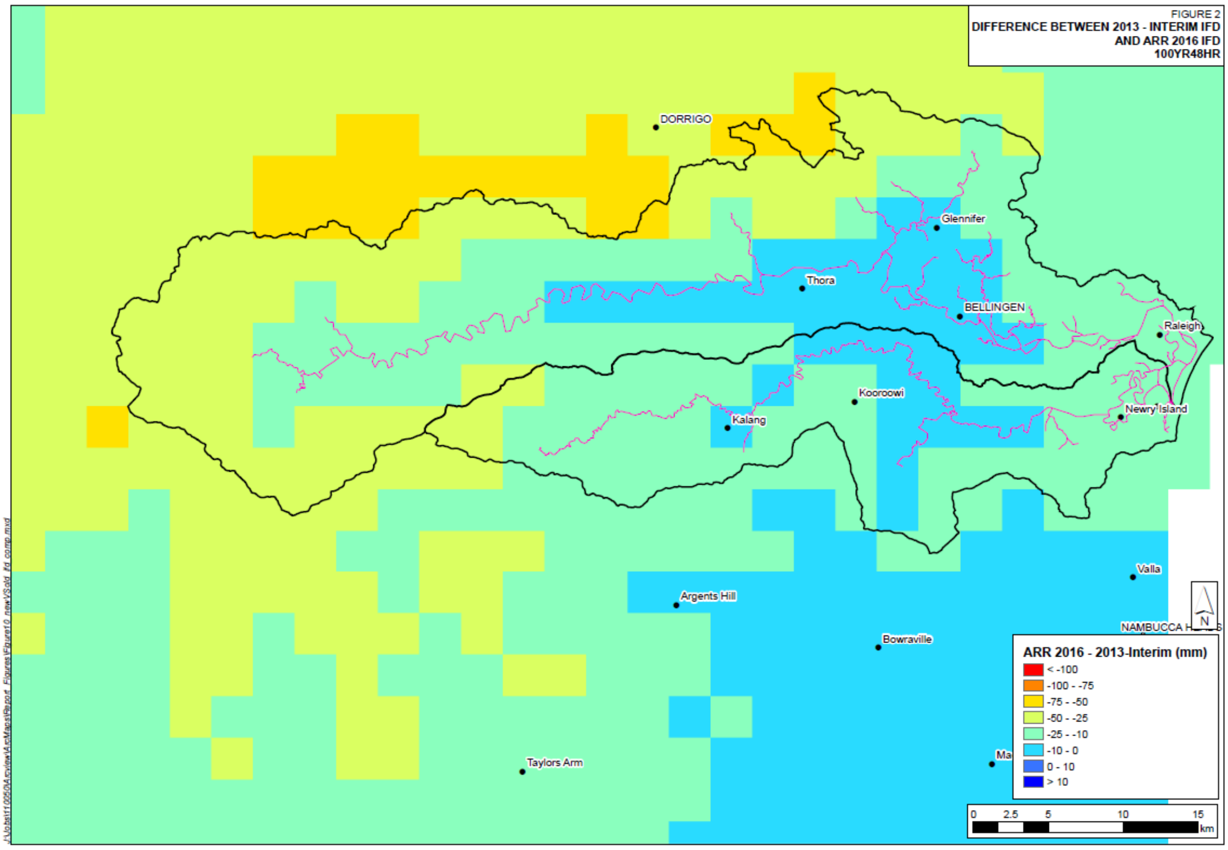


Diagram 4: Difference between 2013 ARR Interim IFDs and ARR 2016 IFDs

5.6. Riverine Flooding – Adopted approach

This study adopted the 2011 IFD which was available for durations from 24hrs to 72hrs A 5 Year ARI was available (18.13% AEP) in the 2011 IFD set and therefore 20% AEP for these durations could not be interpolated. Therefore the 5 Year ARI event has been adopted in lieu of the 20% AEP.

The 2011 IFD coupled with the 2016/2019 ARR ensemble temporal pattern method produced flow values that were considerably below the flood frequency analysis estimates at Bellingen. Pre-burst temporal patterns were available from the BoM for extreme storms for 12, 24, 48, and 72 hour durations. These were added to the burst temporal patterns, to account for durations where the pre-burst depths were greater than the average calibration losses of 47 mm IL and 1.5mm/h CL on the Bellinger River and 52.5mm IL and 0.35mm/h CL on the Kalang River.

Prior to adding pre burst, the critical duration for riverine flooding for all durations was the 72 hour (3-day) event. Adding pre-burst increased peak flows for the 24hr duration to be greater than the 36hr and 48 hour, however the 72 hour remained the critical duration overall. The box plot identifying the critical duration is shown in Diagram 5 for the 1% AEP event.

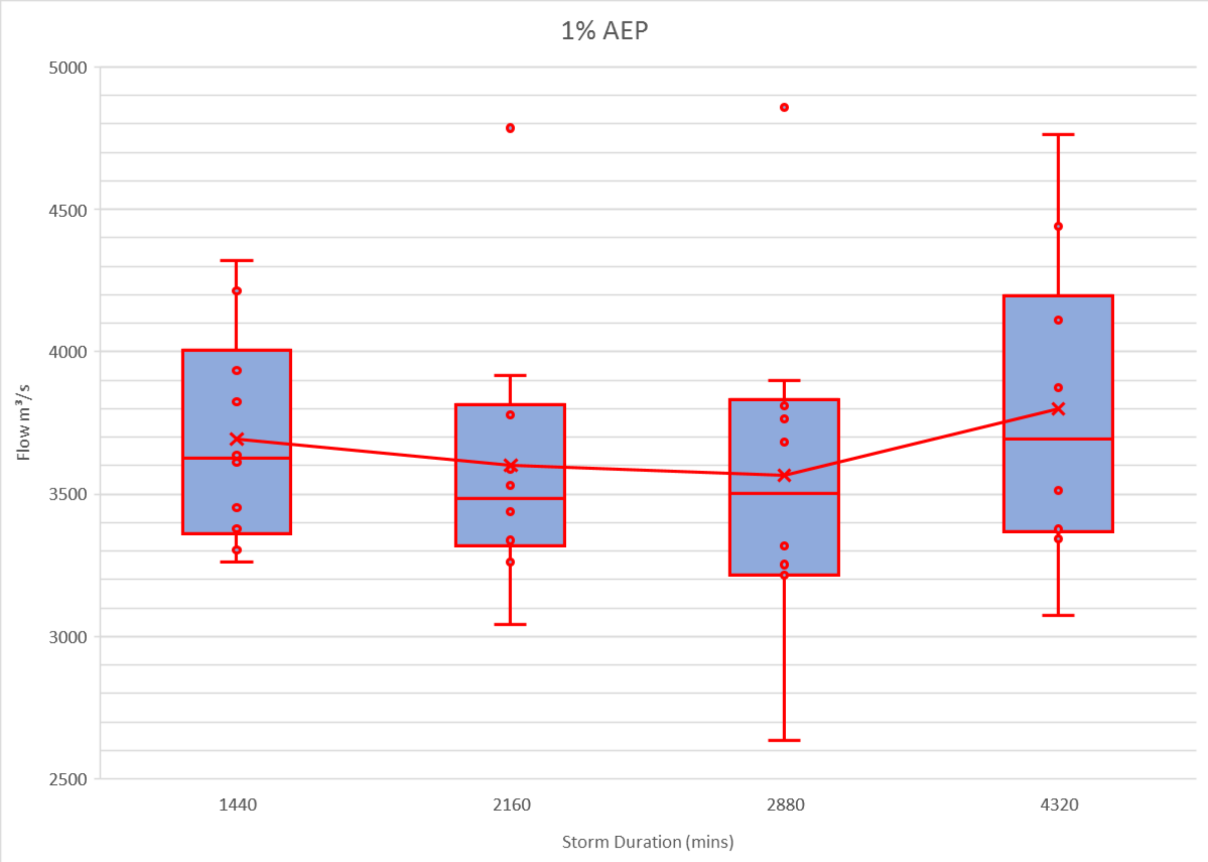


Diagram 5: 1% AEP Critical Duration Box Plot

5.7. Local Catchment Flooding

Local catchment urban flooding is driven by shorter duration events. As the Regional (2011) IFD was not available for durations shorter than 24 hours, the 2016 IFD was used in combination with the ARR 2016/2019 ensemble temporal pattern method.

For urban areas different losses should be applied compared to completely rural catchments. ARR 2016/2019 provides guidance on how losses should be varies depending on the portion of the urban catchment that is effective Impervious Area, Indirectly Connected Impervious Area and Urban Pervious area as shown in Table 3. For the urban flooding hydrologic model, losses were reduced for Urunga, Cemetery Creek/Bellingen and Central Drainage Line/North Bellingen sub catchments. The adopted losses for the hydrological model are shown in Table 4.

Table 3: ARR 2016/2019 guidance on selection of Losses for urban areas

Urban Area	Burst Initial Loss (mm)	Continuous Loss (mm/hr)
Effective Impervious Area	1 – 2 mm	0
Indirectly Connected Area	60 to 80% of rural catchment losses	For south-eastern Australia, a typical value of 2.5mm/h, with a range of 1 to 3 mm/h, would be appropriate. The value should be adjusted based on engineering judgement and reviewing the catchment characteristics such as soil types, interaction of indirectly connected impervious areas with pervious areas etc. For other areas, adopt a range of 1 to 4 mm/h.
Urban Pervious Area	Traditionally, practitioners have adopted similar loss values for these areas as for those they would adopt in rural areas.	

Table 4: Adopted Urban Losses

	Portion of Urban Area (km²)	IL (mm)	CL (mm\hr)
Indirectly Connected Impervious	1.9	29	1
Effective Impervious	0.7	2	0
Pervious	4.7	49	1
Adopted Average Losses		40	0.8

The temporal pattern that resulted in the peak flow above the mean of the ensemble at locations in the Cemetery Creek, Central Drainage Line and Urunga catchments was adopted. Table 5 summarises the temporal patterns and critical durations that were selected to be run in the hydraulic model.

Table 5: Urban catchments critical durations and temporal patterns

Event	**Urban Critical Durations and Temporal Patterns**			
5 Year ARI	120min TP4642	120min TP4636	270min TP4706	270min TP4712
5% AEP	120min TP4626	180min TP4659	270min TP4700	
1% AEP	120min TP4499	270min TP4650	270min TP4686	
0.2% AEP	120min TP4499	270min TP4650	270min TP4686	

6. HYDRAULIC ANALYSIS

6.1. TUFLOW Model Review and Update

As part of this study an update to the hydraulic model was undertaken. This included an reducing the model grid size from 15m to 5m to increase the flood mapping resolution. Also model detail was increased in the following areas:

- Cemetery Creek, Bellingen
- Central Drainage Line, North Bellingen
- Urunga CBD
- South Urunga.

6.1.1. High Performance Computing

In order to assist Council in flood planning a key project aim was to increase the model resolution from the 15m grid size used in the Flood Study to a 5m resolution. However, a grid resolution of that size for an area of 130 square kilometres using the TUFLOW Classic solver adopted for the Flood Study would result in extremely large model run-times. In 2017, a new TUFLOW version was released with High-Performance Computing (HPC). A grid size of 5m provides the best compromise between model detail and run time for this size catchment.

TUFLOW HPC is a finite volume model, which means it can handle high velocities such as those seen though the entrained river entrance at Urunga, with generally with good volume conservation. Finite volume models are also very amenable to parallel computing, which is used in TUFLOW HPC. The TUFLOW standard solver (TUFLOW classic) by comparison uses finite difference.

TUFLOW HPC can be used on both a Graphics Processing Unit (GPU) and a traditional Central Processing Unit (CPU). However, the new HPC models are significantly faster on a GPU processor. The HPC solver allows the timestep to be dynamically reduced for more complex hydraulic aspects of the floodplain.

6.1.2. Modelling Updates

The following modifications have been made to the hydraulic model:

- Addition of the stormwater network in the urban areas of Bellingen and Urunga
- Addition of culverts and bridges along Hungry Head Road south of Urunga
- Modification of the Lavender Bridge modelling approach to align with current TUFLOW advice
- Inclusion of the Cemetery Creek bathymetry based on detailed field survey
- Update of Manning’s Roughness values to reflect the refined grid and inclusion of overland flow modelling for urban areas
- Extension of the ocean boundary to resolve instabilities at the entrance, and to allow for the overtopping of the sand dune into the ocean in extreme events.
- Due to the increased grid resolution a section of one dimensional channel in the upper

reaches of the Kalang River was replaced with a two dimensional grid.

All other model parameters and inputs unless discussed within this report remain the same as those documented in the Flood Study.

6.2. Modelling of Historic Events

The flood study hydraulic model was well calibrated and validated to four events, 1974, 1977, 2001 and 2009. Given that only minor changes to the model were being made and that a number of observed flood levels were available in the urban areas only for the 2009 event a detailed recalibration was not undertaken.

The model results were confirmed to be similar for 1974, 1977 and 2001 events and are not reported herein. The replacement of the one dimensional channel in the upper reaches of the Kalang River, which is particularly sinuous, with a 5m grid significantly improved model stability and results in this area. The observed flood level for the 1974 event in the upper reaches of the Kalang River is 9.7mAHD. The modelled flood level for the 1974 event in the Flood Study model was significantly lower at 7.55mAHD. The modelled flood level using the updated model developed for this study resulted in a level of 8.23mAHD in this location. Improved calibration to the 1977 observed flood level at the Lavenders Bridge was also noted.

6.2.1. 2009 Event

The updated hydrologic and hydraulic model was run for the 2009 event. This event corresponded greater than a 1% AEP on the Kalang River and a comparatively small flood of around a 10% AEP on the Bellinger River.

The calibration of the model to various gauges in the catchment for the 2009 Event is shown on Figure 7 to Figure 10. The calibration in terms timing of the event and peak level is marginally better in the refined model compared to the Flood Study calibration. Overall the good calibration to observed levels is maintained. A number of observed flood levels for the 2009 event were collected by Reference 20 and Bellingen Shire Council in Bellingen and Urunga. These were not surveyed as part of the previous study due to the focus on riverine flooding. The additional flood marks were surveyed as part of the current study.

Figure 11 presents the modelled levels of the 2009 Event in the updated model compared to the observed peak flood levels. A comparison of the observed flood levels to the modelled flood levels is shown in Table 6.

The modelled flood level has a good match to the observed flood level on Ford Street, Bellingen. This is closely located to the observed level at the Oval opposite Creek Lane. This along with contemporary comments on the flood mark indicate this level was not recorded at the peak of the event. Furthermore, the Ford Street point is considered more accurate and it is unlikely that flood levels upstream would be lower than the downstream level.

Table 6: Comparison of observed flood levels to modelled flood levels - 2009 Event

River	Location	Recorded Level (m AHD)	Modelled Level (m AHD)	Difference (m)
Bellinger	110 Gleniffer Road	10.10	10.35	0.25
	110 Gleniffer Road	9.94	10.35	0.41
	1301 Waterfall Way	9.56	9.05	-0.51
	1301 Waterfall Way	9.49	9.04	-0.45
	Lavenders Bridge	8.81	8.72	-0.09
	Cemetery Creek at Ford St, Bellingen	8.53	8.53	0.00
	Oval at Creek Lane, Bellingen	8.20	8.63	0.43
	Waterfall Way	7.00	6.83	-0.17
	794 Waterfall Way	6.38	6.00	-0.38
	895 North Bank Road	5.10	4.52	-0.58
	Valery Road	4.24	3.96	-0.28
	North Street	3.90	3.71	-0.19
	Repton Gauge	3.56	3.41	-0.15
	474 Yellow Rock Road	3.09	2.79	-0.30
	476 Yellow Rock Road	3.07	2.79	-0.28
	Reserve	3.03	2.87	-0.16
	427 Yellow Rock Road	2.95	2.75	-0.20
	427 Yellow Rock Road	2.94	2.75	-0.19
	427 Yellow Rock Road	2.93	2.75	-0.18
Kalang	2 Hains Lane	10.69	9.89	-0.80
	32 Hains Lane	10.17	9.81	-0.36
	88 Hains Lane	9.79	9.05	-0.74
	88 Hains Lane	9.24	8.72	-0.52
	1046 South Arm Road	7.20	6.74	-0.46
	915 South Bank Road	6.69	6.54	-0.15
	869 South Arm Road	6.35	6.44	0.09
	?? Martells Road	4.33	4.20	-0.13
	504 South Arm Road	4.26	4.48	0.22
	Newry Island Gauge	4.19	4.22	0.03
	5 Burrawing Parade	3.65	3.73	0.08
	114 Newry Island Drive	3.59	3.58	-0.01
	Cnr Short Cut Road	3.58	3.52	-0.06
	110 Newry Island Drive	3.56	-	-
	Pacific Hwy	3.56	3.39	-0.17
	219 Newry Island Drive	3.54	3.62	0.08
	2 Marshall Place	3.53	3.46	-0.07
	21 Newry Island Drive	3.53	3.54	0.01
	57 Newry Island Drive	3.51	3.58	0.07
	Urunga Gauge	2.82	2.87	0.05
	Bridge over the Kalang River, Urunga	2.65	2.84	0.19

	Fire Station, Urunga	4.73	4.65	-0.08
	Fire Station, Urunga	4.56	4.65	0.09
	33 Morgo St, Urunga	4.57	4.65	0.08
	24 Newry St E, Urunga	4.61	4.65	0.04
	47 Bonville St, Urunga	4.66	4.65	-0.01
	42 Morgo St, Urunga	3.41	2.33	-1.08
	opp 14 Hillside Dr, Urunga	2.95	3.06	0.11

At Morgo Street in Urunga, there is a metre difference between the recorded flood level and the modelled flood level. It is believed that a typographical error has occurred on the observed level and the recorded value should by 2.41 mAHD. This would align then with nearby observed levels. Observed levels significantly upstream of that point, on Hillside Drive, are 460 mm lower than the Morgo Street level.

The calibration of the updated model to observed flood levels used in the Flood Study is similar. The updated model calibration is generally within 200 mm and the refined model is considered fit for use in the Floodplain Risk Management Study.

6.1. Impact of model update on design events

Table 7 presents the change in level from the flood study to the model update results for the 1% AEP event and the 5y ARI event. A gridded difference between the two models is also presented on Figure 12 for the 1% AEP events. There is generally little difference between the results for each model. For the 1% AEP event, there is a notable change at Lavenders Bridge due to the refinement of the model and revision of the bridge modelling mechanism and as well as an additional decrease in flow with the application of ARR methodology. This is considered acceptable with the design level similar to that produced by the flood frequency analysis.

Table 7: Comparison of Levels between Flood Study results and the Model Update

Location	1% AEP Event - Flood Study	1% AEP Event - Flood Study Update ARR2019	5y ARI Event - Flood study	5y ARI Event - Flood Study Update with ARR2019
Fernmount	7.83	7.77	4.65	4.96
U/S Pacific Highway Bellinger River	5.61	5.64	2.88	3.09
Mylestom	3.82	3.95	2.13	2.05
Confluence Bellinger and Kalang Rivers	2.16	2.32	1.81	1.55
D/S Newry Island	3.45	3.61	1.99	1.74
U/S Newry Island	3.90	3.99	2.15	2.07
U/S Brierfield Bridge	9.38	9.66	Not Flooded	Not Flooded
Confluence Picket Hill Ck	4.57	4.53	2.29	2.33

Opposite Norco	5.01	5.01	2.59	2.75
MHL Newry Island U/S Gauge	3.99	4.07	2.18	2.14
MHL Urunga Gauge	3.30	3.45	1.98	1.72
MHL Repton Gauge	4.58	4.66	2.40	2.48
Lavenders Bridge	11.39	11.08	7.65	7.89
Cemetery Creek U/S of Ford Street	10.27	10.15	Not sufficiently modelled	7.83
Central Drainage Line, US of Wheatley Street	11.51	11.25	Not sufficiently modelled	9.21
Urunga U/S railway	Not sufficiently modelled	3.82	Not sufficiently modelled	3.38
Urunga Bowling Club	Not sufficiently modelled	3.70	Not sufficiently modelled	2.85

6.2. Sensitivity

6.2.1. Blockage

All bridges with spans less than 6m and all culverts were blocked by 50% to determine sensitivity to blockage consistent with the approach used in the Flood Study. The impacts of blockage are localised to the structures and minimal. Table 8 shows the worst affected area is the Urunga CBD, downstream of the railway line where the model has been refined during the current study. This location should be regularly checked for blockage as part of the maintenance program.

Table 8: Blockage comparison

Location	1% AEP Design Event (m AHD)	1% AEP Design Event with 50% Blockage (m AHD)	Difference (m)
Fernmount	7.77	7.77	0.00
U/S Pacific Highway Bellinger River	5.64	5.64	0.00
Mylestom	3.95	3.95	0.00
Confluence Bellinger and Kalang Rivers	2.32	2.31	0.01
D/S Newry Island	3.61	3.60	0.01
U/S Newry Island	3.99	3.99	0.00
U/S Brierfield Bridge	9.66	9.66	0.00
Confluence Picket Hill Ck	4.53	4.53	0.01
Opposite Norco	5.01	5.01	0.00
MHL Newry Island U/S Gauge	4.07	4.06	0.01
MHL Urunga Gauge	3.45	3.45	0.00
MHL Repton Gauge	4.66	4.66	0.00
Lavenders Bridge	11.08	11.16	0.08

Cemetery Creek U/S of Ford Street	10.15	10.15	0.00
Central Drainage Line, US of Wheatley Street	11.25	11.24	-0.01
Urunga U/S railway	3.82	4.57	0.75
Urunga Bowling Club	3.70	4.34	0.64

Note a negative value is an increase in flood levels with blockage applied.

6.3. Design event surfaces

In addition to runoff from the catchment, the lower reaches of the estuary can also be influenced by backwater effects resulting from elevated ocean levels. Hence, the height of the tide at the time of the arrival of the peak runoff from the catchment can also have an influence on flood levels in the lower reaches. However, these two distinct flooding mechanisms may or may not result from the same storm. Consideration must therefore be given to accounting for the joint probability of coincident flooding from both catchment runoff and backwater effects due to elevated ocean levels.

In addition to the above it is not unreasonable to expect that the effects of a severe storm in terms of ocean levels and runoff could be coincident for a catchment of this size. Hence to establish the design flood levels in the present study, the relative phasing of the ocean levels was adjusted such that the peak of the tidal hydrograph would approximately coincide with the peak of the catchment runoff.

Three events were run and enveloped to form the design event flood surface at any location within the catchment:

- Main river dominated flooding (72hr rainfall event) with a low tide level
- Local catchment dominated flooding with a frequent river event
- Ocean dominated event with a frequent river event.

For example a 1% AEP catchment event was run with a 0.9 variable tide. A 1% local catchment event with normal flow in the river. A 1% AEP ocean event was run with a 10% AEP catchment event.

7. EXISTING FLOOD BEHAVIOUR

7.1. Description of flood behaviour

Peak Flood Depth results for the 5yr ARI, 5% AEP, 1% AEP, 0.2% AEP and PMF events are presented in Figure 13 to Figure 27. Peak flood level results for the same events are provided in
Figure 28: Peak Flood Level - 5Y ARI Event
Figure 29: Peak Flood Level - 5Y ARI Event - Bellingen
Figure 30: Peak Flood Level - 5Y ARI Event - Urunga
Figure 31: Peak Flood Level – 5% AEP Event
Figure 32: Peak Flood Level – 5% AEP - Bellingen
Figure 33: Peak Flood Level – 5% AEP - Urunga
Figure 34: Peak Flood Level – 1% AEP Event
Figure 35: Peak Flood Level – 1% AEP Event - Bellingen
Figure 36: Peak Flood Level – 1% AEP Event - Urunga
Figure 37: Peak Flood Level – 0.2% AEP Event
Figure 38: Peak Flood Level – 0.2% AEP Event - Bellingen
Figure 39: Peak Flood Level – 0.2% AEP Event - Urunga
Figure 40: Peak Flood Level – PMF Event
Figure 41: Peak Flood Level – PMF Event - Bellingen
Figure 42: Peak Flood Level – PMF Event - Urunga
to and at key locations in Table 9.

Table 9: Design Flood Levels at Key Locations

Location	5 year ARI	5% AEP	1% AEP	0.2% AEP	PMF
Fernmount	4.96	6.20	7.77	8.61	12.68
U/S Pacific Highway Bellinger River	3.09	4.35	5.64	6.32	9.80
Mylestom	2.05	2.68	3.95	4.90	8.61
Confluence Bellinger and Kalang Rivers	1.55	1.86	2.32	3.65	7.42
D/S Newry Island	1.74	2.09	3.61	4.62	8.45
U/S Newry Island	2.07	2.84	3.99	4.86	8.75
U/S Brierfield Bridge		7.49	9.66	10.67	16.21
Confluence Picket Hill Ck	2.33	3.23	4.53	5.38	9.74
Opposite Norco	2.75	3.99	5.01	5.68	9.19
MHL Newry Island U/S Gauge	2.14	2.93	4.07	4.92	8.87
MHL Urunga Gauge	1.72	2.03	3.45	4.51	8.32
MHL Repton Gauge	2.48	3.58	4.66	5.44	9.09
Lavenders Bridge	7.89	9.39	11.08	11.99	16.74
Cemetery Creek U/S of Ford Street	7.83	8.46	10.15	10.98	15.11
Central Drainage Line, U/S of Wheatley Street	9.21	10.00	11.25	12.06	16.91
Urunga U/S railway	3.38	3.56	3.82	4.32	7.50
Urunga Bowling Club	2.85	3.26	3.70	4.25	7.49

7.1.1. Floodplain

Flooding on the Bellinger and Kalang Rivers is generated by long duration storm events. The low lying floodplain downstream of Bellingen is subject to flood depths typically greater than 2 metres, and long inundation times as described in Section 10.5.3. Once the banks are overtopped on the Bellinger River, velocities in the 1% AEP can exceed 4m/s.

The Kalang River floodplain is narrow compared to the Bellinger floodplain. The floodplain is particularly confined upstream of the Pacific Highway. The floodplain broadens downstream of the Pacific Highway Bridge. High velocity flows particularly in rare events, divert from the main channel around Newry Island, forming a flow path over the island to join back up with the Kalang River upstream of Urunga. Overbank velocities on the Kalang River are typically less than 2.5 m/s.

7.1.2. Cemetery Creek, Bellingen

Cemetery Creek runs through Bellingen. It is characterised by short duration flooding, particularly in the headwaters and in the central parts of Bellingen. It drains to the South East and connects with the Bellinger River. Anecdotally, residents have commented on Cemetery Creek flooding being the major cause of inundation of properties through Bellingen during the 1974 flood, due to elevated river levels.

When it overtops its banks the creek can cause significant inundation of low lying areas to the south of Waterfall Way, particularly between Ford and Prince Streets.

7.1.3. Central Drainage Line, North Bellingen

The Central Drainage line describes a small catchment in North Bellingen that captures overland flow paths from Tamarind Drive, Sunset Ridge Drive, Kenny Close and Elliot Close. Floodwaters flow behind properties to the west of Lyon Street towards Wheatley Street and Hammond Street. While there is a 1.2 m diameter pipe under Wheatley Street, it is overtopped in a 1% AEP event to a depth of 0.42 m. Significant ponding occurs on the property behind the pipe.

The most severe flooding in North Bellingen comes from riverine flooding, rather than local catchment flooding, which results in flood depths of up to 2.5 m at properties on Black Street in the 1% AEP event. Depths greater than 2 m occur on properties along Hammond Road and Dowle Street. In the PMF, a flow path develops between the Bellinger River and the Central Drainage Line, isolating properties between Hobson Close and the Bellinger River.

7.1.4. Urunga Urban Area

In frequent events flood behaviour in Urunga is largely dominated by overland flow while in larger events the longer duration river dominated events generate higher flood levels, except in areas with steep topography such as Lourdes Avenue, and South Street. Riverine levels can restrict the drainage of overland flow. Flood waters pool behind the North Coast railway embankment to depths of 1.7 m within the reserve. There is one 1.2 m diameter circular culvert under the railway embankment, which struggles to convey water beneath the embankment, particularly with elevated downstream levels. Similar flood behaviour is experienced in the 5%, 1% and 0.2% AEP flood events. In the 1% AEP flood event, flood depths in the order of 1 m occur in Pilot Street and at the intersection of Newry St East and Bonville Street. In the PMF event, as the flood approaches the peak, the railway embankment is overtopped with flood waters flowing in a south westerly direction.

7.2. Hydraulic and Hazard Classification

7.2.1. Hazard Classification

Hazard classification plays an important role in informing floodplain risk management in an area as it reflects the likely impact of flooding on development and people. In the Floodplain Development Manual (NSW Government, 2005) hazard classifications are essentially binary – either Low or High Hazard as described in Figure L2 of that document.

The NSW Floodplain Development manual, Managing the floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR, 2016) and Book 6, Chapter 7 of ARR 2016 provide procedures for determining the hazard based on the flood velocity and depth. AIDR (2016) and ARR 2016 provide revised hazard classifications that add clarity to the hazard categories and what they mean in practice. The classification is divided into six categories which indicate the restrictions on people, buildings and vehicles (Diagram 6):

- H1 – No constraints
- H2 – Unsafe for small vehicles
- H3 – Unsafe for all vehicles, children and the elderly
- H4 – Unsafe for all people and all vehicles
- H5 – Unsafe for all people and all vehicles. Buildings require special engineering design and construction; and
- H6 – Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

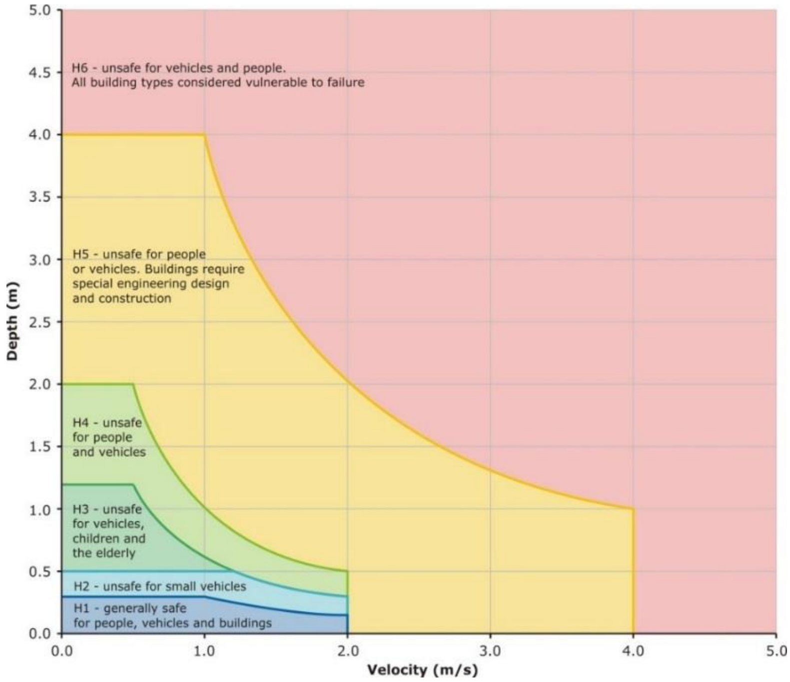


Diagram 6: Hazard classification diagram (Source: AIDR, 2016)

Figure 43, Figure 46 and Figure 49 present the AIDR hazard classifications for the entire study area for the 5% AEP, 1% AEP and PMF events.

Under this classification, for a 1% AEP event much of the floodplain between Bellingen and Urunga is considered unsafe for all people and all vehicles with buildings requiring special engineering design and construction. For a 1% AEP event, large areas upstream of the Pacific Highway crossing of the Bellinger River are considered as H6 (unsafe for people and vehicles. All building types considered vulnerable to failure). In a PMF, only small fringe areas of both the Bellinger and Kalang Rivers are not classified as H6.

The *Floodplain Development Manual* (NSW Government, 2005) requires that other factors be considered in determining the 'true' hazard including: size of flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of floodwaters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows. However, to assess the full flood hazard, all adverse effects of flooding have to be considered. As well as considering the provisional (hydraulic) hazard, threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production should be incorporated into the assessment.

The conversion from 'provisional' hazard to 'true' hazard requires subjective decisions on how these aspects interact with the population at risk. To overcome this problem, practice has evolved to map provisional hazard and to separately identify evacuation risk over the full range of flood events. Evacuation response requirements have been assessed and are discussed in Section 9.1. For this reason, a true hazard conversion has not been carried out.

7.2.2. Hydraulic Categorisation

For the purposes of floodplain risk management in NSW floodplains are divided into one of three Hydraulic categories (floodway, flood storage and flood fringe)

Hydraulic categories describe the flood behaviour by categorising areas depending on their function during the flood event, specifically, whether they transmit large quantities of water (floodway), store a significant volume of water (flood storage) or do not play a significant role in either storing or conveying water (flood fringe). As with categories of hazard, hydraulic categories play an important role in informing floodplain risk management in an area. Although the three categories of hydraulic function are described in the Floodplain Development Manual (Reference 21), their definitions are largely qualitative and the manual does not prescribe a method to determine each area. The Manual gives one indication of how to quantitatively differentiate floodway and flood storage, when it states that flood storage areas, when completely filled with solid material, will not raise peak flood levels by "*more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%"*.

The use of velocity and depth to delineate areas of different hydraulic category follows the approach proposed by Howells et al. in their 2004 paper (Reference 28). At each grid cell, the peak velocity (v), peak depth (d) and their product (v*d) is considered, and the cell is categorised based on the following criteria.

1. *If both v*d > 0.25 and v > 0.25, then 'floodway'*
2. *If both v > 1 and d > 0.15, then 'floodway'*
3. *If neither of the above apply and d > 0.7, then 'flood storage'*
4. *Otherwise, 'flood fringe'.*

The areas were expanded by first changing any 'islands' of non-floodway to floodway, that is, areas that are surrounded by floodway. Then flood runners were manually added to the floodway area, and their width was increased until they were sufficiently wide.

Lowering the thresholds of v, d and v*d may also be used to select more area; however, this was not possible for the study area, as a number of features on the floodplain, including roads and irrigation canals, obstructed small flood runners, and so considering v, d or v*d does not produce any unbroken flood runner or flow path outside the high flow zone.

Hydraulic categorisation is presented in Figure 52, Figure 53 and Figure 54 for the 5% AEP, 1% AEP and PMF events respectively. The majority of the Bellinger River floodplain and Newry Island is considered floodway.

8. CONSEQUENCES OF FLOODING ON THE COMMUNITY

8.1. Road and Bridge Overtopping

A number of low level crossings and roads exist within the catchment. Due to the extent and depth of flooding, these roads can be cut for significant periods of time, severing communities and restricting access to emergency services.

8.1.1. Lavenders Bridge

Lavenders Bridge, Bellingen crosses the Bellinger River and connects Bellingen and North Bellingen. It is closed by Council staff at a flood level between 4.6 and 4.7 m AHD. The bridge is physically inundated at a level of 5 m AHD. The most frequent modelled event in this report, the 5 year ARI flood, reaches a level of 7.76 m AHD at Lavenders Bridge. Therefore in a 5 year ARI event the bridge would be under more than 2.5 m of water.

A method used to quantify the average annual time a bridge is closed is described in AUSTROADS (Reference 32). Using the historical gauge record at Bellingen from 1996 to 2010, the best estimate of the flood probability at which the bridge is closed is equal to approximately 0.4 year ARI (92.18% AEP) which means it is likely to be closed 2 to 3 times per year.

Table 10 presents the average annual time of closure (AAToC) estimate for Lavenders Bridge, Bellingen. For the existing bridge, based on the continuous gauge record, the average time of closure is estimated to be 45.7 hours. However this is considered to be an underestimate as the 14 years adopted for the generation of this record included only 2 floods greater than 8m AHD (a rate of 0.1 per year), where in the full 149 year record, 27 floods over 8m AHD have been recorded (a rate of 0.2 per year).

Table 10: AAToC for Lavenders Bridge (Existing Level)

AEP (%)	ARI (years)	Duration of Closure (hours)	AEP probability of closure	fT(T)	Δp	Δp *ToC
92.18	0.4*	0.00	0.00	0.00	0.00	0.00
18.13	5	41.50	0.80	0.02	0.80	33.20
5.00	20	61.50	0.95	0.01	0.15	9.23
1.00	100	65.00	0.99	0.01	0.04	2.60
0.20	500	70.25	1.00	0.00	0.01	0.56
	PMF	42.75	1.00	0.00	0.00	0.09
					AATOC (hours)	**45.7**

8.1.2. Waterfall Way

Waterfall Way connects Bellingen and surrounding communities with the Pacific Highway and major population centres such as Coffs Harbour. The road is 11.3 km long between Bellingen and the Pacific Highway. It crosses in the order of seven flow paths. The majority of the low points in the road are below a 2 year ARI level. When the road is cut, drivers of vehicles have been known to ignore the closed road signs and continue along the road, posing a considerable safety risk.

The order in which crossings are flooded could be determined by analysing the modelled events. This analysis is based on river dominated flow only, and does not account for any short duration local catchment flooding from water falling to the south of the road. Waterfall Way would be cut for over 2 days in an event.

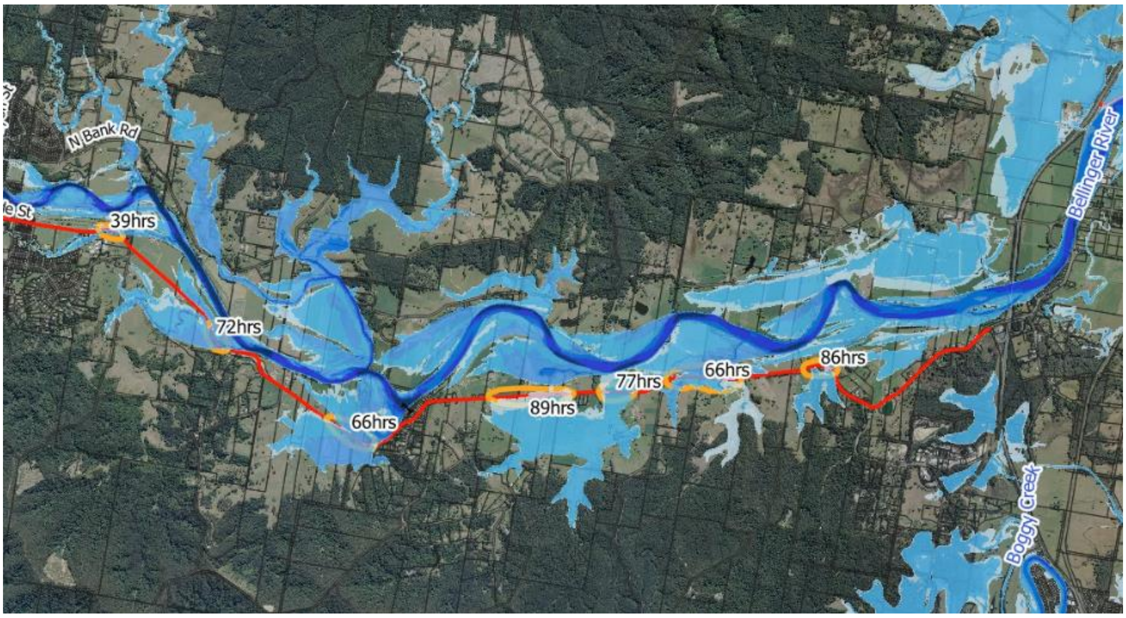


Diagram 7: Time into a 5 year ARI river dominated event Waterfall way low points are flooded

8.2. Impacts of Flooding on Public Infrastructure

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; telephone and electricity supply including transmission poles/lines, sub-stations and underground cables; roads and bridges including traffic lights/signs; and costs to employ the emergency services and assist in post-flood clean up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to Councils from flooding typically comprise;

- Clean-up costs;
- Erosion and siltation;
- Removing fallen trees;
- Inundation of Council buildings;
- Direct damage to roads, bridges and culverts, water and sewer infrastructure;
- Removing vehicles washed away;
- Assistance to ratepayers;
- Increases in insurance premiums;
- Closures of streets;
- Loss of working life of road pavements; and
- Operational costs in the lead up to and during flood events.

Significant damage to wooden bridges has occurred in the upper reaches of the catchment during flood events.

8.3. Economic Impact of Flooding

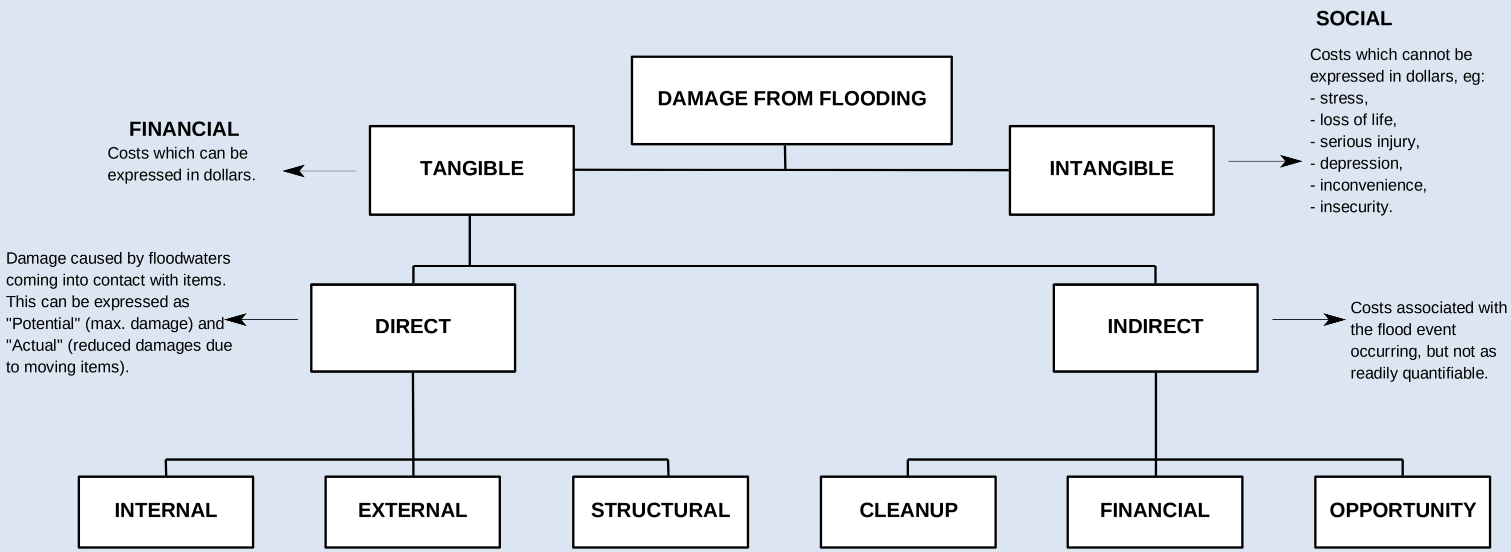
The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also provide a non-subjective means of assessing the merit of flood mitigation works such as retarding basins, levees, drainage enhancement etc. The quantification of flood damages is an important part of the floodplain risk management process. By quantifying flood damage for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood,
- Land use and susceptibility to damages,
- Awareness of the community to flooding,
- Effective warning time,
- The availability of an evacuation plan or damage minimisation program,
- Physical factors such as failure of services (sewerage), flood borne debris, sedimentation, and
- The types of asset and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment, but there is also a need to consider the ecological cost and benefits associated with flooding. Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown in Table 11.

The assessment of flood damages not only quantifies potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding, as shown in Appendix B.

Table 11: Flood Damages Categories (including damage and losses from permanent inundation)



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

8.3.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Table 11). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding, property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. Flood damages estimates are also useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision-making process.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

In order to quantify the damages caused by inundation for existing development, a floor level survey was undertaken. This was used in conjunction with modelled flood level information to calculate damages. Due to the number of properties, number of isolated properties and cost, it was not possible to survey all houses within the PMF extent for the Bellinger and Kalang Catchment. A total of 1025 properties were surveyed as part of the Flood Study. With the updated model, an additional 144 properties were identified as flood affected within the 1% AEP extent, however these properties have not been included in the damages assessment due to funding restrictions.

As part of the Lower Bellinger and Kalang Rivers Flood Study a flood damages assessment was undertaken. The flood damages were revised as part of the current study due to the increased detail in the urban areas.

A flood damages assessment was undertaken for existing development in accordance with current OEH guidelines (Reference 29) and the Floodplain Development Manual (Reference 1). The damages were calculated using a number of height-damage curves which relate the depth of water above the floor with tangible damages. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

8.3.1.1. Direct Internal Damages

Internal damages were assumed follow the relationship with depth of inundation adopted in DECC (2007) for houses. This varies for houses on slab/low set, high set houses and two storey houses. In floods larger than the 1% AEP event there is the possibility that some buildings may collapse or have to be destroyed. The cost of these damages have not been included in the analysis.

8.3.1.2. Direct Structural Damages

Structural damages were assumed follow the relationship adopted in DECC (2007) for houses. This varies for houses on slab/low set, high set houses and two storey houses. In floods larger than the 1% AEP event there is the possibility that some buildings may collapse or have to be destroyed. The cost of these damages have not been included in the analysis.

8.3.1.3. Direct External Damages

External damages (laundry/garage/yard/vehicle) were assumed to $10,050 for houses and $5,025 for tourist accommodation. This assumes that the majority of vehicles and items are moved by residents.

8.3.1.4. Indirect Damages

Indirect damages were assumed to be a linear relationship from $0 at 0 m above floor level to a maximum of $6,990 at 0.5 m.

8.3.1.5. Summary of Damages

Properties in the Lower Bellinger Kalang Catchment were classified into residential and commercial properties. A summary of the damage values for the classified property types is shown in Table 12.

Table 12: Damage Values for Property Types

Damage Type	Residential ($)	Commercial ($)
Direct Internal	$76,500	$111,563
Direct Structural (Low set to High Set)	$45,988 - $61,300	$67,066 - $89,397
Direct External	$10,050	$3,000
Indirect	$6,330	$9,000

Damages calculated for the Lower Bellinger Kalang Floodplain are provided in Table 13. A total of 293 houses within the floodplain are flooded in a 1% AEP event and approximately 1062 properties are flooded above floor level in the PMF event. A total of 31 properties have been identified in the Lower Bellinger and Kalang Rivers catchment, that are flooded above floor level in events of 20% AEP or more frequent. This flood damages estimate does not include the cost of restoring or maintaining public services and infrastructure. It should be noted that damages calculations do not take into account flood damages to any basements or cellars, hence where properties have basements, damages can be under estimated.

Table 13: Estimated Combined Flood Damages for the Lower Bellinger Kalang Floodplain

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
5 Year ARI	121	31	$1,389,400	$11,500
5%	214	62	$3,465,200	$16,200
1%	557	293	$19,327,200	$34,700
0.2%	712	588	$46,140,400	$64,800
PMF	1112	1063	$145,018,900	$130,400
		Average Annual Damages (AAD)	$1,827,800	$1,600

Table 14 provides a breakdown by area. In Bellingen (Cemetery Creek) there is a significant increase in houses flooded in the PMF compared to smaller events indicating that most properties are built above the 1% AEP level. The majority of properties are built at higher levels, possibly due to the frequency of flooding in the area.

In 1% AEP event, there are approximately 38 properties in Urunga and 57 properties in Central Drainage Line (North Bellingen) that are flood affected above floor level.

Table 14: Number of properties first flooded by area and event

Event (AEP)	Urunga		Cemetery Creek		Central Drainage Line		Other	
	First flooded above Ground	First flooded above Floor	First flooded above Ground	First flooded above Floor	First flooded above Ground	First flooded above Floor	First flooded above Ground	First flooded above Floor
Not Flooded	19	28	10	32	10	19	15	21
5 Year ARI	48	8	22	8	31	11	20	4
5%	6	3	15	4	30	6	42	18
1%	44	27	19	15	18	40	262	149
0.2%	24	37	10	15	2	13	119	230
PMF	51	89	80	86	36	39	234	275
Total	192	192	156	160	127	128	692	697

8.4. Climate Change

There is strong evidence that increases in global temperatures will lead to an increase in the intensity of rare rainfall, and that extreme flooding globally has increased over the 20th century (Reference 35). Global warming has been observed for several decades and has been linked to changes in key parts of the hydrologic cycle including changes in rainfall behaviour, rainfall intensity, soil moisture and runoff (Reference 36). Climate change can alter flood behaviour in the catchment by changing:

- Probability of long duration rainfall intensities;
- Storm type and frequency;
- Rainfall spatial and temporal patterns; and
- Antecedent conditions.

The interaction of these characteristics makes predicting the impact of climate change on flood behaviour complex.

8.4.1. Rainfall depth and frequency

The interaction of a warming climate and rainfall is complex. A warmer climate leads to an increase in the potential moisture-holding capacity of the atmosphere which is one of the key factors in the depth of precipitation in rarer rainfall events, however on large catchments like the Bellinger and Kalang Rivers long duration rainfall events are also dependant on sources and transport of moist air. Statistically significant increases in rainfall intensity have been detected in Australia for short duration rainfall events and are likely to become more evident towards the end of the 21st century (Reference 38). Changes in long duration events are expected to be smaller and harder to detect, but projections analysed by Reference 37 showed that an increase in daily precipitation intensity is likely under climate change. It is worth noting that a warming climate can lead to decreases in annual rainfall along with increases in flood producing rainfall.

8.4.2. Storm type and frequency

Nearly all of the large flood-producing events on the Bellinger and Kalang Rivers have been either caused by east coast lows or the interaction of east coast lows and other rain-producing systems. East coast lows are the major flood producing mechanism on large catchments on the east coast of NSW and are being very actively studied. The historical flood record on the NSW and Victorian east coast shows that floods produced by east coast lows are less prevalent further south. If climate change pushes east coast low events further south than it is plausible in the catchment that the frequency of east coast low events will increase.

8.4.3. Spatial and temporal rainfall behaviour

The influence of warmer climate on the spatial and temporal aspects of rainfall is not as well understood as the likely changes in rainfall intensity. Work by Abs et al. (Reference 34) suggests that increases will be more pronounced in areas with strong orographic enhancement which could lead to larger increases in upper reaches of the catchment. Work by Wasco and Sharma (Reference 33) analysing historical storms found that, regardless of the climate region or season, temperature increases are associated with rainfall patterns becoming less uniform, with the larger fractions increasing in rainfall intensity and the lower fractions decreasing.

8.4.4. Antecedent conditions

Changes to rainfall and evaporation as a result of climate change will impact on the antecedent conditions prior to an event. It is likely that evaporation will increase (Reference 36) by 2030 and 2070 by approximately 2%. Increased evaporation in combination with decreased rainfall could result in decreases in annual runoff, and hence drier antecedent conditions. The impact on flood events is likely to be less consistent.

8.4.5. Assessment of climate change impacts

The 2005 Floodplain Development Manual (Reference 21) requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change (sea level rise and rainfall increase) on flood behaviour. A range of climate change scenarios have already been considered in the Flood Study (Reference 31). The following climate change scenarios (rainfall by the year 2070) are considered in this climate change assessment:

- **Increase in peak rainfall and storm volume:**
  - low level rainfall increase = 10%,
- **Sea level rise:**
  - a 0.4m increase in level by year 2050
  - a 0.9m increase in level by year 2100

There are many uncertainties associated with the impact of climate change on rainfall intensity. A research project undertaken by Engineers Australia, CSIRO and the Bureau of Meteorology as part of the revision of Australian Rainfall and Runoff provides direction on the possible impacts of climate change on flooding. This work recommends an interim approach to calculate increases to rainfall intensity based on simple temperature scaling using temperature projections from the CSIRO future climates tool. Scaling based on temperature is recommend as climate models are much more reliable at producing temperature estimates than rainfall, and an ensemble of climate models can be used to estimate annual mean surface temperature. A value of 10% rainfall increase is consistent with the Australian Rainfall and Runoff recommendations. Council should continue to review the climate change literature and its policies periodically.

A 10% increase in rainfall results in up to a 0.47m increase in flood levels with an increase of approximately 0.3m at most locations. A 0.4m and 0.9m sea level rise result in an increase in flood levels in the lower to mid reaches of the Bellinger and Kalang rivers. A 0.4m and 0.9m increase in sea levels would result in a 0.22m and 0.70m increase respectively, in 1% AEP flood levels at the confluence of the Bellinger and Kalang Rivers. Table 15 summarises the impact of climate change on the 1% AEP flood levels. Table 15 and Figure 62 to Figure 68 present the climate change peak flood levels and depths.

Table 15: Climate Change Results

Location	1% AEP Flood Level (mAHD)	Change in Flood Level (m)		
		10% Rainfall Increase	0.4m Sea Level Rise	0.9m Sea Level Rise
Fernmount	7.77	0.30	0.00	0.00
U/S Pacific Highway Bellinger River	5.64	0.25	0.00	0.00
Mylestom	3.95	0.32	0.00	0.00
Confluence Bellinger and	2.32	0.47	0.22	0.70

Kalang Rivers				
D/S Newry Island	3.61	0.34	0.00	0.00
U/S Newry Island	3.99	0.28	0.00	0.00
U/S Brierfield Bridge	9.66	0.37	0.00	0.00
Confluence Picket Hill Ck	4.53	0.28	0.00	0.00
Opposite Norco	5.01	0.22	0.00	0.00
MHL Newry Island U/S Gauge	4.07	0.28	0.00	0.00
MHL Urunga Gauge	3.45	0.36	0.00	0.00
MHL Repton Gauge	4.66	0.25	0.00	0.00
Lavenders Bridge	11.08	0.31	0.00	0.00
Cemetery Creek U/S of Ford Street	10.15	0.29	0.00	0.00
Central Drainage Line, US of Wheatley Street	11.25	0.23	0.00	0.00
Urunga U/S Railway	3.82	0.11	0.00	0.00
Urunga Bowling Club	3.70	0.14	0.00	0.00

9. INFORMATION TO INFORM DECISIONS ON ACTIVITIES IN THE FLOODPLAIN AND MANAGING FLOOD RISK

9.1. Flood Emergency Response Classification

Managing the floodplain: a guide to best practice in flood risk management in Australia (Reference 29) provides guidance on how to categorise emergency response requirements on the Floodplain. Flood studies are required to address the management of continuing flood risk to both existing and future development areas. As continuing flood risk varies across the floodplain, so does the type and scale of the emergency response problem and therefore the information necessary for effective Emergency Response Planning (ERP). Classification provides an indication of the vulnerability of the community in flood emergency response and identifies the type and scale of information needed by the State Emergency Services (SES) to assist in emergency response planning (ERP).

Criteria for determining flood ERP classifications and an indication of the emergency response required for these classifications are provided in the Floodplain Risk Management Guideline, 2007 (Flood Emergency Response Planning: Classification of Communities). Table 16 summarises the response required for areas of different classification. However, these may vary depending on local flood characteristics and resultant flood behaviour, i.e. in flash flooding or overland flood areas.

Table 16: Response Required for Different Flood ERP Classifications

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
Flooded Isolated Elevated	Yes	Possibly	Possibly
Flooded Isolated Submerged	No	Yes	Yes
Rising Road	No	Possibly	Yes
Overland Escape	No	Possibly	Yes
Indirect Consequence	Possibly	Possibly	Possibly

The classifications used are described below, taken directly from the Floodplain Risk Management Guideline.

- Flooded Isolated Elevated (FIE). The area includes enough land higher than the limit of flooding (i.e. above the PMF) to cope with the number of people in the area. During a flood event the area is surrounded by floodwater and property may be inundated. However, there is an opportunity for people to retreat to higher ground above the PMF within the island and therefore the direct risk to life is limited. The area will require resupply by boat or air if not evacuated before the road is cut. If it will not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs. These could be areas that are isolated completely by floodwater, or by a combination of floodwater and terrain impassable by foot.
- Flooded Isolated Submerged (FIS). The area is lower than the limit of flooding (i.e. below the PMF) or does not have enough land above the limit of flooding to cope with the number

of people in the area. During a flood event the area is isolated by floodwater and property will be inundated. If floodwater continues to rise after it is isolated, the island will eventually be completely covered. People left stranded in the area may drown and property will be inundated. These could be areas that are isolated completely by floodwater, or by a combination of floodwater and terrain impassable by foot.

- Areas that are flooded with Rising Road Access (FER) are those areas where access roads rising steadily uphill and away from the rising floodwaters. The community cannot be completely isolated before inundation reaches its maximum extent, even in the PMF. Evacuation can take place by vehicle or on foot along the road as floodwater advances. People should not be trapped unless they delay their evacuation from their homes. For example people living in two storey homes may initially decide to stay but reconsider after water surrounds them.
- Areas that are Flooded with an Overland Escape Route (FEO) are those areas where access roads to flood free land cross lower lying flood prone land. Evacuation can take place by road only until access roads are closed by floodwater. Escape from rising floodwater is possible but by walking overland to higher ground. Anyone not able to walk out must be reached by using boats and aircraft. If people cannot get out before inundation, rescue will most likely be from rooftops.
- Not Flooded, with Indirect Consequences (NIC). These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.

The Emergency Response Classifications for the catchment were derived during the Flood Study using the Categories outlined in the AIDR National Manual (Reference 29).

The ERP classifications for regions within the hydraulic model extent have been defined for the range of flood events including the PMF. These are shown in Figure 55. Based on the classifications, evacuation should prioritise those areas where evacuation access is limited or unsafe, once they become inundated. Based on this assessment, Newry Island should be prioritised for evacuation assistance.

9.2. Flood Planning Constraint Classifications

AIDR National Manual (Reference 29) provides guidance on the how to classify land within the floodplain based on its Flood Risk. The guidance takes into account the Hazard Categorisation and Hydraulic Categorisation of the Design Flood Event and a flood event larger than the Design Flood Event, the Flood Planning Area and the PMF extent.

There are four Flood planning constraint categories. The intent of these categories is to collapse all the flood study mapping outputs into areas of consistent constraints. The FPCCs categorise the floodplain into areas ranging from the most constrained (and therefore least suitable for intensification of land use or development—FPCC1), to the least constrained (and therefore more suitable for intensification of land use or development—FPCC4).

The flood planning constraint classifications are presented in Figure 56 to Figure 58. Those areas classified as FPCC 1 require more planning controls. Those areas include large areas of the floodplain.

10. OPTIONS ASSESSMENT

10.1. Overview

The 2005 NSW Government Floodplain Development Manual (NSW State Gov, 2005) separates risk management measures into three broad categories:

Flood modification measures modify the physical behaviour of a flood (depth, velocity and redirection of flow paths) and include flood mitigation dams, retarding basins and levees.

Property modification measures modify land use and development controls. This is generally accomplished through means such as flood proofing (house raising or sealing entrances), strategic planning (such as land use zoning), building regulations (such as flood-related development controls), or voluntary purchase.

Response modification measures modify the community's response to flood hazard by educating flood affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

Table 17 provides a summary of the floodplain risk management measures that could be considered for the Lower Bellinger and Kalang River floodplains.

Table 17: Floodplain Risk Management Measures

Flood Modification	Property Modification	Response Modification
Flood mitigation dams	Land zoning	Community awareness/preparedness
Retarding basins	Voluntary purchase	Flood warning
Bypass floodways	Building & development controls	Evacuation planning
Channel modifications	House raising	Evacuation access
Levees	Flood proofing	Flood plan / recovery plan
Temporary Flood Barriers	Flood access	Flood insurance

10.1.1. Relative Merits of Management Measures

A number of methods are available for judging the relative merits of competing measures. The benefit/cost approach has long been used to quantify the economic worth of each option, enabling ranking against similar projects in other areas. It is a standard method for using the time value of money to appraise long-term projects in terms of the reduction in flood damages (benefit) compared to the cost of the works. Generally, the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical benefit/cost approach.

10.2. Measures not considered further

10.2.1. Floodways

Floodways are designed to redirect high velocity flows away from critical areas and reduce flood levels in specific locations. However, they require suitable available land, and can increase downstream flooding by diverting floodwaters away from their natural or existing path. Therefore they are not considered further.

10.2.2. Levees, Floodgates and Pumps

Levees are built as means of eliminating the inundation of floors and yards during a flood event (up to the design height of the levee together with a freeboard allowance of typically 0.5 m). Levees can be successfully employed on large river systems where they protect a large number of properties. They often comprise earthen embankments but can also be constructed as concrete walls or other similar structures.

Unless designed for the PMF, levees will be overtopped. Under overtopping conditions the rapid inundation may produce a situation of greater hazard than exists today. This may be further exacerbated if the community is under the false sense of security that a levee has “solved” the flood problem (as happened with Nyngan in 1990 and Hurricane Katrina in New Orleans, USA).

In the event of levee failure, properties impacted are likely to experience relatively short to no warning time of the failure, resulting in high velocities and high inundation depths in a relatively short period of time and therefore a high provisional hazard. It should be noted that overtopping of a levee is not considered failure of the levee, as the levee may have been designed to overtop in some events. A large number of houses are not built to withstand the hydrostatic pressure that would be present following failure of the levee and ponding of floodwater.

Flood gates or rubber flap valves allow local runoff to be drained from an area (say an area protected by a levee) when the external level is low, but when the river is elevated, the gates prevent floodwaters from the river entering the area.

Pumps are generally also associated with levee designs. They are installed to remove local runoff behind levees when flood gates are closed or if there are no flood gates.

Levees, floodgates and pumps were considered in the preliminary options assessment. A levee was initially considered in the vicinity of Ford Street however the benefit was likely to be limited and may result in impacts on nearby houses. As the development within the study area is largely scattered rather than large towns there is limited opportunities to build a levee with large benefits.

10.3. Flood Modification Measures

10.3.1. Introduction

Flood modification measures aim to modify the behaviour of a flood itself by reducing flood levels or velocities or by excluding water from areas under threat. These measures usually involve structural works (often permanent, though temporary structures can also be assessed) which are generally installed to modify flood behaviour on a wider scale.

10.3.2. Flood Mitigation Dams and Retarding Basin

DESCRIPTION

Dams have been used in rural areas of NSW to reduce peak flows downstream. However, typically their main purpose is for water supply. Dams are rarely used as a flood mitigation measure on account of the:

- high cost of construction,
- high environmental damage caused by the construction,
- possible sterilisation of land within the dam area,
- high cost of land purchase,
- risk of failure of the dam wall,
- likely low benefit cost ratio, and
- lack of suitable sites, as a considerable volume of water needs to be impounded by the dam in order to significantly reduce flood levels downstream.

Based on an assessment of the catchment and taking into account the above factors, flood mitigation dams were not considered further.

Retarding basins are small-scale flood mitigation dams commonly used in urban catchments for the same reasons. A retarding basin provides temporary storage for floodwaters, and works by capturing floodwaters during an event, to be released at a lower flow rate once the peak of the flood has passed. Retarding basins can be an effective means of reducing peak flood levels, however depending on the outlet design and operation, may increase the duration of flooding by prolonging the release of stored floodwaters.

DISCUSSION

Although commonly suggested by community members, there are a number of challenges and inherent disadvantages associated with retarding basins, that need to be carefully evaluated. These include:

- Availability of land and appropriate topography – a significant area is needed to achieve the necessary storage capacity,
- Public safety during and following a flood event, particularly for basins of significant area and/or depth,
- Risk of overtopping or failure if the dam is already full when additional rainfall occurs (e.g. long duration floods or multi-burst storms),

- Ongoing maintenance to ensure structural integrity of the basin wall/embankment, and to prevent outlet pipes and gates from silting up or being damaged.

OPTIONS CONSIDERED

10.3.2.1. Basin Upstream of Railway in Urunga (Option FM1)

The North Coast Railway line at Urunga forms an informal basin on currently vacant land upstream of the railway line. Water ponds to a depth of 1.3m in a 1% AEP event. A basin was modelled that required the excavation of an area approximately 600m² up to 2m depth. Increasing the storage behind the railway embankment would not only reduce flood levels for properties upstream of the railway but also for properties in Urunga.

In the 5% AEP event, the basin reduces peak flood levels in residential area upstream of the basin by 0.14m. In the same event, flood levels in Urunga CBD are reduced up to 0.4m at the intersection between Bonville Street and Newry St E. The impacts are displayed in Figure C2 to Figure C6.

The impact of the option on the average annual damages is summarised in Table 18.

Table 18: Reduction in Damages - Basin Upstream of Railway in Urunga

Event	Reduction in Property Flooding	Reduction in Above Floor Level Flooding	Reduction in Damages
5 Year ARI	0	0	$100
5%	1	2	$156,300
1%	0	0	$56,400
0.2%	0	0	$7,200
PMF	0	0	-$700
Average Annual Damages (AAD) Reduction			**$16,200**

The modification of the vacant land would require significant approvals and involve design constraints. The existing railway embankment is unlikely to have been designed to store significant volumes of water. Retrofitting the embankment to withhold water is likely to be costly.

Basins of this size also pose safety issues both within the basin and downstream should failure occur.

The benefit cost ratio of this option is 0.17.

While the safety issues and low benefit cost ratio are noted, this option had some community support during public exhibition.

10.3.2.2. Basin Near Urunga Recreation Ground (Option FM7)

A basin and rerouting of flow from upstream of the railway embankment was suggested by members of the FMC towards the sports ground. This option was considered, however an inspection of the topography and rail corridor reveals this option would not be feasible and has not been assessed in the hydraulic model. This option has not been progressed to the FRMP.

10.3.2.3. Additional Storage on Cemetery Creek (Option FM8)

Additional Storage may be considered in the carpark behind Memorial Hall, Bellingen. While this option has not been assessed in the hydraulic model, a combination of Water Sensitive Urban Design (WSUD) initiatives such as permeable pavements, may reduce the ponding of water in this area. This option has not been progressed to the FRMP.

SUMMARY AND RECOMMENDATIONS
While this option reduces average annual damages, it is not recommended to be progressed into the plan.

10.3.3. Channel Modifications

DESCRIPTION
Channel works include any measure that increases the hydraulic efficiency of the main channel or immediate overbank areas. In this way, flood levels are reduced by either increasing the waterway area or increasing the velocity of flow. Measures include:

- vegetation or other forms of clearing,
- channel widening,
- dredging,
- concrete lining,
- creek shortening,
- removal, raising or upgrading of hydraulic structures (bridges, roads).

All the above measures have been employed at various times on different river systems in NSW. However, apart from local areas, these measures are now generally not considered to be environmentally and economically sustainable. In addition, they may introduce additional problems such as bank erosion, sedimentation, issues with land ownership and permission, increases in flood levels downstream, and these measures require an on-going maintenance regime.

DISCUSSION
As part of the consultation with the committee and as documented in previous studies a number of channel modification options were considered including:

- Increasing the riparian zone upstream of Bellingen (Figure C7)
- Stormwater pipe upgrades under Morgo Street, Urunga (Figure C10)
- Addition of Open drain upstream of Morgo Street, Urunga (Figure C16)

- Increasing culvert capacity under the railway line at Urunga (Figure C18)
- Wheatley Street culvert
- Dredging the Bellinger Kalang River at the Entrance
- Maintenance plan for removal of blockage for culverts (refer to Section 6.2.1)

The hydraulic model was modified to represent these changes to the catchment and assess the impact on flood levels in relevant AEP events.

10.3.3.1. Riparian Vegetation (Option FM2)

The presence of vegetation on the floodplain can both slow the flow of water and increase flood levels. This option involves the revegetation of 2km of river bank for a width of 50m upstream of Bellingen to reduce flood levels within the town.

Figure C8 and Figure C9 show the impacts of the riparian revegetation upstream of Bellingen compared to the existing conditions for the 20% and 1% AEP event. This option created increases in flood level for these events upstream of town of 0.798m and 1.17m respectively. The option did not have a significant impact on peak flood levels in town. Additionally, consultation with the committee revealed anticipated difficulties with the management and maintenance of a mitigation option on privately owned farmland.

While riparian revegetation is very important for an ecological perspective, with benefits of the wetland rehabilitation and increase groundwater recharge rates, large scale replanting can cause increases in flood levels. The Flood Study did an assessment on the increase of roughness (Manning's values) across the catchment with the largest increases (greater than 300mm) occurring at Lavenders Bridge, Fernmount and Brierfield Bridge. Increasing riparian vegetation downstream of these would therefore cause increases for flood levels. Conversely, increases in Manning's values in the vicinity of Newry Island and Urunga cause less than 200mm increase (typically 160mm), which may be acceptable on agricultural land.

Future Studies will assess flooding in the upper Bellinger and Kalang rivers, however an intermediate assessment of increasing the lag parameter results in a 3% reduction in flow from the existing 1% AEP value of 4235 m^3/s at Lavenders Bridge.

SUMMARY AND RECOMMENDATIONS
The specific riparian re-vegetation option modelled is not recommended due to issues with maintenance and impact on flood levels. However, it is recommended that the existing vegetation in the catchment is maintained and protected. Council to encourage revegetation and wetland rehabilitation.

10.3.3.2. Stormwater Upgrades (Option FM3 and FM4)

A number of drainage options have been suggested for Morgo Street Urunga in the past. The Degroot and Benson report (Reference 40) presented design and cost estimates for two options. The options considered are:

- Two 1.2m pipes from Bonville Street to the River (refer to Figure C10 and Diagram 9, FM3)
- A 5m wide drain and pipe option (refer to Figure C16 and Diagram 8, FM4)

Diagram 8: Two 1.2m pipes option- Morgo St Urunga

The twin pipe option consists of two 1.2m diameter pipes that run from Bonville Street along Minerva Lane then across to Morgo Street and through the caravan park to the river. Figure C11 to Figure C15 represent the impacts of the option on flood levels compared to current conditions. The option results in a reduction of flood levels. The maximum reduction achieved for a 1 % AEP event is 0.24m along Newly St E. The impact of the option on the average annual damages is summarised in Table 19. The option reduces the average annual damages by approximately $16,800. The implementation cost of the option is high (estimated by Degroot and Benson to be $700,000 (2009)).

Table 19. Reduction in Damages – Stormwater Upgrade (FM3)

Event	Reduction in Property Flooding	Reduction in Above Floor Level Flooding	Reduction in Damages
5 Year ARI	0	0	$300
5%	0	1	$103,000
1%	2	4	$190,700
0.2%	8	6	$465,900
PMF	0	0	-$1,700
Average Annual Damages (AAD) Reduction			**$16,800**

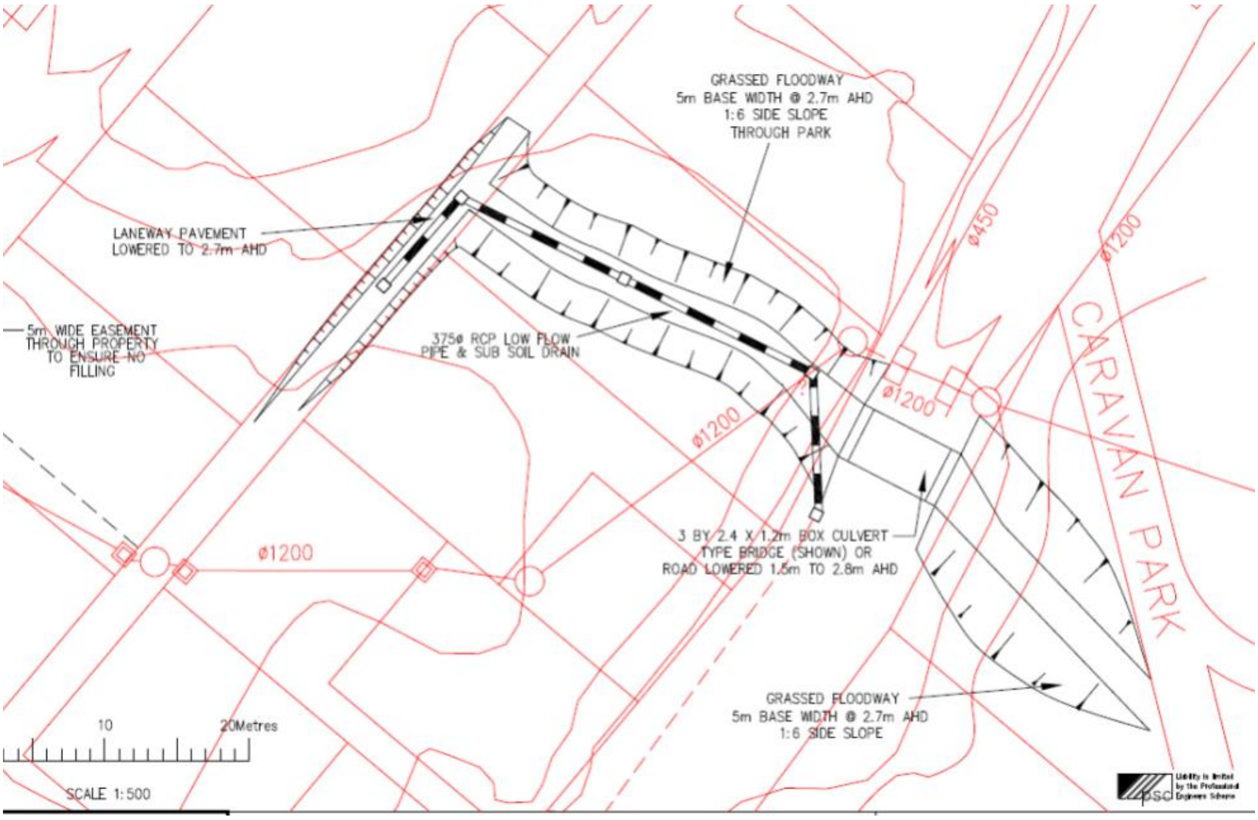


Diagram 9: 5m wide drain and pipe option – Morgo St Urunga (source:De Groot and Benson)

The drain and pipe Morgo Street option (Diagram 9) consists of a 5m wide drain and 3 of 2.4mx1.2m box culverts. The drain and culverts transport floodwaters through the reserve and under Morgo Street.

Figure C17 depicts the impacts in the 1% AEP event for the upgrade of the stormwater system compared to existing conditions. The pipe upgrade option performs better than the open drain option, with the open drain having a very localised and negligible impact on flood levels. The maximum reduction achieved for the 1% AEP event is 0.236m near Newry St E. The implementation cost of the option is estimated by Degroot and Benson to be $325,000 (in 2009).

The benefit cost ratio of this option is 0.18.

10.3.3.3. Increased Culvert Capacity (Option FM5)

Increasing culvert capacity reduces the amount of water stored upstream of the culvert. However it also has the effect of increasing the water downstream of the culvert. This option was considered for the culvert under the North Coast Railway line at Urunga where significant ponding occurs. Figure C18 depicts the location of the increased culvert capacity under the existing railway at Urunga.

While the option does reduce flood levels upstream of the railway it increases downstream flood levels in a 1% AEP by 0.08m (Figure C19).

SUMMARY AND RECOMMENDATIONS
The option was not considered further as it would increase the flooding in the Urunga town centre downstream. Sensitivity testing of the existing culvert shows that a 50% blockage of the existing pipe results in a 0.64m increase upstream of the embankment and a 0.62m increase downstream of the embankment.

10.3.3.4. Wheatley Street Upgrades (Option FM6)

A number of measures for reducing flood risk for Wheatley Street have been suggested, including by GHD 2017. However, these did not consider the interaction of riverine flooding with the local catchment of the North Bellingen Central Drainage Line, and the drainage systems downstream of Wheatley Street. The Lowering of Wheatly Street to reduce the volume of flow ponding upstream of the road was considered by not assessed in the hydraulic model. This is because and lowering of the road is likely to increase flood levels downstream on residential properties in local events, and in river dominated events, the river would backwater over the road to a larger extent.

SUMMARY AND RECOMMENDATIONS
While there is some ponding behind Wheatley Street, a desktop assessment of the topography determined it is unlikely that a basin in this area would provide a sufficient reduction in flood levels. No upgrade works are recommended to be progressed to the Floodplain Risk Management Plan.

Dredging the Bellinger Kalang River at the Entrance (Option FM7)
Prior to floods, there can be a natural accumulation of sediment in the river mouth which is then scoured away during the course of the flood event. Modelling in this report accounts for this scour during events, with the level of scour varying depending on the size of the flood, and is based on survey prior to and after the 2009 flood event (refer to the Flood Study for details).

Dredging in the river is not often successful as it requires a high level of maintenance to be valuable during a flood event. The high level of maintenance results in what are often prohibitive costs unless it is related to other uses such as access for large boats or sand extraction. Additionally, this relatively small benefit is balanced against significant environmental costs, including:

- higher tidal ranges within the estuary,
- extension of the tidal range further up the river,
- ingress of marine sand and sediment into the estuary at higher volumes, which can have both environmental and agricultural impacts, and
- degradation of estuary ecosystem and impact on river ecology.

SUMMARY AND RECOMMENDATIONS
For the above reasons, there to not sufficient benefit to justify the prohibitive cost and environmental impacts of dredging the river entrance, and thus it is not recommended to be included in the plan.

10.3.3.5. Maintenance plan for removal of blockage for culverts (Option FM9)

A hydraulic assessment where all bridges with spans less than 6m and all culverts were blocked by 50% determined that the majority of the study area is insensitive to blockage, however in Urunga, blockage results in an increase of flood levels in the 1% AEP of up to 0.75m. The impacts of blockage are localised to the structures and mostly minimal (refer to Table 8). However this can be a nuisance, and can be mitigated with a maintenance plan for the regular clearing of blockage from culverts.

SUMMARY AND RECOMMENDATIONS

A culvert maintenance plan should be developed and implemented as part of council's general operations with a focus on the urban areas of Urunga and Bellingen.

10.4. Property Modification Measures

10.4.1. Flood Access

DESCRIPTION

One of the main ways of improving evacuation is to ensure that there are adequate evacuation routes available and appropriate warnings as to when the routes will become impassable.

DISCUSSION

Maintaining appropriate access to or from affected areas during times of flooding is important to ensure that:

- people have the chance to evacuate themselves and valuables/belongings before becoming inundated or trapped by rising floodwaters,
- emergency services (NSW SES, ambulance, police, etc.) are not restricted or exposed to unnecessary hazards in carrying out their duties, and
- areas are not isolated for extended periods of time, preventing people from going about their normal routines or business or restricting access to essential services.

There are a number of issues to be considered in raising roads including:

- the relatively high cost,
- the level they should be raised to,
- how much benefit is provided,
- whether the raising of the road causes an unacceptable hydraulic impact, and
- the entire evacuation route needs to be raised to a minimum serviceability level from the affected area to high ground.

A number of road raising options were modelled in the hydraulic model.

10.4.1.1. Bridge Modification Options (Option PM1 and PM2)

Lavenders Bridge, which spans the Bellinger River, is understood by the local community to be highly flood prone, and is largely an accepted flood risk, with closures of the bridge due to flooding at least once per year on average (see Section 8.1.1). The current deck level is 4.7mAHD. Despite some community acceptance of the existing flood risk, the level of the bridge poses a large hazard to residents. During an event, residents in North Bellingen are isolated from emergency services.

The closing of the bridge at such a low level places extra operational stresses on the NSW SES. Increasing the deck level would provide less disruption to daily life during events. Daily life would also return to normal more quickly following an event. It would also give the NSW SES more time at the start of an event to get resources in place. Options to raise the bridge level were evaluated as part of the study.

This option has been assessed for two deck levels to understand what benefits can be achieved:

- PM1 – 50% AEP level (approximately 2m higher than the existing deck)
- PM2 – 5 Year ARI level (3.1m higher than the existing deck)

The hydraulic model was modified to raise the deck level of the bridge. The current bridge pier arrangement is a significant blockage risk therefore less piers and obstruction to flow have been assumed. The bridge has been assumed to be in the same location as the current bridge.

Effect on flood levels

For the 50% AEP deck level option (PM 1) the deck level was modified in the hydraulic model to be 6.6mAHD. The location and size of the option is mapped in Figure C20. Diagram 10 illustrates the existing and proposed deck level and 1% AEP and 5% AEP event flood levels at the Lavenders Bridge cross section.

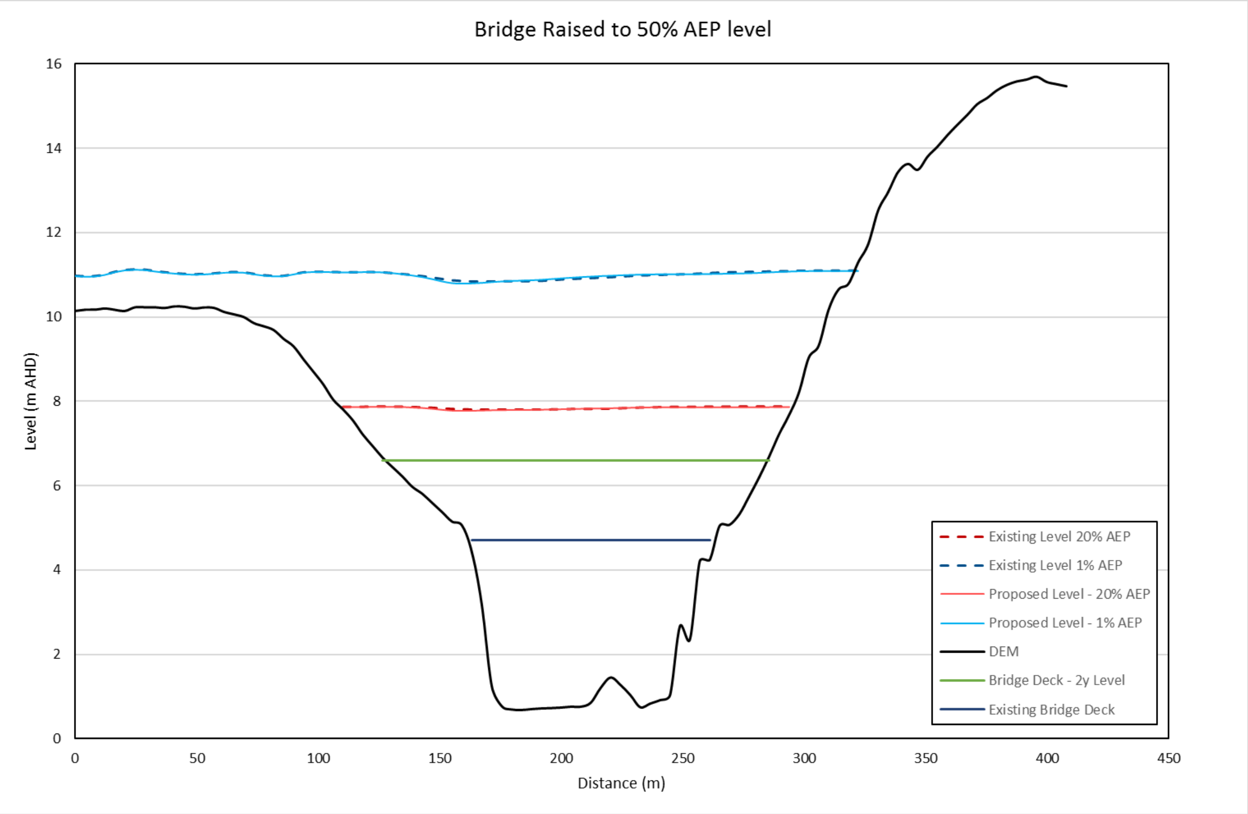


Diagram 10. Raising Lavenders bridge to 50% AEP level – cross section

The results for the 20% AEP and 1% AEP event are shown in Figure C21 and Figure C22. The 20% AEP and 1% AEP events near Lavenders Bridge result in maximum increases in flood levels respectively of 0.012m and 0.046m. Maximum reductions of flood levels of 0.014m and 0.063m occur at Lavenders Bridge for the 20% AEP and 1% AEP event respectively. Flood impacts in the 20% AEP event show that raising Lavenders Bridge does not have a significant impact on the nearby properties. However, in the 1% AEP event, one property experiences an increase in peak flood level of roughly 30 mm.

Option PM 2 involved modelling the bridge deck level at the 1 in 5 ARI level (7.8 m AHD). The location and size of the option is mapped in Figure C23. Diagram 11 illustrates the existing and proposed deck level and 1% AEP and 5% AEP event flood levels at the Lavenders Bridge cross section.

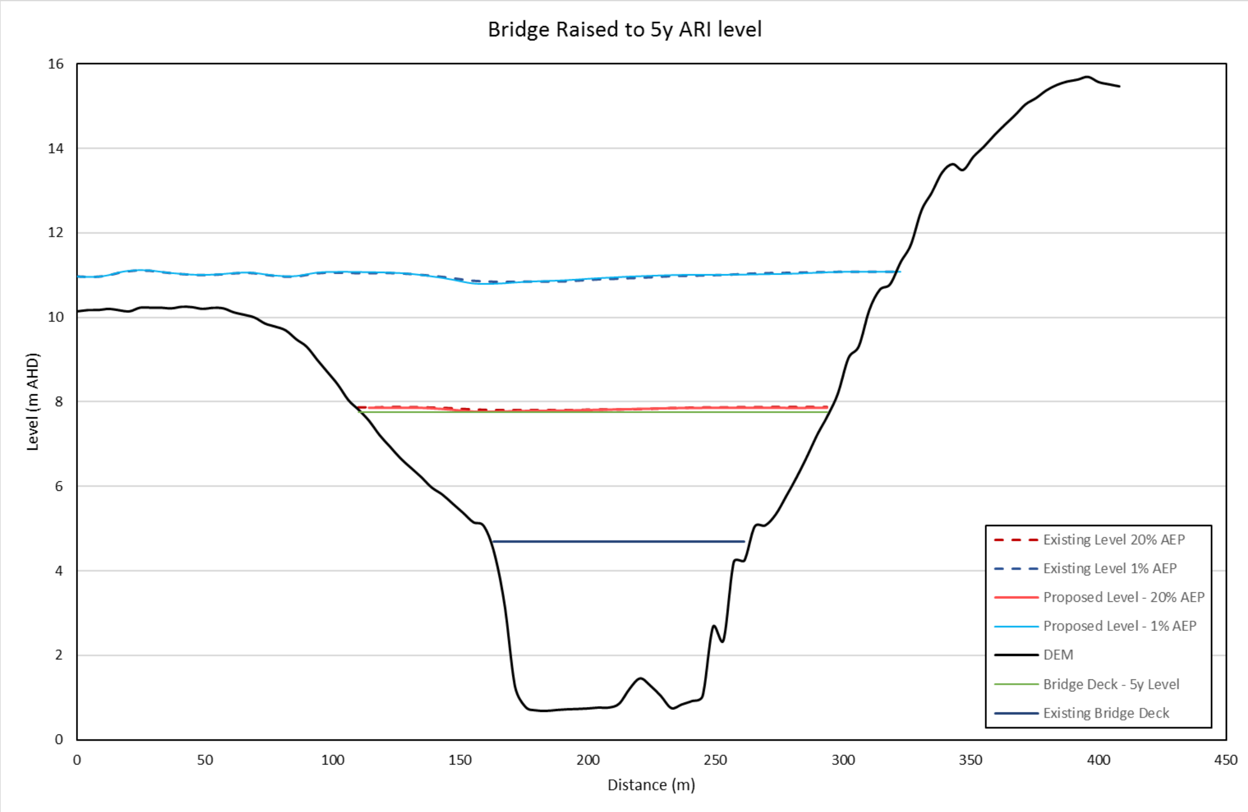


Diagram 11. Raising Lavenders bridge to 5 Year ARI level – cross section

The flood level impacts for the 5y ARI and 1% AEP event are shown in Figure C24 and Figure C25. In the 5y ARI event flood levels through Bellingen are reduced by up to 30mm as the new bridge has been modelled with fewer piers and blockage, making it a more efficient structure than the existing bridge. In the 1% AEP event, some increases of up to 0.049m occur at properties in North Bellingen on Hammond Street. There is no measurable increase in flood level to private properties in the Bellingen CBD in both the 5y ARI and 1% AEP events.

Effect on closure time

The current bridge deck is estimated to be closed for 45.7 hours on average per year. If the bridge was raised by 1.6m to the level of a 50 % AEP flood (approximately 6.6m AHD), the duration of inundation reduces by approximately 30% to 32.9 hours (Table 20). Raising the bridge to the level of the 5 Year ARI event would involve significantly increasing the level of the bridge by 3.1m. This would reduce the AAToC to 12.5 hours. Therefore the bridge would only close for to 25% of the time it currently closes during an year.

Table 20: AAToC for Lavenders Bridge (Raised to a 50% AEP flood immunity)

AEP (%)	ARI (years)	Duration of Closure (hours)	AEP probability of closure	fT(T)	Δp	Δp *ToC
50.00	0.4*	0.00	0.31	0.00	0.00	0.00
18.13	5	41.50	0.80	0.01	0.49	20.46
5.00	20	61.50	0.95	0.01	0.15	9.23
1.00	100	65.00	0.99	0.01	0.04	2.60
0.20	500	70.25	1.00	0.00	0.01	0.56
	PMF	42.75	1.00	0.00	0.00	0.09
					AATOC (hours)	**32.9**

Table 21: AAToC for Lavenders Bridge (Raised to a 5 Year ARI flood immunity)

AEP (%)	ARI (years)	Duration of Closure (hours)	AEP probability of closure	fT(T)	Δp	Δp *ToC
18.13	5	0.00	0.80	0.00	0.00	0.00
5.00	20	61.50	0.95	0.00	0.15	9.23
1.00	100	65.00	0.99	0.01	0.04	2.60
0.20	500	70.25	1.00	0.00	0.01	0.56
	PMF	42.75	1.00	0.00	0.00	0.09
					AATOC (hours)	**12.5**

Discussion

The bridge options assessed have been assumed to be in the same location as the current bridge however subsequent discussions with Council's engineering staff suggest moving the bridge location slightly will make construction easier without disrupting traffic.

Concerns were raised by the community representatives in the Committee with regards to the aesthetic value of the existing bridge. The community value of this highly photographed aspect of Bellingen is acknowledged. All attempts should be made to make use natural materials such as wood or maintain the aesthetic of the existing bridge.

A new bridge would need to be designed to maintain or enhance existing river amenity, including recreational areas on the north and south banks, and access to the river. Additionally, the proposed design of the bridge will need to ensure that any existing traffic congestion is not exacerbated, and this will provide most benefit in the same corridor as the current bridge.

Option PM1 requires the construction of a new, likely concrete structure bridge, 2m higher than the existing bridge, and constitute major works. All efforts should be made to build a bridge that looks as natural as possible. Cost of additional works to ensure the structural integrity of the existing bridge needs to be evaluated and weighted against the cost of the new bridge.

The existing bridge was built in 1993 and may be nearing the end of its design life. A recent survey of the current bridge found it is structurally sound therefore this option should be progressed as an option for when the bridge is no longer sound, should damage occur to the bride during an event or funding becomes available.

Raising Lavenders bridge deck provides a localised reduction in flood levels with minimal impact on surrounding properties. This option has significant intangible benefits including improved flood resilience of the community which cannot be quantified.

10.4.1.2. Raise Frenchmans Creek Low Point (Option PM3 and PM4)

Council is currently considering raising a low point in North Bank Road at Frenchmans Creek as part of its regular maintenance program. Two options were modelled in the hydraulic model. Option PM3 includes the raising of North Bank Road over Frenchmans Creek by 500mm at its low point (Diagram 12). Option PM4 includes the raising of North Bank Road over Frenchmans Creek to achieve immunity up to the 5 Year ARI event (Diagram 13). This section of road is frequently cut in small events, isolating residents with properties along and which access North Bank Road.

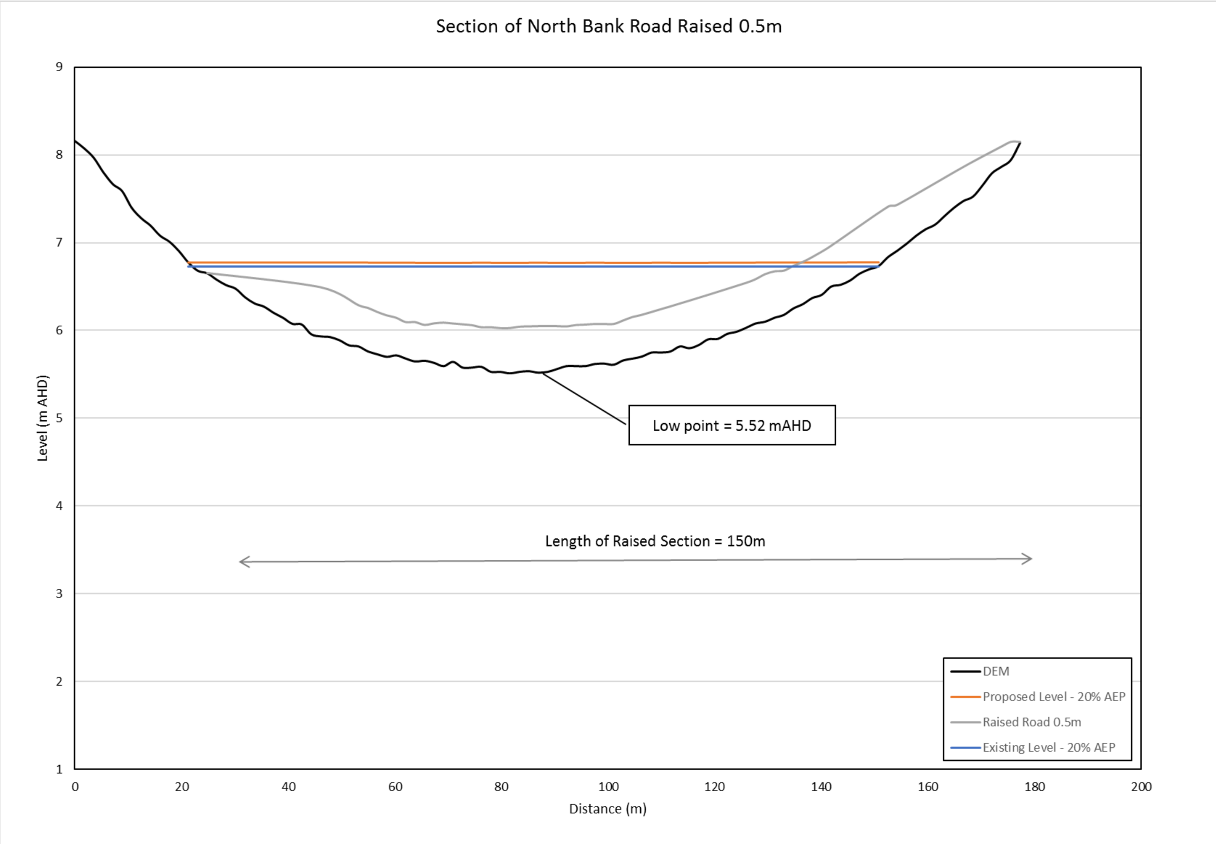


Diagram 12: Option PM3 Cross Section

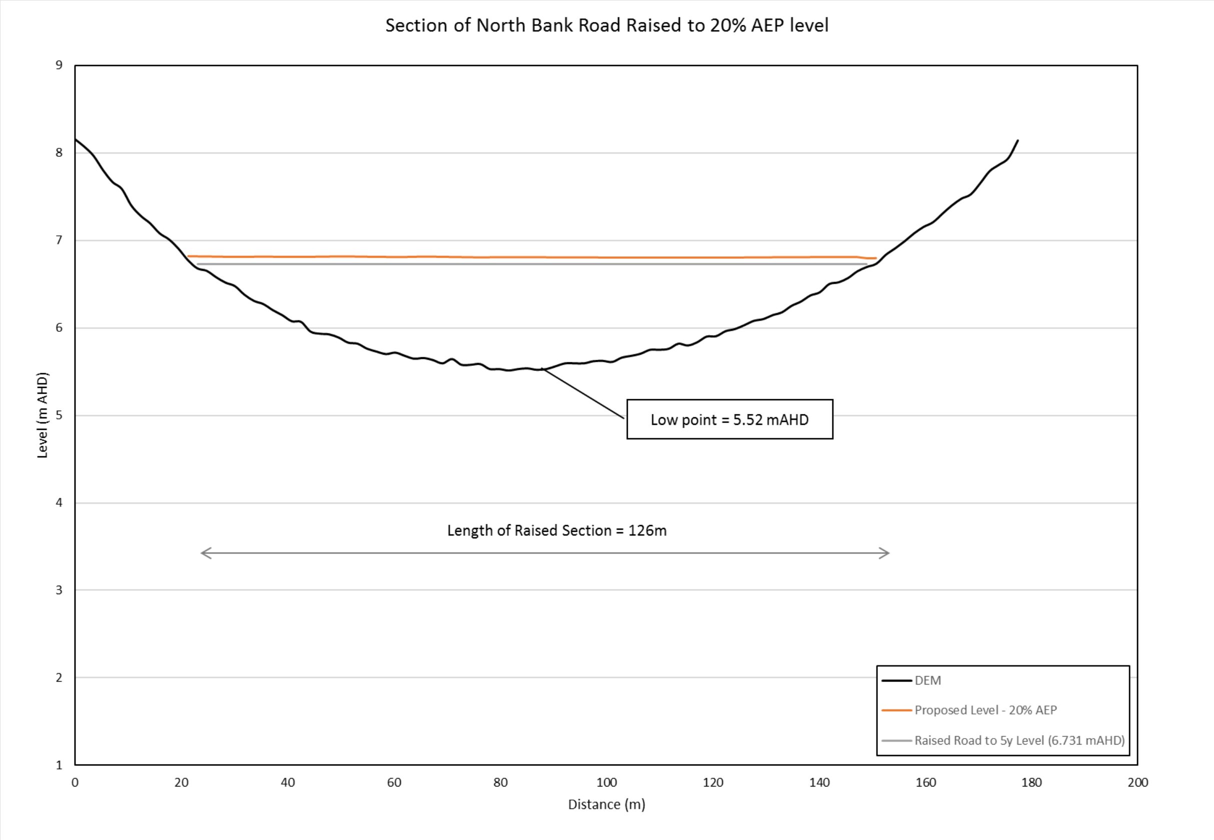


Diagram 13: Option PM4 Cross Section

Impacts of raising the road by 0.5m in a 5 Year ARI event are shown in Figure C27. The maximum increase in flood levels upstream of the road is 0.001m.

Figure C29 depicts the impacts of raising the road at Frenchmans Creek to a 5 Year ARI Level. The maximum upstream impacts are 0.077m. No houses are impacted as a result of the proposed work, and impacts are within the acceptable range for agricultural land uses.

While this option is not a complete fix for the flood affectation along North Bank Road, it is the first low point from Bellingen and a first step in improving evacuation access to evacuation centres in North Bellingen and connectivity of the community. The raising of the low points on North Bank Road should be considered as part of future road maintenance or works budgets. Considering the low impacts of raising to a 5 Year ARI level, this would be beneficial, provided the same consideration is given to other roads that form evacuation routes in the catchment.

10.4.1.3. Raise Waterfall Way lower of 5 Year ARI level or 500mm overlay (Option PM5)

Waterfall Ways is subject to frequent and significant flooding. Parts of the road are inundated in a 1 Year ARI or 2 Year ARI event. Raising the road to a 1% AEP level would be cost prohibitive and have substantial impacts on flood behaviour. This hydraulic model was modified to raise the road to the lower of the following:

- 500mm above the existing level
- equal to the 5 Year ARI flood level

This option (PM 5) has the following benefits:

- increasing the time for evacuation of properties along the route to either Bellingen or the Pacific Highway
- reducing length of time communities such as Bellingen and Fernmount are isolated
- improved access to services and facilities accessed via the Pacific Highway e.g. Coffs Harbour
- Improved access for the NSW SES during the start and recovery periods of the event
- Improved safety.

The maximum flood level increase in a 20% AEP event is 0.072 m and occurs upstream of Short Cut Road. As only riverine flood levels are assessed the maximum reduction in the 20% AEP flood levels is 3.83 m at Sweedmans Lane.

As Waterfall Way is a state road, the maintenance and upgrades are the responsibility of the NSW Government. This means that discussions around raising the road will need to be raised, when other maintenance and improvements are being made. The benefits of this option will be achieved through a broader upgrade over a number of years. The raising of the low points on Waterfall Way should be considered as part of future road maintenance or works budgets. The option has only been assessed for river dominated events and would need to be assessed for local catchment impacts when works were proposed. This option is proposed to be undertaken in stages as funds become available or other works are undertaken e.g. safety works.

SUMMARY AND RECOMMENDATIONS

It is recommended that the following be undertaken:

- Investigate options for raising Lavenders Bridge so that a plan is ready should the existing bridge be damaged or funding be available
- Where possible raise sections of Waterfall way as part of regular maintenance program
- Investigate raising Frenchmans Creek as part of regular maintenance program

10.4.2. Land Use Zoning (Option PM6)

DESCRIPTION

Suitable and correct zoning of flood liable land is a key aspect in managing flood prone areas. It ensures development only occurs in suitable locations compatible with flood risk and hazard. As recognised in the Floodplain Development Manual (NSW State Government, 2005) land use planning cannot be undertaken effectively without a good understanding of the flood risks and the associated consequences.

DISCUSSION

The LEP zones land uses in the Bellingen Shire comply with the current NSW standards. Zoning can be a powerful tool in reducing flood damages. However, overly restrictive zoning can discourage redevelopment that is more flood compatible causing areas to become degenerative. Progressive zoning can be used to encourage long term change in flood resilience.

Up to date flood level information is currently not available outside the study area for the Hydraulic Models. An uncalibrated Mike11 model was used for flood assessments in the upper catchments of the Bellinger and Kalang Rivers, commissioned by Council in 2006. The hydrology of these models was adopted from the 1990's Lower Bellinger and Kalang Rivers. It would be beneficial to update the simplified upper catchment models to use the updated ARR 2016/2019 hydrology and up to date modelling techniques, therefore putting the studies on a consistent platform.

SUMMARY AND RECOMMENDATIONS

- No changes to Councils land use zoning are recommended.
- Council should consider updating the upper catchment flood studies to ARR 2016/2019 methodology.

10.4.3. Voluntary Purchase (Option PM7)

DESCRIPTION

Voluntary purchase (VP) involves the acquisition of flood affected residential properties (particularly those frequently inundated in high hazard areas) and demolition of the residence to remove it from the floodplain. Generally, the land is returned to open space. The following eligibility criteria must be met to allow funding under the VP Scheme:

1. *Only councils are eligible to apply for funding under the program. It is not open directly to individuals.*
2. *VP will be considered only where no other feasible flood risk management options are available to address the risk to life at the property.*
3. *Subsidised funding is generally only available for residential properties and not commercial and industrial properties.*
4. *Funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted by the State Government.*
5. *The individual properties within a scheme should be identified within an FRMP developed in accordance with the Floodplain Development Manual (2005) and adopted by the council.*
6. *Funding under the program is only available for properties identified in a VP scheme that has been fully defined, scoped and prioritised. The report to scope and prioritise the VP scheme is eligible for funding.*
7. *Under limited circumstances, VP can be considered for funding prior to completion of an FRMP. However appropriate investigations and assessments need to be completed and clear and compelling evidence provided as the basis for expediting consideration ahead of a completed FRMP. This would generally include scoping the VP scheme.*
8. *Properties being considered for VP should be located:*
    a. *Within high hazard areas where there is a significant risk to life for occupants and those who may have to evacuate or rescue them. However, a house in a location that is classed as high hazard on the basis of depth or provisional hazard alone would not be automatically eligible for VP. Hazard categorisation should be based on the true hazard assessment and consider a range of other factors that influence*

flood hazard as detailed in the Floodplain Development Manual (2005).

   b. *Within a floodway where the removal of the house may be part of a floodway clearance program aimed to reduce the significant impacts caused by the existing development on flood behaviour elsewhere in the floodplain and enable the floodway to more effectively perform its flow conveyance function.*
   c. *Within the footprint of a proposed flood mitigation measure or where a flood mitigation measure may result in a significant increase in flood risk to a house that cannot be protected. Eligibility will be considered as part of the detailed investigation and design for the works project. Funding the purchase of the property would be considered as part of the total works package which could include preconstruction activities.*

9. *Unless it is being purchased to facilitate a mitigation work, vacant land is not generally eligible for funding as it does not achieve the main aim of VP. Development controls should be used to limit the potential development of vacant land so that this is consistent with the flood function and flood hazard at the location.*
10. *Two or multi-storey properties may be eligible for funding despite the upper floors not being directly affected by over-floor flooding. Residents retreating to the upper floors and their potential rescuers may still face significant risk to life and the building may not be designed to be structurally sound for the potential range of flood conditions. An additional hazard assessment needs to be undertaken to confirm eligibility of multi-storey properties.*

DISCUSSION

Voluntary purchase is mainly implemented over a long period for residential areas in high hazard areas. Voluntary purchase is a means of removing isolated or remaining buildings, thus freeing both residents and potential rescuers from the danger and cost of future floods. It also helps to restore the hydraulic capacity of the floodplain (storage volume and waterway area).

Voluntary purchase has no environmental impacts although the economic cost and social impacts can be high. Many residents do not accept voluntary purchase because it would have significant impact on their community and way of life. Among these concerns are:

- it can be difficult to establish a market value that is acceptable to both the State Valuation Office and the resident,
- in many cases residents may not wish to move for a reasonable purchase price,
- progressive removal of properties may impose stress on the social fabric of an area,
- it may be difficult to find alternative equivalent priced housing in the nearby area with similar aesthetic values or features.

It is not uncommon for the uptake of voluntary purchase properties to slow down once most of the owner-occupied housing stock has been purchased. This can create fragmented neighbourhoods where it is common for the remaining housing to be dominated by rental properties and visually unappealing businesses. The voluntary purchase zoning can encourage rental investors to hold on to properties.

Land swap schemes can also help accelerate the clearance of the floodway, such as that undertaken in Grantham, Lockyer Valley, Queensland following the January 2011 floods. Through such a scheme, people who own land within the floodway would be offered deeds for another parcel of land outside of the floodway in return for their current property, which is returned to Council for demolition and clearance.

Voluntary purchase should be considered for properties in high to extreme hazard (H5 and H6) areas. Properties in hazard category H4 may be considered where the peak flood depths are large enough to make house raising unrealistic or where they are in a particularly dangerous location. Three properties in Bellingen and one in North Bellingen should be considered for voluntary purchase. However, an assessment would need to be made on the benefits of removing these houses.

SUMMARY AND RECOMMENDATIONS

Three properties in Bellingen and one in North Bellingen should further be considered for voluntary purchase and an assessment of their viability undertaken.

10.4.4. Building and Development Controls

These measures include managing flood risk for future development through development controls.

10.4.4.1. Flood Planning Levels (Option PM8)

DESCRIPTION

Flood Planning Levels (FPLs) are an important development control in floodplain risk management. Through planning controls Council has requirements for all new development to set finished floor levels above a given flood level. The Floodplain Development Manual (NSW State Gov, 2005) provides a comprehensive guide to the purpose and determination of FPLs. The FPL is a useful mitigation measure for future flood risk and is derived from a combination of flood level results from a flood event of specific probability, usually the 1% AEP, and freeboard of usually 0.5m. FPLs do not apply to existing development, but through development controls which are enforced on generally all new development.

DISCUSSION

Stipulating FPLs for all new development is one of the most effective measures in reducing flood damages to new properties without preventing development in a flood prone area entirely. Defining the appropriate FPL involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use and development in flood prone areas and of implementing management measures.

Developments more vulnerable to flooding such as hospitals, electricity sub stations, and housing for the elderly or less physically mobile, should consider rarer events than the 1% AEP when determining their FPL. However, the FPL does not address the full range of issues when considering flood and permanent inundation risk such as access and failure of essential services.

According to the 2005 Floodplain Development Manual (NSW State Gov, 2005), the purpose of freeboard is to give reasonable certainty that the reduced flood risk exposure implied by selection of a particular flood as the basis of a FPL is actually provided, given the following factors:

- uncertainties in estimates of flood levels,
- differences in water level because of local factors,
- increases due to wave action,
- the cumulative effect of subsequent infill development on existing zoned land, and
- climate change.

Freeboard of 0.5 m should be included in the FPL and, as recommended in the 2010 Flood Risk Management Guide, it should not be assumed that the freeboard can take full account of climate change. In a real flood, some of the factors described above may reduce the flood level (local factors) or not apply at all (no wave action). Whilst climate change is included as one of the above factors, there is no advice as to what the contribution for each factor should be.

FPLs are generally required to be defined or applied for the following broad land uses:

- community services (schools, halls),
- critical services (hospitals, police stations, Council offices),
- residential (single and multi-unit),
- rural areas,
- commercial/industrial,
- recreational facilities,
- caravan parks,
- additions/extensions to existing structures, and
- public utilities (electricity, sewer, water, phone, etc).

Bellingen Shire Council sets one FPL for all residential, commercial and industrial development other than critical infrastructure which is set to the PMF, and Special Purpose development which adopts the General FPL plus 1 metre.

Council should continue to use the FPL to set flood proofing requirements for non-residential buildings. Council should consider making the FPL and other flood information and extents available on its website.

This study has amended the 1% AEP event flood level throughout the hydraulic model extent from those levels used to define the FPL in the current DCP. Therefore it is recommended that the DCP be updated to reflect this.

UPDATED FLOOD PLANNING LEVEL

For ease of implementation and consistency, a freeboard of 0.5m is recommended for the study area. While a lower freeboard of 0.3m could be applied to overland flow areas, for most of the urban areas within the study area, riverine flooding is dominant. Figure 59, Figure 60 and Figure 61 show the proposed FPL across the catchment. The Flood Planning Area (FPA) is defined as the extent of the FPL.

SUMMARY
It is recommended that Council update its flood planning area and flood planning levels based on the current modelling. Council should consider making the FPL and other flood information and extents available on its website.

RECOMMENDATIONS
Revise FPL and FPA as per the outcomes of this Study. Council should consider making the FPL and other flood information and extents available on its website.

10.4.4.2. Water sensitive urban design (WSUD) policy (Option PM9)

Water Sensitive Urban Design promotes sustainable use of water in an urban environment. Bellingen Shire Council currently has an adopted report on the WSUD guidelines. However this documented is now put of date and no longer aligns with best practice. Council should consider the addition of one to its DCP or an updating of the report.

The key tasks of the policy in the framework of the DCP and proposed developments in urban areas would be to:

- ensure that proposed development does not compromise the existing stormwater capacity and exacerbate localised flooding to downstream properties, including key local roads,
- ensure that proposed development does not cause deterioration of the downstream water quality.

An example of a WSUD policy currently in use in the region is the Coffs Harbour City Council WSUD Guideline, available on their website.

10.4.4.3. Revise LEPs and DCPs (Option PM10)

DESCRIPTION
Updated and relevant planning controls, outlined in several of the preceding sections, are important in flood risk management. Appropriate planning restrictions can significantly reduce flood damages, by ensuring that development is compatible with flood risk. Planning instruments can be used as tools to guide new development away from high flood risk locations, ensure that new development does not increase flood risk elsewhere, and to ensure development in flood prone areas is suitably designed, for example with raised floor levels. They can also be used to develop appropriate evacuation and disaster management plans to reduce flood risks to the existing population.

DISCUSSION
The primary objective of the NSW Government's Flood Policy is "to reduce the impact of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding, utilising ecologically positive methods wherever possible".

Appropriate development controls involve consideration of the social, economic, environmental and risk to life of consequences associated with the occurrence and management of floods. This involves trading off various benefits of reducing the impacts of flooding on development, against the costs of restricting land use in flood prone areas and of implementing appropriate management measures.

The outcomes of this study should feed into an updated DCP in respect to flood related development controls or, alternatively, the existing documents can simply refer to this study and plan. Council has recently updated its LEP to the NSW standard instrument and adopted a revised DCP in 2017 (amended 2019). Section 2 provides a summary of the current LEP and DCP for Bellingen Shire. A review of these documents, and some changes are recommended as detailed below. Typically development controls are based on the 1% AEP and therefore they should be used but the other flood maps are produced by the study so Council can be aware of the full range of flood risk for the sites.

The flood constraint category mapping aims to consolidate all the mapping outputs to assist planners. Council may wish to use this to determine areas where development should be constrained and areas where less restrictions are required. The AIDR guide provides example planning constraints for the various FPCC categories. For example FPCC1 – Development is discretionary provided it doesn't adversely affect flood function. Intensification of existing and new key community, utility and vulnerable, residential and commercial uses may be prohibited.

The Department of Planning, Industry and Environment (DPIE) have proposed updates to the Flood Prone Land Package. At the time this study was going to public exhibition this package was being proposed. At the time of finalisation of this study the package has been adopted, however a detailed review is beyond the scope of this study.

CHANGES TO THE LEP

A new standard clause titled **Floodplain Risk Management** should be included in the LEP to ensure that all development uses are covered. The suggested standard clause to use is:

X.X Floodplain risk management

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

(a) in relation to developments with particular evacuation or emergency response issues—to enable the evacuation of land subject to flooding above the flood planning level,

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

10. This clause applies to:

(a) land between the flood planning area and the line that is shown as the probable maximum flood level on the Flood Planning Map, and

(b) land surrounded by the flood planning area, but does not apply to land below the flood planning level.

11. *Development consent must not be granted to development for the following purposes on land to which this clause applies unless the consent authority is satisfied that the development incorporates appropriate measures to manage risk to life from flood:*

a) caravan parks,
b) correctional facilities,
c) emergency services facilities,
d) group homes,
e) hospitals,
f) residential care facilities,
g) tourist and visitor accommodation,
h) educational establishment.

12. *In this clause, **probable maximum flood** has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7 347 54760) published in 2005 by the NSW Government*

CHANGES TO THE DCP

13. Modify definition of Floor Level Controls to specify what is considered practical, and what would then be acceptable. More detail to be provided around the storage areas as an alternative.

Floor levels to be no lower than the 1% AEP flood. Where this is not practical due to compatibility with the height of adjacent buildings, or compatibility with the floor level of existing buildings, a lower floor level may be considered. In these circumstances, the floor level is to be as high as practical and when undertaking alterations and additions, no lower than the existing floor level.

2. Provide more detail in DCP Appendix 8.3 Flood Study requirements – for example

have a measurable impact on flood behaviour beyond the property boundary *with particular regard to: (i) loss of flood storage; (ii) changes in flood levels, flows and velocities caused by alteration to flood flows and (iii) the cumulative impact of multiple similar developments in the floodplain.*

Definitions of the above terms should be included.

SUMMARY

As part of the Floodplain Management Study, Council's Local Environment Plans and various related Development Control Plans have been reviewed. Council and the community should consider minor changes to its LEP and DCP as discussed.

RECOMMENDATION

- Define a Flood Planning Area based on 1% AEP flood levels plus 0.5 m freeboard.
- In addition to the 1% plus 0.5m freeboard, all other events and flood characteristics should remain the same.
- Council to consider changes to LEP and DCP including a detailed review of Chapter 8 and 12 to align with appropriate development controls which balance the benefits of development with the impacts of managing flooded land water sensitive urban design with the Shire.
- Council to review the flood prone land package update if adopted.

10.4.4.4. Section 10.7 Certificates (Option PM11)

DESCRIPTION

Section 10.7 Planning Certificates (formerly S149 Planning Certificates) are issued in accordance with the Environmental Planning & Assessment Act 1979. They contain information on how a property may be used and the restrictions on development that apply. A person may request a Section 10.7 Planning Certificate at any time to obtain information about his or her own property, but generally the certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919 requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

DISCUSSION

Schedule 4 of the Environmental Planning and Assessment Regulations 2000 gives requirements for inclusions on Section 10.7 Planning Certificates under Section 10.7(2) of the Act. In particular, Schedule 4, Clause 7A refers to flood related development control information and requires that Council include whether or not development on the land or part of the land is subject to flood related development controls.

Council provides information related to flood related development controls on 10.7(2) Planning Certificates for properties within the extent of the riverine flood extent established in the Lower Bellinger and Kalang Rivers Flood Study. This is based on a FPL of the 1% AEP flood level + 0.5 m freeboard but does not cover localised urban flooding. Section 10.7 (5) currently does not provide additional details related to flooding. At present, no information regarding overland flow is provided, however completion of the Lower Bellinger and Kalang River FRMS (this Study) will provide Council with high resolution flood information, as well as overland flooding information, which will enable them to pass on such information to residents.

More sophisticated data and mapping produced in this study will assist in the dissemination of accurate and site-specific information to the community. A GIS based map can provide useful information to a property owner and simplify the identification of issues by a Council staff member.

Section 17.2 and 17.3 of Appendix I to the FDM (23) detail typical examples of information for inclusion in Section 10.7 (2) and (5) Planning Certificates, and include the following:

- Whether the land is within the FPA (overland, riverine, or both) and if flood related development controls apply, (10.7(2)),
- Design flood levels/depths specific to the property for the 1% AEP, 5% AEP and PMF events, (10.7(5)),
- Percentages of lots affected by the FPA(s) if not 100%, (10.7(5)),
- Likelihood of flooding and mechanism (riverine/ overland flow/ both) (10.7(5)),
- Flood hazard (10.7(5)),
- Hydraulic categorisation (e.g. floodway) (10.7(5)),
- Evacuation routes/ constraints (10.7(5)), and
- Associated Mapping for the above items (10.7(5)).

The more informed a home owner is, the greater their understanding of their flood risk. During a flood event, having this understanding may help prepare residents for evacuation and reduce the number of residents that elect to shelter in place in high hazard areas, which can increase pressure on the SES if they are isolated or their homes are inundated.

Land owners will be required to be notified of changes to both the 10.7 (2) and 10.7 (5) Planning Certificates. Land owners can be concerned as to how a notification may impact on their property value or insurance, for example. The Insurance Council of Australia provides detailed fact sheets on how flood information is used for insurance pricing. This should be taken into account when developing a consultation strategy for notification of any changes related to s10.7 Planning Certificates.

RECOMMENDATIONS

- Provide a notice within relevant rate notices regarding the outcomes of this study, and the ability for property owners to request Section 10.7 certificates should they wish.
- In Section 10.7 Planning Certificates, notations regarding flooding should provide information on all mechanisms of flood risk at the site, including riverine, overland flow, or if appropriate, both.
- A greater level of detail can be provided via Section 10.7(5) certificates using high-resolution outputs from this Study.
- Provide flood information as GIS on Council's website.

10.4.5. House Raising (Option PM12)

DESCRIPTION

House raising has been widely used throughout NSW to eliminate inundation from habitable floors. This approach provides more flexibility in planning, funding and implementation than voluntary purchase. However, its application is limited as it is not suitable for all building types and only becomes economically viable when above floor inundation occurs frequently (say in a 10% AEP event or less).

1. *Only councils are eligible to apply for funding under the program. It is not open directly to individuals. Requests from home owners to raise houses for hardship reasons are not eligible for funding.*
2. *Subsidised funding is generally only available for residential properties and not commercial and industrial properties.*
3. *Funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted by the State Government. Properties built after this date should have been constructed in accordance with the principles in the manual.*
4. *The individual properties in a scheme should be identified[3] in an FRMP developed in accordance with the Floodplain Development Manual (2005) and adopted by the council.*
5. *Funding under the program is generally only available for properties identified in a VHR scheme that has been fully defined, scoped and prioritised. The report to scope and prioritise the VHR scheme is eligible for funding.*
6. *Under limited circumstances, VHR can be considered for funding prior to completion of an FRMP. However scoping, prioritisation and assessments need to be completed and clear and compelling evidence provided as the basis for expediting consideration ahead of a completed FRMP. This would generally include scoping the VHR scheme and addressing the issues outlined in Section 3 above.*
7. *Properties which are benefiting substantially from other floodplain mitigation measures – such as houses already protected by a levee or those that will be – will not be funded for VHR.*
8. *VHR should generally return a positive new benefit in damage reduction relative to its cost (benefit–cost ratio[4] greater than 1). Consideration may be given to lower benefit–cost ratios where there are substantial social and community benefits or VHR is compensatory work for the adverse impacts of other mitigation works.*
9. *The scheme should involve raising residential properties above a minimum design level, generally the council's flood planning level (FPL) and comply with the council's relevant development control requirements.*

DISCUSSION

House raising is suitable for most non-brick single storey buildings on piers and is particularly relevant to those situated in low hazard areas on the floodplain. A number of techniques may be used. The benefit of house raising is that it eliminates inundation to the height of the floor and consequently reduces the flood damages. However, it does not reduce the external hazard, evacuation issues or yard/garage damages.

The Floodplain Management Program Grant Funding of this measure generally only cover the basic costs of raising the structure. The subsidy is usually offered on a relative basis depending on the severity of the problem and potential damages. Residents will most likely have to contribute their own funds to make up any difference and to facilitate the associated works or modifications.

Photo 1: Examples of House Raising

Most houses on the lower floodplain which are subject to frequent flooding would have been raised in the past by the owners. However, some may have only been raised to avoid nuisance flooding. In a 5 Year ARI event 26 residential properties are flooded above floor level. A total of 48 residential properties are flooded above floor level in a 5% AEP event, and removing properties that are two storeys and those within H5 and H6 hazard categories, an estimated 18 properties may be eligible for the scheme. A total of 269 residential properties within the catchment are flooded above floor level in a 1% AEP event. The cost of basic house raising is typically in the order of $80-120,000 per house. The event when a property is first flooded above floor level is shown on Figure B5 to Figure B7. It is recommended that Council develop a prioritised list of houses for raising.

An indication of the property's eligibility for house raising could be recorded on the Section 10.7 Certificate to ensure future potential purchasers are made aware of their options.

SUMMARY AND RECOMMENDATIONS

A total of 48 properties were identified as being flooded in frequent events (5% AEP). An estimated 18 residential properties may be eligible for the scheme. It is recommended that:

- Council investigate a house raising program and prioritise houses should funding become available.

10.4.6. Flood Proofing (Option PM13)

DESCRIPTION

An alternative to house raising for buildings that are not compatible or not economically viable, is flood proofing or sealing off the entry points to the building. This measure can be used for all building use types and it is possible to retrofit an existing building. Flood proofing requires sealing of doors and possibly windows (new frame, seal and door); sealing and re-routing of ventilation gaps in brick work; sealing of all under floor entrances and checking of brickwork to ensure there are no gaps or weaknesses in mortar.

Flood proofing is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building but techniques are used to reduce damages while dry proofing aims to totally exclude flood waters from entering a building.

DISCUSSION

Flood proofing is rarely used in NSW for residential buildings and is more suited to commercial premises with only one or two entrances and where maintenance operation procedures can be better enforced.

Dry flood proofing requires the sealing of doors and possibly windows; sealing and re-routing of ventilation gaps in brickwork; sealing of all underfloor entrances and checking of brickwork to ensure that there are no gaps in the mortar. It is generally only suitable for brick buildings with concrete floors. Dry flood proofing is best incorporated into a structure at the construction phase. Alternatively, temporary dry flood proofing can be achieved by flood gates which fit over doors (Photo 2), windows and vents. These are installed by the property occupant before the onset of flooding. These can be more effective than sandbags if correctly installed. Given the warning time for the onset of flooding this option may be used in the Lower Bellinger and Kalang Rivers catchment.

Dry flood proofing should not be used in areas where flooding is deep as hydrostatic pressure of the floodwaters may cause structural issues. This method should only be applied in areas where flood depths are less than 0.5 m although some sources suggest that dry flood proofing could be applied in areas with flooding up to 1 m depending on the structure of the building. Dry proofing is also not ideal in areas with fast flowing water. Dry proofing is not considered viable for residential properties in the study area due to flood depths and velocities. It may be possible for commercial properties in Bellingen and Urunga.

Photo 2: Dry proofing on doors of residential property

Wet flood proofing assumes water will enter the property and is designed to minimise damages and/or reduce recovery times. Electrical outlets are raised above flood levels to reduce risk of electrocution. The choice of materials used in construction can reduce flood damages, for example timber composites are likely to swell. New buildings are designed to allow a property to drain and provide adequate ventilation for drying.

Flood proofing is typically used for commercial buildings and can include raising of easily damaged/high cost items such as commercial stock, equipment and/or machinery. This measure is often employed for low lying commercial properties in Urunga and Bellingen and the Butter factory in Bellingen.

It is a requirement of the Floodplain Development Manual (NSW State Gov, 2005) that floor levels of new residential properties are above the 1% AEP event plus freeboard. Commercial properties are not subject to such requirements unless stipulated by Councils. New commercial buildings can be required to be flood proofed to the Flood Planning Level when constructed. Council would make these requirements through the DCP and planning controls. It is recommended that planning controls allow some flexibility for either dry or wet flood proofing, and temporary flood gate options. New developments or extensions could be required to use flood proofing.

Flood proofing will not reduce flood hazard and in fact the hazard may be increased if the measure results in occupants remain in their premises and a larger flood eventuates.

SUMMARY

Flood proofing is a good solution for reducing flood risk to commercial and industrial properties. Flood proofing for residential dwellings is considered less appropriate as there can still be risk to life if people remain in the building; raising floor levels above flood levels is considered to be safer. However, as existing houses cannot be raised, flood proofing is useful for existing properties.

Grant funding is not usually available for flood proofing. This option is generally less expensive than house raising. Although Council cannot be responsible for flood proofing existing properties, they can enforce flood proofing for any new development within flood prone areas through planning controls. Furthermore, Council can, through a flood awareness campaign targeted at both commercial and residential property owners, make available information on flood proofing existing buildings such as temporary flood barriers.

RECOMMENDATION

- Promote flood proofing for commercial properties in Bellingen and Urunga, and residential properties below the habitable floor level.

10.5. Response Modification Measures

10.5.1. Flood Warning (Option RM1)

DESCRIPTION

The amount of time for evacuation depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

DISCUSSION

Flood warning and the implementation of evacuation procedures by the SES are widely used throughout NSW to reduce flood damages and protect lives. Adequate warning gives residents time to move goods and cars above the reach of floodwaters and to evacuate from the immediate area to high ground. The effectiveness of a flood warning scheme depends on:

- the maximum potential warning time before the onset of flooding,
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators, and
- the flood awareness of the community responding to a warning.

The BOM is responsible for flood warnings on major river systems such as the Bellinger and Kalang Rivers. Given the flashy nature of flooding, no flood warning is provided for overland flooding on Cemetery Creek, Urunga or North Bellingen Central Drainage Line. Flood warning systems are based on stations that automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. This information is then provided by the BOM (who provide flood forecasts) to the SES who undertake evacuations or flood damage prevention measures (sand bagging or raising goods). Studies have shown that flood warning systems generally have high benefit/cost ratios if sufficient warning time is provided. In this regard all residents should be made aware of the types of warnings issued by the BOM (refer flood awareness in Section 10.5.2). There are currently 4 automatic flood warning gauges used by the BOM in the Bellinger Kalang catchment for flood prediction and warning (three on the Bellinger River at Thora, Bellingen, and Repton, and one on the Kalang at Urunga). Never Never Creek gauge is used for prediction only. Two gauges on the Kalang, Newry Island and Kooroowi-Scotchman can be used to inform whether extensive riverine dominated flooding at Urunga may occur.

The NSW SES has recently updated the Local Flood Plan. Due to infrequency of flooding the Local Flood Plan has had limited testing particularly on large events. The NSW SES monitors local gauges in times of flood and maintain a database of flood intelligence records to assist in providing the community with the best possible flood warnings. There is also a network of NSW SES flood wardens, who are community members living on the Bellinger and Kalang Rivers who regularly report on flood levels.

Bellingen Shire Council has installed 4 flood cameras, which monitor flood levels at low level bridges in the Bellinger and Kalang River Catchments. The camera locations are:

- Lavenders Bridge – Bridge Street, Bellingen,
- Lean’s Bridge – Darkwood Road, Thora,
- Moodys Bridge – Kalang Road, Kalang and
- Spicketts Bridge – Bowraville Road, Brierfield.

The system also records relative water level. It is recommended that survey of the gauge zero be undertaken so that this can easily be converted to mAHD. This will provide a valuable source of information in future flood events. It is recommended Council continue to maintain these gauges into the future. Potential sites for additional flood cameras would be Newry Island Bridge and

Frenchman's Creek.

The warning time for the Bellinger and Kalang Rivers catchment is in the order of 12 to 24 hours depending on the flood event. Flood predictions are supplied by the BOM for Bellingen, Urunga and Repton. Predictions for upstream of Newry Island would assist in preparing for events that may be centred on the Kalang River catchment rather than the Bellinger catchment, as with 2009. The travel time of flood waters between warning gauges can be 1-4hrs.

There are limited rainfall gauges within the catchment. An additional rainfall gauge is recommended at:

- Urunga where the daily gauge under recorded the 2009 event,
- Where the Bellinger, Kalang and Nambucca catchments join to assist in capturing the significant orographic rainfall effects that occur in this catchment.

SUMMARY AND RECOMMENDATIONS

- Additional warnings be developed for the Upstream of Newry Island,
- An additional rainfall gauge is recommended for the upper reaches of the catchments and at Urunga,
- Continue to maintain flood cameras recently installed in the catchment,
- Survey gauge zero level of water level sensors at the flood camera site,
- Additional flood cameras on Newry Island Bridge and Frenchman's Creek.

10.5.2. Flood Awareness and Preparedness (Option RM2)

DESCRIPTION

The success of any flood warning system and the evacuation process depends on:

- *Flood Awareness*: How aware is the community to the threat of flooding? Have they been adequately informed and educated?
- *Flood Preparedness*: How prepared is the community to react to the threat? Do they (or the NSW SES) have damage minimisation strategies (such as sand bags, raising of possessions) which can be implemented?
- *Flood Evacuation*: How prepared are the authorities and the evacuees to evacuate households to minimise damages and the potential risk to life? How will the evacuation be implemented, where will the evacuees be moved to?

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc. Photographs and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have survived previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner.

The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including:

- *Frequency and impact of previous floods.*
- *History of residence*.
- *Whether an effective public awareness program has been implemented.*

Residents of the Lower Bellinger and Kalang River Catchments generally have a moderate level of flood awareness, particularly with the flood affectation caused in 2009 and 2013 through the catchment and particularly at Newry Island and Urunga. However, this awareness is usually of the smaller more frequent events in the order of 10% AEP (recent events eg. 2013) and for events that are larger on the Bellinger River than on the Kalang River. The 2009 event was larger on the Lower Kalang River than on the Bellinger River, catching residents off guard. Continued education of residents of the chance of this occurring again is recommended.

While the residents of Bellingen are very familiar with nuisance flooding, a result of Lavendar Bridge being cut on average once a year, this however does not always translate to awareness of significant floods such as the 1% AEP event. Generally the length of time for flood warning and resident awareness allows for a reasonably effective flood warning scheme in the Lower Bellinger and Kalang River Catchments.

For risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and level of awareness, diminishes as the time since the last flood increases.

A major hurdle is often convincing residents that major floods (similar to or larger than 2009, rarer than 1% AEP on the Kalang River) will occur in the future. Many residents hold the false view that once they have experienced a large flood then another will not occur for a long time thereafter. This viewpoint is incorrect as a 1% AEP event (or sometimes termed a 100 year ARI) has the same chance of occurring next year, regardless of the magnitude of the event that may have recently occurred (a 1 in 20 chance each year).

Regular awareness campaigns are recommended to ensure that the level of flood awareness in the Lower Bellinger and Kalang Rivers stays high. This study will provide detailed mapping of flood risk in the urban area of the catchment from local events as opposed to riverine events. It is recommended that a community flood awareness campaign be undertaken in these areas using the new flood tools.

SUMMARY

Based on feedback received from the community it would appear that the majority of residents in the Lower Bellinger and Kalang Rivers Catchment have a moderate level of flood awareness and preparedness. Residents in the upper reaches of the catchment are well prepared and are used to being isolated for a few days. Flood awareness of rare events is higher in the lower reaches of the Kalang River catchment due to the large flood in 2009.

As time passes since the last significant flood, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program that would include Floodsafe brochures, additional flood markers, flood history reminders on significant anniversaries of major events, as well as advice provided on the Council's and SES's websites. These need to be updated on a regular basis. A specific fact sheet should be produced for each catchment relating specifically to the local issues.

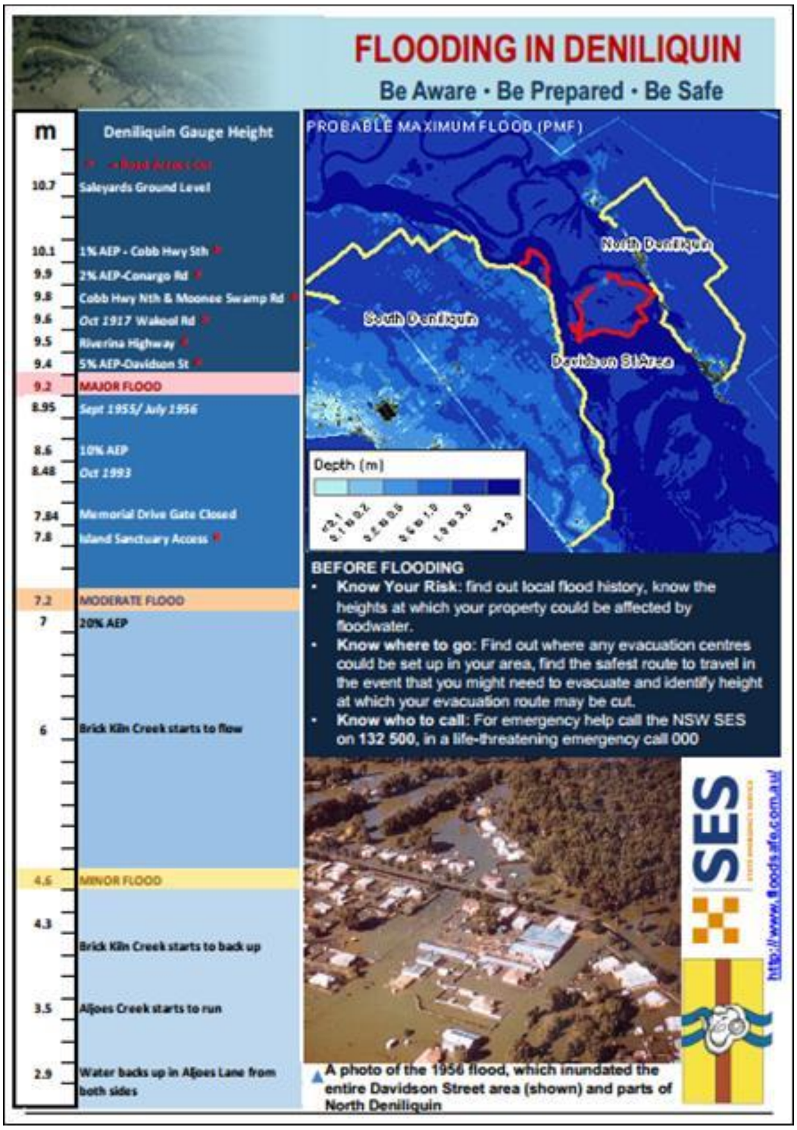
Table 22 provides examples of various flood awareness methods that can be used.

Table 22: Flood Awareness Methods

Method	Comment
Letter/Pamphlet from Council	These may be sent (annually or bi-annually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of subsidies, changes to flood planning levels or any other relevant information. These should also be handed out as part of rental property information.
School Project or Local Historical Society	This provides an excellent means of informing the younger generation about flooding. It may involve talks from various authorities and can be combined with water quality, estuary management, etc.
Displays at Council Offices, Library, Schools, Local Fairs	This is an inexpensive way of informing the community and may be combined with related displays. Include photographs, newspaper articles and information on development controls and standards, flood evacuation and readiness procedures.
Historical Flood Markers or Depth Indicators on Roads	Signs or marks can be prominently displayed in parks, on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators on roads advise drivers of the potential hazards. Particularly appropriate near local waterways and low points which become flow paths during large events.
Articles in Local Newspapers	Ongoing articles in the newspapers will ensure that the problem is not forgotten. Historical features and remembrance of the anniversary of past events make good copy.
Collection of Data from Floods	Collection of data from floods that occur in the future will assist in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible.
Notification of Section 149 Planning Certificate Details	Floodplain property owners were indirectly informed that they were potentially flood affected as part of the public consultation program and floor level survey. Future residential property owners are advised during the property searches at the time of purchase by details provided on the Section 149 certificate.
Web-based tools	Online presentations, activities, gauge data, GIS information on Council website.
Updates on Council website	Council already provide regular updates on the current flood situation on the home page of their website. The website also provides information on flood preparedness, response and recovery.
NSW SES flood awareness programs	The NSW SES are undertaking a flood awareness program in the Lower Bellinger and Kalang Rivers including, leaflets and flyers, and stalls at local events.

The specific flood awareness measures that are implemented will need to be developed by Council taking into account the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed in consultation with affected communities. It is important that the system be web/GIS based and publicly available.

Below is an example of a fridge magnet produced to educate residents on what a specific gauge height means.



RECOMMENDATION

- Develop a flood awareness program including explaining the frequency of flooding experienced in locations such as Lavenders Bridge in Bellingen and the possibility of events centred on the Kalang rather than the Bellinger catchment eg 2009.
- It is recommended that a community flood awareness campaign be undertaken particularly for the newly mapped overland flow areas using the new flood tools developed by this study.

10.5.3. Evacuation Planning (Option RM3)

DESCRIPTION

It may be necessary for some residents to evacuate their homes in a major flood. This would be undertaken under the direction of the SES who are the lead agency under the Displan. Some residents may choose to leave on their own accord based on flood information from the radio or other warnings, and may be assisted by local residents.

DISCUSSION

The main problems with all flood evacuations are:

- They must be carried out quickly and efficiently,
- They are hazardous for both the rescuers and the evacuees,
- Residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers and increasing the risk to the rescuers,
- The number of people to be evacuated,
- The mobility or special requirements to evacuate residents, and
- Evacuation routes may be cut some distance from the residential areas and people do not appreciate the danger.

A number of residents will be required to be evacuated in a flood event. The NSW SES has the skills and experience to undertake the necessary evacuations. Any flood awareness programs should target the need for evacuation.

Access to properties can be cut for some time and residents will try to drive through floodwaters to return home or undertake regular tasks. The NSW SES advice is never to drive through floodwaters but recent past events in Queensland, NSW and Victoria in 2011 demonstrated that many people do not adhere to this advice. Cars can float in as little as 0.3 m depth of water and consequently a number of lives have been lost and the lives of rescuers put at risk in rescuing stranded motorists. Warning signs advising motorists of the risk of driving through floodwaters could be provided at low cost.

The warning times and stream gauges upstream of Bellingen and Newry Island are crucial as the majority of the downstream areas rely on this information being accurate and available.

Appendix B contains information on when properties are first flooded that can be used by the SES for evacuation planning.

The time at which key roads are cut is important for evacuation planning. Figure D 1 shows the total time the catchment is under water during a 1% AEP flood event. Inundation times in low lying areas such as Newry Island are up to 38 hours in the 1% AEP event. Figure D 2 depicts the time at which Waterfall Way is cut in a 1% AEP event related to the nearest flood level gauge (Lavenders Bridge).

SUMMARY AND RECOMMENDATIONS

- The NSW SES Local Flood Plan was prepared in November 2015 and schedule for review in 2020. This should be updated to include the new overland flow information for Urunga, Bellingen and North Bellingen.
- Any major future events within this time should be incorporated into flood intelligence and evacuation planning.
- Signs advising of the risk of driving through floodwaters should be placed on inundated roads to reduce the number of people driving through flood waters.

11. CONCLUSIONS

The Floodplain Management Study has undertaken a review of the full range of management measures with the outcomes providing the basis for the Floodplain Management Plan. An assessment of the relative merits of the measures has been undertaken taking into account:

- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation)
- over the range of flood events;
- number of properties benefited by measure;
- technical feasibility (design considerations, construction constraints, long-term performance);
- community acceptance and social impacts;
- economic merits (capital and recurring costs versus reduction in flood damages);
- financial feasibility to fund the measure;
- environmental and ecological benefits;
- impacts on the SES;
- political and/or administrative issues;
- long-term performance given the possible impacts of climate change;
- risk to life.

Table 23 contains a summary of the options assessment.

Table 23: Options Summary

Option ID	Option Description	Recommendation	Impacts	Costs	Overall Rank*	Reference
FM01	Basin Upstream of Railway in Urunga	Not Progressed	The basin reduces peak flood levels in residential area upstream of the basin by 0.15m to 0.40m in the 1% AEP event	$1,180,000 (BC 0.4)	24	10.3.2.1
FM02	Riparian Vegetation	Not Progressed	1.17m in the 1% AEP		13	10.3.3.1
FM03	Urunga Stormwater – Two 1.2m pipes from Bonville Street to the River	Not Progressed	The maximum reduction achieved for a 1 % AEP event is 0.09m near Newly St E	$1,178,000 (BC 0.3)	18	10.3.3.2
FM04	Urunga Stormwater – 5m wide drain and pipe option	Not Progressed	The maximum reduction achieved for the 1% AEP event is 0.15m near Newry St E		20	10.3.3.2
FM05	Increased Culvert Capacity	Not Progressed	Increases downstream flood levels in a 1% AEP by 0.08m		24	10.3.3.3
FM06	Wheatley Street Upgrades	Not Progressed	Not significant.		23	10.3.3.4
FM07	Basin Near Urunga Recreation Ground	Not Progressed	Not significant.		21	10.3.2.2
FM08	Additional Storage on Cemetery Creek	Not Progressed	Not significant.		21	10.3.2.3
FM09	Maintenance Plan for clearing blockage on culverts	Progressed to FRMP	Not significant for the range of AEPs considered in this study, however likely to have a larger impact in smaller events. Impacts up to 0.75m in Urunga CBD	Minimal	3	6.2.1
PM01	Raise Lavenders Bridge to 50% AEP	Progressed to FRMP	Provides flood free access for longer periods during flood events	High	9	10.4.1.1
PM02	Raise Lavenders Bridge to 5y ARI			High	5	10.4.1.1
PM03	Raise North Bank Road at Frenchmans Creek by 0.5m	Progressed to FRMP	Reduces inundation of North Bank Road	Council Cost	5	10.4.1.2
PM04	Raise North Bank Road at Frenchmans Creek to 5y ARI	Progressed to FRMP	Provides flood free access up to and including the 5 year ARI flood event.	Council Cost	5	10.4.1.2
PM05	Raise Waterfall Way	Progressed to FRMP	Provides flood free access up to and including the 5 year ARI flood event.	Transport for NSW Cost	5	10.4.1.3
PM06	Land Use Zoning	Progressed to FRMP	No changes to current practice	Minimal	17	10.4.2
PM07	Voluntary Purchase	Progressed to FRMP	Reduces risk to residents and emergency workers		9	10.4.3
PM08	Flood Planning Levels	Progressed to FRMP	Ensures new development does not incur flood damages	Minimal	11	10.4.4.1
PM09	Water Sensitive Urban Design Policy	Progressed to FRMP	Ensures new development does not adversely impact runoff	Minimal	13	10.4.4.2
PM10	Revise LEP and DCPs	Progressed to FRMP	Ensures development is compatible with flood risk and an effective measuring in reducing flood damages	Minimal	15	10.4.4.3
PM11	Provision of flood information to residents via Section 10.7 Planning Certificates	Progressed to FRMP	Raise awareness of flooding to those properties within the FPA	Minimal	15	10.4.4.4
PM12	House Raising	Progressed to FRMP	Eliminates inundation to the height of the flood and consequently reduces flood damages	$60,000 per house	3	10.4.5
PM13	Flood Proofing	Progressed to FRMP	Will reduce flood damages	Owner cost	18	10.4.6
RM01	Bellingen Shire Flood Warning System Review	Progressed to FRMP	Improves evacuations and increases preparedness	$20,000 per gauge	11	10.5.1
RM02	Flood Emergency Response	Progressed to FRMP	Reduces Risk to residents and emergency workers	Minimal	2	10.5.2
RM03	Evacuation Planning	Progressed to FRMP	Reduces Risk to residents and emergency workers	Minimal	1	10.5.3

*TBC following comments from Community and Council

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13. REFERENCES

1. Pilgrim DH (Editor in Chief)
Australian Rainfall and Runoff – A Guide to Flood Estimation
Institution of Engineers, Australia, 1987.

2. WBM BMT
Tuflow User Manual – GIS Based 2D/1D Hydrodynamic Modelling
2010

3. WMAwater
Review of the Bellinger, Kalang and Nambucca River Catchments Hydrology
July 2011

4. Boyd M, Rigby T, VanDrie R, and Schymitzek I
WBNM User Guide
2007

5. RTA
Warrell Creek to Urunga Upgrading the Pacific Highway Environmental Assessment - Volume 1 Environmental Assessment
January 2010

6. Cameron McNamara
New South Wales Coastal Rivers Floodplain Management Studies Bellinger Valley
December 1980

7. Outline Planning Consultants
Proposed Industrial Area, Urunga NSW
May 1984

8. PWD
Bellinger River May 1980 Flood Report
1981

9. PWD
Bellinger River Flood History 1843-1979
1980

10. PWD
Lower Bellinger River Flood Study
1991

11. Cameron McNamara
Lower Bellinger River Flood Study, Location of Flood Marks Engineering Survey

Brief
1991

12. PWD
Lower Bellinger River Flood Study Compendium of Data
1991

13. Bruce Fidge and Associates
Bellinger and Kalang River's Floods of February and March 2001
2003

14. Bellingen Shire Council
Floodplain Risk Management Study Stage 2- An Assessment of Floodplain Management Options and Strategies
April 2002

15. Bellingen Shire Council
Upper Kalang River Flood Assessment,
December 2006

16. DeGroot and Benson Pty Ltd
South Arm Road Flood Study (Final)
June 2000

17. Bellingen Shire Council
Upper Bellinger River Flood Assessment
2006

18. WMAwater
Newry Island Flood Study Draft
2008

19. WMAwater
Kalang River 2009 Flood Event
2011

20. Enginuity Design
Bellinger and Kalang Rivers Flood Event of 31 March 2009 Collection and Collation of Flood Data
2010

21. NSW Government
Floodplain Development Manual: The management of flood liable land
April 2005

22. Department of Infrastructure, Planning and Natural Resources
Floodplain Management Guideline No 5 – Ocean Boundary Conditions

23. NSW Government
Draft Sea Level Rise Policy Statement
2009

24. WMAwater
Warrell Creek to Urunga – Pacific Highway Upgrade Modelling
2012

25. Nathan, RJ and Weinmann, E,
Estimation of Large to Extreme Floods, Book VI in Australian Rainfall and Runoff - A Guide to Flood Estimation,
The Institution of Engineers, Australia, Barton, ACT, 1999.

26. MHL
Bellinger and Kalang Rivers Data Collection – July 2008 to September 2009 (MHL Report Number 1951)
NSW Public Works, 2010

27. WMAwater
Hydraulic Modelling Report - Bellinger and Kalang Rivers
2012

28. Howells L, McLuckie D., Collings G., Lawson N.
Defining the Floodway – Can One Size Fit All?
2004

29. Australian Government
Managing the floodplain: a guide to best practice in flood risk management in Australia
2017

30. WMAwater
Advice on the use of the 2013 Design Rainfall for NSW
2014

31. WMAwater
Lower Bellinger and Kalang River Flood Study
2016

32. AUSTROADS
Guide to Road Design
2015

33. Wasco C and Sharma A
Steeper temporal distribution of rain intensity at higher temperatures within Australian storms,
Nature Geoscience Letter, 8 June 2015

34. Abbs, D., and T. Rafter
Impact of climate variability and climate change on rainfall extremes in western Sydney and surrounding areas: Component 4 – dynamical downscaling,
Report to the Sydney Metro Catchment Management Authority and partners, CSIRO Climate Adaptation Flagship, Melbourne, Victoria. 2009

35. Trenberth KE
Changes in precipitation with climate change.
Climate Research 47:123-138, 2011

36. Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds
Climate Change and Water. Technical Paper VI.
Geneva, Switzerland: Intergovernmental Panel on Climate Change.
Available at :
http://www.ipcc.ch/publications_and_data/publications_and_data_technical_papers_climate_change_and_water.htm
2008.

37. CSIRO
Climate change in Australia, Technical report
2007

38. Westra S, Evans J, Mehrotra R, Sharma A,
A conditional disaggregation algorithm for generating fine time-scale rainfall data in a warmer climate,
Journal of Hydrology, 479, 86-99, 2013

39. Engineers Australia
Australian Rainfall and Runoff Discussion Paper: An Interim Guideline for Considering Climate Change in Rainfall and Runoff
November 2014, Engineers Australia

40. De Groot and Benson
Central Urunga Flood Study
2009

41. Cameron McNamara
Bellinger River Morphological Study
1985

Figures

Appendix A

APPENDIX A. GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	

	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood

storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These

conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical/computer models The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State=s rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP) The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability A statistical measure of the expected chance of flooding (see AEP).

risk Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

runoff The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

stage Equivalent to Awater level@. Both are measured with reference to a specified datum.

stage hydrograph A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.

survey plan A plan prepared by a registered surveyor.

water surface profile A graph showing the flood stage at any given location along a watercourse at a particular time.

wind fetch The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

APPENDIX B. PROPERTY FLOOD AFFECTATION

Appendix C

APPENDIX C. OPTIONS ASSESSMENT FIGURES

Appendix D

APPENDIX D. TIME OF INUNDATION FIGURES