

KEMPSEY SHIRE COUNCIL

KEMPSEY CBD FLOODPLAIN RISK MANAGEMENT STUDY

FINAL REPORT



MAY 2017





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Project Kempsey CBD Floodplain Risk Management Study		Project Number 29046
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KEMPSEY CBD FLOODPLAIN RISK MANAGEMENT STUDY

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ACRONYMS

AAD	Average Annual Damages
ABCB	Australian Building Codes Board
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Airborne Laser Survey (LiDAR)
ARI	Average Recurrence Interval
AWE	Average Weekly Earnings
B/C	Benefit Cost Ratio
BoM	Bureau of Meteorology
CBD	Central Business District
CFERP	Community Flood Emergency Response Plan
DA	Development Application
DCP	Development Control Plan
DECCW	Department of Environment, Climate Change and Water (now OEH)
DIPNR	Department of Infrastructure Planning and Natural Resources (now OEH and DoPI)
DoPI	Department of Planning and Infrastructure
EP&A Act	Environmental Planning and Assessment Act
ERP	Emergency Response Planning
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMC	Flood Risk Management Committee
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
LEP	Local Environment Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging (also see ALS)
mAHD	Meters above Australian Height Datum
MHL	Manly Hydraulics Laboratory
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PWD	Public Works Department
RMS	Roads and Maritime Services
SEPP	State Environmental Planning Policy
NSW SES	New South Wales State Emergency Services
SOBEK	A one and two-dimensional (1D-2D) hydraulic model
TUFLOW	A one-dimensional (1D) and two-dimensional (2D) hydraulic model
WBNM	Watershed Bounded Network Model (hydrologic model)
WSUD	Water Sensitive Urban Design

FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is implemented through the NSW Government's Floodplain Development Manual, 2005, which provides guidance to local Councils on the execution of the policy. It 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. State government assists local council by providing financial support by means of grants through the Floodplain Management Program. To be eligible for funding Councils have to demonstrate that they can follow the floodplain risk management process as outlined in the Floodplain Development Manual. State Government also provides specialist technical and policy related advice, administered by the Office of Environment and Heritage (OEH), to assist Councils in the discharge of their floodplain management responsibilities.

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

1. ***Collection of Data***
 - Compiling existing historical and new information.
2. ***Flood Study***
 - Determine the nature and extent of the flood problem.
3. ***Floodplain Risk Management Study***
 - Evaluates management options for the floodplain in respect of both existing and proposed development having regard for social, ecological, economic factors which relate to flood risk.
4. ***Floodplain Risk Management Plan***
 - Includes public exhibition of the Plan – a chance for the community who live and work on the floodplain to provide comments, following which a revision of the draft plan may be required.
 - Formal adoption by Council of a Plan of management for the floodplain.
5. ***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.
6. ***Review of the Implemented Plan***
 - To account for changes in the issues originally addressed and consider any emergent issues since the plan was first implemented. This is an ongoing process which should be undertaken on a regular basis such as every 5 years and when significant changes occur which could affect the plan as well as when further information becomes available such as after significant flood events.

The Kempsey CBD Floodplain Risk Management Study constitutes the third stage of the management process. This study has been prepared by WMAwater for Kempsey Shire Council (KSC) and provides the basis for the future management of flood prone lands in the Kempsey area.

Funding for this study was provided by Kempsey Shire Council and the Office of Environment and Heritage.

This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

EXECUTIVE SUMMARY

STUDY AREA

The Macleay River catchment covers an area of approximately 11500 km²; the upper reaches of which are located within the New England Tablelands. The main tributaries including the Apsley, Styx, Tia, Dyke, Yarrowitch and Chandler Rivers, Christmas, Collombatti and Clybucca Creeks to the north, Belmore River and Kinchela Creek to the south and Parrabel Creek, Five Day Creek and Nulla Nulla Creek upstream of Kempsey. The study area includes:

- Upstream to between Aldavilla and Sherwood
- Downstream to Austral Eden
- East to Frogmore
- Including the townships of Aldavilla, Euroka, West Kempsey, Kempsey, East Kempsey, South Kempsey, Frederickton, Red Hill, Frogmore and part of Austral Eden

FLOOD STUDY

At the commencement of the Kempsey CBD Floodplain Risk Management Study and Plan it was decided to convert Council's existing flood model to a TUFLOW model. *Kempsey Hydraulic Model – TUFLOW update report* (WMAwater, 2016) documents the updating of the Kempsey flood model to take account of new topographic data and improved modelling techniques. This report is a companion document to the *Kempsey Floodplain Risk Management Study* (this report) and should be read in conjunction with this report. The updated hydraulic model provides updated flood levels within the study area. The impact of a changing climate on flood behaviour is also considered.

EXISTING FLOOD PROBLEM

The flood model developed as part of the Kempsey Hydraulic Model TufLOW Update (WMAwater, 2016) was used to define the existing hazard and hydraulic classifications and flood planning areas within the study area.

A flood damages assessment for existing development in Kempsey was undertaken across a range of design events. This assessment was based on a detailed survey of building floor levels. Table i) indicates the estimated number of building floors which are likely to be flooded for a range of event magnitudes and the corresponding tangible damages. No consideration has been given for damages to public structures or utilities (bridges, roads, pumping stations) or for the complete collapse of structures due to flooding.

Table i) Flood Damages – Residential and Commercial

Event	Tangible Flood Damages		Total Tangible Flood damages (\$)
	Residential	Commercial	
PMF	\$ 59,220,400	\$ 42,278,100	\$ 101,498,500
0.2% AEP	\$ 28,276,900	\$ 28,090,900	\$ 56,367,800
0.5% AEP	\$ 20,013,300	\$ 23,721,700	\$ 43,735,000
1% AEP	\$ 10,068,700	\$ 16,611,900	\$ 26,680,600
5% AEP	\$ 3,097,300	\$ 8,312,400	\$ 11,409,700
10% AEP	\$ 1,655,800	\$ 5,287,900	\$ 6,943,700
20% AEP	\$ 117,400	\$ 5,800	\$ 123,200
50% AEP	\$ 64,800	\$ -	\$ 64,800
		AAD(\$)*	\$ 2,102,100

*In 2016 dollar terms

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, and
- Review of Councils 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. Included in the assessment was a long term strategy for reducing the flood risk to the community. 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. A summary of the various floodplain management measures considered during the course of the study is presented in Table ii) together with a brief assessment of their viability for implementation as part of the Floodplain Risk Management Plan for Kempsey.

Table ii) Review of Floodplain Management Measures

Measure	Relevant section	Purpose	Comment	Economic Assessment	Implementation viability	Priority
Flood Modification Measures:						
FLOOD MITIGATION DAMS AND RETARDING BASINS	Section 4.2.1.1	Reduce flows from upper catchment areas.	The use of dams and retarding basins would not be practical. Not appropriate sites	Not undertaken	Not applicable	Not applicable
CHANNEL MODIFICATIONS	Section 4.2.1.2	Increase waterway conveyance to reduce flood levels.	Many issues (cost, environmental, social) and limited effectiveness on a lined channel system.	Not undertaken	Not applicable	Not applicable
LEVEES FLOODGATES AND PUMPS	Section 4.2.2	Prevents or reduces the frequency of inundation of protected areas, assists in reducing problems with local runoff issues.	Existing levees should be repaired to their design height and a system should be established for regular maintenance.	Low Cost	Recommended	High
			Raise Levee Design Heights	Negative Benefits	Not Recommended	Not Applicable
			Levee at South Kempsey or alternative flood mitigation measure.	South Kempsey Levee- \$500,000 – Residential B/C – 2.89	Recommended	Medium
			Modifications to Wide Street levee to remove need for boards during event	Wide Street Cooks Lane – minimal cost	Recommended	High
			Raising of Wide Street Cooks Lane Levee	Not Undertaken	Recommend future investigation	Low
			Floodgates at Gladstone St or alternative flood mitigation measure.	Floodgates Gladstone St- \$200,000 Residential B/C – 9.07	Recommended	Medium
			Eden Street Boat Ramp – investigate filling low point from the boat ramp to Eden Street.	Low Cost	Recommended	Low
			Review of Lower Macleay Flood Mitigation works	Not Undertaken	Recommended	High
			Investigate the drainage of flood waters from behind the levee system	Low cost	Recommended	Low
			Long term integrated flood management scheme recommended. Structures to be regularly maintained. The effects of climate change should be considered in decision making. <ul style="list-style-type: none"> Removal of all buildings and obstructions from the Local floodway No 1; Raising the RSL levee - to design height; A ring levee around CBD Lowering existing ground levels within the natural floodway Raising land on the west of Smith Street Lowering First Lane levee and Eden Street and Flood gates to block backwater areas. 	Integrated scheme -\$3 Million Total B/C – 4.33	Long term. Outside the timeframe of this document.	Long term. Outside the timeframe of this document.
TEMPORARY FLOOD BARRIERS	Section 4.2.3	Demountable defences, wall systems and sandbagging which are deployed before the onset of flooding	Continue current use of sandbagging for low points, residential and commercial properties. Investigate possible raising of low points in future road upgrades and use of other temporary barrier options.	Not undertaken	Recommended	High
FLOODWAYS	Section 4.2.4	Floodways are designed to redirect high velocity flows away from critical areas and reduce flood levels in specific locations.	Council has a number of defined floodways in their DCP (see Section 2.7.2). Removal of all buildings in floodway particularly residential buildings is the only way to significantly reduce their risk.	High. Assuming \$12 Million cost, total B/C = 0.4. Significant intangible benefit.	Recommended	High
FLOOD REFUGE MOUNDS	Section 4.2.5	Flood refuge mounds are used as an effective means of reducing losses for stock during a flood.	Flood refuge mounds are suitable mitigation options for stock only on the floodplain upstream and downstream of Kempsey. Impact on surrounding properties to be confirmed. Should be treated as a back up plan not a primary evacuation plan.	Low Cost	Recommended subject to hydraulic assessment	Low
Property Modification Measures:						
LAND USE ZONING	Section 4.3.1	Key aspect in managing flood prone	Planning controls for floodway that is not hydraulic floodway.	Low Cost	Recommended	High

		areas. It ensures development only occurs in suitable locations compatible with flood risk and hazard.	Adjustments and reassessment of LEP 2013 zoning including areas currently within the floodway: <ul style="list-style-type: none">RE1 Public Recreation,RE2 Private Recreation andRE1 General Residential.			
VOLUNTARY PURCHASE	Section 4.3.2	To remove flood liable houses from the floodplain.	Current voluntary purchase scheme to be continued and accelerated to remove residential houses subject to high hazard from local floodway No 1.	High \$6 Million. Intangible benefits high.	Recommended	High
FLOOD PLANNING LEVELS	Section 4.3.3.1	To minimise flood damages to new developments.	Council has established appropriate controls. Update Flood planning level based on current model outputs.	Negligible costs	Upgrades to be considered.	High
			Consider putting flood information on Council's website	Negligible costs	Upgrades to be considered.	High
REVISE LEPS AND DCPS	Section 4.3.3.2	To ensure new development reduces the flooding impacts on downstream properties.	Council has established appropriate guidelines. However possible upgrades have been suggested. Council to consider minor changes to LEP and DCP. Adoption of Flood Planning Mapping for Electronic Housing Code.	Negligible Costs	Upgrades to be considered.	High
			Adopt Flood Planning Area based on current modelling 1% AEP plus 0.5m freeboard	Negligible Costs	Upgrades to be considered.	High
S149 CERTIFICATES	Section 4.3.3.3	Section 149 Planning Certificates provide information on the planning policies and controls that apply to a particular parcel of land.	Kempsey Council provides thorough S149 certificates. It is recommended that the certificates be updated and reissued based on the outcomes of this study.	Low Cost	Recommended	High
			Issue S149 (5) along with S149(2)	Low Cost	Recommended	High
HOUSE RAISING	Section 4.3.4	Prevent flooding of existing buildings by raising habitable floor levels.	Can be applied. Continue Existing Voluntary House Raising Program. Council to contact those on the list for voluntary house raising and review the list periodically.	High cost per property.	Recommended	High
			Extend list for voluntary raising to include other rural properties	Low Cost	Recommended	High
FLOOD PROOFING	Section 4.3.5	Prevents inundation of floodwaters.	Generally only suitable for non-residential buildings.	Depends upon building. Not funded by the State Government.	To be promoted where applicable.	Low
FLOOD ACCESS	Section 4.3.6	Ensure that there are adequate evacuation routes available and appropriate warnings as to when the routes will become impassable.	Raising of Belgrave St to improve evacuation and post flood recovery.	Tangible benefit hard to quantify. Consider as part of future road works program.	Recommended	Low
			Raising of South West Rocks Road to improve evacuation and post flood recovery.	Tangible benefit hard to quantify. Consider as part of future road works program.	Recommended	Low
Response Modification Measures :						
FLOOD WARNING	Section 4.4.1	Enable people to evacuate and take measures to reduce flood damages.	Conversion of all gauges downstream of Kempsey to AHD	Tangible benefit hard to quantify. Negligible cost.	Recommended	High
			Add Frederickton and Third Lane gauges to ENVIRONMON. Upgrade when technology available.	Tangible benefit hard to quantify. Negligible cost.	Recommended	High
			Additional gauges mid catchment	Approx \$20,000 per gauge. Tangible benefit hard to quantify.	Recommended	Medium
			Correlation between Kempsey and Smithtown gauges	To be done during an event at negligible cost	Recommended	High
			Document gauge management arrangements	Low Cost	Recommended	Medium
FLOOD AWARENESS AND PREPAREDNESS	Section 4.4.2	Educate people to minimise flood damages and reduce the flood risk.	A cheap and effective method but requires continued effort. Examples of methods are provided. Develop a flood awareness program regarding levee overtopping scenarios	Benefits likely to be significant for relatively low cost. Effectiveness reduces with time since last flooding event	Recommended	High
EVACUATION PLANNING	Section 4.4.3	To ensure that evacuation can be undertaken in a safe and efficient manner.	NSW SES to continue to regularly update Local Flood Plan.	Relatively low cost	Recommended	High
			Investigate system of managed entry to CBD during event	Relatively low cost	Recommended	High
			Study to investigate flow times between key upstream gauges.	Not Undertaken	Recommended	Medium
			Signs advising of risk of driving in floodwaters	Low Cost	Recommended	Medium

1. INTRODUCTION

1.1. Study Area

The Macleay River catchment covers an area of approximately 11500 km²; the upper reaches of which are located within the New England Tablelands. The study area for this report is defined as follows (Figure 1 and Figure 2) and is the same as the 2009 Kempsey Flood Study Hydraulic Modelling Report (WMAwater, 2009a):

- Upstream to between Aldavilla and Sherwood,
- Downstream to Austral Eden,
- East to Frogmore, and
- Including Aldavilla, Euroka, West Kempsey, Kempsey, East Kempsey, South Kempsey, Frederickton, Red Hill, Frogmore and part of Austral Eden.

1.2. Objectives

WMAwater (formerly Webb McKeown and Associates) was engaged by Kempsey Shire Council to update its floodplain risk management plan for the area between Kempsey and Frederickton. The previous plan was developed in 2004 (Lower Macleay Floodplain Risk Management Plan – Supplementary report covering the floodplain between Kempsey and Frederickton Webb McKeown and Associates, 2004b). The updated study and plan takes into consideration:

- Updates to hydraulic modelling technology
- NSW Government's Floodplain Development Manual
- Climate change projections for sea level rise
- NSW Government's guidelines for rainfall intensity increases

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. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk at this time and as a result of climate change.

2. BACKGROUND

2.1. Catchment Description

The Macleay River catchment covers an area of approximately 11500 km²; the upper reaches of which are located within the New England Tablelands. The main tributaries including the Apsley, Styx, Tia, Dyke, Yarrowitch and Chandler Rivers rise in the Great Dividing Range and flow eastwards across the New England Tableland before falling into rugged gorge country. The Macleay River itself emerges from the gorges some 35 km upstream of Kempsey. Below Kempsey the river meanders through a wide expanse of low lying floodplain which is subject to frequent and persistent flooding.

While the Macleay River is the dominant watercourse on the floodplain, significant tributaries include Christmas, Collombatti and Clybucca Creeks to the north, Belmore River and Kinchela Creek to the south and Parrabel Creek, Five Day Creek and Nulla Nulla Creek upstream of Kempsey. The Macleay River enters the ocean through a trained entrance at South West Rocks which was first breached during the flood of 1893. Previously the river entrance was at Grassy Head. The old channel between Grassy Head and South West Rocks has now become a complex backwater system. The reach of the Macleay River downstream of Kempsey Traffic Bridge to Seven Oaks forms the first major depositional zone for the estuary.

2.2. Floodplain Management Areas

Floodplain Management Areas have been defined based on areas of similar flood behaviour characteristics. Table 1 describes the floodplain management areas (Figure 1).

Table 1: Floodplain Management Areas

Area	Main localities
Kempsey	Kempsey CBD, residential areas including the voluntary purchase zone, and includes floodway No. 1, Eden Street Levee, RSL levee, First Lane Levee
East Kempsey	East Kempsey, East Kempsey Wetland, Pola Creek
West Kempsey	Includes West Kempsey (West of the railway line), Willow Drain Backwater Area, Dangar Street Backwater Area, Wide Street/ Cooks Lane Levee Overtopping Flowpath
South Kempsey	South Kempsey, Gills Creek, Boat Harbour Creek
Floodplain Upstream of Kempsey	Euroka Creek Floodplain Area, Aldavilla
Floodplain Downstream of Kempsey	Christmas Creek, Floodplain between Kempsey and Frederickton, Old Pola Creek, Red Hill and Frogmore

2.3. Land Use and Zoning

The land use zoning from the LEP2013 are included in Figure 4. The catchment is mixed use with areas of low density residential, industrial, business development, recreation and other non-developed uses in flood affected areas. A large amount of land within the study area is floodprone

with small amounts of high ground left for development. Most land uses in flood affected areas are residential, commercial and primary production.

Generally residential areas are situated in South, East and West Kempsey. Some residential development remains in the Voluntary Purchase Zone. Commercial development is generally located between Smith Street and Belgrave Street in the east and in West Kempsey. Land uses on the floodplain (in areas such as Frogmore, Redhill and Aldavilla) are generally flood compatible with little development. Within Kempsey itself residential and commercial properties are at risk of flooding.

2.4. Social Characteristics

Understanding the social characteristics of the area can help in ensuring that the right risk management practices are adopted. The census data can provide useful information on categories including dwelling and tenure type, languages spoken, age of population, movement of people into and from the area all of which can be useful to understand and have implication of flood risk management. Information has been extracted from the 2011 census (Australian Bureau of Statistics, 2013) for the suburbs of Kempsey and West Kempsey. Kempsey has a residential population of 389 comprising approximately 205 dwellings whilst West Kempsey has a population of 4791 living in 2085 dwellings.

Of interest is the data on population movement in recent years. Generally residents who have lived in an area for a longer period of time will have a better understanding of flooding issues affecting them than those who have recently moved to the area. In the last 5 years 36% have moved into Kempsey (Australian Bureau of Statistics, 2013). The majority of which are from another local suburb or NSW. A large percentage of the population would have been residents within Kempsey at the time of the most recent floods. These people are likely to have an understanding of the flood issues affecting them, but only for minor floods.

It is also useful to consider the tenure of housing. Those living in properties which they own are more likely to be aware of the flood risks and to have put measures in place to reduce them. Rental properties are likely to have a higher turnover of people living in them compared to privately owned properties and therefore those people in rental properties may be less aware of the flood risks unless they have been there for enough time to have experienced flooding or have been sufficiently informed by their landlords. The number of rented properties in Kempsey, West Kempsey, East Kempsey and South Kempsey is 44%, 39%, 36% and 37% respectively. The number of privately owned properties are 51%, 57%, 63% and 59% respectively.

The languages spoken by the population is also useful to consider as it can have implication on providing flood information to the public. In the study area greater than 95% of the population speak English at home.

2.5. Environmental Summary

A number of environmental and estuary management studies have been undertaken on the

Macleay River including the Macleay Estuary Management Study (Geolink, 2010) and Kempsey Coastal Processes and Hazard Definition Study (BMT, 2013). The Macleay River floodplain between Kempsey and South West Rocks contains estuarine deposits below the surface which have the potential for Acid Sulphate Soils (ASS). It is estimated that 31,000 ha of floodplain below Kempsey is underlain by high risk ASS that is either at or near the surface. KSC oversees a program to restore current scalded land to pasture and reduce intensity, frequency and duration of acidic water discharges. A number of wetlands exist in the study area (Diagram 1).

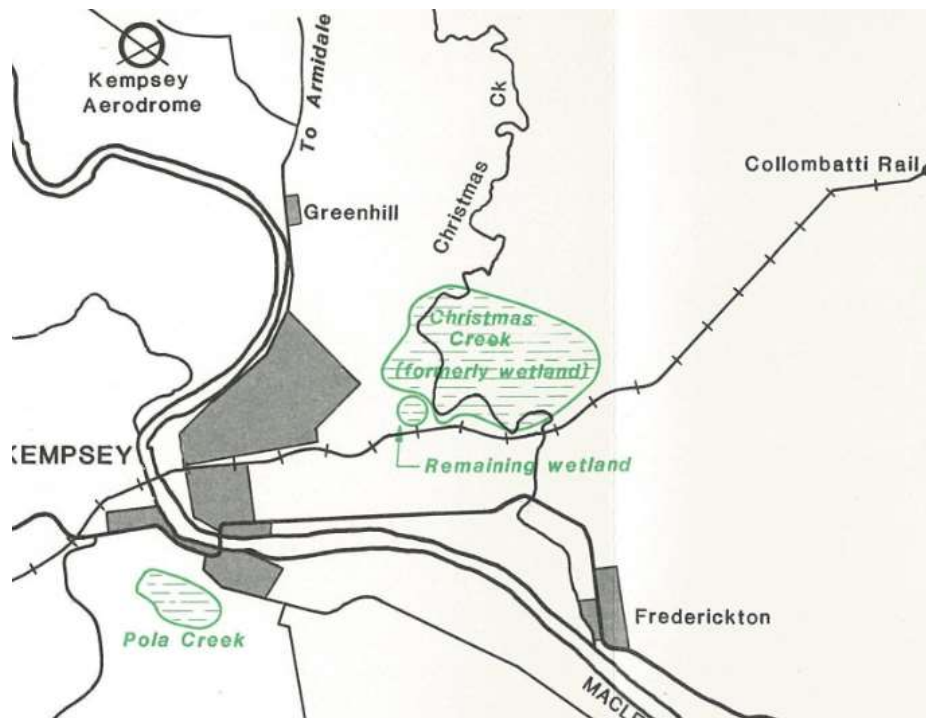


Diagram 1: Wetlands (Source: Laurie Montgomerie Petit, 1980)

There have been a number of studies previously undertaken on the bed dynamics and geomorphology of the lower Macleay River and its floodplain. These include broader assessments covering the entire lower Macleay River below the tidal limit at Belgrave Falls (e.g. WMAwater, 2009a, Webb McKeown and Associates, 1989). Other investigations concentrate on the Macleay River in and around Kempsey (e.g. WMAwater, 2009b). These more localised studies have typically focussed on the value of channel improvements (e.g. dredging works) to assist in the reduction of flood levels. The Macleay River at Kempsey Geomorphologic Assessment (Webb McKeown and Associates, 2008) studied morphological trends in the Macleay River channel for the reach between the Kempsey Railway Bridge and Frederickton. Downstream of Kempsey Traffic Bridge to Seven Oaks forms the first major depositional zone for the estuary.

The 2008 geomorphological assessment for the Macleay River at Kempsey (WMAwater, 2008a) found, that whilst detailed analysis of waterway area and volumetric and depth comparison suggested gradual trend for net deposition particularly towards Frederickton and further downstream, the amount was not thought to be significant. The assessment found that the potential influence of channel geomorphology is more pronounced for smaller flood events where a significant portion of the flow would be expected to be conveyed with the main channel. By

comparison, the impacts of a reduced channel volume in a 1% AEP event were found to be negligible, which is consistent with the different flow distribution likely to occur is an event of this size; flow is not confined to the channel and the overbank and floodplain area convey a significant amount of flow. Although there is a trend for deposition, there is also evidence of scouring in the vicinity of the Kempsey Traffic Bridge following the May 1963 flood (WMAwater, 2009a).

Situated on the banks of the Macleay River are levee structures and bank protection works to ensure they remain effective at containing floods within the river. Poorly maintained structures will eventually collapse under pressure of floodwaters causing economic and social damage. The environmental impact of river banks works and their ongoing maintenance is hard to quantify. The existing banks are a modified environment with little riparian vegetation and so it would be difficult to establish natural riparian vegetation on the banks.

Generally, floodplain mitigation works have fulfilled their design intentions but since the 1980's it has been thought that the levees, drains or control structures have some adverse environmental effects including fish kills and black water. These environmental impacts have caused the community to question the sustainability of the works and their operation policies. However recent evidence suggests that major kills have occurred prior to the construction of the works (MHL, Online Accessed 2015). Over time significant settlement in the Macleay River has allowed the floodplain vegetation to change from plants preferring wet conditions to those more tolerable of dry conditions. During a flood, the dry tolerable vegetation becomes covered with flood water which deoxygenates the flood water causing the black water effect. With the advent of flood mitigation in the 1950s the proliferation of dry tolerable plant species expanded on the Lower Macleay exacerbating an existing problem.

2.6. Floodplain Management Policy

2.6.1. State Legislative and Planning Context

It is important to understand the state legislation that overarches all local legislation so as to ensure appropriate floodplain risk management measures are proposed that are in-keeping with both state and local statutory requirements.

Planning in NSW is primarily governed by two pieces of legislation:

- Environmental Planning and Assessment Act 1979 (EP&A Act)
- Environmental Planning and Assessment Regulation 2000 (EP&A Regulation)

This legislation are in turn supported by other statutory documents. Of particular relevance to this study are State Environmental Planning Policies (SEPPs) and Local Environmental Plans (LEPs). SEPPs deal with matters of State or regional environmental planning significance and outline the NSW Government's approach to dealing with particularly planning issues. LEPs are an integral part of the NSW planning system. They are created by local Councils in consultation with their

community to control the form and location of new development, along with protecting open space and environmentally sensitive area. LEPs guide planning decisions for local government area.

Councils may then provide additional guidance through Development Control Plans (DCPs). A DCP provides detailed planning and design guidelines to support the planning controls in the LEP, and is prepared and adopted by local Councils. It identified additional development controls and standards for addressing development issues at a local level and can be applied more flexibly than an LEP.

A summary of relevant legislation, policy and guidance is provided in the following sections.

2.6.2. Environmental Planning and Assessment Act 1979 – as amended

The NSW Environmental Planning and Assessment Act (1979) (EP&A Act) provides the framework for regulating and protecting the environment and controlling development. Many other Acts relating to the Environment in NSW rely on the EP&A Act to implement their policy.

In relation to flooding, the Act imposes on Council the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy through the preparation of Local Environment Plans (LEPs), with further guidance provided through Development Control Plans (DCPs).

On 22 October 2013 the NSW Government introduced the Planning Bill 2013 and Planning Administration Bill 2013 into parliament. These Bills propose a new planning system for NSW that will ultimately replace the EP&A Act. The new system will only take effect once Parliament has passed the legislation. It is anticipated at existing State Environmental Planning Policies (SEPPs), as well as current Local Environment Plans (LEPs) and Development Control Plans (DCPs), will likely carry over from the current system until new plans and policies are made.

2.6.2.1. Direction No. 4.3 Flood Prone Land

Under the section 117(2) of the EP&A Act, Direction No. 4.3 is specific to managing flood prone land and applies to all Council's that are responsible for flood prone land within their LGA. The objectives of the 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 potential flood impacts both on and off the subject land.*

The direction prevents land within flood planning areas being rezoned from lower vulnerability uses such as recreation, rural or environmental protection zones to higher vulnerability uses such

as residential, business or industrial. Council should refer to the direction for full details on this. The direction also requires that proposals must not allow development in floodways or that will result in significant impacts to other properties. Furthermore, development should not be allowed that would result in substantially increased requirement for government spending on flood mitigation, infrastructure or services. Flood Planning Levels (FPLs) are required to be consistent with the Floodplain Development Manual 2005 (NSW State Government, 2005).

2.6.3. Environmental Planning and Assessment Regulation, 2000

The EP&A Act requires, under Section 149, that a person may apply to Council for a planning certificate (commonly known as a Section 149 or s149 certificate) with respect to any land within the area of the Council. Council should then issue a certificate specifying matters relating to the land whether under this or any other Act or otherwise. The Environmental Assessment and Planning Regulations 2000 set out a prescribed form and manner for information that should be included within the planning certificate.

Schedule 4 of the Regulations gives requirement for inclusions on s149 certificates under Section 149(2) of the Act. In particular Schedule 4 section 7A refers to flood related development controls 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. Further discussion on s149 certificates and flood prone land can be found in Section 4.3.3.3.

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

This SEPP, under the EP&A Act 1979, aims to identify types of development that are of minimal environmental impact that may be carried out without the need for development consent, as well as identify types of complying development that may be carried out in accordance with a complying development certificate as defined in the EP&A Act with a state-wide application.

The SEPP identifies a flood control lot as a lot which flood related development controls apply in respect of developments including dwellings, dual occupancies, multi dwelling housing, residential flat buildings, commercial and industrial uses.

Exempt Where land is identified as a Flood Control Lot and the development is minor in nature.	Complying Where land is identified as a Flood Control Lot
CI 2.29 specifies that Earthworks including retaining walls are not exempt.	Clause 3A.38 to all development under the Rural Housing Code (Part 3A of the SEPP) and sets out development standards for flood control lots. Certain certification by the council or a professional

	engineer specialising in hydraulic engineering is required prior to the development being accepted as "Complying"
CI 2.33 & 2.37 specifies that fences on residential / industrial / business zoned lands are not exempt.	CI 4.4A applies to other forms of residential accommodation and specifies that these are not complying
CI 2.36 specifies that fences on rural / environmental protection or large lot residential are exempt as long as they meet standards specified for height and type and do not interrupt the flow of ground water on that lot.	CI 5.17 & 5.19 applies to carrying out of works, including earthworks, retaining walls ancillary to alterations to industrial or commercial development and is specified as not complying development.
	CI 5A.30 applies to new and altered business and industrial development sets out development standards for flood control lots. Certain certification by the council or a professional engineer specialising in hydraulic engineering is required prior to the development being accepted as "Complying."

Examples of requirements set for development within a flood planning area are included below;

- All habitable rooms to be no lower than floor levels set by Council;
- Development at or below the FPL to be constructed of flood compatible material;
- Able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level;
- Not increasing flood affectation elsewhere in the floodplain;
- Reliable access for pedestrians and vehicles from development at a minimum level equal to the lowest habitable floor level of the development to a safe refuge;
- Open car parking spaces or ports that are no lower than the 5% AEP event flood level; and
- Driveways between car parking spaces and the connecting public roadway that will not be inundated by a depth of water greater than 0.3m during a 1% AEP flood event.

A joint report by a professional engineer who specialises in hydraulic engineering and a professional engineer who specialises in civil engineering is required to confirm the development can withstand floodwater up to the flood planning level and will not increase flood affectation elsewhere in the floodplain.

Generally, aside from rural fencing, any development to be carried out on land subject to flood storage, floodway, flow path or high hazard / high risk area requires a development application and is not complying development.

2.6.5. NSW Floodplain Development Manual

The primary objective of the NSW Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property and reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible. The NSW Floodplain Development Manual (NSW State Government, 2005) relates to the development of flood liable land for the purposes of Section 733 of the Local Government Act 1993 and incorporates this 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, it recognises that a different emphasis is required to address issues particular to rural floodplains. These issues include;

- The large area of land under investigation;
- The complexity of flood behaviour;
- The impacts of protection works for valuable crops on flood behaviour;
- The period of inundation;
- The uncertainties associated with flood related data; and
- The environmental values associated with flood dependent ecosystems on rural floodplains.

While this study contains a number of urban areas, many of the residences are in semi-rural areas.

2.7. Local Council Policy

Up to date and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, and can significantly reduce flood damages.

2.7.1. Kempsey Local Environment Plan 2013 (LEP2013)

The LEP2013 replaces the previous LEP1987, and was prepared to the standard format set by the NSW Government. The draft LEP was on public exhibition until mid-February 2013 and a number of Public Information Sessions were held to discuss the implications of the changes from the LEP1987 and explaining the new land use zones. The final LEP2013 was adopted and commenced on 3 February 2014.

The LEP2013 contains a number of land use zones, shown in Figure 4. For each land use zone, the LEP specifies development which may be carried out with or without consent, prohibited development and objectives for development. There have been some land use changes from the previous LEP1987 the most significant of these in terms of floodplain management is the rezoning of the floodways. Under the LEP1987 floodways were specifically defined as 1(e) Rural Floodway, however in LEP2013 they are defined as E2 Environmental Conservation.

The NSW Department of Planning and Environment (DoPE) has made available a number of model local provisions (or model local clauses) which address common topics raised by councils in the preparation of the standard instrument LEP. Clause 7.3 relates to flood planning. Councils are recommended to use the model local clauses where possible, with minor alterations to suit their specific circumstances to be considered with the appropriate justification. Due to the nature of the flooding in Kempsey, in that it is very different from many areas in NSW, Council have chosen to modify the model clause relating to flood planning.

Clause 7.3 of the LEP 2013 applies to all land at or below the Flood Planning Level (FPL). In the case of Kempsey the FPL is defined as *“the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.”* The clause seeks to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property to enable safe occupation of flood prone land, reduce public and private losses resulting from floods utilising ecologically positive methods, to avoid significant adverse impact on flood behaviour and avoid significant impacts upon the floodplain environment. In considering development consent, for development at or below the FPL, the clause requires that a number of criteria are satisfied including that the development;

- *Is compatible with the flood hazard of the land;*
- *Is not likely to significantly adversely affect flood behaviour, including having regard to cumulative effects of similar development, resulting in detrimental increases in the potential flood affectation of other development or properties;*
- *Incorporates appropriate measures to manage risk associated with development of flood prone land;*
- *Is not likely to significantly adversely affect the environment to cause erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks and watercourses;*
- *Is not likely to result in unsustainable and uneconomic costs to the community as a consequence of flooding;*
- *Is not likely to affect existing floodways, such that it would cause a significant redistribution of flood flow or significant increase in flood levels and is compatible with the flood hazard in the floodway; and*
- *Will enable safe occupation and evacuation of the land.*

These criteria will be enacted through the requirements set out in the DCP (Section 2.7.2). They require that all complying development does not increase flood risk, on or off site, put people at higher flood risk, have detrimental environmental effects in terms of flooding, and is sustainable and economical for the community.

2.7.1.1. Rezoning the Floodway

Under the LEP2013, floodways are now defined as E2 Environmental Conservation. It should be noted that the *Northern Councils Ezone Review Interim Report* was published in September 2013. This review looked at five north coast Council's where issues had arisen in the re-zoning of land to an E zone where previously it had not been. The review recommends that land should only be zoned E2 where significant tangible environmental assets are present, and overlays used to designate areas as, for example, drinking water catchment areas. The review focused on the north coast region as there is specific criteria common to the Council's considered, and we are not aware of intentions to apply the recommendations elsewhere, however the report is still under consideration by the DoPE.

Further discussion and recommendations on amendments to Council's flood policy are included in Section 4.3.1 and 4.3.3 in context of the hydraulic floodplain modelling undertaken as part of this study.

2.7.2. Development Control Plan 2013

The Kempsey Development Control Plan was adopted in February 2014 and supports and expands upon the aims, objectives and other provisions of the Kempsey LEP2013. Reference to flood-related controls is made throughout the document and in particularly Chapter B7 (Floodplain Management). The Development Control Plan states that development must comply with the requirements contained in Council Procedure 1.1.11 Flood Risk Management and any Floodplain Risk Management recommendations.

2.7.2.1. Development Control Policy 1.1.11 – Flood Risk Management

The Development Control Policy 1.1.11 was adopted in August 2012, formerly known as Council Policy on Flood Risk Management CPOL-43. The Policy covers the full LGA and therefore a wider area than the focus of this Study. It sets five objectives with regard to managing flood risk;

- Ensure new development in flood prone land is compatible with flood hazard and adequate flood risk management measures are incorporated minimising the possibility of loss of life and damage to property;
- Encourage redevelopment of existing flood prone lands in a way which would minimise chance of loss of life and damage due to flooding;
- Prevent the creation of any new area of urban development on flood prone lands;
- Prevent any extension of existing urban zoned areas into flood prone land;
- Seek eventual clearance of the Kempsey Local Floodway No. 1.

The Policy defines flood prone land as being inundated by a 1% AEP flood event. Flood planning levels (FPLs) are set as the 1% AEP flood level with 0.5 m freeboard. The Policy states that Council will not support rezoning of land for urban development unless shown to be at or above the FPL. Where development is allowed, a suitable evacuation plan needs to be prepared.

The Policy identifies and maps seven floodways around and through Kempsey (Figure 5). Those key to this study and within the study area, include Kempsey Local Floodway No. 1, Kempsey Central Business District Floodway and other Kempsey Floodways. Each of the defined floodways has a set of development controls associated with it which vary due to the nature of flooding in the area and also the scale and type of existing development.

The floodways referred to in the policy are based on hydraulic modelling from the 1985 Options for Flood Protection Study (Webb McKeown and Associates, 1985), together with earlier physical model studies carried out by the Public Works Department (PWD), and data on depths and velocities provided by Manly Hydraulics Laboratory (MHL). The limits of the various areas defined as floodways also took account of development boundaries at the time and cadastral lots. These have not been scrutinised since defined and therefore have the potential to be out dated given the significant advances in flood modelling technology in recent years as well as the availability of more detailed terrain data.

The LEP 2013 has adopted land use zones within Kempsey to be in line with the standard instrument LEP. Council needs to ensure that its flood management policy in the DCP is compatible with the new LEP land zone classifications (see Section 4.3.3.2 for further discussion).

2.7.2.2. Kempsey Local Floodway No. 1 and other floodways identified within the township of Kempsey – except Kempsey CBD floodway

The objective most fundamental to flood risk management in Kempsey is the removal of all buildings in the Kempsey Local Floodway No. 1. However, although Council policy aims to seek the eventual removal of properties from Local Floodway No. 1, it is recognised there may be circumstances for repairs, renovations and extensions to existing buildings, which are covered in detail in the DCP.

Section 5 discusses the implications of rezoning much of the Kempsey Local Floodway No. 1 as E2 Environmental Conservation, in the LEP2013.

2.7.2.3. Kempsey CBD Floodway

Council notes that it is not practical or appropriate to require the removal of existing urban development in urban centres, and therefore existing and new development will be allowed in the area defined as Kempsey CBD Floodway, providing certain criteria are met, which is covered by the DCP.

2.7.2.4. Other Floodways and Rural Floodways

The same requirements apply for repairs, renovations and extensions as within the Kempsey Local Floodway No. 1 and the CBD Floodway apply to these areas, and are covered by the DCP.

2.7.2.5. Flood Prone Lands, Other than Floodways

Most of the policy is divided into urban areas and rural areas, with urban areas further divided into district catchments. Subdivisions are also addressed. With Council recognising the need for growth and therefore prescribe criteria to ensure that a substantial increase in flood risk does not occur. The Policy also stipulates the requirements for three means of flood proofing; earth mounds, elevated buildings and electrical installations.

2.8. Previous Studies

A large number of previous studies have been undertaken in the Macleay River catchment and in the study area. These studies include hydraulic modelling and floodplain risk management studies. A detailed review of the most relevant studies and a description of the hydraulic model adopted for this study and key flood levels, can be found in the companion document to this report *Kempsey Hydraulic Model- TUFLOW Update* (WMAwater, 2016).

2.9. Available Data

The following data was available for the current study:

- Floor level survey of rural properties undertaken for the Kempsey Bypass project;
- Floor level survey undertaken for Council, December 2012;
- Levee bank survey undertaken by Council, June 2011;
- Previous hydrologic and hydraulic models

3. EXISTING FLOOD ENVIRONMENT

3.1. Flood Behaviour

During major flood events, flood waters drain to the ocean via a number of routes in addition to the river entrance itself. Significant outflows occur at Korogoro Creek, Ryans Cut, Killick Creek and South West Rocks Creek. Water can also flow either into or from the Hastings River catchment to the south via Connection Creek. In the major flood of 1949, other breakouts were reported at various points between Crescent Head and Grassy Head.

Complex interactions between the river and the floodplain affect the characteristics of flooding. Upstream of Kempsey at Belgrave Falls the river is well defined and floodwaters are mainly constrained to the river channel and a relatively narrow floodplain. Downstream of Aldavilla the floodplain broadens significantly with many connecting waterways further downstream. At Kempsey flow is predominantly confined to a relatively narrow area at the Kempsey Railway Bridge. Immediately downstream of this location a large natural floodway cuts northwards through the CBD where the main river channel at Kempsey Traffic Bridge narrows forcing significant flows through the local floodway no 1 and CBD floodway during large floods (greater than 10% AEP event). The peak 1% AEP flow in the Macleay River at Kempsey is approximately 15,000 m³/s. Downstream of the Kempsey Traffic Bridge the flow spreads out across the floodplain with an extent of approximately 4km in the vicinity of Frederickton.

3.1.1. Kempsey

Kempsey is located on the meander of the Macleay River. Kempsey is protected in small events (5 year ARI-10% AEP) by a levee system (Section 3.2.1). The lower CBD becomes flooded when either Eden Street or First Lane levees are overtopped (Section 3.2.1). Floodwaters can enter the area in a 5 year ARI event. Once the levees are overtopped a floodway develops subject to high velocities and significant depths (Photo 1). A number of residential properties and commercial properties are located in the floodway and are subject to regular flooding. Flood depths exceed 4 m in the 1% AEP event with velocities reaching over 2.5 m/s. The majority of the area is considered unsuitable for people and vehicles and buildings should be specially engineered to withstand floodwaters in a 1% AEP event.



Photo 1: Flood marker in Kempsey – Top of pole is the PMF level

3.1.2. East Kempsey

The majority of properties in East Kempsey are located largely on high land to the east of Kempsey itself. East Kempsey also includes some low lying land such as East Kempsey Wetland and Pola Creek. The catchment of East Kempsey Wetland is small in comparison to the Macleay River. Flood levels in the vicinity are dominated by Macleay River flooding. Pola Creek connects East Kempsey Wetland to the Macleay River with floodwaters backing up Pola Creek in flood events. A floodgate exists on Pola Creek between Rudder Street and Washington Street however it is not operational. The benefit of the floodgates should be investigated as part of the Lower Macleay floodplain mitigation works review.

3.1.3. West Kempsey

The majority of West Kempsey is located on high land with many of the critical infrastructure located in this area. Flooding of low lying areas (Willow Drain Backwater Area, Dangar Street

Backwater Area (Photo 2)) occur via underpasses and bridges under the railway line. In events rarer than a 1% AEP the Wide Street/ Cooks Lane Levee overtopping flowpath develops. Overtopping of River street occurs in several locations in events of 0.5% AEP or rarer.



Photo 2: Bridge under railway line – Willow Drain

3.1.4. South Kempsey

Flooding is caused by backwatering of Gills Bridge Creek, Boat Harbour Creek and Gills Drain an open drain near Bloomfield Street. An earthen levee on the river bank prolongs some backwater from entering into the area directly from the Macleay River. The majority of residential properties in South Kempsey is located on high ground. Bloomfield Street may become inundated in events as small as the 5-year ARI event although no properties are subject to significant flood damage from mainstream flooding.

3.1.5. Floodplain Upstream of Kempsey

Upstream of Kempsey at Belgrave Falls the river is well defined and floodwaters are mainly constrained to the river channel and a relatively narrow floodplain by while downstream of Aldavilla the floodplain broadens. The floodplain narrows again downstream of Euroka Creek. A flood runner, called Chapmans Creek, allows flows from the Macleay River to cut across the meander during flooding events. Settlement in this area is scattered and largely flood free. Residents can be isolated during flood events. Flooding of Euroka Creek occurs in a 2 year ARI event.

3.1.6. Floodplain Downstream of Kempsey

Downstream of Kempsey the floodplain broadens. The area includes Christmas Creek, Floodplain between Kempsey and Frederickton, Old Pola Creek, Red Hill and Frogmore. Most properties in this area are involved in agricultural pursuits and are adapted to frequent flooding. Flooding of low lying areas occurs in a 2 year ARI event. Significant flood depths and velocities occur in these areas in large events (rarer than 10% AEP events).

3.2. Existing Flood Mitigation Measures

Kempsey has had several major floods in recent historical times. The 1949 and 1950 floods are considered to be 90-year ARI and 80-year ARI events respectively and caused significant destruction in the town washing away in the order of 50 houses. The 1949 flood in particular cleared a large part of the natural hydraulic floodway through the CBD. These events led to the construction of a series of mitigation works during the 1950s and 1960s including levees, drains and control structures built throughout the floodplain by the Macleay River County Council (subsequently amalgamated into Kempsey Shire Council), drainage unions and private land holders.

An extensive series of levees has been constructed around the town together with a major floodway identified through the middle of the commercial district (see Figure 2). Currently four main levees protect the Kempsey CBD area; Eden Street, First Lane, the RSL wall and Wide Street/Cooks Lane levee. The Eden Street levee was constructed before the 1930s although has been raised several times since then; to 5.9 mAHD in 1958 and again in 1976 to a design level of 7.5 mAHD (WMAwater, 2007). The First Lane levee was raised in 1976 to a height of 5.9 mAHD (Webb Mckeown and Associates, 1997 and Kempsey Shire Council, 2011) as part of a program to increase the level of flood protection at Kempsey. In 1976 a concrete levee was constructed between the Kempsey Traffic Bridge and the RSL (WMAwater, 2007), known as the RSL levee wall. The design height is 7.26 mAHD. The Wide Street/Cooks Lane levee was proposed and subsequently constructed following recommendations in the 1985 Evaluation of Options For Flood Protection report (WMAwater, 2007) and was built to specification at the 1% AEP flood (as per modelled flood level at the time).

The rural flood mitigation works operate to reduce risk from events smaller than 10% AEP event. In small floods with a recurrence interval of 2 to 3 years, flood gates are closed to contain floodwaters in the major streams and prevent floodwaters spilling onto the floodplain downstream of Kempsey. This minimises the frequency of inundation which is the major cause of agricultural damage and maximises the time available for moving stock during major events. For Kempsey the closing of the flood gates has little effect on peak flood levels however can be beneficial for evacuation in adjusting the timing of the peak (Section 3.2.2). The flood gates (located outside the study area – see Figure 1) provide most benefit to Kinchela and Belmore areas which are outside of this study area. In floods between 3 and 10 year recurrence intervals (up to 10% AEP events), flood gates are opened to let floodwaters spill into the floodplain and wetland areas throughout the floodplain. This action helps to reduce flood levels experienced in small rural settlements at the expense of agricultural losses. In larger floods (greater than 10% AEP event), the operation of the flood gates does not significantly change flood levels. The Macleay flood mitigation system is not designed to mitigate floods larger than this and can generally only provide protection in the Lower Macleay up to the “Moderate Flood” level of 5.7 mAHD at the Kempsey Traffic Bridge gauge when general overbank flooding will occur (Macleay River Flood Mitigation System Report). During non-flood times the floodgates are left open to allow normal flushing.

As well as works within the Kempsey CBD area, other mitigation works were undertaken between 1949 and 1963 and included levees constructed on the left bank to protect Glenrock-Tennessee

area, Christmas Creek levee and headworks and Pola Creek headworks. A training wall between Pola Island to a point downstream of the Kempsey Traffic Bridge was also constructed in the mid-1960s (Kempsey Shire Council, 2011). Between 1963 and 1980 new levees were constructed and natural levees were raised on both banks of the Macleay River from Kempsey to Smithtown.

The majority of these works outside of the town are designed to minimise residential, and agricultural damages during small floods up to the 2.5 year ARI event. The town levee system provides protection up to a 10% AEP event. Generally, the works have fulfilled their design intentions, however some adverse environmental effects including fish kills and black water have caused the community to question the sustainability of the works and their operation policies. Although evidence suggests that major kills have occurred prior to the construction of the works (MHL, Accessed online 2015). Over time significant settlement in the Macleay River has allowed the floodplain vegetation to change from plants preferring wet conditions to those more tolerable of dry conditions. During a flood, the dry tolerable vegetation becomes covered with flood water which deoxygenates the flood water causing the black water effect. With the advent of flood mitigation in the 1950s the proliferation of dry tolerable plant species expanded on the Lower Macleay exacerbating an existing problem.

3.2.1. Levees

Several major levees protect the Kempsey CBD (Table 3 and Figure 2);

- *Eden Street levee* – earth embankment, runs along the northern side of Eden St between the railway embankment and high ground in the CBD;
- *First Lane levee* – earth embankment, north of First Lane, runs between the railway embankment at Broughton St and high bank of the Macleay River just north of Cochrane St;
- *The RSL levee wall* – a concrete wall at the end of Belgrave Street beneath the Kempsey Traffic Bridge, it runs along the river bank opposite the RSL tying into high ground at the northern end and free standing at the southern end;
- *Wide Street/Cooks Lane levee* - protects a small number of houses in West Kempsey, it crosses Wide Street to the west. Located on Wide Street and Cooks Lane and comprises a concrete wall. In Cooks Lane the pavement has been raised but during flood events boards are required to be fitted across the road.

Table 2 provides a summary of their construction history.

Table 2: Constructed Levee Works

Year	Levee Construction	Source
1958	Eden Street embankment constructed to 5.9 mAHd.	WMAwater 2007
1958	Levee constructed at Road Bridge to 5.29 m (datum unknown).	WMAwater 1997
1959	Eden Street levee raised to 6.9 mAHd.	WMAwater 1997
1975-1976	Earth levee constructed at First Lane to 5.9 mAHd.	WMAwater 1997 WMAwater 2007
1975-1976	Eden Street levee raised to 7.52 mAHd (2003 survey shows this to be 7.3 mAHd).	WMAwater 1997
1976	RSL Levee constructed to 7.3 mAHd downstream of the Kempsey Traffic Bridge (Kempsey Shire Council survey 2004 shows this to be 7.26 mAHd).	WMAwater 1997

A summary of the levees, design height and when first overtopped is provided in Table 3. Overtopping is assumed when the first spill of water over the crest occurs.

Table 3: Kempsey Levees Design and Survey Heights

Levee	Design Height (mAHD)	Surveyed Height* (mAHD)	Overtopping Location	First Overtopping Event**
Eden Street levee	7.50	7.30 - 7.70	Low point	< 10% AEP
			Full levee length	< 10% AEP
First Lane levee	5.90	5.86	Low points	< 5-year ARI
			Full levee length	< 10% AEP
RSL levee wall	7.26	7.10 - 7.15	Full length of levee	< 10% AEP
Wide Street/ Cooks lane levee	10.90	n/a	Full levee	1% AEP

* Surveyed height is the minimum height of the levee as per Council's 2011 survey of the levees (Kempsey Shire Council, 2011). Wide Street/Cooks Lane levee was not included in this survey.

** The first overtopping event is based on the hydraulic modelling undertaken for this study (detailed in WMAwater, 2015) and is the first modelled design event in which the levee overtops. Overtopping location does not take account of sandbagging.



a) Eden Street levee



b) RSL levee wall



c) First Lane levee (from Kemp Street)



d) Wide Street/Cooks Lane levee (on Wide Street)

Photo 3: Levees

A recent survey by Council (Kempsey Shire Council, 2011) following the June 2011 flood event identified that in general the minimum levels on Eden Street and Cochrane levees were up to 200 mm below the design levels. Currently during flood events, Council is required to place sandbags where Smith Street (the old Pacific Highway now Macleay Valley Way) crosses the Cochrane levee and at the end of Eden Street levee near the Sydney Street intersection with Eden Street (Kempsey Shire Council, 2011).

The variations in crest height on the Eden Street Levee are not considered significant as the flow of floodwater during the 2001 event over the levee crest was uniform with no structural damage to the levee.

The modelling shows the First lane levee to fully overtop in a 10% AEP event. The Council survey established that the levee is generally at the design height with only a few locations along the levee being lower than this. Generally the levee is above 6 mAHD. The lowest point is at Smith Street (old Pacific Highway) where the top of the levee is at 5.86 mAHD. During a flood event this section is sandbagged to maintain the overall levee height.

The RSL levee was found to be slightly lower than the design height (7.26mAHD) at 7.1 to 7.15 mAHD. Wide Street/Cooks lane levee (often called Short Street Levee) was not included in Council's 2011 survey. This levee is first overtopped in the 1% AEP event.

Following the 2011 levee survey Council resolved in October 2011, that restoration/maintenance of the Eden Street and First Lane levees to their design heights be listed for consideration in the 2012/2013 budget under the 2:1 Flood Mitigation Grant Subsidy Scheme. In the 2012/2013 scheme funding was secured for an audit of the existing levee banks of the Lower Macleay Valley floodplain. Raising the levees to their design heights is discussed in Section 5.1.

3.2.1.1. Levee Overtopping Behaviour

The overtopping behaviour of the Kempsey Levees has caused some confusion for both residents, NSW SES personnel and Council Staff. The order in which the levees overtop can vary depending on flood characteristics. The Levee Gradient Assessment (WMAwater, 2007) noted that different shaped hydrographs, those with the same peak level but different rates of rise and volumes, may change the flood gradient along the levees and subsequently impact the sequence and location of levee overtopping.

A close correlation was noted between the rate of water rise and the sequence of levee overtopping and the shape of the hydrograph had a significant impact on the relative sequencing between the Eden Street and First Lane levees. Fast rising floods such as the 1949 flood produce a steeper flood gradient prior to the peak than slow rising floods. Therefore fast rising floods will typically cause the Eden Street levee to overtop first before the First Lane levee. In scenarios where the Eden Street levee is the first to be overtopped, the area between the Eden Street and First lane levees acts as a floodway conveying water northwards/downstream.

When the rate of rise is lower (typically less than 0.1 m/hr) as smaller broad shape event occurs, the First Lane levee may begin to overtop first. In this style of event the area between Eden Street and First Lane levees acts as a backwater area. Water spills over the First Lane levee from downstream flows in a southwards direction towards the CBD and Eden Street.

Once both levees are overtopped they act as a floodway with water flowing from Eden Street to First lane. The area generally is subject to higher velocities in this scenario than when acting as a backwater area. The overtopping scenarios are described in Diagram 2.

The recent 2013 event gave an opportunity to reassess the consequences of different rates of rise. The critical rate of rise is when flood level are near to the current levee crest heights rather than the rate of rise of the entire rising limb which can be deceptive as the floodplain is filling. When the rate of rise is slower, being less than approximately 0.1 m/hr between 6.7 and 6.9 mAHD at Kempsey Traffic Bridge, the First Lane levee may overtop first. With a faster rate of rise occurring at similar water levels, the Eden Street levee is likely to be the first to overtop.

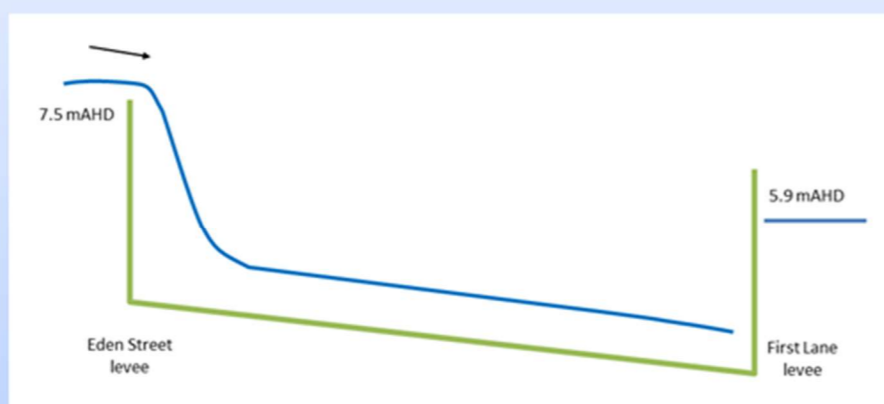
3.2.1.2. Timing of Overtopping

The sequence of overtopping of the levees for the range of design events modelled is given in Table 4. Diagram 3 shows when each levee is overtopped on design event hydrographs at Kempsey Traffic Bridge. This should be considered indicative as this Study has not considered a variation in the shape of the design hydrograph.

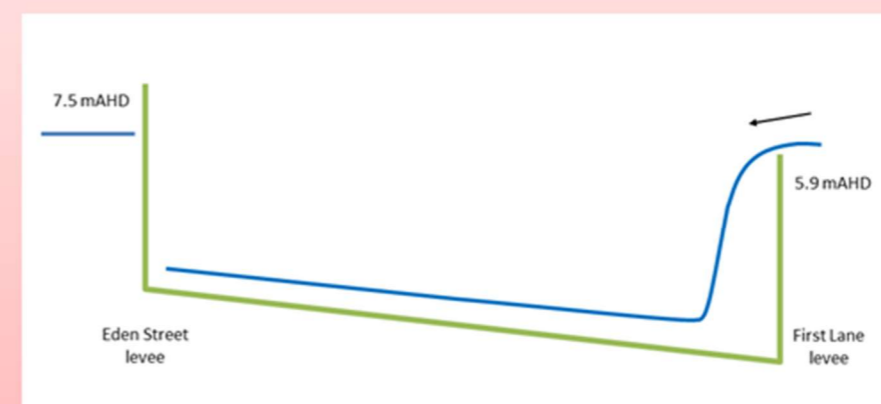
Table 4: Levee Overtopping –Height at Kempsey Traffic Bridge Gauge (mAHD)

Event	Eden Street Levee	RSL Levee Wall	First Lane Levee	Wide Street/ Cooks Lane Levee
2-year ARI	-	-	-	-
5-year ARI	-	-	6.60 (1)	-
10% AEP	6.87 (1)	7.12 (3)	7.08 (2)	-
5% AEP	6.88 (1)	7.12 (2)	7.22 (3)	-
1% AEP	6.89 (1)	7.12 (2)	7.41 (3)	8.3 (4)
0.5% AEP	6.89 (1)	7.12 (2)	7.43 (3)	8.3 (4)
0.2% AEP	6.89 (1)	7.12 (2)	7.43 (3)	8.3 (4)
PMF	6.89 (1)	7.12 (2)	7.43 (3)	8.3 (4)

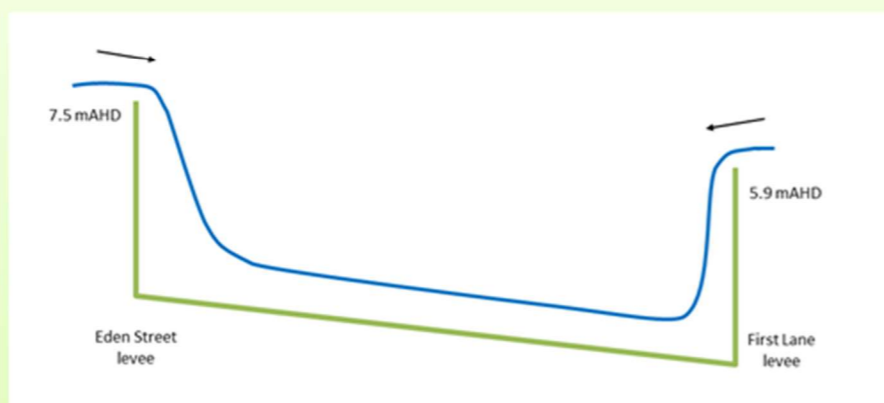
NOTE: Sequence of overtopping of the levees is shown in (brackets). No value indicates levee is not overtopped.

FAST RISING EVENT – Eden Street Overtops

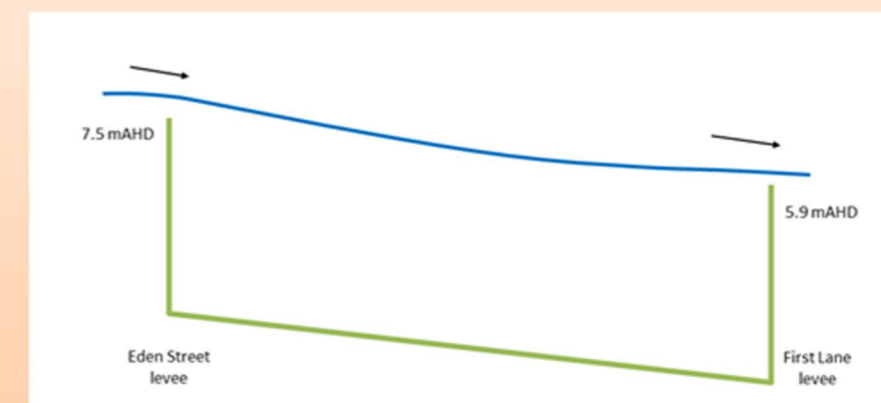
- Eden Street levee overtops water flows northwards through the floodway towards the First Lane levee.
- This scenario is more likely to occur when there is a steeper flood gradient in the river near Kempsey.
- The critical rate of rise between 6.7 mAHd and 6.9 mAHd at Kempsey Traffic Bridge is generally greater than approximately 0.1 m/hr.
- Occurs in events generally rarer than a 10% AEP.
- High velocities in floodway
- Eden street Levee was the first to be overtopped in the 2001 event

SLOW RISING EVENT – First Lane Overtops

- Floodway area acts as a backwater area as water overtopping the First Lane Levee flows southwards towards the CBD.
- This scenario occurs on slow rising events
- When the rate of rise at the critical level between 6.7 mAHd and 6.9 mAHd less than approximately 0.1 m/hr,
- Velocities are generally low.
- Occurred in May 2009 and February 2013 events.

BOTH LEVEES OVERTOPPING

- Both levees are overtopped
- Either levee may be the first to overtop depending on the rate of rise of the flood at the critical level.
- Occurs in events more frequent than 5% AEP or rising limb of rarer events
- Floodway acts as a bathtub filling from both ends
- This scenario occurred in 2001

FLOODWAY OPERATING

- Both levees are overtopped
- This scenario generally occurs in the larger flood events rarer than a 5% AEP.
- Floodway in full operation.
- High Velocities

Diagram 2: Eden Street and First Lane Overtopping Scenarios

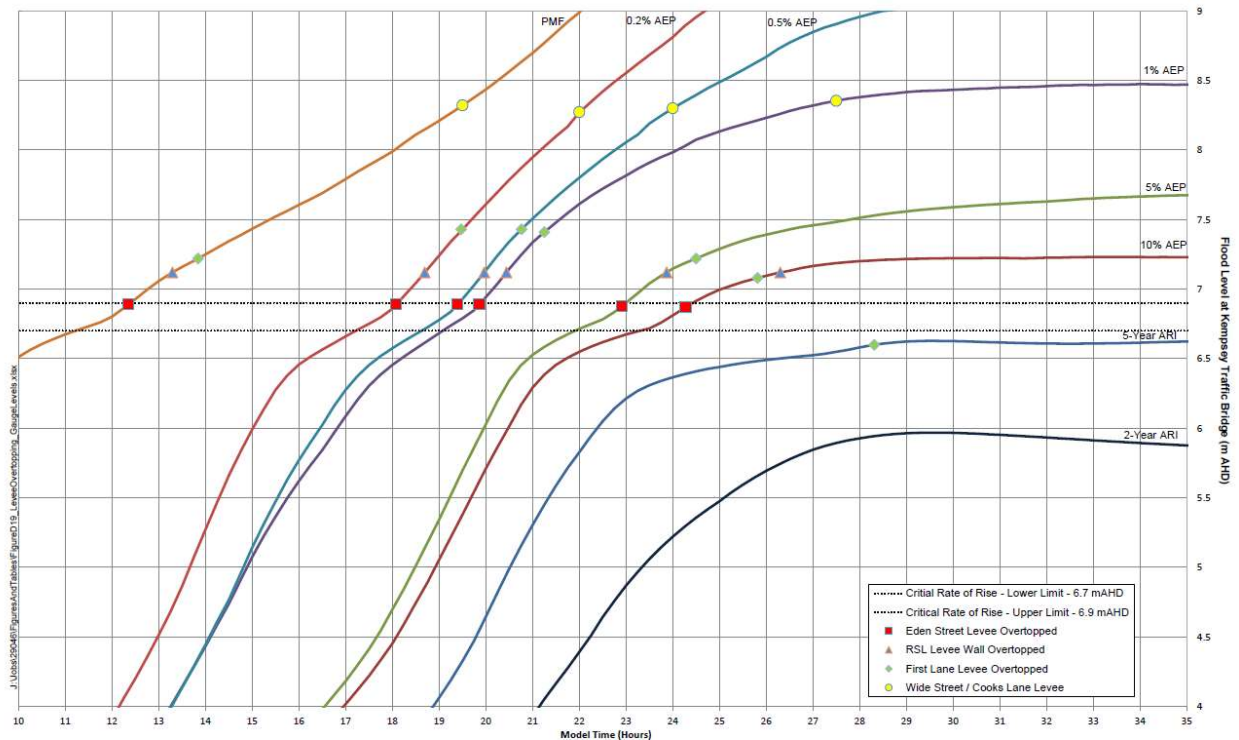


Diagram 3: Time of Levee overtopping at Kempsey Traffic Bridge Gauge – Design Events

3.2.2. Flood Gates

A number of floodgates have been installed within the Macleay River Catchment. While some operate passively, eg. Frederickton under the Pacific Highway, others require human intervention during an event, eg. Belmore River.

At First Lane levee a series of six 1.8 m wide by 1.8 m high culverts allow water to drain from the CBD post event. Council records indicate that there are a number of minor flood gates located at various points adjacent to the Macleay River although the capacity of these are believed to be minor in comparison to those under Cochrane Street.

The efficiency of these floodgates and the rate at which the Floodway area is drained is dependent upon the rate of fall of the Macleay River (refer to WMAwater, 2009b). It would take approximately 26 hours for the CBD area to drain to a level of 4.5 m AHD and three days before flood levels within the levee would be expected to reach a level of 2.5 m AHD. Most existing development within the CBD area is generally located above 4.5 m AHD. At a level of 2.5 m AHD flooding is generally confined to the low lying areas adjacent south of First Lane and in and around the Gladstone Street railway underpass.

Floodgates at Kinchela and Belmore, have little benefit in events greater than the 10% AEP event. Furthermore, although the flood gates provide significant benefit to local areas downstream of Kempsey they have little effect on peak flood levels at the Kempsey Traffic Bridge. Table 5 shows the impacts of the operation of the flood gates is negligible at Kempsey Traffic Bridge regardless of the flood recurrence interval. Operation of the floodgates provide significant flood peak

reduction at 800m from Belmore flood gates under the 2 yr ARI and 10% AEP events but is negligible under the 1% AEP event. The benefit of the floodgates should be investigated as part of the Lower Macleay floodplain mitigation works review.

Further refinement of the flood model in rural areas is required and review of operations manuals as a recommendation as part of any floodplain mitigation works review. The operation manual should also be reviewed.

Table 5: Impact of opening both Kinchela and Belmore food gates at their trigger level (4.64mAHD) on flood levels at Kempsey Traffic Bridge and 800m upstream of Belmore flood gates versus not opening the gates at all

Event	Kempsey Traffic Bridge Flood Level (mAHD)		800m Upstream Belmore Flood gates	
	Opened at Trigger	Closed floodgates	Opened at Trigger	Closed floodgates
2 yr ARI	5.936	5.943	3.452	3.693
10% AEP	7.346	7.347	3.624	3.703
1% AEP	8.551	8.551	4.271	4.276

3.3. Floodways

The 1949 flood cleared a large part of the natural floodway through Kempsey. A government sponsored floodway clearing program followed to clear the residential housing from this floodway. The floodway was the subject of a Commission of Inquiry held in the 1960s which led to significant restrictions on any further development of lands within the floodway.

Kempsey Local Floodway No. 1 (Figure 5) runs from the Macleay River at Eden Street north to past First Lane. In the west the floodway is bound by Memorial Avenue and in the east by the CBD zone and Smith Street. The floodway was zoned 1(e) Rural Floodway under the LEP 1987; and is now rezoned to E2 Environmental conservation in the 2013 LEP. Some areas have been rezoned from 6(a) Open Space to RE1 Public Recreation.

The Kempsey CBD Floodway is immediately adjacent to Kempsey Floodway No. 1. It contains commercial land zoned as B3 Commercial Core under the LEP 2013. Glenrock-Pola Creek Floodway covers Pola Creek and Frogmore areas to the east of the river and Glenrock Drain to the west. A large area is also marked within councils planning documents as Other Kempsey Floodways.

3.4. Local Stormwater Runoff

Stormwater flooding is typically localised and not as extensive as flooding from mainstream sources i.e. the Macleay River. It is not considered further in this study.

During the 2009 and 2011 floods, flooding was observed behind the RSL levee wall. However, this is not attributed to local stormwater runoff, rather it is related to floodwaters from the Macleay

River. During a flood event (usually greater than the 2-year ARI) the Coles car park begins to take on floodwater from the Macleay River. Once the water level in the car park reaches the barrier, located along Lower Belgrave Street, floodwaters flow across the footpath in Lower Belgrave Street into the low point stormwater drainage pit in Belgrave Street. It is then discharged from a pit directly behind the RSL levee wall. This did not present a significant problem at the time due to the relatively short length of the flooding. However, Council have resolved to investigate further.

Coles Management Group and Council met to discuss the issue in 2014. It was resolved to place a permanent barrier along the Lower Belgrave Street property boundary Coles car park interface at a level equal to at least the design level of the RSL levee wall. This permanent barrier will prevent a recurrence of flooding onto Lower Belgrave Street during lower order flood events and build-up of flood water behind the RSL levee wall. To date this has not been built.

3.5. Design Flood Data

As part of the study design flood data for the Hydraulic model extent was updated. No significant change in flood levels occurred. Details of this update is contained in the companion report WMAwater (2016) which should be read in conjunction with this report. The impacts of climate change rainfall increases were also assessed. Peak flood level and depths for the 10%, 1 % AEP and PMF events are reproduced in this report (Figure 6 to Figure 11).

3.6. Hydraulic and Hazard Classification

For the purposes of floodplain risk management in NSW floodplains are divided into one of three Hydraulic categories (floodway, flood storage and flood fringe) and Hazard categories. Further details of this process are provided in the NSW Governments Floodplain Development Manual (2005, Appendix L) (NSW State Gov, 2005).

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 (NSW State Gov, 2005), 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%”*.

Hydraulic categories have been defined by considering detailed assessment of flood behaviour, the available topographic information and interpretation of the hydraulic model results and knowledge of the catchment (Figure 13 and Figure 14). 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. Backwater areas are classified as areas where velocities are generally low to nil and the area is not critical for storing water during an event. However, water in these areas can still be very deep. The hydraulic categorisation in each area is presented in Table 6.

A large area of floodplain is considered floodway. The entire width of the floodplain in the vicinity of Euroka where the floodplain is confined is considered floodway. Much of the floodplain between Kempsey and Frederickton and Pola Creek is also floodway where the floodplain begins to widen. A floodway also forms between Kempsey and West Kempsey when the levees are overtopped. A narrow floodway forms in events of a 1% AEP or rarer when the Short Street levee is overtopped.

Table 6: Hydraulic Categorisation

Area	Hydraulic Categorisation	Hazard Categorisation
Kempsey CBD	Floodway and Flood Fringe	H5, H6
East Kempsey	Flood Storage, Backwater Area, minor Floodway	Small areas of H4, H5, H6,
West Kempsey	Backwater Area	Small areas of H4, H5, H6,
South Kempsey	Backwater area, Flood Storage	Small areas of H4, H5, H6,
Floodplain Upstream of Kempsey	Floodway, Flood Storage, minor Backwater Area	H5, H6,
Floodplain Downstream of Kempsey	Floodway and Flood Storage	Small areas of H3 and H4, H5, H6,

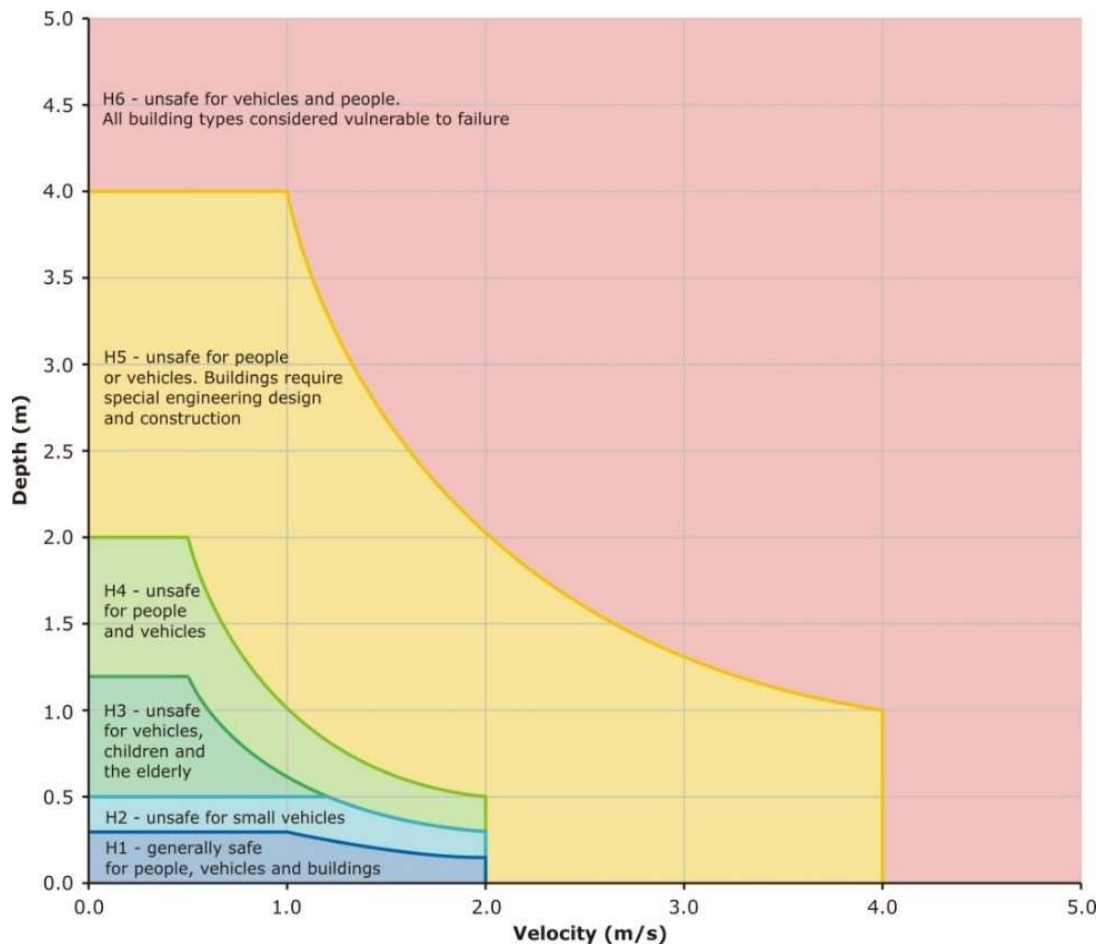


Diagram 4: Hazard Classifications

The majority of the study area would be classified as high hazard using the Floodplain Development Manual hazard curves. In recent years there has been a number of developments in the classification of hazard. *Managing the floodplain: a guide to best practice in flood risk management in Australia* (Australian Government, 2013) provides revised hazard classifications which add clarity to the hazard categories and what they mean in practice. The classification is divided into 6 categories (Diagram 4) which indicate the restrictions on people, buildings and vehicles:

- 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.

Figure 15 to Figure 18 present the provisional hazard classifications for the 10% and 1% AEP events. Under this classification for a 1% AEP event much of the floodplain is considered unsafe for all people and all vehicles with buildings require special engineering design and construction or unconditionally unsafe. A number of houses exist in H6 areas including Hopetoun Street and Memorial Ave.

The Floodplain Development Manual (NSW State Government, 2005) requires that other factors be considered in determining the “true” hazard such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of flood waters, 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 it also incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production. The classification is a qualitative assessment based on a number of factors as listed in Table 7.

Table 7: Hazard Classification

Criteria	Weight	Comment
Size of flood	Low	Hazard changes significantly in Kempsey when the levees are overtopped (greater than 10% AEP). Generally once floods are greater than the 1% AEP event, hazard does not significantly increase and much of the flooded area is already subject to high hazard.
Flood Awareness of the Community	High	Whilst residents are aware that flooding occurs, many will have experienced the relatively small events. The communities outside Kempsey itself will be more aware of flooding. The 2013 event has heightened awareness of the general public to flooding issues although this diminishes over time.
Depth and Velocity of Floodwaters	High	High velocities and large depths of floodwaters mean the risk to life is high.

Effective Warning and Evacuation Times	High	Warning time 24 hours. 12 to 24 hours notice of a levee overtopping event. There is only a very small likelihood that residents would be caught completely unaware but they are unlikely to have the foresight to react appropriately to the situation, particularly if the event happens during the night.
Evacuation Difficulties	Low to Medium	For the majority of residents evacuation should be relatively easy as there is nearby high ground for vehicles and the majority of goods can be saved by raising them 1 m off the ground within the building.
Rate of Rise of Floodwaters	Low	The rate of rise of floodwaters is generally slow.
Duration of Flooding	High	The duration of inundation is relatively long.
Effective Flood Access	Low to medium	Much of the study area is rising road access. The vehicular and pedestrian access routes are all along sealed roads and present no unexpected hazards if the roads have been adequately maintained. SES boats can effectively be used to ferry residents to high ground. Four wheel drive access (by the SES) is possible early in an event.

Based on the above assessment, the provisional flood hazard categorisations will not be changed.

3.7. 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.

Critical services and key infrastructure in Kempsey have undergone a migration to West Kempsey. The police, ambulance, fire station, hospital and Council as well as the NSW SES Headquarters are all located above the 1% AEP level (Figure 21). However, in the 1% AEP event, the fire station, Police Station, Ambulance and Council offices are on a High Island as the Wide Street/ Cooks Lane levee is overtopped and waters flow over River Street into the Dangar Street backwater area. During a flood event the West Kempsey sewage treatment plant may be inundated. Water

and sewage supply may be affected in some events. However, at the time of writing, there is a proposal to move the West Kempsey sewerage plant to higher ground above the 1% AEP event which would avoid this problem in the future.

3.8. Impacts of flooding on Residential, Commercial and Industrial Properties

Residential properties suffer damages from flooding in a number of ways. Direct damages include loss of property contents or damage to the structure of the property. Indirect damage costs can be incurred when occupant may have to move away from the property while repairs are being made or loss of work due to cleaning up afterwards. Of the 106 residential properties flood affected in the 10% AEP event, 31% of these are located within the floodway.

The frequency of flooding of the commercial areas of Kempsey has significant influence on the economic viability of the town and both Council and the business community have identified that the threat of inundation causes significant economic costs to Kempsey.

Loss of business confidence can also affect commercial activities which have been closed due to flooding. Whilst the business has closed customers have moved their business elsewhere and do not return, although this can be more of an issue for larger urban areas where there may be more competition between businesses and also in instances where businesses may be closed for a substantial amount of time.

Appendix B contains a flood damage assessment for both residential and commercial properties.

3.9. Emergency Response Classification

The Floodplain Development Manual (NSW State Gov, 2005) requires flood studies 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 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 8 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 8: Response Required for Different Flood ERP Classifications

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Area with Overland Escape Routes	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapped Perimeter	Yes	Possibly	Possibly
Indirectly Affected Areas	Possibly	Possibly	Possibly

The ERP classifications for the most populated regions of the hydraulic model extent have been defined for a range of events. These are shown in Figure 21 and Figure 22. A summary for each of the floodplain management areas of Kempsey is provided in Table 9 below. Based on the classifications, evacuation should prioritise those areas, which once they become inundated evacuation access is limited or unsafe. The following areas should be priorities for evacuation assistance:

- Current local Floodway No. 1 including the Voluntary Purchase Zone;
- The Eastern CBD; and
- CBD Residential Areas.

Most rural residents are self-sufficient and well prepared for flooding. However if a very rare event occurs they may require significant assistance once access roads are cut.

Table 9: ERP Categorisation of Kempsey

Area	Emergency Response Planning Categorisation
Kempsey CBD	Low Flood Island
East Kempsey	Rising Road Access
West Kempsey	Rising Road Access and Overland Escape Route
South Kempsey	Rising Road Access and Overland Escape Route
Floodplain Upstream of Kempsey	One High Flood Island, Overland Escape Route and Rising Road Access
Floodplain Downstream of Kempsey	Two High Flood Islands, Overland Escape Route and Rising Road Access

3.10. Previous Flood Mitigation Measures Considered

Following the Kempsey Evaluation of Options for Flood Protection Study in April 1985 (Webb McKeown and Associates) a number of physical works were proposed for providing better protection to Kempsey however none were acceptable to the local community. Council subsequently adopted an approach of clearing residential development from the Kempsey Local Floodway No. 1 whilst allowing commercial development to continue within the Kempsey CBD Floodway zone.

The 2004 *Lower Macleay Floodplain Risk Management Plan – Supplementary Reporting covering Kempsey to Frederickton* (Webb Mckeown and Associates, 2004b) proposed a number of options including river bank management, drain management, and improvements to flood warning. The Kempsey CBD options study (WMAwater, 2009b) investigated a number of options for clearing Local Floodway No 1. None of these options were adopted but were recommended for further study.

3.11. Community Consultation

One of the central objectives of the Floodplain Risk Management Study process and the ultimate development of the Floodplain Risk Management Plan is to provide the local community with a community accepted resource that can be utilised for all flood related issues including development, flood warning, response and management/remediation.

Community consultation has been undertaken as part of preparation of this Floodplain Risk Management Study and in the Floodplain Risk Management Plan. A summary of the consultation measures are provided below:

- meetings with the technical sub-committee (OEH and Council Officers) who provide direction on the technical aspects of the project. This includes which management measures should be assessed and the approaches to be undertaken;
- The Draft Floodplain Risk Management Study and Plan were placed on public exhibition from 20 January to 24 February 2017. Council ran community information and business information sessions on the 13 and 15 February 2017 respectively:
 - Residents could provide detailed comments via “Have your say Macleay” - 2 submissions were received relating to floodway zoning.
 - Council website with public exhibition version of the document – visited by 348 people.
 - 5 comments were also provided in writing by residents and the SES.

Through the period of this Study the community have also been engaged on several occasions regarding related studies in Kempsey. Following the 2011 event NSW SES conducted the Post Flood Event Data Collection and Intelligence Review (WMAwater, 2013b) which included a questionnaire sent to residents of the Lower Macleay Valley. The analysed results have been considered in the recommendations made in this current Study.

The main issues raised in the responses were:

- Comments for and against the new floodways
- Practicality issues with the implementation of a ticketing scheme during events
- The need for reliable flood data and a website with all flood data in one place
- Comments relating proposed mitigation measures
 - Comments not supporting Belgrave St and South West Rocks Upgrades
 - Comments for house raising
 - Comments on temporary flood barriers
- Kinchela and Belmore river flood gates -note outside project scope

The draft report was modified to reflect feedback during community consultation.

4. FLOODPLAIN RISK MANAGEMENT MEASURES

4.1. Overview

The 2005 NSW Government's 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 such means 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 10 below provides a summary of the floodplain risk management measures that could be considered for the Macleay River catchment.

Table 10: 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

4.1.1. 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 the ranking against similar projects in other areas. It is a standard method for using the time value of money to appraise long-term projects 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.

4.2. Flood Modification Measures

4.2.1. Flood Modification Measures Not Considered Further

4.2.1.1. Flood Mitigation Dams and Retarding Basins

Flood mitigation dams have frequently been used in rural areas of NSW to reduce peak flows downstream. 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 on 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 for this catchment.

Retarding basins are small-scale flood mitigation dams commonly used in urban catchments for the same reasons. One of the major impediments in their use as a flood mitigation measure for existing development is the lack of suitable sites. Retarding basins and other on-site stormwater detention systems are appropriate for controlling flooding in small catchments (up to 20 km²) or to mitigate the effects of increased runoff caused by development. However, they would have negligible impact on flood levels in the Macleay River.

4.2.1.2. Channel Modifications

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 environmentally and economically sustainable. In addition they are relatively costly to undertake

and may introduce additional problems such as bank erosion, sedimentation, land ownership and permission; increases in flood levels downstream and require an on-going maintenance regime.

Hydraulic modelling (WMAwater, 2008a) indicates that the potential impacts of deposition between 1964 and 2003 in the reach between the Kempsey Traffic Bridge and Seven Oaks are most significant for smaller flood events with increases in flood level of between 0.1 m - 0.15 m in some sections. As expected, for large floods where there is likely to be significant overbank and floodplain flow, these impacts are less important as the relative proportion of total flow in the main channel decreases. The results showed that there was virtually no change in flood level for the 1% AEP flood event resulting from changes in the underlying channel bathymetry adopted in the model.

An assessment of the changing channel profile and cross sections was undertaken as part of Kempsey Evaluation of Options for Flood Protection (Webb McKeown and Associates, 1985) which concluded that, although the channel has changed over time, dredging of the channel would have little impact on reducing flood levels for Kempsey and would also come at a considerable economic and ecological and on-going cost. Although the report suggested that flood levels could be reduced by a maximum 0.42 m based on the design of the current levee system at the time, for any long term benefit it would be essential for regular dredging to be carried out after the initial clearing of the river to ensure that the improvement in hydraulic efficiency was maintained. Where dredging is not regularly undertaken the channel will over time return to its natural equilibrium. An on-going dredging program would rely on regular funding for which there is no guarantee of availability nor is it likely to get approved. Furthermore, there is a risk in relying on flood levels that are based on the assumption dredging has been undertaken; should dredging not be undertaken for some reason, or the program of dredging is too infrequent then flood levels would be liable to change as the channel returns to its equilibrium geometry and therefore dredging can increase uncertainty in flood behaviour.

The study area contains few areas of dense vegetation. Vegetation clearing is likely to have a localised impact on flood levels. As part of the Kempsey Bypass weed species within a stand of trees on Ferry Lane planted originally to honour war veterans were removed. This had an added benefit of a small localised reduction in flood level.

In summary for the reasons given above this measure is not supported.

4.2.2. Levees, Floodgates and Pumps

DESCRIPTION

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 are 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.

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. 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 Hurricane Katrina in New Orleans, USA).

DISCUSSION

A number of levees and floodgates exist within the study area, which are discussed in detail in Section 3.2.1 and 3.2.2. Levee overtopping behaviour and the impact of the main floodgates on flood behaviour is discussed. The Levees within the study area provide protection for small events. Providing protection for large events are unviable from an economic and social perspective.

The Kempsey community are generally in acceptance of levees as a floodplain risk management measure as they are a tried and tested method in the area. However, there are concerns over a levee protecting one area whilst increasing flood levels in another.

Overtopping of a levee can cause high initial velocities and therefore substantial damage could occur. In addition, failure of a levee, such as a breach, could occur prior to overtopping. This situation could be exacerbated by the fact that the levee may have given a false sense of security to the local community protected by the levee and thus substantially reduced flood awareness within the community as was the case at Nyngan in 1990.

In Kempsey floodwaters flow down Local Floodway No. 1 when the Eden Street levee overtops. Failure of the levee would have significant and immediate impact on properties within the CBD as well as longer term impacts over the wider Kempsey area. In 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 within a relatively short period of time. A large number of houses are not built to withstand the hydrostatic pressure which would be present following failure of the levee and ponding of floodwater. 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 such is the case in Kempsey.

Levees require regular maintenance which should be incorporated into future fiscal planning and also required continued community education to ensure that the community are fully informed of the risks and impacts associated with levee failure. Community education on the different mechanisms for the overtopping of the CBD levee are discussed in section 3.2.1.1.

A number of levee options for the Kempsey levees were considered as part of this study (Refer to Section 5 for detailed discussion). A consideration of any proposed levee changes in Kempsey is that the current levee system will be overtopped more frequently in a changed climate (Refer to the companion report WMAwater, 2016). The options assessed in the hydraulic model included:

- repairing the existing levees to their design height (Section 5.1.1),
- raising First Lane Levee (Section 5.1.2.1),
- raising Eden Street Levee (Section 5.1.2.2),
- Raising First Lane and Eden Street (Section 5.1.2.3),
- Large Scale Integrated Flood Management scheme (Section 5.1.3), and
- South Kempsey Levee (Section 5.3.1).

Discussion of each option, benefits, disadvantages and impacts can be found in the relevant sections as above.

During an event in the order of a 1% AEP event Council staff are required to place boards in Cooks Lane to complete the Wide Street Cooks Lane Levee system. The levee is overtopped in a 1% AEP event. The boards are approximately 0.3m high. It is recommended that Council consider as part of future road upgrades, raising the road and therefore removing the need to place the boards during an event.

Raising the Wide Street Cooks Lane Levee to its design height was not modelled in this study, however raising the low points to 11 mAHD and extending the levee 30m north (at 11.1 mAHD) and 30m south (at 11mAHD) would mean that the levee would not be overtopped in a 1% AEP event. A future study should investigate whether it is feasible to raise the Wide Street Cooks Lane Levee above its design height.

The low point near the Boat Ramp, Eden Street in Kempsey could be raised to reduce inundation from nuisance events. This could be done as part of future road works and potential incorporate the footpath. This would have no impact on flood levels.

While not investigated as part of this study the length of time it takes for water to drain from the levee once it is overtopped should be investigated. An investigation should determine if any improvement in drainage time would occur from upgrades to the drainage network.

Some of the key issues regarding levees are summarised in Table 11.

Table 11: Key Features of Levee Systems

ISSUE	COMMENT
ADVANTAGES:	
“Environmentally Sensitive Measure”	A well-designed vegetated earthen embankment set back far enough from the creek and that does not interrupt local drainage, can have minimal environmental impact. However, in many locations it is hard to meet all these criteria. Levees cannot have large trees planted on them because if the trees fall over in a storm it may affect the structural integrity of the levee.
Protects a large number of buildings	Whilst this is generally the case due to the relatively scattered nature of the flood liable properties it is impossible to construct a new levee that would protect a large number of buildings.
Low maintenance cost	A levee system needs to be inspected annually for erosion or failure. In addition there is ongoing weekly or monthly maintenance (grass cutting, vegetation trimming). The annual cost of inspections for erosion or failure will generally be small (for example less than \$5,000 per annum per levee). However this amount can vary considerably depending upon

	the complexity and size of the structure.
DISADVANTAGES:	
Visually obtrusive to residents	Residents enjoy living near the creek system because of the visual attraction of the water or bush and a high embankment could significantly affect their vista. Anything which reduces the vista is unlikely to be accepted by the majority of residents. A freeboard of usually 0.5 m should be added to the design flood level of the levee (level of protection afforded by the levee) to account for wave action, slumping of the levee or other local effects.
High cost	The cost to import fill, compact and construct an earthen levee is dependent on the availability of good quality fill and the associated transport costs, these will vary depending upon the locality. However, generally it is the purchase of land and associated costs (possible services re-location and access) which add considerably to the cost.
Low to medium benefit cost ratio	Whilst the levee system may protect a several buildings from being inundated in a given event, for example the 1% AEP event, it is likely to have a low to medium benefit cost ratio as there are few buildings floors inundated (and so being able to be protected) in the more frequent floods (less than a 10% AEP event).
Local runoff from within the “protected area” or upstream may cause inundation	The ponding of local runoff from within the protected area may produce levels similar to that from the creek itself. At present local runoff already causes problems in several low lying areas. Constructing a levee will compound this problem. It can be addressed by the installation of pumps or flap valves on pipes but these add to the cost and the risk of failure.
May create a false sense of security	Unless the levee system is constructed to above the PMF level it will be overtopped. When this occurs the damages are likely to be higher as the population will be much less flood aware (as happened in New Orleans, USA in August 2005). A regularly used quote regarding levees is that there are only two types of levees. Those that have failed or those that will fail in the future.
Relaxation of flood related planning controls	Most residents consider that following construction of a levee the existing flood related planning controls (minimum floor level, structural integrity certificate) should be relaxed. However, many experts consider that this should not be the case unless the levee is built to the PMF level and the risk of failure is nil. The general opinion is that a levee should reduce flood damages to existing development but should not be used as a means of protecting new buildings through a reduction in existing standards.
Restricted access	A levee will provide restricted access to the area and/or the bush or riverine areas. This can be addressed by (expensive) re-design of entry points.

Pumps have been suggested as a means of addressing the internal drainage problem but are not widely used in levee type situations in NSW. Some of the drawbacks of employing pumps are:

- high capital cost. In many instances two sets of pumps are installed in case one set is being repaired or maintained when the flood occurs;
- high maintenance cost. The pumps have to be regularly maintained and tested by trained personnel; and
- relatively high risk of failure. Experience in other areas has shown that as the pumps are used only infrequently there is a relatively high risk of failure due to:
 - inadequate maintenance of the pumps causing seals or valves to deteriorate;
 - power cuts caused by the storm; and
 - failure of the device which activates the pumps.

The pumps are only required to operate for a short time (several hours) possibly only once or

twice in a five year period. If they fail to start or fail during the event there is practically no likelihood that service personnel will be able to restart them prior to the peak level being reached. An alternative to pumps is to install additional flap gated culverts and these can be more cost effective though also can fail (mainly due to vandalism or vegetation “jamming” the mouth open). There is no pump system within the Kempsey Levee System.

Whilst flood gates and pumps have been used successfully at a number of locations throughout NSW over many years, they require ongoing maintenance to ensure their continued success. Vandalism, corrosion, damage or vegetation growth can all result in failure at critical times. Some form of ongoing maintenance program is therefore required. Ensuring the power supply for pumps remains operable during times of flood can also be problematic. Within NSW floodgates are being replaced with automatic operating smart gates. Floodgates are located in Pola Creek, Belmore River and Kinchela. Section 5.2.1 discusses a flood gate option at the railway underpass on Gladstone Street. A review of the Lower Macleay flood mitigation system is recommended.

SUMMARY

A number of levee and flood gate options were investigated as part of the study. A number were found to provide positive benefits. Low points in Wide Street Cooks Lane, Eden Street, First Lane and RSL Levees should be raised to return the levees to their design heights. A floodgate could be built to protect Gladstone Street to prevent water entering the backwater area to the west in events more frequent than a 5% AEP event. The building of a levee in South Kempsey would provide protection to a 5% AEP event with no impacts on other areas. Temporary boards used to close the Wide Street Cooks Lane Levee should be replaced with a more permanent structure such as raising the road. The integrated flood management scheme should be considered a long term option for Kempsey. Raising Eden Street and Cooks Lane above their current design height is not recommended. The low point near the Boat Ramp (Eden Street) in Kempsey could be raised to reduce inundation from nuisance events.

RECOMMENDATIONS

- Regular maintenance of existing levee structures is recommended,
- Raise levees to their design height,
- A review of lower Macleay flood mitigation works,
- Floodgate Gladstone street,
- Wide Street Cooks Lane Levee
 - raise road as part of regular maintenance to remove need to insert boards to complete the levee
 - Investigate raising levee to its design height or extend levee to prevent overtopping
- Integrated flood management scheme should be considered a long term option, and
- Eden Street Boat Ramp - investigate filling low point from the boat ramp to Eden Street.
- Investigate the drainage of flood waters from behind the levee system

4.2.3. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging which

are deployed before the onset of flooding. They are usually on a larger scale than simply sand bagging at the entrance to a house, but include blocking flood waters from entering through driveways and gaps in existing flood defence levee structures.

DISCUSSION

The effectiveness of these measures relies on a sufficient warning time and the ability of a workforce to install them. They are therefore often used as a means to assist in current mitigation measures rather than the sole protection measure. It is important that temporary barriers are not used without planning and investigation as they can raise flood levels in other locations. Temporary barriers can be effective for closing gaps in a levee if a flood occurs during construction. Temporary barriers should only be used when they do not restrict or block a flow path or reduce flood storage.

During flood events sandbags are deployed at a number of locations in Kempsey to raise low points in the levees or block flows from particular roads. *Council's Procedure for a Flood Event* (Kempsey Shire Council, 2013) requires that sand and sandbags are deployed at Smith Street (Macleay valley Way) as it passes through First Lane levee and the low point on Eden Street Levee across the road when flood approach a Moderate flood (5.7 mAHD at Kempsey Traffic Bridge). Temporary barriers are also used at the Wide Street/Cooks lane levee across Cooks Lane when a Major flood is predicted at Kempsey Traffic Bridge (greater than 6.5 mAHD). Sandbagging of private property and commercial businesses in Kempsey is also undertaken by residents. Council should consider when upgrading levees or roads that tie in with levees raising ground levels to reduce the requirement for sandbagging during an event. However minor sandbagging during an event requires minimal effort and provides a good reminder to the public.



a) Sandbagging of Macleay Valley Way (OEH, 2013)



b) Sandbagging of business in CBD c) Sandbagging of Eden Street levee (2011 flood)
 Photo 4: Examples of sandbagging in Kempsey

SUMMARY

No additional locations for temporary flood barriers were identified as part of the study. Council should investigate use of other temporary barrier options. Council should continue to use temporary barriers and a small amount of sandbagging during an event. If the opportunity arises due to upgrades for other reasons Council should look to raise low points requiring sandbagging.

RECOMMENDATION

If the opportunity arises due to upgrades for other reasons Council should look to raise low points which require sandbagging. Council should investigate use of other temporary barrier options.

4.2.4. Floodways

DESCRIPTION

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.

DISCUSSION

Council has a number of defined floodways in their DCP (see Section 2.7.2). The study area contains a number of natural floodways including through the CBD. This study has defined a hydraulic floodway (Figure 13 and Figure 14) (based on areas on high velocities and velocity depth product. A significant risk to life and buildings in the floodway occurs events as small as a 10% AEP event. Removal of these buildings particularly residential buildings is the only way to significantly reduce their risk. Council has a policy of voluntary purchase for houses in the CBD floodway (discussed in Section 4.3.2). This requirement is based on hydraulic modelling and previous flood studies in the area. However few voluntary purchases have occurred and it would take a long time at the current pace to remove all buildings.

A number of schemes were investigated to increase flow through the CBD floodway. The CBD options study (WMAwater, 2009b) conducted a preliminary assessment on increasing the efficiency of the floodway. The peak flood levels were reduced by between 0.5 to 0.7m upstream

of Belgrave Street due to the removal of the existing car yard on Belgrave Street, which is currently assumed to act as a significant barrier to flow.

This option was also modelled using the TUFLOW hydraulic model with the blockage to flow of cells containing buildings removed (Figure D 2). The Manning's 'n' roughness values were also amended to reflect the change. The option was assessed for the 10%, 5% and 1% AEP events. The impact on flood levels for the 10%, 5% and 1% event are presented in Figure D 3. Conveyance of floodwaters is improved with the buildings removed. Flood levels were decreased by greater than 0.3m in a 1% AEP event. An increase in flood levels, away from existing houses, of up to 0.3m occurs downstream where the houses are removed from the floodway. This option has most benefit in large floods when the floodway is in full operation. At a cost of approximately \$12 million this option would have a total benefit cost ratio of 0.4. However the intangible benefits are significant and hard to quantify. The commercial properties on Belgrave Street were shown to have the greater benefit when removed however if demolished first would have adverse impact on those residential properties downstream.

SUMMARY

Removing buildings particularly houses in the floodway would significantly reduce the risk to life. The removal of buildings from the floodway has limited benefit in terms of flood levels. Any plan to clear the floodway is long term and should be undertaken in conjunction with other measures. Where possible this plan should be accelerated.

RECOMMENDATION

Council should continue with the long term to remove properties from the floodway.

4.2.5. Flood Refuge Mounds

DESCRIPTION

Flood refuge mounds are used as an effective means of reducing losses during a flood and are useful as a last resort evacuation for communities and stock during a flood. They are widely used on floodplains in New South Wales and can provide some benefit for isolated areas and the rural farming properties situated on the Macleay River.

DISCUSSION

Flood refuge mounds should only be considered for stock where access to high ground can be cut early or is far away. Flood refuge mounds can cause localised flow diversions or increases in flood levels. Flood refuge mounds should therefore be located as much as possible in line with the flow path (Diagram 5) and utilise existing high ground. For large rural properties it is unlikely these impacts would extend far enough to affect neighbouring properties. However in accordance with Council policy this should be confirmed for all proposed flood mounds.

Flood mounds are not built to the PMF level and so some residual risk exists. Flood mounds should be treated as a back up plan not a primary evacuation plan. If an event turns out to be larger than expected then evacuation would be required.

The cost to construct the mounds depends entirely upon the availability of fill material. Funding under the NSW Floodplain Management Program is unlikely to be available for these works and they are usually funded by the individual proponent.

Flood refuge mounds for stock only are suitable mitigation options for the floodplain upstream and downstream of Kempsey. A number of stock mounds were built downstream of Kempsey as mitigation measures for the Kempsey Bypass (Photo 5). These were built to the 20 year ARI level. Given the depth of floodwaters on the floodplain the mounds would need to be over 2.5m high to provide refuge in a 1% AEP event.

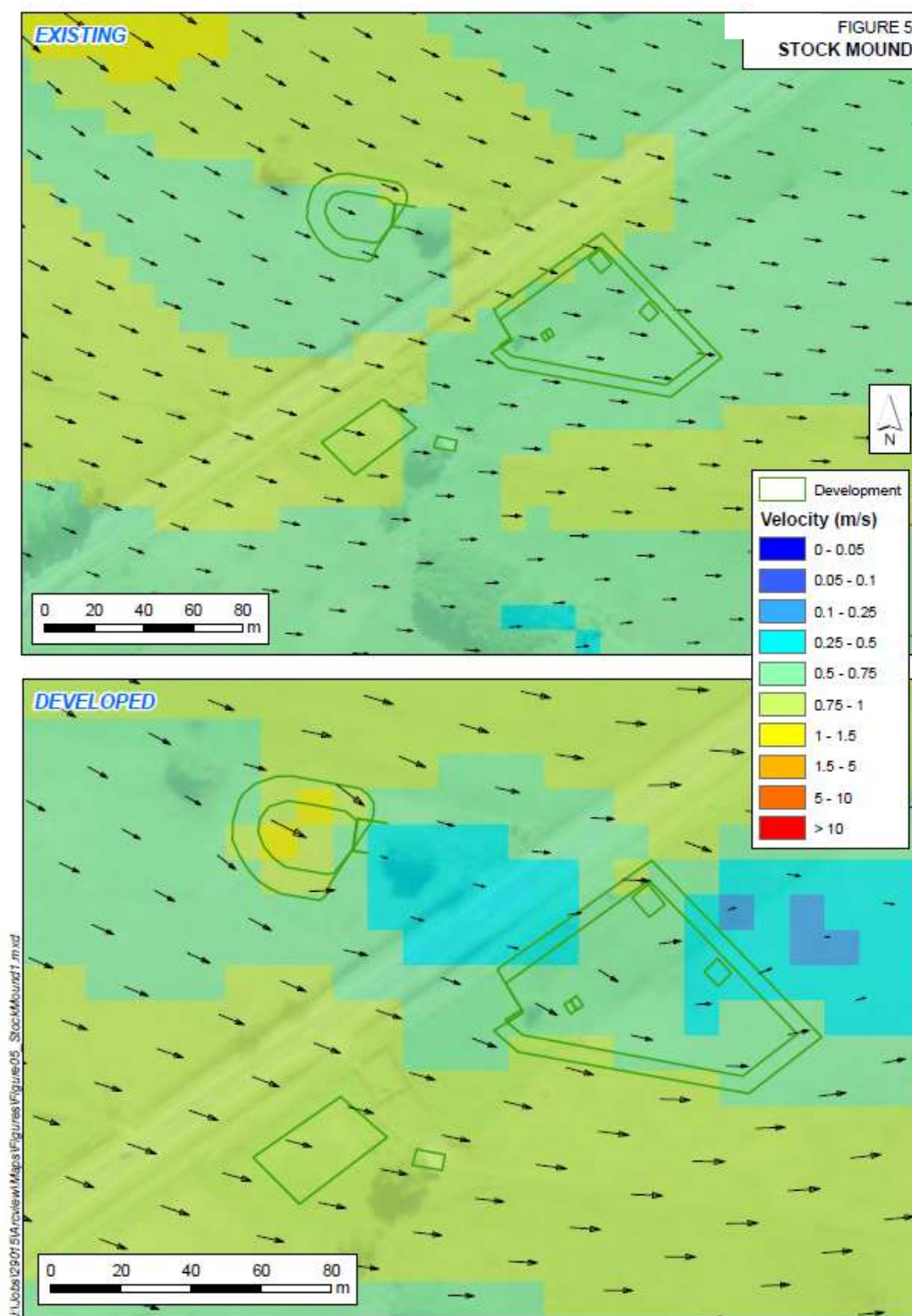




Photo 5: Stock Mound – downstream of Kempsey during a flood event

SUMMARY

Flood refuge mounds are suitable mitigation options for stock only for the floodplain upstream and downstream of Kempsey. Stock flood mounds should be treated as a back up plan not a primary evacuation plan. In accordance with Council policy the impact of flood mounds on neighbouring properties should be confirmed for all proposed flood mounds.

RECOMMENDATION

Council should continue with its policy of requiring property owners wishing to build stock flood refuge mounds to prove that the mound will not impact on surrounding properties.

4.3. Property Modification Measures

4.3.1. Land Use Zoning

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 2013 rezones land uses in Kempsey to comply with the NSW standards. Council's LEP 2013 and DCP has encouraged residential properties to be cleared from the main floodway, Kempsey Floodway No. 1. Commercial development is allowed on the edge of this natural

floodway in the CBD floodway zone.

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.

Through the natural floodway that forms through Kempsey much of the land will be designated as E2 Environmental Protection under the draft LEP 2012. However, within the natural floodway there are still some areas of land zoned as RE1 Public Recreation, RE2 Private Recreation and areas of RE1 General Residential, IN1 General Industrial and B3 Commercial Core on the periphery (Figure 4). Figure 12 identifies those areas which are considered hydraulic floodway and compares with the LEP 2013 land uses. Council may want to consider either rezoning these as E2 (floodway) to be consistent with the other floodway areas or manage and protect these hydraulic floodway areas through strict planning controls and defining a 'floodway' in the DCP.

SUMMARY

Following the outcomes of the Study, the LEP 2013 zoning may require adjustments or reassessment. Any rezoning requirements should also be incorporated into Council's development controls. Further discussion on Council's flood policy, including zoning and development control issues are outlined in Section 2.7.

RECOMMENDATION

Reassess land use zoning to only refer to those areas identified as hydraulic floodway as "floodway" in planning documents and land use considerations. Map the hydraulic floodway in the DCP.

4.3.2. Voluntary Purchase

DESCRIPTION

Voluntary purchase 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, however there may be an opportunity for a new house to be built at a higher floor level, either on fill or on a higher part of the property.

DISCUSSION

Voluntary purchase is mainly implemented for residential areas in high hazard areas over a long period as a means of removing isolated or remaining buildings and 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 right 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 to be returned to Council for demolition and clearance.

The current Kempsey Voluntary Purchase Zone is shown on Figure D 1. Approximately 40 residential properties are located in the zone including a respite centre. Photo 6 shows the voluntary purchase zone flooded in the 2001 event. Voluntary purchase is the most cost effective means of reducing the flood risk for properties located in the floodway who are flooded frequently and subject to high hazard. The flood risk to the voluntary purchase zone will increase with climate change, with the area flooded more frequently. While progress has been made in removing houses at the current rate clearing of the voluntary purchase zone would take another 20 years. No additional properties outside the existing voluntary purchase zone have been identified for removal.



Photo 6: Flooding of voluntary purchase zone – March 2001 flood

The removal of all buildings in the floodway was modelled in the hydraulic model (Section 4.2.4)


and found to reduce flood levels and improve conveyance. The removal of buildings in the floodway would allow for the consideration of other mitigation measures. This may cost up to \$6 Million.

OEH have developed guidelines for voluntary purchase schemes (OEH, 2013) and requires consideration of the issues in Table 12. If approved for a voluntary purchase scheme Council would have access to the state-wide Voluntary Purchase / Voluntary House Raising Pool for a three-year period. The scheme is generally for residential properties but can be used for clearing of floodways. Council should develop a policy or strategy as to how this action might be funded in respect to Council's contribution, including prioritisation of any properties to be acquired and how any acquired land will be managed (community gardens cycleway links etc).

Table 12: Considerations For voluntary purchase of properties

Consideration	Comments
Flood hazard classification and associated risk to life	Figure 15 to Figure 18. The floodway is either unsafe for people, vehicles and buildings should be specially engineered or unconditionally dangerous.
Hydraulic classification in relation to location in a floodway	Figure 13 and Figure 14. This area is critical to conveyance of flow during flood events and clearance would allow the floodway to function more effectively reducing flood risk elsewhere.
The benefits of floodway clearance to flood affected areas	Figure D 3 and reduced damages and risk to life of residents and rescuers.
Economic, social and environmental costs and benefits	Residential properties within the voluntary purchase zone make up some 31% of the total damage costs in the 10% AEP flood event. The social costs are generally to the occupants moved from their homes to other locations although this is generally outweighed by the benefit of reduced flooding. For those who chose to stay, there are social implications in that they end up being isolated from the rest of the community. Environmentally the costs and benefits are negligible.
Viability of the scope and scale of the scheme and how the scheme will be prioritised generally on the basis of degree of flood hazard exposure	As all the properties identified for voluntary purchase are located within areas defined as high hazard and as hydraulic floodway, the priority of all properties is high. Table 13 suggests a prioritised order of removal.
Identification of each affected property and the buildings on them	40 properties have been identified as suitable for voluntary purchase.
The support of the affected community for voluntary purchase as determined through consultation with affected owners	Consultation has been undertaken in previous studies. However, further consultation will assist in reminding residents of the option available and the significant benefits it will provide in terms of reductions in risk to life and property.
An implementation plan for the scheme	An implementation plan for the scheme will need to be developed in consultation with Council, OEH and the affected residents.

Table 13: Priority of Properties for Voluntary purchase

Priority	Street / Location
Highest 	Regent Street, Yaelwood Street, Hopetoun Street, north of Forth Street
	Forth Street
	Properties between Forth and Belgrave Streets
High	Belgrave Street (commercial properties)

The use of planning controls to clear the floodway are a necessity. The use of s149 certificates in Kempsey township could help attain the goal of clearing Local Floodway No. 1. For example under s149(2) Council should state, for any properties within the floodway, that current planning controls require the clearance of the floodway and anyone purchasing property in the floodway will only be allowed to demolish existing buildings. No other construction will be allowed. A time-frame could also be applied to this.

SUMMARY

Voluntary purchase is the most cost effective means of reducing the flood risk for properties located in the floodway who are flooded frequently and subject to high hazard. The flood risk to the voluntary purchase zone will increase with climate change, with the area flooded more frequently. The current voluntary purchase scheme should be continued and accelerated if possible.

RECOMMENDATIONS

Continuation and acceleration of the current Voluntary purchase scheme.

4.3.3. Building and Development Controls

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

4.3.3.1. Flood Planning Levels

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 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 greater 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 which should also be considered.

According to the 2005 Floodplain Development Manual (NSW State Gov, 2005) the purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided 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.

The 0.5 m freeboard 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 these factors 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 use;

- 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).

Kempsey Council currently sets the FPL as the 1% AEP flood level plus a 0.5 m freeboard. The current DCP requires that all habitable floors of residential development are above this level and

for commercial buildings that at least one fifth of the floor area is above this level (Section 2.7).

The 1% AEP flood level varies across the Kempsey and FPLs specific to different areas of the floodplain are defined in Council's Flood Risk Management Procedures (Section 2.7). 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. The recommended Flood Planning Area for Kempsey, the 1% AEP plus 0.5 m level, is shown in Figure 23 and Figure 24. Table 14 summarises the change in 1% AEP flood levels between different models of the study area. The change in flood level is minimal.

Table 14: Comparison of Hydraulic Models 1% AEP levels

Location	River/ Floodplain	Peak Level (mAHD)				
		Rubicon	RMA-2	SOBEK	TUFLOW	
					Kempsey Bypass model	New TUFLOW model
Railway Bridge	River	10.2		10.15	10.15	10.02
Traffic Bridge	River	8.7		8.7	8.57	8.51
Pola Creek	River	8.2	8.1	8.11	8.07	8.03
Glenrock Drain	River	7.7	7.7	7.86	7.79	7.77
Upstream Frederickton	River	7.1	7.1	6.96	6.96	6.98
Frederickton	River	6.7	6.8	6.64	6.62	6.62
Downstream Frederickton	River	6.5	6.5	6.32	6.38	6.37
East Kempsey Wetland	Floodplain	n/a	6.7	6.64	6.76	6.65
Old Station Road	Floodplain	6.6	6.6	6.60	6.72	6.60
Frogmore	Floodplain	5.9	5.9	5.93	6.11	6.05
South West Rocks Road	Floodplain	5.9	5.9	5.87	6.02	5.96
Upstream Bridge Right Bank	Floodplain	5.9	5.9	5.88	6.02	5.96

Council may also want to consider using the FPL to set flood proofing requirements for non-residential dwellings. Although the only area where depths are shallow enough to all this is the current CBD. Council should consider making the FPL and other flood information and extents available on its website.

SUMMARY

The current policy with regards to habitable floor levels of residential development being at or above the FPL is considered to be appropriate given the nature of flooding in Kempsey. Furthermore, the policy for setting commercial floor levels with respect to the FPL is also reasonable considering the less vulnerable nature of commercial development to flooding (in terms of risk to life). 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.

4.3.3.2. Revise LEPs and DCPs

DESCRIPTION

Updated and relevant planning controls are important in flood risk management and have been outlined in several of the above sections. 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, ensure that new development does not increase flood risk elsewhere or ensure development in flood prone areas would be suitably designed, for example raised floor levels. They can also be used to develop appropriate evacuation and disaster management plans to better 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. Detailed discussion of Council's planning documents is contained in Section 2.7. From a review of the documents it is considered that the new land zones proposed by Council in the LEP are generally appropriate.

Council have chosen to modify the recommended model local clause 7.3 in the LEP to suit their circumstances, given the nature of flooding in Kempsey, the criteria in this clause are supported. The LEP classifies the current 1(e) floodway land use as E2 Environmental Protection. Council have included three additional objectives for E2 zoned land in the LEP to make this category relevant to the floodway which are considered to be appropriate in terms of floodplain risk management. Based on the hydraulic modelling some of the areas previously classified as 1(e) floodway in the LEP 1987 are no longer considered to be floodway. Where these have been directly reclassified as E2 under the LEP Council may seek to rezone these areas with a more appropriate land uses. These areas have been indicated on Figure 12.

The LEP has classified the area north of Eden Street and south of Belgrave Street, as well as two areas between Belgrave and Forth Streets, as RE1 Public Recreation. Under the RE1 land use zone a number of uses are permitted with consent that would not be permitted under the criteria for Kempsey Local Floodway No. 1 in the DCP. Council may wish to either rezone these areas to E2 in keeping with the rest of Local Floodway No. 1. However, this may prevent some development which is actually intended in these areas allowed under RE1 but not E2. If the land is not rezoned then the DCP will need to be used to control development in these areas as it currently does. Strict development controls should be applied to floodways defined in the DCP (including this area) to further limit development from that allowed under the LEP land use classification to only that appropriate in a floodway.

As the new LEP standard format does not have specific land zones relating the floodways, it is recommended that the current method of identifying a number of floodways in the DCP is maintained. It is recommended that only those areas defined as hydraulic floodway (Figure 13 and Figure 14) be referred to as floodways. Other areas currently referred to as floodways in Council's DCP should be renamed as flood precincts or similar.

Currently Flood Planning Levels (FPLs) defined in the DCP are based on previous hydraulic modelling. FPLs should be updated to reflect the outcomes of this study. It is recommended that the DCP is reworded to refer to the "latest available flood modelling for the area" or similar rather than stipulating specific levels in the DCP document itself. Council will need to be contacted to provide the latest flood levels relevant to a site. This will assist in future updating of the FPL when new flood modelling becomes available. This also allows more than one hydraulic model to inform flood levels for an area; for example the modelling undertaken for this study will be used to inform the FPLs for the majority of the hydraulic model extent and the previous modelling undertaken for the wider Macleay catchment will be used for areas outside this area.

In addition to defining FPLs, the DCP defines flood prone land as being within the 1% AEP extents and relevant flood management controls apply to all development in this zone. The DCP however, does not account for future increases in flooding due to climate change. Therefore it is recommended that the DCP defines a Flood Planning Area (FPA). This should be defined as the 1% AEP flood level plus 0.5 m, and therefore will encompass a wider area than the current 1% AEP flood extent (Figure 23 and Figure 24).

The DCP currently allows extensions to existing properties in the floodway. By preventing extensions in the floodway, not only will this prevent further obstructions to the floodway but in the long run may encourage people to leave the floodway area as they will need to move to acquire larger property.

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

- Review of floodway definition based on hydraulic modelling
- Define a Flood Planning Area based on 1% AEP flood levels plus 0.5 m freeboard.
- Council to consider minor changes to LEP and DCP

4.3.3.3. Section 149 Certificates**DESCRIPTION**

Section 149 (2) Planning Certificates provide information on the planning policies and controls that apply to a particular parcel of land. Councils issue planning certificates to potential purchasers under Section 149 of the Environmental Planning and Assessment Act of 1979 (EP&A Act). Identification of potential flood affectation and therefore flood related development controls on a Section 149 (2) Planning Certificate is mandatory for residential developments located below the residential FPL.

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on the type of flooding, whether from major rivers or local overland flooding, and the extent of flooding (whether widespread or relatively confined). This information is provided via a S149 certificate.

The S149 certificate is divided into two parts s149(2) and s149(5) relating to the relevant clauses of the EP&A Act 1979. Under Part 2 Council is required to advise if it is aware of the flood risk and any other known risk (bush fire, land slip etc.). A certificate issued under Section 149(2) provides information about the zoning of the property, the relevant state, regional and local planning controls and other property affectations such as land contamination, road widening and flooding. Part 5 provides additional details but is not compulsory. A certificate issued under Sections 149(2) and 149(5) provides both the information available in a Section 149 (2) certificate and additional information on other relevant matters affecting the land such as advice from other authorities, subdivision history and easements where Council has information available. This can include flood levels relevant to the site or in some cases Council choose to mention where properties may be affected by flooding in due to climate change.

The certificate does not specify specific development standards or terms of the instruments. Planning certificates are an important source of information for prospective purchasers on whether there are flood related development controls on the land. They need to rely upon the information under both Section 149(2) and 149(5) in order to make an informed decision about the property. It should be noted that only Part 2 is compulsory when a house is purchased.

The Floodplain Development Manual (NSW State Gov, 2005) suggests that the Section 149 Planning Certificate should not be the only form of acknowledgement that a property is flood prone. The community should be adequately informed about the extent of flood prone land and why the flood classification can change from one property or area to another. Council are thorough on their s149 certificates and provide additional information on flooding where they have it

available. This includes for the rural zoned areas outside of the township, where under legislation this detail is not required but at the digression of Council. As Council information for s149 Certificates and Development Restriction Certificates is obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its web-site.

Data from the hydraulic modelling undertaken for this study should be incorporated into Council's Section 149 planning controls. Wording or description included on the certificate should be clear in describing the flooding implications and/or planning/building restrictions at the property based on the outcomes from the study process. This information may include minimum floor levels for properties within the area affected by the FPL, or, for areas above the FPL, information relating to rarer flood events based on historical information. Details of flood level information should be continually updated as more accurate survey and flood level information becomes available.

The s149 certificate can be used to assist in clearing of the Kempsey Local Floodway No. 1, clarifying to property owners in the floodway that land clearance will be necessary.

SUMMARY

Kempsey Council provides thorough S149 certificates. It is recommended that the certificates be updated and reissued based on the outcomes of this study. It is also recommended that a public awareness program be developed to inform all properties identified as being within the FPA and flood prone properties of their current flood affectation and any development constraints imposed by their Section 149 status.

RECOMMENDATIONS

- Reissue s149 certificates to all affected by the revised FPA.
- Issue 149(5) at same time as 149(2) at no additional cost in order to promote flood awareness.

4.3.4. House Raising

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).

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. 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 grants for 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 7: Examples of house raising in Kempsey

Most houses within the study area which are subject to frequent flooding have been raised in the past. However some may have only been raised to avoid nuisance flooding. Survey identified the average residential floor level as being approximately 1.8 m above ground level. Up to 25 houses, including some of the most flood prone in the area, downstream of Kempsey were raised to the 1% AEP plus 0.5m by the Kempsey Bypass. A number of houses in the floodway are suitable for raising. For houses in the floodway voluntary purchase is considered a more appropriate option as house raising does not reduce hazard.

The cost of basic house raising is typically in the order of \$60,000 per house. For the floodplain downstream of Kempsey, Council has determined a list of the 100 most flood prone rural properties that are suitable for house raising (WMAwater, 2008b). These properties are on a list for a voluntary house raising scheme, subject to funding, where the owner and Government both contribute to the cost of house raising. Council regularly contacts and reviews this list. This list does not cover all rural properties within the study area and should be extended to cover the remaining properties.

Figure B 6 depicts when residential houses are first inundated. The cost of raising the 40 most flood prone houses (to the 1% AEP plus 0.5m) which are flooded in events less than a 5% AEP is approximately \$2,400,000. These houses are shown in Figure B 6 as red, orange, yellow and green dots. This reduces AAD by \$270,037 resulting in a benefit cost ratio of 1.66. The cost of raising 136 houses that are flooded in up to a 1% AEP level has a benefit cost ratio of 0.68. These houses are shown in Figure B 6 as red, orange, yellow, green and purple dots.

An indication of the property's eligibility for house raising could be recorded on part 5 of the s149 Certificate (there is now allowance under the Act for this to be included in Part 2) to ensure future potential purchasers are made aware of their options. However, purchasers often only obtain an s149 (2) certificate as there is not requirement to obtain an s149 (5) (see Section 4.3.3.3 for more discussion on s149 certificates). An alternate would be a levee at South Kempsey, for example.

SUMMARY

For houses in the floodway voluntary purchase is considered a more appropriate option as house raising does not reduce hazard. For houses outside the floodway house raising is considered a viable option. Council has determined a list of the 100 most flood prone rural properties that are suitable for house raising. Council should continue to contact those on the list and review the list. The list should be extended to include all rural properties on the floodplain.

RECOMMENDATIONS

Council to continue to periodically contact those on the list for rural voluntary house raising and review the list periodically. The list should be extended to include all rural properties on the floodplain.

4.3.5. Flood Proofing

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 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 8), 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 Kempsey.

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 are due to flood depths and velocities. It may be possible for commercial properties in Kempsey.



Photo 8: Dry proofing on doors of residential property

Wet flood proofing assumes water will enter the property 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 by commercial properties in the CBD.

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. As part of the

Kempsey Bypass mitigation works flood proofing was undertaken for a property downstream of Kempsey that couldn't be raised.

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 usually not 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 the Kempsey CBD.
- Flood proofing requirements for all new development.

4.3.6. 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;

- 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.

Smith Street (Macleay Valley Way) between Kempsey and Frederickton is cut during a flood

event. The Kempsey Bypass provides better flood access to the north and south and has been built to above the 1% AEP flood level. The road will be closed when events approach a 1% AEP event.

The high level access flood road between Kempsey and Frederickton, Spooners Avenue, is cut for a short time during an event. However, the Kempsey to Eungai Pacific Highway Upgrade EIS (RTA, 2008) found that raising or improving this road would be cost prohibitive, particularly upgrading the existing bridge over the railway line. The Kempsey Bypass reduces the need for Spooners Avenue access.

The raising of Belgrave Street and South West Rocks road have been considered as part of this study to improve flood access (Section 5.1.4 and 5.4.1 respectively). The raising of both roads would provide some improvement to evacuation and recovery times. The benefit of raising these roads on tangible damages is hard to quantify. However they are likely to have benefit in risk to life and reduced hazard during evacuation. Given the cost of raising a large section of road consideration should be given to targeted raising of smaller sections of South West Rocks road.

SUMMARY

The raising of Belgrave Street and South West Rocks should be considered in any future maintenance or road works budgets.

RECOMMENDATION

- Raise Belgrave Street
- Raise South West Rocks road

4.4. Response Modification Measures

4.4.1. Flood Warning

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 Macleay River. Flood warning systems are based on stations which 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 4.4.2).

The warning time for levee overtopping is generally 12 to 24 hours depending on the event. Flood predictions are supplied for Kempsey and now Smithtown. A number of issues have occurred in the past with gauge failure and confusion over the Kempsey Traffic Bridge level. During the 2011 event confusion was caused throughout the event due to the Kempsey Traffic Bridge gauge reading being 200mm above the actual water height as read from the manual gauge boards located nearby.

The NSW SES has recently updated the Local Flood Plan. Due to the frequency of flooding the Local Flood Plan is tried and tested. 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 Macleay River who regularly report on flood levels. Many residents have formed an unofficial flood warning system where they call friends and family upstream for information.

The 2011 data collection study (WMAwater, 2013b) surveyed all gauges in the catchment. It is recommended that all warnings and flood intelligence cards be transitioned to mAHD in the downstream catchment. An education program will be required to familiarise residents, Council and emergency services with the new levels. A peak level correlation between Kempsey and Smithtown was developed as part of WMAwater (2013b) (Diagram 6). This should be further developed in future events.

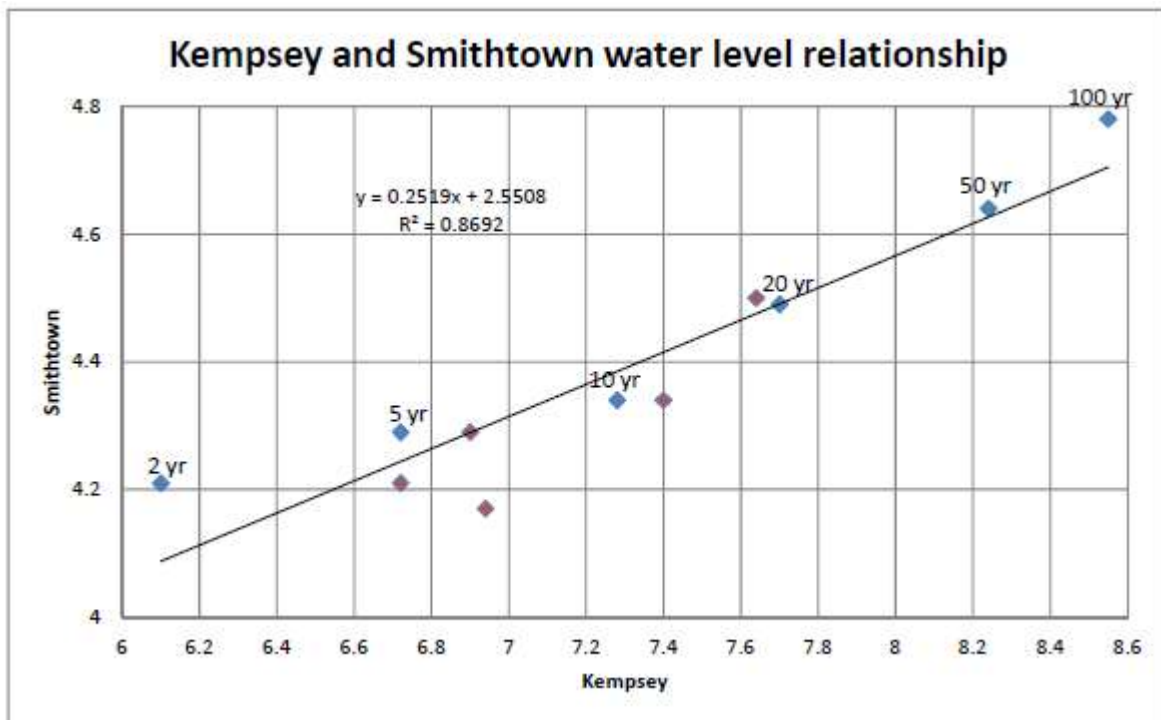


Diagram 6: Peak Height Correlation between Kempsey and Smithtown

Currently there are in excess of 100 telemetry stations operating within the Macleay catchment. Of these there are 30 stations fundamental to the flood alert system operating for the Macleay. Seventeen 17 are rainfall gauges, 13 river level gauges, 9 combined rainfall & river level gauges and 4 repeater stations. Rainfall and Water level gauges in the catchment are owned and maintained by several agencies, BoM, KSC, OEH and MHL. It is important that these gauges are regularly maintenance to improve performance in an event. The agency responsible for maintenance of each gauge should be clarified and a strategic plan for future operation developed. The possibility of upgrading from a gas pressure system to a new compressor, which will not run out of gas should be considered. This will reduce the need for NSW SES personnel to undertake manual readings during an event. Manual readings during a flood event have an impact on NSW SES resourcing and potentially put the NSW SES personnel at risk. During a flood event when the automatic gauge at Kempsey Traffic Bridge is broken gauge boards have to be viewed from a distance with binoculars. Consideration should be given to what can be done to make them easily viewed.

Several new rainfall and water level gauges have been installed in the last 20 years, thus providing a more accurate assessment of flooding. This program should be continued and some of the gauges should be linked to the BOM system so that some real time rainfall recording is available. RMS installed water level gauges at Frederickton and Third Lane as part of the Kempsey Bypass. These gauges would have in the order of 5 years of record including several flood events. These gauges should be continued and incorporated into Council's ENVIROMON system. Additional gauges are recommended in the middle of the Macleay River catchment to enhance flood warning. Council should when possible upgrade the existing ENVIROMON system to an improved system with improved capabilities if available or when developed.

SUMMARY

The BoM has a flood warning for the Macleay River. Flood predictions are provided for Kempsey and Smithtown. With all flood warning systems there is a need for ongoing education to constantly

keep the residents adequately informed. It is recommended that all warnings and flood intelligence cards be transitioned to mAHD. This will require an education program for both the public and emergency services. Additional gauges and the continuation of the Frederickton and Third Lane gauges are recommended to improve flood warnings. Gauges should be regularly maintained and the agency responsible for each gauge formally documented. A peak level correlation between Kempsey and Smithtown was developed as part of WMAwater (2013b). This should be further developed in future events.

RECOMMENDATIONS

- Conversion of all gauges in the lower catchment to mAHD
- Clarification on whether the Frederickton and Third Lane Gauges are still active and incorporation into the ENVIRONMON system and upgrade the existing Environmon system to an improved system with improved capabilities if available or when developed.
- Additional gauges in the middle of the catchment
- Correlation between Kempsey and Smithtown gauges
- Document gauge maintenance arrangements

4.4.2. Flood Awareness and Preparedness

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.*

Kempsey residents are generally have a high level of flood awareness and often relate flooding relative to the levels at the Kempsey Traffic Bridge gauge and/or levee crest heights. However, this awareness is usually of the smaller more frequent events in the order of 10% AEP (recent events eg. 2001, 2009 and 2013). Residents would be less aware of the implication of larger events 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 Kempsey. Most residents have a long history of residence either at the same location or in the area. In the 2001 flood preparations including the lifting or removal of items appeared to have an important influence on the relationship between flood depths and internal building losses where different degrees of flood preparation resulted in variable loss values (Gissing, 2002).

The level of flood awareness for residents and businesses in the area protected by the levee is lower than the rest of the community. This is due to the sense of security that landholders in this area feel due to the presence of the levee. The impacts if the levee fails or a levee overtopping event occurs should be communicated to residents in this area.

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 the 1949) 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.

Regular awareness campaigns are recommended to ensure that the level of flood awareness in Kempsey stays high. It is important to also educate residents on the different mechanisms of flooding. For example the different Kempsey Levee overtopping scenarios. A pamphlet with information similar to Diagram 2 could be used in a flood awareness campaign.

SUMMARY

Based on feedback it would appear that the majority of residents in the Macleay River catchment have a high level of flood awareness and preparedness. Residents downstream of Kempsey are very flood aware and often remain onsite during an event.

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 creek relating specifically to the

local issues.

Table 15 provides examples of various flood awareness methods that can be used.

Table 15: 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. Information should also be provided on levee overtopping.
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. Kempsey Council have already put these measures in place such as the plaque on Clyde Street Mall commemorating the six people who died in the 1949 flood and a pole with the historical flood levels (Photo 1).
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. This notification is also extended to the rural zoned properties outside of the villages on townships on the Lower Macleay.
Web-based tools	Online presentations, activities, gauge data.
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 Kempsey including, leaflets and flyers, and stalls at local events. This should also include information on levee overtopping.

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.

RECOMMENDATION

- Develop a flood awareness program including the different levee overtopping scenarios.

4.4.3. Evacuation Planning

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 SES has the skills and experience to undertake the necessary evacuations. The effectiveness of the Local Flood Plan to undertake evacuations of Kempsey and surrounding villages was tested in the recent 2013 event. The 2011 Flood Intelligence Collection Study (WMAwater, 2013b), found that evacuation was not a popular response to flooding. Any flood awareness programs should target the need for evacuation. There have been issues during flood events with sticky beakers entering the CBD. This could cause a major issue if an evacuation of the CBD is required. A system whereby entry into the CBD in an event is managed with only those with legitimate reasons for entering allowed in, particularly if the levees are expected to be overtopped, should be investigated. The exact agency responsible for this should be investigated. NSW SES would be too busy in an event to manage this.

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 Kempsey are crucial as the majority of the

downstream areas rely on this information being accurate and available. The Local Flood Plan and Flood Intelligence Cards indicate flow times between the four flood gauges in the upstream area along with Kempsey and Smithtown. The exact source of these travel times is unknown. These travel times for flood waters should be further investigated and be understood that each flood is different and times may not be accurate. A hydraulic model should be used to confirm flow times.

SUMMARY

The NSW SES Local Flood Plan was updated in December 2012 and should be updated no later than 2017. 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. Use of a ticketing system in the CBD during a flood to be investigated.

These travel times for flood waters between upstream gauges should be further investigated and be understood that each flood is different and times may not be accurate. A hydraulic model should be used to confirm flow times.

RECOMMENDATION

- Study be undertaken to investigate travel times upstream of Kempsey
- Local Flood Plan to be reviewed no later than July 2017
- Investigate system of managed entry to CBD during event
- Signs advising of risk of driving through floodwaters

5. AREA SPECIFIC FLOODPLAIN RISK MANAGEMENT MEASURES

5.1. Kempsey

5.1.1. Repair Levees to Design Height

Survey undertaken by Council in November 2011 (Kempsey Shire Council, 2011) found that the three main levees (Eden Street, First Lane and RSL Levees) that protect Kempsey are up to 200mm lower than their design height (section 3.2.1). The TUFLOW hydraulic model developed for this study includes the updated levee survey. In order to assess the impact of repairing the levee to their design height the TUFLOW hydraulic model was modified to represent the levees at their correct design height.

The hydraulic model was run for the 5-year ARI, 10% and 5% AEP events with the levees at their design height as these events are the most significant in terms of when the levees first overtop. The impacts were calculated comparing the existing conditions flood levels to the repairing the levees flood levels. The impacts for the 10%, 5% and 1% AEP events are presented in Figure D 4. The largest impact from repairing the levees to their design events will occur in events when they are about to overtop. Given the levees are currently significantly overtopped in a 10% AEP event the impacts of repairing the levee is minimal. In a 5 year ARI event less water overtops First Lane Levee reducing flood levels by up to 0.03m in low lying farmland. The RSL levee currently overtops in a 10% AEP event. However when the levee is raised to its design height the levee is overtopped in events rarer than a 10% AEP however the reduction in flood extent is minimal. Table 16 shows the current and repaired levee overtopping events.

Table 16: Repaired levee overtopping height

Levee	Design Height (mAHD)	First Overtopping Event	
		Existing Levee Height	Improved to Design Height
Eden Street levee	7.50	< 10% AEP	< 10% AEP
First Lane levee	5.90	< 5-year ARI	< 5-year ARI
RSL levee wall	7.26	< 10% AEP	< 5% AEP

This option provides minimal benefit in terms of reduced damages. However in a future climate it will allow the existing level of protection to be maintained for longer. Given the relatively low cost of repairing the levees it should be scheduled into Council's maintenance works when possible.

5.1.2. Raise Levee Design Height

The raising of the Kempsey town levees is often discussed as an option for providing more flood protection for both the residential and commercial properties in Kempsey which are subject to flooding in events less than a 10% AEP event.

Several raising options were considered as part of this study (Table 17 and Figure D 5):

- Raising First Lane Levee
- Raising Eden Street Levee
- Raising First Lane and Eden Street Levees

As these two levees operate together raising one rather than the other, depending on the gradient of the event (refer to Diagram 2) could result in negative impacts within the levee. For example raising First Lane Levee would prevent water entering Kempsey from the north in a slow gradient event but not allow water to leave as easily in an Eden Street overtopping event. Raising the levee would displace water increasing floodwaters elsewhere.

Table 17: Raising First Lane and Eden Street Levee Heights

Scenario	Current Design (mAHD)	Levee Height	Raised Levee Height (mAHD)	Increase in Levee height (m)	Comment
Raise First Lane Levee	5.90		6.65	0.75	0.1m above 10% AEP
Raise Eden Street Levee	7.50		8.07	0.57	0.1m above 10% AEP
Raise First Lane and Eden Street Levees	As above				

In order to assess the impact of raising the levee the TUFLOW hydraulic model was modified to represent the levee heights in Table 17. The hydraulic model was run for the 5-year ARI, 10% and 5% AEP events with the levees at their design height as these events are the most significant in terms of when the levees first overtop. The impacts were calculated comparing the existing conditions flood levels to the raised levee scenario flood levels.

5.1.2.1. Raise First Lane Levee

Figure D 6 presents the impacts of raising the First Lane Levee in a 10%, 5% and 1% AEP event and affected properties. The First Lane Levee first overtops in the 5-year ARI event at low points in the levee. In this scenario the levee would not be overtopped in a 10% AEP event.

Floodwater flowing through the floodway becomes trapped upstream of the First Lane Levee causing peak flood levels to increase up to 0.2 m in the 10% AEP event and 0.16 m in the 5% AEP event. Floodwaters downstream of Kempsey (Christmas Creek) experience a minor reduction. Increases in peak flood levels are less than 0.04 m in the 1% AEP event when the floodwaters are well above the levee height. A total of 18 properties experience increased flooding in a 10% AEP event.

Event	Increase in Number of Properties affected below floor level	Increase in Number of Properties Flooded above floor level
1% AEP	1	7
5% AEP	13	15
10% AEP	18	11

5.1.2.2. Raise Eden Street Levee

Raising Eden Street Levee reduces the flow through the floodway in events when only Eden Street overtops. Figure D 7 presents the impacts of raising the Eden Street Levee in a 10%, 5% and 1% AEP event and affected properties. Floodwaters overtop the raised Eden Street levee in events just larger than a 10% AEP. The flow down the floodway is reduced, increasing flooding upstream of the Eden Street Levee. In a 10% AEP event flood levels upstream of Eden Street levee are increased by up to 0.09m and downstream flood levels reduced by 0.03-0.05m. Floodwaters upstream of Eden Street Levee are increased by 0.2m and 0.4m in a 5% and 1% AEP event respectively. Flood levels in the floodway and West Kempsey are reduced by up to up to 0.04-0.13m and 0.04-0.6m in a 5% and 1% AEP event respectively. In a 1% AEP flood levels downstream of the Wide Street/ Cooks Lane Levee are increased by 0.1m due to water levels increasing in the main river upstream of Eden Street Levee. Flood level increases of 0.05m extend some 4 km upstream including Chapmans Creek and Euroka Creek in all events.

Table 18 summarises the number of properties experiencing increased or decreased flooding in each event. In a 1% AEP Event 6 properties are newly flooded above floor level (including a number near the corner of Kemp and Elbow Streets) and 6 experience lot flooding. The average annual damages changes by \$84,430.

Table 18: Number of affected Properties – Raise Eden Street Levee

Event	Reduction in Number of Properties affected below floor level	Reduction in Number of Properties Flooded above floor level
1% AEP	6	6
5% AEP	-5	-1
10% AEP	0	-1

5.1.2.3. Raise First Lane and Eden Street Levees

The First Lane and Eden Street Levees were modified in the model to both be above the 10% AEP level as per Table 17. As the minor raising of the RSL levee to its design height restores it to a 10% AEP level it was also included in the scenario. All three main Kempsey levees provide a 10% AEP protection in this option.

Figure D 8 presents the impacts of raising the First Lane and Eden Street Levees in a 10%, 5% and 1% AEP event and affected properties. In this scenario a minor amount of floodwaters enter Kempsey in a 10% AEP event (similar to the current 5 year ARI event). Flood levels in Kempsey are reduced by over 3m. This reduces significantly the flood damages for frequent events as the most flood affected properties are protected. 79 properties are now flood free while 4 properties (Eden Street and South Kempsey) experience increased flood levels by 0.04-0.06m. This would also allow the CBD to continue to operate during a small event and increase recovery time in small events. Average Annual Flood damages are reduced by \$500,160.

In a 5% and 1% AEP event the option has a similar problem to just raising Eden Street Levee with

the flow down the floodway reduced, increasing flooding upstream of the Eden Street Levee by up to 0.16m and 0.38m in a 5% and 1% AEP event respectively. Table 19 summarises the impact on properties.

Table 19: Number of affected Properties – Raise First Lane and Eden Street Levees

Event	Change in Number of Properties affected below floor level	Change in Number of Properties Flooded above floor level
1% AEP	8	7
5% AEP	12	9
10% AEP	-136	-72

5.1.3. Large Scale Integrated Flood Management Scheme

5.1.3.1. Background

Kempsey is subject to frequent high hazard flooding under current climate conditions. In a changed climate these high hazards will occur in more frequent events (Refer to WMAwater, 2016). The current floodway operates in a 10% AEP event. With a 10% rainfall increase the current hazards experienced in a 10% AEP event (Figure 16) would occur in a 6 year ARI event. The current levee system would overtop in events more frequent than a 5 year ARI. Therefore Kempsey is faced with a difficult decision regarding the risk to life in a changed climate. Three options are available:

- Retreat from Kempsey,
- Levees along the Macleay River, or
- Large scale integrated flood management scheme.

Retreating from Kempsey requires moving all residential and commercial properties to higher ground. The voluntary purchase scheme partly achieves this. Many businesses and services have already been moved to West Kempsey. West Kempsey would possibly become the main CBD. Commercially/industrial zoned land in South Kempsey could also be used. Another possibility is constructing very large and long levees along the river to stop floodwaters entering Kempsey. This would be extremely hard to do and would not reduce the risk as the levees could still overtop or fail.

Large scale integrated flood management scheme are a complex combination of flood modification, response modification and property modification measures. A large scale scheme is likely to be required for Kempsey to provide the most benefit. However such a scheme due to funding, cost and design and construction issues would need to be staged.

The 1985 *Kempsey Evaluation of Options for Flood Protection Report* (Webb McKeown and Associates) considered a number of longer term options including ring levees around commercial areas and along the western edge of the floodway (near Gladstone Street) and lowering or raising levee heights (Diagram 7). Of the options investigated only Short Street Levee (now Wide Street and Cooks Lane Levee) was constructed. The *Draft CBD options study* (WMAwater, 2009b) found

that amendments to levee heights, land use planning control and clearing the floodway, could provide flood relief to existing occupants whilst potentially freeing areas for future flood appropriate development. Levee schemes such as those in Figures 5 and 6 of the Model Testing of Flood Mitigation Works for the Town of Kempsey 1973 report (Dept Public Works, 1973) could be employed in combination with removal of existing properties within the floodway (such as Scenario F from WMAwater, 2009b).

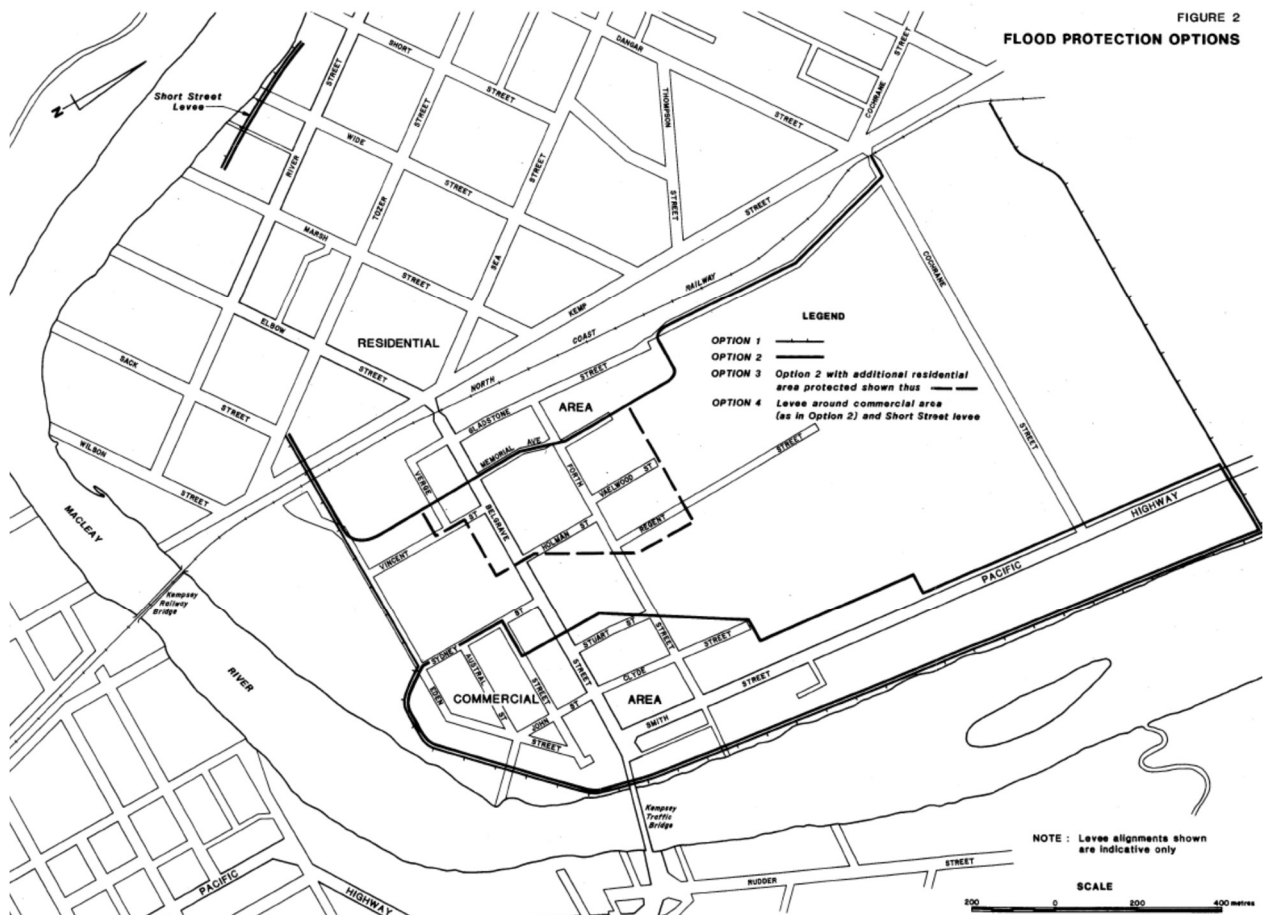


Diagram 7: 1985 Flood Protection Options for Kempsey (Webb McKeown and Associates, 1985)

5.1.3.2. Proposed Option

proposed large scale integrated flood management scheme includes the following works (depicted on Figure D 11):

- *Removal of all buildings and obstructions from the floodway;*
- *Raising the RSL levee - to design height;*
- *A ring levee around CBD and levee on edges of floodway - to 7.5 mAHD (0.5m above 10% AEP) and be tied in with existing buildings;*
- *Lowering existing ground levels within the natural floodway – regrade high hazard areas an approximate gradient of 1 in 700. Tying into existing ground levels;*
- *Raising land on the west of Smith Street (Macleay Valley Way) - to 7 mAHD (0.5m above 10% AEP) to facilitate future development by making floor level requirements achievable;*
- *Lowering First Lane levee to 5.8 mAHD;*

- *Lowering Eden Street levee to 6.8 mAHD;*
- *Flood gates to block backwater areas and*
- *Associated road modifications, culverts and drainage infrastructure.*

The first stage of any large scale scheme would need to be the removal of all buildings from the floodway. This would include the current voluntary purchase scheme. Eden Street and first lane levees could be lowered so that the floodway operated in more frequent events. Gaps in the levees to allow roads (Smith Street, Eden Street and Belgrave Street) to be used in non flood times will require temporary barriers to be installed when an event occurs. The railway bridge near Kemp Street was blocked by temporary flood barriers with a unidirectional 1.8 m diameter culvert. In a future optimisation the bridge could be removed and replaced with embankment and culverts. The levels of the Eden Street and First lane levees were reduced to allow overtopping by 0.3m in a 5 year ARI. The level of the ring levee and training walls has been set to not be visually unappealing.

The option was modelled in the TUFLOW hydraulic model (WMAwater, 2016) for the full range flood events. The option was modelled by raising and lowering the existing ground levels to represent changes to levees and the construction of new levees. The ground levels between Eden Street and First Lane were also modified. Existing buildings in the floodway were removed and the implementation of floodgates as per Section 4.2.4 and 5.2.1.

Impacts of the scheme on flood levels for the 5 year ARI, 10%, 5% 1% and PMF events are shown in Figure D 12 to Figure D 15. In a 5 year ARI event flood levels are reduced by 0.04m upstream of Kempsey, up to 0.06 downstream of Kempsey and 0.02m in South Kempsey (Figure D 12). Flood levels increase in the floodway as the levees have been lowered but all houses have been removed.

In a 10% AEP event flood levels in East and West Kempsey and upstream of Kempsey are reduced by 0.04m (Figure D 13). 26 residential properties and 50 commercial properties in Kempsey are no longer flooded above floor level in a 10% AEP event. Flood levels downstream of Kempsey are increased by up to 0.04m with no properties newly flooded. Flood levels immediately upstream of Eden Street levee are reduced by 0.5m.

In a 5% AEP event (Figure D 14) the ring levee would be overtopped but in the Smith Street area the flood levels are reduced in the order of -0.3 to -0.43m. At the Eden Street levee flood levels are reduced by -1.0m. Localised larger reductions in flood levels occur. Flood levels in South Kempsey are reduced by 0.17m.

In a 1% AEP event (Figure D 15) flood levels are reduced in the Kempsey CBD along Smith Street by 0.15-0.3m (with some localised reductions of 1m). Flood levels in South Kempsey are reduced by 0.27m. Immediately upstream of Eden St flood levels are reduced by 0.87m. A few properties at the northern end of Smith Street experience slight increases (up to 0.04m) in flood levels in a 1% AEP event. A lot of this area currently has no development on it. The majority of the area experiencing increases (0.04m) is agricultural land downstream of Kempsey. Refinement of the option may reduce these increases.

General social and environmental impacts of various flood risk management measures have been discussed in the previous sections of this report. The economic impacts of the scheme are positive. Business in the CBD would be able to resume sooner post event. Social impacts would be associated with the relocation of properties however the reduction in risk to life is a considerable benefit.

A flood damages assessment was undertaken for the option. Average Annual Damages are reduced by \$317,526 and \$562,500 for residential and commercial properties respectively (approximately 30% overall). Table 20 summarises the number of affected properties.

Table 20: Number of Affected Properties – Integrated Option

Event	Residential		Commercial	
	Reduction in Number of Properties affected below floor level	Reduction in Number of Properties Flooded above floor level	Reduction in Number of Properties affected below floor level	Reduction in Number of Properties Flooded above floor level
1% AEP	42	44	12	16
5% AEP	86	34	30	15
10% AEP	77	26	78	50
5 Year ARI	2	0	2	0

Table 21: Flood Damages – Integrated Option

Event	Damages Existing		Damages Integrated Option	
	Residential	Commercial	Residential	Commercial
PMF	\$ 59,220,400	\$ 42,278,100	\$ 39,210,700	\$37,966,600
1% AEP	\$ 10,068,700	\$ 16,611,900	\$ 6,816,700	\$14,797,300
5% AEP	\$ 3,097,300	\$ 8,312,400	\$ 1,116,300	\$ 5,812,700
10% AEP	\$ 1,655,800	\$ 5,287,900	\$ 304,300	\$ 106,000
5 Year ARI	\$ 117,400	\$ 5,800	\$ 116,100	\$ 1,500
AAD	\$ 749,300	\$ 1,352,800	\$ 431,800	\$ 790,300

The cost of the removal of properties from the voluntary purchase scheme are not included in the cost benefit analysis as the voluntary purchase scheme will be undertaken regardless of this scheme. The scheme is likely to cost in the order of \$3 Million. The integrated scheme has a cost benefit of 1.56 for residential buildings only and 4.33 including commercial and residential damages.

If this option were to be implemented a detailed optimisation study would be required including:

- feasibility,
- optimal heights of levees,
- optimal phasing of works,
- detailed costing of works,
- impacts should a flood occur during construction and

- life of works costs eg. Maintenance.

Consideration should be given to what is an acceptable level of risk in the future with climate change. The integrated option modelled in this study provides protection in a 10% AEP event under existing climate. With a 10% climate change the scheme would be overtopped in a 6 year ARI event. A detailed community consultation study on the option would also be required. The benefits of blocking the backwater areas in the context of an integrated scheme should also be investigated.

The scheme should be viewed as a long term solution which would need to be undertaken in stages. For example lowering of the levees cannot occur prior to removal of buildings as it would increase flood levels. The removal of buildings would need to be staged as per Section 4.3.2. Diagram 8 presents a possible staging plan for the option.

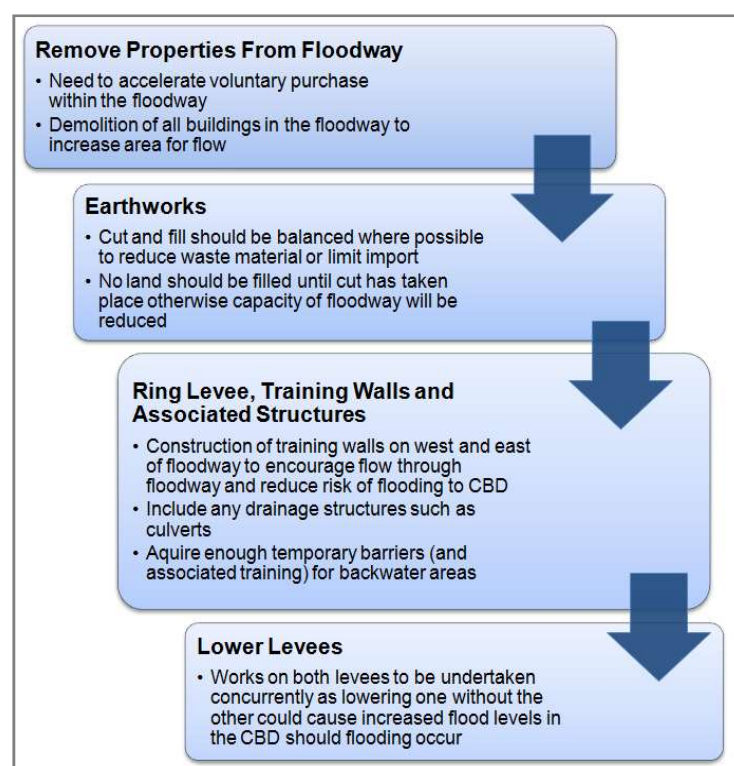


Diagram 8: Possible staging of Integrated Option

SUMMARY

The optimum solution for Kempsey cannot be achieved by simple measures in the short term. The integrated scheme is a long term to reduce flood risk to the existing population. The scheme reduced damages in frequent events which will become more frequent in a future climate. It also reduces overall impacts in a 1% AEP, however the impacts to some individuals may be unacceptable.

5.1.4. Raise Belgrave Street

Belgrave Street is the main east west route connecting Kempsey and West Kempsey. When the

road is cut residents are unable to attend work or access services. The low point in the road is approximately 4.3mAHD. The road is flooded in events more frequent than a 10 % AEP event. Raising Belgrave Street between Holman and Stuart Street for a distance of 250m to a level of between 4.92 and 5 mAHD (tying into existing levels) was investigated. This would reduce the frequency of inundation and reduce the post flood recovery time. The culverts downstream at Forth Street were doubled (0.9m diam.). Raising a larger section of road is likely to be cost prohibitive and difficult.

Figure D 9 depicts the option. The option was modelled in the hydraulic model (described in WMAwater, 2016) for an 10% AEP event. The impact of the raising of Belgrave Street on flood levels is presented in Figure D 10. The impact on peak flood levels is in the order of a few millimetres because the event significantly overtops Belgrave Street. Diagram 9 shows the impact on the flood hydrograph. An additional hour till overtopping is likely to be achieved.

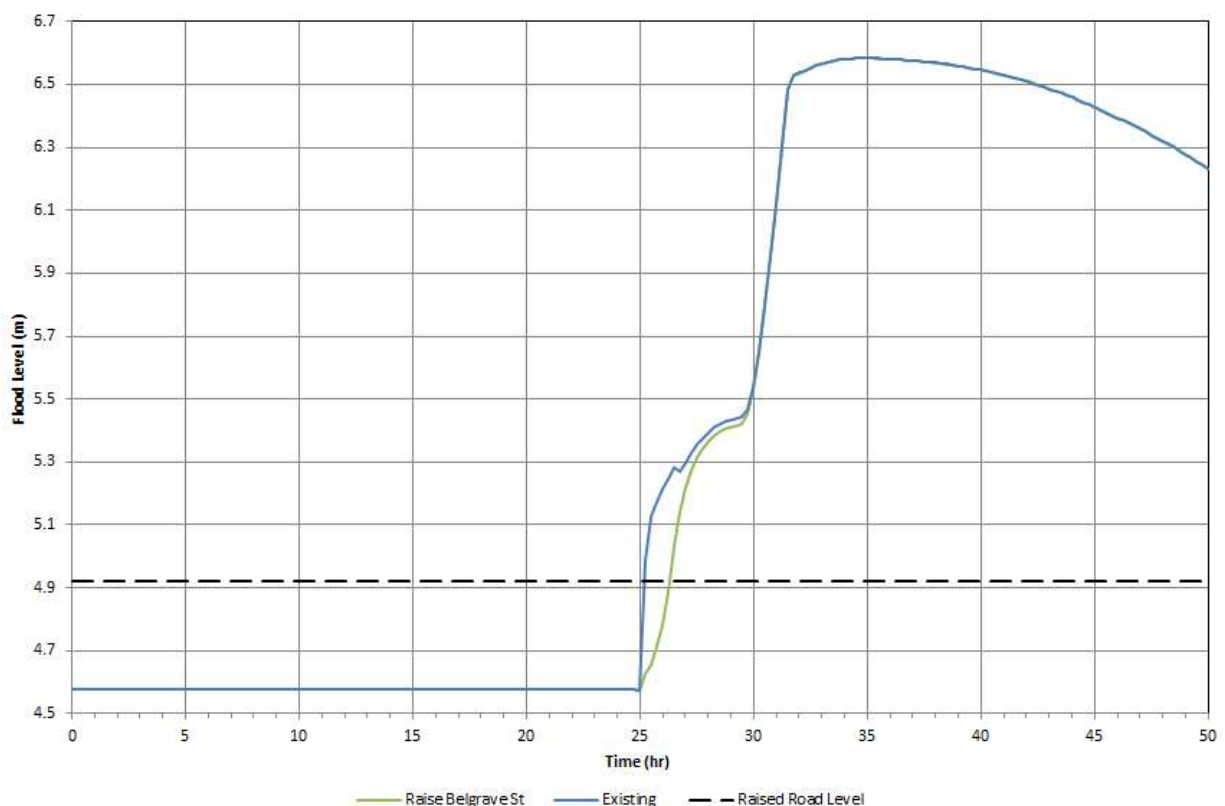


Diagram 9: Impact of Raising Belgrave Street

This option would increase evacuation times, reduce the cost to business during a flood as workers could return to work earlier, customers could access businesses sooner post flood, residents could reenter the area earlier post flood and emergency services could travel through town for longer during an event. It is difficult to assign a monetary value to these benefits. The cost benefit for this option is likely to be greater than 1.



Photo 9: Flooding of Belgrave Street during 2013 event

5.2. West Kempsey

5.2.1. Flood Gate – Gladstone Street

Placement of a floodgate on the railway underpass on Gladstone street (Photo 10) to prevent backwatering into West Kempsey was investigated. The railway is overtopped in events rarer than a 5% AEP event. Currently the area is inundated in events rarer than a 5 year ARI.



Photo 10: Gladstone Street Railway Underpass

The floodgate was modelled using the hydraulic model (Described in WMAwater, 2016) as a complete blockage of the underpass. Two 1.5 m by 2 m unidirectional box culverts were assumed to allow water to drain from the area. Figure D 16 shows the location of the flood gate. Figure D 17 depicts the impact of the flood gates in a 10%, 5% and 1% AEP event. The impact was calculated as the difference in flood level between the scenario case and the existing conditions

case. The area west of the Gladstone Street underpass is flood free in a 10% AEP event. Flooding in the area would be reduced in a 5% AEP event in the order of 1m. In larger events there is no reduction in flood levels. There may still be local drainage issues with local rainfall in the area although this is likely to be relatively minor compared to the flooding from backwater. No impact occurs on flooding to the east.

The floodgate would need to be specially manufactured of steel and secured to the wingwall of the existing underpass. The flood gate would be closed by Council in events when the Eden Street or First Lane levees are expected to be overtopped (moderate level (5.7mAHD) at the Kempsey Traffic Bridge gauge). Consideration would need to be given to how the floodgate would be operated post event when it may have some local floodwaters stored behind it and without erosion of Gladstone Street.

Average Annual Flood damages to residential properties are reduced by \$108,555. Up to 26 residential properties experience reduced flooding (Table 22). The number of residential properties no longer flooded above floor level in a 10% AEP event is 11. It is anticipated the flood gate would cost \$200,000 including construction and refinement of the operating strategy. The stability of the embankment should be investigated should this option be further considered. A cost benefit ratio of 8 is achieved by this project. Possible alternates to a flood gate would be to increase storage in the catchment in the form of a retarding basin near the Council Depot or house raising or applying another levee at Wide Street between the Showground and Catholic Public School and within the existing Thompson Street playing fields. House raising was a preferred option during community consultation.

Table 22: Number of Impacted Residential Properties – Flood Gate Gladstone Street

Event	Reduction in Number of Residential Properties affected below floor level	Reduction in Number of Residential Properties Flooded above floor level
5% AEP	20	10
10% AEP	26	11
5 Year ARI	0	0

5.3. South Kempsey

5.3.1. South Kempsey Levee

An open drain runs through South Kempsey and joins with the Macleay River just downstream of the railway line. The area is subject to Macleay River flooding in small events which mainly affects yards. The majority of properties in South Kempsey are not flooded above floor level until a 1% AEP event. A small earthen embankment currently runs along the river bank.

The height of the embankment could be increased to 8.6m AHD (approximately 0.7m above the 10% AEP) to prevent backwater flooding in events up to a 5% AEP event (Figure D 18). Local event runoff may pond behind the levee and would need to be drained. The levee would need to be fitted with a one way flap gate to drain water from the area after the peak of the Macleay River

flooding has passed. It is unlikely that the local catchment and Macleay River would peak at the same time.

The levee was modelled in the Hydraulic model as approximately 450 m along the river banks between Prince Street and Hill Street with a crest level of 8.6 mAHD. The option was modelled for a 10%, 5% and 1% AEP event. The impact of the option on flood levels for these events is shown in Figure D 19. Increases in flood levels as a result of blocking off the backwater area are minor (<0.1m) and contained within the Macleay River. Flood levels are reduced by 0.001m in a 5% AEP event.

Table 23 summaries the number of properties no longer flooded and those that experience reduced flooding. In the 10% and 5% AEP events 25 and 30 residential properties respectively are no longer subject to yard inundation. In a 5% AEP event 8 houses are no longer flooded above floor level. Average annual damages to residential properties are reduced by \$67,553. The levee would cost in the order of \$500,000 to build giving it a benefit cost ratio of 2. An alternate would be house raising or additional flood storage in the South Kempsey area.

Table 23: Number of affected properties – South Kempsey Levee

Event	Reduction in Number of Properties affected below floor level	Reduction in Number of Properties Flooded above floor level
5% AEP	30	8
10% AEP	25	4
5 Year ARI	6	1

5.4. Floodplain Downstream of Kempsey

5.4.1. Raise South West Rocks Road

South West Rocks Road is inundated in a 2 year ARI event. Raising the road to increase access during frequent events and improve evacuation has been considered on a number of occasions. In particular raising South West Rocks Road between Red Hill Lane and the bend in South West Rocks Road at the corner of Astral Eden Outer road (Figure D 20) would increase access during minor flood events and improve evacuation. This section has been subject to pavement issues due to the high velocities that flow over the area in a flood event. The hydraulic model was modified to represent the section of road raised by 0.3m. Culvert upgrades were not considered as part of the option but may reduce impacts.

The option was considered for a range of flood events (5 year ARI, 5% and 1% AEP). The impact of the road upgrade was calculated as the change in flood level from existing conditions (Figure D 21 to Figure D 23). Overtopping of the road will occur approximately 1 hour later than the current situation in a 5 year ARI event (Figure D 24). In a 5 year ARI event flood levels at three high velocity locations (at the base of Red Hill, Ferry Lane and halfway between the two) are increased by up to 0.2m. However, no houses are impacted all affected properties had their house raised or stock mounds built as part of the Kempsey Bypass. The areas are in some cases slightly

lower or the surrounding topography is funnelling the water in that direction. Any road raising option should consider maintaining these at a lower level. In events that overtop the road the impact is minimal and contained to the low point near Red Hill lane (0.038m in a 5% AEP and 0.02m in a 1% AEP event).

The economic value of this option is hard to quantify, road works alone would cost in the order of \$900,000 but the cost benefit ratio is likely to exceed 1. The option should be considered whenever pavement works are required for South West Rocks road.



Photo 11: Flooding - South West Rocks Road, Red Hill 2011 Event

6. CONCLUSIONS AND RECOMMENDATIONS

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 24 contains a summary of the recommended measures.

Table 24: Recommended Measures

Measure	Relevant section	Comment	Economic Assessment	Implementation viability	Priority
LEVEES FLOODGATES AND PUMPS	Section 4.2.2	Existing levees should be repaired to their design height and regularly maintained.	Low Cost	Recommended	High
		Levee at South Kempsey or alternate flood mitigation measure.	South Kempsey Levee- \$500,000 – Residential B/C – 2.89	Recommended	Medium
		Modifications to Wide Street levee	Wide Street Cooks Lane – minimal cost	Recommended	High
		Raising of Wide Street Cooks Lane Levee	Not Undertaken	Recommend future investigation	Low
		Floodgates at Gladstone St or alternate flood mitigation measure.	Floodgates Gladstone St- \$200,000 Residential B/C – 9.07	Recommended	Medium
		Eden Street Boat Ramp low point	Low Cost	Recommended	Low
		Review of Lower Macleay Flood Mitigation works	Not Undertaken	Recommended	High
		Investigate the drainage of flood waters from behind the levee system	Low cost	Recommended	Low
		Long term integrated flood management scheme recommended. Structures to be regularly maintained. The effects of climate change should be considered in decision making.	Integrated scheme -\$3 Million Total B/C – 4.33	Long term. Outside the timeframe of this document.	Long term. Outside the timeframe of this document.
TEMPORARY FLOOD BARRIERS	Section 4.2.2	Continue current use of sandbagging for low points, residential and commercial properties. Investigate possible raising of low points in future road upgrades	Not undertaken	Recommended	High
FLOODWAYS	Section 4.2.4	Council has a number of defined floodways in their DCP (see Section 2.7.2). Removal of all buildings in floodway particularly residential buildings is the only way to significantly reduce their risk.	High. Assuming \$12 Million cost, total B/C = 0.4. Significant intangible benefit.	Recommended	High
FLOOD REFUGE MOUNDS	Section 4.2.5	Flood refuge mounds are suitable mitigation options for stock only on the floodplain upstream and downstream of Kempsey. Impact on surrounding properties to be confirmed. Should be treated as a back up plan not a primary evacuation plan.	Low Cost	Recommended subject to hydraulic assessment	Low
LAND USE ZONING	Section 4.3.1	Planning controls for floodway that is not hydraulic floodway.	Low Cost	Recommended	High
VOLUNTARY PURCHASE	Section 4.3.2	Current voluntary purchase scheme to be continued and accelerated to remove residential houses subject to high hazard from floodway.	High \$6 Million. Intangible benefits high.	Recommended	High
FLOOD PLANNING LEVELS	Section 4.3.3.1	Council has established appropriate controls. Update Flood planning level based on current model outputs.	Negligible costs	Upgrades to be considered.	High
		Consider putting flood information on Council's website	Negligible costs	Upgrades to be considered.	High
REVISE LEPS AND DCPS	Section 4.3.3.2	Council has established appropriate guidelines. However possible upgrades have been suggested. Council to consider minor changes to LEP and DCP.	Negligible Costs	Upgrades to be considered.	High

Measure	Relevant section	Comment	Economic Assessment	Implementation viability	Priority
		Adopt Flood Planning Area based on current modelling 1% AEP plus 0.5m freeboard	Negligible Costs	Upgrades to be considered.	High
S149 CERTIFICATES	Section 4.3.3.3	Kempsey Council provides thorough S149 certificates. It is recommended that the certificates be updated and reissued based on the outcomes of this study.	Low Cost	Recommended	High
		Issue S149 (5) along with S149(2)	Low Cost	Recommended	High
HOUSE RAISING	Section 4.3.4	Can be applied. Council to contact those on the list for voluntary house raising and review the list periodically.	High cost per property.	Recommended	High
		Extend list for voluntary purchase to include other rural properties	Low Cost	Recommended	High
FLOOD PROOFING	Section 4.3.5	Generally only suitable for non-residential buildings.	Depends upon building. Not funded by the State Government.	To be promoted where applicable.	Low
FLOOD ACCESS	Section 4.3.6	Raising of Belgrave St to improve evacuation and post flood recovery.	Tangible benefit hard to quantify. Consider as part of future road works program.	Recommended	Low
		Raising of South West Rocks Road to improve evacuation and post flood recovery.	Tangible benefit hard to quantify. Consider as part of future road works program.	Recommended	Low
FLOOD WARNING	Section 4.4.1	Conversion of all gauges to AHD in the lower catchment	Tangible benefit hard to quantify. Negligible cost.	Recommended	High
		Add Frederickton and Third Lane gauges to ENVIRONMON. Update technology when available.	Tangible benefit hard to quantify. Negligible cost.	Recommended	High
		Additional gauges mid catchment	Approx \$20,000 per gauge. Tangible benefit hard to quantify.	Recommended	Medium
		Correlation between Kempsey and Smithtown gauges	To be done during an event at negligible cost	Recommended	High
		Document gage management arrangements	Low Cost	Recommended	Medium
FLOOD AWARENESS AND PREPAREDNESS	Section 4.4.2	A cheap and effective method but requires continued effort. Examples of methods are provided. Develop a flood awareness program regarding levee overtopping scenarios	Benefits likely to be significant for relatively low cost. Effectiveness reduces with time since last flooding event	Recommended	High
EVACUATION PLANNING	Section 4.4.3	NSW SES to continue to regularly update Local Flood Plan.	Relatively low cost	Recommended	High
		Investigate system of managed entry to CBD during event	Relatively low cost	Recommended	High
		Study to investigate flow times between key upstream gauges.	Not Undertaken	Recommended	Medium
		Signs advising of risk of driving in floodwaters	Low Cost	Recommended	Medium

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- Kempsey Shire Council
- NSW Office of Environment and Heritage
- Council's Natural Resources Working Group
- The residents of the Macleay Valley
- Roads and Maritime Services

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Figures



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 and 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 diagrammatic 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 'flood liable land' concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs 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 'standard 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	<p>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.</p> <p>existing flood risk: the risk a community is exposed to as a result of its location on the floodplain.</p> <p>future flood risk: the risk a community may be exposed to as a result of new development on the floodplain.</p> <p>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.</p>

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	<p>in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.</p> <p>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.</p>
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	<p>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:</p> <ul style="list-style-type: none"> § 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

	<p>§ 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</p> <p>§ major overland flow paths through developed areas outside of defined drainage reserves; and/or</p> <p>§ the potential to affect a number of buildings along the major flow path.</p>
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	<p>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.</p> <p>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.</p>
minor, moderate and major flooding	<p>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:</p> <p>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.</p> <p>moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.</p> <p>major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.</p>
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 water 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. FLOOD DAMAGES

B.1. Background

A flood damages assessment was also undertaken as part of this Floodplain Risk Management Study. The cost of flood damages and the extent of the disruption to the community depends upon many factors including:

- the magnitude (depth, velocity and duration) of the flood,
- land usage and susceptibility to damage,
- awareness of the community to flooding,
- effective warning time,
- the availability of an evacuation plan or damage minimisation program,
- physical factors such as erosion of the river bank, flood borne debris, sedimentation.

Flood damages can be defined as being “tangible” or “intangible”. Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value (stress, injury, loss to life, etc.). Diagram 10 shows the flood damage categories.

Some historic floor level survey of rural properties was available from survey undertaken as part of the Kempsey Bypass. This was supplemented by additional survey of 580 commercial and residential properties commissioned by Council. A total of 715 properties were included in the damages assessment including 202 commercial properties and 513 residential properties. Figure B 1 depicts the survey sources and locations. Commercial properties included may not include each commercial entity if the building is subdivided on the ground floor although the average floor level per commercial property will provide for this as the larger floor area will have been attributed to one property. For the damages assessment, where buildings have been raised, the lowest habitable floor level is used in the assessment. Where it was not obvious if people lived on the ground floor the lower floor was used to provide a more conservative assessment. The damages assessment does not include damages to rural industry and agriculture. These properties were assessed as residential properties.

There are a number of issues with “assigning” a single flood level to a property to estimate flood damages. These include:

- no account is taken of the actual openings where floodwaters could enter a building relative to the applicable flood gradient. Thus a rear door may allow the water to enter rather than the front door,
- the level “assigned” is usually taken as the flood level midway across the property. For areas with low flood gradients this is appropriate, however in “long” properties and factories or areas with strong flood gradients this may not necessarily be appropriate.
- the “assigned” flood level is only relevant for estimating flood damages and should not be used for development control purposes. These latter levels must be obtained from interpolation of the flood contour maps.

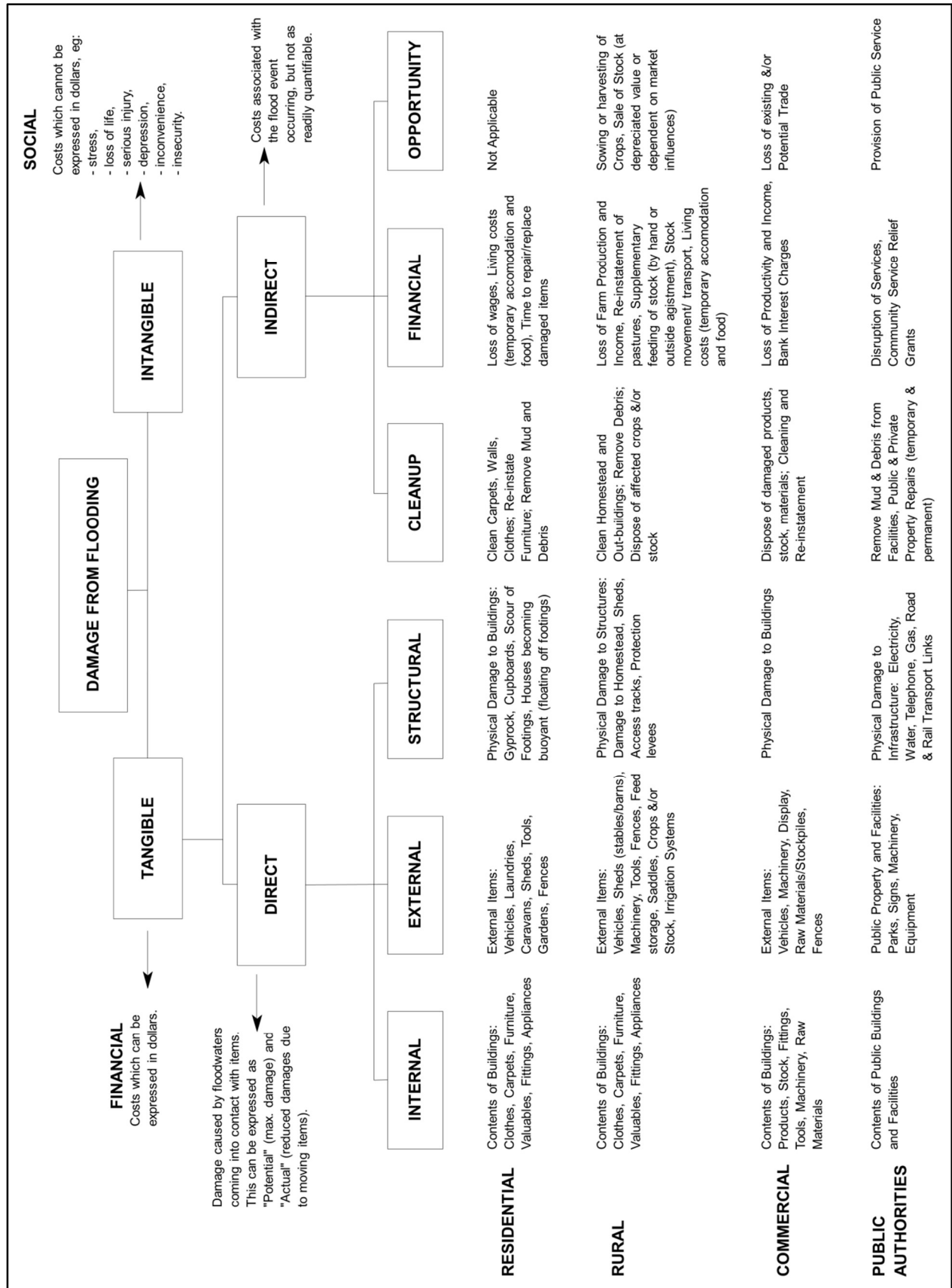


Diagram 10: Types of Flood Damages

B.2. Assessment of Tangible Flood Damages

Quantification of tangible flood damages is generally based upon data derived from post-flood damage surveys obtained following historical flood events. An alternative procedure is to undertake a self-assessment survey of the flood liable properties. This latter approach is more expensive and may not accurately reflect what actually occurs in a flood. Floods by their nature are unpredictable and conditions variable. It is therefore unlikely that a self-assessment survey would have predicted the scale or extent of the damages which occurred in Nyngan in 1990 or North Wollongong in August 1998. For this reason it was decided to use the post-flood damage approach in assessing flood damages for the study area.

The most comprehensive damage surveys include those carried out for Sydney (Georges River - 1986), Nyngan (1990), Inverell (1991) and Katherine (1998). Some of the problems in applying data from these studies to other areas can be summarised as follows:

- varying building construction methods, e.g. slab on ground, pier, brick, timber,
- different average age of the buildings in the area,
- the quality of buildings may differ greatly,
- inflation must be taken into account,
- different fixtures within buildings, e.g. air-conditioning units, machinery, etc.,
- change in internal fit out of buildings over the years or in different areas, e.g. more carpets and less linoleum or change in kitchen/bathroom cupboard material,
- external (yard) damages can vary greatly. For example in some areas vehicles can be readily moved whilst in other areas it is not possible,
- different approaches in assessing flood damages. Are the damages assessed on a “replacement” or a “repair and reinstate where possible” basis? Some surveys include structural damage within internal damage whilst others do not,
- varying warning times between communities means that the potential versus actual damage ratio may change significantly,
- variations in flood awareness of the community.

B.3. Tangible Damages

Tangible direct damages are generally calculated under the following components:

- Internal,
- Structural,
- External.

Tangible indirect damages can be subdivided into the following groups:

- accommodation and living expenses,
- loss of income,
- clean up activities.

Damages may be calculated as either estimated actual damages or estimated potential damages. If potential damages are calculated an Actual/Potential (A/P) ratio is assigned based upon (as well

as other factors) the likely flood awareness of the community and the available warning time.

The flood awareness of the majority of the Macleay River community is likely to be high and the available flood warning time in the order of 24hrs. Based upon the limited data available it is considered that the A/P ratio for the communities within the Macleay Valley would most likely be similar to that applicable at Nyngan and Inverell.

The approach adopted for estimating flood damages was therefore based on that derived from the Nyngan and Inverell flood damages surveys with updating for inflation and the different type of buildings in the catchment.

B.3.1. Direct Internal Damages

Internal damages are based upon the following formulae recommended by OEH (DECC, 2007).

Allowing for inflation and differences in the types of buildings and their contents, a contents value of \$62,750 was adopted for this study for houses. Structural damages were not included in the above figures.

B.3.2. Direct Structural Damages

Structural damages were assumed follow the relationship adopted in DECC (2007) for 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.

B.3.3. Direct External Damages

External damages (laundry/garage/yard/vehicle) were assumed to \$1,500 for houses. This assumes that the majority of vehicles and items are moved by residents.

B.3.4. Indirect Damages

Indirect damages were assumed to be a linear relationship from \$0 at 0 m above floor level to a maximum of \$4,000 at 0.5 m.

B.4. Commercial Damages

Following the 2001 event at Kempsey it was noted that there was an extremely wide variation in damages reported by owners of commercial businesses (Gissing, 2002). The value of damages to commercial properties is much more varied than for residential properties and damage estimates can vary significantly depending on;

- Type of business – stock based or not;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself is closed but when access to it becomes available;
- Ability to move stock or assets before onset of flooding - some large machinery will not be able to moved and in other instances there may be no sufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

No specific methodology is recommended for assessing flood damages to non-residential properties. Therefore for this Study, commercial and industrial damages were calculated using the OEH guidance methodology for residential properties (DECC, 2007) with damage curves modified to be more appropriate to commercial damages. As it is usual that commercial and industrial damages are higher than residential damages a multiplier was applied to the contents by adjusting the typical building size value within the curve development calculations. Other factors including the clean-up costs and external damages were adjusted to reflect the differences between commercial and residential properties and an allowance was made for potential indirect losses. Although the residential damages assessment is not strictly transferable to non-residential properties it is considered a good tool for creating comparable damage figures where both residential and commercial properties are being considered. The damages value figure should not be taken as an actual likely cost rather it is useful when comparing potential management options and in benefit-cost analysis.

External damage was set at \$ 3,000. However, clean-up costs for above floor flooding was set higher, at \$ 9,000.

The 2001 flood event was approximately a 10% AEP event for the area. Commercial damages for the event was estimated at \$28,000 per property not including any clean up costs (Gissing, 2002). Using the damage post 2001 adjustment this is \$42,000 in today's monetary terms. The commercial damages for a 10% AEP flood event are estimated in Table B 3 as \$69,600. While the estimated value is higher than the actual damage in the 2001 flood event it is a reasonable estimate given the large variations possible for commercial damages and the fact it includes additional damages such as clean up costs. In general the damages are overestimated in the more frequent events as those flooded are more experienced and have their own mechanisms for minimising flood damages.

B.5. Results

The number of buildings inundated above floor level are summarised for the range of design flood events in Table B 1. Figure B 2 and Figure B 3 depict when properties are first flood affected. Figure B 4 and Figure B 5 depict when properties are first flooded above floor level. Due to the frequent flooding of low lying areas houses at low levels would have been raised. There is a significant increase in the number of properties flooded between the 5-year ARI and 10% AEP events when the levees are first overtopped. A total of 711 properties are flooded in a PMF.

Properties in the voluntary purchase zone are affected in more frequent events. Properties in the Danger Street and South Kempsey areas are generally not flooded above floor level until the 1% AEP event as they are generally raised off the ground. However below floor flooding can occur in events as frequent as the 5-year ARI. A large number of commercial properties in the CBD are flooded above floor level in events as small as the 10% AEP event when the levees are overtopped.

Table B 1: Affected Properties

Event	RESIDENTIAL		COMMERCIAL		TOTAL	
	No. Properties Affected	Flooded Above Floor Level	No. Properties Affected	Flooded Above Floor Level	No. Properties Affected	Flooded Above Floor Level
2-year ARI	4	2	0	0	4	2
5-year ARI	18	2	3	0	21	2
10% AEP	113	33	79	51	192	84
5% AEP	200	58	121	74	321	132
1% AEP	308	171	159	127	467	298
0.5% AEP	390	284	184	168	574	452
0.2% AEP	431	354	197	181	628	535
PMF	509	497	202	202	711	699

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. By this means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. The Average Annual Damages (AAD) for residential properties based on the above values is estimated to be \$749, 200 (Table B 2). Most dwellings are located above the 5% AEP flood level. The Kempsey Bypass project raised a number of extremely flood prone properties to the 1% AEP plus 0.5m level which has reduced the damages.

Table B 2: Residential Damages

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	Ave. Damage Per Flood Affected Property
2-year ARI	4	2	\$ 64,800	\$ 16,200
5-year ARI	18	2	\$ 117,400	\$ 6,500
10% AEP	113	33	\$ 1,655,800	\$ 14,700
5% AEP	200	58	\$ 3,097,300	\$ 15,500
1% AEP	308	171	\$ 10,068,700	\$ 32,700
0.5% AEP	390	284	\$ 20,013,300	\$ 51,300
0.2% AEP	431	354	\$ 28,276,900	\$ 65,600
PMF	509	497	\$ 59,220,400	\$ 116,300
<i>Average Annual Damages (AAD)</i>			\$ 749,300	\$ 1,700

Average annual damages for commercial properties is greater than that of residential properties despite fewer commercial properties being flood affected. AAD per flood affected commercial property is nearly four and a half times that of residential damages identifying the need for protection of the commercial CBD area (Table B 3). Floor levels of commercial properties tend to be closer to the ground than residential properties and therefore can suffer higher flood damages. Results of the floor level survey undertaken for this Study show that the average floor level of surveyed commercial properties is 0.75 m above ground compared to 1.78 m above ground for residential properties surveyed.

Table B 3: Commercial Damages

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	Ave. Damage Per Flood Affected Property
2-year ARI	0	0	\$ -	\$ -
5-year ARI	3	0	\$ 5,800	\$ 1,900
10% AEP	79	51	\$ 5,287,900	\$ 66,900
5% AEP	121	74	\$ 8,312,400	\$ 68,700
1% AEP	159	127	\$ 16,611,900	\$ 104,500
0.5% AEP	184	168	\$ 23,721,700	\$ 128,900
0.2% AEP	197	181	\$ 28,090,900	\$ 142,600
PMF	202	202	\$ 42,278,100	\$ 209,300
<i>Average Annual Damages</i>			\$ 1,352,800	\$ 6,900



APPENDIX C. RESULTS – MODELLING OF MANAGEMENT OPTIONS

Table C 1: Results of Selected Management Measures

Key Locations		Existing					Impact (m)																											
							Integrated Option					Raise First Lane Levee					Raise Eden Street Levee			Raise First Lane, Eden St and RSL Levee			Gladstone St Floodgates				Raise Levees to Design Height				South Kempsey Levee			
		2 Year ARI	5 Year ARI	10% AEP	5% AEP	1% AEP	2 Year ARI	5 Year ARI	10% AEP	5% AEP	1% AEP	5 Year ARI	10% AEP	5% AEP	1% AEP	10% AEP	5% AEP	1% AEP	10% AEP	5% AEP	1% AEP	5 Year ARI	10% AEP	5% AEP	1% AEP	5 Year ARI	10% AEP	5% AEP	1% AEP	5 Year ARI	10% AEP	5% AEP	1% AEP	
Frogmore	River	2.19	4.08	4.72	5.28	6.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Upstream Bridge Right Bank	River		4.68	4.87	5.28	5.96	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Downstream Frederickton	River	5.24	5.67	5.89	6.05	6.37	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Frederickton	River	5.29	5.77	6.03	6.22	6.62	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Upstream Frederickton	River	5.33	5.88	6.19	6.44	6.98	0.00	-0.02	0.01	0.00	0.00	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Glenrock Drain	River	5.61	6.18	6.61	6.99	7.77	0.00	-0.03	0.02	0.01	0.01	0.00	-0.01	0.01	0.01	-0.01	0.01	0.01	0.00	-0.01	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Old Station Road	River		4.55	4.98	5.58	6.60	0.00	-4.55	-0.01	0.00	0.01	0.00	-0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
East Kempsey Wetland	Flood plain	4.62	4.80	5.15	5.65	6.65	0.00	-0.01	-0.01	0.00	0.01	0.00	-0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
South West Rocks Road	Flood plain		4.07	4.71	5.25	5.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Pola Creek	Flood plain	5.82	6.41	6.89	7.26	8.03	0.00	-0.02	-0.01	0.01	0.01	0.00	0.00	0.02	0.02	0.00	0.01	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Railway Bridge	Flood plain	6.13	6.98	7.89	8.62	10.02	0.00	-0.02	-0.16	0.20	0.28	0.00	0.00	0.00	0.01	0.06	0.12	0.17	0.07	0.12	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Traffic Bridge	Flood plain	5.97	6.63	7.23	7.69	8.51	0.00	-0.01	-0.04	0.06	0.06	0.00	0.01	0.01	0.02	0.02	0.03	0.02	0.04	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
South West Rocks Road (Red Hill)	Flood plain	2.97	4.22	5.08	5.74	6.67	0.00	-0.03	0.01	0.01	0.00	0.00	-0.02	0.00	0.00	-0.01	0.01	0.00	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

