Bomaderry Floodplain Risk Management Study

Bomaderry Floodplain Risk Management Study and Plan

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Executive Summary

Shoalhaven City Council have commissioned Cardno to undertake a Floodplain Risk Management Study for the Bomaderry Township and its surrounds.

Bomaderry Creek is a major tributary of the Shoalhaven River joining between Nowra Bridge and Pig Island. The creek catchment lies on the northern side of the river system and its confluence with the Shoalhaven River is located in the township of Bomaderry.

Bomaderry Creek has a number of tributaries including Good Dog Creek, Browns Creek and Tapitallee Creek.

The upper catchment consists of steep, heavily vegetated lands from the mountain plateau in the northwest consisting of Cambewarra Mountain and Browns Mountain. The central portion of the catchment comprises broad floodplain with predominantly rural land use and where all major tributaries merge to form Bomaderry Creek.

Bomaderry Creek flows into a steep, heavily incised gorge conveying flows to the lower catchment, which consists of mostly urban land-use in the townships of North Nowra and Bomaderry. The creek widens in this low lying area and is heavily influenced by Shoalhaven River tailwater conditions.

In addition to the main creeks a number of significant overland flowpaths have been identified within the study area and result in flood risk outside of the main floodplain. Typically overland flowpath names are not available and naming has been assigned based on nearby landmarks such as road crossings.

An assessment was undertaken on the number of properties to be affected by flooding under different frequency storm events, as well as an estimate of the appropriate economic damage for each event. The following table summarises these results.

Table i Flood Affected Properties and Damages under Existing Conditions

Flood Event	Properties with Over-floor flooding *	Properties with Over-ground flooding *	Flood Damage ($)
20% AEP	5	20	$394,821
10% AEP	8	22	$538,003
5% AEP	11	25	$959,948
2% AEP	15	32	$1,286,950
1% AEP	16	35	$1,652,618
0.5% AEP	19	40	$2,112,372
PMF	77	84	$7,559,141
Average Annual Damage			$166,142

Options to reduce or manage the effects of flooding in the catchment were investigated, and recommendations to manage the risks of flooding were developed. A number potential options for the management of flooding were identified using the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (NSW Government, 2005), and in consultation with the community, Council and state agency stakeholders.

These options included:

- Flood modification measures
- Property modification measures
- Emergency response measures

All potential options were assessed using a multi-criteria assessment (technical, economic, environmental and social). Hydraulic modelling of some of the flood modification options was undertaken to provide a comprehensive analysis of those options that would involve significant capital expenditure.

The assessment found, of the all the options investigated (including flood, property and emergency measures), the top three identified by the multi-criteria analysis were:

1. P 2 Building and Development Control Plans
2. P 1 LEP Update
3. P 8 Flood Proofing Guidelines

Of the structural options assessed, excluding the road raising options for emergency access only, the top three options identified by the multi-criteria analysis were:

1. F 6 Maleen Street and Briniwarr Street Levee
2. F 1 Birriley Street Raising and Culvert Upgrade
3. F 5 Tarawal Street Levee

This ranking is proposed to be used as the basis for prioritising the components of the Floodplain Risk Management Plan. It must be emphasised that the scoring is not "absolute" and the proposed scoring and weighting should be reviewed in light of any additional future information.

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1 Introduction

Shoalhaven City Council is responsible for local planning and land management in the Bomaderry Creek catchment. Council adopted the Bomaderry Creek Flood Study on 23 November 2010 and uses this to inform development and planning decisions. Council has now commissioned Cardno to develop a floodplain risk management study and plan in accordance with the process outlined in the NSW Floodplain Development Manual (**Section 1.1**).

1.1 Study Context

The NSW Government's Flood Prone Land Policy is directed at reducing the impact of flooding and flood liability on individual land owners and occupiers of flood prone property, and reducing private and public losses resulting from floods, utilising ecologically positive methods wherever possible. Under the Policy, the management of flood prone land remains the responsibility of local government. To facilitate this, the Government provides funding in support of floodplain management programs and has published the NSW "Floodplain Development Manual – the management of flood liable land" (NSW Government, April 2005) (the Manual), to provide guidance to Councils in the implementation of the Policy. The Manual describes a floodplain management process comprising the following sequential stages, which are reiterated as required:

1.	Data Collection	Compilation of existing data and collection of additional data.
2.	Flood Study	Defines the nature and extent of the flood problem for the full range of flood events.
3.	Floodplain Risk Management Study	Evaluates management options for the floodplain in consideration of social, ecological and economic factors.
4.	Floodplain Risk Management Plan	Involves formal adoption by Council of preferred options following public comment.
5.	Implementation of the Plan	Implementation of flood, response and property modification measures (including mitigation works, planning controls, flood warnings, education, flood readiness and response plans, environmental rehabilitation, ongoing data collection and monitoring).
6.	Review of Plan	Review of plan to ensure it remains current and appropriate. A review is normally carried out after 10 years.

This report addresses Stage 4.

1.2 Study Objectives

The overall objective of this study is to develop a Floodplain Risk Management Plan for the study area that address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Policy, as detailed in the *Development Manual: the Management of Flood Liable Land* (NSW Government, 2005).

It is expected that this will be essentially undertaken in two phases:

- Phase I - floodplain risk management study in which the floodplain management issues confronting the study area are assessed, management options investigated and recommendations made.
- Phase II – floodplain risk management plan developed from the floodplain risk management study detailing how flood prone land within the study area is to be managed.

2 Catchment Description

The Bomaderry Creek catchment is located approximately 160km south of Sydney in the Shoalhaven River Valley on the New South Wales South Coast. The catchment covers an area of approximately 36km^2 including the town of Cambewarra, and parts of North Nowra and Bomaderry.

Bomaderry Creek is a major tributary of the Shoalhaven River joining between Nowra Bridge and Pig Island. The creek catchment lies on the northern side of the river system and its confluence with the Shoalhaven River is located in the township of Bomaderry.

Bomaderry Creek has a number of tributaries including Good Dog Creek, Browns Creek and Tapitallee Creek.

The upper catchment consists of steep, heavily vegetated lands from the mountain plateau in the northwest consisting of Cambewarra Mountain and Browns Mountain. The central portion of the catchment comprises broad floodplain with predominantly rural land use and where all major tributaries merge to form Bomaderry Creek.

Bomaderry Creek flows into a steep, heavily incised gorge conveying flows to the lower catchment, which consists of mostly urban land-use in the townships of North Nowra and Bomaderry. The creek widens in this low lying area and is heavily influenced by Shoalhaven River tailwater conditions.

The Bomaderry Creek study area is shown in **Figure 2-1**.

In addition to the main creeks a number of significant overland flowpaths have been identified within the study area and result in flood risk outside of the main floodplain. Typically overland flowpath names are not available and naming has been assigned based on nearby landmarks such as road crossings.

Major waterways within the study area are shown in **Figure 2-2**.

3 Available Data

3.1 Previous Reports and Studies

A number of previous studies and assessments have been undertaken relating to the flood behaviour in the Bomaderry Creek catchment. These studies have been reviewed with regards to their implications for this FRMS and a summary is provided in **Table 3-1**.

Table 3-1 Review of Previous Studies

Study	Description	Implications for Bomaderry Creek FRMS&P
Lower Shoalhaven River Floodplain Management Study and Plan, Climate Change Assessment (WMAwater, 2011)	This study comprised an amendment to the 2008 study to incorporate the predicted impacts of climate change. The study adopted NSW Government sea level rise estimates of 0.4m by 2050 and 0.9m by 2100, and increases in precipitation of 10%, 20% and 30% in line with OEH Guidelines. Based on these values, the findings of the previous 2008 study were updated including planning levels, flood damages, flood mitigation options and evacuation procedures.	This study provides information on climate change impacts for assigning downstream tailwater levels in the tuflow hydraulic model for Bomaderry Creek.
Bomaderry Creek Flood Study (BMT WBM, 2010)	This study defines the existing flood behaviour in the Bomaderry Creek catchment, accounting for Step 3 of the Flood Management process for the study area. Detailed survey of major hydraulic structures within the study area was conducted with broadly spaced creek cross sections recorded as a part of this study. The study established an XPRAFTS hydrologic model and a hydraulic model using Tuflow. The modelling has been calibrated using the Bomaderry Creek stream gauge for a rainfall event in February 2008, and validated against observations of the August 1990 rainfall event. The study assesses the 10yr, 20yr, 50yr, 100yr, 200yr, and PMF design flood events for the Bomaderry Creek catchment.	The XPRAFTS and Tuflow models used as part of this study will act as the basis for assessment of floodplain mitigation options.

Study	Description	Implications for Bomaderry Creek FRMS&P
Lower Shoalhaven River Floodplain Risk Management Study (WMAwater, 2008a)	The study built on the initial 1990 study, further investigating key flooding issues and possible solutions. The model incorporated the scenario with Shoalhaven Heads closed but scouring out as the flood progressed. Key issues identified included blockage at Shoalhaven Heads, evacuation access, urban development and expansion. An economic analysis was undertaken which estimated Average Annual Damage at $1.8m with 734 properties affected in the 100yr ARI event. A variety of management measures were discussed including flood modifications (basins, levees), property modifications (raising, voluntary purchase) and response modifications (evacuation planning). Property and emergency response initiatives were considered to be more applicable.	This study provides information on downstream tailwater levels adopted in the hydraulic model for Bomaderry Creek. It also identifies any feasible flood mitigation options in the lower portion of the Bomaderry Creek catchment. It is noted that this area is affected by Shoalhaven River flooding more than Bomaderry Creek flooding or the local catchment.
Lower Shoalhaven River Floodplain Risk Management Plan (WMAwater, 2008b)	The plan outlines the preferred mitigation options, their benefits and how Council may implement these programs. Examples of the mitigation measures proposed include: ▪ Development a post-flood evaluation and review program to further refine models; ▪ Implementation of stormwater management plan for local drainage flooding issues; ▪ Finalise and implement Council's Shoalhaven River Entrance Management Plan for Flood Mitigation (EMPFM); ▪ Update flood polices such as FPL's property set-backs and improve resident flood awareness.	This plan reviews all feasible flood mitigation options within the lower Bomaderry Creek catchment. It identifies the preferred options, their benefits and how Council may implement these programs.
Lower Shoalhaven River Flood Study (WMAwater, 1990)	The flood study for the region was undertaken in 1990 using the WBNM hydrological model, and the CELLS hydraulic model. The models were calibrated to yearly historical floods from 1974 – 1979 and the 1988 flood event. Results were provided for downstream conditions at Shoalhaven Heads for the 20 year, 50 year, 100 year and PMF events. Various levels were determined depending on whether the heads were open or closed.	This study establishes a hydraulic model for the lower Shoalhaven River which is further refined in the 2008 Flood Risk Management Study.

3.2 Initial Survey Information

Topographical information has been provided via Aerial Laser Scanning (ALS) data undertaken in 2010 which extends over the lower portion of the study area. The ALS data excludes the heavily vegetated mountain plateau at the top of the catchment however it includes the key areas of interest within the study area. The 2m x 2m Digital Elevation Model (DEM) used within the Tuflow model was also provided.

Survey information of creek cross sections and hydraulic structures within the study area was undertaken as part of the Flood Study (BMT WBM, 2010). The distribution of creek cross sections represented an average cross section spacing of 200m along all of the main tributaries.

All major hydraulic structures along the major tributaries were surveyed. However, a number of culvert systems along minor tributaries and flowpaths were not surveyed.

3.3 Geographic Information System Data

The following Geographic Information System (GIS) data was provided by Council for use as part of this assessment:

- Cadastre;
- Aerial photography;
- ALS data (2010) covering the majority of the study area;
- Watercourses within the study area;
- Stormwater network information including pit and pipe data;
- Land use zoning information, heritage, conservation and vegetation areas; and
- Nowra Bomaderry Structure Plan 2009.

3.4 Site Inspection

A site visit and inspection of the catchment was undertaken on 19 August 2013 with Council and OEH to identify key areas of interest within the catchment.

Road crossings within the study area were inspected as they offered access to the main tributaries. In addition, the hydraulic structures associated with these crossings are a key concern with the modelling.

3.5 Stormwater Pit and Pipe Data

Council has provided all available data for pit and pipe assets within the study area. Upon review of this data it was found that:

- Some key road crossing culverts in the upper catchment observed during the site inspection have no data available; and
- A significant portion of the pipes within the study area do not have invert levels recorded.

3.6 Floor Level Survey

A total of 162 floor levels have been surveyed for 121 properties within Bomaderry and surrounds, recorded as part of this study by Shoalhaven City Council survey team in March 2014. The location of properties surveyed is shown in **Figure 3-1**.

The floor level survey will be used to determine the extent of overfloor flooding within the study area and associated flood damages.

3.7 Additional Hydraulic Structure and Waterway Survey

Following the site inspection, review of Council's available stormwater pit and pipe data, and the hydraulic structure survey collected as part of the flood study (BMT WBM, 2010), it was found that survey data did not exist for a number of significant culverts and waterways.

While the flood study survey gathered information on the majority of significant road crossings within the study area, a number of smaller culverts were not captured. The location of these culverts is shown in **Figure 3-1**.

Council's survey team was commissioned as part of this study to survey these hydraulic structures including dimensions, invert levels, road crest levels, and photographs.

Review of available ALS datasets, and subsequent site visit, indicated an overland flow channel near Brinawarr Street in Bomaderry with insufficient ground resolution due to dense vegetation. This channel section was surveyed as part of the additional survey and its location is shown in **Figure 3-1**.

4 Consultation

The community consultation undertaken as part of the FRMS has built on the consultation undertaken as part of the Flood Study (Cardno, 2011). The purpose of the Flood Study consultation was to inform the community about the study and gain an understanding of the communities experience with historical flooding in the catchment.

The purpose of the more recent consultation undertaken as part of this FRMS was to inform the community about the study, identify community concerns and attitudes, to gather information from the community on potential options for the floodplain and to develop and maintain community confidence in the study results.

Community consultation has been undertaken in three key phases over the course of the project:

- Resident Brochure Survey
- Community Forums
- Public Exhibition of Draft Flood Study

4.1 Resident Brochure and Survey

Community consultation was undertaken in March 2014. An information brochure and questionnaire were distributed to those property owners within the study area. The brochure and questionnaire are attached in **Appendix A**. The brochure provided an outline of the floodplain risk management process and the objectives of the study. The questionnaire sought information about historical flooding events and flood awareness within the community.

The brochure and questionnaire were delivered to approximately 230 property owners within the catchment area. A summary was also advertised in the local newspaper, informing residents of the study and advising that the survey was being undertaken.

From the distribution, 48 responses were received, representing a return of approximately 21% of direct distribution. This return rate is significantly higher than the typical 10% return rate normally experienced for these types of mail-outs.

The survey was conducted outside of peak holiday times, and was mailed to property owners, so the survey does not take into account the flooding knowledge and experiences of the visitors and tourists that may visit the region.

A summary of the findings of the resident survey are presented below.

4.1.1 Years at Address

One of the questions in the survey related to the length of time that residents had resided at their current address. The majority of respondents were owner occupiers (77% / 38). The remainder of the properties were tenanted, businesses, or other uses.

Of the 48 respondents, 78% (31) have been at their address for over 10 years and 38% (15) have lived at their address for over 20 years. The median time of residence was 15 Years. An overview of the periods of residency is provided in **Figure 4-1**.

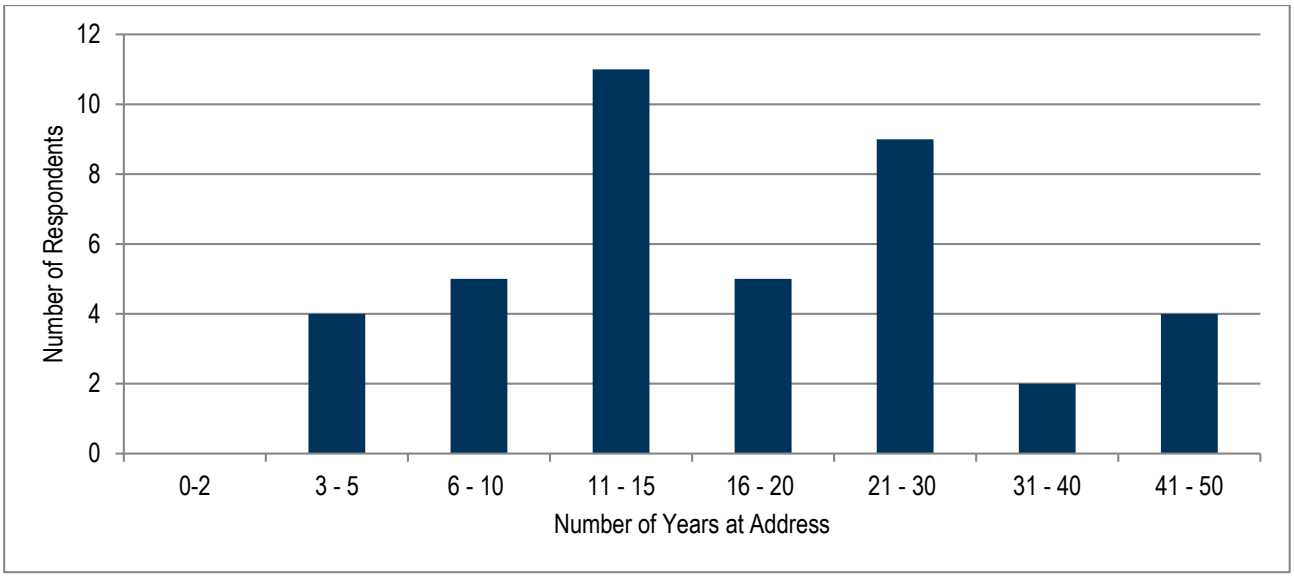

Figure 4-1 Years respondents have been at current address

4.1.2 Community Flood Experiences and Expectations

Residents were asked about their previous flooding experiences, as well as their expected future flooding conditions. Responses to these questions are shown in **Figure 4-2**.

The results show that 37% (17) of respondents have experienced flooding in the past with the majority of these being cases of overground flooding. Only 9% (4) of respondents reported having experienced over floor flooding. No previous flooding experiences were reported by 64% (30) of the respondents.

The results for the expected over-floor future flooding are very similar. In contrast, there was an increase in the expected rate of overground flooding, with an additional 23% (11) of respondents expecting to experience over ground flooding in the future.

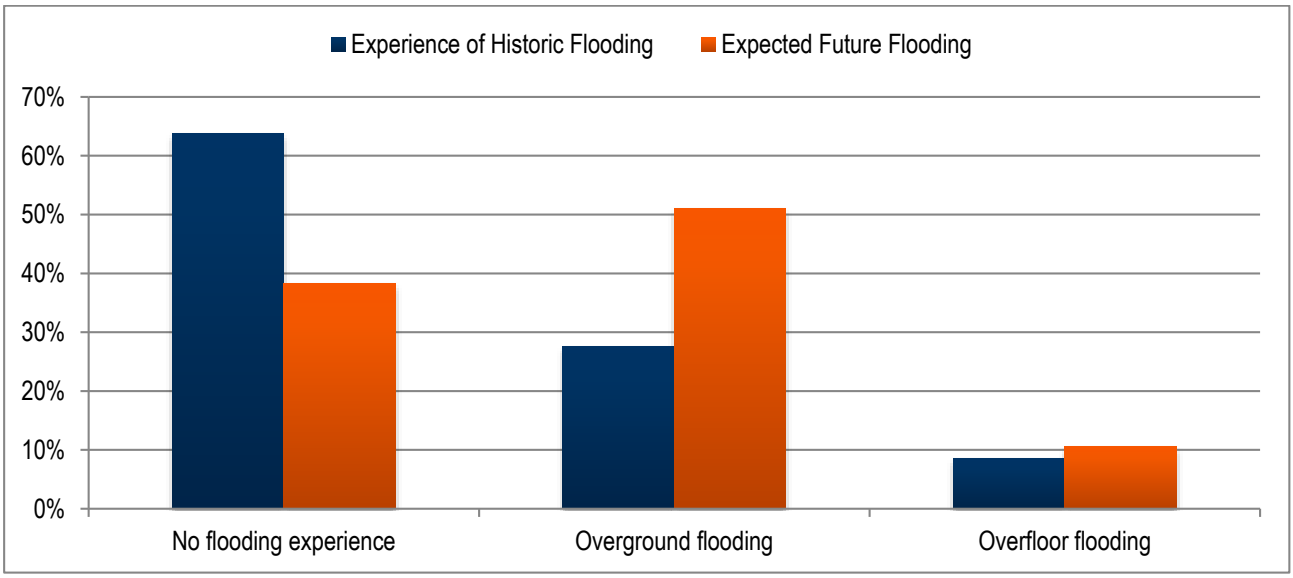

Figure 4-2 Respondent historic and expected flood experiences

4.1.3 Community Preferred Communication Method

Ongoing communication with the community is an important part of the study. Part of the questionnaire asked residents the best method for passing on flood study related information. The results are shown below in **Figure 4-3**.

The most popular method of communication by a large margin was mail outs. Newspaper articles and Council emails were the next most popular. It is noted that these responses may contain some bias, as the data was gathered from a mail out survey.

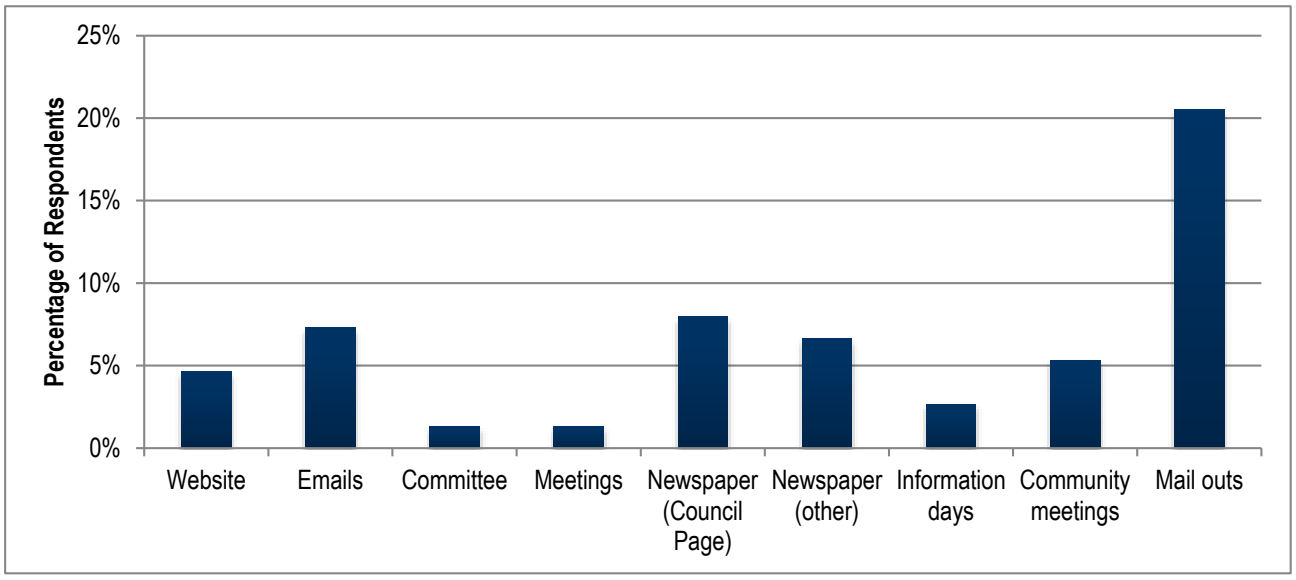

Figure 4-3 **Respondent preferred communication method**

4.1.4 Community Preferred Flood Mitigation Options

The questionnaire asked respondents to give a ranking of 1 – 5 to a variety of potential flood mitigation and management options, with five being the more preferred and one not being preferred. By taking an average of the marks given to each option, the options were ranked based on resident preference. The ranking is shown in **Figure 4-4**.

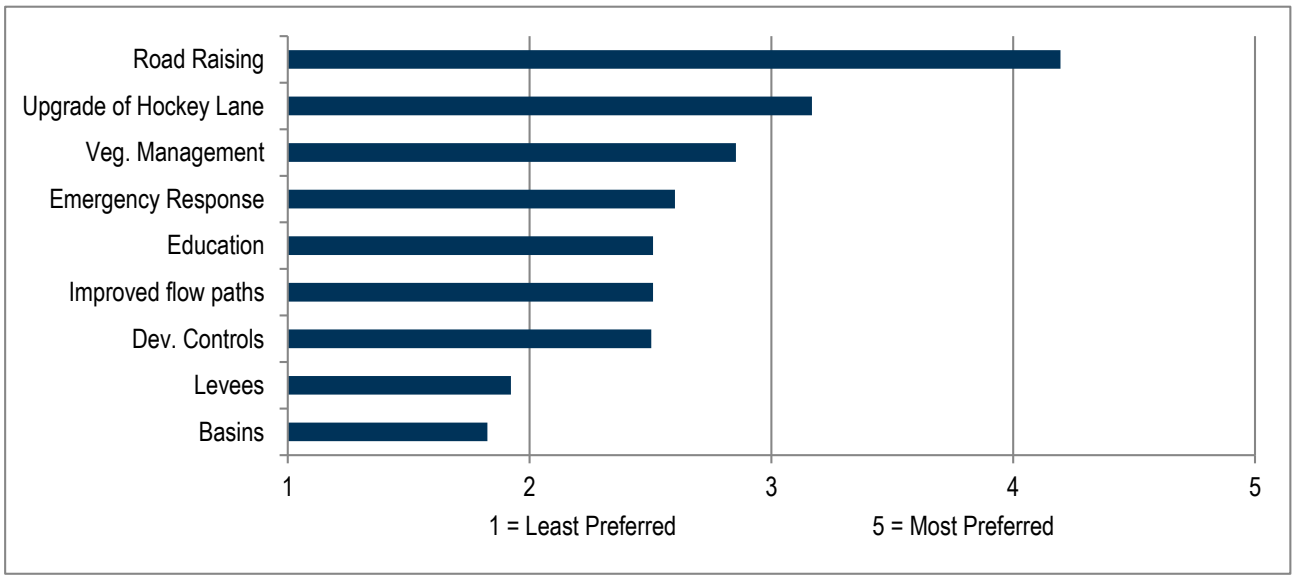

Figure 4-34 **Respondent preferred mitigation options**

The most popular option was road raising. Upgrading Hockey Lane and vegetation management were also popular, as were channel improvements, emergency response improvements and community education.

The structural options, retarding / detention basins diversions and levee banks, were the least preferred.

4.2 Community Forums

As part of the Floodplain Risk Management Study and Plan, two community workshops were held to present the findings of the study to residents, and to gather comments and feedback.

The first workshop was held at Council offices in Nowra on Wednesday, 29 October 2014. The workshop was undertaken to introduce the study to the community, and to hold a preliminary discussion on potential mitigation

The second workshop was held at the Council offices in Nowra on Monday, 23 March 2015. The workshop was undertaken to present to the community the results of mitigation option assessment. The process of incorporating community opinion in the multi-criteria assessment was also discussed to ensure that the ranking appropriately reflected community sentiment.

Key comments and feedback from the community workshops included:

- Low bridges and culverts are often blocked by debris.
- A number of attendees commented on the loss of access along some roads. However, there was agreement that the flooding was typically of short duration and so the impact was minimal.
- There was a discussion on the various flooding mechanisms of the catchment (catchment and elevated Shoalhaven River flooding), and how individual options were capable of protecting the community from each flooding mechanism.

4.2.1 Public Exhibition Period

The public exhibition workshop was held Wednesday 18 November 2015. The public exhibition workshop was the final stage of the community consultation process undertaken throughout the study.

The key discussion points raised at the workshop were:

- That the community were interested in improved communication during flood events;
- That a warning system would be helpful, even if it only provided a short warning time; and,
- A mail-out to residents showing which roads are expected to flood during large events would assist the community in responding safely to large flood events.

5 Existing Flood Behaviour

5.1 Properties with Overfloor Flooding

A detailed assessment of the flood damages and overfloor was undertaken as part of this study. The results are summarised below in **Table 5.1**. Single storey dwellings have been highlighted, as these properties have limited opportunity for vertical evacuation. It is noted that almost all flood affected residential properties are single storey.

Table 5-1 Properties with Overfloor Flooding

Flood Event (AEP)	Residential Properties		Commercial Properties	Industrial Properties
	Single Storey	Total Residential		
PMF	41	47	20	4
0.5%	14	14	8	1
1%	12	12	8	1
2%	11	11	6	0
5%	8	8	5	0
10%	8	8	3	0
20%	5	7	2	0

5.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters (refer **Appendix B**), does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include the:

- Size of the flood,
- Effective warning time,
- Flood readiness,
- Rate of rise of floodwaters,
- Duration of flooding,
- Ease of evacuation,
- Effective flood access.

In the Bomaderry Creek catchment many of the above factors are not applicable in terms of affecting hazard identification. However, to provide a thorough assessment process, all of the above factors have been considered in this report, and are discussed in the following sections.

True flood hazard maps are provided for the 1% AEP event and the PMF event in **Figure 5-1** and **Figure 5-2**.

5.2.1 Size of Flood

The size of a flood and the damage it causes varies from one event to another. For the purposes of this study, flood hazard has been mapped for the PMF event and the 1% AEP event.

5.2.2 Effective Warning Time

The effective warning time is the actual time available prior to a flood during which people may undertake appropriate mitigation actions (such as lift or transport belongings and/or evacuation). The effective warning time is always less than the total warning time available to emergency service agencies. This is related to the time needed to pass the flood warning to people located in the floodplain and for them to begin effective property protection and/or evacuation procedures.

The critical duration storm for the study area has three broad regions. The 2 hour event is critical in the upper catchment, the 6 hour event is critical upstream of and through the gorge, and the 12 hour event is critical in the downstream catchment. However, as discussed in **Section 11**, the shorter duration, non-critical storms in the middle and lower catchment still result in significant flooding. As such, the adoption of the 2 hour event to assess warning times was adopted across the whole catchment.

As such, the peak of the flow generally occurs at various locations within the catchment within 1 hour from the start of the rainfall. Therefore, there is little to no warning time throughout the study area.

However, it is noted that all areas within the study area are exposed to similar flood response times, and therefore it can be considered that no area within the catchment is any more at risk than another.

5.2.3 Flood Readiness

Flood readiness or preparedness can greatly influence the time taken by flood-affected residents and visitors to respond in an efficient pattern to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective.

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. Flood events have occurred in the study area in 2008 and 1990. Based on the responses from the resident survey (refer **Section 4**) approximately 65% of respondents were living in the study area at the time of the 2008 flood event.

Given the recent nature of flooding issues within the catchment, and the strong level of flood awareness demonstrated in the returned questionnaires, the flood awareness within the catchment is taken to be relatively high.

As there is no reason to suggest that a particular part of the catchment is likely to be any more prepared for a flood than another, flood readiness has not been considered in the preparation of hazard extents.

5.2.4 Rate of Rise of Floodwaters

The rate of rise of floodwater affects the magnitude of the consequences of a flood event. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. The rate of rise of floodwaters is affected by catchment and floodplain characteristics.

A rate of rise of 0.5 m/hr has been adopted as indicative of high hazard. However, it is important to note that if an area has a rate of rise greater than 0.5 m/hr this does not automatically result in the area being categorised as high hazard. For instance, if the rate of rise is very high but flood depths only reach 0.2 m, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in defining areas affected by true high hazard.

A flood depth of 0.5 m was selected as the trigger depth for high hazard where the rate of rise was equal to or greater than 0.5 m/hr. A 0.5 m flood depth is well within the range of available information as to when vehicles become unstable even with no flow velocity (NSW Government, 2005).

In the study area, there are no properties with flow behaviour within these constraints for the 1% AEP event which are not already selected by the provisional high hazard criteria (**Section 5.2.5**).

5.2.5 Depth and Velocity of Flood Waters

As outlined above, provisional hazard mapping is determined from a relationship between velocity and depth. The provisional hazard mapping for the PMF and 1% AEP events were undertaken in line with the methodology set out in the Floodplain Development Manual (2005). This provisional hazard mapping has been used as the base to determine true flood hazard.

5.2.6 Duration of Flooding

The duration of flooding or length of time a community, town or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Flooding durations are generally less than a couple of hours, even in the longer duration events. Those properties affected by longer periods of inundation are already selected by the provisional high hazard criteria.

5.2.7 Ease of evacuation

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult due to a number of factors, including:

- The number of people requiring assistance,
- Mobility of those being evacuated,
- Time of day, and
- Lack of suitable evacuation equipment.

The duration of flooding in the catchment is relatively short, as noted above. Therefore, evacuation issues for the majority of the catchment are not considered to be an issue. The exception to this is for properties that experience overfloor flooding in the 100 year ARI and PMF events that do not have a second floor. This allows for limited opportunities for residents to escape the inundation within their properties. There are a total of 14 of these residential properties in the 1% AEP event and 41 in the PMF event.

These have not been included on the figures at this stage due to privacy reasons.

5.2.8 Effective Flood Access

The availability of effective access routes to or from flood affected areas can directly influence personal safety and potential damage reduction measures. Effective access implies that there is an exit route available that remains trafficable for sufficient time to evacuate people and possessions.

For flooding experienced in the Bomaderry catchment, evacuation is generally not recommended (refer **Section 11**). As such, effective flood access is not considered in the True Hazard mapping.

5.3 Flood Emergency Response Planning Classification of Communities

Flood emergency response classification provides an indication of the relative vulnerability of the community and provides the SES with valuable information in managing emergency responses to flood events.

The classifications are shown in **Figure 5-5**.

The classification has been undertaken in accordance with the floodplain risk management guideline 'Flood Emergency Response Planning Classification of Communities' (DECC 2007).

The Flood Emergency Response Planning Classifications are:

- High Flood Island – region not inundated by the PMF, but which is surrounded by floodwaters
- Low Flood Island – region is first surrounded, and then impacted by flooding in the PMF
- High Trapped Perimeter – region is not inundated by the PMF but access may be restricted
- Low Trapped Perimeter – region is first isolated, and then impacted by flooding in the PMF
- Overland Escape Route – region and access impacted by PMF. People can escape rising flood waters by moving overland to higher ground
- Rising Road Access – regions where access roads rise steadily to flood free ground and allow egress as flood waters rise
- Indirectly Affected Areas – regions that are outside the flood limit that retain access throughout the event

6 Current Economic Impact of Flooding

The economic impact of flooding can be defined by what is commonly referred to as flood damages. Flood damages are categorised as various types; these types are summarised in **Table 6-1**.

Table 6-1 Types of Flood Damages

Type	Description
Direct	Building contents (internal)
	Structural damage (building repair)
	External items (vehicles, contents of sheds, etc.)
Indirect	Clean-up (immediate, removal of debris)
	Financial (loss of revenue, extra expenditure)
	Opportunity (non-provision of public service)
Intangible	Social (increased levels of insecurity, depression, stress)
	Inconvenience (general difficulties in post-flood stage)

The direct damage costs, as indicated in **Table 6-1**, are just one component of the entire cost of a flood event. There are also indirect costs. Together, direct and indirect costs are referred to as tangible costs. In addition to tangible costs, there are intangible costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDamage or ANUFLOOD, or via more generic methods using spread-sheets. For the purposes of this project, generic spread-sheets have been used based on a combination of OEH residential damage curves and FLDamage.

6.2 Damage Analysis

A flood damage assessment for the existing catchment conditions has been completed as part of this study. The assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and as such, damage curves from other catchments, and available research in the area, is used as a substitute.

OEH has conducted research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

The damage analysis methodology is provided in **Appendix B**.

6.3 Results

The results from the damage analysis are shown in **Table 6-2**. Based on the analysis described above, the average annual damage for the Bomaderry study area under existing conditions is $166,142.

Table 6-2 Bomaderry Creek Existing Damage Analysis Results

	Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with overground flooding	Total Damages ($)
PMF					
Residential	41	1.04	5.71	64	$ 3,658,963
Commercial	20	0.81	1.41	16	$ 3,283,614
Industrial	16	1.24	2.98	4	$ 616,564
PMF Total	77			84	$ 7,559,141
0.5% AEP					
Residential	10	1.06	1.24	26	$ 937,236
Commercial	8	0.77	1.68	12	$ 906,832
Industrial	1	0.24	0.18	2	$ 268,303
0.5% AEP Total	19			40	$ 2,112,372
1% AEP					
Residential	10	0.57	1.01	21	$ 775,092
Commercial	6	0.58	1.58	12	$ 672,768
Industrial	0	0.09	0.09	2	$ 204,758
1% AEP Total	16			35	$ 1,652,618
2% AEP					
Residential	10	0.38	0.82	19	$ 738,086
Commercial	5	0.57	1.47	12	$ 551,864
Industrial	0			1	$ -
2% AEP Total	15			32	$ 1,289,950
5% AEP					
Residential	7	0.34	0.74	15	$ 531,490
Commercial	4	0.56	1.37	10	$ 428,458
Industrial	0			0	$ -
5% AEP	11			25	$ 959,948
10% AEP					
Residential	5	0.22	0.50	13	$ 463,710
Commercial	3	0.53	0.98	9	$ 74,292
Industrial	0			0	$ -
10% AEP Total	8			22	$ 538,003
20% AEP					
Residential	3	0.22	0.39	12	$ 340,788
Commercial	2	0.45	0.63	8	$ 54,033
Industrial	0			0	$ -
20% AEP Total	5			20	$ 394,821

7 Social Issues

Knowledge of the demographic character of an area assists in the preparation and evaluation of floodplain management options that are appropriate for the local community. For example, the data is relevant in the consideration of emergency response or evacuation procedures (e.g. information may need to be presented in a range of languages and special arrangements may need to be made for less mobile members of the community).

The Bomaderry Creek catchment includes the suburbs of North Nowra, Bomaderry, Cambewarra, Tapitallee and Bangalee. Demographic data for these suburbs was sourced primarily from the Australian Bureau of Statistics (ABS) 2011 Census for the North Nowra Bomaderry Statistical Area (Level 2).

The demographic data for the Bomaderry-North Nowra area showed that:

- Approximately half the people living in the North Nowra-Bomaderry area are aged between 15-54 years (refer **Table 7-1**). This suggests that the community is likely to be generally able-bodied and able to evacuate.
- English was the only language spoken in approximately 90% of homes in the North Nowra-Bomaderry area. Approximately 3% of the population indicated they spoke another language at home (with the remainder as "not stated"). The most common languages spoken at home other than English are Filipino, German, Italian and Spanish. This suggests that language barriers (e.g. during evacuation, or for flood education), are unlikely to occur for the vast majority of the population (refer **Table 7-2**).
- Averaged across all suburbs in the North Nowra-Bomaderry area, the median house price is $447,813 and the median unit price is $211,250 (refer **Table 7-3**). This is relevant to the assessment of potential economic damages (including average annual damage) incurred during a flood event. For comparison, the median house price for NSW is $520,000, and unit price is $540,000 (APM, 2014).

Table 7-1 Age Structure of Nowra-Bomaderry

Age Group (Years)	Persons in Nowra-Bomaderry	% of total persons in Nowra-Bomaderry	% of total persons in NSW
0-14 years	3,010	19.1	12.9
15-24 years	2,096	13.3	12.7
25-34 years	1,591	10.1	13.3
35-44 years	1,859	11.8	13.9
45-54 years	2,174	13.8	14
55-64 years	2,143	13.6	12.9
65-74 years	1,560	9.9	10
75-84 years	977	6.2	10.3
85 years and over	347	2.2	10.3
TOTAL	15,757	100	100

Table 7-2 Languages Spoken at Home in Nowra-Bomaderry (ABS, 2011)

Languages Spoken at Home	Number of People	% of total number of people	% of total homes in NSW
English Only	29,557	89.9	72.5
Filipino/Tagalog	101	0.3	0.7
German	90	0.3	0.3
Italian	70	0.2	1.3
Spanish	64	0.2	0.8
Cantonese	58	0.2	2.0
Greek	50	0.2	1.3
French	45	0.1	0.2
Dutch	45	0.1	0.1
Mandarin	37	0.1	1.5

Table 7-3 Dwelling Structure in Nowra-Bomaderry (ABS, 2011)

Suburb	Median House Price	Median Unit Price
North Nowra	$323,750	$227,500
Bomaderry	$296,500	$195,000
Cambewarra	No data	No data
Tapitallee	$615,000	No data
Bangalee	$556,000	No data
Average	**$447,813**	**$211,250**

8 Environmental Issues

8.1 Topography and Soils

The North Nowra-Bomaderry area consists of relatively flat areas which form the floodplain of the Shoalhaven River and its tributaries, such as Bomaderry Creek. To the north-west, the Cambewarra Range is a prominent feature that forms part of the Great Eastern Escarpment.

A review of the Soil Landscape Map of Kiama (Scale 1:100,000) indicates that the Bomaderry-North Nowra area is located on several soil landscape groups with some limitations to development. Key soil limitations are outlined below and these may need to be considered during floodplain risk management options development and design:

- Alluvial Landscape (Shoalhaven) – Moderate erosion hazard, waterlogging and permanently high water table;
- Erosional Landscape (Coolongatta) – Erosion hazard for non-concentrated flows is extreme. When ground cover is removed, these soils can be highly dispersable, and dams will fail;
- Transferral Landscape (Nowra) – Generally minor limitations to development although erosion hazard may be moderate to high; and
- Transferral Landscape (Wattamolla Road) – Erosion hazard for non-concentrated flows is extreme, development on steep slopes has particularly high limitations.

In addition to the above limitations, acid sulphate soil risk is present in the area according to Council's mapping (SCC, 2014). Acid sulfate soil is the common name for soils that contain metal sulfides. The presence of these soils is to be expected due to the generally low-lying topography of the floodplain areas. In an undisturbed and waterlogged state, acid sulphate soils generally pose no or low risk. However, when disturbed, an oxidation reation occurs to produce sulfuric acid which can negatively impact on the surrounding environment in a number of ways.

According to the mapping, the majority of the area is subject to Class 5 acid sulfate soils, which is the lowest risk class. However, it is recommended that local soil investigations be undertaken should larger structural management options be proposed.

8.2 Contaminated Land and Licensed Discharges

Contaminated land refers to any land which contains a substance at such concentrations as to present a risk of harm to human or environmental health, as defined in the Contaminated Land Management Act 1997. Contamination issues need to be considered at the flood management options development and design stage.

The Office of Environment and Heritage (OEH) regulates contaminated land sites and maintains a record of written notices issued by the Environment Protection Authority (EPA) in relation to the investigation or remediation of site contamination. Searches were undertaken of the online OEH Contaminated Land Record and the List of NSW Contaminated Sites notified to the EPA, on 24 September 2014. The following premises were listed:

- Bomaderry Works Depot - 10 McIntyre Way, Bomaderry
- Caltex Service Station - 246 Princes Highway, Bomaderry
- Caltex Service Station - 341 Princes Hwy, Bomaderry
- Former Shell Depot - 44 Railway Street, Bomaderry
- Mobil Depot - 7 Victa Way, Bomaderry
- State Rail Authority Land - Lot 2 Meroo St, Bomaderry

It is important to note that there are limitations to the registers and sites may be contaminated that are not listed.

A search of the *Protection of the Environment Operations Act 1997* (PoEO Act) licensed premises public register on 24 September 2014identified several premises within the catchment that have pollution discharge licences:

- Australian Co-Operative Foods Limited – 220 Bolong Road, Bomaderry, NSW 2541
- BOC Limited – Lot 241 Bolong Road, Bomaderry, NSW 2541
- Cleary Bros (Bombo) Pty Ltd – Lot 3 Bolong Road, Bomaderry, NSW 2541
- Paper Australia Pty Ltd – 340 Bolong Road, Bomaderry, NSW 2541
- Shoalhaven City Council – Railway Street, Bomaderry, NSW 2541
- Shoalhaven Starches Pty Ltd – 160 Bolong Road, Bomaderry, NSW 2541

8.3 Flora and Fauna

Much of the land associated with the Shoalhaven River Floodplain was cleared of its native vegetation in order to support intensive agricultural use such as cropping, vegetable growing and dairying (Shoalhaven City Council, 2005). A large portion of the study area comprises cleared agricultural land and residential areas. In general, only relatively small areas of remnant vegetation remain, and conservation of these small remnants is important.

A review of OEH (2013) vegetation mapping indicates that several Endangered Ecological Communities (EECs) are present in the catchment, namely:

- Bangalay Sand Forest in the Sydney Basin and South East Corner Bioregions;
- Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions;
- Illawarra Lowlands Grassy Woodland in the Sydney Basin Bioregion;
- Illawarra Subtropical Rainforest in the Sydney Basin Bioregion; and
- Swamp oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner bioregions.

The locations of these are presented in **Figure 8-1**. In addition, a search of the Australian Department of the Environment's Protected Matters Search Tool (DoE, 2014) indicated that *Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion* may occur in the study area.

The Bomaderry Creek Regional Park is located in the catchment, and is protected under the NSW *National Parks and Wildlife Act 1974*. SEPP 14 wetlands do not occur within the study area (the nearest being approximately 5km away).

A search of the various OEH (2014a) databases and datasets was undertaken to assess relevant biodiversity features within the catchment and surrounding areas. A total of 177 threatened flora sightings have been recorded in the catchment and surrounding areas, consisting of 7 species, including *Zieria baeuerlenii* (Bomaderry Zieria), *Eucalyptus langleyi* (Albatross Mallee) and *Solanum celatum*. A total of 582 threatened fauna sightings have been recorded in the catchment and surrounding areas, consisting of 47 species, including the Giant Burrowing Frog, Spotted-tailed Quoll, Square-tailed Kite and Yellow-bellied Glider. Records for both threatened flora and fauna are scattered across the catchment, with clusters tending to form in more vegetated areas (refer **Figure 8-1**). It is noted that records are only approximate and that data has been generalised meaning that several records may exist at the one location.

The large number of threatened communities and species that occurs or has the potential to occur within the catchment areas should be considered in the development and implementation of any proposed flood modification options or flood protection works. Species type, abundance and distribution should be considered, and further investigation may be required if impacts are anticipated.

8.4 Heritage

8.4.1 Aboriginal Heritage

'Traditional Custodians' is the term to describe the original Aboriginal or Torres Strait Islander people who inhabited an area. Traditional custodians today are descendants of the original inhabitants and have ongoing spiritual and cultural ties to the land and waterways where their ancestors lived. The traditional custodians of the land in the Bomaderry Creek Catchment are the Wodi Wodi people (north of the Shoalhaven River). Along with the Wandi Wandian people (south of the Shoalhaven River) these peoples form part of the wider Aboriginal Nation known as the Yuin Nation (DLG, n.d.).

The Bomaderrry Creek catchment is located in the Nowra Local Aboriginal Land Council (NLALC). A preliminary investigation of Aboriginal heritage was undertaken by searching the online Aboriginal Heritage Information Management System (AHIMS) database in September 2014 for known or potential Aboriginal archaeological or cultural heritage sites within or surrounding the study area. There were 75 Aboriginal artefacts and sites listed within the catchment, which is indicative of the substantial Aboriginal presence in this area.

All Aboriginal sites are protected under the *National Parks and Wildlife Act 1974* (NPW Act) and therefore any management options that will impact upon Aboriginal sites must include this in their design. Known Aboriginal sites should be left undisturbed if possible, however if a management option requires their destruction, an Aboriginal Heritage Impact Permit (AHIP) must be sought from OEH. Under the NPW Act it is a requirement that any developments show "due diligence" with regard to Aboriginal heritage in the area

8.4.2 Non-Indigenous Heritage

Non-Indigenous heritage can be classified into three statutory listing classifications based on significance, namely Commonwealth, State and local. The significance of an item is a status determined by assessing its historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic value.

A desktop review of non-Indigenous heritage was undertaken for the catchment. Searches were undertaken of the following databases:

- Australian Heritage Database (incorporates World Heritage List; National Heritage List; Commonwealth Heritage List);
- State Heritage Register;
- NSW Heritage Office – State Heritage Register; and

Within the catchment, no Commonwealth heritage items were recorded.

Two State heritage items were identified as being listed under the NSW *Heritage Act 1977*:

- Bomaderry Aboriginal Childrens Home - 59 Belinda Street, Bomaderry
- Bomaderry Railway Station and Yard - Illawarra Railway, Bomaderry

An additional two items were also identified as being listed by State Agencies under Section 170 of the Act:

- Abernethys Creek Bridge – Prices Highway, Bomaderry
- Bomaderry (Edwards Ave) Overbridge – Edwards Avenue, Bomaderry

There were 22 items of local significance noted to exist in the catchments. The provisions that must be followed in relation to heritage items in the catchment areas are outlined under Part 5, Clause 5.10 of the Shoalhaven LEP 2014.

Depending on the nature of any structural floodplain risk management works proposed for the catchment, a more detailed heritage assessment may be required to assess potential impacts on these features.

Heritage items and areas are shown in **Figure 8-1**.

9 Policy and Planning Review

The Bomaderry Creek catchment is located in the Shoalhaven Local Government Area (LGA) where development is controlled through the Shoalhaven Local Environment Plan (LEP) and various Development Control Plans (DCPs). The LEP is a planning instrument which designates land use and development in the LGA, while DCPs regulates development with specific guidelines and parameters.

9.1 Shoalhaven Local Environment Plan

Due to the Environmental Planning and Assessment Amendment Act 2008 and Environmental Planning and Assessment Amendment Regulation 2009, the standardisation of all NSW Local Authority LEPs is in process. Significant changes within the LGA and in the NSW Planning Reforms implemented by the NSW Government have required the LEP to be updated.

Shoalhaven Council has prepared the Shoalhaven LEP 2014. The LEP incorporates a section on flood affected land. The objectives include the following:

- To maintain the existing flood regime and flow conveyance capacity;
- To enable safe occupation and evacuation of land subject to flooding;
- To avoid significant adverse impacts on flood behaviour;
- To avoid significant effects on the environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and
- To limit uses to those compatible with flow conveyance function and flood hazard.

The land to which this clause applies is the 1% AEP flood extent, plus a 0.5m freeboard.

9.2 Current Land Use Zoning

The zoning of the study area is shown in **Figure 9-1**, and these zones are described in **Table 9-1** as per the Standard LEP Instrument (NSW Government, 2013).

It is noted that the Nowra Bomaderry Structure Plan 2009 results in two main changes in the Draft 2013 LEP as follows:

- A large special purpose corridor has been set aside on the upstream side of the Bomaderry gorge for the proposed footprint of the Princes Highway bypass of Nowra. The existing land use within the corridor is rural; and
- There is a large area of residential land use immediately to the west of this road corridor on the northern side of Bomaderry Creek that is currently rural land use. On the eastern side of the road corridor there are areas of residential, special purpose, and business land use in areas with a rural existing land use. These areas have been identified within the Nowra Bomaderry Structure Plan 2009 as future development area.

Table 9-1 Bomaderry Catchment Land Uses (based on NSW Government, 2013)

Zone	Land Use	Description
Business Zones	B1 Neighbourhood Centre	▪ To provide a range of small-scale retail, business and community uses that serve the needs of people who live or work in the surrounding neighbourhood. ▪ To ensure that development is of a scale that is compatible with the character of the surrounding residential environment.
	B4 Mixed Zone	▪ To provide a mixture of compatible land uses. ▪ To integrate suitable business, office, residential, retail and other development in accessible locations so as to maximise public transport patronage and encourage walking and cycling.
	B5 Business Development	▪ To enable a mix of business and warehouse uses, and bulky goods premises that require a large floor area, in locations that are close to, and that support the viability of, centres. ▪ To allow a diversity of activities that do not significantly conflict with the operation of existing or proposed development.
	B7 Business Park	▪ To provide a range of office and light industrial uses. ▪ To encourage employment opportunities. ▪ To enable other land uses that provide facilities or services to meet the day to day needs of workers in the area.
Environmental Protection	E1 National Parks and Nature Reserves	▪ To enable the management and appropriate use of land that is reserved under the National Parks and Wildlife Act 1974 or that is acquired under Part 11 of that Act. ▪ To enable uses authorised under the National Parks and Wildlife Act 1974. ▪ To identify land that is to be reserved under the National Parks and Wildlife Act 1974 and to protect the environmental significance of that land.
	E2 Environmental Conservation	▪ To protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values and to prevent development that could destroy, damage or otherwise adversely affect those values ▪ To protect water quality, natural water systems, wetlands rainforest and habitat linkages
	E3 Environmental Management	▪ Generally intended to be applied to land that has special ecological, scientific, cultural or aesthetic attributes, or land highly constrained by geotechnical or other hazards. ▪ This zone can also be suitable as a transition between areas of high conservation value and other more intensive land uses such as rural or residential.

Zone	Land Use	Description
	E4 Environmental Living	▪ To provide for low-impact residential development in areas with special ecological, scientific or aesthetic values. ▪ To ensure that residential development does not have an adverse effect on those values.
Industrial	IN1 General Industrial	▪ To provide a wide range of industrial and warehouse land uses. ▪ To encourage employment opportunities. ▪ To minimise any adverse effect of industry on other land uses. ▪ To support and protect industrial land for industrial uses. ▪ To allow a diversity of activities that do not significantly conflict with the operation of existing or proposed development. ▪ To enable other land uses that provide facilities or services to meet the day to day needs of workers in the area.
	IN2 Light Industrial	▪ To provide a wide range of light industrial, warehouse and related land uses. ▪ To encourage employment opportunities and to support the viability of centres. ▪ To minimise any adverse effect of industry on other land uses. ▪ To enable other land uses that provide facilities or services to meet the day to day needs of workers in the area. ▪ To support and protect industrial land for industrial uses. ▪ To allow a diversity of activities that do not significantly conflict with the operation of existing or proposed development.
Residential	R1 General Residential	▪ To provide for a variety of residential housing types and densities, including dwelling houses, multi-dwelling housing, residential flat buildings, boarding houses and seniors housing ▪ Also to provide facilities or services to residents, including neighbourhood shops and child care centres
	R2 Low Density Residential	▪ Land where primarily low density housing is to be established or already exist. ▪ Also to encourage the provision of facilities or services that meet the day-to-day needs of residents
Recreation	RE1 Public Recreation	▪ Generally intended for a wide range of public recreational areas and activities including local and regional parks and open space. For example, recreation facilities

Zone	Land Use	Description
Rural	RU1 Primary Production	▪ To encourage sustainable primary industry production by maintaining and enhancing the natural resource base. ▪ To encourage diversity in primary industry enterprises and systems appropriate for the area. ▪ To minimise the fragmentation and alienation of resource lands. ▪ To minimise conflict between land uses within this zone and land uses within adjoining zones. ▪ To conserve and maintain productive prime crop and pasture land. ▪ To conserve and maintain the economic potential of the land within this zone for extractive industries.
	RU2 Rural Landscape	▪ Rural land with general landscape values or that has reduced agricultural capability but which is suitable for grazing and other forms of extensive agriculture.
	RU4 Rural Small Holding	▪ To enable sustainable primary industry and other compatible land uses. ▪ To encourage and promote diversity and employment opportunities in relation to primary industry enterprises, particularly those that require smaller lots or that are more intensive in nature. ▪ To minimise conflict between land uses within this zone and land uses within adjoining zones.
Special Purpose	SP1 Special Activities	▪ To provide for special land uses that are not provided for in other zones. ▪ To provide for sites with special natural characteristics that are not provided for in other zones. ▪ To facilitate development that is in keeping with the special characteristics of the site or its existing or intended special use, and that minimises any adverse impacts on surrounding land.
	SP2 Infrastructure	▪ Infrastructure land that is highly unlikely to be used for a different purpose in the future, for example cemeteries and major sewage treatment plants ▪ Also appropriate for major state infrastructure or strategic sites such as major hospitals and large campus universities/TAFEs.

9.2.2 Flood Affected Land Use Zones

A number of land uses are affected by flooding in the 1% AEP event and the PMF event, as shown in **Figure 9-2**.

These zones, in order of largest area of inundation, are listed below:

- RU1 – Primary Production 285.1 ha
- RE1 – Public Recreation 45.1 ha
- E2 – Environmental Conservation 32.2 ha
- SP2 – Infrastructure 26.9 ha
- RU4 – Rural Small Holding 10.4 ha
- R1 – General Residential 5.5 ha
- R2 – Low Density Residential 4.6 ha
- B1 – Neighbourhood Centre 2.8 ha
- B4 – Business Park 2.8 ha
- IN2 – Light Industrial 2.6 ha
- E1 – National Parks 2.6 ha
- E3 – Environmental Management 2.3 ha
- IN1 – General Industrial 0.3 ha

9.3 Development Control Plans

Development Control Plans (DCPs) are prepared by Council and apply to specific types of development or areas of land and provide detailed development guidelines and controls. DCP's outline specific controls and parameters that apply to development proposals in Shoalhaven.

In accordance with changes to the planning system in NSW, Council has prepared a single DCP for the LGA. The new DCP, DCP2014, was adopted by Council on 14 October 2014 and came into effect on 22 October 2014.

The following sections of the DCP have relevance to floodplain management.

Chapter G9 – Development on Flood Prone Land

This chapter provides controls for development on flood prone land.

The chapter offers a consolidated document for the relevant flood planning controls, and applicable flood policies in the Shoalhaven LGA. The chapter provides context of all flood planning requirements in the Shoalhaven LGA. An overview of the flood planning controls and policies applicable to the LGA is included, as well as the requirements of management of flood prone land, technical reporting requirements and flood proofing guidelines.

Additionally, this chapter includes site specific locations for which a Floodplain Risk Management Plan has been prepared.

The chapter states that development of flood prone land within the Shoalhaven LGA area is governed by this chapter.

The lower portion of the Bomaderry Creek floodplain lies within the Lower Shoalhaven River floodplain and as such some area specific controls apply as per Schedule 5. These include:

- Minimisation of flood impacts associated with proposed industrial development at Bomaderry;
- The assessment of the impact of fill to be undertaken based on 2050 flood behaviour to reflect current climate change scenarios.
- A merits based approach to assessing development applications above the existing FPL but below the 2050 and/or 2100 FPLs; and,

Chapter G11 – Subdivision

The chapter covers subdivisions within the Shoalhaven LGA.

The chapter states that flood planning levels of subdivisions are to be 0.5m above the 1% AEP flood level for residential developments in the floodway and 0.3m above the 1% AEP flood level in flood storage and flood fringe areas.

The chapter also states that a flood assessment should be undertaken for properties within the floodplain. It is also recommends reference to the NSW Floodplain Development Manual 2001 be updated to the current NSW Floodplain Development Manual 2005.

Chapter G12 – Dwelling Houses, Rural Worker's Dwellings, Additions & Ancillary

As part of the chapter, the following performance criteria are set out for the construction of buildings on flood prone land:

- Dwellings and ancillary structures do not adversely impede the flow of floodwaters on flood liable land;
- The floor level of habitable rooms in a dwelling are above the relevant flood criteria including a suitable free board (i.e. flood planning levels);
- The design of all buildings and construction elements must resist the impacts of flood waters;
- Access is provided to the dwelling during time of localised flooding to assist evacuation; and
- Site works and building structures meet the standards of Councils Flood Policy, and relevant NSW Floodplain Development Manual guidelines. Applicants should also refer to DCP 106.

9.4 Recommended Flood Controls

As a result of the investigation into planning controls, a number of recommendations were proposed to increase the effectiveness of the planning controls. The existing controls are set out in *Schedule 6 – Flood Related Development Controls –DCP2014 G9* which applies to all areas in the Shoalhaven LGA without an implemented Flood Management Plan. Site specific conditions are in addition to, or override, the conditions within DCP2014 were relevant.

Recommended changes to existing controls are summarised in **Table 9-2**.

Table 9-2 Review of Existing Flood Planning Controls

Existing Control	Comments
Floor Levels	
For the majority of developments, floor planning levels are set at 1% AEP flood level + 0.5m freeboard Variations on this overarching control are for minor developments where the above generic floor planning level is preferred, however, if this cannot be achieved the existing habitable floor level or higher is acceptable Additionally, carparks in High Hazard Flood Storage or Flood Fringe areas need to be high enough to ensure a velocity – depth of less than 0.3 m^2/s for a 1% AEP Critical infrastructure which lie in Low Hazard Floodway / Flood Storage / Flood Fringe areas only have to set floor levels up to 5% AEP flood levels	The existing flood planning levels seem appropriate for the catchment, with the exception of car park freeboard. Entrance to carparks should be no lower than 100 year ARI flood level plus 0.5m. All above ground car parks should be designed taking into account vehicle stability up to the PMF event. Vehicle stability can be assessed in accordance with the NSW Floodplain Development Manual (2005) Three options are available: ▪ The floor planning level of the car park is sufficient to prevent the instability of vehicles due to flooding; ▪ The car park is flood proofed to prevent the instability of vehicles due to flooding; and ▪ Bollards are provided to prevent cars being swept away.
Structural Soundness	
Depending on the land use category the building must be able to withstand forces of floodwaters including debris and buoyancy forces up to the PMF, 0.2% AEP or 1% AEP. Most land use categories are also required to show that the structure would not become floating debris during a 1% AEP flooding scenario. Control Number 4. Certification of building foundations by a chartered geotechnical practitioner is required in some circumstances.	The additional control (no. 4) seems to contradict the first three controls relating to the building being able to withstand forces of floodwaters for the 1% AEP or greater events. It is recommended that this control should either be clarified or removed.

Existing Control	Comments
Hydraulic Impact	
Flood impact assessments (for impacts up to the PMF) are required for all developments likely to have a flood impact (except 'Minor Developments') within High Hazard areas. However, no flood impact assessment is required if the building is raised on piers allowing free flow for a 1% AEP flood event.	Depending on the location and the flood behaviour of the proposed works, a structure raised on piers above the 1% AEP flood event may still have impacts associated with events greater than the 1% AEP event. It may be more appropriate to require that in order to demonstrate no adverse effect on flood behavior; a flood impact assessment is required unless a replacement of the exact footprint is proposed. Developments are not to increase the likelihood of flood damage to any other property. In addition, Council may consider reviewing the adoption of the PMF for flood impact assessments. This is a fairly onerous requirement when compared to other Council controls in NSW. The adoption of the 1% AEP as the upper limit for impact assessments may be more suitable.
Flood Evacuation Plan	
All residential and commercial developments (including minor development) within the high hazard areas is required to have a flood evacuation plan that ensures the timely, orderly and safe evacuation of people from the area and that it would not add significant cost and disruption to the community or the SES. A flood evacuation plan is also required for carparks within the flood planning area.	Evacuation plans should also be prepared for properties that experience long duration flooding.

Existing Control	Comments
Management and Design	
Special provisions apply to certain uses regarding storage of hazardous and valuable goods above the 1% AEP Flood Level, bunding to the FPL around hazardous chemical storage areas and animal refuge provisions above the 1% AEP Flood Level.	Council may want to consider increasing the design level for the storage of hazardous and valuable goods and animal refuge to the flood planning level (1% AEP + 0.5m). This would provide consistency with Councils other controls.

10 Flood Planning Level

10.1 Background

The Flood Planning Level (FPL) for the majority of areas across New South Wales has traditionally been based on the 1% AEP flood level plus a freeboard. The freeboard is generally set between 0.3m – 0.5m for habitable floor levels of residential properties, and can vary for industrial and commercial properties.

A variety of factors require consideration in determining an appropriate FPL. Of key consideration in the development of an FPL, is the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain and different types of land use.

The Floodplain Development Manual (NSW Government, 2005) identifies the following issues to be considered:

- Risk to life;
- Long term strategic plan for land use near and on the floodplain;
- Existing and potential land use;
- Current flood level used for planning purposes;
- Land availability and its needs;
- FPL for flood modification measures (levee banks etc);
- Changes in potential flood damages caused by selecting a particular flood planning level;
- Consequences of floods larger than that selected for the FPL;
- Environmental issues along the flood corridor;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);
- Possibility of creating a false sense if security within the community;
- Land values and social equity;
- Potential impact of future development on flooding;
- Duty of care.

These issues are dealt with collectively in the following sections.

10.2 Planning Circular PS 07-003

The Planning Circular was released by the NSW Department of Planning in January 2007, and provides advice on a number of changes concerning flood-related development controls on residential lots. The package included:

- An amendment to the Environmental Planning and Assessment Regulation 2000 in relation to the questions about flooding to be answered in section 149 planning certificates;
- A revised ministerial direction regarding flood prone land (issued under section 117 of the Environmental Planning and Assessment Act 1979); and,
- A new Guideline concerning flood-related development controls in low flood risk areas.

The Guideline states that, unless there are exceptional circumstances, councils should adopt the 1% AEP flood as the FPL for residential development. The need for another FPL to be adopted would be based on an assessment local flood behaviour, flood history, associated flood hazards or a particular historic flood.

10.3 Likelihood of Flooding

As a guide, **Table 10-1** has been reproduced from the NSW Floodplain Development Manual 2005 to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in **Table 10-1** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 1% AEP event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the FPL. Given the social issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 0.5% AEP magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

Table 10-1 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70yrs)

Likelihood of Occurrence in any year (AEP)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
10%	99.9	99.3
5%	97	86
2%	75	41
1%	50	16
0.5%	30	5

10.4 Current FPL

Based on Chapter G9 of DCP2014, Council currently utilises the following flood planning levels:

- For existing residential developments, based on the 1% AEP flood level, floor levels have a minimum freeboard of 0.5m;
- For new residential developments, based on the 1% AEP flood level incorporating a 0.23m sea level rise, floor levels have a minimum freeboard of 0.5m;
- For subdivisions, based on the 1% AEP flood level incorporating a 0.36m sea level rise, floor levels have a minimum freeboard of 0.5m;
- For existing industrial and commercial development, based on the 1% AEP flood level, floor levels have a minimum freeboard of 0.5m;
- For new industrial and commercial development, based on the 1% AEP flood level incorporating a 0.23m sea level rise, floor levels have a minimum freeboard of 0.5m; and,
- Council strongly recommends that any part of a building which extends below the minimum floor level be flood proofed in accordance with Appendix J NSW Floodplain Manual 2005

10.5 Land Use and Planning

The hydrological regime of the catchment can change as a result of changes to the land use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels can be increased.

A potential impact on flooding can arise through the intensity of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. Chapter G9 restricts building within the floodway, and recommends against filling in flood storage areas. In general, DCP2014 limits development in flood prone regions.

Given this, and other controls within the DCP (Section 9.3), this is not considered to be a significant issue within the catchment, as all proposed development is required to demonstrate how it meets the requirements of the DCP.

10.6 Damage Cost Differential between events

Based on an approximate typical overfloor flood damage for a property of $50,000, the incremental difference in Annual Average Damage (AAD) for different recurrence intervals is shown in **Table 10-2**. The table shows the AAD of a given property that experiences overfloor flooding in each design event, and the net present value (NPV) of those damages over 50 years at 7%.

Table 10-2 indicates that the largest incremental difference between AAD per property occurs between the more frequent events. The greatest difference between damages occurs between the 50% and 20% AEP events. It can be seen that the differences between the 2% and 1% AEP event, and the 1% AEP event and the PMF are relatively small, suggesting that increasing the FPL beyond the 2% AEP level does not significantly alter the savings achieved from a reduction in damages.

Table 10-2 Differential Damage Costs between AEP Events

Event (AEP)	AAD	Change in AAD	NPV of AAD	Change in NPV
50%	$25,000	-	$345,000	-
20%	$10,000	$15,000	$138,000	$207,000
10%	$5,000	$5,000	$69,000	$69,000
5%	$2,500	$2,500	$34,500	$34,500
1%	$1,000	$1,500	$13,800	$20,700
PMF	$500	$500	$6,900	$6,900

10.7 Incremental Height Difference between events

Consideration of the average height difference between various flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour, the average incremental height difference between events is shown in **Table 10-3** for selected events. These are determined based on the flood levels determined at each of the properties within the catchment as part of the flood damages analysis. Note that differences are only calculated where flood levels are reported in the 5% AEP event.

Table 10-3 Relative Differences Between Design Flood Levels

Event (AEP)	Difference to PMF (m)	Difference to 0.5% AEP (m)	Difference to 1% AEP (m)	Difference to 2% AEP (m)
0.5%	0.85	-	-	-
1%	0.94	0.09	-	-
2%	1.04	0.19	0.10	-
5%	1.14	0.3	0.21	0.11

Table 10-3 indicates a significantly larger difference in flood level of the PMF event compared to other events. The smallest change is between the 2% and 1% AEP events (0.10m), suggesting that, the adoption of the 1% AEP event would provide an increased level of risk reduction over the 2% AEP event without a significant effect on flood planning levels.

As noted in **Table 10-3** the average difference between the 1% AEP and PMF events is 0.94m. This average is skewed however as a result of a small number of properties that experience high PMF flood depths. 85% of properties have a difference of less than the average. The higher average depth reported is a result of 3 properties that have a difference of 1.6m to 1.7m and two properties with depth differences of 3.5m and 4.7m. These properties are all located on the edge of the 1% AEP in regions where the PMF experiences ponding; 4 in South Nowra, and one in Cambewarra immediately upstream of the gorge.

The adoption of the PMF event as the flood planning level would result in more significant increases in levels over the 1% AEP event (in the order of 1 metre) and would therefore present an issue for the setting of flood planning levels in the catchment.

10.8 Consequences of adopting the PMF as a Flood Planning Level

Analysis of the flood damage indicates that the choice of the PMF event over the 1% AEP event as the FPL would result in limited economic benefits (in annualised terms) to the community.

The difference in average flood levels between the 1% AEP and the PMF even indicate that the use of the PMF as the FPL would result in higher levels and as a result higher economic costs and inconvenience to the community. In addition, the incremental AAD per building from the 1% AEP to the PMF is relatively low.

Given this, the economic costs may in fact outweigh the benefits of using the PMF event as the FPL. The use of the PMF level as the FPL may also conflict with other development/building controls in Councils DCP.

Given the risk of exposure outlined in **Table 10-1**, it is recommended that emergency response facilities be located outside of the floodplain and any other likely critical facilities be limited to areas outside of the floodplain. Other critical facilities, such as schools and day care centres are suggested to have a floor level at the PMF level. Given the significant difference in peak levels between large flood events it is also recommended that any critical infrastructure currently within the PMF should develop evacuation strategies to plan for these events.

10.9 Environmental and Social Issues

The FPL can result in housing being placed higher than it would otherwise be. This can lead to a reduction in visual amenity for surrounding property owners, and may lead to encroachment on neighbouring property rights. This may also cause conflict with other development controls already present within the Council's development assessment process.

10.10 Risk

The selection of an appropriate FPL also depends on the potential risk of different development types. For example, consideration should be given for different FPLs for industrial, commercial and residential properties, which have different implications should overfloor flooding occur.

Critical infrastructure, such as hospitals, fire stations, electricity sub-stations and other critical infrastructure, have wider spread implications should inundation occur. As such, FPLs are typically selected for these types of structures higher than for residential, commercial or industrial properties.

10.11 Freeboard Selection

As outlined in **Section 10.1**, a freeboard ranging from 0.3 - 0.5 m is commonly adopted in determining the FPL. It should be realised that the freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. This consideration may result in the adopted FPL being higher than the PMF in certain cases. However, given the inherent purpose of freeboard, the FPL should still be used in such cases.

The freeboard may account for factors such as:

- Changes in the catchment,
- Changes in the creek/channel vegetation,
- Accuracy of model inputs (e.g. accuracy of ground survey, accuracy of design rainfall inputs for the area)

Model sensitivity:

- Local flood behaviour (e.g. due to local obstructions etc.),
- Wave action (e.g. such wind-induced waves or wash from vehicles or boats),
- Culvert blockage.

The impact of typical elements factored into a freeboard can be summarised as follows:

- Afflux (local increase in flood level due to a small local obstruction not accounted for in the modelling) (0.1m) (Gillespie, 2005),
- Local wave action (allowances of ~0.1 m are typical) (truck wash etc.),
- Accuracy of ground/ aerial survey ~ +/-0.15m,
- Sensitivity of the model ~ +/-0.15m

Based on this analysis, the total sum of the likely variations is in the order of 0.5m.

Given the above, a freeboard allowance of 0.5m is appropriate.

10.12 Flood Planning Level Recommendations

The FPL investigation supports Council's current FPLs, namely:

- For existing residential developments, new residential developments and for subdivisions, based on the 1% AEP flood level, floor levels have a minimum freeboard of 0.5m;
- For existing and new industrial and commercial development, based on the 1% AEP flood level, floor levels have a minimum freeboard of 0.5m;
- Council strongly recommends that any part of a building which extends below the minimum floor level be flood proofed in accordance with Appendix J NSW Floodplain Manual 2005

Commercial and/or Industrial properties have adopted higher frequency flood events such as the 5% AEP planning level based on the perception of risk. These occupiers can make informed commercial decisions on their ability to bear the burden of economic loss through flood damage, while residential lots don't generally provide an income to offset losses. Additionally, inventory, machinery and other assets can be stored above flood levels to lessen economic loss during a flood event.

However, as there are a relatively low number of commercial and industrial sites in the study area that are affected by floods, the adoption of the 1% AEP +0.5m as the FPL for commercial and industrial properties is appropriate for the study area.

For critical infrastructure, such as hospitals, police stations, aged care and schools, the PMF should be adopted as the FPL. It is important that these facilities, which are either difficult to evacuate or are essential during an emergency, remain flood free.

The Flood Planning Area (FPA) arising from this FPL is shown in **Figure 10-1**.

A true hazard map of the FPA is shown in **Figure 10-2**.

The hydraulic categories of the FPA are shown in **Figure 10-3**.

11 Flood Emergency Response Arrangements

11.1 Flood Emergency Responses Documentation

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks to the area. Current flood emergency response arrangements for management flooding in the Shoalhaven LGA floodplain are discussed below.

11.1.1 DISPLAN

Flood emergency management for the Shoalhaven LGA is organised under the Shoalhaven City Local Disaster Plan (DISPLAN) (2011) and has been issued under the authority of the *State Emergency and Rescue Management Act*, 1989 (as amended).

The DISPLAN details emergency preparedness, response and recovery arrangement for the region to ensure the coordinated response to emergencies by all agencies having responsibilities and functions in emergencies.

The plan is consistent with similar plans prepared for areas across NSW and covers roles and responsibilities in emergencies, preparedness measures, response operations and co-ordination of immediate recovery measures.

The DISPLAN outlines the key responsibilities of the different organisations involved in emergency management. It is generally the responsibility of the SES, as the ”combat” agency, to respond to and coordinate the flood emergency response. It is the responsibility of Council and OEH to manage flood prevention / mitigation through development controls, the floodplain management process and mitigation schemes.

The Shoalhaven DISPLAN identifies flood hazard to be a high probability with high consequences. It should be noted that this categorisation is a general one for the whole LGA.

11.1.2 Shoalhaven Flood Emergency Sub Plan

A sub-plan to the local EMPLAN has been prepared by the SES, in conjunction with Council. The Shoalhaven Flood Emergency Plan (the Flood Plan) was prepared in 2014 and covers the preparation, response and recovery of flooding emergencies for the Shoalhaven City Council Area.

The Flood Plan focuses exclusively on flooding emergencies, and more explicitly defines the roles and responsibilities of parties in a flood event. It also makes note of which key roads can be flood affected, and details evacuation centres for flood affected areas of the Shoalhaven catchment.

The Flood Plan notes that Bomaderry is a flood prone region of the catchment. The Flood Plan lists flood evacuation points for flood affected regions. For Nowra, these locations are:

- Bomaderry High School, Cambewarra Road;
- Bomaderry Bowling Club, 154 Meroo Road;
- Community Centre, 13-17 Birrelly Street; and
- Basketball Stadium, Cambewarra Road.

11.2 Emergency Service Operators

The Bomaderry floodplain lies within the Illawarra / South Coast region of the State Emergency Service (SES). The SES maintains a Local Operations Headquarters at 92 Albatross Rd, Nowra. The Illawarra / South Coast region office is located at 6-8 Regent St, Wollongong.

The access road from the Local Operations Centre to the floodplain is the Princes Highway, which may be flood affected during large storm events.

The SES is listed as the "Combat Agency" for flooding and storm damage control in the DISPLAN, as well as the primary coordinator for evacuation and the initial welfare of affected communities.

The SES is primarily a volunteer organisation. In times of emergency, the SES operates a paging service for on-call volunteers. However, more experienced crew know when to mobilise based on their understanding of the local area.

The rate of rise of floodwaters within the floodplain (both upstream and downstream of Bomaderry Gorge) is relatively fast. With peak flood levels occurring in less than 8 hours from the start of the storm event. Therefore the role of the SES in the floodplain is general at the clean-up stage as limited, if any evacuation will be possible in the short timeframe available.

The locations of key emergency services for Bomaderry Floodplain are outlined in **Table 11-1**.

Table 11-1 Emergency Service Providers Locations

Emergency Service	Adopted Value
Shoalhaven Hospital	2 Shoalhaven Street, Nowra
Ambulance Station	West Bunberra St, Bomaderry
Nowra Police Station	88 Plunkett St, Nowra
Nowra Fire Station	Unit 1/34 Norfolk Avenue, Nowra
Rural Fire Service	92 Albatross Rd, South Nowra

11.3 Access and Movement During Flood Events

Any flood response suggested for the study area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation of residents from flood affected areas, medical personnel attempting to provide aid, or SES personnel installing flood defences.

11.3.1 Access Road Flooding

Summarised in **Table 11-2** below are the key access routes out of, and through, the study area. The crossings are shown in **Figure 11.1**. The table shows the time it takes for them to overtop by greater than 0.2m in the 1% AEP, for the 12hr critical duration, and how long they are overtopped for.

The table shows that most roads remain open for a significant period of time, and only remain overtopped for relatively short periods of time during long duration storm events.

In short duration events, the roads both overtop and reopen quickly, due to the short, intense nature of the rainfall and flooding.

It is noted that roads outside of the study area may also be flood affected during storm events, so that even if roads within the study area are flood free, access may still be lost between adjacent townships.

Table 11-2 Flooding Time of Key Access Roads

ID	Location	Time to loss of access (hours)			Time of lost access (hours)		
		2hr Storm	6hr Storm	9hr Storm	2hr Storm	6hr Storm	9hr Storm
1	Bolong Road A	< 0.5	< 0.5	< 0.5	> 6	> 12	> 12
2	Bolong Road B	< 0.5	< 0.5	< 0.5	> 6	> 12	> 12
3	Princes Highway	< 0.5	< 0.5	< 0.5	> 6	> 12	> 12
4	Illaroo Road A	1	2	-	0.5	0.5	-
5	Taylors Lane	0.5	2	2.5	> 6	6	> 12
6	Hockeys Lane	0.5	1.5	1.5	> 6	> 12	> 12
7	Moss Vale Road A	-	4	-	-	1	-
8	Main Road A	0.5	2	3.5	1.5	2	4
9	Illaroo Road B	-	-	5	-	-	0.5
10	Tapitalle Road	1	1.5	1	> 6	8	> 12
11	Main Road B	1	1.5	1	> 6	> 12	> 12
12	Moss Vale Road B	1	2	-	0.5	1	-

11.3.2 Driving Condition Analysis

Movement during a storm event is likely to be undertaken by car, or similar vehicle. The safety of operating such a vehicle needs to be determined if movement options are to be recommended.

During an extreme rainfall event, the intensity of rainfall as well as other factors (such as wind and debris), would make driving either difficult or potentially more dangerous than sheltering in place. These factors would not be unique to a floodplain, and would be equally as dangerous if an extreme event were to occur in any location. It would be expected that the risk to life of driving in these conditions would increase with lower frequency rainfall events.

A review was therefore undertaken on driver safety related to rainfall events.

A study into rainfall effects on single-vehicle crash severities based on an analysis of crash and traffic data for the Wisconsin, USA area for the period 2004-2006 found that rainfall events with a mean rainfall intensity of 3.16 mm/hr resulted in an increased likelihood of crashes ranging in severity from fatal to possible injury (Jung, Qin, & Noyce, 2009).

An analysis of data for the cities of Calgary and Edmonton, Canada during 1979-1983 concluded that the overall accident risk during rainfall conditions was found to be 70% higher than normal (Andrey, 1993).

Andreescu and Frost (1998) in an analysis of data for Montreal, Canada 1990-1992, found that a best fit line of data found a linear increase in number of accidents in relation to increased daily rainfall intensity (mm/day). This is reproduced in **Figure 11.2**. It is noted that there is significant scatter in the source data and that the correlation is relatively low. However, the data does demonstrate a link between daily rainfall and accidents.

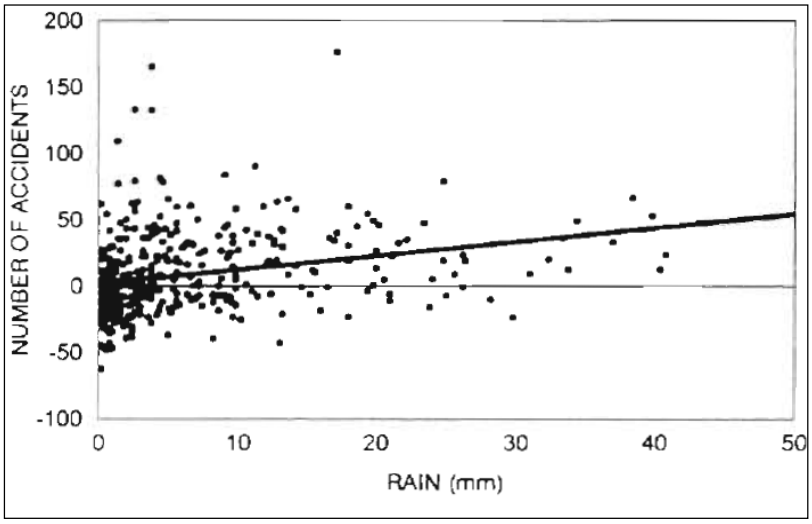

Figure 11.2 Accidents per day vs daily rainfall (Andreescu & Frost, 1998)

The NSW Governments Roads and Traffic Authority (RTA) *Road User's Handbook* (2010) states that "Driving during extreme weather events or conditions should be undertaken with care and caution. Driving should be avoided in extreme conditions."

The rainfall intensity temporal distribution for the 1% AEP 2 hour event and 1% AEP 9 hour event are shown in **Figure 11.3** and **Figure 11.4** respectively. It is noted that these are exclusive of climate change impacts on rainfall intensities.

The figure shows that rainfall intensities are generally greater than 10mm/hr for both durations, with peaks of 159mm/hr, 293mm/hr and 209mm/hr at 25 minutes, 35 minutes and 40 minutes into the storm respectively for the 2 hour event, and 58mm/hr and 96mm/hr at 3 hours and 5 hours into the storm respectively for the 9 hour event.

The literature evaluated does not give a definitive threshold of rainfall intensity for which unsafe driving can be expected (with the exception of Jung (2009) which has a very low intensity of only 3 mm/hr, which can be expected in relatively frequent events).

However, average rainfall intensities for both the 1% AEP 2 hour event and 9 hour event are well in excess of the values identified in the literature as beginning to have an effect on driving risk.

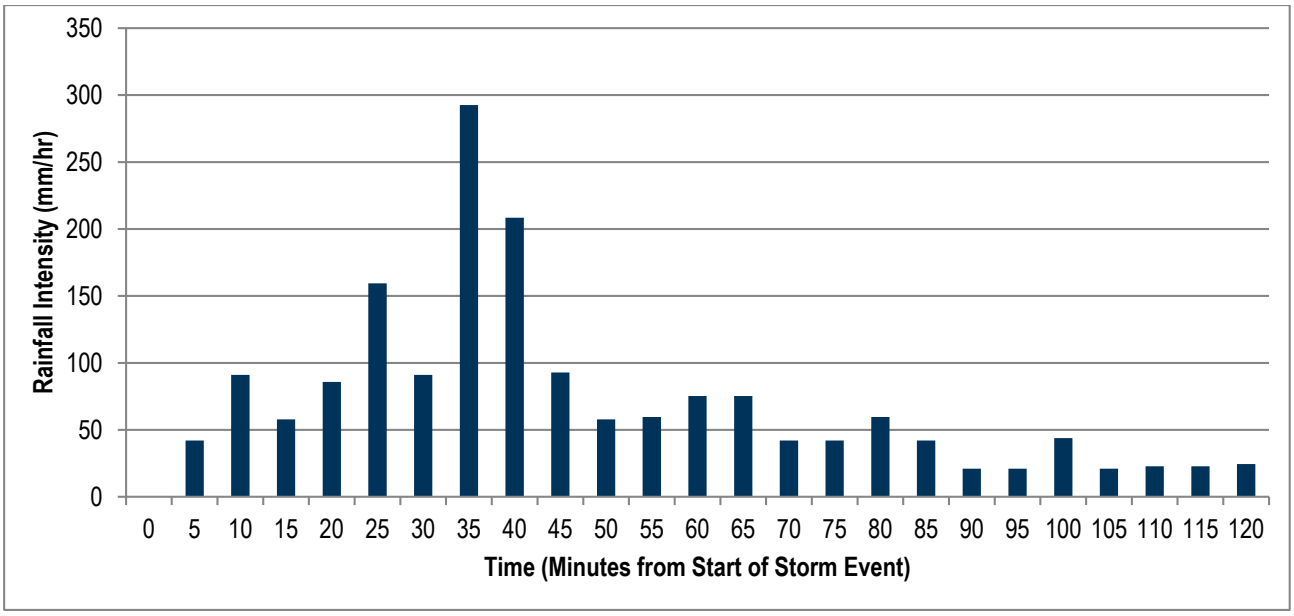

Figure 11.3: 1% AEP 2hr Temporal Rainfall Distribution

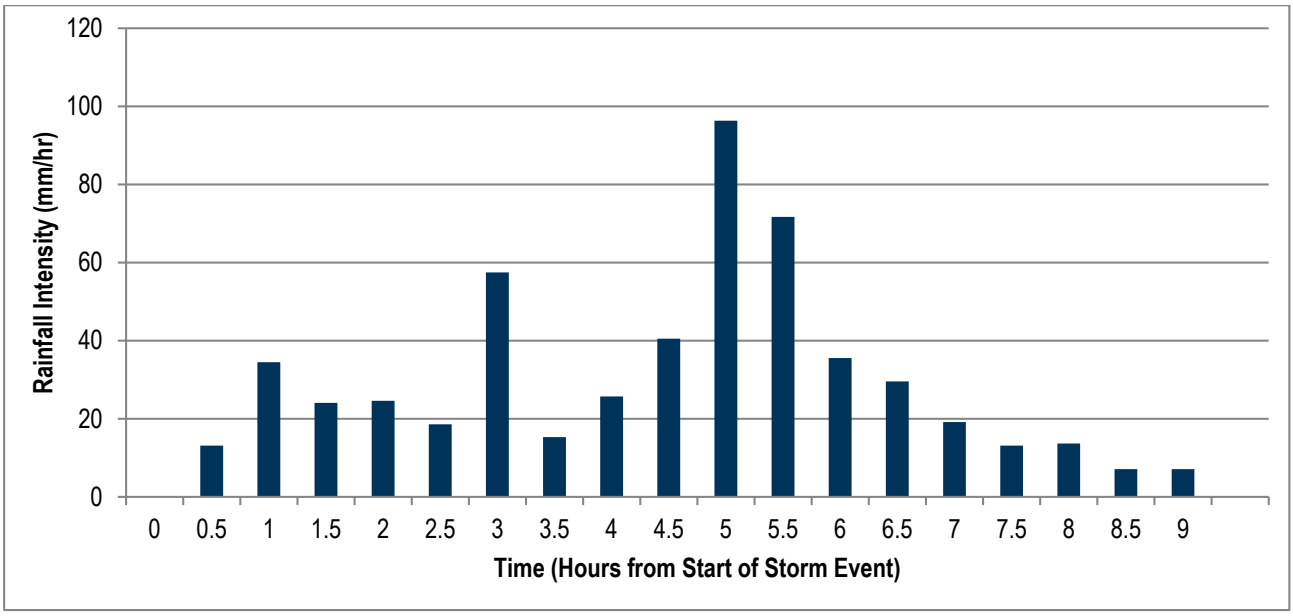

Figure 11.3: 1% AEP 9hr Temporal Rainfall Distribution

From the above, it is not recommended that people attempt to drive during a significant rain event. As the most intense rainfall will be associated with short duration storms, the safer option is to wait for the rain to lessen before attempting to drive. During longer duration events, where flood warning may be possible, the rainfall intensity will be reduced, and may allow evacuation whilst the rain is falling. However, in general, it is recommended that driving not be undertaken during intense rainfall periods unless there is a risk to life at the property resulting from rising flood waters.

11.4 Flood Emergency Response

11.4.1 Catchment Response Time

The Australasian Fire and Emergency Service Authorities Council (AFAC) define flash flooding as:

> *Flash flooding may be defined as flooding that occurs within 6 hours or less of the flood-producing rainfall within the affected catchment. Flash flood environments are characterized by the rapid onset of flooding from when rainfall begins (often within tens of minutes to a few hours) and by rapid rates of rise and by high flow velocity.*

The majority of sub-catchments within the study area are small, with relatively steep upstream areas. This results in the majority of locations within the study area having fast catchment response times where flash flooding is predominant.

Therefore, for the purposes of considering response to flooding in this study it is concluded that the rate of rise for all floodplains within study area can be classed as flash flooding.

Flash flooding poses flood risk with regards to responding to flooding. The available response time is likely to be in the scale of hours, or in many cases sub-hourly, placing more emphasis on the ability to evacuate compared to shelter-in-place as a flood response strategy.

11.4.2 Flood Warning

There is no official flood warning system for the catchment. Furthermore, the catchment is susceptible to flash flooding, meaning that the effectiveness of warning systems are limited due to the relatively short interval between the peak of the flood and the causative rain. However, sources of real-time flood intelligence during times of flooding are:

- Bureau of Meteorology (BoM):
- State Emergency Service (SES):

Warnings are provided as:

- BoM Flood Watches: SES Flood Bulletins are issued by the Illawarra South Coast SES Region Headquarters to various media outlets and agencies each time the BoM issues a Flood Watch.
- BoM Severe Weather Warnings: For the management of coastal erosion and inundation, BoM will issue Sever Weather Warnings to the SES, radio stations and other organisations prior to and during potential and actual coastal erosion events.
- SES Livestock and Equipment Warnings: following heavy rain, or when there are indications of significant creek or river rises, the SES Local Operations Controllers will advise SES Region Headquarters which will issue SES Livestock and Equipment Warnings.
- Evacuation Warnings by radio, door-knocks and telephone.

11.4.3 Regional vs Localised Evacuation Timeline

Evacuation during a flood event may be triggered by either regional notifications or localised observations.

The time for regional evacuation notices is substantially longer, due to the:

- Time required to notify a region;
- Time required for mobilisation of the SES in response to a flood event.

As a result of the above factors, the time to evacuate an at-risk region would be expected to be in the order of 5 or more hours.

Localised evacuation however, occurs at a smaller scale level through a different sequence of events, namely residents visually see flooding in their vicinity and respond instinctively by moving to higher ground.

This sequence relies less on emergency services co-ordination and relies on the common sense of the resident to respond to observed flooding through evacuation. It is not dissimilar to the expected sequence of events for shelter-in-place with the exception that residents evacuate to higher ground rather than elevated buildings.

Compared to the regional timeline above, localised evacuation significantly reduces the time required to evacuate.

Though the time available varies for all areas of the floodplain across the study area, the catchment response time suggests that flood prone areas will have an available evacuation time significantly less than 5 hours.

Consequently, a co-ordinated regional evacuation as an emergency response is not feasible for the study area. This aligns with comments from the AFAC guideline (2013) which states that detection of rainfall or water level provide limited prospects for using such systems to trigger planned and effective evacuation.

Localised evacuation strategies for developments however, may be feasible in certain locations within the floodplain, particularly on the fringes of the floodplain where evacuation routes are shorter.

11.4.4 Community Response to Flooding

11.4.4.1 Short Duration Flooding

As discussed in **Section 11.4.1**, the study area is largely characterised by a quick flood response to rainfall. This limits the options available to the community. The options available may be broadly grouped into local evacuation and shelter in place.

Unlike property damage assessments of flood risk, when determining the flood risk to life the flood hazard for an area does not directly imply the danger posed to people in the floodplain. This is due to the capacity for people to respond and react to flooding, ensuring they do not enter floodwaters.

To help minimise the flood risk to residents, it is important that developments have provisions to facilitate flood emergency response. There are two main forms of flood emergency response that may be adopted by people within the floodplain:

- Evacuation: The movement of residents out of the floodplain before their property becomes flood affected; and,
- Shelter-in-place: The movement of residents to a building that provides vertical refuge on the site or near the site before their property becomes flood affected. Council are not currently pursuing a shelter in place option at this time. Council will continue to liaise with the SES to identify strategies to manage existing flood risk in areas where minimal to no warning time is available.

The evacuation potential of the study area in the event of flooding is considered to be limited due to the flash flooding nature of the catchments within the Bomaderry Creek catchment. Based on the SES evacuation timeline approach, there is insufficient time to co-ordinate a regional evacuation process, however there is potential for localised evacuation of sites near the edge of the floodplain.

As noted in **Section 10.7**, there are some properties that experience PMF flood depths that are significantly larger than the 1% AEP event. All these properties are classified as low flood islands. For these higher risk properties, it is recommended that Council contact the residents and provide them with information on the flood behaviour of their property and, in consultation with the SES, work to develop a flood response plan with these properties.

This conclusion is in accordance with the following relevant sources:

- The AFAC guideline states that evacuation is the most effective strategy, provided that evacuation can be safely implemented, however it may be worse than not evacuating at all. It suggests determination of whether there are barriers to evacuation posed by available warning time, availability of safe routes, and resources available, with evacuation potential found to be minimal.
- Review of flood fatalities in Australia has found that the vast majority (75.7%) of fatalities occurred outside when people have entered flood waters in a vehicle or on foot, with only 12.4% of fatalities occurring in a house (Haynes et al, 2009). Conversely, it should also be noted that flooding in the Lockyer Valley showed the hazard associated with shelter-in-place, with 13 of the 19 fatalities being people sheltering in buildings that were either completely inundated or collapsed under the force of the flood flows (Rogencamp and Barton, 2012)

11.4.4.2 Long Duration Flooding

Longer duration storms, such as those that are critical for the downstream region of the catchment, allow for the possibility of pre-flood responses. These responses include:

- Sand bagging;
- Elevation of property contents;
- Lashing down potential flood hazards;
- Moving vehicles to high ground; and,
- Evacuation.

Flood warning systems utilise rainfall / stream gauges to provide advance warning of approaching flood waters. The warning system may be useful for flood response to inform access routes and to provide emergency responders with an indication of priority areas. However, a warning system would have a limited benefit for resident warnings due to the relatively short timeframe between issuing the warning and the arrival of flood waters.

These warnings could be via alerts issued by the monitoring authority of the gauge. Alternatively, the alerts may be automatically generated by a certain gauge trigger level, and distributed via SMS to high risk locations, and others who have requested the alerts.

This warning would allow residents to install temporary flood proofing (sand bags), relocate items / property to higher ground, and secure items which may come loose during the flood event.

Advance warning from the BOM via a severe weather warning would also allow high risk properties the opportunity to evacuate. Such locations may include caravan parks and aged care facilities.

In the case of evacuation, it is important to assess the benefits, and to determine who is likely to be able to take advantage of this option. It must also be determined if they would be any safer doing so, than staying within their property.

Two key concerns with evacuation are:

- The depth and duration of floodwaters over key access roads,
- Driving conditions occurring during the evacuation period (noting that evacuation to higher ground or evacuation centres will primarily be via private vehicle).

Although a flood warning system may provide some advance warning of flooding, the system would not be able to differentiate between short and long response flooding. If the flood is a short duration event, with a quick catchment response, the warning may result in residents leaving their home shortly before or during the peak of the flood, placing themselves at risk.

As such, it is suggested that the flood response should focus on a ‘remain in place’ policy, and that the community be educated as to the appropriate actions to take in a flood event.

12 Community Education and Awareness

Community awareness of flood behaviour and flood risks is essential to minimise risk to life during flood events. An aware and educated population will be able to respond to flood events quickly and appropriately, reducing risks to themselves, their property and to others.

12.1 Current Community Awareness of Flood Behaviour and Risk

The community survey and workshops undertaken (refer **Section 4**) showed that current residents have a good awareness of flood behaviour and flood risk.

As part of the community consultation process a questionnaire was distributed to residents, and from this information was gathered on respondents' history and awareness of flooding.

During the community workshop that was held as part of the consultation process, attendees demonstrated a high level of awareness of flood behaviour within their Township, and an understanding of the flood risks resulting from this behaviour.

12.2 Maintaining Community Awareness

The aim of the education and awareness program is to maintain and improve the current level of flood awareness within the Community.

As stated above, due in large part to recent flood events in the catchment, there is currently a high level of flood awareness among residents; however, over time new residents will arrive who do not have any experience of flooding within the catchment. It is also possible that there will be a period of time with no rainfall events, over which period peoples' appreciation of flood risks may begin to wane.

12.3 Education and Awareness Program

Discussed below are strategies that may be implemented to raise community knowledge and awareness of flooding within the study area.

12.3.1 Short Term

12.3.1.1 Develop FloodSafe Brochure and FloodSafe Toolkit

The SES has developed Local FloodSafe Guides, which give specific information for areas at risk of floods. These guides are produced in collaboration with Council and regional and local SES units. The SES recommends that these guides are reviewed every 5 years.

The SES has also prepared templates allowing Local Guides to be prepared for individual regions. Different guides may be prepared for general township flooding, flash flooding and rural flooding. Development of the forms can be organised through contacting the SES.

The SES FloodSafe website (www.floodsafe.com.au) also allows for the creation of personal plans and business plans. Variations of plans are also available for riverine and flash flooding regions. It is recommended that a reference to this tool be made in the FloodSafe Guide to make residents and owners aware of this tool, and that residents and businesses are encouraged to prepare a personal or business plan.

12.3.1.2 Develop a Post-Flood Data Collection Strategy

The collection of post-flood data was recommended as part of the Broughton Creek Floodplain Risk Management Study. In addition to this, it is recommended that the data collected be expanded to create information that will help the community to better understand the flood event and general catchment flood behaviour. This may include the collection / determination of data such as:

- The approximate recurrence interval of the rainfall intensity and peak river / creek flows;
- The approximate recurrence interval of any major overground flooding;
- A comparison of the storm event with previous historical events and design events. Comparison could be made against rainfall, flows or depths;
- Timings of peak flows or levels; and,
- The timing and duration of road overtopping / closures.

12.3.2 Medium Term

12.3.2.1 Hold a FloodSafe Launch Event

Following the development of the Flood Safe documents, a public launch may be held to inform the community of the availability of this material and provide an opportunity for the community to discuss flooding issues with Council staff.

12.3.2.2 Develop a Flood Information Package for New Residents

The documents prepared for the Flood Safe initiative will provide new residents an introduction to flood behaviour and risks within the study area. It is recommended that an information package be distributed to new residents that contains a short letter from Council discussing the current flood management program, the flood safe documents, links to further information, and contact details of Council staff should they have any further queries or concerns.

Council may already have a welcome package that they provide to new residents, which would provide an existing process that can be expanded to include flood related information.

12.3.2.3 Develop a Post Flood Information Mail-Out

Following the development of the post-flood collection strategy, a post-flood information mail-out should be developed to pass this information on to the community. The purpose of presenting this data to the community is to allow them to relate their recent flood experience to other historical events and to design events.

Being able to compare their recent flood experience with predicted flows and levels from a 2% or 1% AEP event, would give them a greater understanding of what such an event would look like, and what would be required for them to be safe in such an event.

12.3.3 Long Term

12.3.3.1 Develop and Implement School Education Program

It is important that education and awareness programs target everyone within the community. Children are an important part of a community and can also be influential members of the family unit. They are also a high risk population during a flood event. As such, it is important that children are educated about flood risks and appropriate behaviour during a flood.

The SES has developed a tailored program for school children in primary schools. The program, which includes teacher's resources, newsletters, activities and games, is designed to deliver knowledge and awareness of floods to young children. SES personal are also available to visit schools to talk about flooding and flood response.

The SES has also prepared a broadsheet and associated questions for Year 9 geography students which discusses flooding of the Nepean River Floodplain.

Further details of these programs are available on the SES StormSafe website (www.stormsafe.com.au/information-for-schools)

It is recommended that local schools be informed of these initiatives, and encouraged to take part in them.

It is also recommended that Council contact schools to investigate opportunities for students to be informed of flood hazards and appropriate responses. For example, schools run fire drills frequently to ensure students know how to respond during fires. It may be possible to expand this emergency response training to include a discussion on flood risks and responses. Alternatively, opportunities could be investigated to make presentations concerning flooding to students studying waterways, the environment or natural disasters as part of their school curriculum.

12.4 Triggers for Education & Awareness Actions

It is recommended that the education and awareness program be monitored for its effectiveness, and revised as required based on feedback and new data.

In addition to revisions based on feedback, it is recommended that revisions and actions be undertaken if:

- There is a large flood event; or,
- There has been a period of 3 years without a large flood event.

12.4.1 Actions resulting from a large flood event

Immediately following a large flood event is a good time to encourage residents to take an interest in flood behaviour in the catchment. At this time many residents actively seek flood information on the event and general flood behaviour. This

should also be seen as an opportunity to encourage residents to develop personal flood response plans with the flood event still clear in their minds.

It is recommended that the following actions be undertaken following a large flood event in the catchment:

- Undertake the post-flood data collection;
- If mitigation strategies have been adopted, assess their effectiveness in the flood event;
- Prepare the post flood mail-out for the event; and,
- Undertake the post flood mail-out to inform residents about the recent flood.

12.4.2 Actions resulting from a Period of 3 years without a large flood event

After a period of time without a large flood event, there is a risk that community flood awareness will begin to fall.

As such, it is recommended that if a period of three years elapses without a large flood event, a community mail-out be undertaken to inform / remind residents of flood risks within the catchment.

This mail-out may include a short letter from Council detailing the reasons for the mail-out and discussing historical flood events, the FloodSafe brochures, any previous post-flood mail-out forms, and links to other information sources.

The aim of this exercise is to ensure that residents remain aware of both flood risks within the catchment and appropriate actions to take in flood events to manage the risk.

13 Floodplain Risk Management Options

13.1 Managing Flood Risk

Flood Risk can be categorised as existing, future or residual risk:

- **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding.
- **Future Flood Risk** – buildings and developments that may be built on flood prone land. Such buildings and developments would be exposed to a flood risk when they are built.
- **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it may be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 13-1**.

Table 13-1 Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
Preventing / Avoiding risk	Appropriate development within the flood extent, setting suitable planning levels.
Reducing likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees, and detention.
Reducing consequences of risk	Development controls to ensure structures are built to withstand flooding.
Transferring risk	Via insurance – may be applicable in some areas depending on insurer.
Financing risk	Natural disaster funding.
Accepting risk	Accepting the risk of flooding as a consequence of having the structure where it is.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories of management:

- **Flood modification measures** – Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These options reduce the risk through modification of the flood behaviour in the catchment.
- **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these options aim to modify properties (both existing and future) so that there is a reduction in flood risk.
- **Emergency response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.

13.2 Existing Case

The existing flood behaviour in the Bomaderry Creek floodplain was detailed in the Bomaderry Creek Flood Study (BMT WBM, 2010) and subsequently revised in this study. In order to assess the various management options, it is necessary to define a base case. This base case provides a reference to assess the effectiveness of various flood management options.

13.3 Flood Modification Measures

Based on the flood model results, historical information, community feedback and engineering judgement, possible flood modification options (i.e. structural options) for the study area were identified. These options are outlined in **Table 13-2** and shown in **Figure 13-1** to **Figure 13-6**.

These options were presented to the community at the first community workshop. Based on discussion with the community, Council and OEH, a number of options were selected for assessment with the hydrological model, namely:

- F1 – raising of Birriley Street to 1% AEP level and upgrade of culvert under roadway
- F5, F6 and F14 – levee options at Tarawal Street, Briniwarr Street and Illaroo Road respectively.
- F21 – Detention basin on Good Dog Creek, upstream of Tannery Road

The costs and performance of these options is discussed in **Section 14**.

13.3.1 Environmental Considerations

According to State Environmental Planning Policy (SEPP) (Infrastructure) 2007, flood mitigation works "may be carried out by or on behalf of a public authority without consent on any land". These works include construction, routine maintenance and environmental management works which applies to most of the flood mitigation options. Although consent is not required, most flood mitigation works will require further environmental assessment.

The determining authority, in this case Shoalhaven City Council, is required to "examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity" complying with Section 111 of the EP&A Act, most likely in the form of a Review of Environmental Factors.

When carrying out flood mitigation works, Council will be required to take out further permits, licenses and approvals such as:

- Flood mitigation works which emit into a water body will need an Environment Protection Licence complying with the Protection of the Environment Operations Act (POEO) 1997,
- Any removal of vegetation and debris in the water body may need a Threat Abatement Plan complying with the Fisheries Management Act 1999,
- A licence to harm threatened species, population or ecological community or damage habitat under the Fisheries Management Act 1999.

Table 13-2 Bomaderry Flood Mitigation Options

ID	Upgrade	Location	Site Description	Expected Benefit	Major Constraints
F1	Channel Upgrade	Bomaderry Creek near Birriley Street	The existing flowpath is low capacity with low lying properties adjacent. Existing twin 900mm pipes under road	Reduce flood affectation of surrounding residential properties, reduce overtopping of Birriley Street	Constructed open channel could be increased in size for reasonable cost
F2	Culvert Upgrade	Bomaderry Creek crossing of Birriley Street	The existing flowpath is low capacity with low lying properties adjacent. Existing twin 900mm pipes under road	Reduced flood levels in adjoining properties, reduced overtopping of Birriley Street	Culvert upgrades are considered an expensive option with road closures involved.
F3	Culvert Upgrade	Bomaderry Creek crossing Bunberra Street	Well defined heavily vegetated natural flowpath with 1500mm pipe under Bunberra	Less frequent overtopping of Bunberra Street	
F4	Detention Basin	Bomaderry Creek downstream of Bunberra Street	Natural reserve may offer opportunity for detention basin to ease flood affectation of properties downstream	Reduced flood affectation of properties downstream	Heavily vegetated natural reserve with steep inclines not seen as ideal location for detention basin
F5	Bund	Bomaderry Creek near Tarawal Street	Significant portion of residential properties flood affected adjacent to flowpath	Reduce flood affectation of surrounding residential properties	Available reserve for bund may be difficult, necessary bund height roughly 1 metre
F6	Bund	Bomaderry Creek near Maleen Street	Natural sandstone lined channel with flat overbank area with flood affected residential properties	Reduce flood affectation of surrounding residential properties	Available reserve for bund may be difficult, necessary bund height roughly 1 metre
F7	Culvert Upgrade	Bomaderry Creek crossing Brinawarr Street	Twin 1200mm pipes convey flow from well defined flowpath	Less frequent overtopping of Brinawarr Street	
F8	Bund	Bomaderry Creek adjacent to Tarawara Street	Low lying road and residential properties adjacent to overland flowpath in river tailwater affected area.	Reduce flood affectation of surrounding residential properties, and Tarawara Street	Available reserve for bund may be difficult, necessary bund height roughly 1.5 metres for 100yr and 3.5 metres for PMF
F9	Culvert Upgrade	Bomaderry Creek crossing Bolong Road	Low lying major road with 450mm pipe conveying flowpath flows, located in river tailwater affected area. Road currently overtopped by both local and river flooding scenarios.	Less frequent overtopping of Bolong Road for local flooding in particular, increasing serviceability of road	
F10	Road Upgrade	Bomaderry Creek crossing Bolong Road	Low lying major road with 450mm pipe conveying flowpath flows, located in river tailwater affected area. Road currently overtopped by both local and river flooding scenarios.	Less frequent overtopping of Bolong Road for local flooding in particular, increasing serviceability of road	Road will need to be raised 2.3 metres for 100yr and 4.4 metres for PMF river flooding
F11	Road Upgrade	Beinda Street at Lower Bomaderry Creek	Low lying road and residential properties adjacent to overland flowpath in river tailwater affected area.	Less frequent overtopping of Bolong Road (for local and river flooding), increases regional evacuation time available	Road will need to be raised 1.4 metres to be flood free in the PMF river event.
F12	Detention Basin	Mahogany Creek upstream of Illaroo Road	Natural reserve upstream of Illaroo Road, flows into three cell culvert 2.4mW x 1.2mH. This discharges to well defined natural channel downstream. Significant affectation of adjacent properties upstream with fringe affectation of properties downstream	Reduce flood affectation of surrounding residential properties, reduce overtopping of Illaroo Road	Heavily vegetated natural reserve not seen as ideal location for detention basin
F13	Culvert Upgrade	Mahogany Creek crossing Illaroo Road	Natural reserve upstream of Illaroo Road, flows into three cell culvert 2.4mW x 1.2mH. This discharges to well defined natural channel downstream. Significant affectation of adjacent properties upstream with fringe affectation of properties downstream	Less frequent overtopping of Illaroo Road	Culvert upgrades are considered an expensive option with road closures involved
F14	Bund	Mahogany Creek downstream of Illaroo Road	Natural reserve upstream of Illaroo Road, flows into three cell culvert 2.4mW x 1.2mH. This discharges to well defined natural channel downstream. Significant affectation of adjacent properties upstream with fringe affectation of properties downstream	Flood free residential properties	Available reserve for bund may be difficult, necessary bund height roughly 0.75 metres for 100yr and 1.25 metres for PMF

ID	Upgrade	Location	Site Description	Expected Benefit	Major Constraints
F15	Culvert Upgrade	Tapiatlee Flowpath crossing Illaroo Road	Local flowpath crossing Koloona Drive, Illaroo Road and residential properties, fringe affectation of residential properties	Less frequent overtopping of Illaroo Road	Culvert upgrades are considered an expensive option with road closures involved
F16	Road Upgrade	Hockeys Lane crossing Tapitalee Creek	Low lying causeway crossing Tapitalee Creek overtopped in frequent events. Above this low lying section (about 50m long), there is a wider section of road still within the 5 year floodplain (about 200m long).	Better serviceability of commonly used road to Cambewarra	To raise road above the 5 year or greater requires road raising of the entire 200m long section as well as a bridge at low lying section.
F17	Bund	Moss Vale Road near Bomaderry Creek	Relatively low lying section of major road adjacent to Bomaderry Creek floodplain with a number of PMF affected properties adjacent.	Flood free access for Moss Vale Road and no flood affectation for adjacent residential properties	The road would need to be raised less than 0.5m for a small section of road to be flood free up to the 100yr. To be flood free to PMF, a 600m section of road would need to be raised up to maximum of 5 metres.
F18	Road Upgrade	Taylors Lane near Bomaderry Creek	Low lying road with twin 450mm pipes conveying flow from local rural catchment. Within Bomaderry Creek PMF floodplain	Flood free access for Taylors Lane properties	The road would need to be raised less than 0.5m for a small section of road to be flood free up to the 100yr. To be flood free to PMF, a 150m section of road would need to be raised up to maximum of 3 metres.
F19	Bund	West Cambewarra Road near Bomaderry Creek	8 properties on the fringe of Bomaderry Creek PMF floodplain upstream of gorge, with 2 of these within 100yr floodplain.	Reduce flood affectation of surrounding residential properties	Bund height of 2m for a 250m long section to make properties flood free up to the 100yr. To be flood free to PMF, a 700m section of bund would need to be raised up to maximum of 7 metres.
F20	Culvert Upgrade	Cambewarra Flowpath crossing Tannery Road	Flowpath through the centre of Cambewarra township, flows through open space reserve upstream of Tannery Road. Twin 750mm pipes convey flow under Tannery Road. Fully blocked pipe runs through rear of properties downstream of Tannery Road with overland flowpath above conveying floodwaters. Flood affectation of a number of these properties for the 100yr and greater events	Reduce flood affectation of surrounding residential properties, reduce overtopping of Tannery Road	Culvert upgrades are considered an expensive option with road closures involved
F21	Detention Basin	Cambewarra Road upstream of Tannery Road	Flowpath through the centre of Cambewarra township, flows through open space reserve upstream of Tannery Road. Twin 750mm pipes convey flow under Tannery Road. Fully blocked pipe runs through rear of properties downstream of Tannery Road with overland flowpath above conveying floodwaters. Flood affectation of a number of these properties for the 100yr and greater events	Reduce flood affectation of surrounding residential properties, reduce overtopping of Tannery Road	Existing open space reserve could be a good location for a detention basin to detain flow.
F22	Culvert Upgrade	Barfield Road crossing flowpaths	Low lying section of unsealed road with a number of flowpaths crossing adjacent to each other. One crossing has a newly constructed 900mm pipe, while the other has a 450mm pipe. The low lying section of road is 100 metres long	Flood free access for upper Tannery Road properties	
F23	Road Upgrade	Good Dog Creek crossing Main Road	Bridge structure over Good Dogs Creek runs from elevated township to the west to lower lying rural area to the east which is flood affected.	Flood free access for Cambewarra township	Would involve road raising of floodplain land of up to 1.2 metres for 100 year ARI and 2. 4 metres for PMF levels as well as potential bridge upgrades.
F24	Road Upgrade	Good Dog Creek crossing Tannery Road	Low lying causeway over Good Dog Creek with flood depths of 3 metres in the 100yr and 4 metres in the PMF.	Flood free access for Cambewarra township	Would require the construction of a bridge structure / road raising combination for a length roughly 75 metres long to be flood free for 100 year and 150 metres long for the PMF
F25	Road Upgrade	Browns Creek crossing Main Road	Bridge over Browns Creek with wide expanse of low lying road	Flood free access to the township of Cambewarra	Would require the construction of a bridge structure / road raising combination for a length roughly 150 metres long to a depth of 0.7 metres to be flood free for 100 year and 150 metres long to a depth of 1.2 metres for the PMF event

13.4 Property Modification Options

A number of property modification options were identified for consideration in the Kangaroo Valley floodplain. These options fall into two categories; those for which OEH support is available, and those which would be required to be implemented fully by Council.

Options for which funding may be available from OEH are:

- House Raising P 1
- Voluntary Purchase P 2

Details of the OEH grants available may be found at: www.environment.nsw.gov.au/coasts/Floodgrants.htm

Additional property modification options that may be pursued by Council are:

- Building and Development controls P 3
- House Rebuilding P 4
- Land Swap P 5
- Council Redevelopment P 6
- Flood Proofing P 7

These options are discussed in detailed below.

13.4.1 P 1 – House Raising

As there are no properties which experience over floor flooding in the frequent events, and minimal numbers of properties in the mid-range AEP events, the cost of raising is significantly greater than the benefit achieved. Consequently, house raising is not considered a viable option for the Bomaderry Creek catchment area.

13.4.2 P 2 – Voluntary Purchase

As no properties were found to be within high hazard floodways, or affected by frequent flooding, voluntary purchase is not considered a viable option for the Bomaderry Creek catchment area.

13.4.3 P 3 – Building and Development Controls

The key document for flood related controls in the Shoalhaven LGA is DCP2014, and recommended updates to this document are discussed in **Section 9**.

13.4.4 P 4 – House Rebuilding

As no properties were found to be flood affected in frequent evets, this option is not considered viable for the Bomaderry Creek catchment area.

13.4.5 P 5 – Land Swap

As no properties were found to be flood affected in frequent evets, this option is not considered viable for the Bomaderry Creek catchment area.

13.4.6 P 6 – Council Redevelopment

As no properties were found to be flood affected in frequent events, this option is not considered viable for the Bomaderry Creek catchment area.

13.4.7 P 7 – Flood Proofing

Flood proofing involves undertaking structural changes and other procedures in order to reduce or eliminate the risk to life and property, and thus the damage caused by flooding. Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding.

These include modifications or adjustments to building design, site location or placement of contents. Measures range from elevating or relocating, to the intentional flooding of parts of the building during a flood in order to equalise pressure on walls and prevent them from collapsing.

Examples of proofing measures include:

- All structural elements below the flood planning level shall be constructed from flood compatible materials
- All structures must be designed and constructed to ensure structural integrity for immersion and impact of debris up to the 1% AEP flood event. If the structure is to be relied upon for shelter-in-place evacuation then structural integrity must be ensured up to the level of the PMF
- All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the flood planning level

In addition to flood proofing measures that are implemented to protect a building, temporary / emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of the building. These measures are generally best applied to commercial properties. It is noted that there are 3 commercial / industrial properties that experience flooding in the 5% AEP event or greater.

These measures should be carried out according to a pre-arranged plan. These measures may include:

- Raising belongings by stacking them on shelves or taking them to a second storey of the building
- Secure objects that are likely to float and cause damage
- Re-locate waste containers, chemical and poisons well above floor level
- Install any available flood proofing devices, such as temporary levees and emergency water sealing of openings

The SES business *Flash Flood Tool Kit* (SES, 2012) provides businesses with a template to create a flood-safe plan and to be prepared to implement flood proofing measures. It is recommended that this tool kit is distributed to the flood affected businesses within the Bomaderry Creek floodplain.

13.5 Emergency Response Modification Options

A number of emergency response modification options are suitable for consideration within the Bomaderry Creek floodplain. These are:

- Information transfer to the SES EM 1
- Flood Warning System EM 2
- Public awareness and education EM 3
- Flood warning signs at critical locations EM 4

These options are discussed in detail below.

13.5.1 EM 1 – Information transfer to SES

The findings of the Flood Study and the Flood Risk Management Study and Plan provide an extremely useful data source for the State Emergency Service. Information of this transfer will be detailed in the Flood Emergency Plan, to be prepared as part of the next stage of the study.

13.5.2 EM 2 – Flood Warning System

The critical duration and response times for the majority of the study area limit the implementation of a flood warning system. As discussed in **Section 11** the short duration flooding experienced in local systems is not well suited to flood warning systems. Severe weather warnings are likely to be the only assistance for these areas.

13.5.3 EM 3 – Public Awareness and Education

Flood awareness is an essential component of flood risk management for people residing in the floodplain. The affected community must be made aware, and remain aware, of their role in the overall floodplain management strategy for the area. This includes the defence of their property and their evacuation, if required, during the flood event.

A strategy to manage and improve public awareness and education is discussed in **Section 12**.

13.5.4 EM 4 – Flood Warning Signs at Critical Locations

A number of public places in the catchment experience high hazard flooding in the 1% AEP event. It is therefore important that appropriate flood warning signs are posted at these locations. These signs may contain information on flooding issues, or be depth gauges to inform residents of the flooding depth over roads and paths.

It is recommended that additional depth gauges be installed at road crossings which are subject to inundation in frequent events, such as those along Nugents Creek, Town Creek and Myrtle Creek, which experience overtopping in the 2% AEP event.

13.6 Data Collection Strategies

This would involve the preparation of a flood data collection form and the use of this form following a flood event. This would allow for more information to be gathered concerning the nature of flooding within the catchment, building on the knowledge from the Flood Study.

14 Economic Assessment of Options

It is possible to quantitatively assess the economic benefits of some of the options, namely those that were hydraulically modelled, and those with known benefits. For those options, a benefit-cost ratio can be calculated.

This calculation is described below.

14.1 Preliminary Costing of Options

Cost estimates were prepared for those options which allow for an economic assessment. A summary of these estimated capital costs are provided in **Table 14-1**. Details of these costings are provided in **Appendix C**.

For other options, broad estimates were made for the purpose of comparison in the multi-criteria assessment. These are detailed in **Section 15**.

Prior to an option proceeding, it is recommended that in addition to detailed analysis and design of the option, that these costs be revised prior to budget allocation to allow for a more accurate assessment of the overall cost. Detailed rates and quantities will also be required at the detailed design phase.

Table 14-1 Costs of Quantitatively Assessed Options

Option ID	Option	Capital Cost	Ongoing Costs
F1	Birriley Street Raising and Culvert Upgrade	$428,600	$7,500
F5	Tarawal Street Levee	$131,100	$5,000
F6	Maleen Street & Briniwarr Street Levee	$104,800	$5,000
F14	Illaroo Road Levee	$209,600	$5,000
F21	Good Dog Creek Basin	$989,800	$10,000

14.2 Average Annual Damage for Quantitatively Assessed Options

The total damage costs were evaluated for each of the options assessed by hydraulic modelling (quantitative assessment). The average annual damage (AAD) for each of the options is shown comparatively against the existing case in **Table 14-2**.

The results in **Table 14-2** show that the most effective option in reducing damages was the large central channel, closely followed by the caravan park levee. The vegetation management option also had a relatively substantial reduction in damages.

Formalisation of Town Creek only resulted in a minor reduction in damages, while the detention basin option had no real impact on flood damages.

Whilst the AAD is reduced to various degrees for different options, this reduction needs to be offset against the capital and recurrent costs of the option. This is investigated below.

Table 14-2 Average Annual Damage for Quantitatively Assessed Options

Option ID	Option	AAD	Reduction In AAD Due to Option
Existing	Existing Scenario	$166,142	-
F1	Birriley Street Raising and Culvert Upgrade	$164,534	$1,608
F5	Tarawal Street Levee	$166,028	$114
F6	Maleen Street & Briniwarr Street Levee	$122,061	$44,081
F14	Illaroo Road Levee	$165,944	$198
F21	Good Dog Creek Basin	$164,692	$1,450

14.3 Benefit Cost Ratio of Options

The economic evaluation of each modelled option was assessed by considering the reduction in the amount of flood damage incurred by various events and comparing this value with the cost of implementing the option.

The existing condition (or the 'do nothing' option) was used as the base case to compare the performance of modelled options. The PMF, 1% AEP, 2% AEP 5%AEP, 10% AEP, 20% AEP and 50% AEP events were considered for this evaluation. Preliminary costs of each option were prepared and a benefit-cost analysis of each option was undertaken on a purely economic basis.

Table 14-3 summarises the overall economics for each option that was able to be economically assessed. The indicator adopted to rank options on economic merit is the benefit-cost ratio (B/C).

The B/C ratio provides an insight into how the damage savings from an option, relate to its cost of construction and maintenance:

- Where the B/C is greater than 1 the economic benefits are greater than the implementation costs.
- Where the B/C is less than 1 but greater than 0, there is still an economic benefit from implementing the option but the cost of implementing the option is greater than the economic benefit.
- Where the B/C is equal to zero, there is no economic benefit from implementing the option.
- Where the B/C is less than zero, there is a negative economic impact of implementing the option.

Table 14-3 Summary of Economic Assessment of Management Options

Option	AAD	Reduction in AAD	NPW of Benefit *	Capital Cost	Recurrent Cost	NPW of Option *	B/C Ratio	Rank
F1	$164,534	$1,608	$22,192	$428,600	$7,500	$532,106	0.0	2
F5	$166,028	$114	$1,573	$131,100	$5,000	$200,104	0.0	5
F6	$122,061	$44,081	$608,351	$104,800	$5,000	$173,804	3.5	1
F14	$165,944	$198	$2,733	$209,600	$5,000	$278,604	0.0	4
F21	$164,692	$1,450	$20,011	$989,800	$10,000	$1,127,807	0.0	3

***** NPW – Net Present Worth is calculated using 7% interest over 50yrs.

It is noted that only Option F6 (Maleen Street & Briniwarr Street Levee) had a benefit cost greater than one. All the other options have benefit cost ratios that were effectively zero, indicating that construction costs substantially outweighed damage reductions.

The primary reason for this is that the frequency of inundation for most properties which experience overfloor flooding is quite low – generally only in events larger than the 2% AEP. As a result, the annualised damage savings of these events are relatively small. For instance, a saving of $100,000 in 1% AEP damages is reduced to a difference of $1,000 once the damages have been annualised.

14.4 Economic Assessment of Desktop Assessed Options

Where a desktop assessment was utilised for options (as opposed to hydraulic modelling), a detailed economic analysis was not undertaken. Instead, a judgement on the economic benefits of the options was made. This is described in **Section 15**.

15 Multi Criteria Assessment

Evaluating what constitutes an appropriate strategy for floodplain management is a significant analytical and policy challenge. Urban areas impacted by flooding are valued in a number of ways by communities, organisations and individuals. Impacts associated with flooding include risk to assets and risk to life. Such challenges have led to the exploration of alternative policy analysis tools, one being Multi Criteria Assessments (MCA). The goal of MCA is to attempt to directly incorporate multiple values held by stakeholders into the analysis of management alternatives while avoiding the reduction of those values into a standard monetary unit. In so doing, one can consider different floodplain management options in the context of economic criteria as well as other criteria such as social, political or environmental aspects. Stakeholders can also assign explicit weights to those values to reflect their preferences and priorities.

A Multi Criteria Assessment approach has been adopted for the comparative assessment of all floodplain management options identified within the Shoalhaven LGA using a similar approach to that recommended in the Floodplain Development Manual (2005). This approach uses a subjective scoring system to assess the merits of various options. The principal merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute "right" answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations.

15.1 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain as well as the community preferences. The scoring is based on a triple bottom line approach, incorporating economic, social and environmental criterion. The criterion adopted includes:

Economic	Benefit cost ratio
	Capital and operating costs
	Reduction in risk to property
Social	Reduction in social disruption
	Reduction in risk to life
	Community acceptance
	Council support
Environmental	Meeting of flow and water quality objectives
	Fauna / Flora

The scoring system is shown in **Table 15-1** for the above criteria.

Table 15-1 Details of Adopted Scoring System

Category	Category Weighting	Criteria	Criteria Weighting	Score				
				-2	-1	0	1	2
Economic	2	Benefit Cost Ratio	2	0 to 0.2	0.2 to 1	1	1 to 1.5	>1.5
		Capital and Operating Costs	1	Extreme >$2 million	High $500,000 - $2 million	Medium $200,000 - $500,000	Low $50,000 - $200,000	Very Low $10,000 - $50,000
		Reduction in Risk to Property*	1	Major increase in AAD	Slight increase in AAD	No Improvement	Slight decrease in AAD	Major decrease in AAD
Social	1	Reduction in Risk to Life	1	Major increase in risk to life	Slight increase in risk to life	No change in risk to life	Slight reduction of risk to life	Major reduction of risk to life
		Reduction in Social Disruption	1	Major increase in social disruption	Slight increase in social disruption	No change to social disruption	Slight reduction of social disruption	Major reduction of social disruption
		Council Attitude	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Community support	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Compatible with Policies and Plans	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
Environment	1	Compatible with Water Quality and Flow Objectives	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
		Fauna/Flora Impact	1	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit

* Values of likely AAD reduction assumed where actual assessment not undertaken

15.1.2 Economic Assessment Overview

The economic assessment involved an appreciation of:

- Benefit Cost Ratio;
- Capital and Operating Costs; and
- Reduction in Risk to Property.

Capital and operating costs for options were quantitatively assessed for the hydraulically modelled options, whilst a judgement of the likely capital and recurrent costs was made for the remaining options by experienced engineers.

It is noted that the Benefit Cost Ratio incorporates both the capital & operating costs, and the reduction in the Risk to Property. However, these are included to provide an overall measure of both the affordability of an option (the magnitude of the cost) as well as the overall benefit of the option. The Benefit Cost Ratio, while providing a representation of the economic efficiency of the option, does not provide this information.

15.1.3 Social Impact Assessment

The social impact assessment involved an appreciation of:

- Reduction in Social Disruption;
- Reduction in Risk to Life;
- Council Attitude; and
- Community Support.

In general, there is a high level of flood awareness in the community. The nature of the population in the area is such that the population is fairly stable with some growth expected. However, regardless of the awareness in the area, the social disruption due to flooding (via the effects of property inundation, loss of access and traffic disruption) remains present. Similarly, while there is an understanding of the potential for flooding, the reduction in the risk to life is an important criterion to be taken into account. This criterion is highly subjective as it is difficult to assess the behaviour of persons under extreme conditions such as flooding.

The community support for a particular option was derived by converting the community responses received in the consultation period into a numerical score. This will be updated following community workshops and exhibition of the draft report, and feedback from the community

The attitudes of Shoalhaven Council to different options were subjectively assessed based on discussions with representatives over the course of the study.

15.1.4 Environmental Assessment

The environmental impact assessment involved an appreciation of both:

- Compatibility of the option with Water Quality and Flow Objectives, and
- Fauna/flora impact.

It is important to recognise that the watercourses of the area need to be managed in a sustainable way, in recognition of the modified nature of the system.

15.2 Multi-Criteria Matrix Assessment

The assignment of each option with a score for each criterion is shown in its entirety in **Appendix D**. The score for each category (i.e. economic, environment and social) is determined by the score for each criterion, factored by a weighting as shown in **Table 15-1**.

The overall score for the option is then calculated by the weights for each of the categories.

It is noted that the economic category is given more weight than either the environment or social categories. This is due to the economic category being the most direct measure of both the effectiveness of the option on flooding as well as its affordability. Options that rank highly on environmental or social categories do not necessarily provide significant flooding benefits.

A rank based on the total score was calculated to identify those options with the greatest potential for implementation. The total scores and ranks are also shown in **Appendix D**.

Of the options investigated, the top three identified by the multi-criteria analysis were:

1. P 2 Building and Development Control Plans
2. P 1 LEP Update
3. P 8 Flood Proofing Guidelines

Of the structural options assessed, the top three identified by the multi-criteria analysis were:

1. F 6 Maleen Street and Briniwarr Street Levee
2. F 1 Birriley Street Raising and Culvert Upgrade
3. F 5 Tarawal Street Levee

However, an analysis of the benefits and costs arising from the structural options showed that only the first option delivered a benefit-cost ratio above one. The other options had ratios of 0.0, showing that the costs of implementing the option were significantly higher than the resultant reduction in damages. Consequently, aside from of the Maleen Street and Briniwarr Street levee, no other structural options are considered viable.

This ranking is proposed to be used as the basis for prioritising the components of the *Floodplain Risk Management Plan*. It must be emphasised that the scoring shown in **Appendix D** is not “absolute” and the proposed scoring and weighting should be reviewed at regular intervals to ensure they are still representative.

16 Floodplain Risk Management Plan

The results of the Floodplain Risk Management Study were used to form the Bomaderry Creek Floodplain Risk Management Plan (Cardno, 2015), which has been prepared as a supplementary document to this, this Floodplain Risk Management Study.

17 Conclusions

Shoalhaven City Council have commissioned Cardno to undertake a Floodplain Risk Management Study for the Bomaderry Township and its surrounds.

Flooding in the region can pose a hazard to some residents and properties near creeks and overland flowpaths. The purpose of this study was to identify and examine options for the management of flooding within the Bomaderry Creek catchment.

An assessment was undertaken on the number of properties to be affected by flooding under different frequency storm events, as well as an estimate of the appropriate economic damage for each event. The following table summarises these results.

Table i Flood Affected Properties and Damages under Existing Conditions

Flood Event	Properties with Over-floor flooding *	Properties with Over-ground flooding *	Flood Damage ($)
20% AEP	5	20	$394,821
10% AEP	8	22	$538,003
5% AEP	11	25	$959,948
2% AEP	15	32	$1,286,950
1% AEP	16	35	$1,652,618
0.5% AEP	19	40	$2,112,372
PMF	77	84	$7,559,141
Average Annual Damage			$166,142

Options to reduce or manage the effects of flooding in the catchment were investigated, and recommendations to manage the risks of flooding were developed. A number potential options for the management of flooding were identified using the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (NSW Government, 2005), and in consultation with the community, Council and state agency stakeholders.

These options included:

- Flood modification measures
- Property modification measures
- Emergency response measures

All potential options were assessed using a triple bottom (technical, economic, environmental and social). Hydraulic modelling of some of the flood modification options was undertaken to provide a comprehensive analysis of those options that would involve significant capital expenditure.

The assessment found, of the all the options investigated (including flood, property and emergency measures), the top three identified by the multi-criteria analysis were:

1. P 2 Building and Development Control Plans
2. P 1 LEP Update
3. P 8 Flood Proofing Guidelines

Of the structural options assessed, excluding the road raising options for emergency access only, the top three options identified by the multi-criteria analysis were:

1. F 6 Maleen Street and Briniwarr Street Levee
2. F 1 Birriley Street Raising and Culvert Upgrade
3. F 5 Tarawal Street Levee

This ranking is proposed to be used as the basis for prioritising the components of the Floodplain Risk Management Plan. It must be emphasised that the scoring is not “absolute” and the proposed scoring and weighting should be reviewed in light of any additional future information.

18 References

BMT WBM (2010), *Bomaderry Creek Flood Study,* prepared for Shoalhaven City Council

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