





Robertson Village Overland Flow Study Stage 1

Final Floodplain Risk Management Study and Plan

Wingecarribee Shire Council

September, 2016

WINGECARRIBEE SHIRE COUNCIL

Robertson Village Overland Flow Study – Stage 1

Final Floodplain Risk Management Study & Plan

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GLOSSARY OF TERMS

12D Model is a powerful terrain modelling, surveying and civil engineering software package used to develop the underlying surface for the 2D modelling.

Airborne Laser Survey (ALS) is a technique for obtaining a definition of the surface elevation (ground, buildings, power lines, trees, etc.) by pulsing a laser beam at the ground from an airborne vehicle (generally a plane) and measuring the time taken for the laser beam to return to a scanning device fixed to the plane. The time taken is a measure of the distance which, when ground truthed, is generally accurate to + 150mm.

Annual Exceedance Probability (AEP) is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.

Average Recurrence Interval (ARI) means the average statistical interval (in years) between occurrences of floods, storms and flows of a particular magnitude.

Australian Rainfall and Runoff (AR&R) refers to the current edition of Australian Rainfall and Runoff published by the Institution of Engineers, Australia.

CatchmentSIM is a 3D-GIS application specifically tailored to hydrology based applications. CatchmentSIM is used to delineate a catchment, break it up into sub catchments, determine their areas and spatial topographic attributes and analyse each sub catchment's hydrologic characteristics to provide insight into the rainfall response of various catchments and the resultant assignment of hydrologic modelling parameters.

Council refers to Wingecarribee Shire Council

Digital Terrain Model (DTM) is a spatially referenced three-dimensional (3D) representation of the ground surface represented as discrete point elevations where each cell in the grid represents an elevation above an established datum.

DRAINS is a software package is used to performs design and analysis calculations for urban stormwater drainage systems and models the flooding behaviour of rural and urban catchments. It has many applications, from sizing of single drainage pipes to complex analyses of large, established pipe drainage systems and catchments.

Floodplain Development Manual (FDM) and Guidelines (April 2005), the FDM is a document issued by DECCW that provides a strategic approach to floodplain management. The guidelines have been issued by the NSW DPE to clarify issues regarding the setting of FPL's.

Floodplain Risk Management Study and Plan (FRMS&P) refers to this report, which forms part of the "Floodplain Development Manual: the management of flood liable land", NSW Government 2005 (FDM, 2005).

Hydrograph is a graph that shows how the stormwater discharge changes with time at any particular location.

Hydrology The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

J. Wyndham Prince Pty Ltd (JWP) Consultant Civil Infrastructure Engineers and Project Managers undertaking these investigations

Peak Discharge is the maximum stormwater runoff that occurs during a flood event3

Probable Maximum Flood (PMF) is the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends." largest flood that could be

Triangular Irregular Network (TIN) is a technique used in the created DTM by developing a mass of interconnected triangles. For each triangle, the ground level is defined at each of the three vertices, thereby defining a plane surface over the area of the triangle

TUFLOW is a computer program that provides two-dimensional (2D) and one-dimensional (1D) solutions of the free surface flow equations to simulate flood and tidal wave propagation. It is specifically beneficial where the hydrodynamic behaviour, estuaries, rivers, floodplains and urban drainage environments have complex 2D flow patterns that would be awkward to represent using traditional 1D network models.

XP-RAFTS runoff routing model that uses the Laurenson non-linear runoff routing procedure to develop a sub-catchment stormwater runoff hydrograph from either an actual event (recorded rainfall time series) or a design storm utilising Intensity-Frequency-Duration data together with dimensionless storm temporal patterns as well as standard AR&R 1987

1 EXECUTIVE SUMMARY

J. Wyndham Prince has been commissioned by Wingecarribee Shire Council (Council) to prepare the "*Final Floodplain Risk Management Study and Plan*" for Robertson Village.

The overall objective of this study is to develop a flood study, preliminary floodplain risk management assessment as well as a flood and drainage master plan for Hoddle Street. The study addresses the existing, future and continuing flood problems, taking into account the potential impacts of climate change, in accordance with the NSW Government's Flood Policy. This report represents Phase 2 (Stages 3 and 4) of the "Floodplain Development Manual: the management of flood liable land" (FDM, 2005).

The report builds upon the findings of the Phase 1 works with a particular focus on identifying, reviewing and recommending the most feasible measures which will better manage the risk of flooding and its impact on life and property across the Village.

Recommendations are then made as to how the measures can be implemented, the cost estimated of these measures, and on potential modifications to Council's flood related policies required to ensure these measures fit seamlessly into Council's operation.

The key objectives of this FRMS&P include the following:

- Reduce flooding of Hoddle Street for events up to and including the 1% AEP.
- Reduction of the flood hazard and risk to people and property in the existing community.
- Prioritisation of proposed flood mitigation works in accordance with their importance focussing on those that can provide the greatest flood damage impact for the most economical construction cost.
- Prepare a risk management plan which is in a suitable format to be integrated into Council's existing business and strategic plans, emergency management plan and existing and proposed planning proposals.

Floodplain Risk Management Measures

A range of opportunities to improve the flood hazard and risk (along with the above objectives) have been identified and investigated. Consideration has been given to "flood modification", "property modification" and "response modification" measures.

Flood Modification Measures

The purpose of "flood modification measures" is to modify flood behaviour and to reduce the effects of flooding (i.e flood extents, levels or velocities) through the implementation of physical upgrades.

Due to the size and complexity of the study area, flood modification measures are proposed to be implemented across numerous locations to address historical and ongoing flooding concerns in the Village. Whilst these can be assessed in an overall model, it is important that the FRMS&P also considers each measure individually in order to better inform the decision making process.

The following scenarios have therefore been considered:

- Scenario A - Hoddle Street Option 1 (New Basin)
- Scenario B - Hoddle Street Option 2 (Culvert Crossing)
- Scenario C - Northern and Southern Upgrades
- Scenario D – Combination of Scenarios A, B and C

Scenario D includes a combination of each of the Scenarios (i.e Scenario A + Scenario B + Scenario C) being run as one management solution. It is noted that whilst Scenarios A and B may not provide the most economical benefits (in terms of the cost benefit analysis), they do target the primary objective of the study which is improving flooding at Hoddle Street.

Property Modification Measures

A review of the 1% AEP "High Hazard" areas within the Floodplain has been undertaken to identify those properties which are at risk of high hazard flows and should form part of a potential "voluntary house purchase acquisition" scheme.

Results of the assessment have identified that there are seven (7) dwellings across the study area, which are located within 5m of a "High Hazard" during the 1% AEP event. A further three (3) properties have been identified as potential properties, which could be acquired, and / or property owners negotiated with to obtain an easement in order to address local flood concerns.

There may be an opportunity to purchase these properties under a VHP scheme VHP schemes are often expensive and securing a funding for VHP can be difficult. More detailed study and analysis in relation to those properties are required for further consideration of this option.

Response Modification Measures

A review of the *Wingecarribee Local Flood Plan* confirms that Robertson Village lies within the limits of the local flood plan. A specific plan for Robertson Village is however not currently included in the current plan.

Information from the FRMS&P is consequently provided within Section 6.8 (including flood intelligence information, flood maps and summary of affected roads) for review by the NSW SES and for consideration for future updates to the Wingecarribee Local Flood Plan.

Floodplain Risk Management Plan

Results of the FRMS&P demonstrate that by adopting the proposed flood modification measures, the overall objectives of the study will be achieved. In particular, above floor flooding will be removed across fifteen (15) properties whilst Hoddle Street will not overtop during the 1% AEP event.

The capital cost of the FRMS&P is broken up into the following:

- Scenario A - Hoddle Street Option 1 (New Basin) - $1.64M
- Scenario B - Hoddle Street Option 2 (Culvert Crossing) - $1.07M
- Scenario C - Northern and Southern Upgrades - $0.51M
- Scenario D – Combined Upgrades (Scenario A, B and C) - $2.26M
- Voluntary House Purchase Scheme - ($3.8 – 4.76M)

By implementing Scenario D (combined upgrades), the damage savings would be around $4.75M, which results in an overall benefit – cost ratio of 2.11. Results therefore indicate that the costs of not doing the proposed upgrade works are greater than the cost of works across the assumed 50-year life cycle. (Note: Voluntary house purchase not included in the cost-benefit assessment).

Importantly, the upgrades at Hoddle Street also provides benefits by improving the flood affectation of Hoddle Street, but does not necessarily provide a tangible benefit (i.e removing damages).

As discussed in Section 10, the cost-benefit ratio for individual Scenarios (A, B and C) provides a further breakdown. For Scenarios A, B and C these include cost-benefit ratios of 0.8, 1.1 and 2.9 respectively in the 1% AEP event.

The implementation of the proposed measures will improve flood affectation and reduce the risks to property and life within the study area. The FRMS&P also provides sufficient technical details to support future funding applications and the required design processes for these mitigation works.

Post Exhibition

Prior to placing the Draft FRMS&P on exhibition, J. Wyndham Prince met with the Floodplain Risk Management Committee (20 June 2016) in Council chambers. The Draft FRMS&P was generally well received and subsequently was accepted to be listed on public exhibition.

Attendees at the meeting included representatives from DPE, NSW SES, Sydney Catchment Authority, multiple divisions of Council and several residents from the wider Wingecarribee community.

Several responses from the community were raised throughout the public exhibition period. Responses are included in Section 12.

Historical Flood Events

During the preparation of the FRMS&P, a heavy rainfall event occurred within the study area which resulted in a number of properties experiencing above floor flooding.

The TUFLOW model has been run for the historical rainfall event under “Existing” conditions with results generally consistent with those areas, which have been reported as being flooded by the community. This therefore provides further confidence in the flood modelling and supports the recommendations being made in the FRMS&P.

2 INTRODUCTION

J. Wyndham Prince has been commissioned by Wingecarribee Shire Council (Council) to prepare the "*Final Floodplain Risk Management Study and Plan"* for the Robertson Village, as shown on Plate 2.1 and on Figure 1.1 in Appendix A.

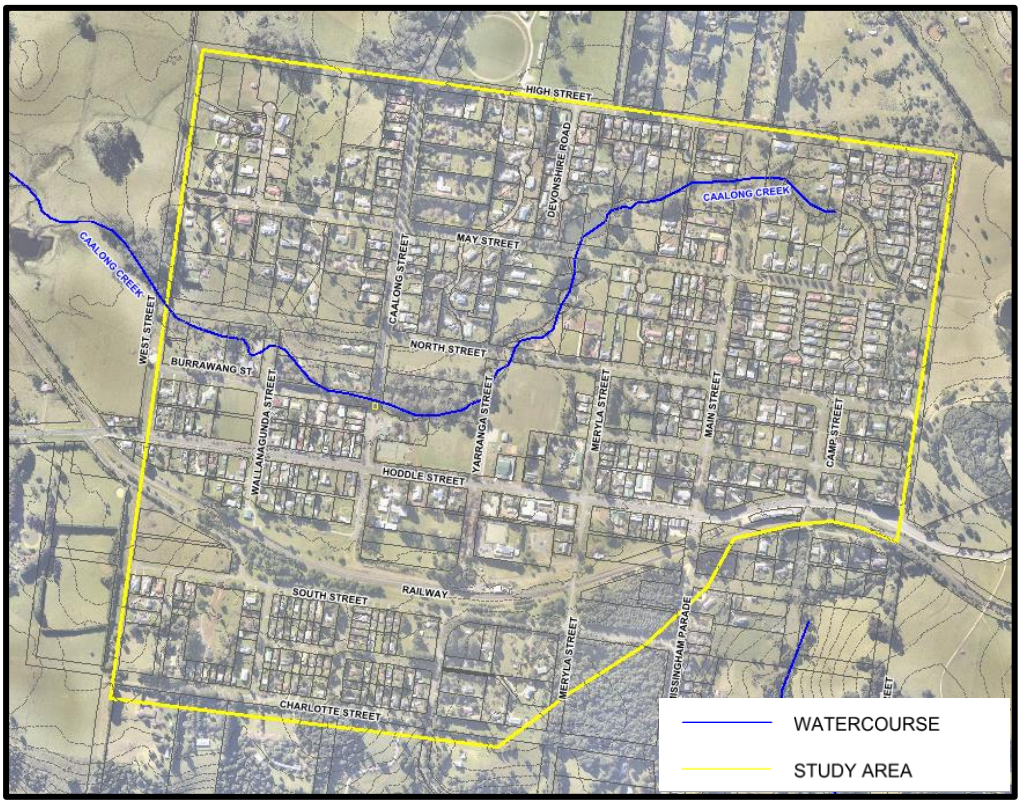


Plate 2.1 – Robertson Village Study Area

Robertson Village is located within the South - East part of Wingecarribee Shire and is situated in a very high intensive rainfall zone. The village lacks a comprehensive formal drainage system and instead consists of a series of overland flow paths, swales, open channels, drainage through roads and small length piped drains.

A particular focus of the assessment is in the vicinity of Hoddle Street (Illawarra Highway), which bisects the Village and is a hub for non-residential activity. Such facilities include the School of Arts hall, pre-school, primary school, community centre, recreation club, police station and commercial properties.

Hoddle Street is relatively flat through the western end of the study area (near the railway) and includes a sag - which is cut off by flood events as low as the 20% AEP. The drainage system at Hoddle Street is undersized and is generally limited to deep road side swales and small pipe crossings, which ultimately discharge to Caalong Creek via swales / flowpaths through residential properties.

The village is also bisected by Caalong Creek, which drains to Wingecarribee River and ultimately forms part of the Greater Hawkesbury - Nepean Catchment. The creek generally bisects through the rear of existing properties and includes remnants of Yarrawa Brush rainforest and woodland vegetation (which are important environmental features).

Mainstream flooding occurs across Caalong Creek and varies in width through each of the properties. The terrain on the northern side of Caalong Creek is typically quite steep and limits the extent of floodwaters, whilst there are areas on the southern side of Caalong Creek which are much flatter and consequently larger areas are susceptible to shallower floodwaters.

In addition to mainstream flooding along Caalong Creek and local flooding along Hoddle Street, there are also numerous local overland flowpaths which impact upon properties elsewhere in the catchment. Together, these flooded areas have the potential to impose flood risks to life and property. Thus Council and Department of Planning and Environment (DPE) are seeking to improve both infrastructure on the ground and Council's flood related policies in order to provide a safer "Robertson Village" for its residents.

2.1 Floodplain Risk Management Process

The primary objective of the New South Wales Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.

Through the Office of Environment & Heritage (OEH), the DPE and the State Emergency Service (SES), the NSW Government provides specialist technical assistance to Local Government on all flooding and land use planning matters. The "Floodplain Development Manual: the management of flood liable land", NSW Government 2005 (FDM, 2005) is provided to assist Councils to meet their obligations through the preparation of floodplain risk management plans. Figure 2.1 from the Manual, reproduced below, documents the process for plan preparation, implementation and review process.

The steps in the floodplain management process are summarised in Plate 2.2. This report presents the *Floodplain Risk Management Study and Plan* (FRMS&P) for Robertson Village.

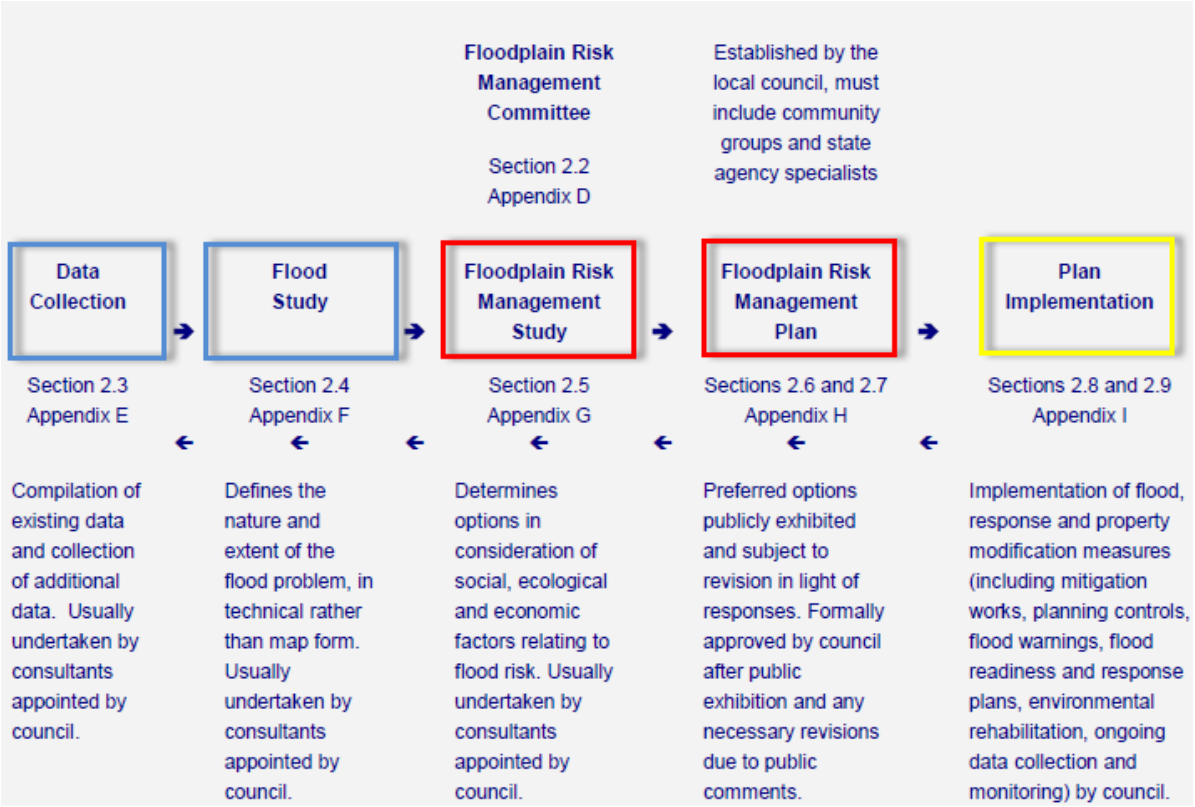


Plate 2.2 – Floodplain risk management process in NSW

Blue – Steps already completed by J. Wyndham Prince

Red - Steps undertaken in this study

Yellow – Future steps by Council

2.2 Study Objectives

Wingecarribee Shire Council is responsible for local planning and land management in the Caalong Creek catchment including the management of the floodplain and of the drainage system.

The overall objective of this project is to develop a flood study, preliminary floodplain risk management assessment as well as a flood and drainage master plan for Hoddle Street. The study is to address the existing, future and continuing flood problems, taking into account the potential impacts of climate change, in accordance with the NSW Government's Flood Policy, as detailed in the "Floodplain Development Manual: the management of flood liable land", New South Wales Government, April 2005 (the Manual).

A particular focus will therefore be to identify, review and recommend the most feasible measures which will better manage the risk of flooding to life and property within the Village.

The key objectives of the project include:

Phase 1:

Undertake a flood study to assess historical and existing conditions, with particular attention on the following:

- Identify possible ways to modify and/or upgrade existing drainage infrastructure to improve the flow capacity of the system.
- Develop strategies for flood mitigation within the catchment and for worst affected properties.
- Provide suggestions about future land uses, zoning and proposed lot sizes.
- Consult with State Emergency Services regarding emergency management issues.
- Undertake a sensitivity analysis to assess the influence of Climate Change.

Phase 2:

Undertake a review of Council's planning policies and long-term planning strategies for the study area. In particular, focus will be given to the following:

- Reduce flooding of Hoddle Street for events up to and including the 1% AEP.
- Reduction of the flood hazard and risk to people and property in the existing community.
- Prioritisation of proposed flood mitigation works in accordance with their importance focussing on those that can provide the greatest flood damage impact for the most economical construction cost.
- Prepare a risk management plan which is in a suitable format to be integrated into Council's existing business and strategic plans, emergency management plan and existing and proposed planning proposals.

2.3 Study Progress

The project is therefore divided into two (2) phases as follows:

- **Phase 1:** Undertake a Flood Study to assess flooding issues within the study area and also identify management options which are to be investigated as part of Phase 2.
- **Phase 2:** Prepare a Floodplain Risk Management Assessment and a Flood and Drainage Master Plan, to detail how flood prone land within the study area is to be managed.

Phase 1

J. Wyndham Prince has previously completed the *"Stage 1 – Data Collection, Review and Community Consultation"* (JWP, 2015a). As part of the Stage 1 works, a preliminary *TUFLOW* model was established based on supplied data to produce preliminary mapping. All responses from the community consultation were also summarised for consideration in the study.

The report was then updated to also include all additional details of the *"Stage 2 – Model Calibration and Validation"* (JWP, 2015b). As part of the Stage 2 information, the *TUFLOW* model was further validated and calibrated using detailed survey information and feedback provided by the community. A sensitivity assessment was also completed in order to document the potential impacts of Climate Change.

The "Flood Study" Report (JWP, 2016) was then finalised and included all Flood depth, Flood hazard and Flood Category mapping across each of the designated events (20%, 10%, 5%, 2%, 1%, 0.5% AEP and PMF events). A preliminary Flood Damage Assessment was completed across each of the modelled events with damage estimates based on assumed damage curves.

Phase 2

As part of Phase 2, J. Wyndham Prince issued a "Draft" FRMS&P report which presented recommendations of the flood and drainage masterplan.

The "Draft" report built upon the findings of the Phase 1 works with a particular focus on identifying, reviewing and recommending the most feasible measures which will better manage the risk of flooding across the Village.

The flood mapping and updated damages assessment generated in Phase 1 formed the base for the Option Assessment.

Recommendations were then made as to how the preferred measures can be implemented and any potential modifications to Council's Flood Related policies.

In July 2016, J. Wyndham Prince presented the findings of the Draft FRMS&P to the Floodplain Risk Management Committee and was subsequently endorsed by the committee.

The "Draft" FRMS&P report was subsequently placed on public exhibition in August 2016 with several responses provided by the community. Section 12 of this "Final" FRMS&P report includes discussion of the Post – Exhibition submissions.

A recent heavy rainfall event occurred on the 4 to 6 June 2016 which is understood to be close to a 20% AEP flood event, with several instances of flooding reported by the community. An assessment has subsequently been undertaken to model the historical rainfall event in order to provide confidence in the flood modelling results prepared as part of this study. Refer to Section 13 for further discussion.

3 DATA COLLECTION AND REVIEW

3.1 Review of Council's planning instrument / policies

A comprehensive review of all relevant Council policies, long term strategies, current and future land use zoning has been undertaken to fully understand constraints and opportunities across the study area.

The following Council policies (which are relevant to flooding and flood evacuation) have been reviewed to inform the development of mitigation options.

- *Robertson Village Precinct Plan – Wingecarribee Local Planning Strategy 2015 – 2031*
- *Robertson Village Development Control Plan (rev 4, September 2012)*
- *Council's Engineering Design Specification*
- *Council's Engineering Standards (Drawings and Notes)*
- *Wingecarribee Local Environment Plan (2010 Maps)*

The following Sections 3.1.1 to 3.1.5 summarise the key stormwater related items from the above related documents.

3.1.1 Robertson Village Precinct Plan – Wingecarribee Local Planning Strategy 2015 – 2031

In 2010, Council began the preparation of a new Local Planning Strategy for the Shire to replace the current Wingecarribee Our Future Strategic Plan *(2002)*.

At its Ordinary Meeting of 24 June 2015, Council resolved to place the draft Wingecarribee Local Planning Strategy 2015-2031 on public exhibition. This exhibition was completed and submissions considered.

At its Ordinary Meeting of 23 March 2016 Council resolved to adopt the draft Local Planning Strategy as amended post exhibition. The adopted Strategy has been finalised to incorporate those submissions which Council resolved to include in the relevant Precinct Plan. The adopted Strategy is now with the Department of Planning and Environment for endorsement.

Part Two of the *Wingecarribee Local Planning Strategy 2015 – 2031* details the *"Robertson Village Precinct Plan"*.

The Robertson urban area is contained within the red boundary shown on Plate 3.1.

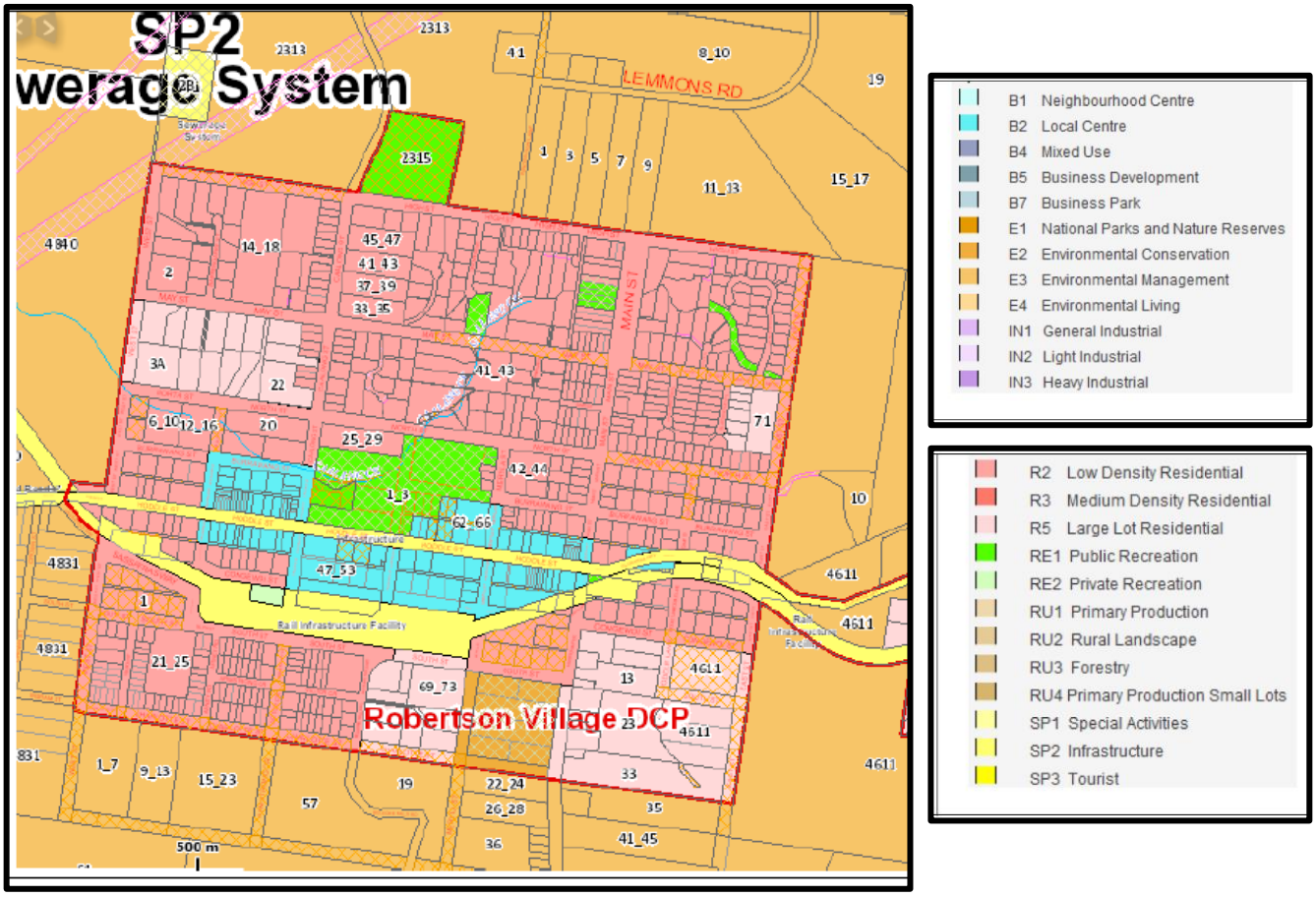


Plate 3.1 – Floodplain risk management process in NSW

The key features relevant to this FRMS&P include the following:

- In 2010 and 2011 a series of workshops were held across all towns and Villages (including Robertson Village). The purpose of the workshops was to obtain feedback from participants as to what they considered to be the current strengths and weaknesses of their locality and what they perceived to be the main opportunities and threats for the future.
- Some 40 property owners attended the Robertson workshop on 12 August 2010 at the St John's Church Hall. The comments relevant to the FRMS&P include:

  Strength

  - Lifestyle – village atmosphere, friendly, safe, rural, large blocks of land.
  - No floods or bushfire threats.

Weaknesses

- Poor pedestrian and bikeway facilities around village - Lack of pedestrian access, particularly across the creek and railway line.
- Lack of pedestrian and cycle ways around the village.
- Poor access across the railway line is a particular problem for children going to school.
- Village has developed a 'suburban' look, especially since the paved footpath, with lines, was put in.
- Poor stormwater management, particularly around the school.

- The weather – it is often wet and windy.

Opportunities

- Make the village more attractive and connected with a real 'focus'.
- Make the main street more attractive.
- Develop main street as a green, tree-lined pedestrian area with shops, cafes etc.
- Walking and cycling paths to better connect the village and provide interest for tourists.
- Foot bridge over Caalang Creek.

- In 2014 Council began working with the Robertson community as part of the Our Village Our Future initiative. The purpose of the initiative is to establish a vision for the village, and use existing strengths within the village to devise tangible actions to work towards achieving this vision.

  One of the suggestions from the community was to improve access across Caalong Creek. Council has implemented one of these requests and have recently completed the Caalong Street Bridge upgrade in late 2015.

3.1.2 Robertson Village Development Control Plan (rev 4, September 2012)

Section 4 of the *Robertson Village DCP* entitled "Flood Liable Land" outlines the context, background and controls which are applicable to land affected by flooding (flood liable or flood prone land) within the Village.

The policy is based upon the State Government's Flood Prone Land Policy and the FDM. Importantly, it will form the basis of the review and update as part of this FRMS&P.

The objectives of the DCP are to:

- Increase public awareness of the hazard and extent of land affected by all potential floods, including floods greater than the 100 year average recurrence interval (ARI) flood and ensure essential services and land uses are planned in recognition of all potential floods.
- Inform the community of Council's policy for the use and development of flood prone land.
- Manage the risk to human life and damage to property caused by flooding through controlling development on land affected by potential floods.
- Provide detailed controls for the assessment of applications lodged in accordance with the Environmental Planning and Assessment Act 1979 on land affected by potential floods.

The following chapters are included in Section 4 of the DCP:

- Requirements and Controls
  - How to determine compliance
  - Flood Risk Precincts
  - Land Use Categories
- Controls for General Development
- Controls for Fencing on Flood Liable Land
- Controls for Overland Flow

- Information Requirements
- Terms Used in Section of the Plan (including flood compatible materials)

Each section has been reviewed as part of this FRMS&P with recommendations provided in Section 6.7.3.

3.1.3 Wingecarribee Shire Council's Engineering Design Specification

Council's "*Development Design Specification Stormwater Drainage Design"* (WSC, 2016) provides guidelines for the requirements for stormwater drainage and civil works.

The overall objective of this policy is to achieve an optimum environment in the context of the principles and guidelines of the total stormwater management plan and as such the provision of storm water drainage systems shall achieve the following objectives:

- To provide safety for the public
- To minimise and control local and catchment flooding
- To stabilise landform and control erosion and sediment
- To minimise the impact of urban runoff on receiving waters by retaining within each catchment as much catchment and as much incident rainfall as possible and appropriate for the planned use and the characteristics of the catchment.

Refer to Appendix B for further details.

3.1.4 Wingecarribee Shire Council's Engineering Standards (Drawings and Notes)

Council's guidelines includes specifications and drawings for a number of features, these include (but are not limited to):

- Stormwater Drainage General C220
- Pipe Drainage C221
- Precast Box Culverts C222
- Drainage Structures C223
- Open Drains including Kerb and Gutter C224

3.1.5 Wingecarribee Local Environment Plan (2010)

The *Wingecarribee Local Environmental Plan* was developed by Council in 2010 and was recently updated on the 11th March 2016.

The Flood planning items are addressed in Section 7.9 and are summarised below. **Importantly, it is noted that the Flood Planning Area denoted on the plans do not cover the study Area.** These maps are generally limited to those areas surrounding Mittagong and Moss Vale. As discussed in Section 6.8, this assessment may allow for future revisions to include a map to be included for Robertson Village.

- **7.9 Flood planning**

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

  - to minimise the flood risk to life and property associated with the use of land,
  - to allow development on land that is compatible with the land's flood hazard, taking into account projected climate change,
  - to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

- land that is shown as "Flood Planning Area" on the Flood Planning Area Map, and
- other land at or below the flood planning level.

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

- is compatible with the flood hazard of the land, and
- will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and
- incorporates appropriate measures to manage risk to life from flood, and
- will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and
- will not be likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

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

(5) In this clause:

- **flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metres freeboard.
- **Flood Planning Area Map** means the Wingecarribee Local Environmental Plan 2010 Flood Planning Area Map.

3.2 NSW Flood Related Policies and Planning Controls

In addition to Council's standard planning instruments and policies, there are a number of State and NSW Flood Related Policies and Planning Controls which are considered when informing the FRMS&P. A general description of the key controls in each of these policies are summarised in the following sections.

3.2.1 (Exempt and Complying Development Codes) 2008

The State Environmental Planning Policy (2008) defines those developments which are permitted to be "exempt" from obtaining development consent.

The policy defines 'Flood Control Lots' as those properties where 'flood-related development controls apply'. In particular, these lots will require a notation on its Section 149 Certificate. Such controls are generally specified in a Council DCP or LEP.

Flood control lots have not been defined within this FRMS&P, however sufficient information is provided to inform the future definition of flood control lots based on hazard and risk categories.

3.2.2 Floodplain Development Manual (2005)

In 2005, the *"Floodplain Development Manual"* (FDM) was released to provide guidance on the development of flood liable land.

The FDM encompasses the NSW Flood Prone Land Policy, which aims at reducing the impacts of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods.

The FDM suggests that a merit based framework be undertaken to assist with floodplain risk management and indicates that the responsibility for the management of flood risk remains with local government. The FDM provides clear guidance for Council for the management of flood prone land including guidance on how to develop and implement local floodplain risk management plans.

3.2.3 Guidelines on Development Controls in Low Flood Risk Areas, 2007

In 2007, the *"Guidelines on Development Controls on Low Flood Risk Areas – Floodplain Development Manual"* was released to be read in conjunction with the FDM.

The guidelines provided additional guidance on how flood planning levels (FPL) and flood related development controls on residential development in low flood risk areas should be determined.

The guidelines have recognised the need to consider the full range of flood sizes, up to and including the Probable Maximum Flood (PMF) and the risks associated with each flood.

3.2.4 NSW State Flood Plan (2008)

The NSW State Flood Plan (NSW SES, 2008) is a sub-plan of the State Disaster Plan. The Plan sets out the emergency management aspects of prevention, preparation, response and initial recovery arrangements for flooding. It also sets out the responsibilities of agencies and organisations with regards to these functions.

3.2.5 Wingecarribee Shire Local Flood Plan

The *"Wingecarribee Local Flood Plan"* (SES, 2010) is a sub-plan of the *Wingecarribee Shire Local Emergency Management Plan* (EMPLAN).

The plan covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the Wingecarribee Shire Council Area. These areas include Mittagong, Bowral, Moss Vale and a number of smaller towns and villages.

A review of Map 1 of the plan confirms that Robertson Village lies within the limits of the Local Flood Plan. A specific plan for Robertson Village is however not currently included.

The Local Flood Plan outlines the general responsibilities of emergency services organisations and support agencies, whilst specifically setting out:

- **Preparedness**
- **Response**
- **Recovery**

Key features of the Local Flood Plan includes:

- The Wingecarribee Shire consists of rugged country in the north-west, north-east and south, and low-lying or undulating country in its central portions.
- The Wingecarribee River is recognised as the primary tributary within the Shire which rises near Robertson and flows in a westerly direction past Moss Vale and Bowral and through Berrima.
- Flood-producing rains can occur over all of these catchments and at any time of the year. They can be caused by severe thunderstorm activity or by the passage of frontal systems. Most floods have occurred soon after short, sharp bursts of rain falling within the council area, but floods on the Wollondilly River proper may emanate from areas well to the south and take longer to rise. Most thunderstorm

activity is in the summer months, frontal systems being more common in winter. Much of the flooding which affects the Shire, particularly its more populated areas, is 'flash' flooding

Preparedness

- Establish and maintain floodplain risk management committees and ensure that key agencies are represented on such committees.
- Provide levee studies, flood studies and floodplain management studies to the NSW SES.

Response

- Close and reopen council roads (and other roads nominated by agreement with the RMS) and advise the NSW SES Wingecarribee Shire Local Controller and the Police.
- A key feature of the study includes the Preparedness and the willingness to maintain the plan. There is opportunity to:
    - review the content "when new information from flood studies become available"
    - SES to participate in local floodplain risk management committee activities when committees are formed
- Flood Intelligence which describes flood behaviour and its effect on the community can be provided to inform a review of the plan
- Available information about the estimated impacts of flooding at different heights can be provided to inform development of warning systems.
- Annexure A summarises the "Effects of flooding on the community" are included for affected areas such as Bowral and Berrima. It is also recognised that "very heavy rainfalls can produce sudden-onset short-duration stormwater flooding at Hilltop, East Bowral and Moss Vale, where the Illawarra Highway (Argyle St) can be cut".

3.3 Survey Works

The project surveyor (Tim Scully and Associates) has completed field work for Phases I – III and has prepared a series of detailed survey plans which have been submitted separately to Council.

4 COMMUNITY CONSULTATION

In August 2015, the community at Robertson was invited to contribute to the *Robertson Village Overland Flow Study* by providing any historical records such as photographs and completing a questionnaire.

A summary of the responses and photographs are included in Appendix C with a figure also included to demonstrate the location of each recorded response.

The following key items were identified by residents as part of the consultation process:

- Since the pipe upgrade has replaced the channel outside the school, Caalong Street floods whenever it rains and children cannot jump off the bus to attend school.
- Robertson is generally exposed to high intensity rainfall.
- Several instances of flooding were reported at Hoddle Street around the railway crossing in August 2006, May to June 2007, April 2008 and in 2011.
- Flooding has been observed to overtop the wooden bridge along Caalong Creek. In June 1991, the Caalong Street culvert crossing was overtopped with 34 inches of rain in 5 days (It should be noted that this bridge has now been reconstructed).
- There was some concern on whether a flood study was undertaken prior to the new bridge being constructed and why a flood study has not been previously undertaken.
- Concerns were also raised over the road levels along Caalong Street being higher than adjacent private properties, which directs water into the properties.
- Natural springs are noted to occur throughout Robertson.
- There is some concern of blockages from debris along Caalong Creek. In particular, willow and blackberry clogging and silting up the creek along with weeds.
- Several reports were made in regards to overland flow through properties and localised nuisance flooding issues. In particular,
    - 12 Devonshire Road has provided video evidence of “flash flooding” through the backyard, onto the terrace which almost enters the house. See Plate 4.2.
    - 2 Coachwood Place has provided photographic (and a sketch) showing overland flow through the backyard. See Plate 4.3.
- 58 – 60 Hoddle Street has been flooded around ten (10) times in ten (10) years with water entering the building beneath the glass doors. Flood mitigation works carried out on Hoddle Street and on the driveway has helped and this has not happened since.
- Concerns were raised over evacuation routes (flooding, fire or major emergency) and the planning associated with access to and from the township.

Plate 4.1 – Hoddle Street Drainage

Plate 4.2 – Overland Flow in Properties (2 Coachwood Place)

Plate 4.3 – Overland Flow in Properties (12 Devonshire Place)

Fifty Two (52) questionnaire responses, photographs and video evidence which have been received from the community provides a reasonable understanding of the key issues which affect the community and gives a better understanding of the significant events / issues which historically have occurred across the study area.

The feedback from the community has been carefully considered to ensure that the flood model is as accurate as possible. In particular, flood results have been compared against observations and against empirical estimation techniques to replicate the flood impacts.

4.1 Liaison with Key Stakeholders

J. Wyndham Prince has contacted several key stakeholders to gain feedback on the study.

4.1.1 Sewer and Water (Council)

Council have confirmed the following:

- *Sewer network was constructed in 2013 so there shouldn't be any need to upgrade or renew in the near future.*
- *Some parts of the water network were installed before 1980 and may require upgrade or renewal, however nothing has been identified for renewal in the next 5 years in Robertson.*
- *There is a sewer pump station at the western end of Burrawang St which collects all the sewage from Robertson town and pumps it to the STP to the north.*
- *A copy of the work as executed drawings for the pump station and rising main is supplied.*
- *Any future alignment of a channel in the vicinity of the STP shall be discussed with Council's sewer / water.*

It is therefore recommended that the future implementation of the Final FRMS&P be discussed with Council's internal departments.

4.1.2 Planners (Council)

Council have confirmed the following:

- *The draft Local Planning Strategy, of which the Robertson Precinct Plan is a part, is due for adoption March or April this year (2016). There are no proposed land use changes for Robertson.*

4.1.3 Railway (Australian Rail Track Corporation - ARTC)

The study area is bisected by a railway line which is owned by the Australian Rail Track Corporation (ARTC). There is a number of crossings under the railway line with flows directed through the township. Most notably, where the Railway line intersects with Hoddle Street (Illawarra Highway) there is a large amount of ponding which is then directed to the East (along the Highway) via 2 x 600 dia pipes to the sag in the township.

Contact has been made with ARTC to confirm the following:

- *Whether there are any proposed upgrade works in the region? so that these may be considered in the development of options*
- *If there is opportunity to amplify the drainage (where the Railway Line intersects Hoddle St) to reduce flood impacts by extending to the channel to the North-East. Was this option ever considered in the past?*
- *Culvert crossings which have been identified under the Railway Crossing are circled on plan. Are any other assets in the area?*

No formal response has currently been received. It is recommended that further liaison be undertaken with ARTC as part of the future implementation of the Final FRMS&P and detailed design.

4.1.4 Major Roads (Roads and Maritime Service - RMS)

The study area is bisected by Hoddle Street (Illawarra Highway), which is understood to be owned by the Roads and Maritime Service (RMS) Existing Flood results show that the highway is inundated during even the smallest rainfall events.

Contact has been made with RMS to confirm the following:

- *If there are any proposed road or structure upgrade works in the region? so that these may be considered in the development of options for the town.*
- *The heavy vehicle use of the highway and possible costs which may be associated with any proposed disruption to the Highway.*

No formal response has currently been received. It is recommended that further liaison be undertaken with RMS as part of the future implementation of the Final FRMS&P and detailed design.

4.1.5 NSW State Emergency Service (SES)

Preliminary discussions (phone conversation dated 24th May 2016) with the SES confirm that Robertson is not traditionally recognised as a known flooding area since it is located in the upper reaches of the Wingecarribee River. Instead those downstream areas such as Bowral, Moss Vale and Berrima are generally impacted due to the steep side slopes along the watercourses. Notwithstanding any additional flood information is always welcomed to improve the preparedness and potential updates to the Local Flood Plan.

Refer to discussion in Section 6.8.

5 FLOOD MODELLING (EXISTING)

An essential part of the Floodplain Risk Management Process is the preparation of the "Flood Study", which includes mapping of the existing flood behaviour across the full range of AEP events and the PMF.

In March 2016, J. Wyndham Prince finalised the flood study report and submitted to Council and DPE for endorsement. Details of the flood study included all flood depth, flood hazard and flood category mapping across each of the designated events (20%, 10%, 5%, 2%, 1%, 0.5% AEP and PMF events). A preliminary flood damage assessment was also performed across each of the events with damage estimates based on assumed damage curves.

The assessment of mainstream and overland flows was undertaken within *TUFLOW* software. *TUFLOW* has the ability to record peak flows, peak velocities and duration of overland flows via "Plot Output Lines" (PO) at key locations throughout the study area.

TUFLOW Flood mapping results were provided in order to identify those properties and critical infrastructure which are at risk of flooding. Results clearly demonstrated the impacts / risks of flooding across the catchment to inform development of suitable management/mitigation strategies as part of Phase 2 investigation.

The following Sections 5.1 to 5,2 are included in this report to provide a summary of the key findings which are used to inform the FRMS&P. For further details and flood mapping, reference should be made to the full report entitled "*Robertson Village Overland Flow Study Stage 1 - 3 Report"* (JWP, 2016).

A copy of the "Existing" flood depth and velocity maps for the full range AEP events (20% AEP to PMF) is included in Volume 2. Refer to Figures 4.8 to 4.41. For further details and flood mapping, refer to the full report entitled "*Robertson Village Overland Flow Study Stage 1 - 3 Report"* (JWP, 2016)

5.1 Model Development

The "Existing" Condition *TUFLOW* model was established based on Council's supplied LiDAR, GIS information and detailed survey information using the "direct rainfall" modelling approach (which includes rainfall being applied directly to the grid).

Model development considered the following:

- **Terrain** - The TUFLOW model included comprehensive surface information along Caalong Creek and Hoddle Street (prepared by Tim Scully Surveyors) which included the definition of road side swales and pit / pipe networks in the vicinity of Caalong Street, Hoddle Street and Yarrunga Street (including all driveway crossings and street drainage).
- **Farm Dams** – Farm Dams and associated structures have the potential to significantly affect flood extent mapping and floodway definitions (i.e due to depression storage).

  For the purpose of modelling, the water level in the dams have therefore been artificially filled to the spillway height for the storm durations assessed. Provision is also made for those flows from the embankment crest to be conveyed to the downstream channel.
- A large online dam with formal spillway was located along Caalong Creek, which has the potential to significantly affect flood extent mapping and floodway definitions (i.e due to depression storage). For the purpose of this study, the water level in the dam has been artificially filled to the spillway height of RL 734.77 m AHD.

- **Bridge Crossing** - The recently constructed bridge crossing at Caalong Street (across Caalong Creek) was modelled based on the detailed survey and included as a 1D channel with flows in excess of the bridge's capacity allowed to spill into the 2D domain. All details were based on site observations and detailed survey information.

Plate 5.1 – Caalong Street Bridge Crossing

- **Cross Sections** - As part of the detailed survey works, floodway sections were at regular intervals along Caalong Creek. A review of these cross sections was made against the LiDAR DTM surface and was found to be generally consistent.

  Given the meandering nature of the creek and the consistency of the LiDAR data with the surveyed cross sections, the 2D modelling approach was therefore adopted as it provides a realistic representation of flood behaviour.

5.1.1 Hydrology Modelling

A hydrological model was developed within *XP-RAFTS* to determine peak flows at key locations in order to provide confidence in flood modelling results.

The overall catchment area draining to Caalong Creek was determined at 305 Ha and divided into 17 sub-catchments using Catchment SIM software (refer to Figure 4.5) These upstream catchments draining to Robertson include residential areas to the South of the railway line, West of the railway crossing along Hoddle Street and rural pastures to the North and East. Refer to the general layout in Plate 5.2.

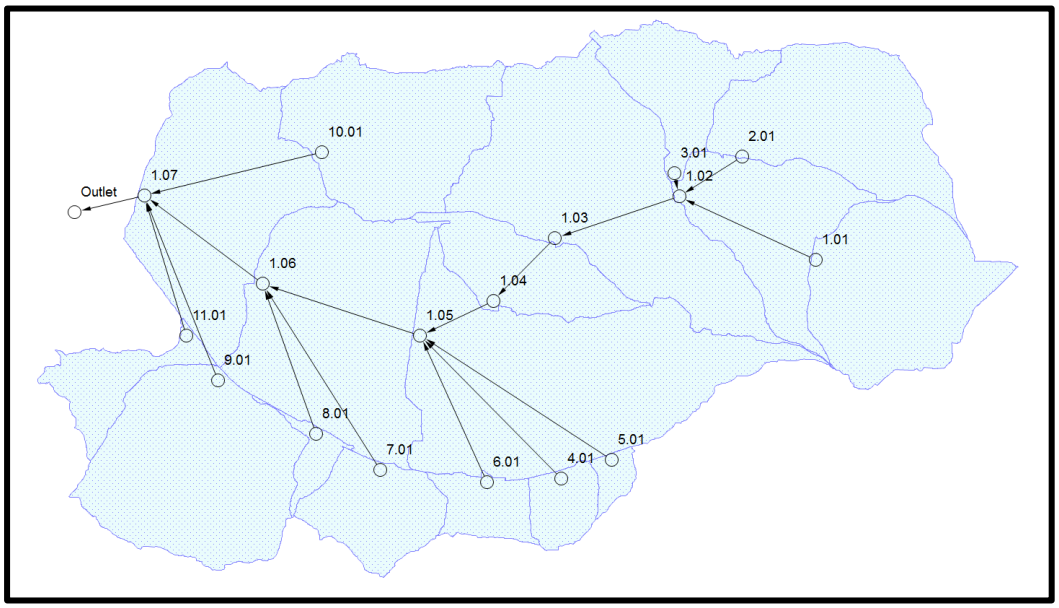


Plate 5.2 – XP-RAFTS General Layout

Results demonstrate that the critical duration of the 1% AEP event exiting the model (at Node 1.07) is the 120 minute duration with a peak flow estimated at 109 m^3/s.

5.1.2 Model Calibration

The Flood Study included model calibration between the *TUFLOW* and *XP-RAFTS* models, to provide confidence in the flood modelling results.

A comparison of peak hydrographs was completed between the *XP-RAFTS* and the Stage 1 (preliminary) and Stage 2 (calibrated) *TUFLOW* results (refer Plate 5.3). Peak flow results for the three (3) models are provided in Table 5.1 indicate that:

Table 5.1 – Peak Flows at Model Outlet (1% AEP 120 min storm event)

XP - RAFTS	Stage 1 TUFLOW	Stage 1 TUFLOW (Calibrated)
110.02	109.33	110.540

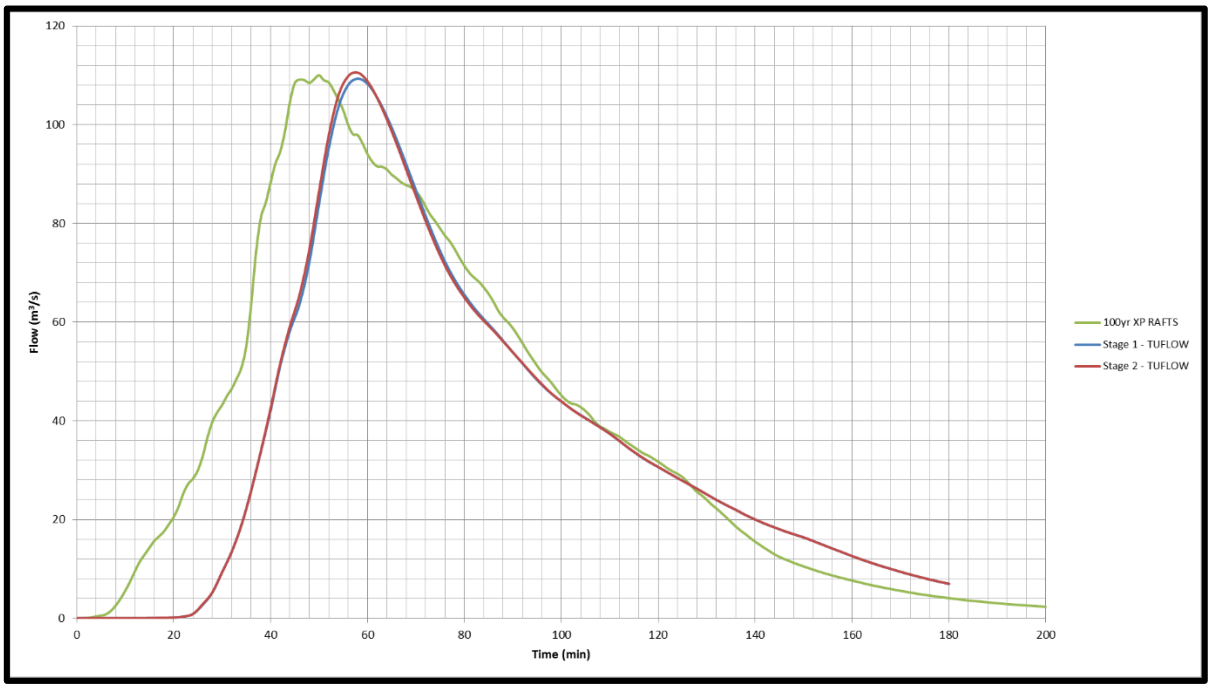


Plate 5.3 – 1% AEP Hydrograph Comparison at Model Outlet

Results demonstrated a similar hydrograph shape and peak flows between the three (3) models, with peak flows exiting the calibrated *TUFLOW* model varying 0.5% from the *XP-RAFTS* model in the Stage 2 assessment.

Notwithstanding, *TUFLOW* results indicate that there is a greater delay in stormwater runoff at the beginning of the storm event. In particular, *XP-RAFTS* results indicate that flows commence around 7 minutes into the event whilst *TUFLOW* results show no runoff until approximately 25 minutes into the event.

Results from the calibration assessment indicate that the *TUFLOW* and *XP-RAFTS* models are generally consistent, with some minor variability in catchment timing (i.e the time to peak in *XP-RAFTS* is around 53 min and the time to peak in *TUFLOW* is around 58 min into the event). Notwithstanding, the similar hydrograph shapes and peak flows indicate that the flood model provides a representative flow for the catchment and study area.

5.1.3 Model Sensitivity

A series of sensitivity assessments was also undertaken for the 1% AEP storm event in order to assess the impact of varying modelling parameters in the *TUFLOW* model. The sensitivity assessments have determined peak flood heights and flows in Caalong Creek event in the 120 min storm event. The sensitivity assessments undertaken in the *TUFLOW* model include:

- **Climate Change** – Assessment upon the impact of climate change by increasing rainfall intensities across the catchment by 15% in the 1% AEP event.
- **Sensitivity 1** - Increasing the material Manning's 'n' roughness of general surface types by 25% (refer Table 5.2).
- **Sensitivity 2** - Decreasing the material Manning's 'n' roughness of general surface types by 25% (refer Table 5.2).

Table 5.2 – *TUFLOW* Manning's 'n' Sensitivity Assessments

Surface	Base Model	25% Increase Manning's 'n'	25% Decrease Manning's 'n'
Rural Pastures / Default Floodplain	0.05	0.063	0.038
Road pavement	0.013	0.013	0.013
Open Space (grass only)	0.035	0.044	0.026
Railway Embankments	0.04	0.05	0.03
Residential	0.04	0.05	0.03
Commercial / Industrial	0.03	0.038	0.023
Light Vegetation	0.05	0.063	0.038
Medium Vegetation	0.08	0.1	0.06
Average material along creek	0.045	0.056	0.034
Buildings	Depth Varying	Depth Varying	Depth Varying
Water body	0.02	0.02	0.02
School	0.03	0.03	0.03

A comparison of peak hydrographs was completed between the sensitivity assessments and the Stage 2 (calibrated) *TUFLOW* model (refer Plate 5.4), which demonstrates the impact on flows in Caalong Creek under the different scenarios.

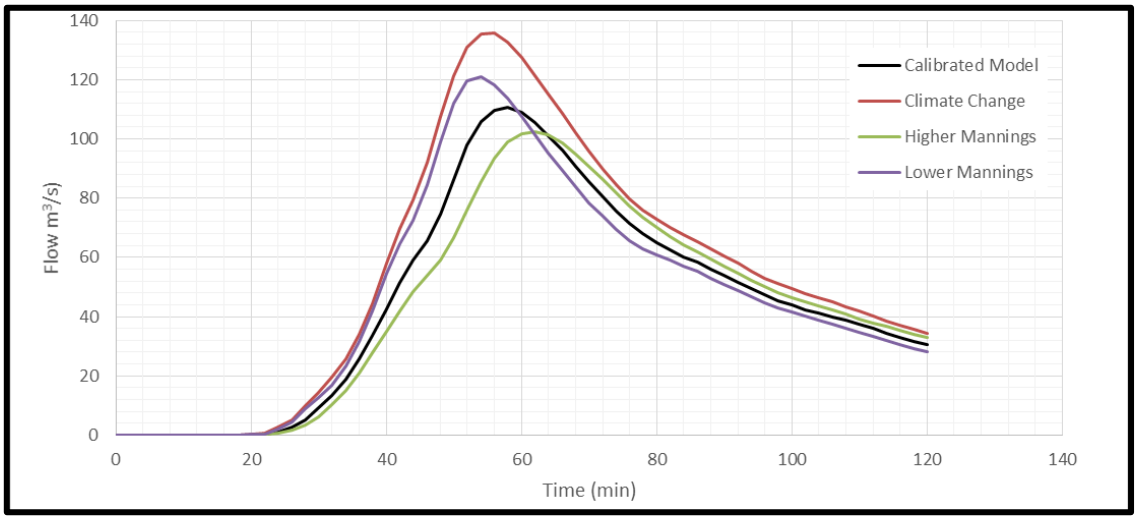


Plate 5.4 – 1% AEP Hydrograph Comparison at Model Outlet

TUFLOW Flood mapping for the 1% AEP sensitivity assessments was undertaken with flood difference maps demonstrating the impact on each sensitivity assessment on peak water surface levels.

Importantly, each of the sensitivity assessment results demonstrate that that the *TUFLOW* model is behaving sensibly. In particular, during the climate change assessment, depths are increased along Caalong Creek and within isolated reaches (refer Figure 4.7).

By introducing the "higher Manning's" values in Scenario 1, there is a greater resistance to flows and therefore flood depths along Caalong Creek are generally increased due to its impact upon the coincidence of flooding. Whilst with the "lower Manning's" values in Scenario 2, there is less resistance to flow and therefore flood depths along Caalong Creek are generally decreased.

The sensitivity analysis therefore shows a close comparison of results and provides confidence in its accuracy.

5.2 Flood Modelling Results

The "Existing" condition *TUFLOW* was run for each of the design runs specified in the brief (20%, 10%, 5%, 2%, 1%, 0.5% AEP and PMF events). These results form the "base case" for the option assessment under the FRMS&P.

Figure 4.3 in Appendix A demonstrates the overall "Existing" flood depth and height contours for the 1% AEP event.

A copy of the "Existing" flood depth and velocity maps for the full range AEP events (20% AEP to PMF) is included in Volume 2. Refer to Figures 4.8 to 4.41. For further details and flood mapping, refer to the full report entitled "*Robertson Village Overland Flow Study Stage 1 - 3 Report"* (JWP, 2016)

The following observations were made in the Flood Study:

- Flooding is evident along Hoddle Street across the full range of AEP events. Most notably, the ponding observed during the 1% AEP at the intersection of Sassafras Way with Hoddle Street (near the Railway line) is also shown to occur across the full range of AEP events.

  During the 20% AEP, the sag in Hoddle Street is overtopped with the westbound lane being inundated by between 0.1 - 0.35m, whilst the eastbound lane is inundated by < 0.05m. The corresponding depths in the road side swale vary up to 1.25m deep.

  The full range of design runs demonstrate that the larger AEP events continue to further inundate Hoddle Street (Illawarra Highway) until the entire road width is cutoff.

  The Westbound lane is cutoff during the minor 20% AEP event. Whilst the Eastbound lane reaches a flood depth of around 0.08 – 0.1m during the 1% AEP event at the sag. Further details are provided in Plate 5.5.

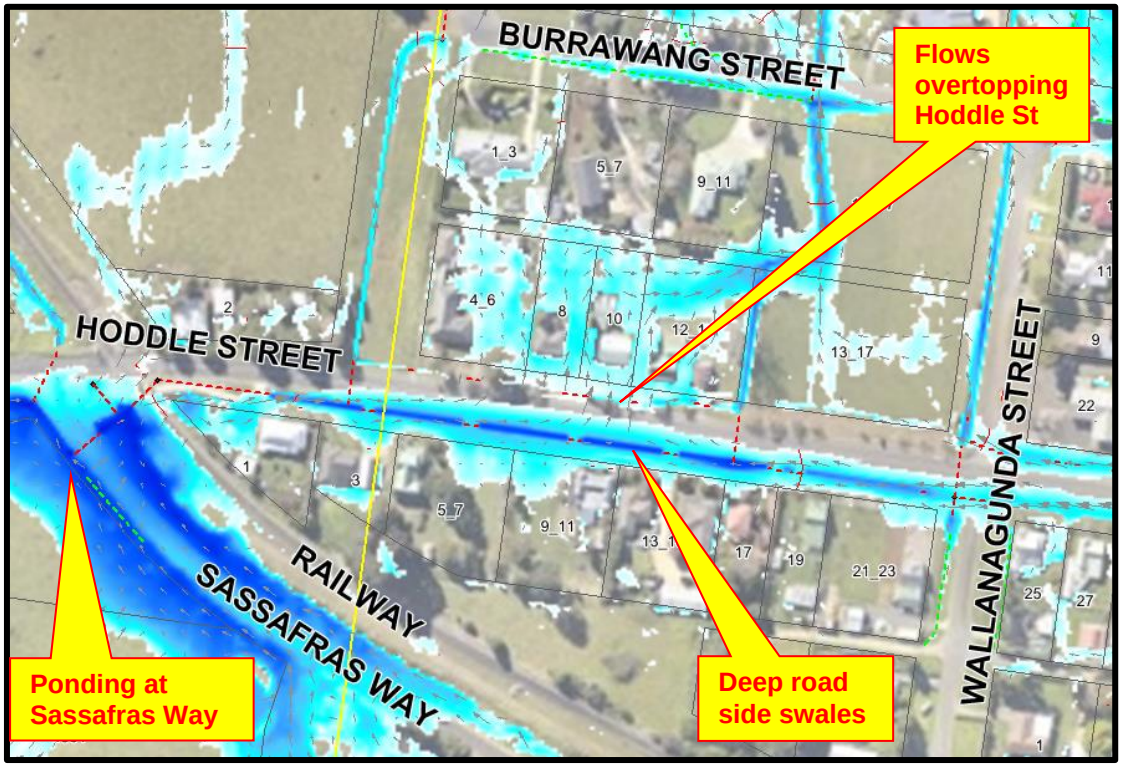


Plate 5.5 – Hoddle Street West (20% AEP)

- Widespread flooding is observed to overtop the existing channel and enter properties between Caalong Street and Wallanagunda Street (near the School) across a range of AEP events. These flows are generated from the large catchments to the South (to the south of the Railway line).

  The large upstream catchment contributes to flooding along Hoddle Street, and in particular where there is no existing pit and pipe network. Similar to the abovementioned sag location, the Westbound lane is also inundated by up to 0.45m during the 20% AEP. The Eastbound lane would then also be cutoff in larger events with 0.1m depth occurring across the lane in the 10% AEP. Further details are provided in Plate 5.6 below.

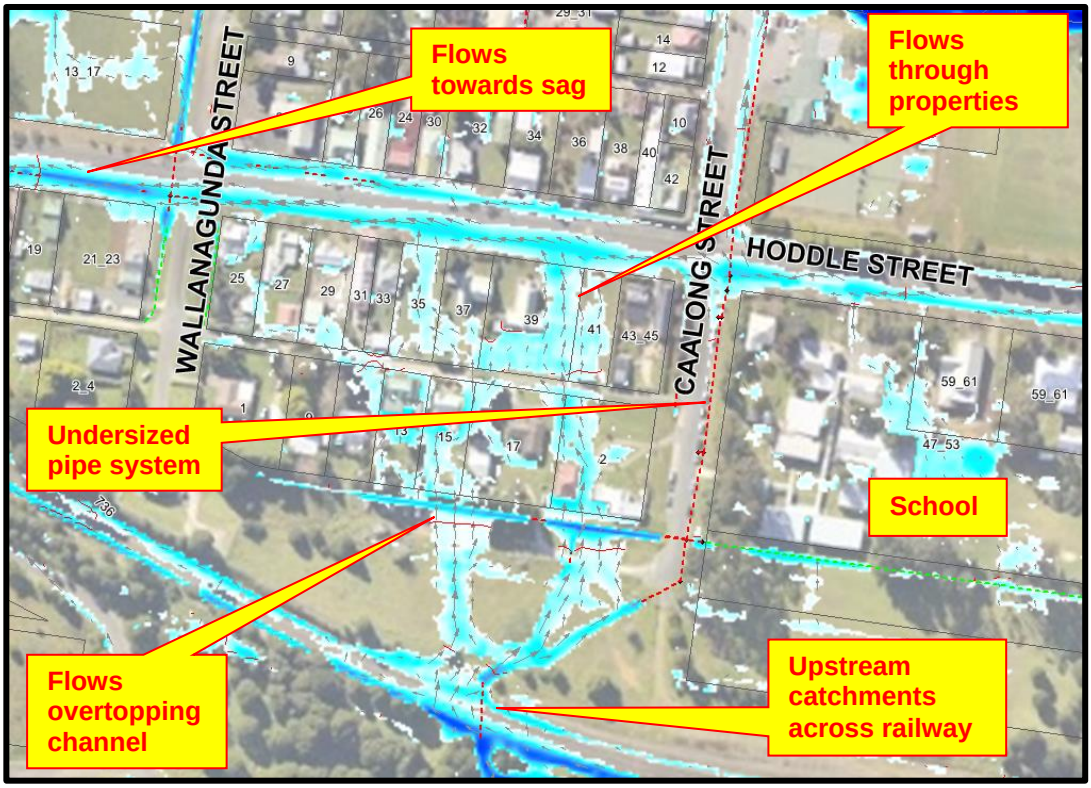


Plate 5.6 – Hoddle Street East (20% AEP)

- Flooding is observed to overtop the existing channel at Meryla Street during the full range of AEP events and enter the commercial properties fronting Hoddle Street with significant flood depths present at No. 79 - 81 Hoddle Street during the 1% AEP. Refer to Plates 5.7 and 5.8.

Plate 5.7 – 79 – 81 Illawarra Highway (Corner of Meryla Street and Hoddle Street)
(Photo courtesy of Google Maps)

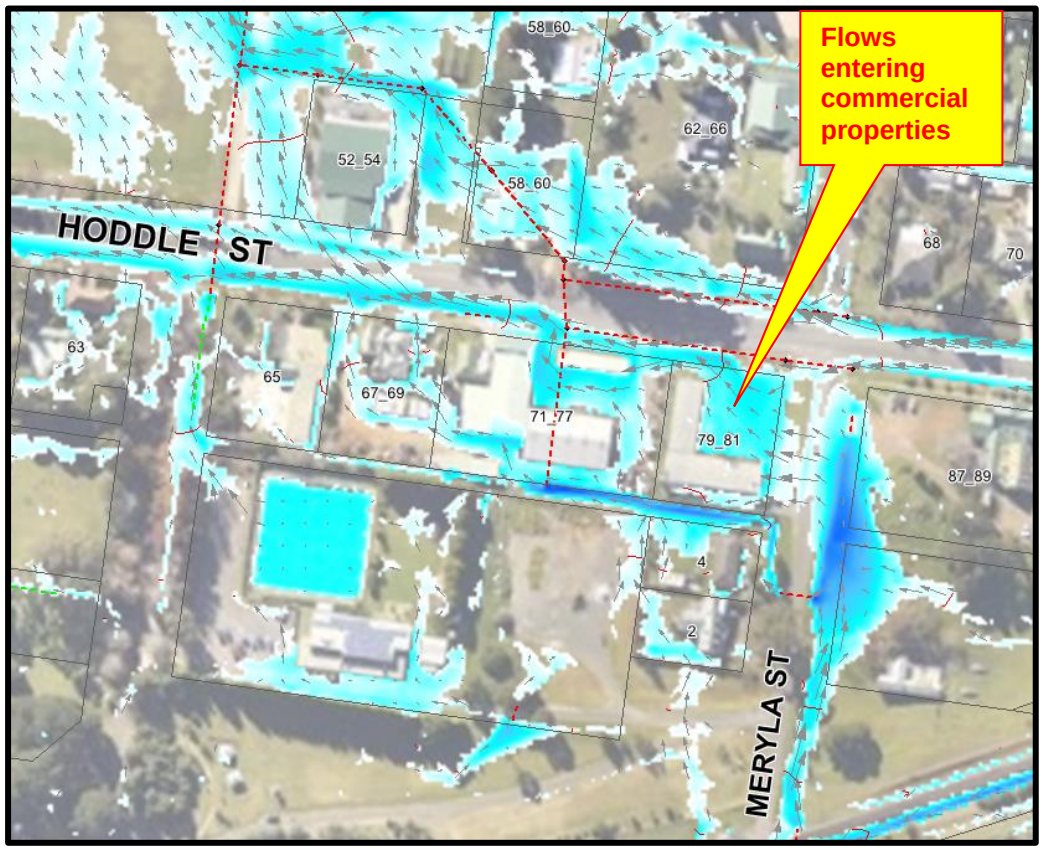


Plate 5.8 – Corner of Meryla Street and Hoddle Street (1% AEP)

- In the upper reach of Caalong Creek, mainstream flooding is observed to breakout towards existing residential properties along Shackleton Street. Details provided in Plate 5.9

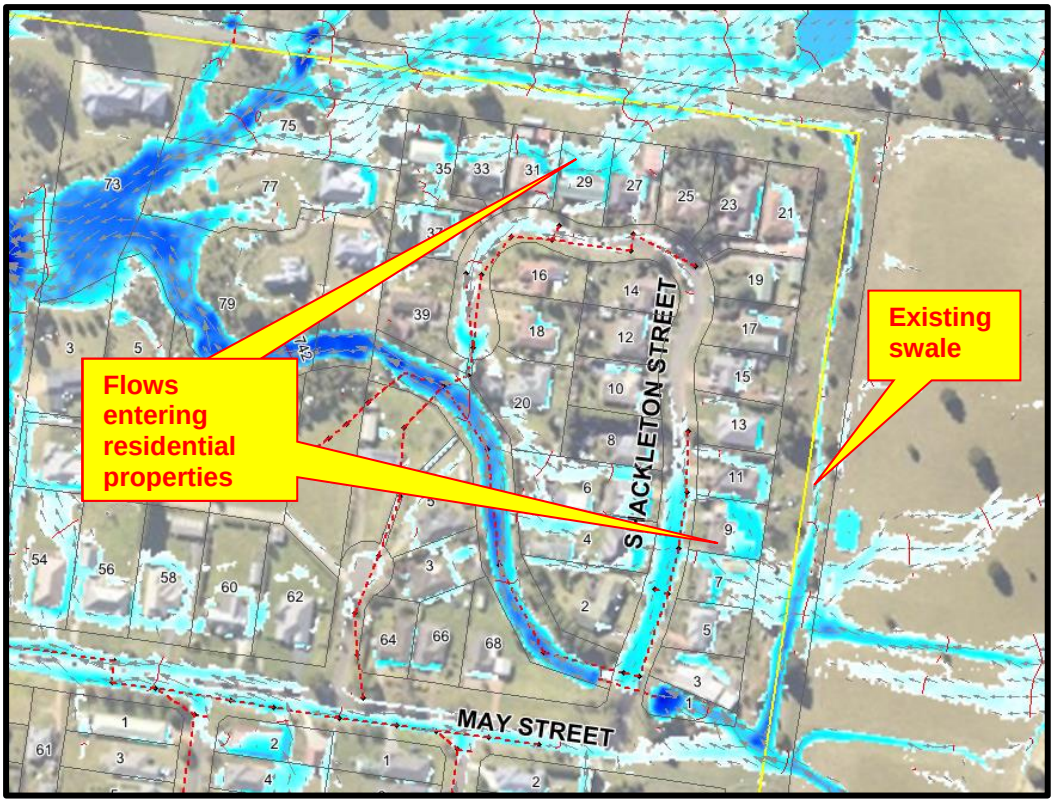


Plate 5.9 – Shackleton Street (1% AEP)

- Flooding through No .12, 14 and 15 Devonshire Road (as reported during the community consultation) is observed across all AEP events including the minor 20% AEP event. Refer to Plates 5.10 to 5.11.

Plate 5.10 – Swale upstream of Devonshire Place

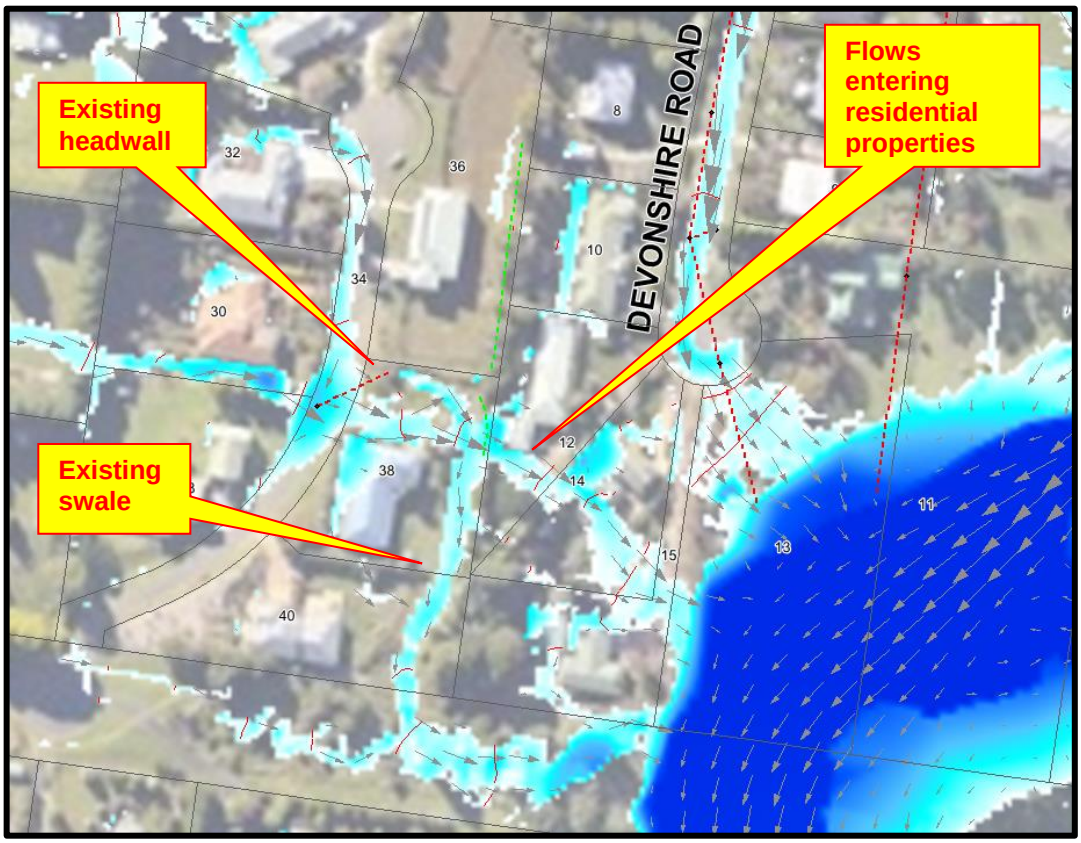


Plate 5.11 – Devonshire Road (1% AEP)

5.2.1 Flood Hazard

Hazard can be considered to be a measure of the impact that floodwater may have on both people and / or property. Hazard mapping was undertaken for each of the design runs specified in the brief (20%, 10%, 5%, 2%, 1%, 0.5% AEP and PMF events).

Figure 4.4 demonstrates the flood hazards for the 1% AEP event across the overall catchment. For further details and mapping refer to the *Flood Study (JWP, 2016)*

Hazard maps derived in the Flood Study were divided into three (3) Hazard categories consistent with the *NSW Floodplain Development Manual (FDM,2005*) as follows.

- Low Hazard
- Transitional Hazard
- High Hazard

Hazard maps are useful to obtain an appreciation of the relative depth and velocity of floodwater within a locality and are a critical element in determining:

- The locations of critical public infrastructure such as hospitals and aged care facilities.
- The areas in the floodplain for which public safety is “at risk”.
- Assist in the flood emergency response and evacuation management process.

It should be noted that during the PMF event, significant areas of the study area are affected. The potential impact on infrastructure within high hazard areas is considered in this report. Refer to Section 6.8 which discusses potential roads which could be cutoff in major rainfall events.

5.2.2 Flood Categorisation

The NSW floodplain development manual (2005) characterises flood hazards into three (3) distinct hydraulic categories, namely:

- Floodway
- Flood Storage
- Flood Fringe

Floodways are defined as those “areas where a significant volume of water flows during floods and are often aligned with obvious natural channels”. Any potential filling as these areas would likely adversely affect other areas. “They are often but not necessarily, areas with deeper flow or areas where higher velocities occur”.

Flood Storage areas are “those parts of the floodplain that are important for the temporary storage of floodwaters, during the passage of a flood”.

Flood Fringe is the “remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect” on flooding.

It is noted that the *Floodplain Development Manual (2005)* does not provide an explicit criteria for defining categories. The following methodology has therefore been adopted in this study to provide hydraulic category mapping:

- **Floodway** – Floodway definition is based upon TUFLOW results and has been assigned where the “Velocity-Depth” (V * D) product is greater than 0.4.

- **Flood Storage** - The variation of peak flood depths and velocities outside of the floodway extent was mapped to identify those areas which are inundated to depths of up to 0.3m. The depth of 0.3m is assumed based on what point depth is considered to start to become hazardous to people and vehicles.
- **Flood Fringe** – Flood fringe refers to all remaining areas affected by Flooding.

The "Existing" flood categorisation maps for the 1% AEP event is provided in the *Flood Study (JWP, 2016)*.

6 FLOODPLAIN RISK MANAGEMENT MEASURES

As discussed in Section 2.2, the key objectives of this FRMS&P include the following:

- Reduce flooding of Hoddle Street for events up to and including the 1% AEP.
- Reduction of the flood hazard and risk to people and property in the existing community.
- Prioritisation of proposed flood mitigation works in accordance with their importance focussing on those that can provide the greatest flood damage impact for the most economical construction cost.
- Prepare a risk management plan which is in a suitable format to be integrated into Council's existing business and strategic plans, emergency management plan and existing and proposed planning proposals.

The *Flood Study (JWP, 2016)* has defined flood behaviour across a range of AEP events and identified those "hot spot" areas where flooding currently imposes a flood hazard and risk to people and property.

In accordance with the *Floodplain Development Manual (2005)*, opportunities to improve the flood hazard and risk (along with the above objectives) have been identified and investigated. Refer to Sections 6.1 to 6.3 for detailed discussion.

6.1 Flood Modification Measures

The purpose of "flood modification measures" is to modify flood behaviour and to reduce the effects of flooding (i.e flood extents, levels or velocities) through the implementation of physical upgrades. Such upgrades may include measures such as basins, trunk drainage channels, road side swales, pit and pipe system, levees and the like.

Robertson Village is bisected by Caalong Creek and is subject to very high rainfall intensities. The existing flood extents modelled in TUFLOW demonstrates that there is a combination of both mainstream and overland flows - which is relatively widespread across the study area.

Preliminary flood mitigation options were initially identified and presented to Council and DPE as part the Phase 1 works. Several of these options were subsequently agreed with Council and DPE to require investigation in detail as part of the FRMS&P (meeting dated 18th February 2016).

Due to the size and complexity of the study area, flood modification measures are proposed to be implemented across numerous locations to address historical and ongoing flooding issues. Whilst these can be assessed in an overall model, it is important that the FRMS&P also considers each measure individually in order to better inform the decision making process.

For the purposes of this study, the following scenarios have therefore been considered:

- Scenario A - Hoddle Street Option 1 (New Basin)
- Scenario B - Hoddle Street Option 2 (Culvert Crossing)
- Scenario C - Northern and Southern Upgrades
- Scenario D - Combined upgrades

Scenario D represents a combination of each of the scenarios (i.e Scenario A + Scenario B + Scenario C) being run as one management solution.

The feasibility of implementing each option was initially assessed against the criteria listed in Table 6.1. Further discussion is then also provided in 6.1.1 to 6.1.4.

It is noted that whilst Scenarios A and B may not provide the most economical benefits (in terms of the cost benefit analysis), they do target the primary objective of improving flooding at Hoddle Street.

Table 6.1 – Summary of Options / Feasibility

Option	Floodplain Management Measure	Works on Council land, ARTC land, RMS land or private?	Landtake required? (Y/N)	In close proximity to structures? (Y/N)	Presence of existing services? (Y/N)	Street Furniture affected? (Y/N)	Spoil disposal required? (Y/N)	Potential impact on Stream Health (erosion or sediment)? (Y/N)	Construction or maintenance issues?	Public health and safety issues?	Issues with amenity? (Y/N)
Scenario A - Hoddle Street Option 1 + New Basin											
6.1.1	Road Widening	Council / RMS	N	N	Y	Y	Y	N	Y	Y	Y
6.1.1	Detention Basin	Council / ARTC	Y	N	Y	N	Y	N	Y	Y	Y
6.1.1	Pit and Pipe Upgrade (Hoddle Street Option 1)	Council / RMS	N	N	Y	Y	Y	N	Y	N	N
6.1.1	Swale Upgrades	Council / private	Y	Y	Y	Y	N	Y	Y	Y	Y
Scenario B - Hoddle Street Option 2 + Culvert Crossing											
6.1.2	Culvert Crossing Upgrade	Council / RMS	N	N	N	N	Y	N	Y	Y	N
6.1.2	Road Widening	Council / RMS	N	N	Y	Y	Y	N	Y	Y	Y
6.1.2	Pit and Pipe Upgrade (Hoddle Street Option 2)	Council / RMS	N	N	Y	Y	Y	N	Y	N	N
6.1.2	Swale Upgrades	Council / private	Y	Y	Y	Y	N	Y	Y	Y	Y
Scenario C - Northern and Southern Upgrades											
6.1.3	Road Swales (High Street)	Council	N	N	Y	N	Y	Y	Y	N	N
6.1.3	Flood Protection Mounds and / or Diversion Channel (Shackleton Way)	Council	N	N	N	N	Y	Y	Y	N	N
6.1.3	Flood Protection Mound / wall (Devonshire Place)	private	N	N	N	N	N	N	Y	N	Y
6.1.3	Flood Protection Mound (Caalong Street)	Council	N	N	N	N	N	Y	Y	N	Y
6.1.3	New outlet pipe from ponding area (Meryla Street)	Council	N	Y	Y	Y	Y	Y	Y	N	N

**The following items are not currently included in the feasibility assessment:

6.2 Scenario A – Hoddle Street Option 1 (New Basin)

Flooding is evident along Hoddle Street across the full range of AEP events. Most notably, ponding occurs at the intersection of Sassafras Way with Hoddle Street (near the Railway line) and overtops at the sag and at scattered locations in the eastern portion of the Village.

Results of the *Flood Study* have confirmed that even in events as low as the 20% AEP, the sag in Hoddle Street is overtopped with the westbound lane being inundated by between 0.1 - 0.35m, whilst the eastbound lane is inundated by < 0.05m (along with the road side swales having depths up to around 1.25m deep). Flooding then further overtops Hoddle Street across each of the larger events – with the roadway ultimately being cutoff.

The "Existing" flood hazard map (Figure 4.4) also demonstrates that in addition to the flooding at the sag, there are also numerous other "hot spots" of high hazard classification along Hoddle Street in the 1% AEP due to the lack of formal drainage networks.

The sparse number of existing pits and pipes also means that the gutter flow widths easily exceed the accepted the design standard of Max 2.5m width during the 20% AEP.

In the vicinity of the Caalong Street and Robertson Primary School, widespread flooding is observed to overtop an existing channel and enter properties between Caalong Street and Wallanagunda Street. These flows are recognised to be generated from the large catchments to the south (to the south of the Railway line).

Plate 6.1 – Hoddle Street Drainage

The western end of Hoddle Street includes four (4) existing swales which convey flows towards Caalong Creek (refer also to Plates 6.2 to 6.5).

- **Swale 1** – table drain along Wallanagunda Street (approximately 3 m wide x 0.3 m high). Connects to an existing 525 mm dia culvert under Burrawang Street before draining through properties to Caalong Creek to the north.
- **Swale 2** – swale which meanders through existing vacant lots to the north. Connects to an existing 600 mm dia culvert under Burrawang Street before draining through properties to Caalong Creek to the north.
- **Swale 3** – large trapezoidal channel (5 m wide x 1 m high) located within the unformed West Street. The channel currently ends at Burrawang Street and drains under the STP via a single 600 mm pipe.
- **Swale 4** – Channel alongside the railway line (within ARTC land). Runs approximately 114 m to a small box culvert under the railway. Flows in excess of the culvert are conveyed to the North – West towards Caalong Creek.

Plate 6.2 – Swale 1 Location

Plate 6.3 – Swale 2 Location

Plate 6.4 – Swale 3 Location

Plate 6.5 – Swale 4 (alongside railway line)

6.2.1 Proposed Upgrades

This scenario has been developed to target the key objectives of both (a) reducing the number of flood affected properties; and (b) improving flood inundation across Hoddle Street to become flood free for the 1% AEP.

The upgrades tested under this option included the following (refer also to Plate 6.9 and Figure 7.1):

Road Widening

Widen the road carriageway of Hoddle Street between Wallanagunda Street and the railway line by around 5.5m (to become a half road width of 10 m - consistent with the remainder of Hoddle Street).

The road widening allows for the removal of the existing deep road side swale (which are a high hazard) and replacement with a new kerb and gutter, road pavement, verge / footpath and formal pit and pipe network.

The removal of the roadside swales improves the flood hazard along the frontage of the existing properties at Hoddle Street.

Detention Basin

To improve overland flooding through properties (between Caalong Street and Wallanagunda Street) and the volume of runoff being directed to the Hoddle Street sag, a detention basin in proposed at the southern end of Caalong Road (adjacent to the railway line).

A new 900 mm dia outlet pipe along Caalong Street would then enable flows to be directed to Caalong Creek (near the bridge) rather than into properties in a managed way.

Whilst it is recognised that a future public pool is proposed in this area, there may be potential for both a pool and a detention basin to be constructed and provide both flood management and community benefits.

Pit and Pipe Upgrade

One of the key objectives of the flood study is to assess the likely benefits of an upgrade to the drainage system along Hoddle Street to reduce flooding for events up to and including the 1% AEP.

A new minor / major pit and pipe network has therefore been designed in DRAINS to comply with *Council's Design Guidelines (WSC, 2016)* and was ultimately tested in TUFLOW. Refer to Section 7.1 for discussion.

Swale Upgrades

Swales 1 to 3 are proposed to be reconstructed to enable flows to more effectively drain away from Hoddle Street. A shallower grade on the swales will also enable adequate cover over the proposed pipe system upgrade in Hoddle Street.

Importantly, whilst Swale 3 has a relatively large existing capacity, results demonstrate that only a small portion of flow is directed to the channel (since it only includes a single 600mm dia pipe upstream). The pit and pipe upgrade therefore also includes upgrading the existing 2 x 600mm dia pipes from under the railway with a new headwall connection to the Swale 3.

Plate 6.6 – Hoddle Street Road Swales

Plate 6.7 – Detention Basin Location

Plate 6.8 – Detention Basin Location (Upstream Culvert)

Plate 6.9 – Flood Mitigation Option – Scenario A

6.3 Scenario B – Hoddle St Option 2 (Culvert Crossing)

Scenario B also seeks to improve flooding along Hoddle Street. The focus however is on the potential to intercept the large amount of ponding which occurs at the intersection with Sassafras Way (near the railway line) before it overtops the railway line and drains to the sag in Hoddle Street.

Under existing conditions, the ponding at Sassafras Way (near the railway) discharges in two (2) directions via:

- A 0.8 m x 0.45 m box culvert which drains a portion of flows under Hoddle Street to the rail corridor. The 1% AEP results indicate that approximately 1.2 m^3/s is conveyed alongside the railway via Swale 4 to the North-West.
- Two (2) x 600 mm dia pipes which run under the railway line (alongside Hoddle Street) and discharge to the road side swales in Hoddle Street. Results indicate approximately 1.7 m^3/s being piped.

The existing results indicate that in the 1% AEP, ponding is up to approximately RL 732.5 m AHD which overtops the railway line to the sag in Hoddle Street and also to the north resulting in Hoddle Street becoming non trafficable in events greater than the 10% AEP.

6.3.1 Proposed Upgrades

The option to upgrade the existing crossing 0.8 m x 0.45 m box culvert under Hoddle Street in order to intercept and redirect flows away from the sag in Hoddle Street was investigated. This was initially discussed and agreed by Council and DPE (meeting dated 18th February 2016).

This option includes the following upgrades (refer also to Plate 6.12 and Figure 7.2):

Culvert Crossing Upgrade

Upgrade the existing crossing 0.8 m x 0.45 m box culvert to three (3) x 1050 mm pipes under Hoddle Street. Works also includes reshaping of the verge to suit the new culvert size with scour protection.

Road Widening

Widen the road carriageway of Hoddle Street between Wallanagunda Street and the railway line similar to Scenario A by around 5.5m (to become a half road width of 10 m - consistent with the remainder of Hoddle Street).

The road widening allows for the removal of the existing deep road side swale and be replaced with a new kerb and gutter, road pavement, verge / footpath and formal pit and pipe network.

The removal of the roadside swales improves the flood hazard along the frontage of properties.

Pit and Pipe Upgrade

One of the key objectives of the flood study is to upgrade the drainage system along Hoddle Street to reduce flooding for events up to and including the 1% AEP.

A new minor / major pit and pipe network has therefore been designed in DRAINS to comply with *Council's Design Guidelines (WSC, 2016)* and was ultimately tested in TUFLOW. Refer to Section 7.1 for discussion.

Swale Upgrades

Swales 1 to 3 are proposed to be reconstructed to enable flows to more effectively drain away from Hoddle Street similar to Scenario A. A shallower grade on the swales will also enable adequate cover the provided over the proposed pipe system upgrade in Hoddle Street.

The pit and pipe upgrade includes an upgrade of the existing 2 x 600mm dia pipes from under the railway with a new headwall connection to the Swale 3.

The reconstruction of the existing box culvert under Hoddle Street as 3 x 1050 mm dia pipes will enable flows draining to Swale 4 (alongside the railway) to be significantly increased. Importantly, the bypass significantly improves the flooding at the sag in Hoddle Street but does increase flooding along the Swale 4 towards Caalong Creek.

This option will need to be discussed further with ARTC

Plate 6.10 – Culvert under Hoddle Street (under railway line)

Plate 6.11 – Culvert under Hoddle Street (under railway line)

Plate 6.12 – Flood Mitigation Option – Scenario B

6.4 Scenario C – Northern and Southern Upgrades

In addition to the areas affected by flooding along Hoddle Street, TUFLOW results have confirmed that a number of other properties across the study areas are impacted in the 1% AEP event via overland flooding.

In particular, the northern portion of the study area shows:

- In the upper reach of Caalong Creek, mainstream flooding is observed to breakout towards existing residential properties along Shackleton Street
- Flows generated from large catchments on the northern side of High Street overtop the roadway and enter properties before ultimately draining to Caalong Creek.
- Flooding through No .12, 14 and 15 Devonshire Road is evident across all AEP events including the minor 20% AEP event
- Similarly, the southern portion of the study area shows:
- Flooding entering No. 18 and 20 Caalong Street just to the north on the bridge crossing.
- Flooding is observed to overtop the existing channel at Meryla Street during the full range of AEP events and enter the commercial properties fronting Hoddle Street.

It is noted that these commercial properties are set reasonably low compared to the surrounding roads and therefore any flooding which overtops the roadway and / or the channel along the rear of the properties enters directly into the properties.

Under existing conditions, the ponding on the eastern side of Meryla Street is wide and already extends across parts of land owned by Robertson Inn (87 – 89 Illawarra Highway) and the adjacent residential property (1 Meryla Street).

6.4.1 Proposed Upgrades

This option has been developed to target the key objective of reducing the number of flood affected properties and reduce the risk of flood damage to property and life.

The upgrades tested under this option included the following (refer also to Plate 6.16 and Figure 7.3):

Road Swales (High Street - Northern)

The eastern end of High Street currently includes roadside swales which partially intercept upstream flows and convey towards a tributary of Caalong Creek.

The capacity of these road swales were increased in the model to a depth of 1m in order to intercept additional flows and direct away from the affected properties.

Flood Protection Mounds and / or Diversion Channel (Northern)

Modelling has included a diversion channel and a flood protection mound(s) in the upper reaches of Caalong Creek to remove the flood affectation of properties at Shackleton Street.

These measures were implemented within the unformed High Street reserve.

It is noted that there is an existing swale and mound along the rear of the properties to the east (near the corner of May Street and Shackleton Road). The mound in this location will therefore be further raised by 0.5m - 1m to improve capacity and better manage overland flow from the local catchments.

Flood Protection Mound / wall (Devonshire Road – Northern)

Modelling has included a flood protection mound / wall to be incorporated as part of the existing swale at the rear of the May Street properties in order to remove overland flooding that currently enters No. 12, 14 and 15 Devonshire Place.

The mound / wall has been modelled at 1 m high and will need to be suitably designed / constructed to prevent erosion and flows breaking out to the properties to the east and will need to consider the existing vegetation in the area.

Plate 6.13 – Swale upstream of Devonshire Place

Flood Protection Mound (Caalong Street - Southern)

Modelling has included a flood protection mound along Caalong Street (just north of the bridge crossing) to prevent overland flooding breaking out towards the existing property (No. 18 and 20 Caalong Street).

The mound has been modelled at 1 m high and will need to be suitably designed/constructed to consider the existing vegetation in the area.

New outlet pipe from ponding area (Meryla Street – Southern)

Several options were considered (and modelled) to improve the flood affectation imposed on the commercial properties at the corner of Hoddle Street and Meryla Street.

Modelling of this option includes a new 900 mm pipe to intercept flows from the existing 0.9 m x 0.47 m culvert and bypass flows away from the commercial properties towards the playing fields. An additional 1.8 m x 0.6 m box culvert pipe crossing is also included under Meryla Street to collect as much flows as possible.

Importantly, other TUFLOW runs have confirmed that raising Meryla Road (and part of Hoddle Street) by around 0.5 – 1 m would further improve flood affectation on the commercial properties. (see Plate 6.4). This has however not been presented as an option given it would require significant raising of levels along Hoddle Street (which may have superelevation issues in the future road pavement resulting in an unsafe situation). This would impose additional ponding on the Hoddle Street properties to the east (potentially affecting parts of the Robertson Inn and the adjacent residential property at 1 Meryla Street). Refer to Section 7.1 for further discussion.

Plate 6.14 – Potential areas affected by raising road (Hoddle St and properties) (Photo Courtesy of Google Maps)

Plate 6.15 – Flood Mitigation Option – Scenario C

6.5 Scenario D – Combined upgrades

This option includes each of the flood modification measures outlined in the three (3) previous Scenarios A through to C and demonstrates the cumulative effect that these upgrades will provide for the Robertson Village.

6.5.1 Proposed Upgrades

The upgrades tested under this option included the following (refer to Plate 6.16 and Figure 7.4):

- Road Widening (Scenario A)
- Detention Basin (Scenario A)
- Pit and Pipe Upgrade (Scenario A)
- Swale Upgrades (Scenario A)
- Culvert Crossing Upgrade (Scenario B)
- High Street Road Swales (Scenario C)
- Flood Protection Mounds and / or Diversion Channel (Scenario C)
- Devonshire Place Flood Protection Mound / wall (Scenario C)
- Caalong Street Flood Protection Mound (Scenario C)
- New outlet pipe from ponding area at Meryla Street (Scenario C).

Refer to Section 6.2 to 6.4 for discussion of each element.

Plate 6.16 – Flood Mitigation Option – Scenario D

6.6 Debris Control

Blockage of road crossings (bridge or culverts) can back up floodwater, causing flood levels to locally increase and impact upon properties which would not normally be flood affected.

Control structures can sometimes be designed to protect bridges and / or culverts from becoming blocked from debris during flood extents. Alternatively, regular maintenance of creeks upstream from crossings via regular inspections in creeks (and removal of debris such as dumped rubbish, shopping trolleys, dumped or fallen trees) has the ability to minimise the potential for blockages.

During the detailed site visit, several forms of debris were observed which potentially could cause blockages within Caalong Creek and in particular at the recently constructed Caalong Street bridge crossing. These include items such as a bathtub and tree branches (which had been cut elsewhere and dumped). Refer to Plates 6.18 and 6.19.

Plate 6.17 – Caalong Street Bridge Crossing

Plate 6.18 – Debris

Plate 6.19 – Debris

The potential for blockages at the Caalong Street crossing of Caalong Creek is considered to be medium risk. Whilst the channel surrounding the newly formed bridge has a trapezoidal formation, the upstream catchment is located partially within a park with easy public access which may be susceptible to dumping and partially within heavily forested woodland. Given that results also show that the crossing is undersized, this would also increase the chance of blockages.

It is therefore recommended that Council implement a maintenance program to minimise blockages. It is anticipated that the cost of implementing the maintenance program could be included in Council's ongoing maintenance budget.

6.7 Riparian Management

Native riparian vegetation within natural watercourses is a desirable environmental outcome given they provide habitats for both native flora and fauna.

In addition to the environmental benefits, specific native riparian species often have the ability to regenerate after large rainfall events.

Given the rural residential nature of Robertson Village, there are several opportunities to improve plant species along Caalong Creek. These are particularly evident around Caalong Road and the playing fields.

It is therefore recommended that Council implement a riparian management scheme. This scheme would generally include the removal of existing exotic species and re-vegetation with selected riparian species without impacting on flood behaviour.

It is anticipated that the cost of implanting the program could be included in Council's ongoing maintenance budget.

6.8 Property Modification Measures

6.8.1 Identified Houses

A review of the 1% AEP "High Hazard" areas within the floodplain has been undertaken to identify those properties which are at risk of high hazard flows and should form part of a "Voluntary House Purchase Acquisition" Scheme.

The methodology to identify those 'at risk' houses has adopted the "Scenario D" flood hazard results. Importantly, the approach assumes that each of the flood modification measures proposed in Section 6.1 have been undertaken, thus avoiding any potential double ups in the overall cost estimates (That is, so that property modification measures are not proposed on houses where flood modification measures are already proposed).

Upon implementation of the flood modification measures, several locations have been identified to have buildings within a 5m buffer of the High Hazard areas during a 1% AEP event (refer to Plate 6.20):

Plate 6.20 – identified Properties for Potential Voluntary Purchase

6.8.2 Voluntary House Purchase

Results of the assessment have identified that there are seven (7) dwellings across the study area which are located within 5m of a "High Hazard" during the 1% AEP event. Refer to Table 6.2 below.

A further three (3) properties have been identified as potential properties which could be acquired and / or negotiated with owners to obtain an easement in order to address local flood issues. That is,

- 13 – 17 Burrawang Street – which is currently bisected by the existing swale 2 and conveys from Hoddle Street towards Caalong Creek. There does not appear to be an existing easement to permit flows to enter nor maintenance access by Council.
- 1 Meryla Street and 87 – 89 Illawarra Highway – As discussed in Section 7.2.1, there may be potential to acquire a portion of these properties in order to address flooding issues through the nearby commercial properties.

Table 6.2 – Summary of Voluntary House Purchases

Address
13-17 BURRAWANG STREET
25-27 BURRAWANG STREET
29-31 BURRAWANG STREET
6-10 BURRAWANG STREET
12-16 BURRAWANG STREET
16 CAALONG STREET
1 MERYLA STREET
87-89 ILLAWARRA HIGHWAY (ROBERTSON INN)
10 MERYLA STREET
3 SHACKLETON STREET

Possible acquisition to address local issues
Property affected by High Hazard

By adopting an assumed land value of \$250 / m^2 (for land clear of high hazard) and \$65 / m^2 (for land within high hazard), the corresponding purchase costs are estimated at \$3.8M for those properties affected by high hazard and a further \$0.96M for those to address local issues.

6.8.3 Planning Policy Revisions

A detailed review of the Robertson Village DCP, with a particular focus on "Section 4 – Flood Liable Land" has been undertaken in order to inform a possible amendment to the DCP from the outcome of this assessment.

Section 4 generally covers all aspects of good floodplain management, however in our view the Flood Matrix (Figure A4.3 of the current DCP) could be simplified.

After review of the *Moss Vale town DCP*, The Moss Vale Floodplain Matrix (Figure A4.2 in the Moss Vale DCP) provides an improved understanding of the flood related controls and a simplified approach in determining the "criteria" that would apply to an individual application.

This Matrix (see Table 6.3) has been provided below and is recommended for inclusion in the Robertson Village DCP update.

Table 6.3 – Revised Flood Matrix

	Flood Risk Precincts (FRP's)																							
	Low Flood Risk						Fringe-Low Flood Risk						Medium Flood Risk						High Flood Risk					
Planning Consideration	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development
Floor Level		3						3	2, 6, 7	5, 6, 7	1, 6,	4, 7,			2, 6, 7	5, 6, 7	1	4, 7					1	4, 7
Building Components		2						2	1	1	1	1			1	1	1	1					1	1
Structural Soundness		3						3	2	2	2	2			2	2	2	2					1	1
Flood Effects		2						2	2	2	2	2			2	2	2	2					1	1
Car Parking & Driveway Access		1, 3, 5, 6, 7						1, 3, 5, 6, 7	1, 3, 5, 6, 7	1, 3, 5, 6, 7	2, 3, 4, 6, 7	6, 7, 8			1, 3, 5, 6, 7	1, 3, 5, 7, 8	2, 3, 4, 6, 7	6, 7, 8					2, 3, 4, 6, 7	6, 7, 8
Evacuation		2						2	2	1 or 2	3	2			2	1 or 2	3	2					3	2
Management & Design		1, 4, 5						1, 4, 5	1	1, 2, 3, 5	1, 2, 3, 5	1, 2, 3, 5			1	1, 2, 3, 5	1, 2, 3, 5	1, 2, 3, 5					1, 2, 3, 5	1, 2, 3, 5

Importantly, the detailed Overland Flooding Map and assessment now available from this study will provide a useful development tool for Council. This tool will allow Council to identify and flag both existing and future development sites which may be impacted by overland flows and require an individual assessment.

Figure 7.38 and an extract provided in Plate 6.21 below has been developed from a series of AEP's mapped as part of this assessment.

Plate 6.21 shows the simplified flood extent for the 1% AEP event together with the PMF extent. This plan should be used to inform future development and the potential flood related controls that may be applicable to the property.

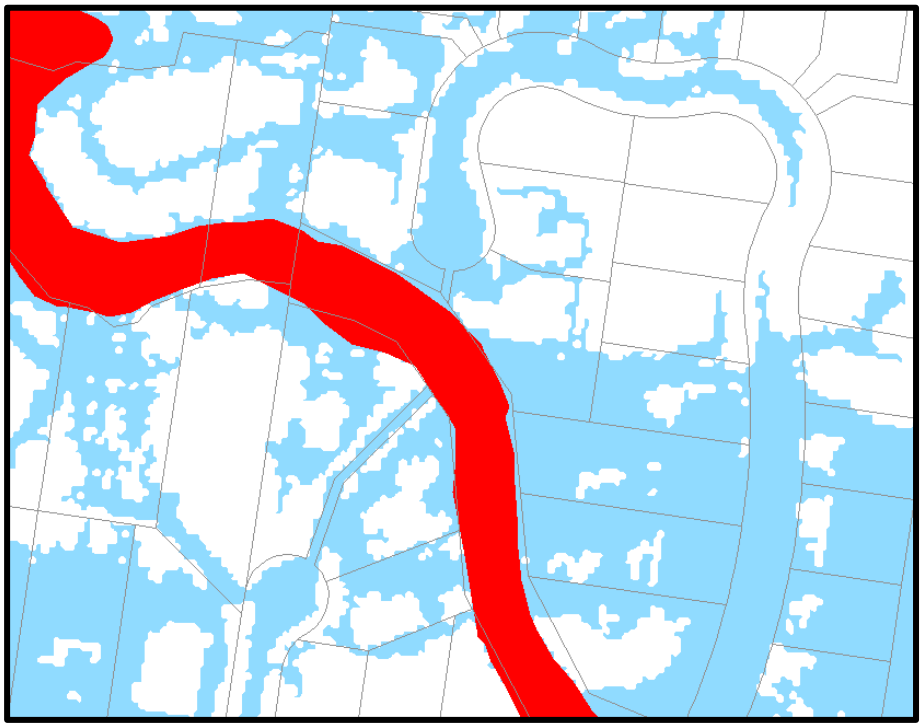


Plate 6.21 – Example of Overland Flowpath Map

6.8.4 Flood Planning Levels

Flood planning levels (FPLs) are an important tool in the preparation of flood development controls within areas affected by flooding. The purpose of FPLs is to reduce the likelihood of future buildings and infrastructure being exposed to dangerous flood situations, while ensuring relevant planning controls are imposed on future developments within the catchment. Importantly, FPLs indicate properties where there is a risk of major flooding and as such, where relevant flood development controls will need to apply for any future developments.

In accordance with the *Wingecarribee Shire Council LEP - Part 7 Clause 7.9* (2010), the FPLs for Robertson have been based on the **1% AEP event plus a 0.5 m freeboard**. Once the FPLs have been developed, the associated Flood Planning Area (FPA) has been determined based on all areas within the study area located at or beneath the FPLs.

6.8.5 Selection of Flood Planning Area

This FRMS&P has determined flood extents under both “existing” conditions and “future” conditions – which includes the proposed floodplain mitigation measures. Given the construction of these proposed flood mitigation measures are not guaranteed, FPLs have been determined based on the “existing” condition assessment.

It is noted that flood modelling has adopted “direct rainfall” with rainfall being applied directly to the catchment ‘grid’. The subsequent flood results include a combination of mainstream flooding, overland flooding and local minor ponding.

It is noted that in some instances, localised ponding may occur around buildings or roads, but do not necessarily form part of a recognised “flowpath”. The base results have subsequently been refined to allow for the FPLs and Flood Planning Areas (FPA) to only consider major flood prone areas along Caalong Creek and the local tributaries. The following parameters have been used to define the FPL:

- Areas located along Caalong Creek and major flow paths that are classified as “transitional” or “high” hazard in the 1% AEP (refer to Appendix A for further discussion).
- Areas located along Caalong Creek and major flowpaths that have a depth of ponding greater than 300 mm in the 1% AEP.

Based on the above criteria, the 1% AEP flood results have been adjusted and FPL contours and FPA’s for mainstream flooding have been developed and are shown on Figures 7.37 and 7.38.

6.9 Response Modification Measures

A review of the *Wingecarribee Local Flood Plan* confirms that Robertson Village lies within the limits of the Local Flood Plan. A specific plan for Robertson Village is however not currently included.

The Local Flood Plan outlines the general responsibilities of emergency services organisations and support agencies, whilst specifically setting out:

- Preparedness
- Response
- Recovery

Preliminary discussions (phone conversation dated 24th May 2016) with the SES confirm that Robertson is not traditionally recognised as a known flooding area since it is located in the upper reaches of the Wingecarribee River. Instead those downstream areas such as Berrima, Bowral and Moss Vale are generally impacted due to the steep side slopes along the watercourses. Notwithstanding any additional flood information is always welcomed to improve the preparedness and potential updates to the Local Flood Plan.

A review of the Local Flood Plan confirms:

- Flood-producing rains can occur over all of these catchments and at any time of the year. They can be caused by severe thunderstorm activity or by the passage of frontal systems. Most floods have occurred soon after short, sharp bursts of rain falling within the council area, but floods on the Wollondilly River proper may emanate from areas well to the south and take longer to rise. Most thunderstorm activity is in the summer months, frontal systems being more common in winter. Much of the flooding which affects the Shire, particularly its more populated areas, is 'flash' flooding
- SES has the ability to close and reopen council roads (and other roads nominated by agreement with the RMS) and advise the NSW SES Wingecarribee Shire Local Controller and the Police.
- A key feature of the study includes the Preparedness and the willingness to maintain the plan. There is an opportunity to:
    - review the content "when new information from flood studies become available"
    - SES to participate in local floodplain risk management committee activities when committees are formed
- Flood intelligence which describes flood behaviour and its effect on the community can be provided to inform a review of the plan
- Available information about the estimated impacts of flooding at different heights can be provided to inform development of warning systems.
- Annexure A summarises the "Effects of flooding on the community" which are included for affected areas such as Bowral and Berrima. It is also recognised that "very heavy rainfalls can produce sudden-onset short-duration stormwater flooding at Hilltop, East Bowral and Moss Vale, where the Illawarra Highway (Argyle St) can be cut".

6.9.1 Recommendations

The following information from this FRMS&P has been supplied for review by the NSW SES and consideration for any potential updates to the Wingecarribee Local Flood Plan:

- Plate 6.22 shows the roads identified as being flood affected by flooding in the 1% AEP under "Existing" Conditions.
- Flood intelligence information is supplied for Hoddle Street and Caalong Street.
- Flood maps
- Summary of affected roads

6.9.2 Roads affected by flooding

The results of the Flood Study indicate that under "existing" conditions, both Hoddle Street (Illawarra Highway) and Caalong Street are inundated across numerous AEP events. Refer to Plate 6.22 to 6.24 which shows those major roads which are inundated.

It is noted that if proposed flood modification measures are undertaken, then the magnitude / frequency of flooding at Hoddle Street would be reduced and improved management of floods surrounding Sassafras Way would be achieved.

Plate 6.22 – Flood Affected Roads (1% AEP)

6.9.3 Flood Intelligence

Flood Intelligence has been summarised for the flood affected roads for a series of AEP events. Refer to Tables 6.4 and 6.5. "M" represents Major roads and "L" is local (or minor) roads.

Table 6.4 – Summary of Flooding over Major Roads

			Existing Flood Levels (m AHD)				
ID	Location	Road Level (crest)**	20%**	5%**	2%**	1%**	PMF**
M1	Caalong St (bridge crossing)	728.82	728.94	729.11	729.21	729.34	730.75
M2	Hoddle St (near railway)	732.16	732.27	732.35	732.39	732.43	732.68
M3	Hoddle St (sag)	729.78	729.90	729.93	729.95	729.95	730.02
M4	Hoddle St (near Wallangunda St	730.23	730.35	730.37	730.38	730.39	730.51
M5	Hoddle St (near school)	733.26	733.31	733.36	733.37	733.39	733.54

**note - depths and levels vary based on road crossfall. Comparison points are therefore indicative only

Table 6.5 – Summary of Flooding Depths over Major Roads

			Existing Flood Depths (m)				
ID	Location	Road Level (crest)**	20%**	5%**	2%**	1%**	PMF**
M1	Caalong St (bridge crossing)	728.82	0.12	0.29	0.38	0.52	1.92
M2	Hoddle St (near railway)	732.16	0.10	0.19	0.23	0.26	0.52
M3	Hoddle St (sag)	729.78	0.12	0.15	0.16	0.17	0.24
M4	Hoddle St (near Wallangunda St	730.23	0.11	0.13	0.14	0.16	0.27
M5	Hoddle St (near school)	733.26	0.05	0.10	0.11	0.12	0.27

**note - depths and levels vary based on road crossfall. Comparison points are therefore indicative only

6.9.4 Summary of affected roads

The following summary of affected roads is included for consideration within Annexure B of the Local Flood Plan Flood.

Table 6.6 – Summary of Flood affected roads (Minor and Major)

ID	Location
Major Roads	
M1	Caalong St (bridge crossing)
M2	Hoddle St (near railway)
M3	Hoddle St (sag)
M4	Hoddle St (near Wallangunda St)
M5	Hoddle St (near school)
Minor Roads	
L1	Sassafras Way (near railway)
L2	Burrawang St (West)
L3	Burrawang St (East)
L4	Meryla St (South)
L5	Meryla St (North)
L6	May St (private culdesac)
L7	Shackleton Way
L8	High St (West)
L9	High St (East)

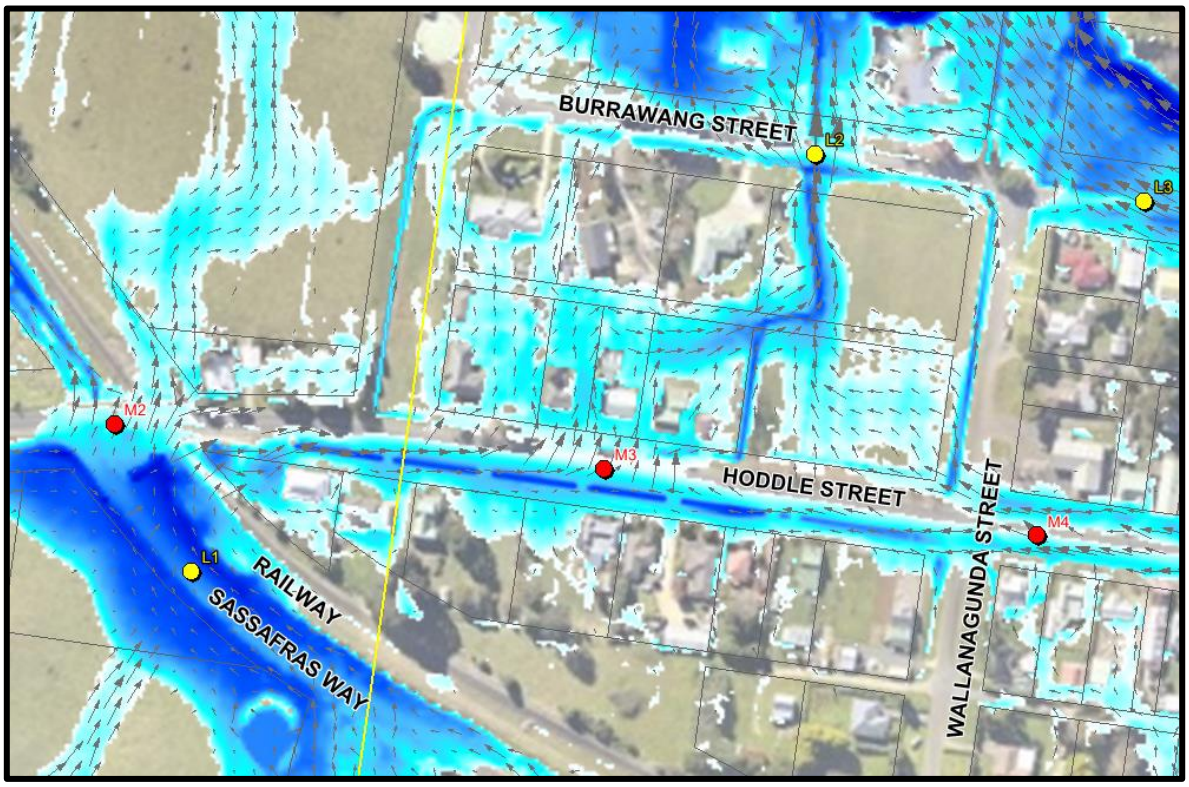


Plate 6.23 – Flood affected Roads (Hoddle Street – 1% AEP)

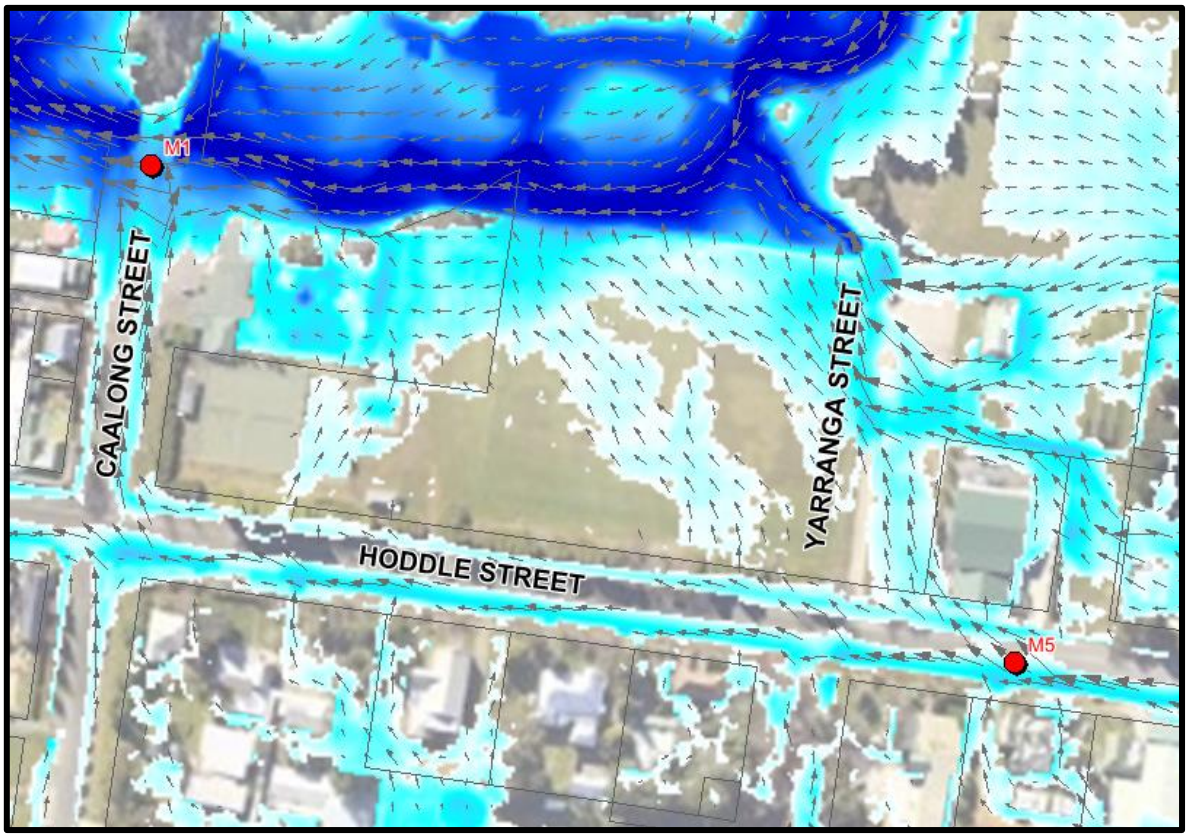


Plate 6.24 – Flood affected Roads (Hoddle Street – 1% AEP)

7 FLOOD MODELLING (PROPOSED)

Following the adoption of the *Draft Flood Study* by Council in March 2016, the development and testing of various flood mitigation options commenced.

DRAINS software was adopted as the design tool to size the proposed infrastructure upgrades along Hoddle Street. The objectives of this assessment aimed to:

- Reduce the flooding at Hoddle Street for events up to and including the 1% AEP; and
- Reduce the flood hazard and risk to people and property in the community.

Once the initial configuration and sizes were confirmed in DRAINS, the network upgrades were then adopted in TUFLOW to test the overall performance in the locality.

Preliminary concept designs have been developed for each option. The performance of each option assessed within TUFLOW particularly focused on the minor (20% AEP) and major (1% AEP) events.

7.1 DRAINS Assessment

7.1.1 Design Criteria

In accordance with Council's guidelines (WSC, 2016), the DRAINS assessment has been based on the following design criteria:

- Target level of service (minor): 20% AEP event
- Target gutter flow width within roadways: 2.5 m in 20% AEP event (however consideration may be given to wider flow widths if grades < 0.5% provided that Velocity depth < 0.4 m2 / s)
- Minimum pipe size to be 375 mm diameter
- Maximum kerb inlet length of 4 m
- Target level of service (major): 1% AEP event
- The maximum allowable depth of water in a major (1% AEP event) is 0.2 metres and the maximum velocity x depth product of $0.4m^2/s$ is permitted. Where the safety of only vehicles can be affected, a maximum velocity x depth product of $0.6m^2/s$ is permitted
- Pit blockages for on grade pits adopted at 20%.
- Pit blockages for sag pits adopted at 50%.
- Design to comply with Council's *Engineering Design Specification* (WSC, 2016) and Council Standards

Importantly, to address Council's objective for reducing flooding up to and including the 1% AEP, consideration has also been given to ensuring that the traffic lane(s) of Hoddle Steet are flood free during the 1% AEP. This will ensure that the road is not cutoff for events up to the 1% AEP and aids in the management of flood evacuees.

7.1.2 Concept Design

The concept design for the proposed upgrades in Hoddle Street is shown on Figure 7.1 to 7.4 with screenshots on Plates 7.1 to 7.3. Where possible, the alignment has been selected to improve the capacity of the system whilst having the least disturbance on the operation of the township, driveways and Hoddle Street (Illawarra Highway)

Upgrades are discussed in detail in Section 6.1.

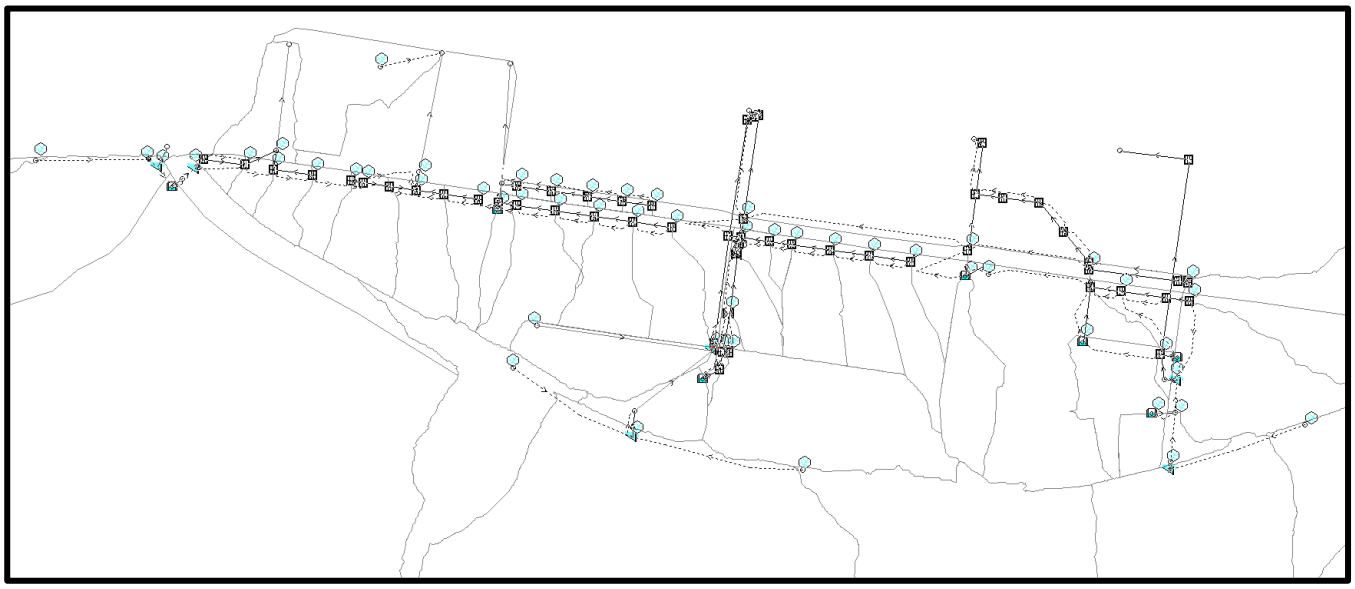


Plate 7.1 – Overall DRAINS Model

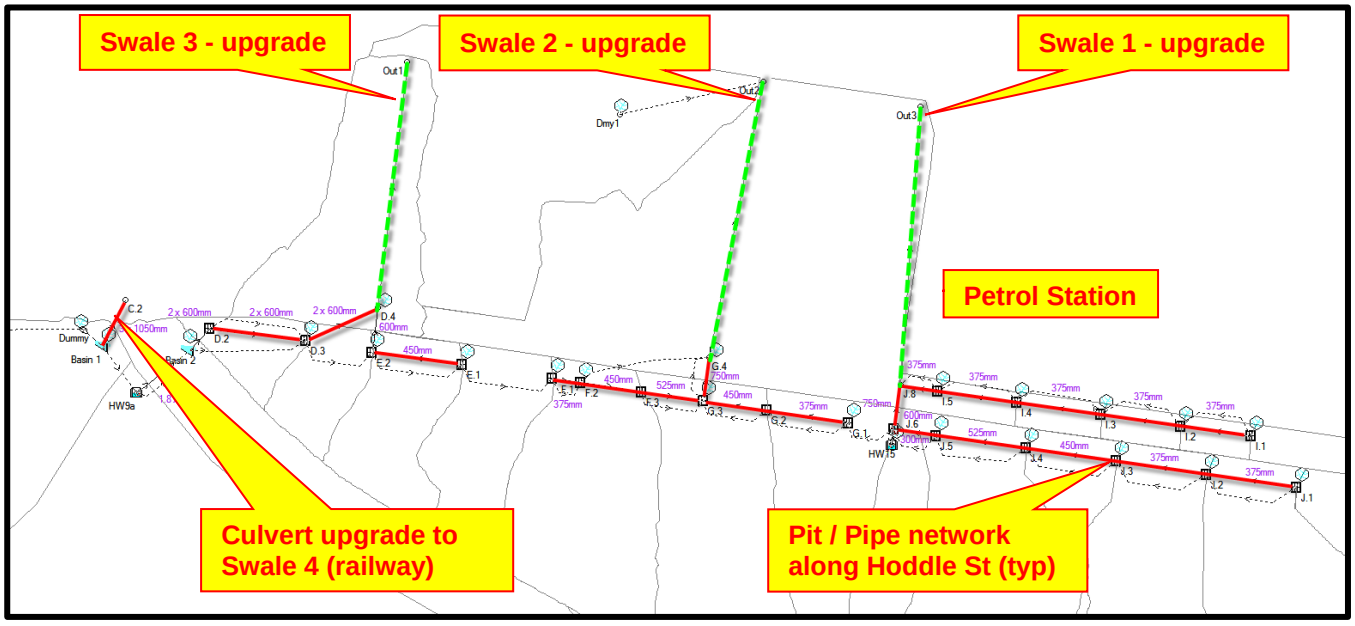


Plate 7.2 –DRAINS Model Hoddle St Sag (Option 1)

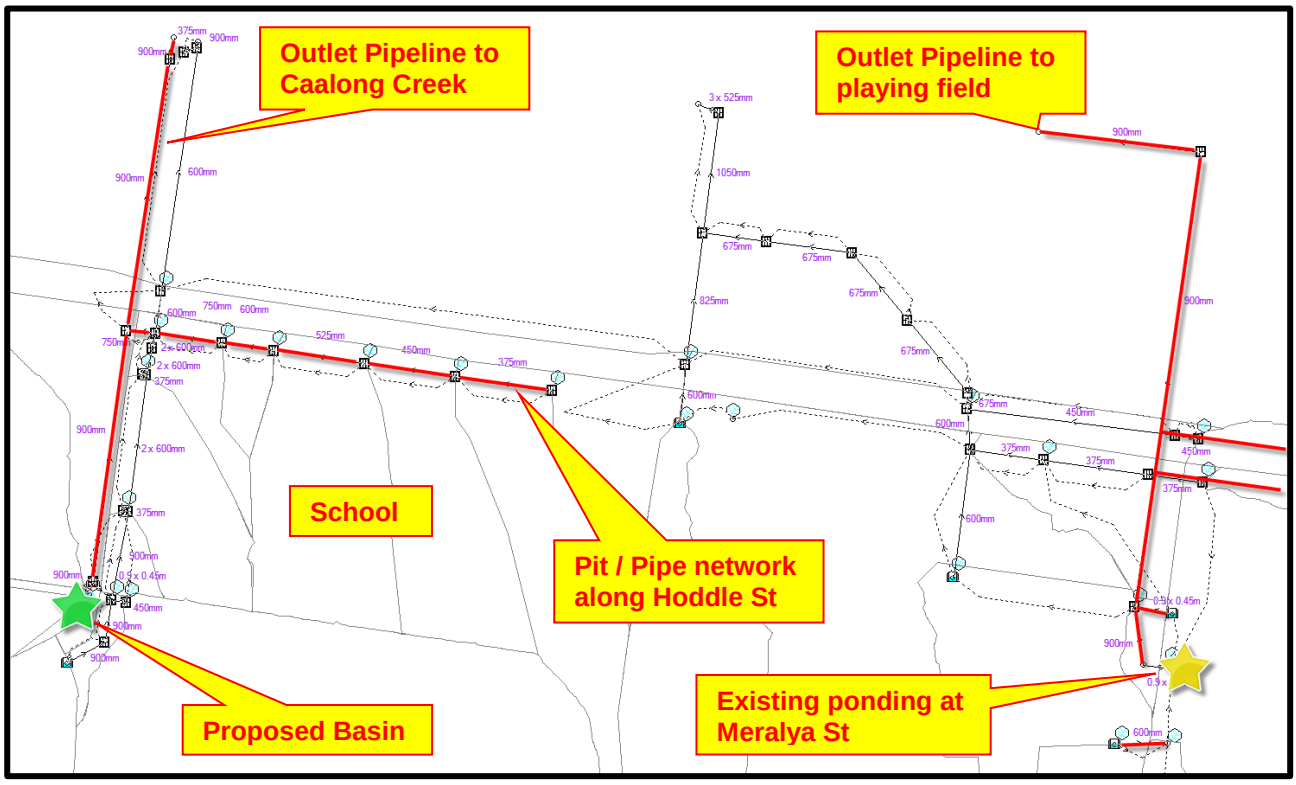


Plate 7.3 –DRAINS Model Hoddle St East (Option 2)

7.1.3 Results

The results of the *DRAINS* assessment indicates the following:

- By upgrading the pipe system along Hoddle Street, flow widths during the 20% AEP event are generally limited to around 2.5m. Due to the flat nature of Hoddle Street however, there are a few locations where the flow width exceeds 2.5m, but has a velocity-depth < 0.4 m^2/s. It is expected that these areas could be further refined during detail design.
- The reconstruction of Swales 1 to 3 to shallower grades (Swale 1 – 0.5%, Swale 2 – 1.2% and Swale 3 – 0.8%) through to Burrawang Street is an important element in the design. This not only increases the capacity of the flows being drained from the sag in Hoddle Street, but also allows for adequate cover to be provided over the proposed pit and pipe network in Hoddle Street.
- DRAINS modelling confirms that the proposed pit and pipe configuration along Hoddle Street will generally convey the 20% AEP event with freeboard at each pit.

  This configuration has generally adopted pits at 30 – 40 m pit spacing and includes kerb inlet pits with 3.6m lintels, due to the flat nature of the area and the high rainfall intensity.

  The concept design also includes a series of pits within the kerb line along Hoddle Street to collect local overland flows. It is noted in some instances an offset pipe will likely be required within the roadway to avoid potential service clashes and improve constructability. However a detailed service investigation has not been undertaken.
- The proposed basin at Caalong Street will attenuate flows in order to prevent flooding across lots, with around 1.7m^3/s being conveyed via the outlet pipe to Caalong Creek in the 1% AEP. Results indicate that a basin volume of around 8000 m^3 would be required – which could be achieved via a new embankment, earthworks in the vacant parcel of land.

- It is noted that the existing pipe system outside the school would appear to be undersized from our assessment, in particular since it includes 2 x 600 mm pipes discharging to 1 x 600 mm pipe across Hoddle Street. Results indicate that this existing system can partially drain the basin, however the additional larger outlet pipe is also required.
- The proposed culvert upgrade to 3 x 1050 pipes near Sassafras Way has the ability to direct approximately 8 m^3/s to the rail corridor in the 1% AEP (increased from 1.2 m^3/s under existing conditions).

  Whilst this large diversion of flows will need to be managed, importantly it does improve the flooding of properties and the magnitude of flooding on Hoddle Street.
- The proposed upgrade works will limit the velocity - depth product along Hoddle Street in the 1% AEP to less than 0.4 m^2 / s – which is safe for pedestrians.
- The construction of a new outlet pipe extending from Meryla Street to the playing field could intercept and divert approximately 1.5 m^3/s away from the commercial properties.

  This pipeline is however quite deep (up to a maximum of 3.7 m).

  It is noted that there may be potential to further increase the amount of flow being diverted to the playing field by doing the following:

  - Raise Meryla Road by around 0.5 to 1 m
  - Provide additional ponding within the two (2) residential lots to the east (which have ponded areas under existing conditions). These lots include the residential property at 1 Meryla Street and 87 – 89 Illawarra Highway (Robertson Inn).

  This has the potential to further reduce the magnitude of flooding towards the commercial properties, however would significantly increase the flood Impact on residential properties. (thus has not been pursued as part of the detailed assessment). Refer to Plate 7.4.

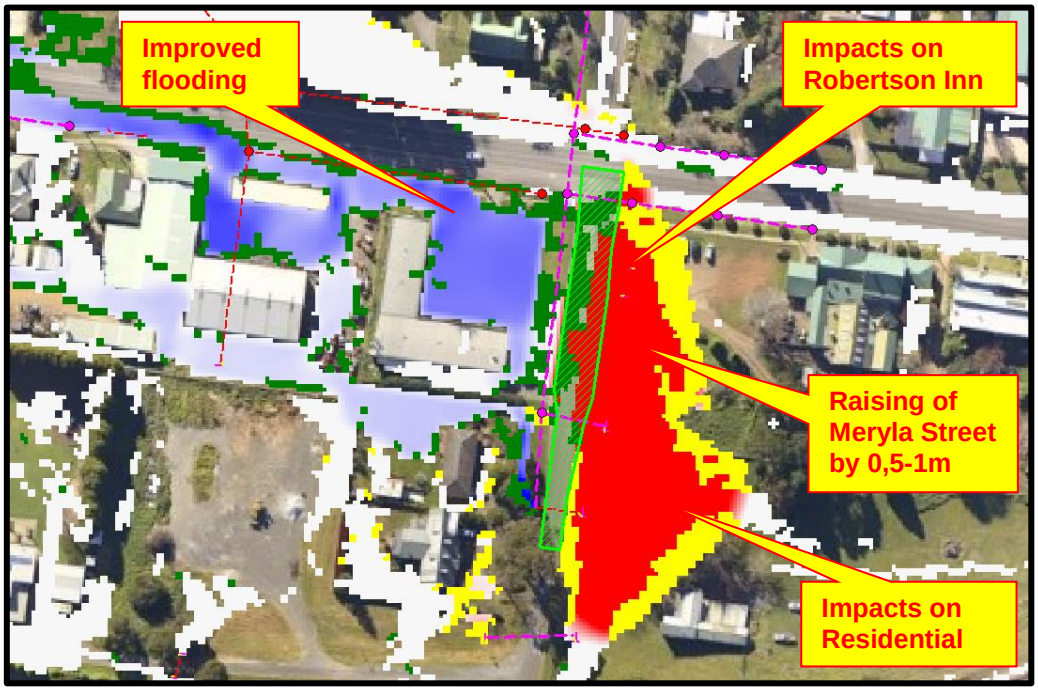


Plate 7.4 – Impact on Commercial Properties if Road Raised (1% AEP)

Whilst DRAINS provides a sound starting point, it is noted that due to the various options which are available (i.e Scenarios A to D in Section 6) and the complex nature of flooding

within the Robertson Village, testing of the overland flooding is further assessed in TUFLOW.

7.2 TUFLOW Modelling

Phase 2 has included TUFLOW modelling for both the 20% AEP and 1% AEP events in order to quantify the potential flood benefits associated with the proposed flood modification options (Scenarios A, B and C).

Scenario D, which encompasses all of the aforementioned Scenarios has been modelled across the full range of design runs (20%, 10%, 5%, 2%, 1%, 0.5% AEP and PMF events) to assess the cumulative impacts.

7.2.1 Flood Modelling Results – Scenario A Hoddle St Opt 1 (New Basin)

The flood mapping and flood difference maps for Scenario A are included on Figures 7.5 to 7.8 in Appendix A.

Results indicate the following (refer also to Plate 7.5 on the next page for more details):

- The introduction of the proposed basin will collect and manage upstream flows, with approximately 2.1 m^3/s – 2.8 m^3/s being conveyed direct to Caalong Creek via the new 900 mm dia pipe.

  Whilst the basin adopted in TUFLOW is relatively coarse (mound over existing terrain with a new piped outlet), the results demonstrate the potential benefits associated with a basin. Such benefits will include three (3) less houses affected by above floor damages and less flow being directed towards the Hoddle St sag.

  It is however noted that the detailed design would need to consider NSW Dam Safety committee considerations and Council's desire to accommodate a future pool in the area.

- Flooding will no longer overtop the sag in Hoddle Street during the 20% AEP event, however gutter flow widths do still exceed the 2.5m width and partially enter the west bound traffic lane.

  As a result of not overtopping Hoddle Street, the flood affectation of those properties directly to the north are significantly reduced in the 20% AEP event.

- In the 1% AEP event however, flooding will still overtop Hoddle Street at the sag and enter those properties directly to the north.

  The flood difference does however show that the depth of inundation is improved by 30 – 50 mm in these properties.

- The pit and pipe upgrades proposed in Hoddle Street improves local flooding with flows more effectively being collected and conveyed away from Hoddle Street.

  Importantly, results indicate that the existing Swale 3 (which is a large trapezoidal channel) is more effectively utilised with approximately 2 m^3/s of additional flow now being managed by the swale.

- The proposed flood mitigation options under Scenario A will remove above floor flooding from three (3) properties during the 1% AEP and a further four (4) properties which had property damage.

- The flood difference maps (Figures 7.6 and 7.8) demonstrate that as a result of the Scenario A works, there are some minor increases in flood depths along Caalong Creek.

  During the 1% AEP, this occurs locally around the bridge at around 30 to 40 mm. Whilst in the 20% AEP, the affected areas is more widespread and covers an approximate area of 1.3Ha at 30 mm.

The impact on flood levels during the 20% AEP is more noticeable due to the quantum of mainstream flows. That is, the flows being piped to the creek is approximately 9% of the 20% AEP mainstream flows (29.3 m^3/s) but only 3% of the 1% AEP flow (80 m^3/s).

Importantly however, the proposed works demonstrate that flows can be delivered direct to the natural creek and away from houses. Whilst flood level increases are observed in a 20% AEP, they are located at the existing watercourse and the flood extents remain very similar to existing.

Importantly, the increases in the 20% AEP are still located within the 1% AEP flood extent and therefore do not impose additional flood development controls on these lots.

- The flood difference maps (Figures 7.6 and 7.8) show increases in flood depths on Caalong Street outside the school. It is expected that these increases can be addressed as part of the detailed design of the basin and potential upgrades to pit inlets to ensure improvements in flood conditions.

Plate 7.5 – Scenario A Flood Depths and Flood Difference

7.2.2 Flood Modelling Results – Scenario B Hoddle St Opt 2 (Culvert Crossing)

The Flood mapping and Flood difference maps for Scenario B are included on Figures 7.9 to 7.12 in Appendix A.

Results indicate the following (refer also to Plate 7.6 on the next page for further details):

- The introduction of the proposed culvert upgrade 3 x 1050 mm dia pipes under Hoddle Street (near Sassafras Way) has a significant impact on localised ponding at Sassafras Way and flooding at the Hoddle Street sag.

  During the 20% AEP event, flooding is seen to no longer overtop the railway line and breakout towards the sag - with approximately 6.5 m^3/s instead being directed to Swale 4 (in the railway corridor) and ultimately towards Caalong Creek. (Existing flows to Swale 4 under 20% AEP is around 1.2 m^3/s)

  Together with pit and pipe upgrades along Hoddle Street, less flooding is consequently observed to occur on those properties to the North of the sag (No. 4 – 14 Hoddle Street) during the 20% AEP.

- In the 1% AEP event, flooding is seen however to still overtop the railway line towards the sag – with approximately 8.6 m^3/s instead being directed to Swale 4 (in the railway corridor) and ultimately towards Caalong Creek. (Existing flows to Swale 4 under 1% AEP is around 1.2 m^3/s)

- During the 20% AEP event, these redirected flows are conveyed along Swale 4 (in the railway corridor) towards Caalong Creek with only minor additional flood extents within the paddock to the north.

  Whilst during the 1% AEP event, flood depth increases are evident both along Swale 4 and in the paddock (albeit in an existing flood area) to the north of the railway.

- Importantly however, together with pit and pipe upgrades along Hoddle Street, less flooding is consequently also observed to occur on those properties to the North of the sag (No. 4 – 14 Hoddle Street) during the 1% AEP.

- Whilst improved, it is important to note that Scenario B works alone will not solely prevent flooding from overtopping the sag in Hoddle Street during the 20% AEP event.

- Gutter flow widths during the 20% AEP exceed the 2.5m width and partially enter the west bound traffic lane

- The pit and pipe upgrades proposed in Hoddle Street improves local flooding with flows more effectively being collected and conveyed away from Hoddle Street.

- Importantly, results indicate that the existing Swale 3 (which is a large trapezoidal channel) is more effectively utilised with approximately 1.7 m^3/s of additional flow now being conveyed by the swale.

- The proposed flood mitigation options under Scenario B will remove above floor flooding from four (4) properties during the 1% AEP

Plate 7.6 – Scenario B Flood Depths and Flood Difference

7.2.3 Flood Modelling Results – Scenario C (Northern and Southern Upgrades)

The Flood mapping and Flood difference maps for Scenario C are included on Figures 7.13 to 7.16 in Appendix A.

Results indicate the following (refer also to Plate 7.7 and 7.8 for further details):

Northern Upgrades

- By increasing the capacity of the roadside swales in High Street, overland flows are better collected and conveyed direct to Caalong Creek and away from properties.

  It is recognised however that the flood affectation is not completely removed for those properties to the South of High Street, but is improved.

  There may be potential to further increase the capacity of the road swales, which would further improve flooding at properties. This should be investigated as part of the detailed design.

- In the upper reaches of Caalong Creek, the introduction of a flood protection mound and diversion channel (within the High Street unformed road) will remove the flood affectation of six (6) houses along the northern side of Shackleton Way.

  Similarly, raising the existing embankment along the rear of the properties to the east (near the corner of May Street and Shackleton Road) will remove flood affectation upon a further six (6) houses along the eastern side of Shackleton Way.

- The flood protection mound / wall proposed on the existing swale at the rear of the May Street properties will enable flows to more effectively be conveyed in the existing channel and directed to the south. Thus removing the flood affectation of No. 12, 14 and 15 Devonshire Place. This work address one of the issues raised by the community during the consultation phase.

Southern Upgrades

- The flood protection mound proposed along Caalong Street (just north of the bridge crossing) will remove flood affectation for both No. 18 and 20 Caalong Street.

- The construction of a new 900mm pipe extending from the existing ponded area will bypass approximately 1.5 – 1.7 m^3/s (in the 1% AEP) away from the commercial properties towards the playing fields.

  It is noted however that this only slightly improves flooding through the commercial properties given they are positioned lower than the surrounding areas. The improvement in flood conditions is generally around 40 mm in the 1% AEP.

  As discussed in Section 7.1.3, further opportunity may be possible if additional flooding is permitted on those properties to the East if the road was raised.

- The proposed flood mitigation options under Scenario C will remove above floor flooding from ten (10) properties during the 1% AEP

Plate 7.7 – Scenario C (Northern) Flood Depths and Flood Difference

Plate 7.8 – Scenario C (Southern) Flood Depths and Flood Difference

7.2.4 Flood Modelling Results – Scenario D (Combined upgrades)

To assess the cumulative effects of Scenarios A, B and C, this option considers all recommended measures together. The following maps are provided in Appendix A:

- 1% AEP Flood Depth and Velocities – Figure 7.17 to 7.21.
- 1% AEP Flood Difference - Figure 7.22.

Results indicate the following (refer also to Plate 7.9 for focus around Hoddle Street):

- The combined effect of the culvert upgrade and the proposed basin will prevent 1% AEP flows from overtopping Hoddle Street at the sag.

  This reduces the degree of flood affectation on those properties directly to the north across the full range of AEP events. Importantly, this achieves the key objective of Phase 2 assessment and minimises the potential for Hoddle Street to be "cutoff" across a range of AEP events.

- The introduction of the proposed culvert upgrade under Hoddle Street with 3 x 1050 mm pipes (near Sassafras Way) has a significant impact on localised ponding at Sassafras Way and flooding at the Hoddle Street sag.

  Importantly, around 8.6 m^3/s of flow is directed away from the sag in Hoddle Street and into Swale 4 (in the railway corridor) which ultimately drains to Caalong Creek.

  This provides a positive impact for Hoddle Street and the railway crossing, however does impact on the rural pastures (and potentially the railway line further to the north) down to Caalong Creek.

- It is noted that the current flood modification measures only considers road widening and pit and pipe upgrade along the southern side of Hoddle Street (in the vicinity of the sag). There may be opportunity to further improve flooding on those properties to the north if a similar upgrade was undertaken (not currently investigated).

- The proposed flood mitigation options under Scenario D will remove above floor flooding from fifteen (15) properties during the 1% AEP

Plate 7.9 – Scenario D Flood Depths and Flood Difference

7.2.5 Flood Hazard and Categorisation

Hazard can be considered to be a measure of the impact that floodwater may have on both people and / or property. Hazard mapping was undertaken for each of the design runs across Scenario D (20%, 10%, 5%, 2%, 1%, 0.5% AEP and PMF events). Refer to Figures 7.23 to 7.29 in Appendix A.

By adopting a similar approach to the *Flood Study (JWP, 2016),* both flood hazard and flood categories have been generated for Scenario D. The mapping has been undertaken for each of the design runs (20%, 10%, 5%, 2%, 1%, 0.5% AEP and PMF events) and includes the following:

- Scenario D Flood Hazard Maps - Figures 7.23 to 7.29
- Scenario D Flood Category Maps – Figures 7.30 to 7.36

Importantly, Figure 7.23 demonstrates that by implementing each of the proposed upgrades the hazards along Hoddle Street is generally limited to "Low" Hazard. There are two (2) locations of hot spots which could be addressed in detailed design.

7.2.6 Summary Table

Each of the flood modification measures tested in TUFLOW (Scenarios A, B, C and D) provide varying level of benefits.

The following Tables 7.1 and 7.2 are provided to assist in the decision making process.

Table 7.1 – Summary of Flood Modelling Results (20% AEP)

Scenario	Number of Affected Properties				Hoddle Street	
	Existing		After implementing measures		Does road overtop?	
	Above Floor	Property Damage	Above Floor	Property Damage	Existing	After implementing measures
A	14	117	13	106	Y	N
B	14	117	14	114	Y	Y
C	14	117	11	117	Y	Y
D	14	117	10	106	Y	N

Table 7.2 – Summary of Flood Modelling Results (1% AEP)

Scenario	Number of Affected Properties				Hoddle Street	
	Existing		After implementing measures		Does road overtop?	
	Above Floor	Property Damage	Above Floor	Property Damage	Existing	After implementing measures
A	35	104	32	100	Y	N
B	35	104	31	108	Y	Y
C	35	104	25	113	Y	Y
D	35	104	20	107	Y	N

Results therefore indicate that Scenario D will reduce the above floor flooding upon eleven (15) properties, whilst also ensuring that Hoddle Street does not overtop during the 1% AEP event.

8 FLOOD DAMAGES

Flood damages assess the economic and social implications of flooding on a community. As identified in the *Floodplain Development Manual* (2005), there are two (2) main categories of flood damages including tangible and intangible damages, as shown on Plate 8.1.

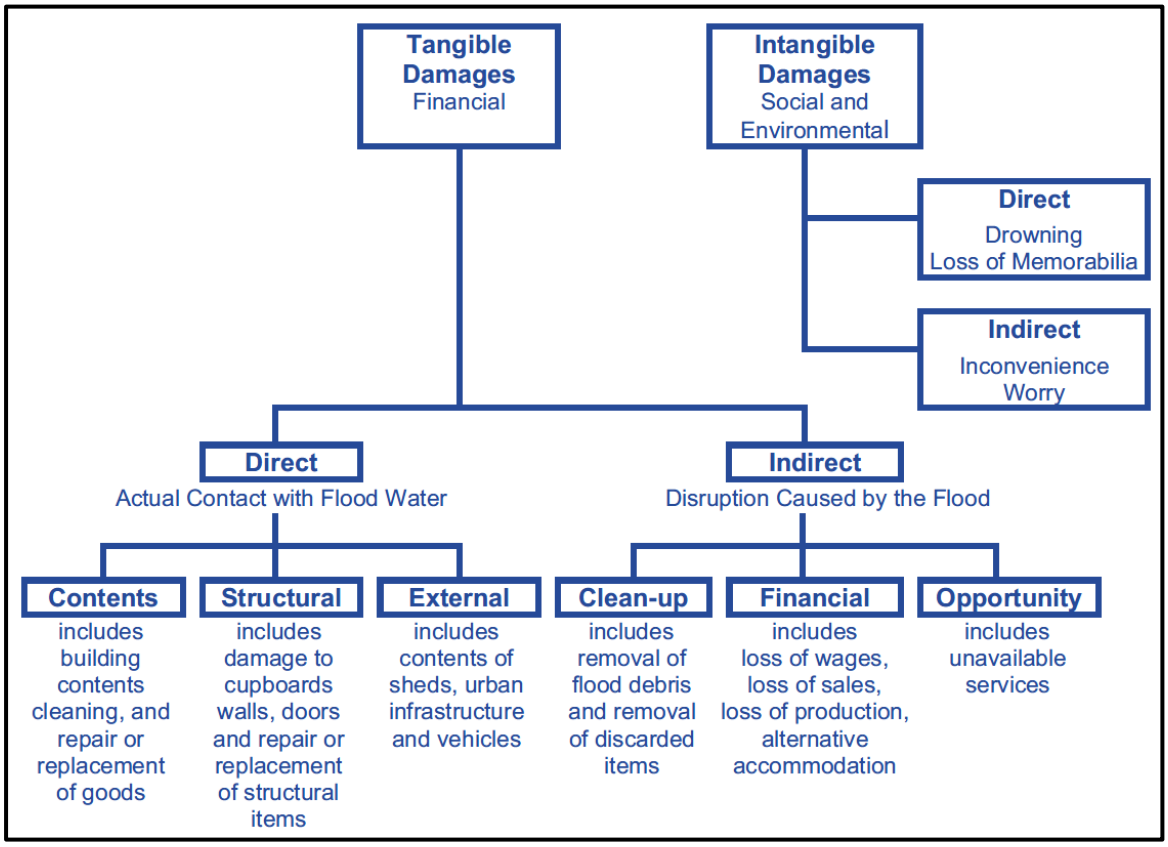


Plate 8.1 – Types of Flood Damages (Source: FDM, 2005)

Tangible damages are primarily assessed financially, from costs associated with the repairing and/or replacing of damaged or lost property due to a flood event. Direct tangible damages include: damages to structures, property contents and facilities which can be measured from reconstruction measures. Indirect tangible damages include costs associated with flood damages that cannot be directly anticipated or modelled prior to a flood event. These include loss of business for commercial properties, alternative accommodation costs for residential victims, loss of wages and clean-up costs for the community (FDM, 2005).

Intangible damages are unquantifiable in nature and represent the social, environmental and emotional damages caused by a flood event. These are often associated with the mental and physical damages caused to victims of a flood. That is, the impacts of a major flood event on an individual may include substantial levels of stress, anxiety, frustration or fear for their livelihoods and the lives of others (FDM, 2005).

This assessment has been undertaken to determine the tangible damages caused by flooding in the 20%, 10%, 5%, 2%, 1% and 0.5% AEP and PMF flood events at Robertson Village upon:

- Residential dwellings
- Commercial properties
- Infrastructure and services

The objective of this assessment is to determine the flood damage costs under "existing conditions" to provide a "base case", as well as under "proposed" conditions that include the recommended flood mitigation measures. This will then enable the financial benefits of any proposed upgrade works to be quantified by comparing flood damage costs.

Given the modelling methodology used in this assessment (Direct Rainfall), the assessment of damages was refined to only include properties that are within 4 m (one TUFLOW cell width) from the major flow path within Robertson Village and have a direct connection to Caalong Creek. All buildings were digitised using supplied aerial imagery.

Each of the properties has been assigned a reference number dependent on whether it is Residential "R", Commercial "C" or School "S".

For the purposes of this assessment, Flood Damages are categorised into the following:

- **Direct Residential Dwelling Damages** - damages to residential properties with above floor flooding of the main dwelling.
- **Direct Residential Property Damages** - damages to residential properties external of the main dwelling.
- **Indirect Residential Damages** - 15% of total direct damages to residential properties, as per the ANFLOOD method (Taylor, Greenway and Smith, 1983).
- **Direct Commercial Damages** - damages to commercial properties with above floor flooding.
- **Indirect Commercial Damages** - 50% of total direct damages to commercial properties.
- **Infrastructure Damages** - associated with public and service infrastructure such as roads, bridges, water, gas and electric services, council parklands and emergency costs. Infrastructure damages have been adopted as per the *Georges River Floodplain Risk Management Study* (Bewsher, 2004) as follows:
    - 30% of total damages for flood events up to the 1% AEP.
    - 20% of total damages for flood events over the 1% AEP.

8.1 Flood Damage Curves

8.1.1 Residential Flood Damage Curves

For the purposes of this assessment, residential flood damage curves have been calculated using the *Office of Environment and Heritage – Residential Flood Damage Calculation Sheet* based on variables which J.Wyndham Prince have previously adopted in other similar rural – residential areas. Refer to Table 8.1 for the various inputs within this calculation.

Table 8.1 – Input Variables for Damages Estimation

Variable	Input Value
Regional Cost Variation Factor	1
Post late 2001 adjustments	1.48
Post Flood Inflation Factor	1.4
Typical Duration of Immersion	6 Hours
Building Damage Repair Limitation Factor	0.9
Typical House Size	131 m^2
Contents Damage Repair Limitation Factor	0.85
Level of Flood Awareness	Low
Effective Warning Time	2 Hours
Typical Table/Bench Height	0.9
External Damage	$6,700
Clean-up costs	$4,000
Likely Time in Alternative Accommodation	8 Weeks
Additional Accommodation Costs	$220

In order to determine tangible damages for residential properties, a Total Contents Adjustment Factor (TCAF) was determined to incorporate flood risk mitigation factors and limitations to repair costs. The TCAF is calculated from multiplying a Damage Reduction Factor (DRF) and Contents Damage Repair Limitation Factor (CDRLF) which are described as follows:

- A DRF is applied to incorporate flood response measures undertaken by individual property owners and the community. These measures could include the raising of contents to 0.9 m, which resembles a typical table/bench height, removal of contents during evacuation procedures, or emergency responses undertaken in the community (i.e. sand bagging or temporary levee construction).
- A CDRLF is applied to address repair costs which are required to be provided by the individual land owner. This is associated with lack of insurance and self-funded works. For this assessment, a CDRLF of 0.85 has been applied.

The TCAF factors adopted for this study are therefore:

- For depths less than 0.9 m, TCAF = 1.16
- For depths greater than 0.9 m, TCAF = 1.26.

The "residential" flood damage curves which have been extracted from the *Office of Environment and Heritage – Residential Flood Damage Calculation Sheet* are shown in Plate 8.2 below.

Three (3) separate curves were generated for the different types of residential dwellings at Robertson Village, which include:

- Single storey dwelling with a concrete slab base (low set)
- Elevated single storey dwelling (high set)
- Two-storey dwelling (double storey).

Based on field investigations and Google "Street View", each property was subsequently assigned a building type and associated flood damage curve.

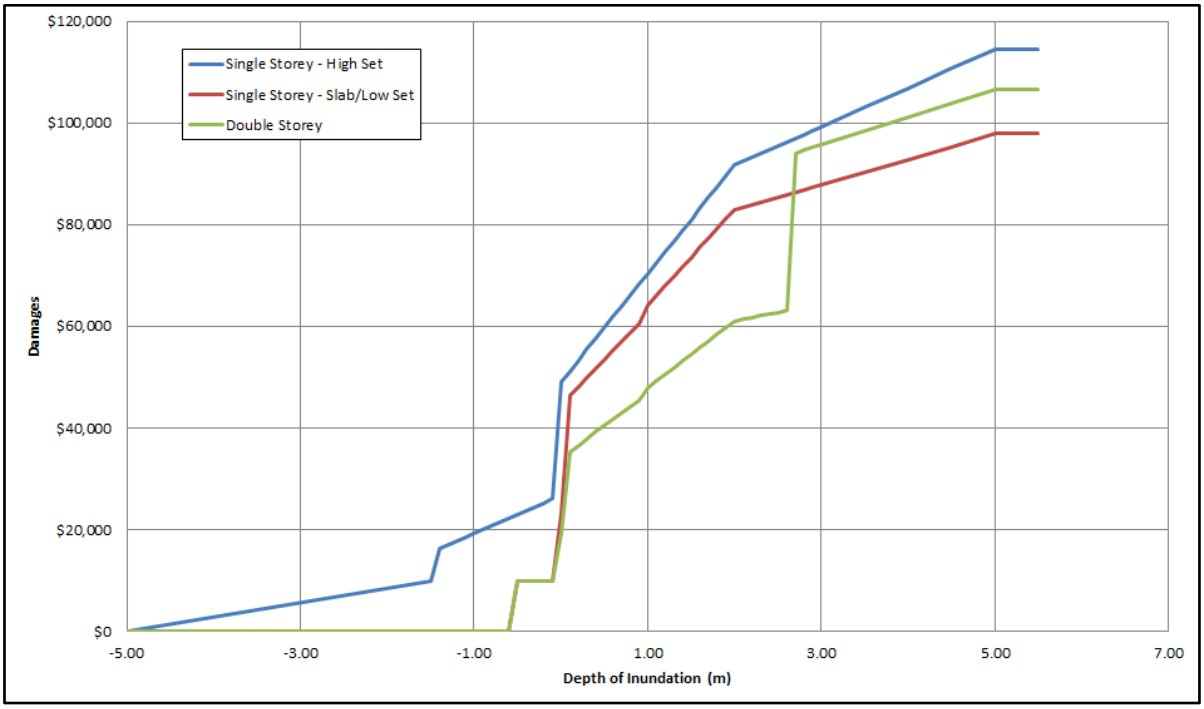


Plate 8.2 – Residential Staged Flood Damage Curves

8.1.2 *Commercial Flood Damage Curves*

"Commercial" Flood Damage Curves have been adopted from the *Georges River Floodplain Risk Management Strategy* (Bewsher, 2004) with staged costs included in Appendix D.

As the *Georges River Floodplain Risk Management Strategy* (Bewsher, 2004) was completed in 2003, the stage-damage costs for commercial properties have been increased by a factor of 36.4 % (Reserve Bank of Australia, 2014) to account for inflation between 2003 and 2015.

Three (3) separate curves were generated to represent the different types of commercial properties which may appear at Robertson, including:

- **Low Value** – such as florists, offices, post offices, public halls and churches.
- **Medium Value –** such as grocers, banks, hairdressers, small retail and take-away food shops.

- **High Value** – such as restaurants, newsagents, chemists, petrol stations and bottle shops.

Based on field investigations and Google "Street View", each property was subsequently assigned a commercial value type and associated damage curve.

For each property type, the flood damages cease increasing after a depth of inundation of 2 m as applied in the *Georges River Floodplain Risk Management Strategy* (Bewsher, 2004). Refer to Plate 8.3 below.

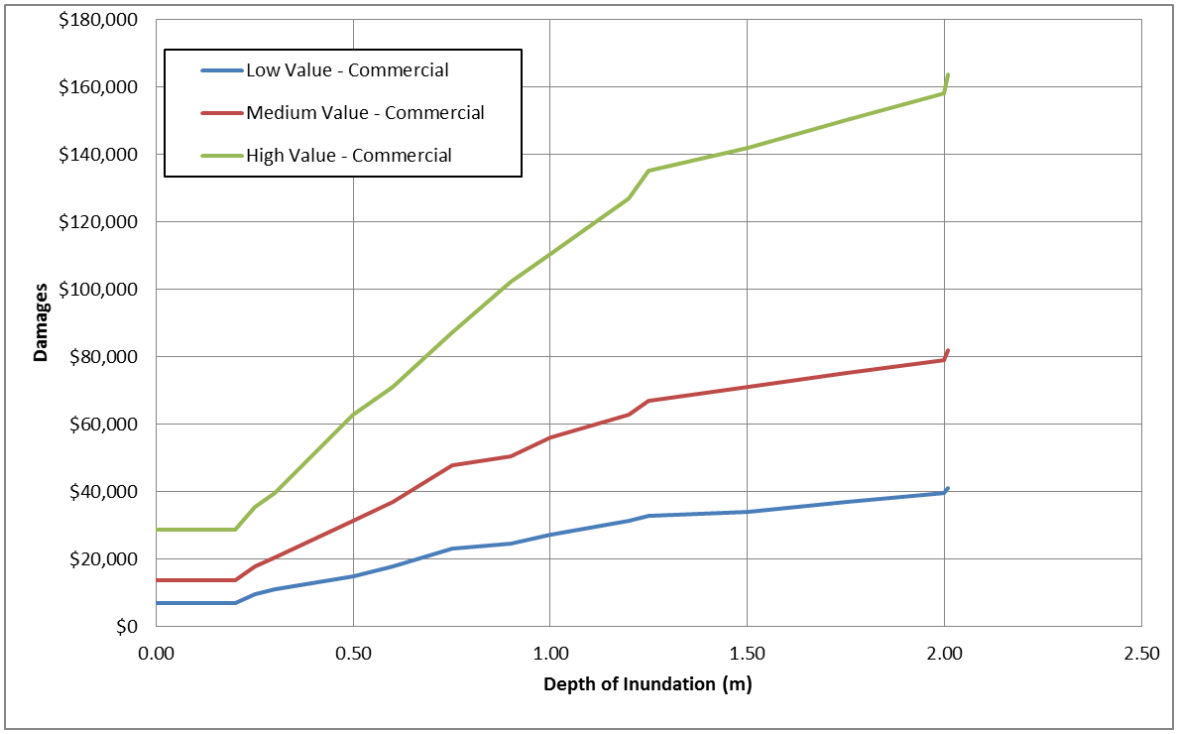


Plate 8.3 – Commercial Staged Flood Damage Curves

8.2 Assumptions

The following assumptions were applied for the flood damages assessment:

- It is noted that a 0.05 m cut-off is applied to flood mapping in order to differentiate between sheet flow and flooding. Those properties which experience a depth of inundation less than 0.05 m are therefore assumed to be 'flood free' and have not been assessed for damages. This is because flood depths less than 0.05 m generally do not enter a property as a minimum slab depth for properties is approximately 0.15 m (BMT WBM, 2013).
- In the absence of floor level information, each dwelling has been artificially raised in TUFLOW by an assumed 0.3 m from the underlying ALS data. A freeboard has not been included in OEH spreadsheet calculations.
- Damages have only been considered on properties where an existing dwelling is located. Those vacant lots have been excluded from calculations.
- Dwellings located within a 4 m distance of the 0.5% AEP extent along major flow paths within the study area have been assessed for flood damages up to the 50% AEP. All dwellings located within the PMF extent along the major flow paths were assessed for flood damages in the PMF.
- In the absence of flood level information for minor storm events, it is assumed that during the 1 Exceedances Per Year (1 yr ARI) event, no flood damages are generated in the catchment.

8.3 Flood Damage Results

In order to provide Council with an appreciation of the flood damages within the study area, the flood damages assessment has considered the following scenarios:

- Existing Conditions – All Modelled Events
- Scenario A – 50% and 1% AEP events only
- Scenario B – 50% and 1% AEP events only
- Scenario C – 50% and 1% AEP events only
- Scenario D – All Modelled Events

8.3.1 Flood Damages Results Existing Conditions

The "existing" Flood damage costs ($) for residential and commercial properties at Robertson Village are summarised in Table 8.2. For further details refer to Appendix D.

Results indicate that under existing conditions, a large number of residential properties are affected for the 20 % AEP event and above. It is noted that in many instances the damages are associated with property damage (i.e damages which are not above floor flooding).

Table 8.2 – Existing Conditions Flood Damages Summary

Storm Event	Direct	Indirect	Infrastructure	Total
1 EY	$ -	$ -	$ -	$ -
20 % AEP	$ 2,133,083	$ 319,962	$ 735,914	$ 3,188,959
10 % AEP	$ 2,327,292	$ 349,094	$ 802,916	$ 3,479,301
5 % AEP	$ 2,498,868	$ 377,217	$ 862,826	$ 3,738,911
2 % AEP	$ 2,782,785	$ 426,966	$ 962,925	$ 4,172,676
1 % AEP	$ 3,090,712	$ 477,929	$ 1,070,592	$ 4,639,234
0.5 % AEP	$ 3,362,971	$ 524,974	$ 1,166,384	$ 5,054,329
PMF	$ 6,197,775	$ 1,128,742	$ 2,197,955	$ 9,524,472

In order to assess the average damage cost for Robertson Village for any given year, the "Average Annual Damage" (AAD) has been calculated. The AAD is a multiplication of flood damage costs with the flood event probability of occurrence and indicates the average cost of flood damages for a community in any given year (Bewsher, 2004). Results of the AAD are summarised in Table 8.3, with further details provided in Appendix D. I

Table 8.3 – Average Annual Damages (Existing Conditions)

Damage Category	Existing	
	AAD	% of Total AAD
Direct - Residential	$1,342,649	66.7%
Indirect - Residential	$201,397	10.0%
Direct - Commercial	$2,837	0.1%
Indirect - Commercial	$1,419	0.1%
Infrastructure	$464,491	23.1%
Total	**$2,012,793**	**100%**

Results indicate that 67% of the AAD are due to direct damages associated with residential and commercial properties at Robertson Village.

8.3.2 Flood Damages Results Scenarios A - C

To provide Council with an appreciation of the impact on flood damages generated by Scenarios A - C, a flood damages assessment has been completed for these scenarios under the 20% and 1% AEP events. This demonstrates the performance of each scenario and can inform the future prioritisation and staging of works.

Results indicate that under existing conditions, a large number of residential properties are affected for the 20 % AEP event and above. It is noted that in many instances the damages are associated with property damage (i.e damages which are not above floor flooding).

Table 8.4 – Flood Damages (Scenarios A – C)

Storm Event	Existing	Scenario A	Scenario B	Scenario C
20% AEP	$3,188,959	$2,222,258	$2,407,500	$2,280,323
1% AEP	$4,639,234	$3,323,199	$3,472,090	$3,137,493

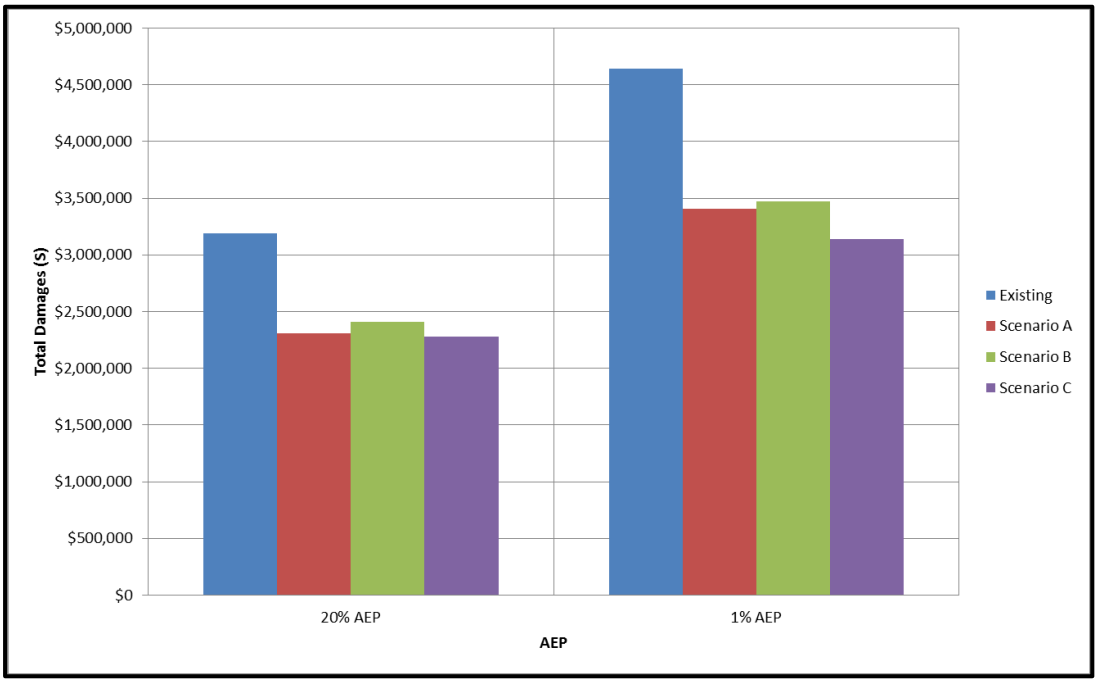


Plate 8.4 – Flood Damages Chart (Scenarios A – C)

Results for Scenarios A – C indicate that:

- Under Scenario A, a reduction in flood damages of approximately $880k - $1.2m occurs in the 50% and 1% AEP events respectively. This is due to the proposed flood mitigation options, which has improved the stormwater drainage capacity of Hoddle Street. Refer to Figure 7.6 for details of the flood difference generated along Hoddle Street under Scenario A.
- Under Scenario B, a reduction in flood damages of approximately $780k - $1.1M in the 50% and 1% AEP events respectively.
- Under Scenario C, a reduction in flood damages of approximately $910k - $1.5M in the 50% and 1% AEP events respectively.

8.3.3 Flood Damages Results Scenarios D

To determine the overall improvement to flood damages generated by the proposed flood mitigation measures, a detailed flood damages assessment has been completed for Scenario D. The findings of this assessment will provide Council with an appreciation of the overall reduction in flood damages that may occur once each proposed flood mitigation measure is constructed.

The flood damage costs ($) for residential and commercial properties at Robertson Village are provided in Appendix D with a summary provided in Table 8.5.

Table 8.5 – Scenario D Conditions Flood Damages Summary

Storm Event	Direct	Indirect	Infrastructure	Total
1 EY	$ -	$ -	$ -	$ -
20 % AEP	$ 1,796,363	$ 269,454	$ 619,745	$ 2,685,563
10 % AEP	$ 1,954,790	$ 293,219	$ 674,403	$ 2,922,412
5 % AEP	$ 2,101,867	$ 315,280	$ 725,144	$ 3,142,291
2 % AEP	$ 2,245,344	$ 341,576	$ 776,076	$ 3,362,995
1 % AEP	$ 2,486,539	$ 382,529	$ 860,720	$ 3,729,788
0.5 % AEP	$ 2,795,752	$ 430,343	$ 967,828	$ 4,193,923
PMF	$ 5,818,184	$ 1,047,456	$ 2,059,692	$ 8,925,331

An assessment of the AAD with the proposed mitigation options has been completed, with a summary of the results provided in Table 8.6, with further details provided in Appendix D.

Table 8.6 – Average Annual Damages (Scenario D)

Damage Category	Scenario D	
	AAD	% of Total AAD
Direct - Residential	$1,129,205	66.7%
Indirect - Residential	$169,381	10.0%
Direct - Commercial	$1,880	0.1%
Indirect - Commercial	$940	0.1%
Infrastructure	$390,421	23.1%
Total	**$1,691,826**	**100%**

Results indicate that 67% of the AAD are due to direct damages associated with residential and commercial properties at Robertson Village.

8.4 Flood Damages Conclusion

The flood damages assessment has determined the anticipated economic impact of major flooding within Robertson Village. Results indicate that under existing conditions, during the 1% AEP and PMF events, tangible flood damages within Robertson Village are $4.6 million and $9.5 million respectively. Furthermore, the Average Annual Damage, which reflects the average cost of damages in any given year due to major flooding, is currently $2 million.

As a result of a combination of the proposed flood mitigation measures, the total flood damages at Robertson Village will reduce the costs to the community by approximately $600,000 and $800,000 in the 1% AEP and PMF events respectively. Furthermore, adoption of the proposed flood mitigation measures will improve the Average Annual Damage by approximately $250,000 per year.

9 COST / BENEFIT

9.1 Costs

Preliminary cost estimates have been determined for the proposed flood mitigation measures outlined in Section 6.0. The overall costs for each option have been provided in Table 9.1. Refer to Appendix E for the breakdown of these costs.

Table 9.1 –Preliminary Cost Estimates

Scenario	Description	Cost Esimate
Scenario A	Hoddle St Option 2 (Culvert	$1,640,000
Scenario B	Hoddle St Option 1 (New	$1,073,000
Scenario C	Northern and Southern	$510,000
Scenario D	Combined	$2,256,000

9.2 Cost Benefit

A cost benefit assessment has been completed to determine the financial benefits of the proposed works associated with the reductions in flood damages. The assessment has been based on the preliminary cost estimates completed for each Scenario and the flood damages calculations undertaken in Section 8.0.

As the flood modelling has investigated a variety of different storm events, a separate cost benefit assessment has been completed for Scenarios A-C and Scenario D. Refer to Sections 9.2.1 and 9.2.2 for further details.

9.2.1 Scenarios A – C

The flood modelling assessment for Scenarios A-C has determined the flood extents and level of inundation for the 20% and 1% AEP events, to support the hydraulic performance of the proposed mitigation measures. To determine the financial benefit generated by Scenarios A-C a comparison of the flood damages for these Scenarios against the preliminary cost estimates for the mitigation works have been completed. Refer to Tables 9.2 and 9.3 for the cost benefit results for the scenarios for the 30% and 1% AEP events respectively.

Table 9.2 –Cost Benefit Results (20% AEP event)

Scenario	Damages	Damages Reduction	Cost Estimate	Cost / Benefit
Existing	$3,188,959	-	-	-
Scenario A	$2,222,258	$966,701	$1,640,000	0.6
Scenario B	$2,407,500	$781,459	$1,073,000	0.7
Scenario C	$2,280,323	$908,635	$510,000	1.8

Table 9.3 –Cost Benefit Results (1% AEP event)

Scenario	Damages	Damages Reduction	Cost Estimate	Cost / Benefit
Existing	$4,639,234	-	-	-
Scenario A	$3,323,199	$1,316,034	$1,640,000	0.8
Scenario B	$3,472,090	$1,167,144	$1,073,000	1.1
Scenario C	$3,137,493	$1,501,741	$510,000	2.9

9.2.2 Scenario D

Further to the flood damages assessment in Section 8.0 and cost benefit assessment for Scenarios A - C, a comparison of the cost / benefit is also undertaken on Scenario D in order to support the proposed upgrade works.

An assessment of the Net Present Value (NPV) of each option and flood damages has been undertaken with a 7 % discount rate in accordance with the *"Georges River Floodplain Risk Management Study and Plan"* (2004) along with an assumed design life of 50 years.

The NPV provides a comparison between the capital / on-going costs of the proposed flood mitigation measures versus the reduction in flood damages over the design life.

Calculations are applied in accordance with the *Office of Environment and Heritage – Residential Flood Damage Calculation Sheet.* Results are summarised in Table 9.4.

Table 9.4 – Net Present Value

Description	Design Life	AAD	NPV
Existing	50	$ 2,012,793	$ 29,790,842
Scenario D	50	$ 1,691,826	$ 25,040,292

Comparison of the proposed and existing cumulative flood damages indicate the long term financial benefits associated with the proposed mitigation measures. These financial benefits are then compared against the preliminary cost estimates (provided in Appendix E) to determine the benefit / cost ratio – indicating the overall financial benefit for the proposed flood mitigation measures over a 50 year design life. The benefit / cost ratio for Scenario D, incorporating all proposed flood mitigation measures, is provided in Table 9.5.

Table 9.5 – Benefit / Cost Ratio

Description	NPV of Damages	Preliminary Cost Estimate	Reduction in Damages	Benefit / Cost Ratio
Existing	$ 29,790,842	-	-	-
Scenario D	$ 25,040,292	$ 2,256,000	$ 4,750,550	2.11

9.3 Recommendations

Results indicate that the cost / benefit associated with Scenario D, which incorporates all proposed flood mitigation measures, is 2.11 – indicating that the costs of not doing the proposed upgrade works are greater than the cost of works across the assumed 50 year life cycle.

Importantly, the cost benefit analysis for Scenarios A, B and C indicates that each scenario in isolation provides an improvement of flood damages in the 1% AEP event that exceeds the cost to construct each scenario.

However a number of items need to be considered in determining the "effectiveness" of the proposed flood mitigation measures. These include:

- A substantial portion of the preliminary cost estimate for Scenario D included works to upgrade the capacity of the street drainage system within Hoddle Street. As the drainage system upgrades do not directly improve flood damages results, the improvement to local nuisance flooding along Hoddle Street will be a significant improvement to Robertson Village and provide significant social benefits to the community.
- The proposed flood mitigation measures will remove above floor flooding in 15 residential properties within Robertson Village.

The implementation of the proposed Scenario D flood mitigation measures will benefit the community, reduce flood affectation within both residential and commercial properties within the township and address nuisance / local / overland issues and achieve Council's objectives of flood management and reduction in flood affectation within Robertson Village and are recommended.

10 ASSESSMENT OF SOCIAL AND ENVIRONMENT IMPACTS

A desktop assessment of the social and environmental impacts has been undertaken for each of the proposed "Flood Mitigation" measures identified in Section 6.1. The assessment is based on detailed site inspections and a review of aerial imagery.

Council's LEP Maps define several key areas which are zoned "RE1 – Public Recreation" and "E1 National Parks and Nature Reserves". Development is not permitted in these areas.

Importantly, it is understood that Caalong Creek which bisect through the rear of existing properties, includes remnants of Yarrawa Brush rainforest and woodland vegetation (which are important environmental features). In the absence of any supplied GIS information, vegetation areas have been digitised from aerial imagery and presented on Plate 11.1.

Whilst these digitised areas may not entirely represent the exact areas of significant woodland, they are considered appropriate for this level of assessment. Further detailed environmental assessments shall however be undertaken (by others) in due course to support the future approval / implementation of any flood modification measures.

10.1 Road Widening and Pit / Pipe Upgrade

The proposed widening of Hoddle Street and upgrades to the pit and pipe network will improve the level of serviceability of the Highway during extreme rainfall events, reduce the risk of high hazards and improve the stormwater infrastructure in accordance with Council guidelines.

Retrofitting stormwater infrastructure into urbanised catchments always presents design challenges. In particular, negotiation around existing services is generally challenging with often a broad range of services.

Existing services along and in the vicinity of Hoddle Street include (but not necessarily limited to) electrical, telecommunications, water and sewer. The existing deep road side swale which is to be replaced by the proposed road widening includes scattered power poles in the batter, with above ground electrical wires.

The detailed design will need to carefully consider all existing services and the most appropriate configuration of stormwater network to avoid clashes (where possible). There is however a risk that some service adjustments may be required.

There are several key social issues which will need to be considered with the proposed upgrades to Hoddle Street.

- Traffic Management - Consideration would need to be given to Traffic Management during construction. Hoddle Street forms part of the Illawarra Highway and subsequently works will need to be staged in order to maintain regional connectivity. This is particularly important with the railway nearby (to avoid queuing across the railway line)
- Consideration will also need to be given to staging works around the commercial areas of Hoddle Street – to minimise disruption to shop owners.
- There are numerous driveways which access Hoddle Street. Suitable safe access will need to be provided for each owner / tenant throughout the implementation of any future construction works.

10.2 Detention Basin

The construction of a detention basin will improve the level of flood affectation upon nearby properties and will reduce the volume of flow directed to the Hoddle Street sag.

A key constraint / social impact is associated with both the current and future land use of the available area. The land is currently clear, with scattered low vegetation. It is zoned as both "R2 Low Density Residential" (which appears to be a paper road), "RE2 Private Recreation" and "SP1 Special Activities".

It is understood that the local community is seeking to construct a "public pool" in this area. However given the significant benefits of the basin, it is recommended that consultation be undertaken with the community to negotiate an agreed outcome that could deliver both flood mitigation and public pool outcomes.

Modelling results suggest that a detention basin and a public pool could possibly both be adopted in the available space, but would be subject to detailed design.

Other social impacts of the basin include the existing informal driveway accesses, which appear to extend from the end of Caalong Creek to those properties to the West. It is unclear if these accesses are Council approved.

The formation of the basin upgrade will determine the level of potential flood risk in the event of a dam failure. Detailed design and liaison with the NSW Dam Safety Committee will be required.

10.3 Swale Upgrades (Hoddle Street)

The reconstruction of the swales 1 to 3 will enable flows to more effectively drain away from Hoddle Street towards Caalong Creek, whilst enabling adequate cover over the proposed pipe system upgrade in Hoddle Street.

Swales 1 and 3 are located within Council land (road reserve) and can be reformed to a shallower grade and increased capacity without the need to liaise with landowners. The vegetation is quite sparse and appears to be maintained sparingly by Council.

Swale 2 however bisects the existing private properties (vacant land) just to the north of Hoddle Street. Based on GIS information supplied by Council, there does not appear to be an easement over this existing swale. It is recommended that liaison be undertaken with the landowner to negotiate easement rights, construction approval and the rights for ongoing maintenance access.

Existing services along, and in the vicinity of, the swales include (but not necessarily limited to) telecommunications, water and sewer.

The extension of Swale 3 is proposed to be positioned on the western side of the existing Sewerage Treatment Plant (STP). Interestingly, the STP appears to have been located in Council's unformed road reserve, which impedes the ability for the swale to be extended to Caalong Creek and remains in public land.

Notwithstanding, detailed design should be undertaken to investigate whether the proposed swale can fit alongside the STP (within the paper road formation). Alternatively, the swale will need to be located in the adjacent open pasture – which would require property acquisition / easement.

There may be potential for environmental impacts at the discharge point of the Swale 3 extension to Caalong Creek. Detailed design therefore needs to consider the need for energy dissipation and a flow spreader to minimise erosion issues.

During construction, sediment and erosion control measures will need to be implemented in accordance with best industry practice in order to ensure preservation of the condition of Caalong Creek.

10.4 Culvert Crossing Upgrade

The proposed upgrade of the existing crossing 0.8 m x 0.45 m box culvert under Hoddle Street to become 3 x 1050 mm pipes will intercept and redirect flows away from the sag in Hoddle Street towards the rail corridor and ultimately Caalong Creek to the North.

There are some potential key environmental and social issues which will need to be considered:

- Traffic Management - Consideration would need to be given to Traffic Management during construction. Hoddle Street forms part of the Illawarra Highway and subsequently works will need to be staged in order to maintain regional connectivity. This is particularly important with the railway nearby (to avoid queuing across the railway line)
- The additional flows being redirected to Swale 4 is around 8.6 m^3/s (increased from 1.2 m^3/s) during the 1% AEP.

  This provides a positive impact for Hoddle Street and the railway crossing, however does impact on the rural pastures (and potentially the railway line further to the north) down to Caalong Creek.

  Further discussion / negotiations will need to be undertaken by Council with ARTC and individual landowners in order to progress the approval of this option.

10.5 Road Swales (High Street)

The minor upgrades to road side swales along High Street will improve the amount of flow being directed towards Caalong Creek and away from existing houses.

There appears to be minimum social and environmental impacts associated with reforming the existing table drains alongside High Street. Both the functionality and discharge point will remain the same, however the capacity increased.

Notwithstanding, the potential for environmental impacts at the discharge point where the swale extends to Caalong Creek is still applicable. Detailed design therefore will need to consider the need for energy dissipation and a flow spreader to minimise erosion issues.

During construction, sediment and erosion control measures will need to be implemented in accordance with best industry practice.

10.6 Flood Protection Mound / Wall (Devonshire Road).

The proposed construction of a flood protection mound / wall along the existing swale at the rear of the May Street properties will remove overland flooding which currently enters No. 12, 14 and 15 Devonshire Place

The configuration and constructability of the wall / mound will need to deliver bank stability and consider the level difference to the downstream properties.

The existing swale does include a variety of established trees along the edge of the swale, which will need to be carefully considered. It is anticipated that the alignment of the proposed mound / wall could be positioned to avoid all significant vegetation and to minimise environmental impacts.

During construction, sediment and erosion control measures will need to be implemented in accordance with best industry practice.

10.7 Flood Protection Mounds and / or Diversion Channel (Shackleton Way)

The proposed construction of a flood protection mound and diversion channel in the upper reaches of Caalong Creek (near Shackleton Way) will remove flood affectation through properties.

By restricting the limit of works to Council's unformed road reserve, there will no need to negotiate with individual landowners. It is recognised however that there may be social impacts associated with the existing informal driveway accesses, which appear to be made from the end of High Street to the rear of those properties to the East. It is unclear if these accesses are Council approved.

There may be potential for environmental impacts associated with the existing vegetation within the unformed road reserve. It is anticipated that the alignment of the proposed swale and mound could be positioned around any significant vegetation to minimise impacts.

There may be potential for environmental impacts at the discharge point where the swale extends to Caalong Creek. Detailed design therefore needs to consider the need for energy dissipation and a flow spreader to minimise erosion issues.

During construction, sediment and erosion control measures will need to be implemented in accordance with best industry practice.

10.8 Flood Protection Mound (Caalong Street)

A small flood protection mound along the frontage of No. 18 – 20 Caalong Street properties will provide a benefit by improving the flow conveyance of flows towards Caalong Creek and away from existing houses.

The proposed mound may potentially impact upon existing trees along the frontage of the properties. Detailed design is to consider an alignment to try and retain the vegetation (if possible).

Similarly, the potential for environmental impacts where the swale / mound directs flows to Caalong Creek will need to be considered. Detailed design therefore will need to consider the need for energy dissipation and a flow spreader to minimise erosion issues.

During construction, sediment and erosion control measures will need to be implemented in accordance with best industry practice.

10.9 New outlet pipe from ponding area (Meryla Street)

The construction of a new outlet pipe extending from the existing ponded area at Meryla Street to the playing fields is provided to try and improve the flood affectation upon commercial properties at the corner of Hoddle Street and Meryla Street.

The potential social and environmental impacts include the following:

- Additional low flows will be directed to the playing fields. Whilst it is expected that these would be managed via the existing swale around the fields, it would add additional flows during each storm event.
- The proposed pipe line is relatively deep towards the northern end (up to 3.7 m deep) which may impose some constructability issues.

Plate 10.1 – Social and Environmental Assessment

11 FLOODPLAIN RISK MANAGEMENT PLAN

11.1 Objectives

The overall objective of the FRMS&P is to develop a long-term approach to flood and floodplain management for Robertson Village that addresses the existing and future flood risks, in line with the principles of the NSW Floodplain Development Manual.

Specific objectives include:

- Reduce the flood hazard and risk to people and property, now and in the future; and
- Ensure floodplain risk management decisions integrate economic, environmental and social considerations.

Given there are no (or limited) flood studies previously undertaken in the study area, the significance of the FRMS&P is recognised as a key outcome to improving flood affectation across Robertson Village.

11.2 Recommended Measures

The recommended measures for the FRMS&P have been selected from the suite of options introduced in Section 6 and assessed in Section 7.

This assessment focused on the impact of flood risk along with the economic, environmental and social factors. Recommendations are presented in Table 11.1 and on Figure 7.39.

11.3 Plan Implementation

11.3.1 Costs

The capital cost of the FRMS&P is broken up into the following:

- Scenario A - Hoddle Street Option 1 (New Basin) - $1.64M
- Scenario B - Hoddle Street Option 2 (Culvert Crossing) - $1.07M
- Scenario C - Northern and Southern Upgrades - $0.51M
- Scenario D – Combined Upgrades (Scenario A, B and C) - $2.26M
- Voluntary House Purchase Scheme - ($3.8 – 4.76M)

By implementing Scenario D (combined upgrades), the proposed measures will reduce above floor flooding across fifteen (15) houses during the 1% AEP. The damage savings would be around $4.75M, which results in an overall benefit – cost ratio of 2.11. (Note: Voluntary House Purchase not included in the cost-benefit assessment).

Importantly, the upgrades at Hoddle Street provides benefits by improving the flood affectation without necessarily providing a tangible benefit to the impact of flood (i.e removing damages). As discussed in Section 10, the cost-benefit ratio for individual Scenarios (A, B and C) provide a further breakdown. For Scenarios A, B and C these include cost-benefit ratios of 0.8, 1.1 and 2.9 respectively in the 1% AEP event.

The implementation of the proposed measures will therefore improve flood affectation and reduce the risks to property and life in the study area.

The FRMS&P also provides technical details to support future funding applications and the required design processes for these mitigation works.

11.3.2 Priorities and Timing

Each of the proposed measures are presented in Table 11.1 with a priority and a timeframe being assigned.

The “priority” ratings represents the urgency of the option from the perspective of reducing flood risk to property and life. Whilst the “timing” represents an estimate on the timeframe which may be required based on capital expenditure and the need for further investigation or stakeholder / community consultation.

11.4 Plan Maintenance

It is recommended that the FRMS&P is updated every 5 to 10 years based to asses or align with any additional flood events, flood modelling, planning changes, budgetary commitments or climate change information. Refer Table 11.1 on the following page and Figure 7.39 in Appendix A.

Table 11.1 – Summary of Proposed Measures

12 POST EXHIBITION

The Draft FRMS&P was placed on public exhibition by Wingecarribee Shire Council from 14 July 2016 to mid August 2016. Several submissions were made as part of the exhibition process. Details of the main concerns are summarised below.

12.1 Meeting with the Floodplain Committee

Prior to placing the Draft FRMS&P on exhibition, J. Wyndham Prince met with the Floodplain Risk Management Committee (20 June 2016) in Council chambers. The Draft FRMS&P was generally well received and subsequently was accepted to be listed on public exhibition (email correspondence dated 21 June 2016).

Attendees at the meeting included representatives from DPE, NSW SES, Sydney Catchment Authority, multiple divisions of Council and several residents from the wider Wingecarribee community.

The need to undertake an assessment of the recent heavy rainfall event (which occurred on 4 – 6 June 2016) was raised in order to provide further confidence in the assessment of proposed options that form part of the FRMS&P. This has since been undertaken and discussion is included in Section 13.

12.2 Community Consultation

Several items were raised by the community during the post exhibition period. The following responses are provided to each of the following key items:

- Shackleton Way
- Emergency Access (along Illawarra Highway)
- Upper Caalong Street
- Charlotte Street and Armstrong Street
- Areas outside of the study area (Old Kangaloon Road and Wilson Lane)
- Maintenance
- Open Channel at Meryla Street
- Open Channel between Caalong Street and Wallungunda Street

12.2.1 Shackleton Way

Feedback from the community has confirmed that historical flooding experienced at Shackleton Way "*is almost exactly how it has been modelled"…….*

"We therefore welcome the mitigation measures proposed to fix this problem, namely upgrading the diversion channel and constructing a diversion mound / bund. We would argue that they should be done as a matter of urgency"

Response: Feedback from the community has provided additional confidence in modelling and further justification of the proposed measures recommended in the FRMS&P. The measure has been classified as a "High" priority to be undertaken in the next 1 – 2 years (refer Table 11.1).

12.2.2 Emergency Access

The community has raised some concerns regarding the potential impacts of flooding on the ability for *"emergency vehicles to come in or go out of town".* The need for a *"public strategy to be put in place"* was also raised regarding emergency access and road closures to improve safety of residents during heavy rainfall events.

It was also commented that *"the only northern access to the town is Caalong Street and recommend for Occupational Health and Safety that Main Street* (which currently is an unformed road reserve) *must be constructed to allow in case of emergency access to the northern parts of this village in emergency situations".*

Response: The flood mitigation measures proposed within this FRMS&P are aimed at improving the serviceability of Hoddle Street (Illawarra Highway) to ensure that emergency vehicles can utilise the highway during extreme events (up to the 1% AEP).

The "*Wingecarribee local flood plan*" does not currently include a specific map for Robertson Village. A copy of this FRMS&P has been provided to the NSW SES to improve preparedness and to inform future potential updates of the plan. Refer discussion in Section 6.8 of this report.

12.2.3 Upper Caalong Street

The community has raised concerns regarding several properties which have historically flooded in the upper reaches of Caalong Street (between High Street and May Street). These properties flooded as recently as the 4 – 6 June 2016 event.

The concerns from the community suggest that the recent road upgrade works (undertaken by Council) have elevated road levels and redirected flows into private property, no visitor parking due to deep roadside swales and are subject to ongoing flooding issues.

Response: Council have engaged J. Wyndham Prince to undertake separate assessment to specifically address this local catchment and are currently working with the community to resolve local flooding issues.

12.2.4 Charlotte Street and Armstrong Street

The community has raised concerns about historical flooding at 15 Armstrong Street. The feedback advised that volunteers were required to intervene in order to prevent above floor flooding which allegedly originates from the lack of formal drainage systems in Charlotte Street (i.e no swales, pits or pipes).

Response: A review of the existing flood maps confirms that flooding during the 1% AEP event enters properties from local catchments. There appears to be opportunity for roadside swales and a pipe crossing to be incorporated along Charlotte Street to manage / divert runoff. Refer to Plate 12.1 below.

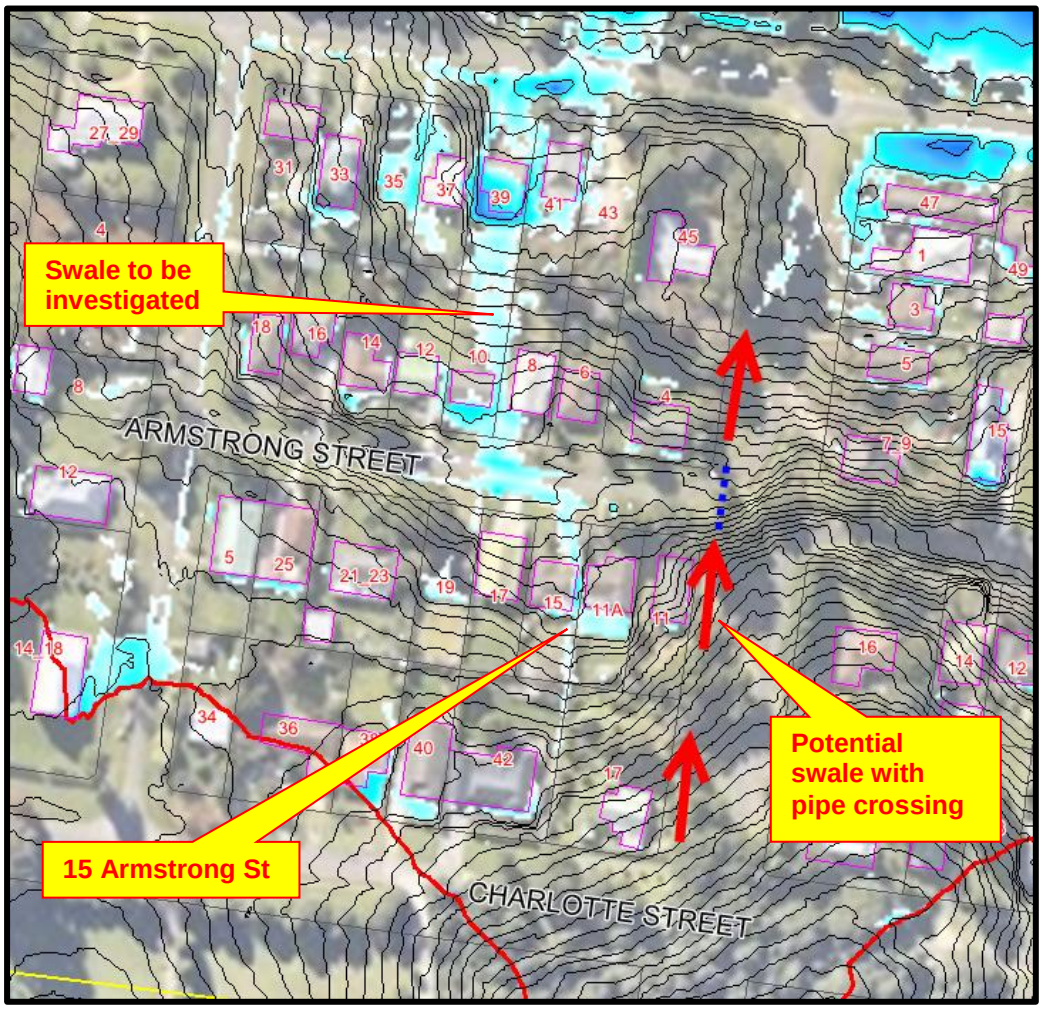


Plate 12.1 – Charlotte and Armstrong Street (1% AEP)

It is recommended that a separate assessment be undertaken in this area to specifically address the local catchment issues and the recommendation from this assessment be included in the Council's future capital works program.

12.2.5 Areas outside study area

The community has raised a number of concerns associated with areas which are situated outside the study area. These included the intersection of Wilson Way and Illawarra Highway (which allegedly is cut off during flood events and restricts emergency access) and Old Kagaloon Road (where there is limited space to pull off the road should a vehicle need to pass).

Response: Responses have been received by Council and will be reviewed separate to this FRMS&P

12.2.6 Maintenance

The community has raised several concerns over the level and frequency of maintenance which is undertaken by Council throughout Robertson Village during the "drier times", with a particular focus on existing stormwater pipes and channels.

Such easements include the following:

- Arney Street, between Armstrong Street and South Street
- Under the railway line at Hoddle Street and western end of Alcorn Lane

- Beside 10 Armstrong Street and 39 South Street

Response: It is recommended that Council implement a maintenance program to include regular clearing and maintenance of these areas. It is anticipated that the cost of implementing the maintenance program could be included in Council's ongoing maintenance budget.

12.2.7 Open Channel at Meryla Street

The community has raised concerns over the open channel which is located at the rear of the Robertson Farm Machinery and the "*continual damming up on the Eastern side of Meryla Street".*

Response: As shown on Plate 5.8, flooding is observed to overtop the existing channel at Meryla Street during the full range of AEP events and enter the commercial properties fronting Hoddle Street. Modelling results also show ponding to the east of Meryla Road. This FRMS&P has investigated upgrade options in the vicinity of Meryla Street (see discussion in Section 7.1).

12.2.8 Open Channel between Caalong Street and Wallungunda Street

The community has raised concerns over the large open channel located near the unformed Conjewoi Street. The concerns particularly relate to the channel has not being maintained / cleared by Council, being often subject to rubbish dumping and stormwater overtopping into properties.

Response: The mitigation measures proposed in this FRMS&P includes a new detention basin in this area. Results show that it will improve the level of flood affectation upon nearby properties and will reduce the volume of flow directed to the lowpoint of Hoddle Street adjacent to No. 9-11.

13 HISTORICAL FLOOD EVENT

During the preparation of the FRMS&P, a heavy rainfall event occurred within the study area which resulted in a number of properties experiencing above floor flooding.

Rainfall data was obtained from the Bureau of Meteorology from numerous stations for the 4 to 6 June 2016. It is noted however that some of the stations were limited to "daily" data instead of "minute" data which is the data necessary to actually model flood impacts.

Records confirm that the total precipitation during the 4 to 6 June 2016 rainfall event observed within Robertson Village was 580 mm, however this station only included daily data. The nearest station which included minute data was at "Moss Vale – AWS". The Moss Vale AWS station included a similar distribution across the three (3) days, however the total precipitation was only around half that observed at Robertson.

In order to simulate an accurate event in TUFLOW, the Moss Vale AWS minute rainfall data was therefore increased by a factor of 2.07 – which resulted in total precipitation of 579.19 mm. This is therefore considered to be a good match with the historical event. Refer to Plate 13.1.

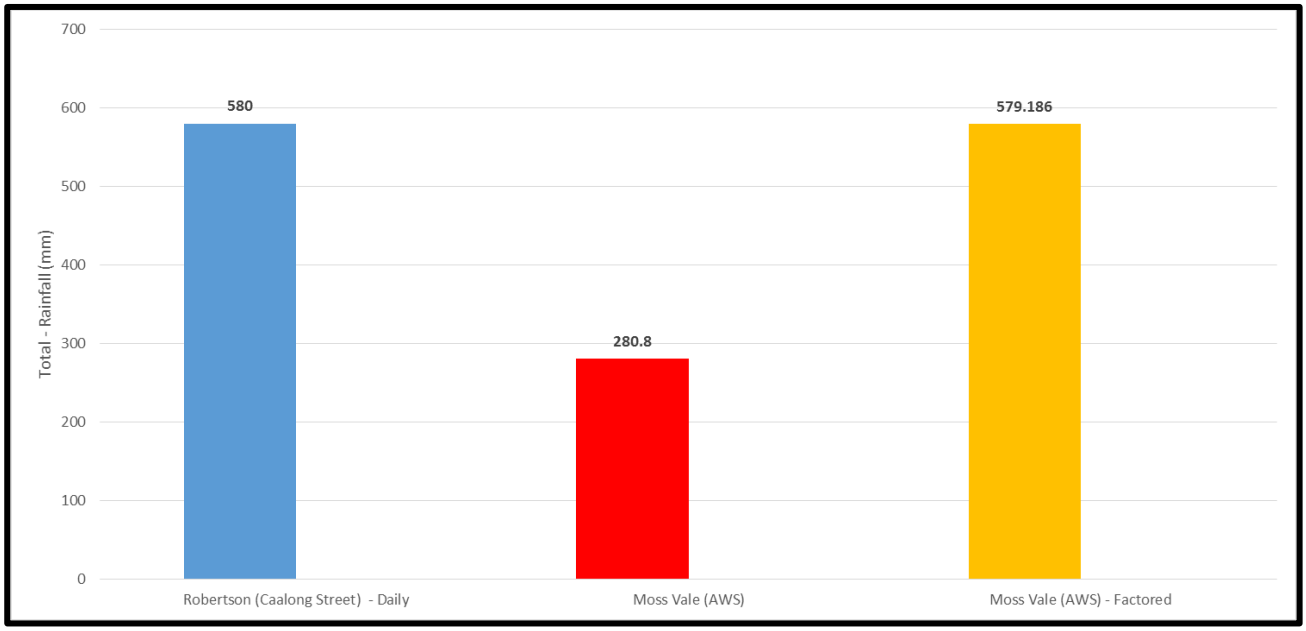


Plate 13.1 – Total Rainfall Data (4 to 6 June 2016)

Consultation with Council confirmed that the historical event was close to a 20% AEP event. (or 5 year ARI).

13.1 Flood Modelling Results – Historical Event

The TUFLOW model has been run for the historical rainfall event under "Existing" conditions. A flood depth map for the historical event is included on Figure 13.1 in Appendix A.

A comparison between the 20% AEP event (Figure 4.12) and the historical flood event (Figure 13.1) shows relatively similar flood extents across the Robertson study area.

In some areas, the flood extents for the 20% AEP event are observed to be slightly wider since modelling has taken into consideration all durations (including the peak durations of 90 min and 120 min). Overall however, the flood extents are comparable.

Importantly, the flood extents for the historical event assessment are generally consistent with those areas which have been reported as being flooded by the community. In particular, these areas include 46 – 56 and 68 Caalong Street, 29 Shackleton Way and 15 Armstrong Street. This therefore provides further confidence in the flood modelling is representative and supports the recommendations being made as part of this FRMS&P.

14 CONCLUSION

This *"Final Floodplain Risk Management Study and Plan*" report represents Phase 2 of the Robertson Village Overland Flow Assessment which has been completed on behalf of Wingecarribee Shire Council.

The report builds upon the findings of the Phase 1 works with a particular focus on identifying, reviewing and recommending the most feasible measures which will better manage the risk of flooding and its impact on life and property across the Village.

Recommendations are then made as to how the measures can be implemented, the cost estimated of these measures, and on potential modifications to Council's flood related policies required to ensure these measures fit seamlessly into Council's operation.

The key objectives of this FRMS&P include the following:

- Reduce flooding of Hoddle Street for events up to and including the 1% AEP.
- Reduction of the flood hazard and risk to people and property in the existing community.
- Prioritisation of proposed flood mitigation works in accordance with their importance focussing on those that can provide the greatest flood damage impact for the most economical construction cost.
- Prepare a risk management plan which is in a suitable format to be integrated into Council's existing business and strategic plans, emergency management plan and existing and proposed planning proposals.

Floodplain Risk Management Measures

A range of opportunities to improve the flood hazard and risk (along with the above objectives) have been identified and investigated. Consideration has been given to "flood modification", "property modification" and "response modification" measures.

Flood Modification Measures

The purpose of "flood modification measures" is to modify flood behaviour and to reduce the effects of flooding (i.e flood extents, levels or velocities) through the implementation of physical upgrades.

Due to the size and complexity of the study area, flood modification measures are proposed to be implemented across numerous locations to address historical and ongoing flooding concerns in the Village. Whilst these can be assessed in an overall model, it is important that the FRMS&P also considers each measure individually in order to better inform the decision making process.

The following scenarios have therefore been considered:

- Scenario A - Hoddle Street Option 1 (New Basin)
- Scenario B - Hoddle Street Option 2 (Culvert Crossing)
- Scenario C - Northern and Southern Upgrades
- Scenario D – Combination of Scenarios A, B and C

Scenario D includes a combination of each of the Scenarios (i.e Scenario A + Scenario B + Scenario C) being run as one management solution. It is noted that whilst Scenarios A and B may not provide the most economical benefits (in terms of the cost benefit analysis), they do target the primary objective of the study which is improving flooding at Hoddle Street.

Details for each of the proposed flood modification measures are presented in Section 6.1.1 to 6.1.4 with results included in Section 7.2.

Property Modification Measures

A review of the 1% AEP "High Hazard" areas within the Floodplain has been undertaken to identify those properties which are at risk of high hazard flows and should form part of a potential "voluntary house purchase acquisition" scheme.

Results of the assessment have identified that there are seven (7) dwellings across the study area, which are located within 5m of a "High Hazard" during the 1% AEP event. A further three (3) properties have been identified as potential properties that could be acquired and / or property owners negotiated with to obtain an easement in order to address local flood concerns.

There may be an opportunity to purchase these properties under a VHP scheme. VHP schemes are often expensive and securing funding for VHP schemes can be difficult. More detailed study and analysis in relation to these properties are required for further consideration of this option.

Response Modification Measures

A review of the *Wingecarribee Local Flood Plan* confirms that Robertson Village lies within the limits of the local flood plan. A specific plan for Robertson Village is however not currently included in the current plan.

Information from the FRMS&P is consequently provided within Section 6.8 (including flood intelligence information, flood maps and summary of affected roads) for review by the NSW SES and for consideration for future updates to the Wingecarribee Local Flood Plan.

Floodplain Risk Management Plan

Results of the FRMS&P demonstrate that by adopting the proposed flood modification measures, the overall objectives of the study will be achieved. In particular, above floor flooding will be removed across fifteen (15) properties whilst Hoddle Street will not overtop during the 1% AEP event.

The capital cost of the FRMS&P is broken up into the following:

- Scenario A - Hoddle Street Option 1 (New Basin) - $1.64M
- Scenario B - Hoddle Street Option 2 (Culvert Crossing) - $1.07M
- Scenario C - Northern and Southern Upgrades - $0.51M
- Scenario D – Combined Upgrades (Scenario A, B and C) - $2.26M
- Voluntary House Purchase Scheme - ($3.8 – 4.76M)

By implementing Scenario D (combined upgrades), the damage savings would be around $4.75M, which results in an overall benefit – cost ratio of 2.11. Results therefore indicate that the costs of not doing the proposed upgrade works are greater than the cost of works across the assumed 50 year life cycle. (Note: Voluntary house purchase not included in the cost-benefit assessment).

Importantly, the upgrades at Hoddle Street also provide benefits by improving the flood affectation of Hoddle Street, but do not necessarily provide a tangible benefit (i.e removing damages).

As discussed in Section 10, the cost-benefit ratio for individual Scenarios (A, B and C) provides a further breakdown. For Scenarios A, B and C these include cost-benefit ratios of 0.8, 1.1 and 2.9 respectively in the 1% AEP event.

The implementation of the proposed measures will improve flood affectation and reduce the risks to property and life within the study area. The FRMS&P also provides sufficient technical details to support future funding applications and the required design processes for these mitigation works.

Post Exhibition

Prior to placing the Draft FRMS&P on exhibition, J. Wyndham Prince met with the Floodplain Risk Management Committee (20 June 2016) in Council chambers. The Draft FRMS&P was generally well received and subsequently was accepted to be listed on public exhibition.

Attendees at the meeting included representatives from DPE, NSW SES, Sydney Catchment Authority, multiple divisions of Council and several residents from the wider Wingecarribee community.

Several responses from the community were raised throughout the public exhibition period. Responses are included in Section 12.

Historical Flood Events

During the preparation of the FRMS&P, a heavy rainfall event occurred within the study area, which resulted in a number of properties experiencing above floor flooding.

The TUFLOW model has been run for the historical rainfall event under “Existing” conditions with results generally consistent with those areas that have been reported as being flooded by the community. This therefore provides further confidence in the flood modelling and supports the recommendations being made in the FRMS&P.

15 REFERENCES

- Bewsher Consulting Pty. Ltd., 2004, *'Georges River Floodplain Risk Management Study'*, prepared for the Georges River Floodplain Management Committee.
- J. Wyndham Prince (2015) Horsley Village Drainage Investigation and Design – In Depth Option Assessment
- J. Wyndham Prince (2016) Robertson Village Overland Flow Study – Stage 1 -3 Report
- NSW State Flood Plan (2008)
- New South Wales State Government, 2005, *'Floodplain Development Manual'*, Department of Infrastructure, Planning and Natural Resources
- Reserve Bank of Australia, 2015, *'RBA Inflation Calculator'*, http://www.rba.gov.au/calculator/annualDecimal.html
- Wingecarribee Shire Council's Engineering Design Specification
- Wingecarribee Shire Council's *Engineering* Standards (Drawings and Notes)
- Wingecarribee Shire Council (2010) *Local Environment Plan*
- State Emergency Services (2013) Wingecarribee Shire Local Flood Plan
- Wingecarribee Shire Council (2012) Robertson Village Development Control Plan
- Wingecarribee Shire Council (2015) Robertson Village Precinct Plan – Wingecarribee Local Planning Strategy 2015 – 2031
- Guidelines on Development Controls in Low Flood Risk Areas (2007)

APPENDIX A – Figures

APPENDIX B – Council Guidelines

Wingecarribee Shire Council's Engineering Design Specification

Council's "*Development Design Specification Stormwater Drainage Design"* (WSC) provides guidelines for the requirements for stormwater drainage and civil works.

The overall objective of this policy is to achieve an optimum environment in the context of the principles and guidelines of the total stormwater management plan and as such the provision of storm water drainage systems shall achieve the following objectives:

- To provide safety for the public
- To minimise and control local and catchment flooding
- To stabilise landform and control erosion and sediment
- To minimise the impact of urban runoff on receiving waters by retaining within each catchment as much catchment and as much incident rainfall as possible and appropriate for the planned use and the characteristics of the catchment.

Key features of the policy include the following:

- Council will require proof that downstream easements from the subject property have been obtained for stormwater runoff. The easement shall be continuous from the subject property through to a watercourse defined on a topographical map or to a Council drain or drainage reserve
- Stormwater drainage should be designed according to the major / minor concept.
- The major system shall be designed assuming blockage of minor systems being 59% or one cell whichever is the greater. The major system shall be via overland flow and shall not be via a piped system.
- Onsite detention or other solutions including downstream drainage augmentation may be required to ensure that development does not have adverse impacts on downstream drainage infrastructure and public safety
- Trunk drainage is defined as any structure with a flow >1m^3/s for the 1% AEP storm, or where an open channel, or any structure where another public facility such as a cycleway is parallel to the drainage structure and within the overflow path
- All trunk drainage is to be located within a Drainage Reserve and dedicated to Council.
- All other drainage that is not within a public road or community land shall be located within a Drainage Easement. Easements over interallotment drains shall be in favour of the property served.
- Council encourages innovation in the design of stormwater systems and the implementation of Water Sensitive Urban Design. Council requires all proposed innovative stormwater systems to be submitted to Council for approval.
- Recurrence intervals for minor events depend on the development. The minor system design ARIs shall -be selected in accordance with the following: -

LAND USE	ARI
Road Drainage	
Residential Areas	5
Commercial & Industrial Areas	10

Road Crossings

To meet the total requirement of 100 year ARI with VxD<0.4	
Minimum Requirement for culvert crossing	5
Site Drainage	
Standard Residential Dwelling	5
Standard Residential Units	10
Commercial! Industrial Land Use	10
Institutional or Important Site (Hospitals, Town Hall, Schools etc)	10

- MINOR SYSTEM CRITERIA

(1) The acceptable gutter flow width in the 5-year ARI event is 2.5 metres maximum. Wider flow widths may be approved on roads with grades less than 0.5%, however Velocity x Depth must be less than 0.4.

(2) Minimum conduit sizes are given below:

- The minimum pipe size shall be 375mm diameter.
- The minimum box culvert size shall be 600mm wide x 300mm high.

(3) Minimum and maximum velocity of flow in stormwater pipelines shall be 0.6m/sec and 6m/sec respectively.

(4) The use of Water Sensitive Urban Design for minor systems only is encouraged, and shall be in accordance with the design principles laid down in "Managing Urban Stormwater" handbook published by the EPA.

- PITS

(1) Inlet Pits shall be spaced so that the gutter flow width is limited in accordance with this specification and so that the inlet efficiency is not affected by adjacent inlet openings. Preference shall be given to the location of drainage pits at the upstream side of allotments.

(2) The maximum recommended spacing of pits where flow widths are not critical are given below:

	Pipe Size (mm)	Spacing (m)
Generally	less than 1200	100
	1200 or larger	150

(3) Maximum kerb inlet lengths to side entry pits are to be a preferred maximum of Inlet Capacity 3.0m, with an absolute maximum of 5.0m where the grade is 10% or more, and an absolute maximum of 4.0m where the grade is less than 10%.

(4) None of these pit charts include any blockage factors. The percentage of theoretical capacity allowed in relation to type of pit is given below: -

Condition	Inlet Type	Percentage of Theoretical Capacity Allowed
Sag	Side entry	80%
Sag	Grated	50%
Sag	Combination	Side inlet capacity only Grate assumed completely blocked
Sag	"Letterbox"	50%
Continuous Grade	Side entry	80%
Continuous Grade	Grated	50%
Continuous Grade	Combination	90%

- MAJOR SYSTEM CRITERIA

(1) Major systems shall be designed for a blockage factor of 50% at all culvert inlets and other major system structures. Allowance shall be made for the resultant afflux, and the resultant surcharge flows shall be accommodated within overland flow paths.

(2) Surcharging of drainage systems which would provide for water depth above the top of kerb will not be permitted except as defined below. Surcharging of drainage system for storm frequencies greater than 5% probability may.be permitted across the road centreline where the road pavement is below the natural surface of the adjoining private property. Flow across footpaths will only be permitted in situations specifically approved by Council, where this will not cause flooding of private property.

(3) The velocity x depth product of flow across the footpath and within the road reserve shall be such that safety of children and vehicles is considered. The maximum allowable depth of water is 0.2 metres and the maximum velocity x depth product of 0.4m2/s is permitted. Where the safety of only vehicles can be affected, a maximum velocity x depth product of 0.6m2/s is permitted. In open channels the above velocity x depth product criteria will be followed where possible or the design shall address the' requirements for safety in relation to children by providing safe egress points from the channel or other appropriate methods.

(4) Freeboard requirements for floor levels and levee bank levels from flood levels in open channels, roadways and storm water surcharge paths are given below:

(5) Generally: -

- A minimum freeboard of 0.5 m shall be provided between the 100-year flood level and floor levels on structures and entrances to underground car parks. A higher freeboard may be required in certain circumstances.
- Where the road is infill and overtopping of stormwater through adjacent low side properties may occur during conveyance of the 1:100 year ARI flow, a 100mm freeboard shall be provided between the ponding level of water in the road and the high point in the footpath. Driveway construction in these instances needs to consider this requirement.

In Surcharge Paths: -

- A minimum freeboard of 0.5 shall be provided between the 100 year flood level and floor levels on structures and entrances to underground car parks.

In Open Channels: -

- A minimum freeboard of 0.5m shall be provided between the 100-year flood level and floor levels on structures and entrances to underground car parks.
- A minimum freeboard of 0.3 m shall be provided between the 100-year flood level and the top of the channel.

(6) Flow capacities of roads should be calculated using Technical Note 4 in Chapter 14 of the current version of AR&R.

- OPEN CHANNELS

(1) Generally, open channels will only be permitted where they form part of the trunk Safety drainage system and shall be designed to have smooth transitions with adequate access provisions for maintenance and cleaning. Where Council permits the use of an open channel to convey flows from a development site to the receiving water body, such a channel shall comply with the requirements of this Specification.

(2) Where the product of average Velocity and average flow Depth for the design flow rate is greater than $0.4m^2/s$, the design will be required to specifically provide for the safety of persons who may enter the channel.

(3) Maximum side slopes on grassed lined open channels shall be 1 in 4, with a preference given to 1 in 6 side slopes, channel inverts shall generally have minimum cross slopes of 1 in 20. Channels in private property shall have a maximum slope of 1 in 6.

(4) Open channels floodways shall be designed for a capacity of 100 year ARI storm event with freeboards

(5) Maximum velocity in grassed channels shall be 2.0m/s for flows up to the 100 year ARI storm event

- RETARDING BASIN

(1) For each ARI a range of storm events shall be run to determine the peak flood level and discharge from the retarding basin. Storm patterns shall be those given in the current version of AR&R Volume II.

(2) The critical storm duration with the retarding basin is likely to be longer than without the basin. A graph showing the range of peak flood levels in the basin and peak discharges from the basin shall be provided for the storms examined.

(3) Flood Routing should be modelled by methods outlined in the current version of AR&R.

(4) The high level outlet to any retarding basin shall have capacity to allow the passage of a minimum of the 100-year ARI flood event. Additional spillway capacity may be required due to the hazard category of the structure. The hazard category should be determined by reference to ANCOLO (1986).

(5) The spillway design shall generally be in accordance with the requirements for Open Channel Design in this Specification.

(6) Pipe systems shall contain the minor flow through the Retarding Basin wall. Outlet pipes shall be rubber ring jointed with lifting holes securely sealed. Pipe and culvert. Bedding shall be specified to minimise its permeability, and cut off walls and seepage collars installed where appropriate.

(7) The low flow pipe intake shall be protected to prevent blockages.

(8) Freeboard - Minimum floor levels of dwelling shall be 0.5m above the 100 year ARI Freeboard at flood level in the basin.

- STORMWATER DETENTION

(1) Installation of Stormwater Detention may be required for any development site within the Shire.

(2) For all situations, the maximum discharge for the 1: 1 00 year storm shall not exceed the pre-development discharge, -unless it is demonstrated by means of a hydraulic assessment that it is not required.

(3) The allowable discharge for the 1:10 year storm from a development site is to be limited to 0.04s / m^2 of the allotment area where the discharge is to kerb and gutter. A further limitation of 32Vs per discharge point with a minimum spacing of 15 metres between discharge points shall also be applied.

(4) If the stormwater runoff generated from the total developed site is greater than the above criteria an On Site Stormwater Detention System shall be designed so the above requirements can be met.

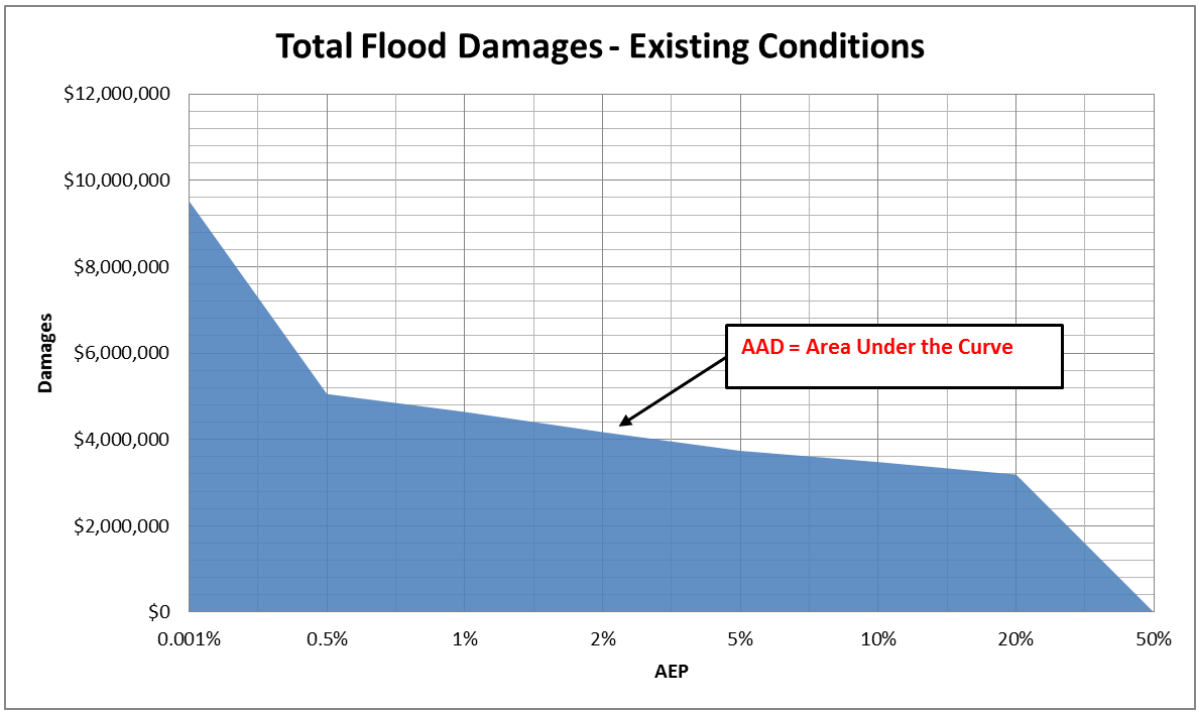
- The Developer is to comply with Development Control Plan No 34 - Potentially Flood Affected land, and Clause 34 of the local Environment Plan. OCP No 34 details Council's requirements regarding development of potentially flood affected land. Among other requirements, it contains details relating to the submission of flood studies and hazard assessment.

APPENDIX C – Community Consultation

APPENDIX D – Flood Damages and Cost Estimates

Existing Conditions Results

	Direct - Residential	Indirect - Residential	Direct - Commercial	Indirect - Commercial	Infrastructure	Total
20 % AEP	$ 2,133,083	$ 319,962	$ -	$ -	$ 735,914	**$ 3,188,959**
10 % AEP	$ 2,327,292	$ 349,094	$ -	$ -	$ 802,916	**$ 3,479,301**
5 % AEP	$ 2,492,048	$ 373,807	$ 6,820	$ 3,410	$ 862,826	**$ 3,738,911**
2 % AEP	$ 2,755,505	$ 413,326	$ 27,280	$ 13,640	$ 962,925	**$ 4,172,676**
1 % AEP	$ 3,049,792	$ 457,469	$ 40,920	$ 20,460	$ 1,070,592	**$ 4,639,234**
0.5 % AEP	$ 3,304,319	$ 495,648	$ 58,652	$ 29,326	$ 1,166,384	**$ 5,054,329**
PMF	$ 5,628,987	$ 844,348	$ 568,788	$ 284,394	$ 2,197,955	**$ 9,524,472**



Scenario D Conditions Results

Storm Event	Direct - Residential	Indirect - Residential	Direct - Commercial	Indirect - Commercial	Infrastructure	Total
20 % AEP	$ 1,868,274	$ 280,241	$ -	$ -	$ 644,555	**$ 2,793,070**
10 % AEP	$ 2,026,701	$ 304,005	$ -	$ -	$ 699,212	**$ 3,029,919**
5 % AEP	$ 2,173,778	$ 326,067	$ -	$ -	$ 749,953	**$ 3,249,798**
2 % AEP	$ 2,303,615	$ 345,542	$ 13,640	$ 6,820	$ 800,885	**$ 3,470,502**
1 % AEP	$ 2,531,170	$ 379,676	$ 27,280	$ 13,640	$ 885,530	**$ 3,837,295**
0.5 % AEP	$ 2,764,380	$ 414,657	$ 31,372	$ 15,686	$ 967,828	**$ 4,193,923**
PMF	$ 5,318,960	$ 797,844	$ 499,224	$ 249,612	$ 2,059,692	**$ 8,925,331**