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GREATER TAREE CITY COUNCIL

Wingham Floodplain Risk Management Study

For the development of a Wingham Floodplain Risk Management Plan

301015-01997

12-May-2011

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GREATER TAREE CITY COUNCIL
WINGHAM FLOODPLAIN RISK MANAGEMENT STUDY
FOR THE DEVELOPMENT OF A WINGHAM FLOODPLAIN RISK MANAGEMENT PLAN

FOREWORD

The Wingham Risk Management Study utilises the work undertaken in the Wingham Flood Study (WorleyParsons, 2010) in combination with the process outlined in the New South Wales Floodplain Development Manual, to assess strategies aimed at dealing with the different types of flood risk with the study area.

The holistic objective of this process is to reduce the impact of flooding and to reduce private and public losses resulting from floods whilst avoiding the unnecessary sterilisation of flood prone land by recognising the benefits arising from its use, occupation and development.

The Wingham Risk Management Study identifies, quantifies and assesses all potential floodplain risk management strategies which are aimed at leading to the development of a Wingham Risk Management Plan by which the community as a whole is better off.

Disclaimer

PROJECT 301015-01997 - WINGHAM FLOODPLAIN RISK MANAGEMENT STUDY

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Internal Review	J Merhebi	D McConnell	N/A	22-Jan-2010	N/A	
B	GTCC Draft Review	J Merhebi	D McConnell	N/A	22-Feb-2010	N/A	
C	Revised Draft	J Merhebi	D McConnell	N/A	20-April-2010	N/A	
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CONTENTS

Appendices

1. INTRODUCTION

1.1 Overview

Wingham is located approximately 45 kilometres upstream along the Manning River at the confluence of Cedar Party Creek. Due to the importance of the Manning River as a transport route, Wingham was established at the furthest point supply boats could reach up the river and therefore became the region's major port.

A large portion of Wingham is elevated high above the floodplain; however some portions, including Wingham peninsula, consist of undulating river terrace at a general elevation of less than 12. There are also portions of central and northern Wingham where tributary drainage gullies feeding Cedar Party Creek are now part of the urbanised area.

In its 178 years of European settlement, many floods of varying severity and impact have been recorded in Wingham. However in this time, none have had an Annual Exceedance Probability (AEP) greater than 1%, with the largest being approximately equal to a 1% AEP and occurring in July 1866. More recent floods of moderate magnitude have occurred in 1978 and 1990. The 1978 flood in particular was one of the largest floods on record (estimated to be less than a 1% but greater than a 2% event) which required the evacuation of residents and led to substantial property damage.

These events, and other significant floods in Wingham, have led to large property losses, injury and in some instances, loss of life.

The Wingham Flood Study, 2010, undertaken by WorleyParsons, constructed a RMA-2 Model that was successfully calibrated and verified against historic data and previous studies. This provided simulated flood data for Wingham, information on the hydraulic nature of flooding in this region and the hazards that exist. This constituted a major step in the floodplain management process with the next stage involving the detailed examination of flood risk in Wingham and a range of floodplain mitigation options.

1.2 Objectives

This floodplain management study aims to generate, weigh and cost a set of options that will potentially address the different types of flood risk in Wingham. The benefit of these management strategies will be ascertained by reference to the cost of doing nothing, that is, the long term cost of flooding In Wingham to the wider community.

The overall objective of this Floodplain Risk Management Study is to provide the mechanism by which an appropriate mix of management measures can be selected as part of a Floodplain Risk Management Plan to collectively mitigate or manage the flood risks.

Flood Risks are divided into the following categories:

- **Existing Risk**; involves ensuring that current development is compatible with flood risk. Flood modification measures are the traditional means of mitigating damage to existing properties to an acceptable level. In addition, measures such as land use controls and flood readiness education can also be used to reduce existing flood risk. All these flood modification measures have associated environmental, economic and social costs that require evaluation.

- **Future Risk**; involves measures that ensure that future development is compatible with flood risk. Property modification measures, such as land use and development controls are typically the most effective means of doing this and must be evaluated based on the common good of the community as a whole.
- **Continuing Risk**; in most cases, the PMF is not adopted as the basis for floodplain risk management strategies because this would unnecessarily sterilise large areas. As a result, strategies that are developed to manage flood risk will at some stage be overwhelmed by a larger flood and response measures must be developed to deal with this risk. Typical measures include readiness, response and recovery plans.

The Floodplain Risk Management Study must objectively evaluate all possible strategies that will manage the aforementioned flood risks to acceptable levels. In order to be successful, the study will:

a) be congruent with any relevant, current Greater Taree City Council flood risk management policies, strategies or planning instruments

b) gather community input, enable participation in the decision making process and gain acceptance of the management study findings

c) determine the hazard categories within Wingham

d) identify and assess floodplain risk management measures for existing developments aimed at reducing the social, environmental and economic loss of flooding, both existing and future

e) Assess the impacts of proposed management measures from all perspectives.

1.3 Flood Standard and Considerations

The Selection of an appropriate flood standard is an integral step in the development of a floodplain management plan as the Floodplain Development Manual clearly states. The current General Flood Planning Level (FPL) employed by the Greater Taree City Council is based on the 1% AEP plus a 500 mm freeboard.

This is considered to be a sound basis for planning in Wingham because

- it is recommended by the Floodplain Development Manual
- it is widely understood and used throughout Australia
- it has been in use since the Council's *Interim Flood Policy* was introduced in 1987
- it was recommended by the *Manning River Floodplain Management Study* in 1996
- it is used in the Greater Taree Development Control Plan (DCP) 2010
- a higher standard would increase mitigation costs to the community and Council

- a lower standard would expose residents to unacceptable risk of which the costs would potentially be borne by the wider community

Therefore the current FPL using the 1% AEP event plus a 500 mm freeboard is recommended to be maintained and is used as a basis for developing management strategies in this study.

Whilst this may limit the risk to property, the risk to life is far more complex than a single FPL. There is a need, as also stated in the Floodplain Development Manual, to consider the difficulty of the conditions that could be expected if an extreme flood occurred. Hazards can dramatically increase because of greater flood depths and velocities, and rates of rise can give little warning of dangers and the cutting off of evacuation routes. Therefore, whilst the management of the risk to property will involve the management of risk up to and including the 1% event, the risk to life necessarily involves the management of all risk (up to and including the PMF).

From the flood study results, the level of the 1% AEP event through the majority of Wingham is between 13.6 and 13.8. Therefore the FPL will vary between 14.1 and 14.3 for the majority of properties located in Wingham (although the flood study results should be consulted for site-specific levels).

1.4 Study Area

The study area involves a small subset of the larger area analysed in the Wingham Flood Study, 2010 (herein referred to as the “Flood Study”). The streams of interest in the study area are Cedar Party, Stony (Gorman) Creeks and the Manning River. The study area was focuses on Wingham, covering areas north of the Manning River on both sides of Cedar Party Creek to the Stony Creek Confluence.

Figure 1 shows the approximate focus of the study area for this Floodplain Risk Management Study.

The Manning catchment drains an area of approximately 8200 km^2 and extends over 175 km inland from the coast. Tidal influence on the Manning River extends to Abbotts Falls, approximately 5km upstream of Wingham. The Cedar Party Creek sub-catchment drains an area of approximately 143 km^2 and extends approximately 22 km north of Wingham.

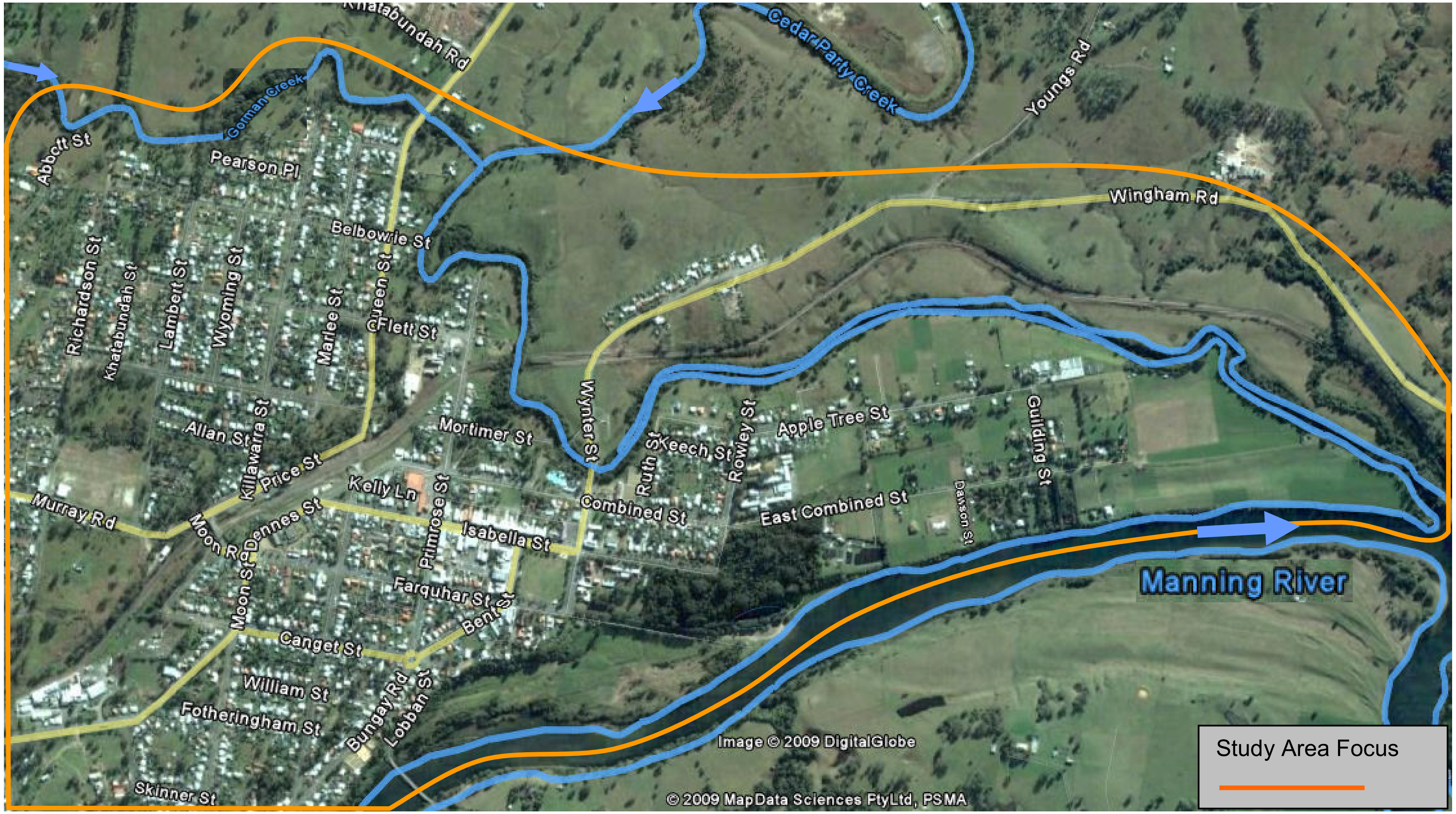

Figure 1: Map showing the approximate extents of Floodplain Risk Management Study Area

1.5 Flood History

The SES *FloodSafe* guide to Wingham indicates that a peak flood level less than 4.90 can be classified as 'minor', up to 8.90 as 'moderate' and greater than 11.90 as 'major'. It must be emphasised that this flood classification system is based on the extent of human impact and not on recurrence interval.

According to the "*Manning River Flood History 1931-1979*" (Public Works Department New South Wales), floods reaching a height of at least 10.6 at Wingham Bridge can be considered "significant". Using this same level as a guide, which corresponds approximately to the level of a 20% AEP flood, at least 29 significant floods have been recorded in Wingham since 1831 (when European records begin). The irregularity at which significant floods can occur is highlighted by the fact that some significant floods are very closely spaced, even occurring within the same year (1870, 1956); while at other times there are long periods without significant flooding (1831 to 1857, 1930 to 1950, and 1990 to present). The three largest floods recorded in Wingham occurred in 1866, 1929 and 1978 and reached a peak level of 15.5, 14.9 and 14.9 respectfully. Figure 2 shows the significant floods that were recorded in Wingham with a time scale that also shows that there were periods where no significant flooding occurred. Figure 3 shows only the years where significant floods were recorded in Wingham since 1831.

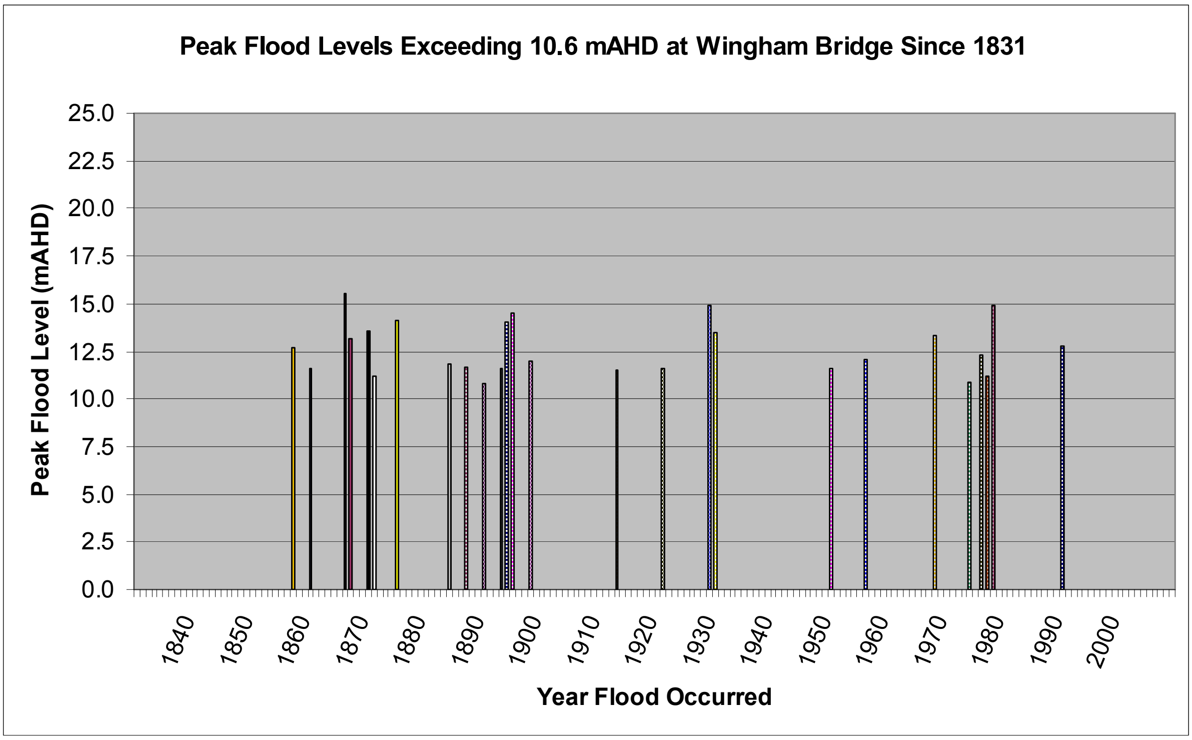

Figure 2: Floods recorded at Wingham Bridge exceeding 10.6 since 1831

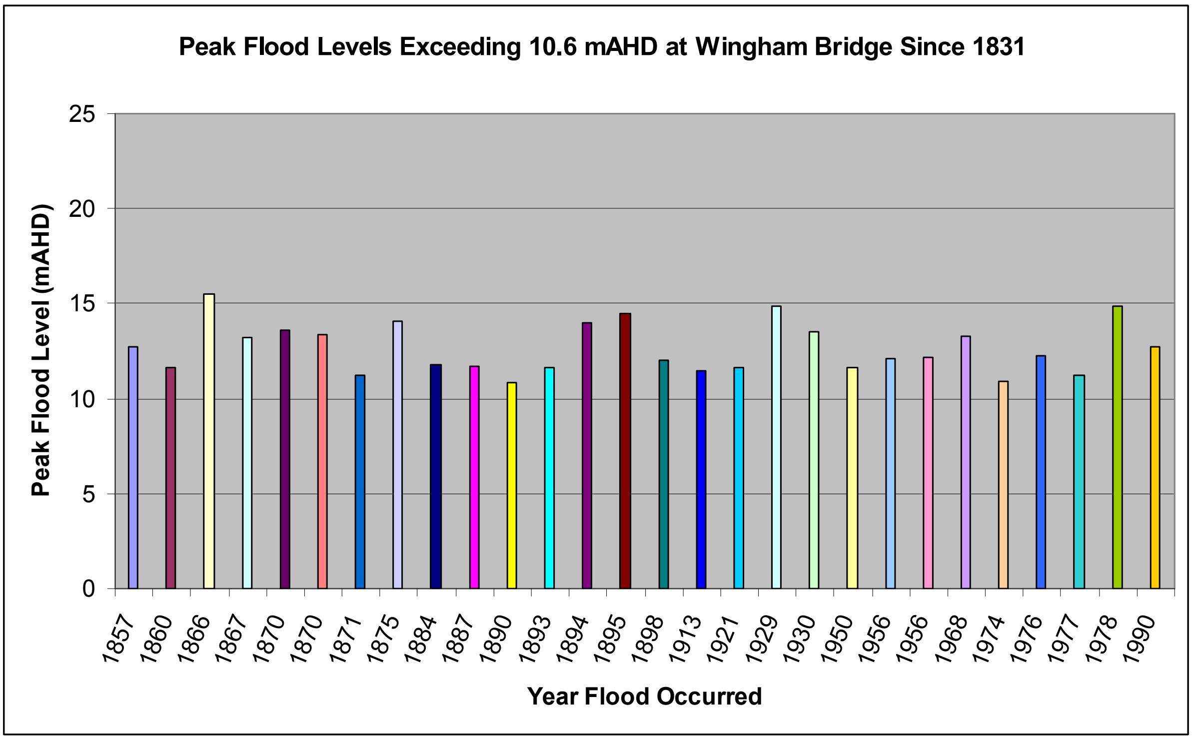

Figure 3: Years where floods recorded at Wingham Bridge exceeded 10.6

The 1978 flood event, of which a significant amount of information exists, had a rate of rise as high as 1.5 m per hour at Wingham and caught many by surprise who did not expect flood levels to rise to their ultimate peak. The difference in time between when the major flood warning from the Bureau of Meteorology / SES was given and the time at which the major flood level was exceeded in Wingham was in the order of 4 hours. This highlights the potential danger that exists in Wingham, when a delay in a decision to evacuate, or a misjudgement on the peak level of a rising flood, can rapidly lead to severe risks to life and property. More recently, Wingham has experienced ‘moderate’ flooding in March 1995 when 10.35 was recorded at Wingham Bridge which was only marginally below the 10.6 ‘significant’ level.

Since European settlement, Wingham has not experienced an extreme flood event. These have the potential to reach a peak level of 22.3.

1.6 Previous Studies and Policy

In 1986 the NSW Government released the first Floodplain Management Manual to assist in the management of flood liable land. This has been twice since revised in 2001 and 2005. The current NSW Floodplain Development Manual (FPDM) aims to optimally maintain the safe use of the floodplain whilst reducing the impacts of flooding, both publicly and privately. The most recent revision sought to ensure consistent interpretations of important strategic variables such as the flood planning level (FPL) and its interaction with rare events up to the PMF.

The FPDM provides a framework for the implementation of a policy based on the following steps:

1. Data Collection; which involves the review and compilation of all relevant data to be used
2. Flood Study; providing technical and quantitative information on flooding in the study area
3. Floodplain Risk Management Study; determining options in consideration of social, economical and ecological factors relating to flood risk
4. Floodplain Risk Management Plan; a selection of options from the study based on community and council endorsement, that will reduce flood risk
5. Plan Implementation; where flood, response and property modification measures are implemented and data collection and monitoring are continued.

After the initial release of the 1986 Manual, the Greater Taree Council implemented an *"Interim Flood Management Policy"* (1987) which specified a FPL equal to the 1% AEP, with fewer restrictions on commercial and industrial developments. Following this, other studies which constituted steps 2, 3 and 4 in a broad sense for the Manning Catchment, were produced. These included the;

- *"Manning River Flood Study" (NSW Public Works Department; 1991)*
- *"Manning River Floodplain Management Study" (Greater Taree City Council; 1996)*
- *"Wingham Peninsula Floodplain Management Study & Plan" (Patterson Britton & Partners; 2000)*

WorleyParsons completed a refined Flood Study with a focus on Wingham in 2010. Both hydrologic and hydraulic models were developed and calibrated and used to simulate design flood behaviour in the study area based on methods in Australian Rainfall and Runoff, 1997. This provided an updated and more accurate picture of how flooding affects Wingham with fine detail.

With this, the need for an updated Floodplain Risk Management Study for Wingham based on these refined flood study results was required such that more accurate information could be used to ultimately create a well-informed Wingham Floodplain Risk Management Plan.

1.7 Data Collection

The following list comprises local and region studies / policies that have relevance to the development of a Wingham Floodplain Risk Management Study

- *"Wingham Flood Study; Review and Upgrade" (WorleyParsons; 2010)*
- *"Interim Flood Management Policy" (Greater Taree City Council; 1987)*
- *"Manning River Floodplain Management Study" (Greater Taree City Council; 1996)*
- *"Wingham Peninsula Floodplain Management Study & Plan" (Patterson Britton & Partners; 2000)*
- "*Floodplain Development Manual" (New South Wales Government; 2005)*
- *SES Archive Data (State of New South Wales through NSW State Emergency Service)*

Further to these sources, a community consultation program was implemented in order to obtain input from the Wingham Community to ensure that strategies developed would also deal with relevant concerns of residents.

This comprised of:

- the generation of a webpage on the Greater Taree City Council website containing a summary of the objectives, process and progress of the Flood Study, Floodplain Risk Management Study and Plan
- a survey gathering information regarding flooding in Wingham and providing potential management strategies where reader feedback was encouraged
- a local newspaper add and letter drop informing the public of the website and the survey
- an email address made available to the public for the purpose of obtaining further information and / or providing suggestions and / or feedback
- A community workshop where the draft Flood and Floodplain Risk Management Studies were available to the public for review. From this, data was collected enabling a more accurate calibration of the flood study model which in turn provided better information on which base the risk management study.

2. SUMMARY OF FLOOD BEHAVIOUR

From the Flood Study, several clear facets of flooding in Wingham become clear.

- **Peak levels for a given flood risk are much higher for the Manning River than Cedar Party Creek**;
  - Whilst some areas of Wingham are significantly inundated by flows from Cedar Party Creek, the ultimate peak level of inundation in Wingham is derived from the backwater flow from the Manning River.
  - During the early stages of a flood event, Cedar Party Creek has a greater effect on areas of Wingham upstream of the Wynter Street Bridge.
- **Peak levels do not vary significantly throughout Wingham for a given flood**;
  - Inundated areas of Wingham are within several centimetres of the peak value
  - This is primarily due to the slow backwater filling of Wingham and the relatively broad hydrograph of the Manning River in this region.
  - Some variation exists in areas inundated directly by the Manning River, upstream of Wingham Brush, however this only affects developed areas in extreme flooding (such as those bounded between Wynter Street and Wingham Brush).
- **Peak flow velocities are small for the majority of Wingham**;
  - With the exception of the southern half of Wingham Peninsula which is affected by expanding flow from the Manning River, flood hazard in developed areas of Wingham is primarily depth related.

The following sections provide further details on the characteristics of flooding in Wingham.

2.1 Floods with an AEP of less than 5%

For more regular floods that have a 20 year recurrence interval or less, peak levels do not exceed 11.5 in Wingham and the vast majority of properties below this level are inundated with slow moving back-water of low to moderate depths (less than 1.5 metres).

The following roads are inundated by floodwaters; eastern portions of East Combined Street, Guilding Street, small north-east portions of Ruth, West Appletree and Keech Streets, Farquhar Street, Wynter Street surrounding the bridge, Combined and Primrose Streets in the vicinity of central Wingham extending to the commercial district on Isabella Street, Mortimer and Flett Street as well as portions of Queen Street North including Peter Garrett Bridge by Stony Creek. Wingham Road at two locations near the brickworks would also become inundated as well as Cedar Party Creek Bridge.

Peak depths exceed 4 metres in portions of the gullies located near existing development on Wingham peninsula which isolates a small number of properties south of East Combined Street from road access. Cedar Party Creek Bridge would be covered by over 4 metres of flow. Peak depths near the intersection of Combined and Primrose Streets and 200 metres east along Combined Street exceed 1.5 metres. This isolates some properties on Combined Street, between Primrose and Wynter Streets from road access. Some properties on Combined and Mortimer Streets experience peak flood depths in excess of 3 metres with some properties on Mortimer Street isolated from road access by up to 5 metres of over road flood depth. Peter Garrett Bridge would be inundated by at least 1.5 metres of flood water. Wingham Road would be inundated by over 2 metres of flood water near the Brickworks.

Flow velocity through existing development in Wingham is slow, with peak velocities generally not in excess of 0.1 m/s emphasising the backwater affect that the Manning River has on Cedar Party Creek. However, relatively small, southern portions of Wingham Peninsula experience expanding flow from the Manning River with flow nearby some properties on East Combined Street experiencing peak velocities of up to 1.3 m/s.

2.2 Floods with an AEP of up to 1%

For flood risk up to that of the FPL, peak levels do not exceed 13.8 in Wingham. This is of a similar order to the flood of 1866. (Whilst this peak level is experienced on a small part of the peninsula, the majority of Wingham does not exceed a peak level of 13.6.)

The roads inundated are of a similar composition to that discussed in the previous section, albeit to a greater extent:

- Properties along low areas of East Combined, Guilding and the south side of Appletree Streets are inundated by up to 3.5 metres of floodwater. Properties affected on the north side of Appletree Street are generally inundated by less than 1 metre.
- Properties along West Appletree Street and a small number near the intersection of Ruth and Keech Streets are inundated by up to 2.6 metres of water, leading to the isolation of properties in the early stages of flooding.
- Floodwaters extend over Wynter Street from the railway line to the intersection with Combined Street.
- Properties in low areas of Combined Street between Primrose and Wynter Streets are inundated by up to over 4 metres of floodwater which leads to their rapid isolation during the early stages of flooding.
- Several properties south of Combined Street along Primrose and Isabella Streets are inundated by up to 2 metres.
- The intersection of Primrose and Combined Streets is inundated by over 3.5 metres, which isolates a large portion of properties to the north up to the Flett Street Bridge from road access.
- The intersection of Primrose and Isabella Streets is inundated in excess of 2.2 metres and the intersection of Primrose and Farquhar Streets is inundated by up to 0.2 metres.

- Mortimer Street east of the railway line is inundated by over 5 metres of flood water in the vicinity of some properties which leads to the isolation of properties in the very early stages of flooding.
- Properties along the east side of Primrose Street north of Combined Street and the west side of Primrose north of Flett Street are inundated by up to 2 metres with some properties along Flett Street inundated by up to 3 metres.
- The south and majority of the eastern side of Queen Street is inundated by up to 3 metres whilst a number of properties on the west side of Queen Street are inundated by up to 1 metre of floodwater.
- The Peter Garrett Bridge and Wingham Road, in the vicinity of the Brickworks, is inundated by over 3 metres.

Flow velocity throughout the vast majority of existing development in Wingham west of the peninsula remains slow, with peak velocities less than 0.1 m/s. Localised flow velocities along the eastern sides of Mortimer Street see increases in peak values of up to 0.8 m/s as flow from Cedar Party Creek expands into low areas. Some localised areas on the east side of Queen Street North and Primrose Street also experience a similar expansion in flow, with velocities increasing to 0.2 m/s in some instances.

As seen in the previous sections, the trend for flow to increasingly break from the Manning River across southern portions of Wingham Peninsula continues. Expanding flows break across the Peninsula beginning in the vicinity of Farquhar Street near the Nature Reserve. This flow is directed across to the gully between East Combined and Appletree Streets. Peak Velocities through existing developments on the southern side of East Combined Street are generally less than 1.1 m/s; however some properties on the banks of the Manning River experience velocities in excess of 1.5 m/s. Properties on the north side of East Combined, Guilding and the east end of Appletree Street experience peak flow velocities that do not exceed 0.4 m/s. In the remaining inundated portions of the Peninsula, on the west end of Appletree, West Appletree, Keech and Ruth Streets, peak flow velocities do not generally exceed of 0.1 m/s.

Less than 3% of Manning River flows expand onto Wingham Peninsula. This shows that although the peak velocities are higher than the rest of Wingham, only a relatively small portion of the total Manning River flow expands over the peninsula.

The peak rate of rise of floodwaters is in the order of 1.1 metres per hour, however the average rate of rise of floodwaters, is closer to 0.5 metres per hour.

2.3 Extreme Flooding

An extreme flood would produce levels that approach 23 throughout the majority of Wingham.

Large portions of Wingham are inundated including all of Wingham Peninsula. North of the railway line, all areas east of Marlee Street are inundated. This includes all of Marlee Street and Queen Street North, as well as large portions of Mortimer, Flett, Price and Belbowrie Streets. Some areas south of Mortimer Street, including portions of Killawarra, Allan and Irvine Streets are inundated. In the vicinity of Stony Creek, northern portions of Pearson, Killawarra, Abbott, Richardson and Belbowrie Streets are inundated. Between Stony and Cedar Party Creeks, the inundation extends up Comboyne Road to Racecourse Road. On the eastern side of Cedar Party Creek, a large portion of Wingham Road is inundated as well as portions of Youngs Road.

In central Wingham, the majority of areas east of Queen Street North are inundated. This includes all of Combined, Isabella, Primrose and Mortimer Streets, as well as large areas of Farquhar, Queen, Dennes, Wynter, Bent, Lobban, William and Fotheringham Streets and Bungay Road. Floodwaters extend onto northern portions of Central Park although the majority remains unaffected. More elevated areas to the south, including the portions of Farquhar and Bent Street to south-west of the Central Park also evade inundation although this area becomes isolated by flow in the Manning River that overtops Bungay Street.

Peak velocities in excess of 3 m/s flow over Bungay Road near Fotheringham Street. These rapidly decrease to 0.5 m/s at William and Canget Street as the flow continues north into the large inundated area of central Wingham. Peak flow velocities decrease rapidly to below 0.2 m/s for the majority of north, west and central Wingham with some increases of up to 4 m/s. Peak flow velocities in the vicinity of Wingham High School exceeds 1.5 m/s. South-east of the high school, expanding flow over Wingham Peninsula has peak velocities near East Combined Street between 2 and 4 m/s. Peak flow velocities along the northern side of East Combined Street and Guilding Street is between 1 and 2 m/s. Peak flow velocities on Steele Street and east along Appletree Street are generally less than 0.8 m/s where flows start to slow as they meet expanding flow from Cedar Park Creek. West of Steele Street, peak velocities along Appletree Street do not generally exceed 0.4 m. Along Wingham Road north of the Railway line, flow velocities do not exceed 0.2 m/s and on Young's Road are in the order of 0.4 m/s.

The peak rate of rise of floodwaters is in the order of 3.5 metres per hour; however the average rate of rise of floodwaters is closer to 1.3 metres per hour.

Over 15% of Manning River flows expand onto Wingham Peninsula whilst less than 0.2% expands into central Wingham via the overtopping of Bungay Street.

During the rising limb of an extreme flood, the following areas of Wingham become isolated:

- **Mortimer Street**
    - Occurs for most flood risks during the very early stages of flooding as an initial result of Cedar Party flows
    - Isolates properties on Mortimer Street between Primrose Street and Cedar Party Creek
    - Safe evacuation would be extremely difficult due to the time of isolation. Self-evacuation would become readily impractical (no rising egress).
- **Flett, Primrose and Mortimer Streets by the inundation of the intersection between Primrose and Combined Streets**

  - Occurs for most flood risks during the early stages of flooding as a primary result of Cedar Party flows
  - Isolates properties on these streets bordered by the Flett Street Bridge, Cedar Party Creek and Combined Street
  - Safe evacuation possible on foot with some access modifications

- **Combined Street just east of Primrose Street**
  - Occurs for most flood risks during the early stages of flooding as an initial result of Cedar Party flows
  - Isolates properties on Combined Street between the intersection of Primrose Street and a large gully
  - Safe evacuation possible on foot, with appropriate planning and active response

- **West Appletree Street**
  - Occurs for most flood risks during the early stages of flooding as an initial result of Cedar Party flows
  - Isolates properties on West Appletree Street
  - Safe evacuation possible on foot with some access modifications, although if a choice to remain is made, safe self-evacuation becomes readily impractical (western parts have no rising egress).

- **East Combined and Guilding Street**
  - Occurs over a relatively short time frame as a result of Manning River backwater flows
  - Isolates properties on Guilding Street and the eastern half of East Combined Street
  - Safe evacuation possible with appropriate planning and active response, although if a choice to remain is made, safe self-evacuation becomes readily impractical (no rising egress).

- **East Portions of Wingham through the inundation of the intersection between Isabella and Rowley Streets**
  - Occurs over a medium time frame by expanding Manning River flows
  - Isolates properties on Rowley, Ruth , Keech, West Appletree Streets as well as Wingham Peninsula (and evacuates located at the High School)
  - Primary evacuation route to the flood risk-free areas of Wingham
  - Safe evacuation possible with appropriate planning, active responses and some access modifications

- **Steele Street**
    - Occurs over a medium time frame as a result of Manning River backwater flows
    - Isolates properties on Steele Street
    - Safe evacuation possible with appropriate planning, active responses, however when fully isolated it would become difficult
- **Wynter Street north of the railway line**
    - Occurs over a long time frame as a result of Manning River backwater flows
    - Isolates approximately 30 houses by cutting off access to Young's Road
    - Some flood risk-free areas available for safe evacuation
- **Central Park and the elevated areas surrounding it to the south**
    - Occurs over a long time frame at the peak of the extreme flood as a result of Manning River flows overtopping the bank near Bungay Road
    - Temporarily isolates the primary evacuation point of Wingham but cutting Bungay Street

3. HAZARD CATEGORISATION

Flood Hazard categorisation provides an indication as to the severity of risk and therefore which areas require floodplain risk management strategies to be developed.

A comprehensive analysis of flood hazard requires the detailed assessment of factors such as;

- Depth and Velocity of Floodwaters
- Rate of Rise of Floodwaters
- Effective Warning Time
- Effective Flood Access
- Duration of Flooding

Other important factors which are less quantitatively defined include:

- Flood Readiness
- Evacuation Problems
- Type of Development

According to the Floodplain Development Manual, Appendix L, the first step and primary influence on flood hazard can be based on the depth and velocity of floodwaters. This essentially measures the amount of energy associated with a location for a given flood.

The manual's approach to hazards involves two categories, "low" and "high". This is usually combined with a parallel hydraulic categorisation of the site, which provides a qualitative description of flood behaviour. As the Floodplain Development Manual states, it is impossible to provide explicitly quantitative criteria for defining the hydraulic categories and therefore this approach can be difficult, as well as highly subjective. These categories are utilised in the Greater Taree City Council DCP 2010.

The "Provisional Hydraulic Hazard Categories" are defined as follows:

- **Low Hazard**; depth < 1.0 m and velocity < 2.0 m/s (although with a velocity times depth limit)
- **High Hazard**; all outside this range

This is shown graphically in Figure 4.

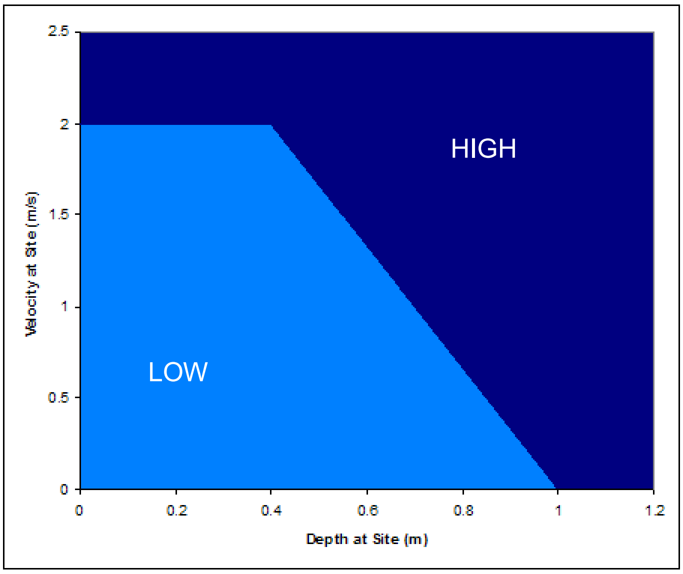

Figure 4: Provisional Hydraulic Hazard Categories (from the FPDM)

An alternative approach to assessing the risk is the hydraulic hazard categorisation scheme discussed in *"New Directions in Defining Flood Hazard and Development Control Planning"; McConnell and Low, 2001*. The objective of this method is to facilitate cadastral based flood hazard classifications and associated criteria to assist in strategies to achieve equitable management of floodplains. This method is based on quantities derived from the Flood Study and therefore there is little, if any, difficulty or subjectivity in defining the hydraulic hazards.

The hydraulic hazard structure and methodology used to assess risk to property and prepare the maps in Appendix B are based on the following categorisation scheme (using the 1% AEP event):

- **Low Hazard**; depth < 0.4 m and velocity < 0.5 m/s
  - Limit for the stability of cars
- **Medium Hazard**; depth < 0.8 m, velocity < 2 m/s and velocity times depth < 0.5 m^2/s
  - Limit for the stability of heavy vehicles
  - Safe wading of able bodied adults
- **High Hazard**; depth < 1.8 m, velocity < 3m/s and velocity times depth < 1.5 m^2/s
  - Limit for the stability of light framed construction (timber frame, brick veneer, etc.)
- **Very High Hazard**; velocity > 0.5m/s and < 4m/s and velocity times depth < 2.5 m^2/s
  - Limit for the stability of heavy framed construction (steel frame, etc.)
- **Extreme Hazard**; velocity times depth > 2.5 m^2/s with a minimum velocity of 0.5 m/s
  - Development considered unsuitable and likely to adversely impact flood levels

The following diagram shows the base flood hazard categorisation used:

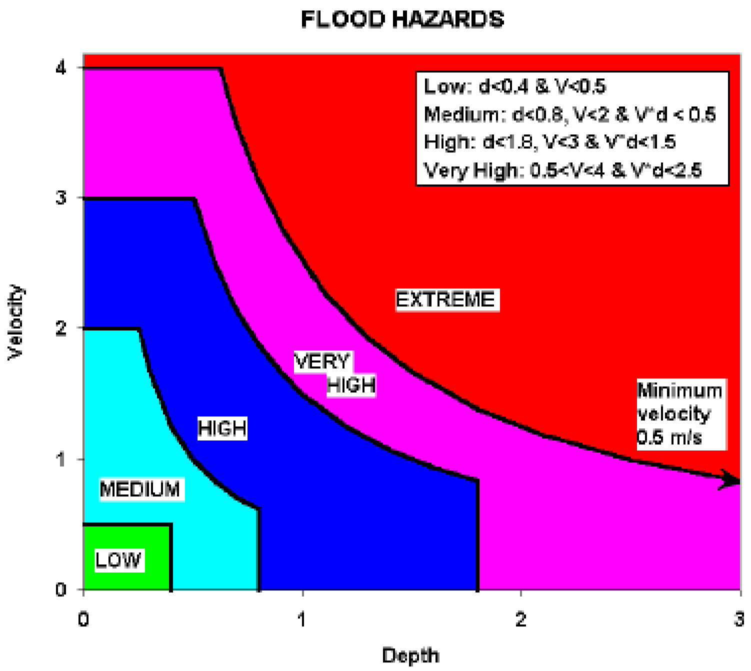

Figure 5: Alternative provisional hydraulic hazards used in this study

These hydraulic hazard categories essentially measure the amount of energy associated with a location for a given flood. This method is based on quantities derived from the Flood Study and therefore there is little, if any, subjectivity in defining these. Provisional hydraulic hazard maps for Wingham using this alternative scheme are shown in Figure 6 and Figure 7.

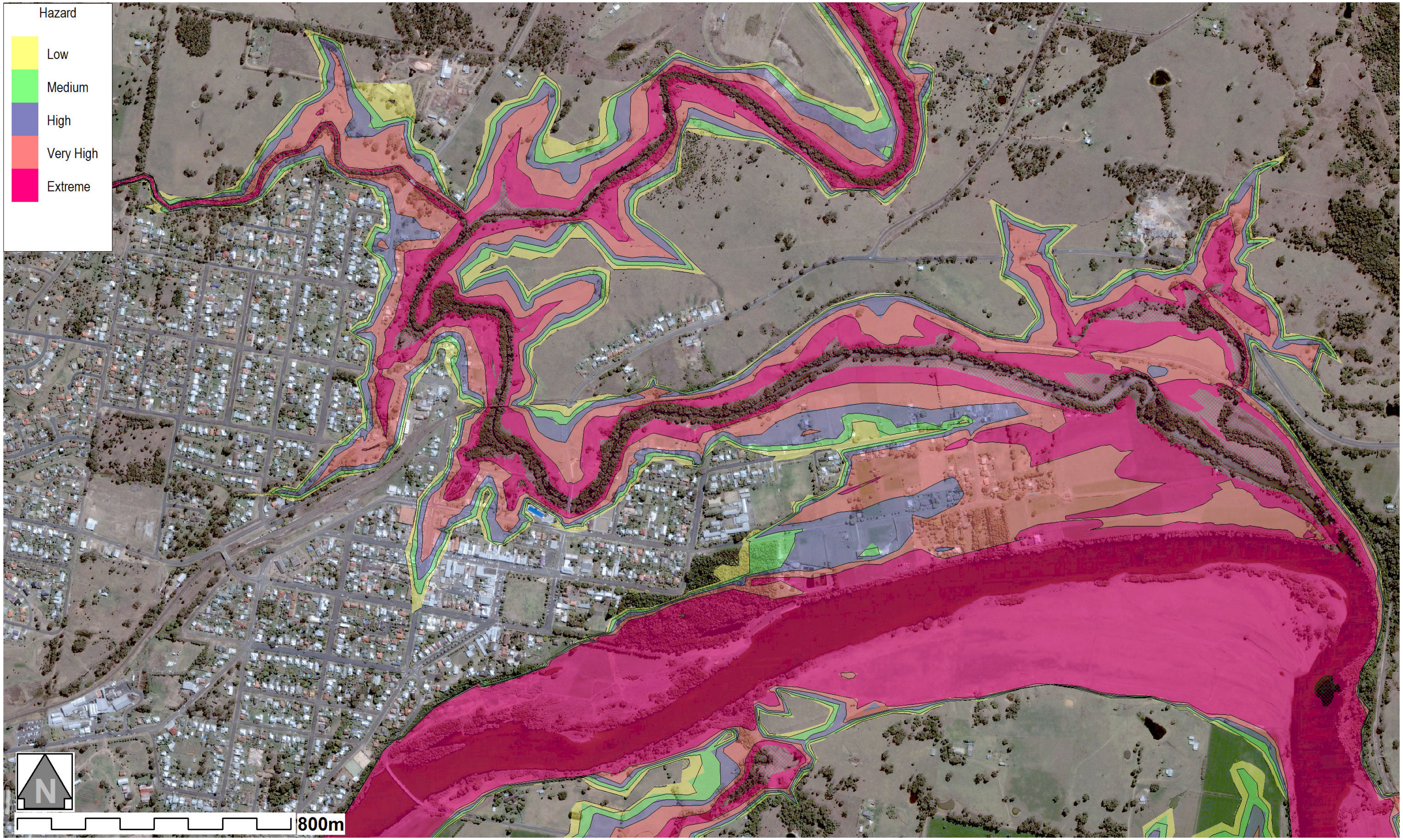

Figure 6: Hydraulic Hazard Map of Wingham based on the 1% AEP event

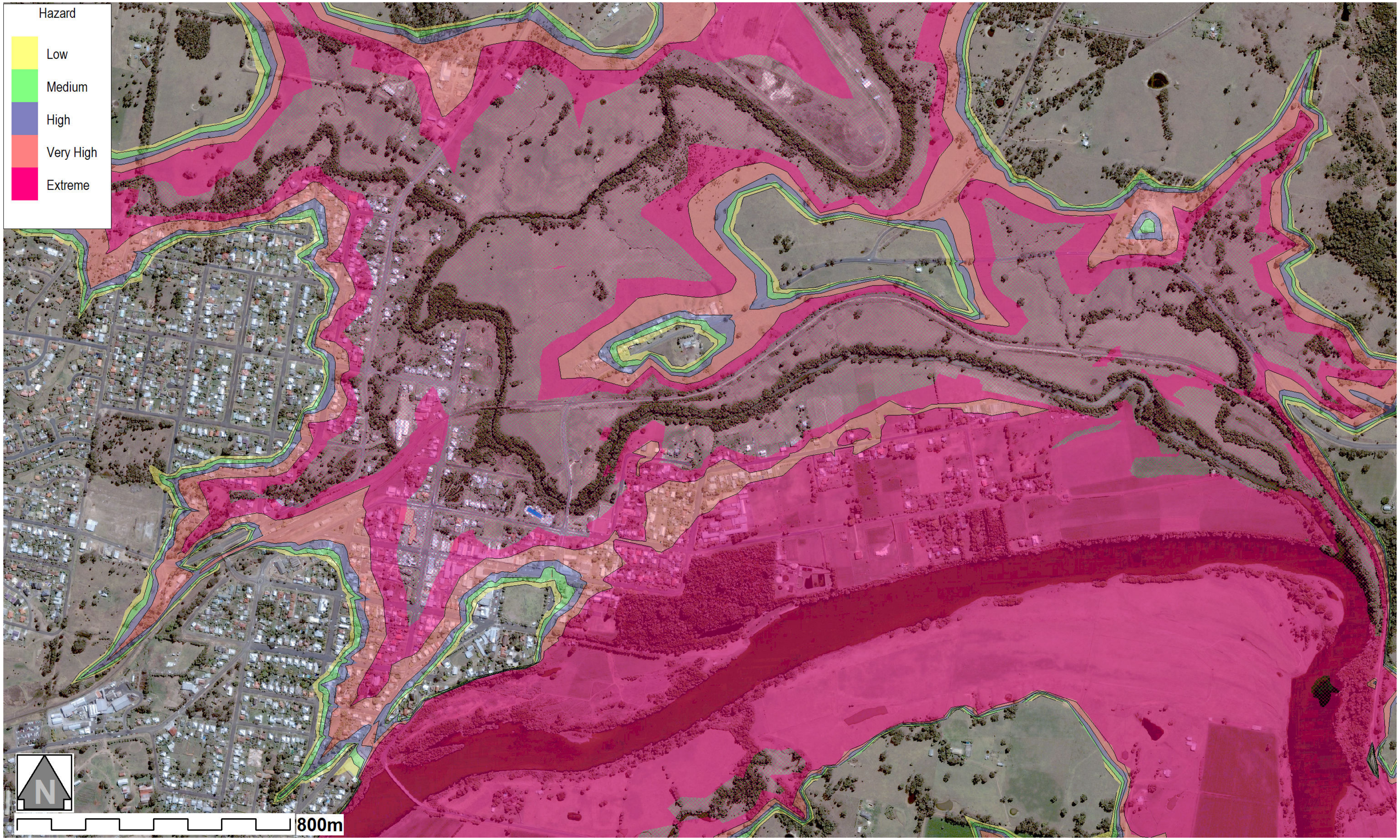

Figure 7: Hydraulic Hazard Map of Wingham based on the PMF

There is a need, as also stated in the Floodplain Development Manual, to consider the difficulty of the conditions that could be expected if an extreme flood occurred. In other words, there is a need to recognise a greater variety of risks associated with rarer floods. This is because hazards can dramatically increase because of greater flood depths and velocities, and rates of rise can give little warning of dangers and the cutting off of evacuation routes.

Therefore the management of the risk to life is extended to consider the hazards associated with the full range of flood events with respect to requirements for evacuation or on-site refuge. In other words, if a site is within a zone of acceptable risk to property but becomes isolated in more extreme flooding, this can be “acceptable” if safe evacuation and / or on-site refuge can be undertaken. Obviously safe evacuation becomes the only option if hazards for rarer floods approach very high or extreme. The following is an extract from *McConnell and Low, 2001,* which describes the logic associated with risk to life:

Category 1 – *Evacuation Required* – an escape route up and away from rising floodwaters is available at all times or sufficient warning is available.

1a: *Adequate warning times available and indications of flood rise provided* – flood response plan is required for businesses and institutions. Response plan to be reviewed annually. Flow conveyance capacity is to be maintained without adverse increase in flood levels or disruption to flowpaths where hazards become high or greater.

1b: *Rapidly rising floodwaters with no effective warning time* – rising egress route is necessary otherwise site becomes Category 2a. Flood response plan including a warning mechanism is required for businesses and institutions. Response plan to be reviewed annually.

1c: *Rapidly rising floodwaters with hazards becoming high or greater and no effective warning time* – rising egress route is necessary otherwise site becomes Category 2b. Flood response plan including a warning mechanism is required for businesses and institutions. Response plan to be reviewed annually. Flow conveyance capacity is to be maintained without adverse increase in flood levels or disruption to flowpaths.

Category 2 – *On-site Refuge Required* – the site or area becomes enclosed by rapidly rising floodwaters with no effective warning time and no obvious escape route, or escape route is cut *(ie. becomes high hazard)* within half an hour of being flooded. Fail safe refuge is required on-site for residents/occupiers and visitors, and building must be able to withstand dynamic and static forces of floodwater plus an allowance for debris loading.

2a: *Hazard remains or becomes low to medium* – engineer's certification of structural design is required to the satisfaction of Council. May be categorised as 1b if rising egress is available.

2b: *Hazard becomes high to very high* – determination of structural design is required to the satisfaction of Council. Inspection and approval of flood resistant design is required. Flow conveyance capacity is to be maintained without adverse increase in flood levels or disruption to flowpaths. Suitable for light construction with appropriate design modifications. Not acceptable for places of assembly or critical institutions.

2c: *Hazard becomes extreme* – determination of structural design is required to the satisfaction of Council. Inspection and approval of flood resistant design is required. Flow conveyance capacity is to be maintained without adverse increase in flood levels or disruption to flowpaths. Unsuitable for light construction. Not acceptable for places of assembly or critical institutions.

4. CONSEQUENCES OF FLOODING IN WINGHAM

There are two basic components of flood damage;

1. **Tangible damages** result in direct, measureable, financial costs such as property damage but also indirect costs such as those associated with the clean up as well as financial costs such as loss of wages/business.
2. **Intangible damages** are those costs on the communities that are more difficult to quantify, such as the trauma and stress associated with flooding.

This section will outline the consequences of flooding in Wingham, in terms of the aforementioned flood damage categorises.

4.1 Wingham Property Details

Appendix A shows a table compiled from Council and WorleyParsons site survey data containing the approximate ground level, floor level and approximate over-floor peak inundation for properties experiencing the 1% AEP flood.

4.2 Tangible Damages

Tangible flood damages are comprised of direct and indirect costs. The direct costs may include:

- **Internal Contents Costs**; associated with the damage, repair and replacement of household contents such as furniture, electrical equipment, clothing etc.
- **Internal Structure Costs**; associated with the damage, repair and replacement of household components such as carpet, flooring, cupboards, doors, walls etc.
- **External Property Costs**; associated with the damage, repair and replacement of sheds, fences, driveways, gardens, vehicles etc.
- **External Structure Costs**; associated with the partial or complete destruction of a dwelling

The indirect costs may include:

- **Clean-up Costs**; associated with individual properties or the community as a whole
- **Financial Costs**; associated with loss of wages, sales, production

To calculate the tangible damage associated with flooding in Wingham the following information was used:

a) **Peak flood levels throughout the study area for the full range of design floods**

b) **Property floor levels**; these were obtained through previous studies, WorleyParsons site surveys or estimates for all properties within the bounds of the 1% AEP flood

c) **Wingham Damage Curves**; which gives the cost per increment of depth for several different types of residential properties in Wingham. This was estimated using the Department of Natural Resources calculation program, in combination of information from the Bureau of Statistics, Rawlinson's and data collected by WorleyParsons through site visits. This information is plotted in Figure 8.

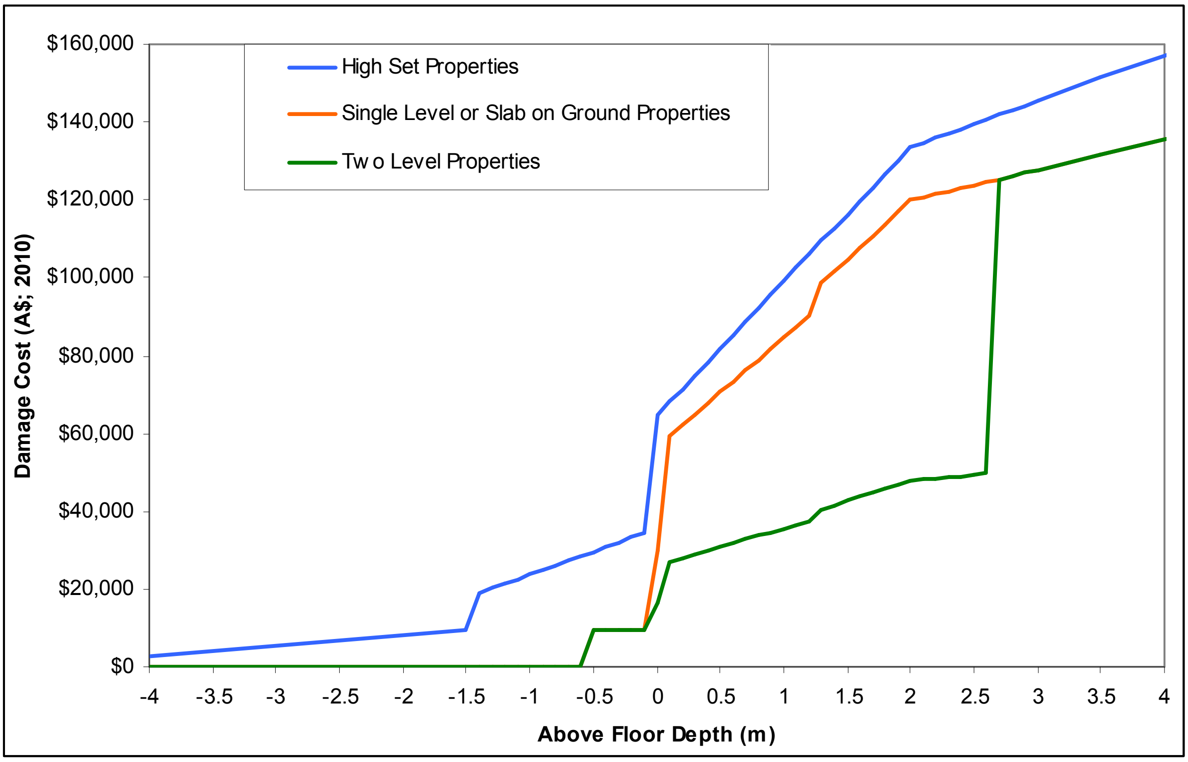

Figure 8: Wingham Flood Damage Curves

This information was input into the waterRIDE Flood Manager Software package and a damage analysis performed.

Properties within the Very High to Extreme hazard categories were considered to have a chance of complete destruction due to the energy associated with the flood velocity and depth. The potential for this destruction was expressed as a range with a sensitivity of 25% and 75%; that is the actual house destruction was set at 25% and 75% of the number of houses experiencing Very High or Extreme hazard.

Table 1 and Table 2 show the tangible flood damages over the range of design floods, for the Cedar Party Creek catchment alone, as well as the wider Manning Catchment, respectively.

As seen in the flood study, the effects of flooding from the Cedar Party sub-Catchment alone is limited to relatively minor portions of Wingham and this is reflected in the associated tangible costs. Furthermore, there is little value in analysing the flood costs of Cedar Party Creek alone because flooding would almost always result from the wider Manning catchment.

Table 1: Estimated Tangible Flood Damages in Wingham; Cedar Party Sub-Catchment Flooding Only[1]

Flood AEP	No. houses with over floor flooding	No. of houses within a 'Very High' or 'Extreme' Hazard	No. of houses potentially destroyed	Tangible Damages (no house destruction)	Total Tangible damages
5%	10	0	0	$73,000	$73,000
2%	12	0	0	$111,000	$111,000
1%	17	0	0	$183,000	$183,000
0.5%	18	1	0 to 1	$342,000	$342,000 to $559,000
PMF	157	125	31 to 93	$18,027,000	$24.75M to $38.42M

Table 2: Estimated Tangible Flood Damages in Wingham; Manning Catchment Flooding[1]

Flood AEP	No. houses with over floor flooding	No. of houses within a 'Very High' or 'Extreme' Hazard	No. of houses potentially destroyed	Tangible Damages (no house destruction)	Total Tangible damages
5%	50	2	0 to 2	$1,025,000	$1.24M to $1.46M
2%	94	17	4 to 13	$3,775,000	$4.64M to $6.60M
1%	118	37	9 to 28	$5,750,000	$7.70M to $11.82M
0.5%	145	86	22 to 65	$11,175,000	$15.95M to $25.28M
PMF	159	159	40 to 119	$23,975,000	$32.65M to $49.80M

4.2.1 Average Annual Damages

Over a long period of time, Wingham will be subject to a variety of floods leading to a variety of damage. The annualised average of the damaged (AAD) for all floods over a very long period of time is a useful measure of the likely long term costs of flooding in Wingham, and can be used to assess mitigation options and how these are likely to benefit the community.

The AAD is determined by plotting damage costs against the design flood exceedance probabilities and determining the area under the curve.

Similar to common financial assessments, the present value of potential flood damages can be determined through a net present value analysis of the AAD, typically over a planning horizon of 50 years. Treasury guidelines specify a discount rate of 7% for this analysis with a sensitivity assessment of ± 3%.

Table 3 summarises the AAD over a typical 50 year period in Wingham and provides a total present value in 2010 Australian Dollars (PV) using an average treasury-defined valuation change rate of 7%.

Table 3: Average Annual Damages and Present Value of this over 50 years for Wingham in 2010 dollars[1]

	AAD	PV (7%)
Cedar Party Sub-Catchment Alone	$68,000 to $104,000	$942,000 to $1.43M
Manning Catchment	$331,000 to $494,000	$4.56M to $6.81M

In other words, for a typical 50 year period assuming the current level of development remains constant, the average annual cost of flooding in Wingham will be in the order of $331,000 to $494,000. The total present value of this over the next 50 years is between $4.56 million and $6.81 million.

Therefore the cost of strategies or options to mitigate flood damage in Wingham can be measured against the costs of doing nothing.

4.3 Intangible Damages

Flooding imposes a range of damages on victims that are difficult to put a monetary value to. These are known as intangible damages and have proven to be significant when large floods occur. These damages are associated with the emotional, mental and physical health of flood victims and studies have shown that these damages ultimately derive from the financial and social impact of flooding but in general can be associated with:

- loss of life
- personal injuries
- disruption to the personal and work lives
- Disruption to essential services such as schools, power, water, sewerage etc.
- opportunity losses such as those resulting from the suspension of education and government services
- environmental damage

Intangible damages have the added detriment that they have been shown to potentially linger for many years after a large flood.

[1] *It must also be remembered that only a selected number of houses (159) were used in these calculations. This number represents all houses within the fringe of the 1% AEP flood extents and therefore the cost of flooding in Wingham for events in excess of the 1% AEP will likely have greater costs. This however does provide a good indication for measuring the benefit of floodplain risk management strategies as the Council's FPL is in line with the 1% AEP.*

5. FLOODPLAIN RISK MANAGEMENT OPTIONS

The following section outlines floodplain risk management options for Wingham. There are essentially three ways in which flood risk can be mitigated:

1. **Property Modification**; which deals with modifications to existing properties and controls on future development
2. **Response Modification**; which deals with modifications to the response of the population to better understand and handle the flood risk
3. **Flood Modification**; which deals with modifications to the behaviour of the flood itself

A well-rounded composition of strategies to deal with the flood risk in Wingham will likely contain elements of all these categories.

Of course, the option of “do nothing” also exists, but the previous section showed that in the long-term, the costs of doing nothing accumulates for individuals and the community as a whole. Therefore the cost of a “do nothing” approach can be used to compare the cost and benefit of floodplain management options.

5.1 Risk to Property and Life Issues in Wingham

The management of existing and continuing flood risk are much more difficult to manage than future flood risk because of a conflict between what *should* be done with flood prone location as opposed to what has *already* been done. Therefore, before floodplain risk management options can be analysed, the risk to property and life for existing development in Wingham needs to be further distilled from the results of the Flood Study.

The first step involves the use of the 1% AEP flood event, (which is the basis for the FPL). Using the hazard map, in combination with the peak velocity and depth maps, there are:

A) 6 properties in Wingham that face a flow depth and velocity that would likely lead to the partial or complete destruction of the property (that is, located in an area of “extreme” hazard according to the 1% AEP event). This represents an unacceptable risk to life for the occupants of these properties.

B) 31 properties that are either completely within a “very high” hazard area or partially within a “very high” hazard area that also experiences a flow velocity of at least 0.5 m/s. These properties are subject to a very large depth of floodwater (up to 4 metres) with small to moderate velocity that poses a potential risk to life for the occupants of these properties.

The second step involves the use of the PMF flood event, which represents the most extreme flood risk that exists. This event is used to evaluate the likely risk to life that evacuation places on occupants and / or rescuers. Using the same 159 houses located in flood prone land of Wingham, time-varying flood study data for depth, velocity and hazard the following information was extracted regarding the likely number of properties that would need to be evacuated in a given time. The maximum time has been based on safe-wading for an able bodied adult and therefore would be greater than the time required for vehicular evacuation, the elderly or impaired.

C) 8 properties[2] are isolated very early, before adequate warning based on river levels is available. These properties are isolated by flows from the Cedar Party Creek catchment that do not subside prior to levels rising in the Manning River and reaching the SES 'Major Flood' level at Bight Bridge. These properties represent a significant problem for evacuation as warning times may have to be related to rainfall and evacuation may need to be undertaken before a waterway begins to significantly rise.

D) 51 properties would have less than 3 hours to evacuate *after* the SES 'Major Flood' level was reached at Bight Bridge

E) 94 properties would have at least 3 hours to evacuate, *after* the SES 'Major Flood' level was reached at Bight Bridge

Of all these properties, a significant portion would require an SES managed evacuation or rescue due to the extreme hazards that arise if occupants do not evacuate within the required time.

Those affected by Cedar Party Creek, where a managed evacuation may not be possible due to the small effective warning time, would need to self-evacuate within a short time frame.

In categorising these properties, it has been assumed that some essential upgrades to evacuation routes have been made as listed in Section 5.2.1. These works represent some basic upgrades to the primary evacuation routes used for many properties and would increase the evacuation risk for many properties in Wingham if not undertaken.

Other recommended works were not considered to have been completed.

[2] The number of properties potentially affected in this category depends on the rainfall distribution over the catchment and the resulting time difference in peak levels between the Cedar Party sub-catchment and the greater Manning Catchment (8 properties represents the likely number considering the historic difference in peak levels which was used to model the design flood events).

5.2 Property Modifications

The following Property Modification options were considered for Wingham:

1. Flood Access Works
2. Voluntary House Purchase
3. Development Controls and Zoning
4. Voluntary House Raising

5.2.1 Flood Access Works

In coastal regions, where floods occur over relatively small time scales, adequate flood access and evacuation is essential for managing the flood risks to life. Whilst it may be acceptable for some areas to become isolated during a minor flood, safe evacuation routes needs to be available in the event of more extreme flooding. A number of areas in Wingham where improvements could be undertaken were identified by using the time-varying flood study data for the extreme flood.

These works have been divided into two categories as a measure of their degree of importance. *Essential* works are assumed to have been undertaken when evaluating other floodplain risk management options in this report. The financial benefit of these works is difficult to measure because it would be reflected in the cost of other floodplain management options (such as Voluntary House Purchase (Section 5.2.2)) and flood risk to life as a whole.

Essential Works

The following plot shows the locations of essential evacuation works in Wingham.

The availability and any potential legal requirements of using the land proposed would need to be investigated further. Cost estimates (reasonably) assume that the land is Council-owned.

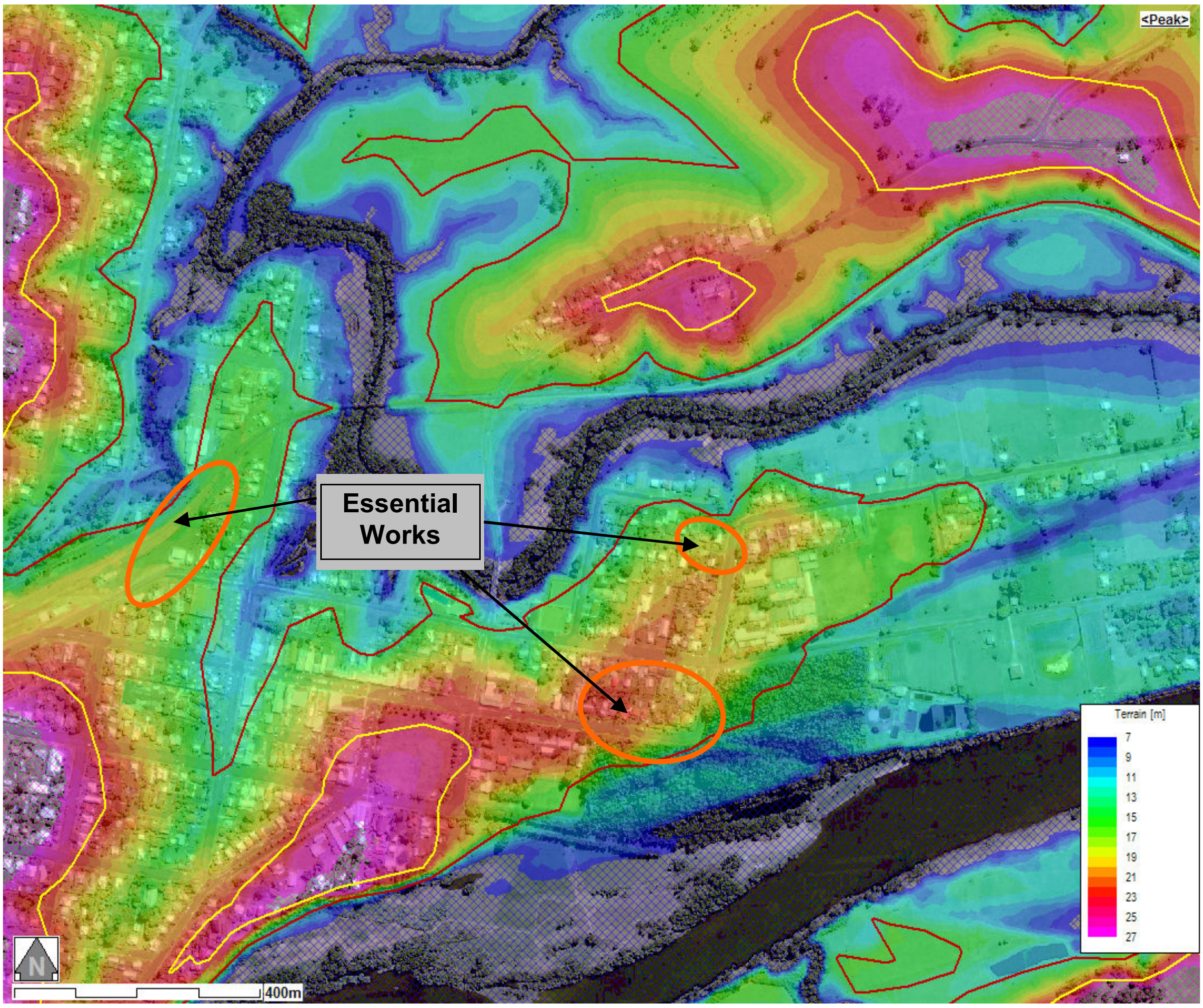

Figure 9: Location of Essential Works Required for Evacuation, showing the terrain elevation; the 1% AEP flood extents are shown in red whilst the PMF extents are shown in yellow.

❖ **Footway between West Appletree Street and Rowley Street**

Figure 10: Location of the proposed footway connecting West Appletree Street with Rowley Street

West Appletree Street becomes isolated by the relatively early inundation of northern Ruth Street.

It is understood that stairs were installed following the previous Floodplain Risk Management Plan that give access to Rowley Street; however after the inundation of West Appletree begins, residents must walk or wade across some undeveloped land to access these stairs. Some variations in the topography of this land, combined with the likely effects of intense rainfall make this less than ideal. To enable the safe evacuation of occupants on West Appletree with a rising egress route, a footway should be built through this undeveloped land, linking West Appletree Street with the stairs that give access to Rowley Street.

The length of this proposed route is approximately 20 metres and would require some fill to ensure the ground is uniform. The width of the footway should be determined in conjunction with the available space but should not be less than 2 metres and should contain high visibility bollards along its length.

The total cost of the footway between West Appletree Street and Rowley Street, using the aforementioned design criteria is approximately \$6 940. This was estimated based on the following cost guide, derived from Rawlinson's, 2008;

- Site preparation;
  - \$1.96 per m^2 = \$390 total
- Concrete paving of footway, including reinforcement, expansion joints, edge forms and finish;
  - \$55.70 per m^2 = \$2 230 total
- 500 mm high bollards with concrete footing and weatherproof 250W mirror-backed sodium floodlight and internal control gear at 10 metre intervals;
  - \$1080 each = \$4 320 total

❖ **Elevated Footway at the intersection of Rowley and Isabella Streets**

Figure 11: Location of the proposed footway connecting the high ground on Rowley and Isabella Streets (yellow). The red square shows the location where an alternative approach could be undertaken.

The evacuation route for Wingham Peninsula, Rowley, Ruth, West Appletree and eastern parts of Combined Street becomes increasingly inundated at the intersection of Rowley and Isabella Streets for flood risks in excess of the 2% AEP. Evacuation along Combined Street is not possible due to the inundated of the Wynter Street intersection much earlier.

In an extreme flood, the hazard at the Isabella-Rowley Street intersection becomes extreme, completely isolating the elevated properties to the north. Eventually, flow inundates the isolated region. The need to maintain a rising egress route at this location is deemed essential as it could potentially affect 130 households, considering that Wingham High School is used as an evacuation point.

Raising the road at this location would be expensive because it would require the purchase or detailed modification to several adjacent properties.

Instead, there are two approaches that can be considered.

OPTION 1

The first option involves an elevated footway that would link the high ground on Rowley Street near East Combined Street, following the eastern side of Rowley Street to the south and around the bend to the high ground on Isabella Street. In this way, it would not affect access along Rowley or Isabella Streets, making use of the vacant nature strip bordering the Wingham Brush Conservation area.

The footway would be approximately 200 metres long and raised to approximately 19 m AHD, meaning that approximately 50% would be elevated above ground level by more than 1 metre. At its highest point on the corner of Isabella and Rowley Streets, the footway would be 3.5 metres above existing ground level and therefore part or all of the footway should be enclosed. The width of the footway should be determined in conjunction with the available space but should not be less than 2 metres (according to design standards) and should contain high visibility guide markers at both entrances. The footway would need to be built to accommodate the loads associated with the rising limb of the PMF in this region.

The total cost of the elevated footway, using the aforementioned design criteria is approximately $664 000. This was estimated based on the following cost guide, derived from Rawlinson's, 2008;

- Site preparation;
  - $1.96 per m^2 = $3 920 total
- Excavation, foundations and approach works;
  - $418 per m^2 = $167 200 total
- 2 m wide reinforced concrete footbridge including safety rails and balustrades;
  - $1 163 per m^2 = $465 200 total
- Four 500 mm high bollards leading to both entrances at intervals of 10 m with concrete footing and weatherproof 250W mirror-backed sodium floodlight and internal control gear;
  - $1080 each = $8 640 total
- Weatherproof 250W mirror-backed sodium floodlighting every 10 metres along footbridge (dual side);
  - $380 each = $15 200 total
- General purpose 1000W sodium floodlight with weatherproof control gear installed at both ends of footway;
  - $1638 each = $3 275 total

OPTION 2

An alternative approach to this evacuation route is shown in the red square on Figure 11. This region represents an area with an elevated topography. The alternative approach would involve the purchase of two properties in this area (one on Combined Street and the other adjoining on Isabella Street). These properties would be removed, the site cleared and either a road or footpath constructed in its place. This would give access between Combined and Isabella Streets, along a naturally elevated area providing a rising egress route to flood-free land. The advantage of this approach would be the potential for vehicular access and a higher RL evacuation route that follows the ground topography.

Costs for this alternative are difficult to gauge because the primary component involves the value of the property required for purchase and any incentives used. A footpath would involve the least cost as well as providing "left-over" land for Council use whilst a road would most likely be substantially more and use the majority of the purchased real estate. The total cost of a footpath, with 2 m width, linking Combined and Isabella Streets (no vehicular access), is approximately $672 000. This was estimated based on the following cost guide, derived from Rawlinson's, 2008;

- Property Purchase, assuming a house price of $217 000 plus an allowed variability/incentive of 25%;
    - $543 000 total
- Demolition, removal of debris and site preparation;
    - $42 500 total
- Concrete paving of footway, including reinforcement, expansion joints, edge forms and finish;
    - $55.70 per m^2 = $40 100 total
- Four 500 mm high bollards leading to both entrances at intervals of 10 m with concrete footing and weatherproof 250W mirror-backed sodium floodlight and internal control gear;
    - $1080 each = $43 200 total
- General purpose 1000W sodium floodlight with weatherproof control gear installed at both ends of footway;
    - $1638 each = $3 275 total

❖ **Primrose Street Footway bypass**

Figure 12: Location of the proposed footway connecting Mortimer and Combined Streets

The intersection of Combined and Primrose Streets becomes increasingly inundated during the early stages of flooding which leads to the isolation of at least 33 residences to the north. For more extreme flood events, this isolated region becomes fully inundated. The alternative evacuation route, via the Flett Street Bridge, also becomes inundated in the early stages of flooding.

In order to maintain a rising egress route for the isolated properties, a footway bypass is proposed that connects the high ground at the end of Mortimer Street near the Railway line with Combined Street (adjacent to the Wingham SES building). The footway would pass alongside the railway line and would have a length of approximately 140 metres.

Again, the width should be determined according to available space but should not be less than 2 metres with high visibility guide markers along its length.

The total cost of the Primrose Street footway bypass, using the aforementioned design criteria is approximately $70 400. This was estimated based on the following cost guide, derived from Rawlinson's, 2008;

- Site preparation;
  - $1.96 per m^2 = $2 700 total
- Concrete paving of footway, including reinforcement, expansion joints, edge forms and finish;
  - $55.70 per m^2 = $15 596 total
- Drainage along footway;
  - $66.40 per m = $18 592 total
- 500 mm high bollards with concrete footing and weatherproof 250W mirror-backed sodium floodlight and internal control gear at 10 metre intervals;
  - $1080 each = $30 240 total
- General purpose 1000W sodium floodlight with weatherproof control gear installed at both ends of footway;
  - $1638 each = $3 275 total

Recommended Works

❖ Evacuation Guide Posts

Evacuation may need to take place at night, at which time the power can be expected to have been cut off by rising floodwaters. This, combined with rainfall and low level floodwater covering evacuation routes, would make wading or driving to safety extremely difficult. Therefore, high visibility guide posts should be installed along all primary evacuation routes with an interval of 50 metres. In low lying areas subject to more frequent inundation, this spacing should be reduced to 25 metres.

The total estimated cost would be in the order of $180,000. This was estimated based on the following cost guide, derived from Rawlinson's, 2008;

- 500 mm high bollards with concrete footing and weatherproof 250W mirror-backed sodium floodlight and internal control gear at 10 metre intervals;
  - $1080 each = $180 360 total

❖ **Flood Access to Individual Properties**

Whilst a property may have frontage to an evacuation route, securing access to that evacuation route from the dwelling on the property is very important. Some properties in Wingham have long access routes that undulate significantly, meaning that whilst levels in the dwelling and on the adjacent evacuation route may pose a low hazard to evacuation, the link between these may pose a severe risk to life. This is particularly true for rescue workers who would not be familiar with these inconsistencies when assisting residents to evacuate. Compounded with rain, flowing floodwater and the presence of darkness, can mean that a property's access poses an unacceptable risk to life. Some properties have access routes that vary by several metres in elevation compared with the dwelling elevation and that of the external evacuation route.

Properties where flood access is currently a problem need to be compiled sorted and surveyed. From WorleyParsons field surveys, ALS data and satellite imagery, it is estimated that at least 25 properties should have their individual flood access improved. These are primarily located on Wingham Peninsula, Primrose and Queen Streets. The number of properties may be reduced as some of these properties are located in areas where Voluntary House Purchase is applicable (Section 5.2.2).

Costs will vary depending on the improvements required, but assuming an average site requires 40 m^3 of stabilised fill, the total cost would be in the order of $59,850. This was estimated based on the following cost guide, derived from Rawlinson's, 2008;

- Clean fill;
  - $45 per m^3 = $1 800 total (each property)
- Compaction, levelling and side support if necessary;
  - $29.70 per m^2 = $594 total (each property)

❖ **Steele Street access via the High School Sports Grounds**

Steele Street contains several houses elevated well above the majority of Wingham Peninsula. Whilst these properties remain unaffected for more frequent flooding, they do become isolated and eventually are subject to more threatening conditions during extreme flooding. When flooding prohibits evacuation of Steele Street via road, the safest evacuation route involves traversing the sports field of the adjacent High School to the east. Along this route, the elevation decreases by up to 1.2 metres, meaning that if evacuation of these properties is not undertaken prior to the realisation of extreme flooding, then relatively dangerous wading may be required to evacuate.

To increase the safety of this potential evacuation route, consideration should be given to the following options:

1. Filling of low points to ensure the route is level across both sports fields; it is estimated that this would require minimal expenditure
2. Guide posts along the field boundary to ensure that evacuates do not stray off the elevated ground
3. The laying of a hard surface (footpath) around the extremity of the field to ensure that the ground does not become unstable during a flood event.

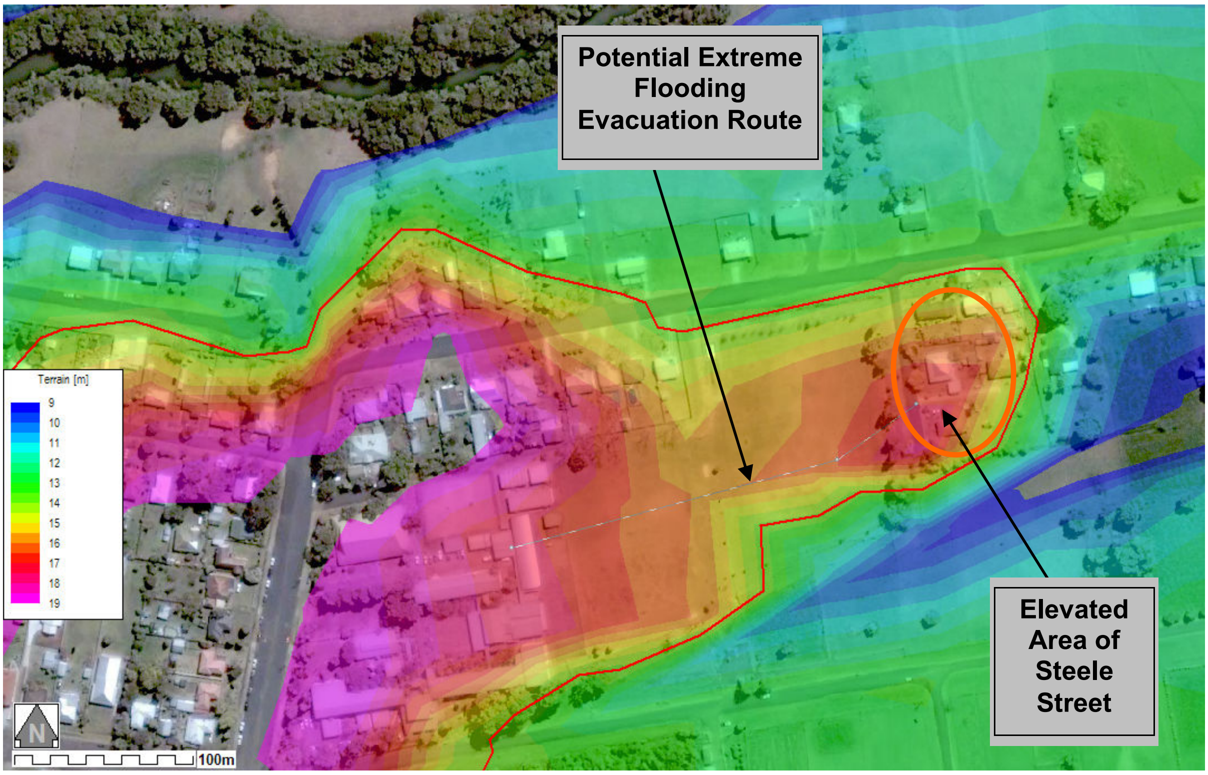

Figure 13: Location of Steele Street and potential evacuation route where works are recommended. The figure is coloured by elevation and the red line shown indicates the extent of the 1% AEP event. During extreme flooding, all areas within this figure are inundated by metres of flow.

❖ Combined Street access to Isabella Street

Several houses on Combined Street become isolated and subsequently inundated during more frequent flood events. Whilst evacuation to high ground in the alley between Combined and Isabella Streets is possible, for more extreme flooding this high ground also becomes inundated. To alleviate this isolation, access to this alley through the shops on Isabella Street should be provided. This may involve the designation of a route through a shop in this area, should this be required. Alternatively, works could be undertaken to ensure a proper evacuation route exists.

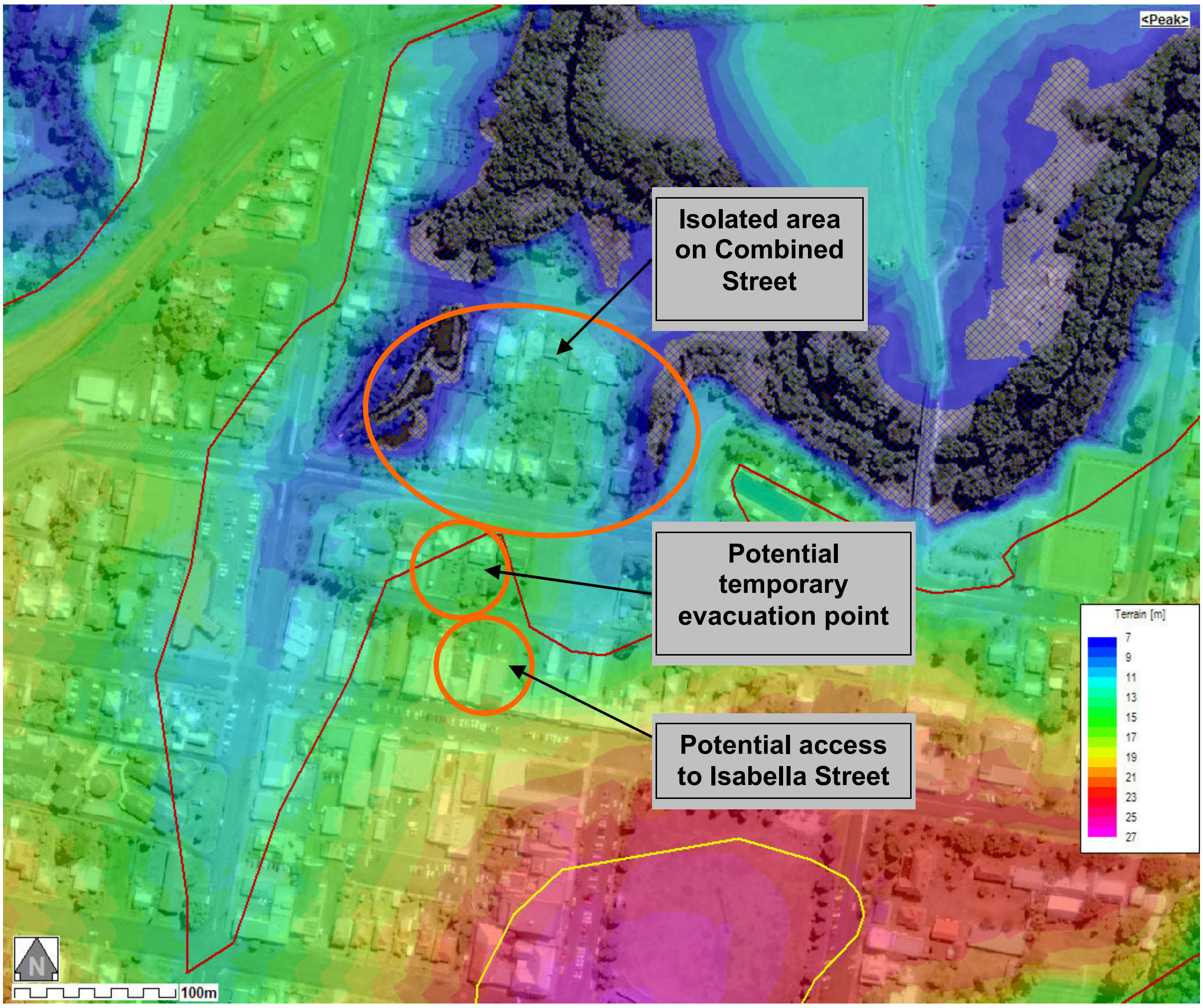

Figure 14: Location of isolated area on Combined Street and where a potential evacuation route is recommended. The figure is coloured by elevation and the red line shown indicates the extent of the 1% AEP event with the yellow line showing the extent of the PMF.

5.2.2 Voluntary House Purchase

In areas where Very High or Extreme hazards exist, there are little practical or economical options that can be employed to mitigate the risk to property and life. One option, that can be used in this case, is the Voluntary House Purchase (VHP) Scheme. It essentially removes the risk by ceasing the occupation of the Very High and Extreme hazard areas. This not only frees the residents of potential danger and cost, but also those in the rescue services who might otherwise be called upon during a flood.

VHP Eligibility and Conditions

The conditions for VHP are as follows:

1. A fair purchase price is offered; a valuation of the property is obtained from the NSW Valuer General *that ignores all flood hazards at the property*. Therefore the price offered is a fair price in line with the worth of the property to the owner.
2. It is completely voluntary; property owners are provided with their eligibility and have the option to continue living there or accepting the Council's offer to purchase their property.
3. Priorities given; if the number of people wanting to participate in VHP exceeds the annual budget allocated, properties will be prioritised based on the hazards outlined in VHP Eligibility, the age/health of occupants and the date of application.

Houses would be eligible based on the following requirements. They are either:

1. within an area where flood energy would lead to partial or complete destruction of the property (that is, according to points A) and B) of Section 5.1 where the property is in a Very High or Extreme hazard according to the 1% AEP event)
2. Within an area of Very High or Extreme Hazard for any flood risk up to the PMF and evacuation places the occupants or rescuers at an unacceptable risk to life. These could potentially be some of the properties listed in points C) through E) of Section 5.1. This would typically be because of an evacuation route:
   a. *descends*; which means that the occupants or rescuers would need to pass through a region subject to more severe hazards in order to evacuate.
      i. An example of this: A house is located at the end of a dead-end street next to a stream. The property and the street near the property are elevated at 15. From the property over a distance of 40 metres, the street descends to 5 before going back up to 25 and connecting to another road another 50 metres away. In a large flood, the occupants need to evacuate their property because the hydraulic hazard is Very High and on-site refuge is not an option. Their only evacuation route is along their street. During this flood, the occupants remain at their property because they have seen many similar floods in the past that have not threatened their property, but only engulfed the lower surrounding land and road nearby. In this flood however, the water continues to rise, and it becomes clear to the occupants that they cannot remain at their property as it is becoming extremely dangerous. However at this stage, the highly hazardous floodwaters over the low surrounding land and their road make evacuation impossible.
   b. *Remains approximately level for a significant distance*; which means that the occupants or rescuers would need to travel a significant distance through a continuing level of hazard that would increase with time. If this distance or the timeframe needed is unrealistic for safe wading and the location of the property is in a region where the rate of rise of floodwater is high, this would constitute an unacceptable risk to life.
      i. An example of this: The same house is located at the end of a dead-end street next to a stream. The property and the street near the property are elevated at 15. The street remains relatively constant in elevation for a kilometre before rising

to connect to another road. During a large flood, the occupants need to evacuate however in the time that it will take them to wade a kilometre, the hazards associated with the floodwater will be too high. Furthermore, although the occupants may know their street well, if it is night time, raining and covered in floodwater, it would be easy to wade slightly off track into deeper, more hazardous water.

Therefore, considering these eligibility requirements and the risk to property and life summarised in Section 5.1, between 6 and 37 houses should be considered eligible for VHP, where the variability lies in:

- the structural stability of the houses noted as being in a very high hazard area for the 1% AEP event (where velocities are less than 0.5 m/s)
- the ability of the relevant authorities to manage short time frames and the corresponding risk to life associated with the evacuation

The number of properties eligible would rise if the proposed "essential" evacuation route upgrades (section 5.2.1) are not undertaken.

Benefits and Limitations to VHP

The following table outlines the benefits and limitations of this option:

Benefit	Limitation
Removes the most extreme risk to life for occupants	Home owners may have a strong sentimental / emotional attachment to their property
Less strain on emergency services	Optional; does not guarantee that a homeowner will take up the offer
A reduction in stress and post-flood trauma	Only a limited number of purchases per year are budgeted for; some homeowners might have to wait
A reduction in tangible costs associated with personal property damage	
Optional; homeowners have a clear choice	
Equitable price offered that does not factor in any flood risk – unlike the wider market	

Cost and Rating

An estimate of $217,000 was used to gauge the cost of VHP based on average regional sales prices.

The total cost of VHP would then be in the order of $1.302 million to $8.029 million.

If this were, for example, undertaken over a 10 year period, the total present value cost would be between $910,000 and $5.62 million (using a 7% average treasury rate).

Table 5 shows a revised AAD and PV cost of flooding in Wingham over the next 50 years along with the benefit in these quantities obtained from a VHP scheme (the benefit represents the cost of flooding with the VHP scheme subtracted from the cost of flooding with a do-nothing approach).

Table 4: Average Annual Damages and Present Value over 50 years for Wingham in 2010 dollars, considering VHP undertaken over a 10 year period

Lower Bound (6 houses)	AAD	PV (7%)
Damages with VHP Scheme	$306,000 to $437,000	$4.22M to $6.03M
Benefit compared to existing	$25,000 to $57,000	$340,000 to $780,000
Benefit to Cost Ratio	0.37 to 0.85	

Upper Bound (37 houses)	AAD	PV (7%)
Damages with VHP Scheme	$166,000 to $226,000	$2.29M to $3.12M
Benefit (compared to existing)	$165,000 to $268,000	$2.27M to $3.69M
Benefit to Cost Ratio	0.40 to 0.65	

Using the lower bound of eligible houses for a VHP scheme, the benefit to cost ratio is between 0.37 and 0.85, whilst using the upper bound gives a benefit to cost ratio between 0.40 and 0.65 if undertaken over a ten year period.

The Wingham Community Survey, output by WorleyParsons and the Greater Taree City Council to the residents of Wingham, showed that a VHP scheme had an average support rating of 61% (amongst those who completed the survey).

The VHP scheme could also be considered to be extended to privately-owned vacant land according to similar applicability rules however this would raise the cost significantly without providing any measureable financial benefits. However this may assist in the consolidation of land that can be later re-zoned for appropriate use by Council (see Section 5.2.3).

5.2.3 Development Controls and Zoning

Future development within areas of high risk to property or life should be permitted only for a particular flood compatible land use (for example, broad acre farming). This includes areas that are subject to very high or extreme hazards that are within the extent of the FPL as well as those areas where evacuation poses unacceptable risks for all flood risk up to the PMF. The FPL through the majority of Wingham is between 14.1 and 14.3 (1% AEP plus 0.5 m freeboard). However site specific information should be obtained directly from the flood study results.

In line with this idea, the land obtained by Council through VHP should be consolidated and rezoned.

Future development within areas where risk to property and life can be managed should have controls implemented that ensure this is the case. These are associated with:

- **flood access**; to ensure that evacuation of the occupants can be reasonably undertaken
- **floor levels**; to ensure that tangible flood damage costs are reduced
- **impact on flood behaviour**; to ensure that levels and or velocities are not detrimentally increased in surrounding areas
- **construction type**; to ensure its stability during an extreme flood where on-site refuge is required

The *Greater Taree DCP 2010; Part E, Flooding Requirements* gives information on the use of flood prone land and its conditions according to the FPDM Hazard Categories. This is considered to adequately address the required Development Controls and Zoning in Wingham. FPDM Hazard maps are shown in Appendix C should be used in conjunction with the DCP 2010 in order to assess the controls and requirements of flood prone land in Wingham.

The Wingham Community Survey, output by WorleyParsons and the Greater Taree City Council to the residents of Wingham, showed that Development Controls had an average support rating of 52% (amongst those who completed the survey).

5.2.4 Voluntary House Raising

Voluntary House Raising (VHR) has a long history in NSW with use in low hazard frequently flooded areas. The initiative involves the provision of Government financial assistance towards the cost of raising the property above the FPL.

This type of option is aimed at reducing the personal cost of flooding for properties that do not pose an unacceptable risk to life during flooding or through evacuation.

VHR Eligibility and Conditions

Houses in Wingham affected by floodwater within the Council's FPL would be considered for VHR.

Of these properties, those houses physically eligible for VHR must be:

a) Constructed of the right materials; houses of single or double brick construction or slab-on-ground construction are generally either impossible or too expensive for VHR. Houses made of timber-frames and clad with non-masonry materials are best suited and are the only ones considered eligible for VHR in this study.

b) Within a low, medium or high hazard zone; houses within a very high or extreme hazard zone can be destroyed by floodwater and raising the property does not remove this risk. Those properties that are in a very high or extreme hazard zone for the 1% AEP are not considered. Furthermore, evacuation difficulties, summarised in the previous section (Voluntary House Purchase, VHP Eligibility; Point 2. a. and b.) are also relevant considerations when ascertaining the eligibility of a property for VHR.

It is estimated that 3 houses, out of the 61 affected by over floor flooding in the 1% AEP in Wingham would be eligible for VHR based on the aforementioned criteria. Building materials and construction type was estimated with the use of site photos (further information would need to be obtained in order to obtain a more accurate assessment of eligibility).

Benefits and Limitations to VHR

The following table outlines the benefits and limitations of this option:

Benefit	Limitation
Home owners retain their property which they may have a strong sentimental / emotional attachment to	It is not suitable for very high or extreme hazard areas
A reduction in tangible costs associated with personal property damage	Not all houses are suitable for raising.
A potential reduction in the danger to personal safety	May result in increased strain on emergency services if residents choose to remain at their property and a larger flood occurs
A reduction in stress and post-flood trauma	

Cost and Rating

An average estimate of $55,000 was used to gauge the cost of VHR. This cost reflects the cost associated with plans/approvals, the lift and restump of the house, modification to plumbing and electric connections and the addition of external stairs, railings, etc. This cost assumes that the house is suitable for VHR (VHR Eligibility and Conditions).

The total cost of VHR would then be in the order of $165,000.

Using this data, a revised AAD and PV cost of flooding in Wingham over the next 50 years is shown in Table 5 along with the benefit in these quantities (the benefit represents the cost of flooding with the VHR scheme subtracted from the cost of flooding with a do-nothing approach).

Table 5: Average Annual Damages and Present Value considering VHR over 50 years for Wingham in 2010 dollars

	AAD	PV (7%)
Damages with VHR Scheme	$322,000 to $485,000	$4.45M to $6.69M
Benefit	$9,000	$110,000

This represents a benefit to cost ratio of 0.67 and would reduce the costs of flooding for less than 2% of houses in Wingham affected within the 1% AEP event.

The Wingham Community Survey showed that a VHR scheme had an average 61% support rating amongst those who completed the survey.

5.3 Response Modification

The following Response Modification options were considered for Wingham:

1. Flood Predication and Warning
2. Flood Education and Community Awareness
3. Local Flood Planning

5.3.1 Flood Prediction and Warning

Currently, two river gauges located at Mount George and Killawarra; provide flood warning for the Wingham SES through the correlation of readings and historic data. These gauges are supplemented with readings from many other river gauges in the upper catchment areas of the Manning Valley.

The SES are also typically provided with confidential, predicted flood information from the BoM using simulated systems based on rainfall in the catchment. These compliment the BoM's flood warnings based on river readings that are publicly provided.

These sources of information together allow the SES to apply their community evacuation plan when required with its effectiveness based on the accuracy of the information and the warning time provided. It is understood that the current system allows between four to eight hours warning time before major flooding occurs in Wingham. This does not include the Cedar Party sub-Catchment, which has little or no warning mechanisms for use by the SES.

In order to increase the accuracy of the information provided, more river and rainfall gauges could be installed throughout the catchment, however it is unlikely that this would provide a substantial benefit over the current Manning River system.

The rapid response of the Cedar Party sub-catchment gives it the ability to isolate parts of Wingham early during extreme events, which are then inundated by the Manning River. Rainfall and river gauges in this sub-catchment could provide a mechanism for better flood predication and warning in Wingham, however any benefits are likely to be limited because the Cedar Party sub-catchment responds very rapidly.

To increase the Manning River and Cedar Party flood warning time, potential flood levels could be simulated based on predicted rainfall; however such a system is likely to be high cost with no substantial benefit provided over the current system.

The Wingham Community Survey showed that improvements and support for flood prediction and warning systems had an average 76% support rating amongst those who completed the survey.

5.3.2 Local Flood Planning

The flood affected properties were grouped by location (Section 5.1) into several categories based on their evacuation needs during an extreme flood.

Whilst the SES is responsible for preparing and implementing flood evacuation plans, Council must ensure that evacuation routes are accessible and consideration is given to works that could alleviate the load on the SES (Section 5.2.1).

The requirements of each area in Wingham that has a specialist evacuation need should form part of the education and community awareness program (Section 5.3.3). Many inundated areas in Wingham have a sufficient time for self or assisted evacuation. After this time elapses, evacuation becomes rapidly hazardous to life, and support relies on rescue missions which may place SES personnel's lives at risk.

This will ensure that areas where self and assisted evacuation is identified, the residents informed and plans developed that account for potential problems such as blockages to evacuation routes or unwillingness of residents evacuate in critical areas of the floodplain.

Furthermore, flood recovery plans should be developed to ensure that the efforts can be readily implemented, especially for more extreme flooding when Wingham as a whole may be cut off from other communities.

The Wingham Community Survey showed that improvements and support for flood education and readiness had an average 84% support rating amongst those who completed the survey.

5.3.3 Flood Education and Community Awareness

This forms the mechanism by which Flood Prediction and Warning as well as Local Flooding Planning are introduced to the community. A flood educated community will inherently have a lower cost associated with flooding because property damage and evacuation risks can be minimised for both rescue workers and residents.

Flood Education and Community awareness should be divided into several categories:

- Education about Flood Risk

  Flood risk tends to mislead or be misinterpreted by people and this should be confronted in the education program.

  No living resident of Wingham has experienced a flood with a magnitude that is greater than 1%. The more frequent low level flooding that occurs in Wingham does not prohibit larger floods from occurring nor does it mean that Wingham is only subject to small floods. This by definition is what flood risk defines – the chance of smaller floods occurring is much higher than the chance of larger floods. In any area, in any catchment, small floods occur much more often than larger floods.

Larger floods do occur and these occur over larger time scales. Whilst Wingham has not experienced a more extreme flood since it was founded, the land where Wingham is located certainly has experienced these floods, and will in the future.

Sustaining the appropriate level of flood readiness is not easy and scepticism is understandable in the absence of large floods. Historic flood information should be provided on similar catchments, showing that more extreme floods do occur as well as information on past floods in the Manning Catchment.

- Education about flood warning, the SES' role and what can be expected during flooding

This allows people to have a general plan when flood warnings are issued and understand what these warnings mean, potentially reducing the personal costs of flooding.

- Specific information about evacuation

This allows the SES and other workers to focus on evacuation rather than rescue if residents do not evacuate when required, reducing the risk to life that exists. The reasons for evacuation, the route and destination of evacuation should be understood.

All information can be provided or distributed to the community via the media, special brochures, school education, physical means (e.g. flood markers) and community noticeboards (within shopping centres, public areas etc.).

As the Floodplain Development Manual states, "the cost of such efforts should be regarded as the maintenance for a flood warning and evacuation scheme".

The Wingham Community Survey showed that improvements and support for flood education and readiness had an average 84% support rating amongst those who completed the survey.

5.4 Flood Modification

Flood modification measures are aimed at modifying the behaviour of the flood itself, by reducing levels or velocities or through the exclusion of floodwaters. These mechanisms may require significant capital works to gain a benefit and may be suited only for certain scenarios.

During design flood simulation, Cedar Party Creek has shown that although it does not govern the ultimate peak flood level experienced in Wingham, it leads to the rapid inundation and isolation of many areas of Wingham prior to levels in the Manning River becoming influential. This leads to two problems in terms of risk to property and life:

1. Properties are subject to "flash-flooding" from Cedar Party Creek, leading to a higher amount of property damage because residents will have little if any warning time to prepare. Ultimate flood peaks derived from the Manning River take much longer to arrive and therefore these *can* be better prepared for.
2. The earlier isolation of some properties in Wingham due to Cedar Party Creek increases the risk to life of occupants and potential rescue workers because flood waters may not recede prior to the arrival of the much greater Manning River flows. In

other words, Cedar Party Creek inhibits evacuation efforts for some areas of Wingham which are later subject to a greater level of flooding from the Manning River.

These two areas of concern can be substantially reduced by delaying or inhibiting flooding that derives from Cedar Party Creek, providing a substantial tangible and intangible benefit to Wingham.

The following Flood Modification options were considered for Wingham. The first two options aim to provide solutions to the aforementioned problems derived from Cedar Party Creek flows, whilst the third options deals more broadly with flooding as a result of the Manning River:

1. Cedar Party Creek Floodway Bypass
2. Cedar Party Creek Flood Retardation Basin
3. Central Wingham Levee

5.4.1 Cedar Party Creek Floodway Bypass

The proposed Cedar Party Creek Floodway Bypass makes use of the existing topography with modification in order to divert excess flow from Cedar Party Creek "around" Wingham.

The suggested floodway is shown in Figure 15, linking the reach of Cedar Party Creek adjacent to Wingham Racecourse below Young's Road to the low ground on the south side of Wingham Road. A cross-sectional profile is provided in Figure 16.

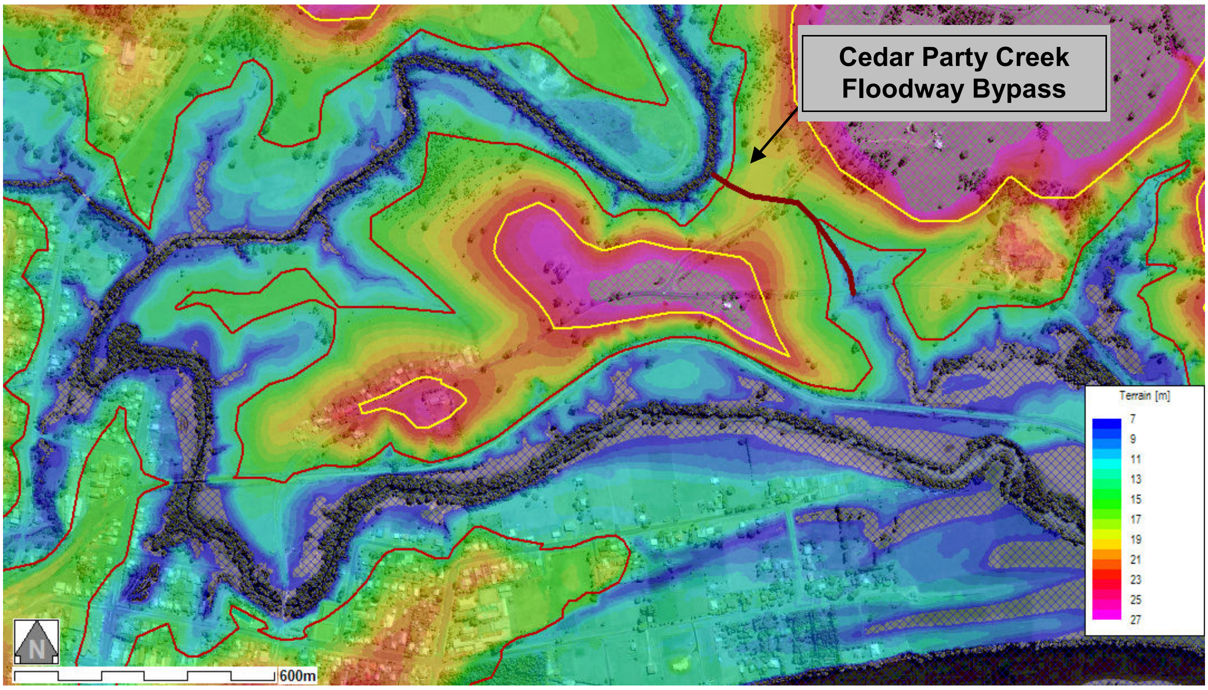

Figure 15: Proposed Cedar Party Creek Bypass Floodway; with elevation coloured, showing the extents of the 1% AEP event in red, the PMF in yellow and the floodway in brown.

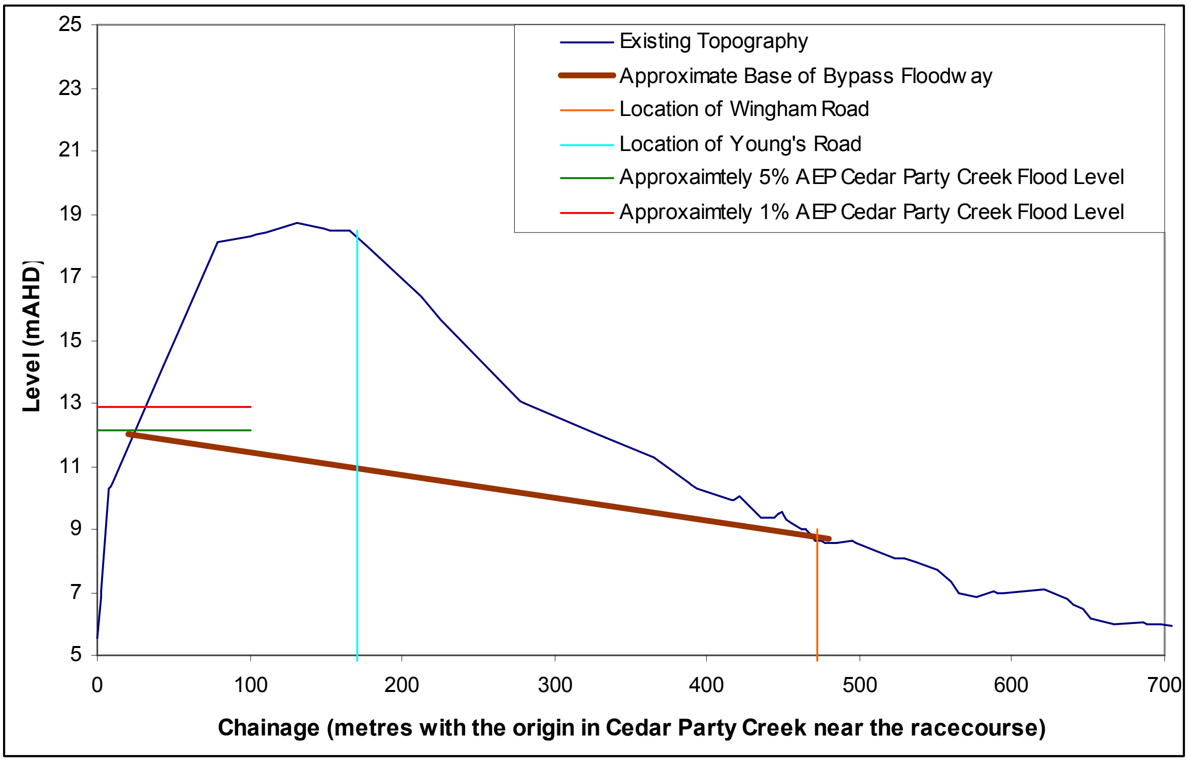

Figure 16: Cross-sectional view of the proposed Cedar Party Creek Bypass Floodway

The proposed details of the bypass floodway are as follows:

- In order to conserve the ecology of the Cedar Party Creek environment, it is proposed that this floodway be designed to divert flow only when levels exceed the 5% AEP flood level. The approximate peak level and discharge of the 5% AEP event near the racecourse is 12.15 and 585 m^3/s respectively.

- To provide a measurable benefit against the stated aims of the floodway, the flow conveyed should be able to reduce the 1% AEP discharge and levels to that of the 5% AEP event. The approximate peak level and discharge of the 1% AEP event near the racecourse is 12.85 and 625 m^3/s respectively. The floodway should therefore have a capacity of at least 40 m^3/s with a depth of flow of at least 0.7 m.

- The floodway should extend from Cedar Party Creek to the immediate south side of Wingham Road to prevent the effect of floodwaters on Wingham Road, which is an arterial route to Taree. The length of the floodway should therefore be at least 450 m. After this point, the topography allows floodwaters to flow through a series of existing gullies, culverts and creeks that are tributaries to Cedar Party Creek. Excess flow would therefore bypass the main channel from the racecourse to the confluence of Cedar Party Creek and the Manning River. The Flood Study shows that at the likely time when peak flows in Cedar Party Creek are produced, levels in the Manning River are yet to significantly respond, meaning that these floodwaters would be able to drain downstream without significant risk to existing levels in the downstream location of the floodway.

- The slope of the floodway would be approximately 1 metre per 140 metres, linking an upstream elevation of approximately 12.0 adjacent to Cedar Party Creek with 8.7 on the south side Wingham Road.
- Using this data, the floodway is required to be at least 20 metres wide. Allowing for reasonable side slopes, this would require an excavation of approximately 40 000 m^3, with a bridge required for Young's Road and upgraded culverts required for Wingham Road.
- The total cost of the Cedar Party Creek bypass floodway, using the aforementioned design constraints is approximately $1 216 000. This was estimated based on the following cost guide, derived from Rawlinson's, 2008;
  - Excavation of 40 000 m^3 of site with an average depth of 5 metres, including planking and strutting, removal and disposal of material;
    - $20.30 per m^3 = $812 000 total
  - Preparation and turfing of approximately 10 000 m^2 channel surface area;
    - $6.10 per m^2 = $61 000 total
  - Young's Road two lane, single span bridge over floodway covering an area of 220 m^2;
    - $1495 per m^2 = $328 900 total
  - Culvert beneath Wingham Road extending over the width of the bypass floodway;
    - $530 per m = $13 250 total

The Cedar Party Creek bypass will not function to reduce overall peak flood levels that derive from the Manning River, however, it will provide more time for flood preparation and evacuation that will lead to the reduction of risk to property and life.

These two areas of concern can be substantially reduced by delaying or inhibiting flooding that derives from Cedar Party Creek, providing a substantial tangible and intangible benefit to Wingham.

The Wingham Community Survey showed that the construction of better flood flow paths had an average 74% support rating amongst those who completed the survey.

5.4.2 Cedar Party Creek Flood Retardation Basin

The proposed Cedar Party Creek Flood Retardation Basin makes use of the existing geomorphology with some modifications, in order to divert and store flow from Cedar Party Creek upstream of Wingham.

The proposed basin is shown in Figure 17, adjacent to the confluence of Stony (Gorman) and Cedar Party Creeks.

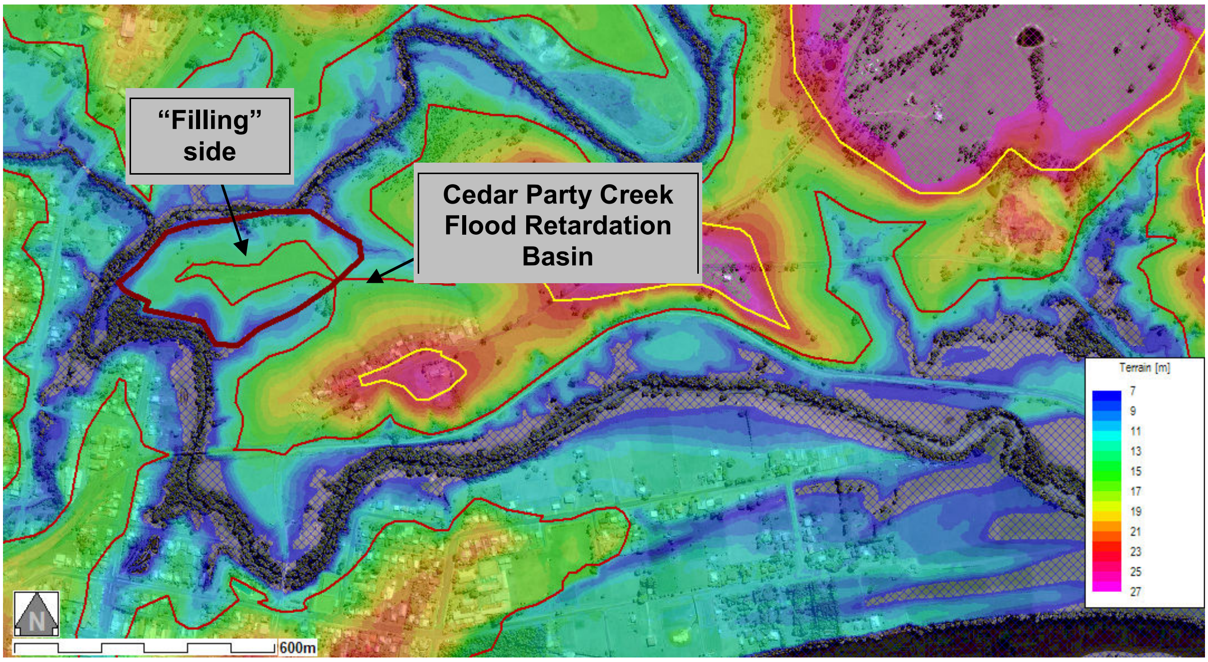

Figure 17: Proposed Cedar Party Creek Flood Retardation Basin with elevation coloured, showing the extents of the 1% AEP event in red, the PMF in yellow and the basin in brown.

The proposed details of the flood retardation basin are as follows:

- To provide a measurable benefit against the stated aims of the basin, the flow volume that is diverted would need to be able to reduce or delay the peak discharge of the 1% AEP event. At the same time, the ecology of Cedar Party Creek should be conserved and in this way, it is proposed that the basin be designed to divert and store flow only when levels exceed the 5% AEP flood level. The approximate peak level and discharge of the 5% AEP event in the vicinity of the proposed site is 9.8. Therefore the basin should have a bank elevation of approximately 9.8.
- In order to store the flow conveyed should be able to reduce the 1% AEP discharge and levels to that of the 5% AEP event. With a crest level of approximately 9.8, the basin would need to hold a volume of 1 600 000 m^3 of flow from the 1% AEP hydrograph in this location to reduce its effects to that of the 5% AEP event. However the storage volume is partially limited by the geomorphology of the site which has a maximum area of approximately 110 000 m^2. In order to approach this level of storage, the site would need to be excavated to a general elevation of approximately -4.7 (with the current site have a general elevation that varies between 5.5 and 14.5). Therefore the stated aim is unachievable as the required elevation can not be feasibly achieved. If the level of the basin was excavated to an achievable level this would provide storage for 473 000 m^3 of flow, which would not provide any measurable benefit for events with an AEP greater than 5%.
- The excavation costs alone for the flood basin would be in excess of $32 480 000, without considering its feasibility (the costs to excavate to an elevation of 5.5 would be in excess of

$12 280 000). Further costs associated with drainage, flow paths and structural works would increase this considerably.

- Excavation of 1 750 000 m^3 with an average depth of 15.7 metres (11 average elevation excavated to -4.7), including removal and disposal of material;
  - $20.30 per m^3 = $35 060 000 total

The Cedar Party Creek storage basin is unfeasible from an engineering and financial viewpoint. If the excavation depth is reduced in order to lift engineering constraints, the financial cost is likely to be prohibitive considering that the function and benefit of the basin would be negligible.

5.4.3 Central Wingham Levee

The proposed Central Wingham Levee aims to reduce the impact of flooding by preventing flow from entering Central Wingham via Cedar Party Creek for flood events with a recurrence interval of less than 100 years (1% AEP) plus a freeboard of 500 mm.

This flood modification measure deals with peak flood levels and therefore is designed to the response of the Manning River.

In order to be effective and preclude floodwaters from entering Central Wingham, it must be fully enclosed with high terrain and therefore the proposal links the elevated ground on Primrose Street, with that on Combined Street (near the Wynter Street Bridge) (Figure 18). A cross-sectional profile of the terrain along the track of the proposed levee is provided in Figure 19.

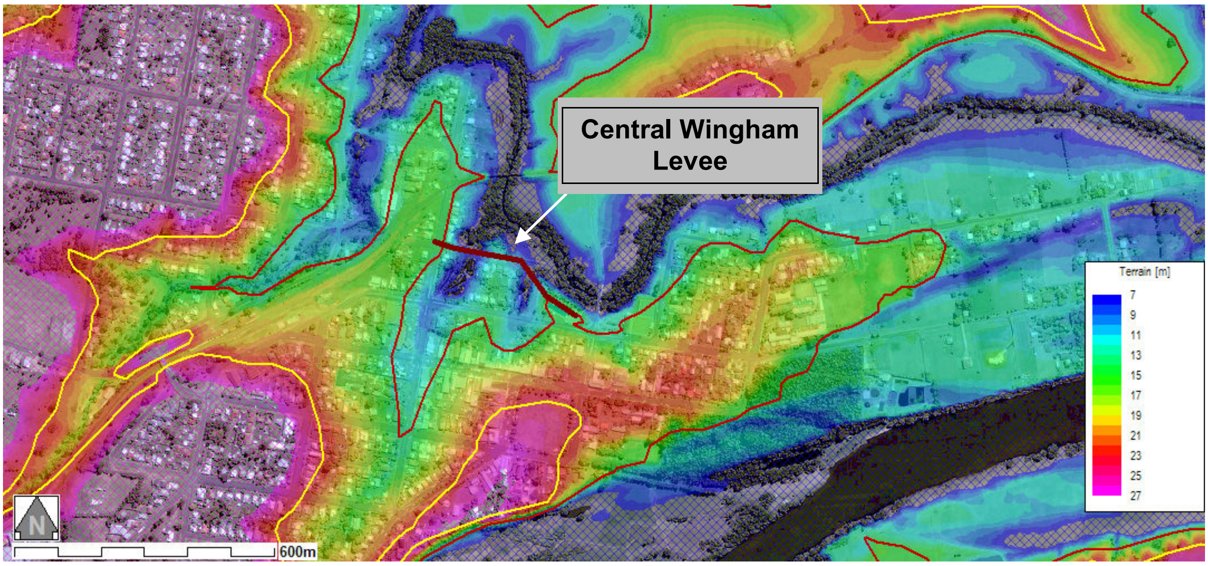

Figure 18: Proposed Central Wingham Levee; with elevation coloured, showing the extents of the 1% AEP event in red, the PMF in yellow and the levee in brown.

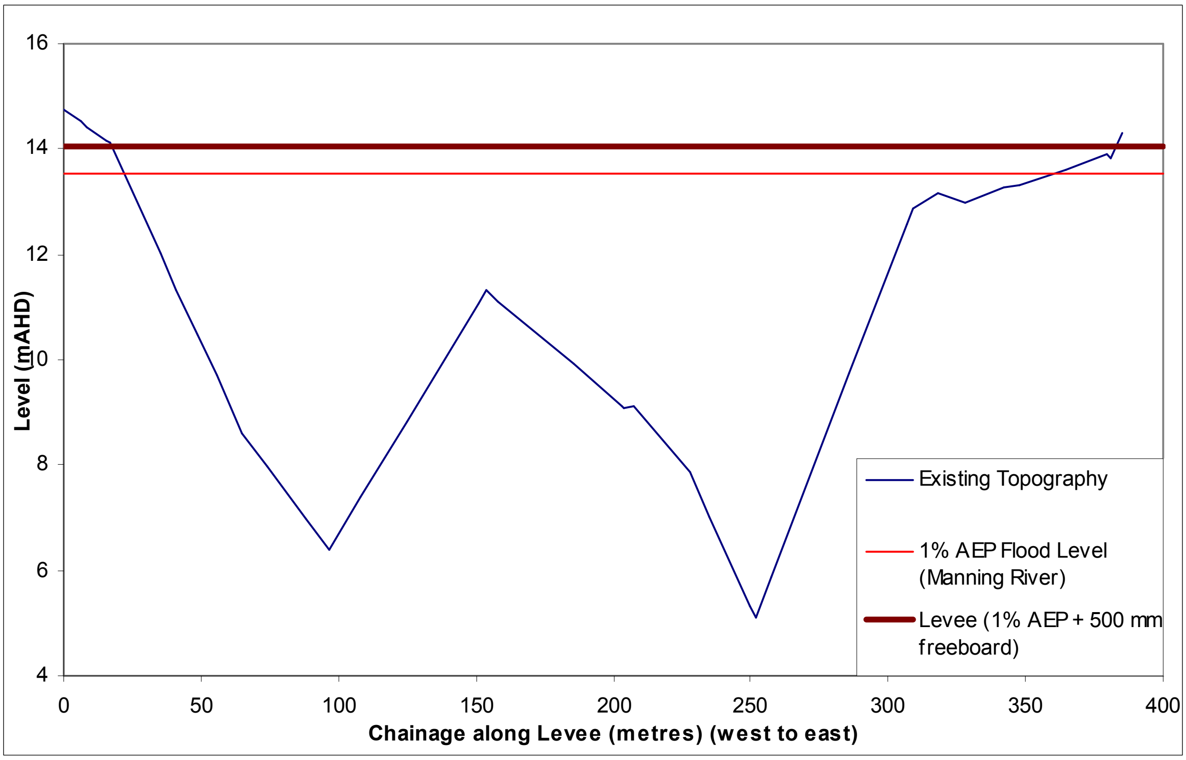

Figure 19: Cross-sectional view of the proposed Central Wingham Levee

The proposed details of the levee are as follows:

- The levee is aimed at preventing floodwaters with an AEP of less than 1% from entering the enclosed region, plus a freeboard of 500 mm. This places the levee at a height of 14.1 in the location proposed and would provide protected to approximately 25 residential properties (20 properties with floor levels below the 1% AEP level of 13.6) as well as the commercial centre of Wingham.
- The levee wall will have a maximum height from the ground of 9 metres in some regions, with an average ground height in the order of 3.5 metres and a thickness of 600 mm.
- The total span of the levee will be approximately 385 metres, primarily following the north side of Mortimer Street.
- The levee will disrupt two natural gullies and therefore adequate drainage will be required with the use of flood gates. In addition, a pump station should be installed in the event that the levee is overtopped and / or to provide drainage for local runoff within the levee.
- The total cost of the Central Wingham Levee, using the aforementioned design criteria is approximately $1.534M. This was estimated based on the following cost guide, derived from Rawlinson's, 2008;
  - ➢ Site preparations, excavation, clearing of vegetation and minor road works;

  - $63.50 per m^2 = $122 238

- Construction of heavy duty concrete block wall with reinforced footing along 385 metres, with a height that varies according to the profile provided in Figure 19;
  - $927 per m^2 = $1 249 133
- Installation of culverts, stormwater drains and floodgates along existing drainage channels;
  - $92 755 total
- Installation of dual pump station with excavation and piping;
  - $69 600 total

Using this data, a revised AAD and PV cost of flooding in Wingham over the next 50 years is shown in Table 6 along with the benefit in these quantities (the benefit represents the cost of flooding with the levee scheme subtracted from the cost of flooding with a do-nothing approach). It should be noted that the damages are estimated considering only residential properties. The levee would also provide significant benefit to some commercial properties in Central Wingham and therefore the benefit to cost ratio can be viewed as reasonably conservative.

Table 6: Average Annual Damages and Present Value considering the construction of the Central Wingham Levee over 50 years in 2010 dollars

	AAD	PV (7%)
Damages with VHR Scheme	$302,000 to $451,000	$4.16M to $6.22M
Benefit	$29,000 to $43,000	$400,000 to $590,000

This represents a benefit to cost ratio of between 0.26 and 0.38 and would reduce the costs of flooding for approximately 15% of houses in Wingham affected within the 1% AEP extent, as well as several commercial properties.

The Wingham Community Survey showed that a Wingham levee had an average 53% support rating amongst those who completed the survey.

6. CLIMATE CHANGE

The Floodplain Development Manual recognises that climate change will affect flood behaviour in two distinct ways:

1. increases in sea level due to thermal expansion of water and melting of ice (This will exacerbate flooding problems in coastal regions), and
2. altered weather patterns due to increased evaporation and changing wind patterns (This will change the way storms affect regions and may lead to increasing rainfall intensities or distributions)

Floodplain Risk Management involves timescales of decades in which current estimates of climate change will become more prevalent. Whilst flood planning levels incorporate a factor of safety (0.5 m above the 1% AEP event), this freeboard should be clarified or increased if the predicted effects of climate change will exceed this value.

Current advice as to the conditions imposed by climate change is preliminary and provided by the NSW Department of Environment, Climate Change and Water (DECCW) and the NSW Government. *Australian Rainfall and Runoff* (Engineers Australia), is currently being updated and is expected to provide further advice.

DECCW currently predicts that climate change will lead to rainfall events trending toward larger scale storms with a change of between -10% and+5% in Extreme Rainfall (40 Year 1 day rainfall total) projected change by 2030[3]. In other words, rainfall intensities by 2030 in the Manning Catchment vary in estimates of between a 10% reduction to a 5% increase.

Figure 20 shows an indication as to how an average change in rainfall intensity affects the probability of a given design storm. In other words, a given design storm will be more likely to occur with an increase in rainfall intensity and vice versa. Using a conservative approach where a 5% increase in rainfall intensity occurs in the Manning Catchment, a 100 year storm now will be similar to an 80 year ARI storm in 2030. This may not necessarily lead to the same increase in flood ARIs because the increase may not be seen in the critical rainfall duration for the Manning Catchment. This increase therefore represents a conservative approach based on preliminary climate study data.

[3] *Practical Consideration of Climate Change; DECCW 2007*

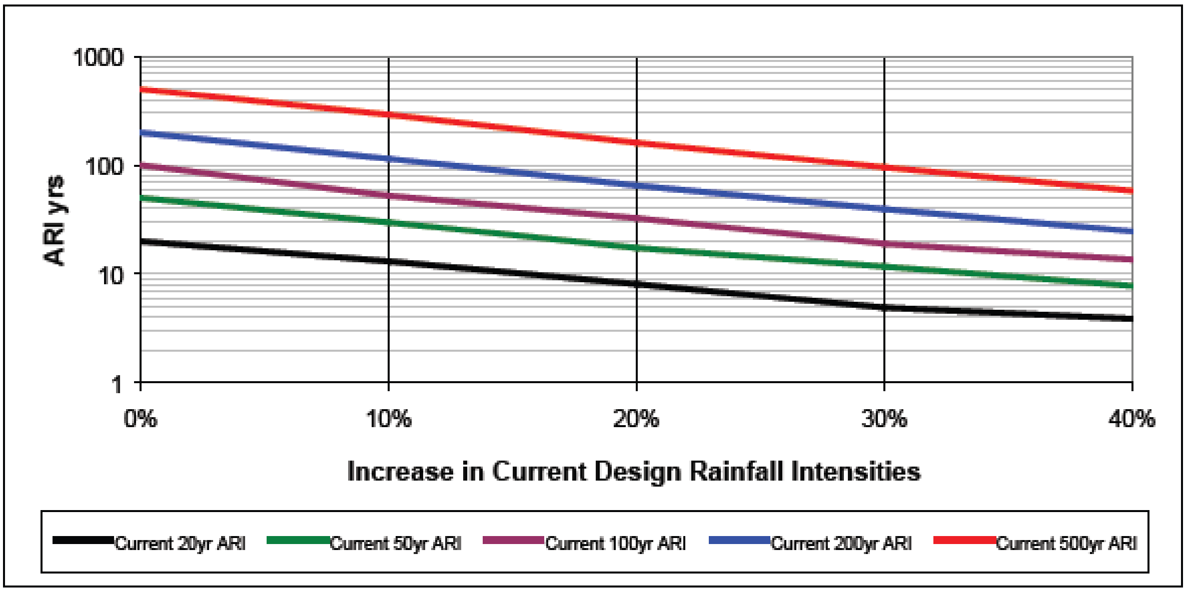

Figure 20: Indicative Change in Design ARI as Rainfall Intensities Increase[4]

In a more detailed analysis of the northern river catchments, the NSW Government and DECCW, as part of the NSW Climate Change Action Plan, suggest that runoff is likely to increase in summer and autumn and decrease in winter and spring. This report provides more details on a monthly basis as follows:

- In summer, there is likely to be a major increase in summer runoff depth (with estimates ranging from +4% to +15%).
- In autumn, there will more likely than not be a slight increase in autumn runoff depth, (with estimates ranging from –12% to +16%).
- In winter, there is likely to be a moderate decrease in runoff depth (with estimates ranging from –20% to +8%).
- In spring, there is likely to be a major decrease in runoff depth (with estimates ranging from –14% to +4%).

In light of this available data, it is prudent to investigate the flood effects of two conservative scenarios where a 10% and 20% increase in flows for the 1% AEP event for Wingham has occurred by 2030.

The current peak flow rate of the 1% AEP event is approximately 12 480 m^3/s so the two climate change scenarios would lead this to increase to approximately 13 730 m^3/s and 14 970 m^3/s respectively. The peak of the current 0.5% AEP event is approximately equal to 14 970 m^3/s and

[4] *McLuckie et al, 2005*

therefore, using this preliminary data conservatively means that the 1% AEP event in 2030 could be the same as the current 0.5% AEP event.

Plots of the estimated water level and resulting hydraulic hazards are shown in Figure 21 through Figure 24[5]. Shown on the water level plots are the existing extents of the 1% AEP event. Currently, the peak level experienced in Wingham for the 1% AEP (100 year ARI) flood event is between 13.6 and 13.8. By 2030, a conservative estimate of how climate change will affect Wingham indicates that 1% AEP levels could increase by 0.35 m (for the 10% increase in flows) and 1.0 m (for the 20% increase in flows).

Therefore the potential impacts of climate change, using this conservative approach, may exceed the FPL freeboard allowance of 0.5 m, leading to an increase in tangible damages. However, from the water level plots, it is clear that the extents of the potential 2030 1% AEP events are not vastly different from those of the current 1% AEP event. Therefore the potential changes will mostly affect properties already within the extents of the current 1% AEP event.

[5] This was obtained by iterating through the 0.5% design event to achieve the required peak flow level at Wingham for the two scenarios.

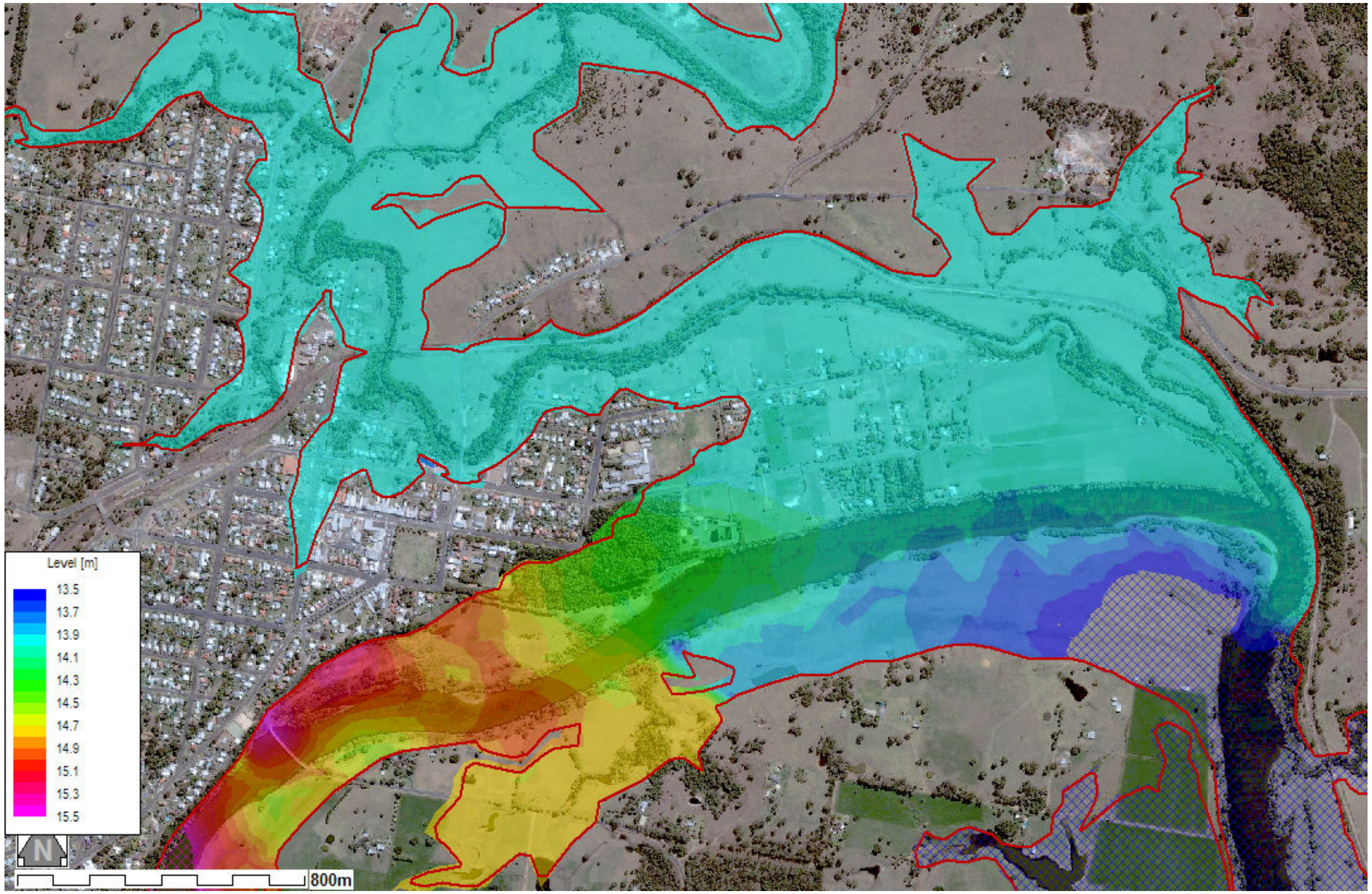

Figure 21: Climate Change Scenario Levels with a 10% increase in flows for the 1% AEP event by 2030 (the extent of the current 1% AEP event is shown in red)

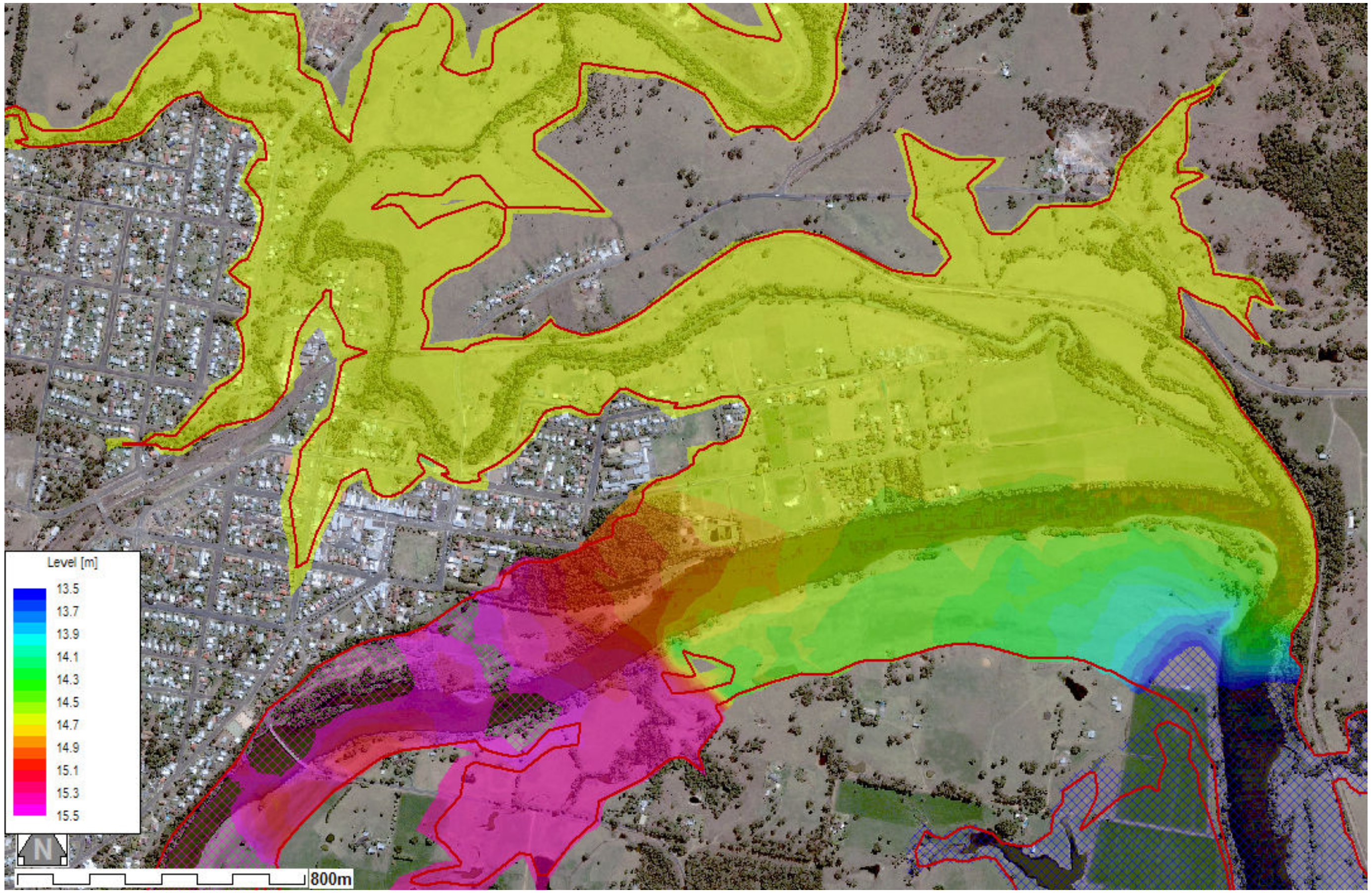

Figure 22: Climate Change Scenario Levels with a 20% increase in flows for the 1% AEP event by 2030; now approximately the 0.5% event (the extent of the current 1% AEP event is shown in red)

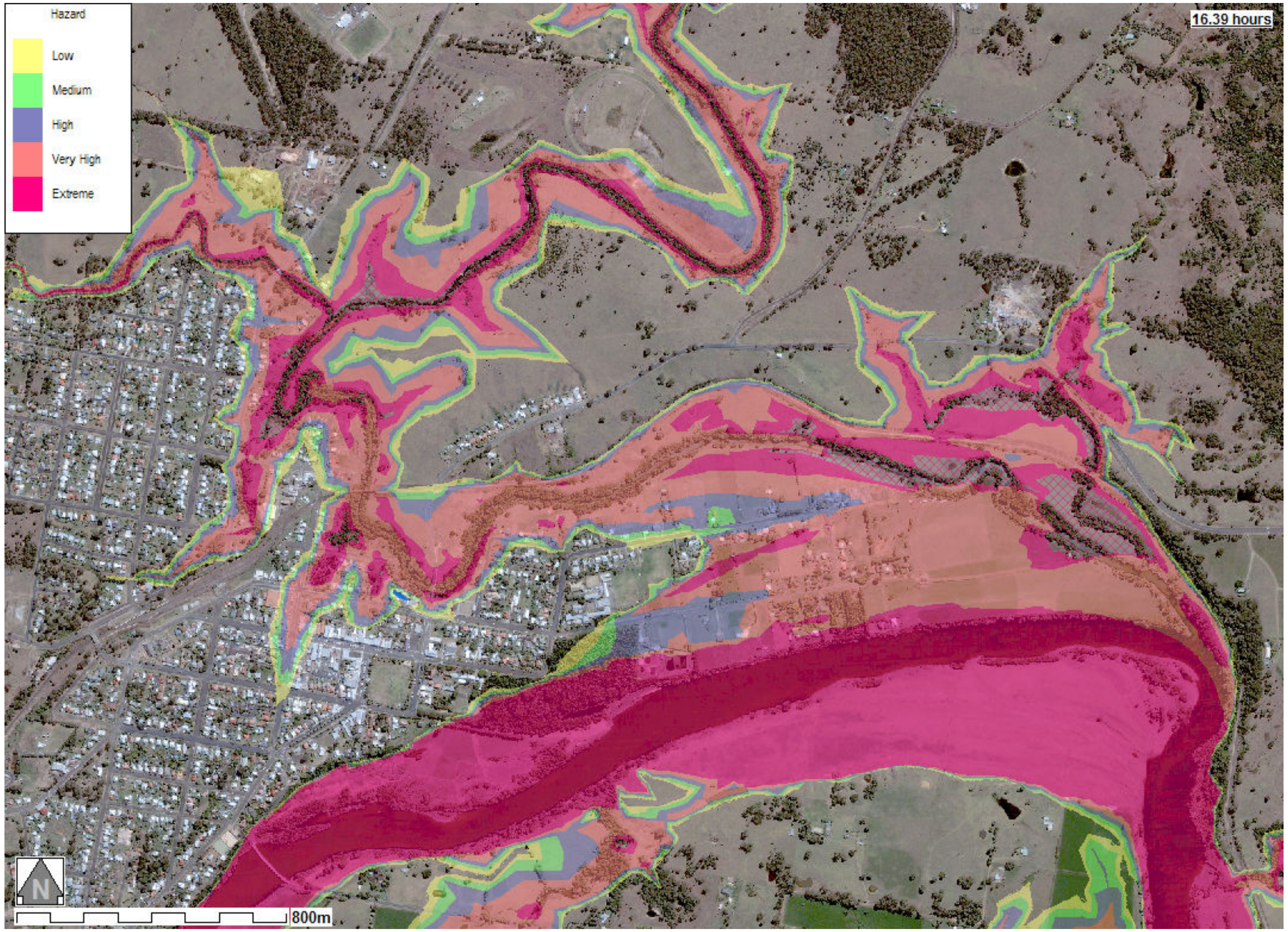

Figure 23: Climate Change Scenario Hydraulic Hazards with a 10% increase in flows for the 1% AEP event by 2030

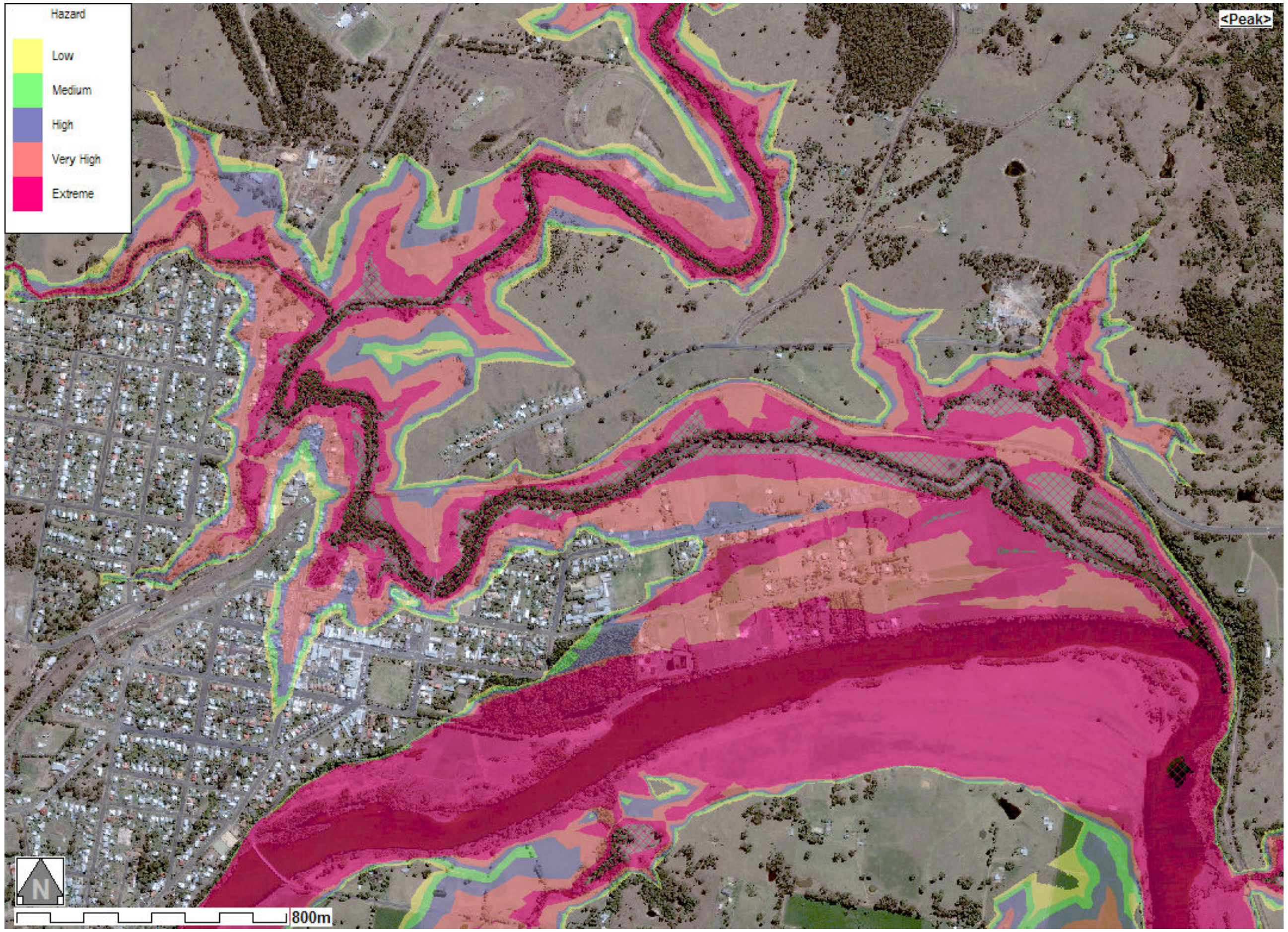

Figure 24: Climate Change Scenario Hydraulic Hazards with a 20% increase in flows for the 1% AEP event by 2030; now approximately the 0.5% event

Appendix A – Details on Selected Residential Properties

The following table consists of most (if not all) the residential properties in Wingham affected by the 1% AEP Design Flood.

House Number	Street Name	DTM Average Ground Level ()	Approximate Floor Level ()	Approximate Depth of flooding above the floor (m)
5	Steele	16.60	17.10	None
6	Steele	15.40	15.70	None
7	Steele	16.95	17.25	None
22	Appletree	15.50	15.80	None
24	Appletree	14.95	14.95	None
26	Appletree	14.30	15.36	None
25	Appletree	12.80	13.57	None
21	Appletree	12.40	12.45	1.09
19	Appletree	12.15	12.15	1.39
9	Appletree	15.60	16.15	None
13	Appletree	12.70	12.85	0.69
14	Appletree	15.20	17.75	None
16	Appletree	15.00	16.75	None
18	Appletree	14.70	16.72	None
4	Kindarun	12.30	12.45	1.09
28	Appletree	14.20	14.78	None
23	Appletree	12.60	14.35	None
33	Appletree	11.85	14.35	None
37	Appletree	12.80	13.61	None
39	Appletree	12.85	13.98	None
45	Appletree	12.60	13.50	0.04
47	Appletree	12.70	13.50	0.04
50	Appletree	12.80	14.35	None
54	Appletree	12.05	14.48	None
40	Appletree	13.00	13.59	None

42	Appletree	13.00	14.35	None
44	Appletree	12.70	14.35	None
38	Appletree	13.20	13.78	None
36	Appletree	13.20	14.03	None
30-34	Appletree	13.00	13.61	None
49-51	Appletree	12.60	13.31	0.23
25	Combined	10.00	9.95	3.59
27	Combined	12.00	9.95	3.59
29	Combined	14.50	15.00	None
31	Combined	13.20	13.70	None
33	Combined	12.40	14.35	None
35	Combined	12.30	14.35	None
37	Combined	11.10	12.05	1.49
66	Combined	13.50	14.35	None
68	Combined	14.00	14.50	None
70	Combined	13.30	13.80	None
72	Combined	12.95	13.45	0.09
74	Combined	12.20	12.70	0.84
60	Combined	13.95	14.45	None
62	Combined	13.05	13.55	None
62a	Combined	12.05	12.55	0.99
1-3	East Combined	12.60	13.96	None
2	East Combined	12.50	13.34	0.20
4	East Combined	12.50	13.59	None
6-8	East Combined	12.00	14.66	None
5	East Combined	12.25	14.35	None
7	East Combined	12.30	13.17	0.37
9	East Combined	11.95	13.78	None
13	East Combined	12.15	12.60	0.94
15	East Combined	12.05	13.01	0.53
17	East Combined	11.70	12.53	1.01
20-22	East Combined	11.40	11.93	1.61
24-26	East Combined	11.60	11.65	1.89

28-30	East Combined	11.50	11.65	1.89
14	East Combined	11.70	12.47	1.07
16	East Combined	11.10	12.44	1.10
14a	East Combined	11.30	13.25	0.29
12	East Combined	12.10	12.90	0.64
10	East Combined	11.30	11.60	1.94
33-35	East Combined	11.30	11.91	1.63
37-39	East Combined	11.00	11.42	2.12
23	East Combined	11.40	14.40	None
25	East Combined	11.35	11.92	1.62
29	East Combined	10.90	12.05	1.49
31	East Combined	10.70	11.08	2.46
3	Guilding	11.00	11.05	2.49
5	Guilding	10.20	10.25	3.29
6	Guilding	10.80	11.10	2.44
7	Guilding	10.10	10.10	3.44
9	Guilding	10.00	10.25	3.29
19	Guilding	11.20	12.70	0.84
24	Guilding	11.00	12.45	1.09
29	Guilding	11.30	11.70	1.84
8-10	Guilding	10.20	10.55	2.99
2	Mortimer	10.80	12.60	0.94
4	Mortimer	11.70	14.35	None
6	Mortimer	12.10	14.35	None
8	Mortimer	12.00	14.35	None
10	Mortimer	10.60	12.15	1.39
12	Mortimer	8.50	9.85	3.69
5	Flett	13.65	14.15	None
7	Flett	13.10	14.35	None
9	Flett	11.60	14.35	None
11	Flett	12.15	14.35	None
14	Primrose	12.60	14.10	None
16	Primrose	13.60	15.10	None

18	Primrose	14.30	15.80	None
19	Primrose	12.80	14.35	None
21	Primrose	11.55	12.05	1.49
23	Primrose	11.80	12.30	1.24
25	Primrose	12.45	12.95	0.59
27	Primrose	13.00	13.50	0.04
29	Primrose	13.05	13.55	None
30	Primrose	13.60	15.10	None
32	Primrose	13.10	13.60	None
34	Primrose	13.05	14.55	None
36	Primrose	13.20	14.70	None
38	Primrose	12.70	15.20	None
39	Primrose	10.85	11.45	2.09
43	Primrose	11.00	11.25	2.29
31-33	Primrose	13.30	14.80	None
35-37	Primrose	11.50	11.95	1.59
32	Queen	11.55	14.05	None
34	Queen	12.45	12.95	0.59
36	Queen	13.80	14.30	None
38	Queen	13.60	14.10	None
40	Queen	14.20	15.70	None
42	Queen	15.20	16.70	None
44	Queen	15.00	16.50	None
46	Queen	14.45	15.95	None
54	Queen	13.10	15.60	None
60	Queen	13.35	14.85	None
62	Queen	14.05	15.55	None
64	Queen	14.35	15.85	None
57	Queen	10.60	12.35	1.19
59	Queen	10.90	11.85	1.69
61	Queen	10.50	10.75	2.79
63	Queen	12.35	14.70	None
65	Queen	12.40	14.35	None

67	Queen	11.30	11.50	2.04
73	Queen	12.15	13.65	None
69	Queen	12.80	14.35	None
66	Queen	14.60	15.10	None
68	Queen	14.25	14.75	None
70	Queen	13.95	14.45	None
72	Queen	13.55	14.05	None
74	Queen	13.15	14.35	None
80	Queen	11.90	12.40	1.14
82	Queen	13.05	14.35	None
84	Queen	13.30	13.80	None
86	Queen	13.05	13.55	None
88	Queen	12.95	15.45	None
13	Keech	15.00	15.55	None
14	Keech	14.80	15.80	None
15	Keech	14.30	15.15	None
16	Keech	12.80	14.50	None
17	Keech	13.20	14.81	None
19	Keech	12.30	14.35	None
1	Ruth	14.80	15.65	None
2	Ruth	15.00	15.95	None
3	Ruth	15.20	15.75	None
5	Ruth	14.60	15.55	None
7	Ruth	12.60	14.35	None
1A	Ruth	15.00	15.95	None
5	West Appletree	12.55	12.60	0.94
7	West Appletree	12.30	14.45	None
9	West Appletree	12.20	12.65	0.89
11	West Appletree	11.80	12.35	1.19
13	West Appletree	11.80	13.95	None
15	West Appletree	12.10	14.00	None
17	West Appletree	11.70	11.70	1.84
246	Comboyne	10.60	11.60	1.94

248	Comboyne	13.40	14.60	None
252	Comboyne	13.70	14.90	None

Appendix B – Flood Planning Level Maps

This section provides a summary of important level maps from the *Wingham Flood Study, 2010.* Figure 25 shows the 1% AEP design flood levels with a focus on Wingham whilst Figure 26 shows the FPL in the same region (that is, the 1% AEP level plus a 0.5 metre freeboard). Both figures show levels in 0.5 metre increments (at 0.1 and 0.6 metres) with the majority of Wingham subject to a 1% AEP design flood level of 13.6 and a corresponding FPL of 14.1.

The extent of flood prone land is shown as a red outline (the extent of the PMF).

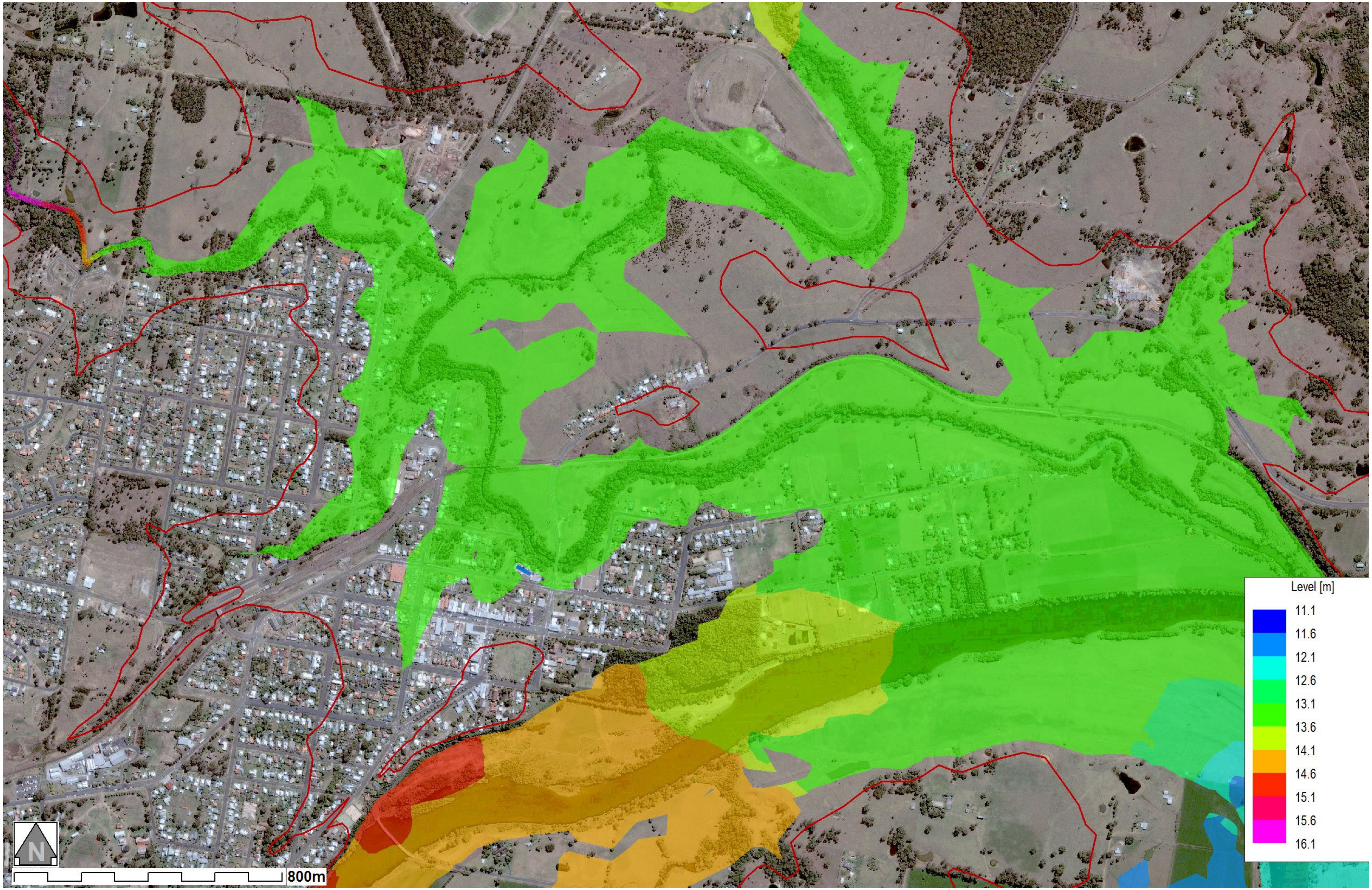

Figure 25: 1% AEP Design Flood Levels in Wingham showing 0.5 m contours. The extent of flood prone land is shown as a red outline (extent of the PMF).

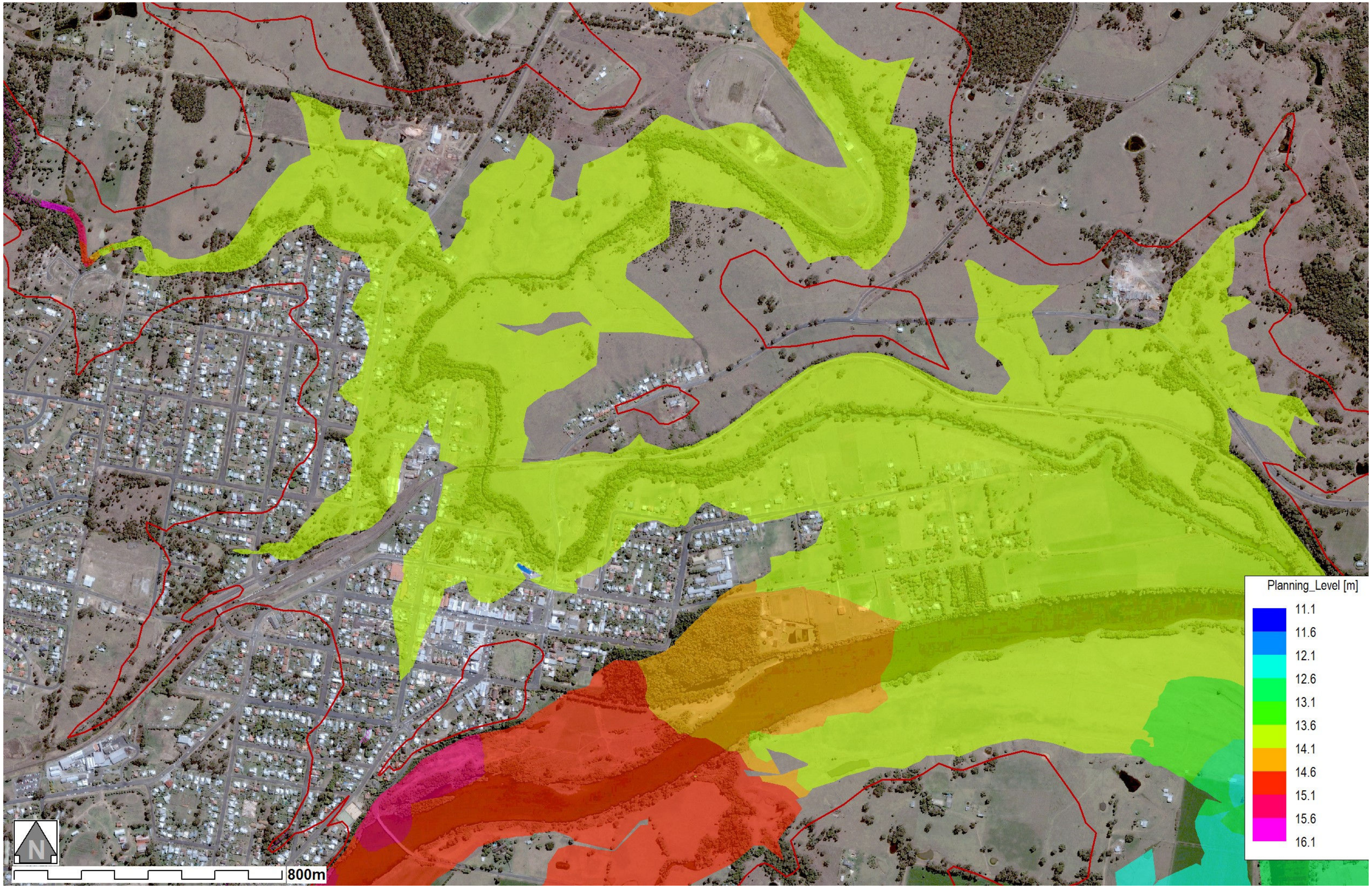

Figure 26: The Flood Planning Level in Wingham (using the 1% AEP Design Flood Level plus 0.5 m freeboard); showing 0.5 m contours. The extent of flood prone land is shown as a red outline (extent of the PMF).