GREAT LAKES COUNCIL

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NABIAC FLOODPLAIN RISK MANAGEMENT STUDY

FINAL

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NABIAC FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL

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Project **Nabiac Floodplain Risk Management Study and Plan**	Project Number **111028**
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NABIAC FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

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AAD	Average Annual Damage
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AHIMS	Aboriginal Heritage Information Management System
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning (ALS and LIDAR are synonymous)
BOM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DA	Development Approval
DCP	Development Control Plan
DECC	Department of Environment, Climate Change
DECCW	Department of Environment, Climate Change and Water (now OEH)
DIPNR	Department of Infrastructure, Planning and Natural Resources
FERP	Flood Emergency Response Plan
FPL	Flood Planning Level
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
IPO	Indian Pacific Oscillation
LEP	Local Environmental Plan
LGA	Local Government Area
LIDAR	Light Detecting and Ranging (ALS and LIDAR are synonymous)
m	metre
m^3/s	cubic metres per second
OEH	Office of Environment and Heritage
OSD	On-site Stormwater Detention
PMF	Probable Maximum Flood
RTA	Roads and Traffic Authority (now the RMS)
RMS	Roads and Maritime Services (formerly the RTA)
SES	State Emergency Service
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood simulation software program (hydraulic computer model)
WBNM	Watershed Bounded Network Model
WSUD	Water Sensitive Urban Design
1D	One Dimensional hydraulic computer model
2D	Two Dimensional hydraulic computer model

1. FOREWORD

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

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

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

1. Flood Study
Determine the nature and extent of the flood problem.

2. Floodplain Risk Management
Evaluates management options for the floodplain in respect of both existing and proposed development.

3. Floodplain Risk Management Plan
Involves formal adoption by Council of a plan of management for the floodplain.

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

The Nabiac Flood Study (Reference 1) was completed in July 2010 and constituted the first stage of the management process. The study considered both inundation from the Wallamba River as well as inundation from overland flows from local creek catchments in Nabiac. The possible effects of a climate change induced increase in design rainfall intensities were also analysed. Previously in 1985 the Wallamba River Flood Study (Reference 2) was undertaken but the area near Nabiac was updated as part of the 2010 Nabiac Flood Study.

The Nabiac Floodplain Risk Management Study and Plan constitute the second and third stages of the management process for the township of Nabiac and surrounds. The study area includes only those properties within the Great Lakes Council local government area. As part of this present study the Wallamba River Flood Study was updated and included as Appendix B.

Together these reports provide the basis for the future management of flood liable lands within Nabiac and surrounds and within the Great Lakes Council local government area. Funding was provided from the NSW State Government's Floodplain Risk Management Program and Great Lakes Council. The study and plan have been developed for the Great Lakes Council's Floodplain Risk Management Committee by WMAwater for the future management of flood liable lands in the study area.

2. INTRODUCTION

2.1. Study Area

The study is focused on the village of Nabiac, with a population of approximately 600, located on the Pacific Highway roughly 15 km north-west of Forster on the New South Wales Mid North Coast (Figure 1). The study area (Figure 2) includes the catchments of Town Creek, Woosters Creek and Pipeclay Creek in the vicinity of Nabiac, bounded by the Pacific Highway to the north and west, and bounded by the Wallamba River to the south. This area is within the Great Lakes Council Local Government Area (LGA), however the upper parts of these catchments to the immediate north are in the Taree Council LGA, with the boundary roughly delineated by the Pacific Highway.

Nabiac has a history of flooding problems, and in a recent community survey (Nabiac Flood Study – Reference 1), many residents reported instances where they had observed or been affected by flooding. Flooding in Nabiac can occur from both the Wallamba River and from local catchment runoff (Town Creek, Woosters Creek and Pipeclay Creek), however the general consensus of the community is that the majority of flood issues are caused by flash flooding, particularly in Town Creek (which runs through the town centre) and Woosters Creek. Overtopping of Clarkson Street by these two creeks was the most commonly reported flood prone area in the community survey of residents which assessed the nature and extent of flood issues in Nabiac.

The local drainage system within the village is primarily grass-lined swales draining towards the natural creek channels, the banks of which are generally vegetated with a mixture of weeds and native and exotic vegetation. There a several crossings of each of the creeks, comprising bridges, box culverts, pipes and causeways.

The land usage within the study area is primarily rural and low density residential, with a concentration of commercial and light industrial properties at the town centre near the intersection of Nabiac and Clarkson Streets, where Town Creek passes through the town. Woosters Creek passes through Crown Reserve bushland, roughly parallel to residential areas on Hoskins Street and Donaldson Street. The upper catchment areas upstream of the Pacific Highway, and the Pipeclay Creek catchment to the east, are primarily comprised of rural properties.

2.2. Background

WMAwater was engaged by Great Lakes Council to undertake a Floodplain Risk Management Study and Plan for Nabiac. The study includes a review of the 2010 Nabiac Flood Study Reference 1 and assessment of floodplain risk management measures for Nabiac. As part of the Flood Study review this present study has developed news hydrologic and hydraulic models of the Wallamba River to supersede those used in the 2004 Wallamba River Floodplain Risk Management Study (Reference 3) and prior 1985 Wallamba River Flood Study (Reference 2). An assessment of the potential impacts of sea level rise and rainfall increases due to climate change has also been undertaken as part of this review.

This study addresses flood risk in Nabiac from both the Wallamba River, using updated modelling undertaken by WMAwater, and from local catchment flows in Town Creek, Woosters Creek and Pipeclay Creek, using modelling from Reference 1. An assessment of a range of floodplain risk management measures and strategies is undertaken to estimate their effectiveness in managing the range of flood risk.

The study also includes a community consultation program, as public participation is a vital component of developing a realistic and practical risk management plan for the community.

2.3. Floodplain Risk Management Process

As described in the Floodplain Development Manual (Reference 4), the Floodplain Risk Management Process entails four sequential stages:

Stage 1: *Data Compilation & Flood Study.*
Stage 2: *Floodplain Risk Management Study.*
Stage 3: *Floodplain Risk Management Plan.*
Stage 4: *Implementation of the Plan.*

The Nabiac Floodplain Risk Management Study constitutes the second stage in the process. The Flood Study stage was completed in July 2010 with publication of the Nabiac Flood Study (Reference 1). A combination of hydrologic and hydraulic models was used in that study to determine design flood levels resulting from local catchment flows for the town of Nabiac.

Design flood behaviour at Nabiac resulting from floods in the nearby Wallamba River has previously been addressed in the Wallamba River Flood Study (Reference 2), and options to mitigate the risk at Nabiac from Wallamba River flooding were previously assessed in the Wallamba River Floodplain Risk Management Study and for Nabiac, Failford and Minimbah Areas (Reference 3 and Reference 5). Modelling of Wallamba River flooding has been revised for the purposes of this study and is reported in Appendix B.

2.4. Study Objectives

The objectives of the Study are to identify and compare various management options, including an assessment of their social, economic and environmental impacts. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk at this time and as a result of climate change (due to sea level rise and potentially rainfall intensity increases). This Study and subsequent Plan will update the previous Wallamba River Floodplain Risk Management Study (2004 – Reference 3) and Plan (2004 – Reference 5) for Nabiac, as well as including consideration of flooding from local catchments.

A glossary of flood related terminology is provided in Appendix A.

3. BACKGROUND

3.1. Catchment Description

The Wallamba River flows in an eastwards direction, passing approximately 1 km to the south of Nabiac, with a contributing upstream catchment area of approximately 325 km^2, out of a total catchment area of 495 km^2 to Wallis Lake. Nabiac is positioned at the upstream tidal limit of the Wallamba River, which provided a major transport link for the village (via Bullock Wharf at the eastern end of Nabiac Street) until well into the 20th century. Land use in the upstream Wallamba River catchment is primarily rural with isolated pockets of bushland. The headwaters of the Wallamba River are in Mt Talawahl, and the river eventually discharges into Wallis Lake just west of Tuncurry.

The village of Nabiac comprises mainly low density residential development, with commercial buildings (shops and cafes) in the north-west part of town. There is some light industrial development immediately downstream of the main centre on Town Creek. Upstream of the Pacific Highway the land use of the study area catchments is predominantly rural.

Three creeks (Town, Woosters and Pipeclay) flow southwards into the Wallamba River through the study area from north of the Pacific Highway, in the vicinity of the urban areas of Nabiac. The easternmost and the largest is Pipeclay Creek, with a 9.5 km^2 catchment upstream of the Pacific Highway. As it passes mainly through rural land without substantial development in lower lying areas, there have been few reported problems with local creek flooding in this part of the study area, although Wallamba River flooding has been recorded in lower lying areas.

Woosters Creek has a catchment area of around 3.5 km^2 upstream of the Pacific Highway, and enters the study area near the eastern end of Clarkson Street. After crossing under the bridge at Clarkson Street, Woosters Creek flows through Crown Reserve bushland, before joining Pipeclay Creek and discharging into the Wallamba River near the end of Wharf Street. Overtopping of Clarkson Street has been reported to occur reasonably frequently, but there have been few reported instances of flooding from Woosters Creek for residential developments in Farnell, Hoskins or Donaldson Streets.

There is a tributary of Woosters Creek that also crosses the Pacific Highway, and enters the study area near the Motorcycle Museum near the northern end of Hoskins Street. There is no formal channel for this tributary, so flow tends to occur as shallow sheet flow along the Museum driveway and across Clarkson Street, before joining Woosters Creek just north of Farnell Street. Shallow flooding of yards has been reported by properties adjacent to the driveway.

Town Creek has the smallest catchment area of the three creeks (about 1.5 km^2 upstream of the Pacific Highway). It crosses Clarkson Street very close to the intersection with Nabiac Street, in the vicinity of some long-standing commercial and residential premises (such as the “Amish shop”). Town Creek then drains southwards past a relatively new light industrial precinct, before winding through rural land and joining the Wallamba River around 1 kilometre to the south of the town centre.

3.2. Development Controls

The Great Lakes Local Environment Plan 1996 (Reference 6), amended October 2011, provides a framework for development of land and land use in the Great Lakes Council LGA. It contains provisions relating to flooding which are applicable at Nabiac. In particular Clause 25 states that for flood-liable land, development requires consent of Council, which must only be given with consideration to the provisions of Council's Flood Management Policy.

Under the LEP, Council may refuse consent to an application to carry out any development which in its opinion will significantly:

- adversely affect flood behaviour, including the flood peak at any point upstream or downstream of the proposed development and the flow of floodwater on adjoining lands, or
- increase the flood hazard or flood damage to property, or
- cause erosion, siltation or destruction of riverbank vegetation in the locality, or
- affect the water table on any adjoining land, or
- affect riverbank stability, or
- affect the safety of the proposed development in time of flood, or
- restrict the capacity of the floodway, or
- require the Council, the State Emergency Service or any other Government agency to increase its provision of emergency equipment, personnel, welfare facilities or other resources associated with an evacuation resulting from flooding, or
- increase the risk to life and personal safety of emergency services and rescue personnel.

The LEP also states (Schedule 1, Clause 11) that flood mitigation works undertaken by Council or the relevant state department do not require consent, except for the erection or substantial reconstruction/alteration of buildings, or road access works.

The LEP provides the following flood-related definitions:

- ***Flood-liable land*** *means land identified by the Council as being affected by flooding and indicated as such on the map.*
- ***Floodway*** *means the channel of a river or stream and those portions of the flood-plain adjoining the channel which constitute the main flow path for floodwaters.*

Land use zoning as defined in the LEP is shown on Figure 14. Land to which these flood-related provisions apply is defined as land shown as "Flood Planning Area" on the Flood Planning Maps which are published with the LEP, and "*other land at or below the flood planning level, defined as the 1:100 ARI flood event plus 0.5 metre freeboard*".

3.3. Flood Policy

Great Lakes Council first adopted a flood policy in December 1985 with the 100 year ARI event as the flood standard. A freeboard of 0.5 m applied to property development on flood liable land below the 100 year ARI level. However, land above the 100 year ARI level was only subject to a minimum floor level requirement of 0.3 m above ground level, leading to an inconsistency for properties on land just above the 100 year ARI level (Reference 3). The policy has since been changed to require a minimum habitable floor level of 0.5 m above the 100 year ARI flood level.

Great Lakes Council current flood policy framework is outlined in a document titled “Policy: Flood Management,” (Reference 7) reviewed on 19 September 2000. The aims and objectives of the policy are to:

- Provide the community with the basis of Council’s assessment of development on flood liable land within the area.
- Recognise the extent of existing development and resources in flood liable areas and their value to the community when assessing applications for new development, alterations, or additions to existing development.
- Encourage construction and development which is compatible with the flood risk of the area and, where appropriate build main floors at least 0.5 metres above the flood standard.
- Insist that buildings and other structures built in flood liable areas are designed and constructed to withstand the likely stresses of the highest probable flood.

The Policy provides a number of definitions, which include the following:

Flood Liable Land:	Land which would be inundated as a result of flood.
Maximum Probable Flood:	The flood calculated to be the maximum which would occur.
Standard Flood:	The flood selected for planning purposes.

In order to achieve the above aims and objectives, the Policy contains a number of development control requirements. Council has indicated that reviewing the Flood Policy is a priority, as there are some outdated sections that need revision, but such a review has not yet been undertaken.

3.4. Section 149 Planning Certificates

Great Lakes Council currently has a notation which it places on Section 149(2) Planning Certificates which alerts the purchaser of that certificate that the subject land is affected by flooding. Great Lakes Council provides additional flood information on Section 149(5) Planning Certificates. The S149(s) wording is:

“Council’s records indicate the land may be affected by the 1 in 100 year flood level which in this location is X.XX mAHD and any development will be assessed in accordance with Council’s Flood Management Policy. The levels of this land can be ascertained by field survey.”

3.5. Flood Planning Levels

Under Great Lakes Council's Flood Management Policy (Reference 7) the 100 year ARI flood is adopted as the design flood standard for planning and general risk management purposes. This policy also sets the minimum habitable floor level (Flood Planning Level or FPL) consisting of the 100 year ARI flood level plus a freeboard allowance of 0.5 m which defines the minimum habitable floor level.

FPLs for commercial and industrial development are not specified in the Flood Management Policy, although structures are required to be certified as capable of withstanding hydrostatic forces from flooding and the impact of debris in floodwaters. Additionally, "*development consent in relation to applications for new buildings, alterations to existing buildings or change of use shall be endorsed with advice on matters affecting the land including flood damage*."

The Flood Management Policy states that Council has adopted the 100 year ARI flood as the "standard flood" for indicating flood liable areas to:

- create an awareness of potential hazard in developed areas;
- highlight a potential impediment to development in undeveloped areas.

3.6. Flood Response Planning

Flood response planning for Nabiac is addressed as part of the Great Lakes Local Flood Plan (Reference 8), which is a sub-plan of the Great Lakes Local Disaster Plan. The draft plan, dated September 1995, covers the entire Great Lakes Council LGA, and encompasses preparedness measures, direction of response operations, and co-ordination of recovery efforts after flooding has subsided. Specifically, the plan covers the following issues:

- allocation of responsibilities and duties for Great Lakes Council, the Great Lakes SES Local Controller; and Nabiac Unit Controllers among others;
- a requirement that the plan be reviewed no less frequently than every three years;
- sources of flood intelligence and flood warnings;
- deployment and communication protocols for SES personnel and other response organisations during flood operations;
- operational details for road closures, flood rescue, evacuation, and logistics (including resupply);
- guidance for recovery and debriefing.

There are several annexes to the Local Flood Plan containing general information about flood mechanisms in the Great Lakes Council LGA, identification of specific risk areas in various urban and village areas (including Nabiac), and a summary of flood level gauges in the area.

With regards to Nabiac, the Plan identifies Nabiac Showground on Nabiac Street as the appropriate evacuation centre for the community. Based on recent flood modelling (Reference 1 and Appendix B), the showground site is flood-free in the PMF for both Wallamba River and local catchment flooding, and serves as a suitable evacuation site in close proximity to inundated areas of Nabiac, particularly those areas between Town and Woosters Creek where pedestrian or vehicle egress from the village along Clarkson Street to the Pacific Highway would be cut relatively early in a major flood.

Evacuation considerations for Nabiac are assessed in further detail in Section 4.6.

The Local Flood Plan is currently due for review (at the time of writing). Some sections of the report, such as the information about flood intelligence and warnings are out of date and require updating. Similarly, the flood risk information in Annexure B should be revised to incorporate the most recent flood studies for each area, including recently completed studies for Wallis Lake, Nabiac, Stroud and others.

3.7. Flood Warning

The Bureau of Meteorology issues Flood Watches ahead of most major floods for the Wallamba River catchment, as well as severe thunderstorm and flash flood warnings for smaller catchments.

The Bureau monitors the Wallamba River catchment via an ALERT rainfall gauge and two river height gauges near Nabiac, primarily using this information for the Flood Warning service at Wallis Lake rather than to provide detailed flood warnings for Nabiac. A Flood Warning system is commonly based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. Consideration is also given to ocean storm surge and tidal anomalies (where applicable) by the use of a simple tidal algorithm. Analysis is then undertaken to determine the expected time and height of the flood peak. At present there is a relatively sophisticated system for Wallis Lake, with its major tributaries (Coolongolook River, Wallamba River and Wang Wauk River) monitored as well as the lake levels and ocean influence.

The Flood Warning system allows SES personnel to monitor flooding developments on the Wallamba River, through real-time water level results as well as guidance on anticipated flood severity. The present system has never been tested during an actual flood (there has not been a major flood on the Wallamba River in the last 20 years or so) and for this reason relies upon limited historical data.

There is no warning system currently in place for the local creek catchments (Town, Woosters and Pipeclay Creeks), as flash flooding of these catchments can occur within a very short time period (within an hour or two). Current weather forecast technology is not sufficiently accurate to provide required lead times for responding to such floods. Regional severe thunderstorm and flash flood warnings are provided by the Bureau of Meteorology when heavy storms are anticipated.

3.8. Previous Studies

3.8.1. Wallamba River Flood Study (1985)

This study (Reference 1) was the first comprehensive study that established design flood levels for the Wallamba River and covered the reach from 1 kilometre upstream of Nabiac to 1 kilometre downstream of Failford. The study sourced all available data and established a hydrologic and a hydraulic model (Cordery-Webb unit hydrograph and HEC2 hydraulic model – refer to Reference 9 for details). The models were jointly calibrated to the March 1978 event and subsequently used for design flood estimation.

The hydraulic model was based on surveyed cross sections but these generally do not define the floodplain topography to the same extent modern LiDAR (or ALS) data, and therefore it is likely that a considerable amount of floodplain storage was not accounted for in the modelling approach.

3.8.2. Forster/Tuncurry Flood Study (1989)

This study (Reference 10) undertook a Flood Study for Wallis Lake which included the lower part of the Wallamba River. A WBNM hydrologic model was established, which replaced the Cordery-Webb unit hydrograph method used previously. A Wallingford hydraulic model of the Wallis Lake catchment, including the Wallamba River as far upstream as Nabiac, was also established.

3.8.3. Wallamba River Floodplain Risk Management Study for Nabiac, Failford and Minimbah Areas (2004)

In 2004, the Department of Infrastructure, Planning and Natural Resources (DIPNR) completed a Floodplain Risk Management Study (FRMS, Reference 3) and Floodplain Risk Management Plan (FRMP, Reference 5) for the Wallamba River, focusing on the areas of Nabiac, Failford and Minimbah.

The studies assessed flooding from Wallamba River but did not consider potential flooding from local catchment flows such as from Town Creek, Woosters Creek or Pipeclay Creek at Nabiac. This was recognised as a shortcoming, as it was noted that flooding in Nabiac occurred in February 2002 due primarily to local creek flows without significant concurrent Wallamba River flooding. This observation of the importance of local catchment flooding was a primary driver for the commissioning of the Nabiac Flood Study (Reference 1), as the first stage leading towards a comprehensive Floodplain Risk Management Plan for Nabiac.

Wallamba River flood behaviour had previously been investigated in the 1985 Wallamba River Flood Study (Reference 2), however for the 2004 study DIPNR refined the existing hydrologic model and updated the hydraulic modelling using the Mike11 package. The models were calibrated against the March 1978 flood, with consideration of historical flood levels from other events including 1927, 1929, 1947, 1957, and 1983. Design flood modelling was then undertaken for the 20 year, 50 year and 100 year ARI event and the Extreme (3 times the 100 year ARI flow) flood events.

The study assessed a wide range of risk management options with regards to their effectiveness for reducing flood risk, environmental impact, and cost effectiveness. The study found that the flood modification measures considered were either too costly or had significant adverse environmental impacts. A range of property and response modification measures were assessed in detail. A summary of the effectiveness of the measures is reproduced in Table 1.

It was recommended that voluntary raising of houses below the 50 year ARI flood level (to above the FPL of the 100 year ARI level plus 0.5 m freeboard) would be the most cost effective way to reduce flood damages, and that voluntary purchase of the worst affected properties should be considered where those houses were unsuitable for raising.

Table 1: Mitigation Measures Previously Assessed in Reference 3 (Table 4.5)

	Existing Development				Future Development			
	Existing Risk		Continuing Risk		Existing Risk		Continuing Risk	
	Danger *	Damage #	Danger *	Damage #	Danger *	Damage #	Danger *	Damage #
Property Modification Measures								
Zoning and Development Control					High	High		
Voluntary House Raising	Low	High						
Voluntary Purchase	High	High	High	High			High	High
Flood Proofing		Low						
Response Modification Measures								
Community Flood Readiness	Low	Low	Medium	Medium			Medium	Medium
Local Flood Plans	Low	Low	Medium	Medium			Medium	Medium
Upgrading Access	High @		High @		High @		High @	
Flood Predictions and Warnings	Medium	Low		Low				Low

** Danger to personal safety*

 # Damage to private property

@ From specific areas (potential only). Dependent on evacuation planning as part of updating the local flood plan.

A range of changes to Council's Flood Policy and Development Controls were recommended to mitigate flood risk arising from future development. Recommendations were also made relating to community education and flood awareness as a means to mitigate continuing flood risk to the community.

However the study indicates these measures were not particularly strongly supported (inasmuch as they related to Wallamba River flooding), with community feedback generally relating to local drainage and flooding from local creek systems in Nabiac. Notwithstanding this, the study suggested that the recommended measures should be explored for Council to fulfil its flood management responsibilities.

3.8.4. Wallamba River Floodplain Risk Management Plan for Nabiac, Failford and Minimbah Areas (2004)

The Plan (Reference 5) was completed by DIPNR in July 2004. An implementation plan was create to apply the management measures identified in the study, which were ranked in order of priority for completion and target start date. The measures are summarised in Table 2 below:

The Plan also raised the issue of the bypass flowpath from the Wallamba River that occurs through the centre of Nabiac in around the 500 year ARI event. It was recognised that the scale of this flowpath increases dramatically for even more extreme events. The plan identified that while rare, such an occurrence could potentially result in catastrophic consequences, as large parts of Nabiac could be isolated prior to land and buildings being inundated. This remains an issue to be addressed for flood awareness and emergency response. This issue is discussed further in Section 4.6.

Table 2: Mitigation Measures Previously Recommended in Reference 5 (Table E1)

Priority	Description	Indicative Cost	Target Start Time	Benefit Cost Ratio	Eligible for Funding
1	Development Controls & s149 Certificates	Low-Medium, Council resources. Advice provided in Floodplain Management Manual	Year 1	n/a	No
2	Components 2a to 2c	As below	As below	1.7	See below
2a	Flood Response Plan & Warning Procedures	$10,000 capital, $2,000 annual maintenance	Year 2		Part
2b	Flood Education and Awareness		Year 2/3		No
2c	Ongoing Data Collection		Ongoing		No
3	Review of this Floodplain Risk Management Plan	Following completion of investigations into flooding from local creeks and major drainage	Max 5 years or as required	n/a	Yes
4	Access Issues identified in Emergency Management planning	Unscoped	Year 4	n/a	Possibly
5	Voluntary House Raising of all below 50 year ARI flood level that can be raised	$120,000	Year 5	0.29	Yes
6	Voluntary Purchase of houses below the 20 year ARI that cannot be raised in worst locations	$480,000**	Year 6	0.13	Yes
Overall Scheme	Integration Scheme of Items 1 to 5	$610,000 plus	Year 1	0.169	As above

3.8.5. Nabiac Flood Study (2010)

Local catchment flooding was identified as a significant issue as part of the Wallamba River Risk Management Study and Plan. Anecdotes from residents suggest that local catchment flows through Nabiac create a more frequent flood issue than backwater from the Wallamba River. As a result, Great Lakes Council commissioned a Flood Study on Town Creek, Woosters Creek and Pipeclay Creek at Nabiac (Reference 1).

The following tasks were undertaken in the Flood Study:

- collection of historical flood data;
- development of hydrologic and hydraulic models, calibrated against historical flood behaviour (June 2007, February 2002 and October 2004);
- design flood estimation (including the 5 year, 10 year, 20 year, 50 year, 100 year and 200 year ARI events as well as the PMF);
- assessment of provisional flood hazard (for the PMF, 200 year, 100 year, 20 year and 5 year ARI events) and hydraulic categories (for the PMF, 100 year, 20 year and 5 year ARI events); and
- assessment of average annual damages resulting from local catchment flooding.

The Nabiac Flood Study, in conjunction with the updated Wallamba River Flood Study undertaken as part of this present study (Appendix B), provides the foundation to consider management of flood risk at Nabiac from both the local catchment and the Wallamba River backwater flood mechanisms. Aspects of the Nabiac Flood Study that have particular relevance to this study are discussed in more detail in Section 5.1.

3.8.6. Other Studies

The following additional reports were reviewed, but were not as relevant as those discussed in detail above:

Forster/Tuncurry Floodplain Management Study (1998) – Department of Land and Water Conservation. The hydraulic modelling updates (from Wallingford to Mike11) undertaken for this study included Nabiac at the upstream extent of the Wallamba River, but the study did not address flood issues at Nabiac in any detail.

Forster/Tuncurry Floodplain Management Plan (1998) – Department of Land and Water Conservation. This study was concentrated on the Forster/Tuncurry floodplains and did not address flood issues at Nabiac.

Draft Wallis Lake Floodplain Risk Management Study: Flood Study Review (2010) – While this study did not directly assess flood behaviour at Nabiac, it defined tailwater conditions for the Wallamba River Flood Study modelling, as documented in Appendix B.

Draft Wallis Lake Floodplain Risk Management Study (2010) – This study assessed floodplain risk management measures for Wallis Lake.

Draft North Tuncurry Lower Wallamba River Flood Study (2010) – The hydraulic modelling of the lower Wallamba River at North Tuncurry (TUFLOW) undertaken for this study formed the basis of updated Wallamba River modelling for the current study, as documented in Appendix B.

3.9. Environmental Considerations

Reference 3 contained a review of the flora, fauna and archaeological qualities of the area, identifying the following studies:

- Great Lakes Greening Strategy (Daintry Gerrand and Associates, 2001)
- Bundacree Creek to Possum Brush Pacific Highway Upgrade Environmental Impact Statement (Sinclair Knight Merz, 2001);
- Threatened Species Assessment – Bundacree Creek to Possum Brush Pacific Highway Upgrade (Ecotone Ecological Consultants, 2000); and
- Great Lakes State of the Environment Report (Great Lakes Council, 1998/1999).

The review suggests that there are diverse and threatened flora/fauna communities in the vicinity of Nabiac, as well as a high likelihood of Aboriginal cultural sites in the area. Flood management measures which may affect any of these environmental values will require a detailed assessment.

3.9.1. Vegetation

Two high priority habitat areas consisting of open forest communities have been identified in the vicinity of Nabiac:

- south of Nabiac, between Glen Ora Road and Minimbah Road; and
- north of Nabiac, from south of Brushgrove Park Road to south of Pipe Clay Creek Road.

Additionally, the threatened plant species *Allocasuarina defungens* and *Asperula asthenes* have been identified within a 10 kilometre radius of Nabiac.

The physical works assessed as part of this study are confined to areas near the centre of Nabiac, where heavy clearing and development has occurred in the past. It is therefore considered highly unlikely that impacts on the threatened species identified above will occur as a result of the proposed measures.

3.9.2. Fauna

Reference 3 reported that the following threatened fauna species have been observed in the vicinity of Nabiac:

- Squirrel glider (*Petaurus norfolkensis*),
- Koala (*Phascolarctus cinerus*),
- Eastern mastiff bat (*Mormopterus norfolkensis*),
- Brush-tailed phascogale (*Phascogale tapoatafa*),
- Masked owl (*Tyto novahollandiae*),
- Large bent-wing bat (*Minopterus schreiberseii*),
- Little bent-wing bat (*Miniopteris australia*),
- Southern myotis (*Myotis macropus*),
- Australian Bittern (*Botaurus poiciloptilus*).

The physical works proposed in this study are generally confined to the area of Town Creek between Clarkson Street and the light industrial area at the end of Ferris Place, or along existing road corridors, where relatively heavy development has already occurred. It is considered unlikely that the proposed measures will result in disturbance of habitat for any of the above threatened fauna species, although the potential for such disturbance should be considered during the preparation of any works plan for the measures.

3.9.3. Heritage

The Great Lakes Council area includes sites of indigenous and non-indigenous heritage. A search of the Aboriginal Heritage Information Management System (AHIMS), maintained by the NSW Office of Environment and Heritage, indicates there are 2 recorded sites in the vicinity of the study area. Implementation of any physical works which disturb the natural ground surface or require clearing of vegetation should incorporate a more detailed review of the AHIMS database to determine whether an archaeological survey is required.

4. FLOOD BEHAVIOUR

4.1. Flooding Mechanisms

Flooding in Nabiac may occur as a result of:

- Backwater from elevated water levels within the Wallamba River;
- Elevated water levels within the open channel sections of Town Creek, Woosters Creek or Pipeclay Creek, as a result of intense rainfall over these catchments. The water levels in these channels may be affected by constrictions such as bridges, culverts, blockages, fences and buildings;
- Flow along roads and through private property as a result of intense rainfall over the local Nabiac catchment areas; or
- Local runoff that accumulates (ponds) in low-lying areas, such as sags on roads or areas where overland flow paths are blocked. This type of flooding may be exacerbated by inadequate or blocked local drainage, and/or restricted overland flow paths.

These factors may occur in isolation or in combination with each other. Elevated water levels in the Wallamba River would typically result from long duration rainfall systems, which may or may not occur in conjunction with intense rainfall that causes significant flooding in the local creek catchments.

Most of the recent flood events within Nabiac (within the last 10 years) have been primarily a result of local catchment runoff, without coincident flooding of the Wallamba River. It has been a relatively long time since a major flood occurred in the Wallamba River. The two largest Wallamba River floods on record occurred in 1927 and 1929, and the most recent significant floods occurred in 1978 and 1983.

A collection of historical flood photographs from various sources is provided in Appendix C.

4.2. Historical Flood Behaviour

Nabiac has a long history of flooding, with several instances being reported by residents of Nabiac within the last 10 years (Table 4.1, Reference 1). The areas where flooding has been most frequently observed are Town Creek and Woosters Creek at Clarkson Street, and the Woosters Creek tributary along the driveway to the Motorcycle Museum. The most severe flooding of recent times occurred in February 2002, as a result of intense local rainfall in combination with slightly elevated Wallamba River levels. Significant local rainfall events also occurred in October 2004 and June 2007, causing flooding of Town, Woosters and Pipeclay Creeks. Wallamba River levels were apparently slightly elevated for the 2007 event, but the 2004 flooding was primarily caused by local catchment flooding.

Based on these recent experiences, there is a general perception in the community that local catchment flooding is the primary mechanism for flood problems in the village. However, there are several historical recorded floods of the Wallamba River that resulted in flood heights at Nabiac Bridge above 7 mAHD, high enough to cause backwater flow up Town Creek as far as

Clarkson Street. In 1929, a level of nearly 8 mAHD was recorded.

The community perception is probably correct that local catchment flows are the primary cause of regular and nuisance flooding, particularly in the town centre. This perception has most likely been reinforced by recent increases to flow in Town Creek, as a result of increased catchment area caused by road works at Candoormakh Creek Road finishing around 2007 (see Section 6.2 and 14.4 of Reference 1). However it should be recognised that the Wallamba River can cause flooding in isolation, or worsen local catchment flooding through backwater interactions, as seems to have occurred in 2002 (see Photograph 1).

Photograph 1: Flooding of Town Centre in 1947 (top left), 2002 (top right) and 2007 (bottom).

4.3. Design Flood Levels

The Nabiac Flood Study (Reference 1) reported design flood data for current catchment conditions. Design results from Reference 1 indicate overflow from local creeks in the 5 year ARI event (the most frequent event modelled), with overtopping of Clarkson Street at bridge crossings, and overland flow on Nabiac, Hoskins and Farnell Streets, as well as in drainage swales at the rear of Hoskins Street properties. Thus for the majority of the study area the capacity of the roadside swale and creek system is probably exceeded in events less than 5 year ARI.

The above scenario of less than 5 year ARI capacity is relatively poor for the main road of a regional town, and is more typical of the subsurface drainage capacity of a typical urbanised catchment. In newly developed areas drainage systems are typically designed (or development is set back from major channels) to accommodate the 10 year ARI capacity, with greater flows being conveyed along streets or drainage easements with minimal impact on surrounding developments.

However it should be noted that even in the more recently developed areas of NSW, rainfall events will occur that are greater than the design capacity of the overland flow system and in these rare events damage to surrounding developments will occur. Examples of this are the floods of November 1996 and March 2009 at Coffs Harbour, North Wollongong in August 1998 and Newcastle in June 2007 that inundated large parts of the residential and commercial areas of each region.

The Flood Study determined that the critical storm duration (produces the highest peak level) for local creek flooding for the 100 year ARI event is the 9 hour event, but that peak flood levels arising from the 2 hour design event are only slightly lower. Results presented in the Flood Study were for an envelope of durations from 15 minutes to 12 hours. For the present study, the 9 hour duration was used for all additional modelling, as it would have been impractical to use the envelope approach given the number of scenarios investigated (particularly in relation to climate change). The critical storm duration used for the PMF ranged from 45 minutes to 2 hours for local catchment flooding, using Reference 11 to define Probable Maximum Precipitation (PMP).

Design flood levels resulting from Wallamba River flooding were determined in the Wallamba River Flood Study (Appendix B). The critical storm duration for design flood modelling of the Wallamba River is 36 hours. In the 100 year ARI Wallamba River flood, river levels are sufficient to cause backwater flooding up Town Creek as far as Nabiac and Clarkson Streets, with a similar level of flood affectation as caused by local catchment 100 year ARI flooding (i.e. the 100 year ARI flood level is approximately 7.4 mAHD to 7.6 mAHD in Town Creek at Nabiac Street for both Wallamba River and local catchment floods. Very few existing buildings would be affected by 100 year ARI flooding from backwater flooding, with above-floor inundation mainly confined to the properties adjacent to Town Creek on Nabiac Street and Clarkson Street.

For floods in the Wallamba River greater than the 100 year, there is potential for a new flow path to form, breaking out on the north bank upstream of the Pacific Highway bridge, flowing through town from west to east, then back into the Wallamba River via the Woosters Creek floodplain. Modelling indicates that a low hazard flow path through town would occur in a Wallamba River flood with 30% greater rainfall intensity than the current 100 year ARI (see Figure 6A), equivalent to approximately a 400 or 500 year ARI flood under current climatic conditions. Although a significant number of properties in Nabiac would be affected by this flowpath, the overall influence on average annual flood damages is unlikely to be high, due to the rarity of the event for which the flow-path would occur.

In storm events, debris from roads and tree litter is likely to block smaller pipes. Blockage can be a significant factor in severe storm events, as it can significantly raise flood levels upstream of the structure. The design conditions assumed 100% blockage of the culverts at the industrial area access crossing off Ferris Place, based on historical evidence that these culverts were blocked in both the February 2002 and October 2004 events and required clearing before drainage from the area occurred (Section 7.6, Reference 1). Other larger culverts in the study area were assumed not to be blocked for design event modelling.

Peak height profiles, design flood contours, velocities and provisional hazard classification maps are provided in Reference 1.

4.4. Hydraulic Categories

The Floodplain Development Manual (Reference 4) defines three hydraulic categorises which can be applied to define different areas of the floodplain. The hydraulic categories of flood prone land include:

> "***Floodways*** are those areas where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow or a significant increase in flood levels."
>
> "***Flood storage areas*** are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood."
>
> "***Flood fringe*** is the remaining area of flood prone land after floodway and flood storage areas have been defined."

There is no technical definition of hydraulic categorisation that would be suitable for all catchments, and different approaches are used by different consultants and authorities, based on the specific features of the study catchment in question.

For this study, hydraulic categories were defined by the following criteria for local catchment flooding:

- Floodway is defined as areas where:
  - the peak value of velocity multiplied by depth (V*D) > 0.25 m^2/s **AND** peak velocity > 0.25 m/s, **OR**
  - peak velocity > 1.0 m/s **AND** peak depth > 0.05 m (in urban areas)l **OR**
  - areas within 10m of the centreline of a creek.

  The remainder of the floodplain is either Flood Storage or Flood Fringe,
- Flood Storage comprises areas outside the Floodway where peak depth > 0.5 m (for local catchment flooding) or > 1.0 m (for Wallamba River flooding); and
- Flood Fringe comprises areas outside the Floodway where peak depth < 0.5 m (for local catchment flooding) or < 1.0 m (for Wallamba River flooding).

Hydraulic categories for Wallamba River flooding were defined using different criteria as defined in Appendix B. The above hydraulic classifications have been applied to the Nabiac catchment based on available hydraulic model results together with knowledge of the catchment and experience in other catchments.

4.5. Flood Hazard Classification

The provisional hazard categorisation for the study area was quantitatively determined using depth and velocity for each design event in accordance with the provisional hydraulic hazard categorisation (Appendix L, Reference 4). The provisional hazards were reviewed in this study to consider other factors such as rate of rise of floodwaters, duration, threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production. These factors and related comments are given in Table 3.

Table 3: Weightings for Assessment of True Hazard

Criteria	Weight (1)	Comment
Rate of Rise of Floodwaters	High	The rate of rise in the local creek channels and onset of flow along roads would be very rapid, which would not allow time for residents to prepare. The rate of rise for Wallamba River flooding is less rapid, and would allow some degree of preparation.
Duration of Flooding	Low	The duration for local catchment flooding will generally be less than around 6 hours, resulting in inconvenience to affected residents but not likely to significantly increase the hazard. Wallamba River floods can be more protracted, potentially lasting for up to three days.
Effective Flood Access	High	Roads within the catchment can be inundated and may restrict vehicular access during a flood but pedestrian access to high ground is generally available.
Size of the Flood	High	The hazard can change significantly with the magnitude of the flood, particularly for Wallamba River floods greater than the 100 year ARI. However, these higher hazard areas are generally captured by the provisional hazard criteria.
Effective Warning and Evacuation Times	High	There is very little, if any, warning time. During the day residents will be aware of the heavy rain but at night (if asleep) residential and non-residential building floors may be inundated with no prior warning.
Additional Concerns such as Bank Erosion, Debris, Wind Wave Action	High	The main concern would be debris blocking culverts or bridges. This is considered to have a high probability of occurrence and will significantly increase the hazard. There is also the possibility of vehicles being swept into the main channels (as occurred in Newcastle in June 2007) causing blockage. Wind wave action is unlikely to be an issue but waves from traffic may be, due to the proximity of flood prone properties to main traffic routes.
Evacuation Difficulties	Low	Given the quick response of the catchment evacuation is not considered to be necessary (it is safer to remain than to cross fast flowing floodwaters) except in a few instances and therefore was not given significant weight for assessing true hazard.
Flood Awareness of the Community	Low	The flood awareness of the community is quite high due to the frequency of recent flood events. As a result of this awareness of problem flood areas, this factor is assigned a low weight in assessing true flood hazard.
Depth and Velocity of Floodwaters	High	In areas of overland flow roads are subject to fast flowing water. In the main creek channels velocities and depth would be high. There is always a risk of a car or pedestrian being swept into the open channel while attempting to cross swiftly flowing waters at major creek crossings. However this factor is largely included in the provisional hydraulic hazard calculation metrics.

Note: (1) Relative weighting in assessing the true hazard.

For the Nabiac study area catchment these factors do not significantly alter the provisional hazard classifications for the 100 year ARI and PMF events (Figure 3 and Figure 4). In general it was found that areas where a high flood hazard would be justified based on consideration of the high-weight criteria in Table 3, the area was already designated high hazard as a result of the depth/velocity criteria used to develop the provisional hazard.

Other provisional hazard and hydraulic categorization figures are provided on Figures 5 to 10.

4.6. Flood ERP Classification of Communities

WMAwater undertook delineation of floodplain communities into Flood Emergency Response Planning (FERP) categories, in accordance with the guidelines in Reference 12. Separate classifications were undertaken for the local catchment and Wallamba River flood mechanisms.

FERP mapping for Wallamba River and local catchment flooding is provided in Figure 11 and Figure 12 respectively. Mapping is provided for the 5% AEP, 1% AEP and PMF events.

Vehicular access is one of the most important features of Nabiac with regards to the FERP classification. There are only two access points to Nabiac from the Pacific Highway: (1) at the western end of Clarkson Street near the town centre, and (2) via Dibbs Street near the eastern end of Clarkson Street. However, Clarkson Street is likely to be cut quite close to these access points (at the Town Creek and Woosters Creek crossings) in large local catchment or Wallamba River floods. The overtopping of these crossings is likely to occur relatively early in the flood, in comparison to potential inundation of house floors.

Another important factor for FERP classification purposes is that a large proportion of homes in Nabiac are flood liable for the Wallamba River PMF, particularly in the area between Town Creek and Woosters Creek. These two factor results in large portions of the study area being classified as "Flood Island."

In the area of Nabiac bordered by Town and Woosters Creeks, there are two main areas that are flood-free in the PMF for both local catchment and Wallamba River flooding. These locations are:

1. Nabiac Showground, Nabiac Street; and
2. The area north of Clarkson Street and west of Hoskins Street, accessible either via Hoskins Street or through private property on Clarkson Street.

In the 200 year ARI Wallamba River flood, a new flowpath through town from west to east will form, presenting a high risk to life as the usual vehicle access routes to town will be unavailable. The two areas identified above would provide flood refuge locations for floods greater than the 100 year ARI up to the PMF, particularly from Wallamba River flooding.

There are several areas in the eastern part of town (eastern end of Nabiac Street, Martin Street, and rural properties between Woosters and Pipeclay Creeks) where rising floodwaters will cut vehicular and pedestrian access to high ground prior to house floors being flooded in the PMF. Although in most cases these properties would not be inundated by the 100 year ARI, in a larger event evacuation from these properties would need to occur prior to the roads being cut as there are no other refuge locations. As a result, these areas have been classified as "Low Flood Island" for Wallamba River floods.

4.7. Previous Flood Mitigation Measures Considered

A summary of previous flood mitigation measures considered is provided as part of the review of the Wallamba River Floodplain Risk Management Study and Plan for Nabiac in Sections 3.8.3 and 3.8.4.

5. FLOOD STUDY REVIEW AND CLIMATE CHANGE ASSESSMENT

5.1. Flood Study Review

The hydrologic and hydraulic models previously developed for the study area were reviewed in this study, to assess their suitability for:

- defining flood behaviour;
- estimating the extent of existing flood problems;
- evaluating risk management options;
- identifying potential impacts of climate change.

The review included two previous studies:

1. Nabiac Flood Study, 2010 (Reference 1), which established models for local creek (Town, Woosters and Pipeclay) flood behaviour, and local overland flow from runoff within the study area, for a range of design events.
2. Wallamba River Floodplain Risk Management Study for Nabiac, Failford and Minimbah Areas, 2004 (Reference 3), which included a refinement and upgrade of existing models for the Wallamba River.

The scope of these studies is discussed above in Section 3.8.

5.2. Summary of Review Outcomes

In general, the studies were found to address the required objectives, and provide a suitable platform for undertaking this Nabiac Floodplain Risk Management Study. However, some limitations were identified which have significance for the present study. The nature of these issues and the means by which these issues were addressed are summarised below.

The review of the Flood Study (Reference 1) identified some localised issues with the flood modelling methodology which resulted in a significant overestimation of flood levels for a small minority of properties (less than 10 properties). The affected properties featured prominently in the flood damage calculations, resulting in an over-estimation of average annual flood damages in the study area.

The issues were found to be mainly confined to the area around Hoskins Street, where flooding occurs mainly by localised rainfall (i.e. not from Town Creek, Woosters Creek etc, but from intense rainfall in the immediate vicinity of the houses). The modelling issues arose due to localised trapped areas in the digital representation of the topography, where the model resolution was not fine enough to represent the drainage path. Three houses on Hoskins Street in particular were affected, where modelled runoff entering the back yards of the houses could not drain to the swale out the front (as can be expected to occur from looking at the houses). Instead, the (modelled) runoff ponded until it was high enough to spill over the side fences of the houses. This resulted in flood levels for some houses that are over a metre higher than other nearby houses. A detailed site inspection of the area indicated that these flood levels are unrealistic.

This finding has implications for the flood damages assessment provided in Reference 1 and also setting flood planning levels for these houses. As a result of the obstructions to flow in the model, the affected houses in Hoskins Street are indicated as having over-floor flooding in the 10 year ARI and above (3 out of the 4 indicated in Table 13.5 of the Flood Study), when the floor levels of the houses are similar to other nearby houses and may in fact not be inundated in the 100 year ARI. The damages from this over-floor flooding are a significant part of the total assessed flood damages, which skews the annual average damages result.

It was not considered necessary to undertake a major revision of the modelling to address this issue. It was considered sufficient to continue with the FPRMS using the available models, but the flood levels for the houses in question were adjusted using indicative results from nearby properties for the damages calculations, and for the purposes of assessing flood mitigation measures as part of this study.

However, it is recommended that Council be aware of this issue and revise the design flood levels applying to these properties, as the current flood planning levels for the affected houses will be too high. If the houses are renovated or rebuilt and development controls are applied, this could result in the owner being required to raise the floor level excessively high at significant expense.

In light of the above, this study revised the flood damages assessment for local catchment flooding, resulting in a reduction in the estimate for average annual damages. As well as removing the properties with erroneous flood levels in Hoskins Street, the assumed damages for the commercial properties near Town Creek (the butcher/bakery and “Amish” store) were reduced to be more reflective of the relatively low value stock and machinery stored on these premises. The revised damages calculations are presented in Section 5.5 below.

As part of the review of the previous Risk Management Study for the Wallamba River (Reference 3), it was identified that the hydraulic models used should be updated. As part of this present study a new two-dimensional (2D) hydraulic model of the Wallamba River was developed, replacing the existing one-dimensional (1D) model from Reference 3. This model development was undertaken because of advantages from a two-dimensional approach in estimating flood extents and overbank flow behaviour, and because an existing model of the lower Wallamba River near Tuncurry from a previous study (Reference 13) that could be readily extended to include the reach near Nabiac.

Details of the Wallamba River model development are provided in Appendix B, which is essentially a Flood Study report. Discussion of the revised design flood levels is provided in Section 4.3.

5.3. Climate Change Modelling

5.3.1. Background

Intensive scientific investigation is ongoing to estimate the effects that increasing amounts of greenhouse gases (water vapour, carbon dioxide, methane, nitrous oxide, ozone) may be having on the average earth surface temperature. Changes to surface and atmospheric temperatures may affect climate and sea levels. The extent of any permanent climatic or sea level change can only be established through scientific observations over several decades. Nevertheless, it is prudent to consider the possible range of impacts with regard to flooding and the level of flood protection provided by any mitigation works.

Based on the latest research by the United Nations Intergovernmental Panel on Climate Change evidence is emerging on the likelihood of climate change and sea level rise as a result of increasing greenhouse gasses. In this regard, the following points can be made:

- greenhouse gas concentrations continue to increase,
- the balance of evidence suggests human activity has resulted in climate change over the past century,
- global sea level has risen about 0.1 m to 0.25 m in the past century,
- many uncertainties limit the accuracy to which future climate change and sea level rises can be projected and predicted.

The best available estimate of the projected sea level rise (including ice melt) along the NSW coast is up to 0.9 m by around the year 2100. Great Lakes Council has adopted sea level rise planning benchmarks of 0.5 m by 2060 and 0.9 m by 2100 relative to 1990 levels (Reference 14).

5.3.2. Discussion on Increases to Design Rainfalls

The Bureau of Meteorology has indicated that while revisions to design rainfalls to take account of potential for climate change may be required, there is insufficient information at present to define appropriate adjustments, as the implications of temperature changes on extreme rainfall intensities are presently unclear. There is no certainty that a warming global climate would in fact increase design rainfalls for major flood producing storms, particularly on larger catchments (such as the Wallamba River). There is some recent literature by CSIRO that suggests extreme rainfalls may increase by up to 30% in parts of NSW (in other places the projected increases are much less or even decrease); however this information is not of sufficient accuracy for use as yet (Reference 15).

Any variation in design flood rainfall intensities will directly change the frequency, depth and extent of inundation across the catchment. It has also been suggested that the cyclone belt may move further southwards. The possible impacts of this on design rainfalls cannot be ascertained at this time as little is known about the mechanisms that determine the movement of cyclones under existing conditions.

Projected increases to evaporation are also an important consideration because increased evaporation would lead to generally dryer catchment conditions, resulting in lower runoff from rainfall. Mean annual rainfall is projected to decrease, which would also result in generally dryer catchment conditions. The influence of dry catchment conditions on river runoff is observable in climate variability using the Indian Pacific Oscillation (IPO) index (Reference 16). Although mean daily rainfall intensity is not observed to differ significantly between IPO phases, runoff is significantly reduced during periods with fewer rain days.

The combination of uncertainty about projected changes in rainfall and evaporation makes it extremely difficult to predict with confidence the likely changes to peak flows for large flood events at Nabiac under warmer climate scenarios.

In light of this uncertainty, the NSW State Government advice (Reference 15) recommends sensitivity analysis on flood modelling should be undertaken to develop an understanding of the effect of various levels of change in the hydrologic regime at Nabiac. Specifically, it is suggested that increases of 10%, 20% and 30% to rainfall intensity be considered.

5.3.3. Climate Change Modelling Scenarios

The revised Wallamba River and local catchment models were used to undertake a range of scenarios to investigate the potential impacts of climate change of flood behaviour in the study area. Table 4 indicates the combination of climate change scenarios that were modelled, and for which maps of hydraulic hazard and hydraulic categories were prepared (Figures 3 to 10).

Table 4: Matrix of Climate Change Model Scenarios for 100 year ARI

	Sea Level Rise Scenario		
Rainfall Scenario	**Year 2010 (+0.0 m)**	**Year 2060 (+0.5 m)**	**Year 2100 (+0.9 m)**
Current rainfall	✓ † ‡	✓	✓ † ‡
+10%	✓		
+20%		✓	
+30%			✓ † ‡

✓ Flood depths and velocities modelled
† Flood hazard classification mapping undertaken
‡ Hydraulic categories mapping undertaken

5.4. Implications of Climate Change

Modelling indicated that projected sea level rise benchmarks will have a negligible impact on flood risk at Nabiac, in terms of peak flood levels, extents and flood hazard. For the 100 year ARI event incorporating a 0.9 m sea level rise increase, estimated impacts on peak flood levels were less than 0.1 m in the Wallamba River near Nabiac, with a negligible impact at the centre of Nabiac.

The effect of increasing the design rainfalls by 10%, 20% and 30% was evaluated for the 100 year ARI event, resulting in a relatively significant impact on peak flood levels compared to sea level rise. Table 5 shows impacts on peak flood levels for each scenario. As with the current climate modelling, the 100 year local catchment runoff was assumed to occur in conjunction with a 5 year ARI flow in the Wallamba River.

Table 5: Climate Change Rainfall Sensitivity – Peak Flood Level Impacts

ID	Creek	Location	100 year ARI Peak Level (mAHD)	Impact +10% Rainfall (m)	Impact +20% Rainfall (m)	Impact +30% Rainfall (m)
1	Town	U/S Pacific Hwy	**8.16**	0.12	0.19	0.25
2	Town	D/S Pacific Hwy	**7.66**	0.04	0.06	0.08
3	Town	U/S Clarkson St	**7.64**	0.04	0.05	0.06
4	Town	U/S Nabiac St	**7.63**	0.03	0.05	0.08
5	Town	D/S Nabiac St 1	**7.47**	0.03	0.04	0.05
6	Town	D/S Nabiac St 2	**7.46**	0.03	0.04	0.05
7	Town	D/S Nabiac St 3	**7.45**	0.03	0.04	0.05
8	Town	35m U/S Ferris Pl	**7.28**	0.03	0.04	0.05
9	Town	35m D/S Ferris Pl	**6.71**	0.11	0.19	0.28
10	Town	90m D/S Ferris Pl	**6.65**	0.11	0.21	0.31
11	Town	230m D/S Ferris Pl	**6.46**	0.16	0.30	0.46
12	-	Cnr Nabiac/Farrell	**7.52**	0.02	0.02	0.01
13	-	Cowper St	**6.75**	0.03	0.02	0.05
14	-	Cnr Hoskins/Stuart	**6.29**	0.01	0.01	0.02
15	Woosters	D/S Abbott St	**5.73**	0.08	0.17	0.31
16	Woosters	U/S Farnell St	**5.45**	0.08	0.16	0.29
17	Woosters	D/S Cowper St	**4.25**	0.08	0.23	0.37
18	Woosters	Stuart St	**3.79**	0.10	0.33	0.49

Each incremental 10% increase in design rainfalls results in approximately 0.08 m to 0.15 m increase in peak flood levels in the lower reaches of Town, Pipeclay and Woosters Creek, due mainly to increases in the Wallamba River. Increases to local catchments rainfalls have a less significant effect on peak flood levels, with increases generally less than 0.1 m between the Pacific Highway and Nabiac Street in Town Creek, primarily as a result of the flow constriction at the Pacific Highway crossing.

Maps of flood hazard for selected climate change scenarios are provided on Figure 5 and Figure 6, and hydraulic categories are shown on Figure 9 and Figure 10. Comparison with the maps for current conditions indicates that projected sea level rise benchmarks will have a negligible effect on these classifications. Increases to rainfall, which are less certain to occur (see Section 5.3.2), would have a more noticeable effect.

5.5. Damages Assessment

The cost of flood damages and the extent of the disruption to the community depend upon many factors including:

- the magnitude (depth, velocity and duration) of the flood,
- land usage and susceptibility to damage,
- awareness of the community to flooding,
- effective warning time,

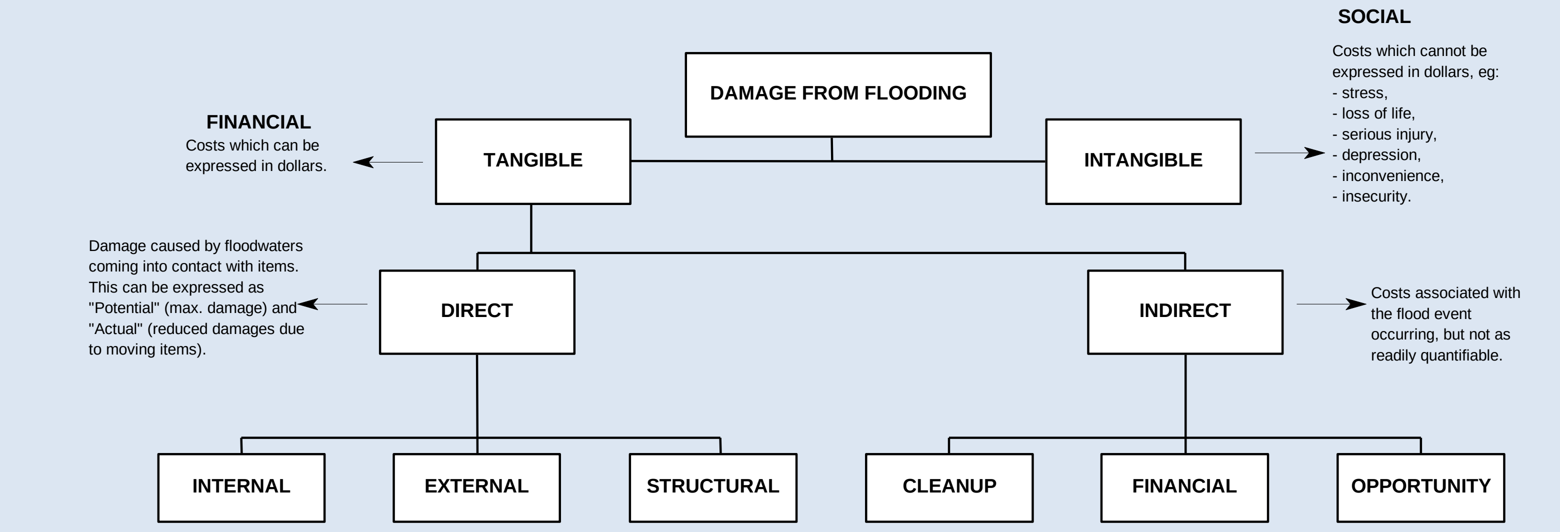
- the availability of an evacuation plan or damage minimisation program,
- physical factors such as erosion of the river bank, flood borne debris, sedimentation.

Flood damages can be defined as being “tangible” or “intangible”. Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value (stress, injury, loss to life, etc.). A summary of the types of flood damages is provided as Table 6.

While the total likely damages in a given flood are useful to get a “feel” for the magnitude of the flood problem, it is of little value for absolute economic evaluation. When considering the economic effectiveness of a proposed mitigation measure, the key question is what are the total damages prevented over the life of the measure? This is a function not only of the high damages which occur in large floods but also of the lesser but more frequent damages which occur in small floods.

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

Table 6: Breakdown of Flood Damages Categories



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

5.5.1. Limitations of Flood Damage Assessment at Nabiac

A flood damages assessment was undertaken for local creek flooding as part of the Nabiac Flood Study (Reference 1). As discussed in Section 5.2, the review of this study revealed that the damages assessment was overly sensitive to results at a small number of key properties.

A significant limitation of flood damages assessment techniques is that they become less reliable when a smaller number of properties are affected. This is because many of the assumptions made for calculating flood damages are based on averages for a range of property types, and can be sensitive to inaccuracies in the estimated flood depth for an individual property.

In a catchment with a large number of flood-affected properties, errors in flood level estimates at individual properties, or in surveyed floor and ground levels, or assumptions about the cost of above-floor inundation, can generally be assumed to average out when the damage estimates for all properties are aggregated. However the damage estimates from the Nabiac Flood Study are highly sensitive to erroneous flood level estimates at a small handful of properties, as well as assumptions about the value of damages at commercial properties.

WMAwater have revised the flood damages estimates from Reference 1 using existing spreadsheets from the Nabiac Flood Study, with modifications as follows:

- revisions to peak flood levels at properties in Hoskins Street; and
- revisions to the commercial damages curve, to provide a more realistic reflection of the value of goods and equipment stored on site at flood affected commercial properties in Nabiac.

The revised damages assessment was only undertaken for existing development for local creek flooding. Only properties which have surveyed floor levels have been included in the flood damages assessment. It should be noted that inundation from the Wallamba River will also occur and there is some overlap in terms of property inundation and damages. However damages from the Wallamba River flooding in isolation would only be significant in events much greater than the 100 year ARI (approximately the 500 year ARI and greater).

5.5.2. Revised Flood Damages Estimates

It is important to note that the limitations described above, relating to the small number of flood affected properties that comprise a large proportion of flood damages, still apply to the revised estimates in Table 7. The absolute dollar values should be considered to have a high level of uncertainty. There is more confidence in the estimates of changes to damages as a result of mitigation measures presented in Section 6, as some of the sources of uncertainty have less influence on the comparative damages calculations.

Table 7: Revised Flood Damages Calculations – Local Creek Flooding

Property Type	Properties with over floor flooding	Properties with overground flooding	Total Damage ($ June 2008)
PMF			
Residential	69	106	**$3,135,247**
Commercial	8	11	**$959,826**
Industrial	1	2	**$107,048**
PMF Total	**78**	**119**	**$4,202,121**
200 Year ARI			
Residential	6	34	**$411,936**
Commercial	2	5	**$77,023**
Industrial	0	0	**$0**
200 Year ARI Total	**8**	**39**	**$488,959**
100 Year ARI			
Residential	5	30	**$383,142**
Commercial	2	5	**$74,619**
Industrial	0	0	**$0**
100 Year ARI Total	**7**	**35**	**$457,761**
50 Year ARI			
Residential	5	29	**$359,940**
Commercial	2	4	**$72,001**
Industrial	0	0	**$0**
50 Year ARI Total	**7**	**33**	**$431,940**
20 Year ARI			
Residential	3	23	**$240,520**
Commercial	2	4	**$67,577**
Industrial	0	0	**$0**
20 Year ARI Total	**5**	**27**	**$308,097**
10 Year ARI			
Residential	2	20	**$194,999**
Commercial	2	4	**$67,577**
Industrial	0	0	**$0**
10 Year ARI Total	**4**	**24**	**$262,576**
5 Year ARI			
Residential	1	12	**$114,982**
Commercial	2	4	**$67,577**
Industrial	0	0	**$0**
5 Year ARI Total	**3**	**16**	**$182,559**

The revised estimate for Average Annual Damages (AAD) from local creek flooding is **$124,000**, reduced from $277,000 in Reference 1.

Damages for the Wallamba River flood are not expected to be significant at Nabiac for events up to the 100 year ARI, based on relatively few properties lying within the inundation extents (e.g. Figure 3B). For events greater than the 500 year ARI up to the PMF, significant additional damages would occur affecting most properties in Nabiac. However, due to the rarity of the event, the additional contribution to AAD is expected to be relatively small.

Assuming a total tangible damages estimate of $20M for the Wallamba River PMF event, the combined AAD value for both Wallamba River and local catchment flooding increases to approximately **$200,000**.

5.6. Selection of Flood Planning Levels

The definition of flood prone land and application of the 100 year ARI as the standard flood (see Section 3.5) is not consistent with the approach currently recommended in the Appendix K of the NSW Floodplain Development Manual (Reference 4), which deals with FPLs. In particular, there is no provision under Council's Flood Policy for the consideration of the PMF, particularly in regard to risk to personal safety, flood awareness, evacuation and other emergency management issues.

Application of 100 year ARI flood level with a 0.5m freeboard as the FPL for residential property is generally consistent with the recommendations of the Floodplain Development Manual (Reference 4) and the Wallamba River Floodplain Risk Management Plan for Nabiac (Reference 5). However, the FPL policy should be revised to include consideration of extreme flood events up to the PMF for flood awareness and emergency management, and for developments such as aged care facilities with particular evacuation issues, or critical public infrastructure (SES building).

It is also recommended that a default FPL for the commercial and industrial development be specified (possibly the 100 year ARI flood level without freeboard), with lower FPLs to be allowable on a merits-based approach taking into account the nature of the development and appropriate level of flood risk.

Finally, Council should consider implementing a different Flood Planning Level policy in local overland flow areas. While a 0.5 m freeboard is generally appropriate for creek and riverine floodplains, in areas of Nabiac affected only by local stormwater runoff flowing towards the creeks, a 0.5 m freeboard is generally excessive, as in many cases it will exceed the PMF level. It is recommended that a simplified FPL rule be considered for areas around Hoskins Street, Farnell Street and Cowper Street (see green polygon on Figure 3B), such as a requirement that habitable floor levels be placed 0.5 m above surrounding ground levels on the site. This simplified rule would reduce issues arising from modelling uncertainties and local features such as fences, which can result in inconsistent modelled flood levels for these areas (as described in Section 5.5.1).

6. FLOODPLAIN RISK MANAGEMENT MEASURES

6.1. Introduction

The NSW Government's Floodplain Development Manual (Reference 4) separates floodplain management measures into three broad categories:

> **Flood modification measures** modify the flood's physical behaviour (depth, velocity) and include flood mitigation dams, retarding basins, on-site detention, channel modifications, diversions, levees, floodways, flood gates or catchment treatment.
>
> **Property modification measures** modify land use including development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), planning and building regulations (zoning) or voluntary purchase.
>
> **Response modification measures** modify the community's response to flood hazard by informing flood affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

Several of the measures mentioned above were clearly not applicable to the flood situation at Nabiac and were removed from consideration at an early stage of the study (see Section 6.2). Measures which were subjected to more detailed consideration are discussed in the subsequent sections.

A number of methods are available for judging the relative merits of competing measures. The benefit/cost approach has long been used to quantify the economic worth of each measure on a relative basis enabling ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the Net Present Worth of the reduction in flood damage (benefit) compared to the cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles such as anxiety, risk to life, ill health and other social and environmental effects. In this study the reduction in tangible damages to public utilities as a result of implementation of a floodplain management measure has not been included.

The potential environmental or social impacts of any proposed flood mitigation measure are of great concern to society and these cannot be evaluated using the classical benefit/cost approach. The public consultation program carried out as part of this study (Section 6.7) was designed to ensure that identifiable social and environmental factors were considered in the decision making process.

6.2. Measures Not Considered in Detail

Early in the study, a range of possible floodplain management measures which could be applied in the study area were identified. A preliminary assessment of the measures was undertaken, where the measures were classified with regard to likely reduction in flood level, social effect, environmental impact, cost to implement and benefit/cost ratio.

A number of measures were identified that did not warrant further consideration and these are summarised in Table 8 and in the following sections.

Table 8: Summary of Mitigation Measures Not Considered in Detail

Measure	Impact				
	Reduction in Flood Level	Social Effect	Environ-mental Impact	Cost to Implement	Benefit/ Cost Ratio
FLOOD MODIFICATION MEASURES:					
Flood Mitigation Dams, etc.	Yes but minimal	Nil	Very High	Very High	Low
Levees, Floodgates and Pumps	Yes, up to the design event	Low	High	Very High	Very Low
PROPERTY MODIFICATION MEASURES:					
Voluntary Purchase of all Buildings Inundated in the PMF	Nil	High	Nil	High per building	Probably Low
Rezoning of land inundated in the PMF.	Nil	Very High	Nil	High	Unknown
RESPONSE MODIFICATION MEASURES:					
Flood Insurance	Nil	Low	Nil	Very high (when including cost of any subsidies).	Low

6.2.1. Flood Mitigation Dams

Flood mitigation dams have frequently been used in rural areas of NSW to reduce peak flows downstream. However dams have several characteristics that can make them unsuitable in certain situations, particularly in relatively small catchments. Factors to be considered include:

- high cost of construction,
- high environmental damage caused by the construction,
- possible sterilisation of land within the dam area,
- potentially high cost of land purchase,
- risk of failure of the dam wall,
- generally low benefit/cost ratio, and
- general lack of suitable sites. A considerable volume of water needs to be impounded by the dam in order to achieve a significant reduction in flood level downstream.

Generally it requires a narrowing of the channel at a location that captures a suitable portion of the upstream catchment, and favourable geotechnical conditions at the site.

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

6.2.2. Levees, Flood Gates and Pumps

Levee banks are a means of excluding floodwaters from previously inundated areas up to a designated level and have been widely used for this purpose. The banks are generally made of compacted earth and can usually be successfully landscaped to produce minimal visual impact. There are currently no formal levees protecting existing properties in or around Nabiac.

Flood gates can be constructed as a separate modification measure or as part of the levee design, generally to allow local drainage through the levee, or infrastructure access such as a railway line. Flood gates could allow local creeks waters to drain to the Wallamba River, but during times of elevated Wallamba River flows might be closed to prevent floodwaters from entering (or exiting). If a levee system was built to protect Nabiac from Wallamba River backwater flooding, all local drains/creeks discharging to Wallis Lake would require the installation of flood gates.

Pumps are generally also associated with levee designs. They are installed to remove local floodwaters behind levees when flood gates are closed or there are no flood gates. They are generally only suitable where there is a small contributory catchment upstream of the areas contained by the levee, and thus only a small volume of water needs to be discharged.

Due to the importance of local catchment flood mechanisms at Nabiac, and the potential for local flooding to be exacerbated by the introduction of a levee/gate system, these measures were not considered further in this study. Additionally, as discussed in Reference 3, the spread of development along the river means that economic benefits of a levee system would be very low. A long levee would be required to protect a relatively small area, and would likely have adverse impacts in very large floods.

One of the most important negatives of levees and associated structures is that they may provide a false sense of security and make residents less flood aware.

6.2.3. Voluntary Purchase of all Flood-Liable Residential Buildings

Voluntary purchase of all the residential buildings inundated above floor level in the 100 year ARI flood (say $400,000 per building) cannot be economically or socially justified. Generally, Government funding is only available for voluntary purchase of buildings that are frequently flooded in a high hazard area.

As discussed in Section 5.2, WMAwater have reservations about the flood damages assessment from Reference 1 for properties in Hoskins Street. The original damages assessment indicates that there are 3 houses in Hoskins Street that are inundated above floor level for the 10 year ARI and larger events. However close inspection of the modelling results suggests that the damages estimates are heavily influenced by localised modelling features (in particular, the omission of sub-grid scale drainage paths), leading to an overestimation of inundation frequency and flood damages for these properties

Once these factors are accounted for, it appears that few residential properties are subject to a significant depth of above-floor flooding in the 100 year ARI flood, and in some cases this flooding is due to local overland flow rather than overbank flooding from creeks. It is unlikely that the residential properties identified by Reference 1 as being inundated in the 100 year ARI event would be appropriate for voluntary purchase, except for the building at 5 Nabiac Street between the butcher and Town Creek. This building is located within a light industrial zoned area under the 2012 LEP zoning, and Council may wish to approach the owner of this individual property for voluntary purchase.

Voluntary purchase schemes can introduce a number of social problems (residents are unwilling to sell or find alternative accommodation with similar attributes) which can be difficult to resolve. A broad-scale voluntary purchase scheme for Nabiac is not considered economically justified, as there are relatively few properties with sufficiently high risk profiles.

6.2.4. Rezoning

Figure 14 shows the current zoning for Nabiac under the Draft 2012 LEP, primarily a mixture of low-density and large-lot residential, rural landscape, and public recreation with small areas designated neighbourhood centre and light industrial. These zonings are generally consistent with the flood risk of the village.

Rezoning of flood liable land for higher density development could encourage people to purchase and demolish existing flood liable property and redevelop the area in accordance with Council's flood related development controls. This strategy is difficult to implement, as generally the surrounding residents, who are not flood affected, consider that the quality of the area would be adversely affected by the increased building density.

Furthermore, there are a number of vacant lots suitable for development currently available in Nabiac, and these lots are likely to prove more attractive to prospective developers than sites with existing flood problems. The cost to purchase the existing land, demolish and redevelop can make this measure financially unattractive to developers.

6.2.5. Flood Insurance

Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments (premiums) for an individual. At present, flood insurance is provided by some insurance companies but is not generally available for all residential buildings or for all commercial and industrial properties. The types of flood damage that are covered, and premiums for flood cover, vary significantly between providers. The issue of flood insurance and its appropriateness as a flood mitigation measure is being examined by the NSW Government and by the Insurance Council of Australia, with the issue being brought into particular focus by the widespread residential flooding in Brisbane and Ipswich in January 2011.

Due to the relative predictability of flooding compared to other natural disasters, and improved mapping from recent developments in modelling techniques, insurance companies can develop a reasonably accurate quantification of flood risk for an individual property. High annual premiums may be required to adequately cover properties that are known to be at relatively high risk of flooding, unless non-flood-liable properties are also required to pay for flood insurance, thereby subsidising flood-liable properties. The high premiums mean that property owners are likely to “take the risk” that a flood will not occur (i.e. self-insure).

Another issue with flood insurance is that it can diminish restraint in capital investment for flood-liable land. A property owner may be more likely to develop/renovate if potential losses from flooding are perceived to be covered. These circumstances may actually result in an increase in gross economic damages.

Due to these inconsistencies between available flood cover, types of flood cover, and potential to change perceived flood risk, flood insurance is not recommended as an appropriate flood mitigation measure for Nabiac.

6.3. Flood Modification Measures

6.3.1. Local Drainage Issues

DESCRIPTION

The village of Nabiac has a mixture of kerb and gutter drainage systems and roadside swales, without any substantial sections of underground pipe network. Local runoff therefore generally occurs as overland flow along the roadways and swales. Driveway entrances to properties that cross the roadside swale typically have a small culvert to provide cross-drainage. Local drainage issues are therefore generally limited to possible overtopping of driveways due to runoff exceeding the capacity of these pipes or potential blockage of pipes, as well as ponding of local runoff in depressions. These issues may cause inconvenience, but are unlikely to present a significant risk to community safety or economic damage.

DISCUSSION

Local ponding results from rainfall over the local catchment being unable to quickly drain away. Water accumulates at low points in the streets and yards causing minor inconvenience as a result of the lack of relief from land to the creek. Generally, modelling results from the Flood Study indicate that the following locations in the study area may be susceptible to accumulation of local runoff in severe storm events (Photograph 2):

- On Farnell Street between Hoskins and Nabiac Streets, adjacent to the school playing fields (Photograph 2);
- In portions of the kerbside swale along the southern end of Hoskins Street (Photograph 2);

- The open swale at the rear of private properties between Hoskins Street and Nabiac Street (Photograph 3); and
- Along the driveway of the Motorcycle Museum and the continuation of the swale downstream of Clarkson Street (Photograph 4).

Photograph 2: Roadside drainage swale on Nabiac Street (left) and Hoskins Street (right)

Photograph 3: Drainage easement between properties on Hoskins and Nabiac Streets

Photograph 4: Overland flow near Motorcycle Museum on 19 October 2004 (Tracey Lumsden)

Local drainage issues can be a common problem in such areas which have developed over a long period with limited development controls in place at the time of development.

ACTIONS

Local residents should ensure that all issues with local drainage, such as localised obstructions or trapped depressions where water takes excessive amounts of time to drain, are adequately documented (written and photographic) and reported to Council. This will assist in identifying problem areas and obtaining solutions, assisting Council to address these issues where appropriate.

Awareness of potential flood issues should be promoted to prevent unintentional obstruction of local drainage features through modifications to private development, such as fences, sheds and garden beds for example. Council should also prepare a drainage plan (if not already completed) showing the major drainage lines and pipe sizes, topography and the location of any flap gated culverts.

6.3.2. Removal/Replacement of Structures and Blockage Prevention

DESCRIPTION

Reviews of the August 1998 North Wollongong, June 2007 Newcastle and March 2009 Coffs Harbour storms highlighted the significant effects blockage of structures can have on flood levels. Evidence from the North Wollongong event indicates that there is significant potential for culvert openings less than 6 m width to be partially or fully blocked during a flood.

Blockage deflector devices (a series of bars that deflect debris over the road above a culvert) are available for natural channels. However they are not recommended for a lined channel due to the high velocities (over 5 m/s) and risk that they may increase the likelihood of blockage.

Photograph 5: Nabiac Street pedestrian bridge over Town Creek

There are a few key bridge/culvert crossings of the creeks, particularly Town and Woosters Creeks, which have a significant influence on flow in the more heavily trafficked areas of Nabiac such as Clarkson Street and Nabiac Street. These structures have the potential for blockage or may not be designed to convey flow of a sufficiently high ARI. Blockage and/or under-capacity of these structures may have the potential to significantly increase flood risk, and upgrading the capacity of such structure or reducing the propensity for blockage may be a cost effective mitigation measure.

DISCUSSION

On Town Creek, the Flood Study outcomes indicate that two crossings have a significant influence on flood levels near the town centre – the pedestrian bridge (Photographs 5 and 6) and the pipes under the industrial area access road at the end of Ferris Place ("Industrial Culverts", Photograph 7).

Photograph 6: Flooding of Nabiac Street footbridge in June 2007 (source: Bruce Weller)

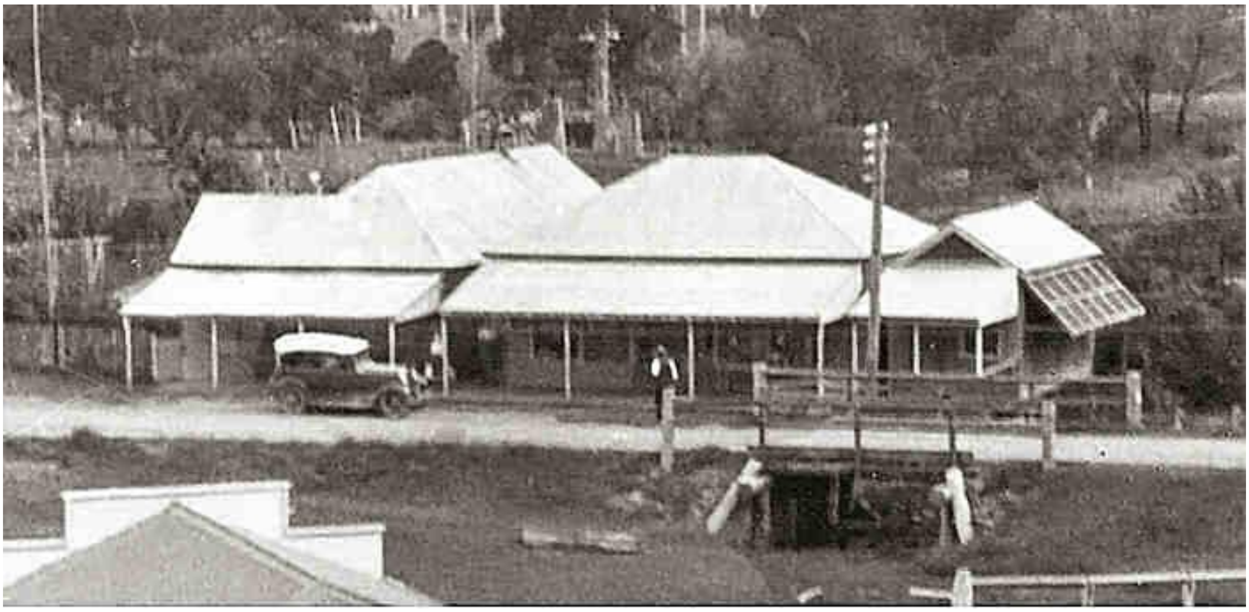
Photograph 7: "Industrial culverts" at Ferris Place overtopping in June 2007 (left), and afterwards partially blocked by debris (right). (Source: Bruce Weller)

1) Industrial Culverts. Several resident eye witness accounts of the floods in February 2002 and October 2004 indicated that the Ferris Place culverts were essentially completely blocked to flow during these events, causing a major obstruction and a significant backwater effect to occur up to Clarkson Street. Bruce Weller (local resident) indicated in an interview on 14th July 2011 that in February 2002 the residents removed a large plastic sheet that was completely obstructing the culvert entrance, and drainage of the area only commenced after the removal of the sheeting (see Photograph 8). The effects of blockage for this culvert are pronounced by the relatively high level of the road surface at this crossing that must be overtopped for flow to occur in case of blockage. In addition to the propensity for blockage, the capacity of the culverts is significantly lower than the Clarkson Street culvert further upstream.

Photograph 8: "Industrial culverts" at Ferris Place blocked during February 2002 flood event. From east (left) and west (right).

2) Nabiac Street Footbridge. The footbridge at Nabiac Street also has a significantly smaller waterway area than the Clarkson Street culverts. Historical photos of this area suggest that prior to the footbridge construction, when Nabiac Street was still trafficable by car, the bridge opening was significantly larger than it is now (see Photograph 9).

Photograph 9: Nabiac Street bridge was historically open to vehicle traffic (estimated date 1930s. Source: Nabiac Village Futures Group).



Removal of the Ferris Place culverts is unlikely to be feasible as there are no alternative access routes to the industrial estate. Similarly removal of the pedestrian footbridge is unlikely to be supported by the community, due to the benefits and convenience of pedestrian-only access and visual considerations. However, modelling (Table 9) indicates that upgrading both the footbridge waterway cross-section and the Ferris Place culverts to match the capacity of the Clarkson Street culverts (Photograph 10) would result in significant reductions (up to 0.2 m) in peak flood levels for a range of flood events.

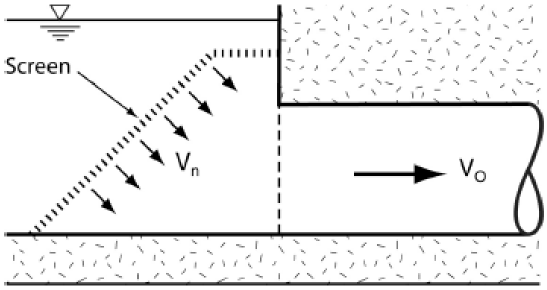
Table 9: Upgrade of Ferris Place Culverts and Footbridge – Peak Flood Level Impacts

ID	Creek	Location	5y ARI Peak Level (mAHD)	Upgrade Impacts (m)	100y ARI Peak Level (mAHD)	Upgrade Impacts (m)
1	Town	U/S Pacific Hwy	**7.27**	0.00	**8.16**	-0.07
2	Town	D/S Pacific Hwy	**7.18**	0.00	**7.66**	-0.06
3	Town	U/S Clarkson St	**7.18**	0.00	**7.65**	-0.06
4	Town	U/S Nabiac St	**7.17**	-0.04	**7.62**	-0.06
5	Town	D/S Nabiac St 1	**7.10**	0.04	**7.47**	-0.10
6	Town	D/S Nabiac St 2	**7.09**	-0.23	**7.46**	-0.11
7	Town	D/S Nabiac St 3	**7.08**	-0.24	**7.45**	-0.12
8	Town	35m U/S Ferris Pl	**7.03**	-0.17	**7.28**	-0.21
9	Town	35m D/S Ferris Pl	**6.18**	0.21	**6.70**	0.00
10	Town	90m D/S Ferris Pl	**6.17**	0.19	**6.64**	0.00
11	Town	230m D/S Ferris Pl	**6.05**	0.13	**6.45**	0.00
12	-	Cnr Nabiac/Farrell	**7.44**	0.00	**7.52**	-0.02
13	-	Cowper St	**6.68**	0.00	**6.75**	0.00
14	-	Cnr Hoskins/Stuart	**6.27**	0.00	**6.29**	0.00
15	Woosters	D/S Abbott St	**5.45**	0.00	**5.72**	0.00
16	Woosters	U/S Farnell St	**5.29**	0.00	**5.44**	-0.01
17	Woosters	D/S Cowper St	**3.90**	0.00	**4.17**	-0.01
18	Woosters	Stuart St	**2.97**	0.00	**3.50**	-0.01

Photograph 10: Clarkson Street bridge at Town Creek in July 2011

Installation of a blockage prevention device at the inlet of the Ferris Place culverts would be likely to reduce the risk of blockage, at relatively little additional expense if installed at the same time as the culvert upgrade works. A rising deflection grate (see Photograph 11 below) could reduce the risk of blockage from vegetation and debris in this area.

Photograph 11: Example of a rising deflection grate for prevention of culvert blockage



3) Clarkson Street Bridge – Woosters Creek. The previous timber bridge was replaced by the current concrete structure in 2005. Some residents have observed that the underside of the new bridge deck is lower than the previous structure, resulting in more significant afflux upstream and more frequent overtopping of the road (Photograph 12). Additionally, the grading of the southern approach appears to have resulted in poor drainage from the road, extending the period of ponding when the road is inundated and exacerbating access issues.

Photograph 12: Overtopping of Woosters Creek bridge on Clarkson Street in February 2002 (left) and June 2007 (right). (Source: Bruce Weller)

However based on modelling results from Reference 1, the structure does not cause flooding of nearby residential properties, which have relatively high floor levels. It is unlikely therefore that reconstruction of this relatively new bridge at a higher level would be cost effective for the benefits achieved. Any future works at the bridge should be viewed as an opportunity to raise the bridge deck, reduce the blockage propensity of guard rails, and amend road grading issues at the approaches.

ACTIONS

The culverts under the access road to the industrial estate at the end of Ferris Place should be upgraded to a similar capacity as the Clarkson Street crossing of Town Creek. The upgrade will have the dual effect of increasing waterway capacity, as well as reducing the likelihood of blockage in future events, since debris will be more likely to pass through the culvert. As of late 2012, subsequent to the draft version of this report, the Ferris Place culverts have already been upgraded by Council to have the same capacity as the Clarkson Street culverts.

The Nabiac Street footbridge waterway area should also be upgraded to provide a similar capacity, either by implementation of a culvert under the footbridge, or widening of the channel cross-section in combination with fortification from rip-rap to maintain the channel dimensions.

The upgrades are expected to provide a benefit to the residential property at 5 Nabiac Street for a range of flood events, as well as additional properties on Nabiac and Clarkson Streets for the 100 year ARI and larger events, and several of the commercial properties in the vicinity of the town centre. The estimated benefit in terms of average annual damages is $21,000, with a cost benefit ratio of between 1.0 and 1.75 assuming the cost of works at $300,000 to $500,000 and a lifespan of 25 years.

The Clarkson Street bridge at Woosters Creek is subject to frequent overtopping, but flooding does not threaten nearby houses. Future works at the bridge should review whether an increase in the deck height is appropriate to maintain access, as overtopping of this bridge results in closure of one of the two main access routes to Nabiac, with the other route also subject to inundation at the Town Creek crossing.

6.3.3. Channel Modifications

DESCRIPTION

Channel modifications are usually undertaken to either increase the capacity of the channel and/or improve the conveyance of floodwaters, which in turn can reduce peak flood levels. Channel modifications encompass a broad range of measures and include amplification, straightening, concrete lining, removal of structures, dredging and vegetation clearing.

DISCUSSION

Amplification and Dredging

Channel amplification involves increasing the capacity of the creek or drainage system, thereby reducing the frequency with which floodwaters overtop the banks. The main problem with channel amplification in natural creeks is that the channel often tends to return to its original state via accumulation of sediment in the dredged or widened reach of the channel.

This study did not identify any areas where channel amplification is likely to provide a significant reduction in flood risk. Generally, constrictions in channel capacity in the local creeks are due to bridge and culvert structures, or vegetation, rather than the channel dimensions. It is considered that measures which address these issues would be more effective, and less expensive, than widespread channel amplification works.

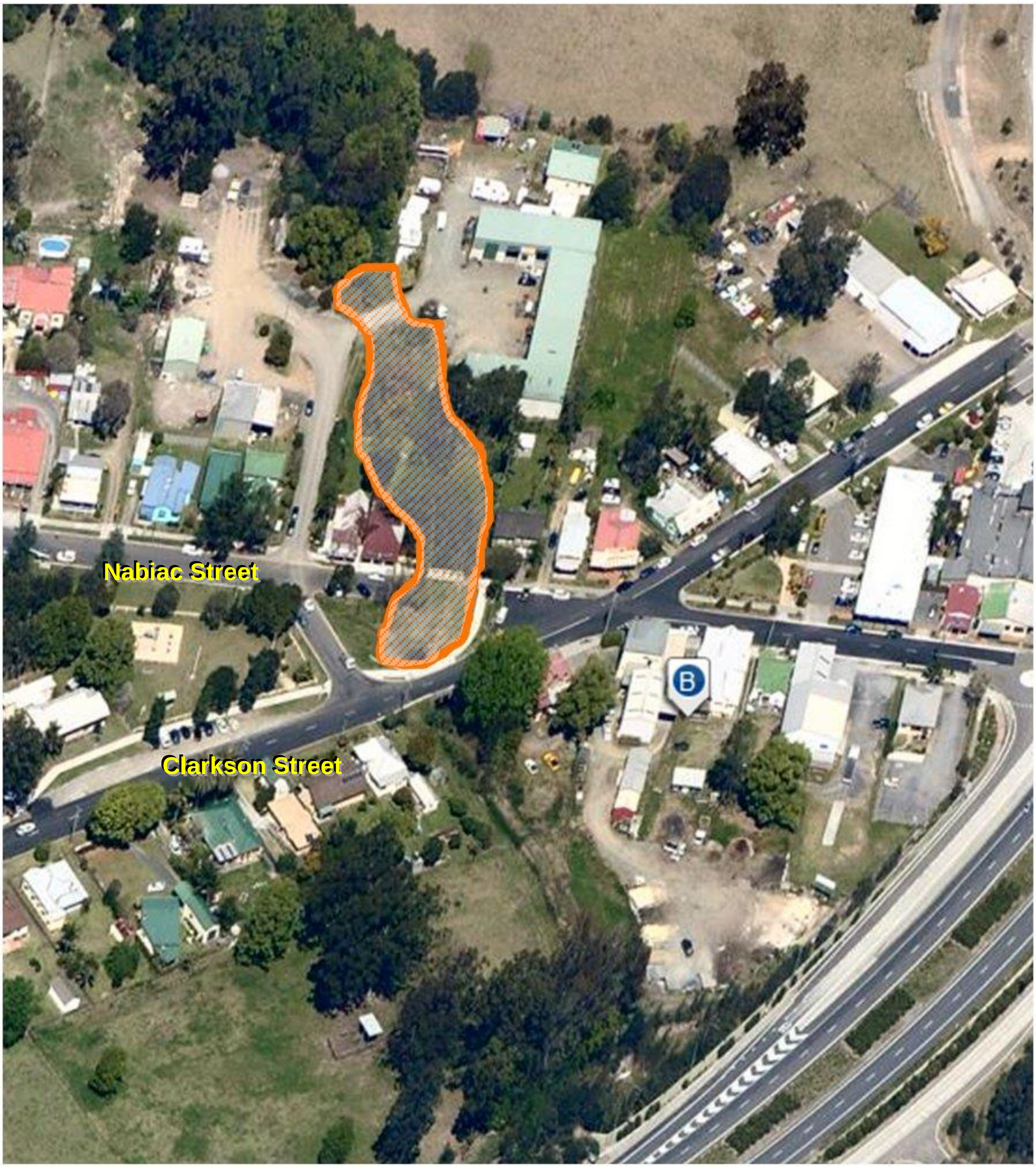
Straightening, Concrete Lining,

These measures are generally undertaken in order to increase the conveyance of water through the channel system. However, they are relatively expensive and have significant impacts on the environment and visual amenity, and are generally not suitable for rural centres. These measures have not been considered further for Nabiac.

Vegetation Clearing

Removal of vegetation from the channel and banks can lower flood levels in a localised area around the works. The main problem with this approach is that weeds can quickly regrow in the cleared section of channel, and routine maintenance programs to keep the channel clear are often untenable with the resources typically available to Council for such works. However, vegetation clearing for a targeted area can be practicable, and is generally more successful, if there is a community involvement and sense of ownership from local residents (such as through a local Landcare group).

Photograph 13: Aerial view of heavily vegetated area of Town Creek (source: www.nearmap.com)



The reach of Town Creek between Clarkson Street and the industrial area access (see Photograph 13) is heavily vegetated, with a significant concentration of weeds (Photograph 15). Debris and rubbish from the commercial area upstream will tend to collect in this area, potentially exacerbating flooding upstream (see Photograph 14). In the community consultation process undertaken for the Flood Study, several residents expressed frustration at the level of debris and vegetation growth in the channel, particularly between the footbridge and the industrial area access road.

Historically this area has been cleared, and it is unlikely there would be any ecological benefit in retaining the vegetation in this area.

Photograph 14: Town Creek between Clarkson and Nabiac Streets (left), during the June 2007 flood (right)

The likely impacts of vegetation clearing are provided in Table 10.

Table 10: Vegetation Clearing – Peak Flood Level Impacts

ID	Creek	Location	100y ARI Peak Level (mAHD)	Upgrade Impacts (m)
1	Town	U/S Pacific Hwy	8.16	-0.16
2	Town	D/S Pacific Hwy	7.66	-0.23
3	Town	U/S Clarkson St	7.65	-0.24
4	Town	U/S Nabiac St	7.62	-0.29
5	Town	D/S Nabiac St 1	7.47	-0.26
6	Town	D/S Nabiac St 2	7.46	-0.24
7	Town	D/S Nabiac St 3	7.45	-0.24
8	Town	35m U/S Ferris Pl	7.28	-0.13
9	Town	35m D/S Ferris Pl	6.70	0.02
10	Town	90m D/S Ferris Pl	6.64	0.07
11	Town	230m D/S Ferris Pl	6.45	0.08
12	-	Cnr Nabiac/Farrell	7.52	-0.04
13	-	Cowper St	6.75	0.00
14	-	Cnr Hoskins/Stuart	6.29	0.00
15	Woosters	D/S Abbott St	5.72	0.00
16	Woosters	U/S Farnell St	5.44	-0.01
17	Woosters	D/S Cowper St	4.17	-0.01
18	Woosters	Stuart St	3.50	-0.01

The estimated benefit in terms of average annual damages is around $32,000 if the channel remains cleared, although this number should be heavily discounted due to the high likelihood of regrowth and return of the vegetation density to current levels. A cost benefit ratio cannot be determined as the success of the measure will rely on ongoing community involvement and labour, the cost of which cannot be readily quantified.

Photograph 15: Lantana and other dense vegetation upstream of the "industrial culverts" at Ferris Place.

ACTIONS

There is likely to be a tangible benefit for reduction of flood levels near the intersection of Nabiac and Clarkson Streets resulting from vegetation clearing in Town Creek between Clarkson Street and the southern end of Ferris Place. Due to the likelihood of regrowth, persistent benefits are unlikely to be achieved unless a regular maintenance program is established, including involvement and ownership from the local community. Given the existing heavy level of vegetation density in this area, Council assistance is likely to be required to establish such a program.

Vegetation clearing of this area will provide positive outcomes for flooding for the residential properties on Nabiac Street (particularly at 5 Nabiac Street), as well as the commercial properties in the area, and should be considered further. While Council should assist in removal of invasive noxious weeds (such as lantana), it is unlikely that Council can provide sufficient resources to maintain this vegetation clearing in the long term, and community involvement (through the Landcare group for example) will be required.

6.3.4. Flowpath Diversion

DESCRIPTION

Diversion of catchment runoff along an alternative flow path can reduce or prevent flow through a particular area and considerably reduce flood risk. This approach is often not feasible due to physical constraints of the system, as the existing creek or flow path typically follows the lowest path through the catchment, and there is a lack of alternative flow paths without resorting to pumping or diversion channels with very shallow grade. When diversion of flow away from a given area is possible, care must be taken not to cause adverse flood impacts on the area to which the flow is redirected.

DISCUSSION

Possible Measures: The Town Creek catchment area upstream of the Pacific Highway was identified as a location where diversion of flow is likely to be a viable flood modification measure. The factors which contribute to the feasibility of a flow diversion at this location (discussed in more detail below) include:

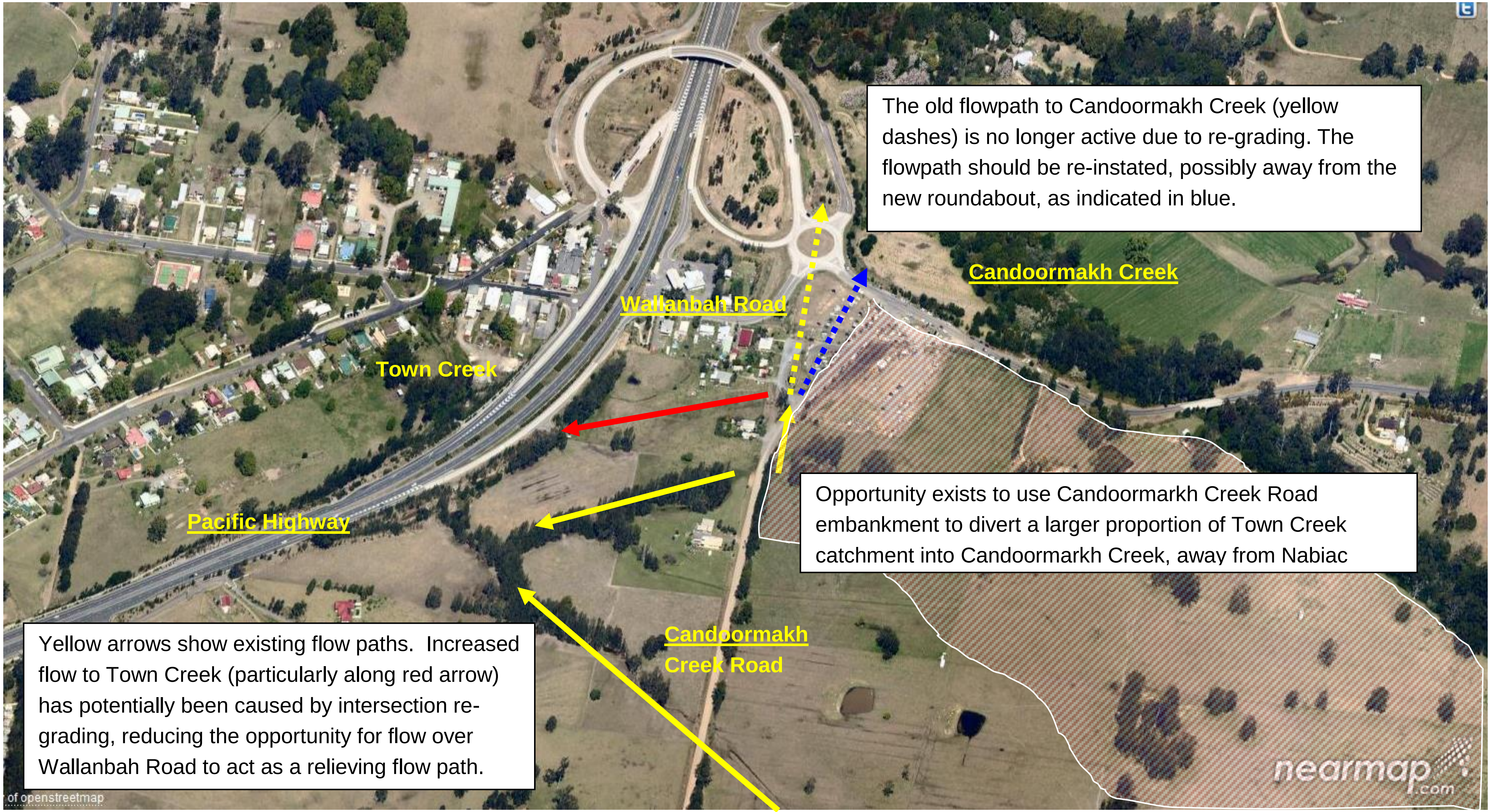
1. the existence of an alternative waterway (Candoormakh Creek), to which a sizable proportion of catchment runoff can be diverted without significant topographical modifications, and without causing adverse flood impacts in the receiving waterway;
2. the evidence that prior to upgrading of the Pacific Highway and Nabiac interchange, when significant regrading of the area was undertaken, a portion of catchment runoff was redirected from Candoormakh Creek into Town Creek (i.e. diverting the flow back to Candoormakh Creek would be a reversion to historical behaviour);
3. the significant number of residential houses upstream of the Pacific Highway in the Taree LGA which are subject to flood risk from the flows in Town Creek, which could be reduced by redirection into Candoormakh Creek.

An on-site interview with Mr Kevin Griffis, who resides at one of the affected properties within the Taree LGA indicated that as a result of road works, his property and neighbouring properties were subject to increased frequency of inundation, including over-floor inundation, even in relatively minor storm events. He also indicated that floodwaters now take longer to drain from the impacted area (refer to the red arrow on Diagram 1, following page), and there are local drainage problems with the newly constructed bus shelter.

Detail survey data of the area collected by the Roads and Traffic Authority (now Roads and Maritime Services) prior to the road works supports the assertion that the road works resulted in a change to catchment flow behaviour (in that the “relief valve” of flow over Wallanbah Road is raised), potentially increasing the flow into Town Creek at the rear of the properties on the eastern end of Wallanbah Road.

Mr Griffis’ account of the historical flowpaths was also supported by statements from Mr Ron Guthry, who lives upstream of Candoormakh Creek Road on Wallanbah Road, and indicated that the natural direction of flow through his property was towards the intersection of Wallanbah and Candoormakh Creek Roads.

Diagram 1: Aerial photograph (courtesy of Nearmap) schematic of Town Creek flow paths upstream of the Pacific Highway



Photograph 16: The re-grading of Candoormarkh Creek Road (at right) is significantly higher than the previous Wallanbah Road levels (at left)

Photograph 17: Re-graded access to eastern end of Wallanbah Road, from Candoormakh Creek Road

Based on the site inspection, interviews with residents, and review of the detail survey prior to the road works, it is considered that the re-grading and removal of pipes and overland drainage paths associated with the road works, particularly the changes to the intersection of Candoormakh Creek Road and Wallanbah Road, have resulted in an obstruction of the relieving flow path to Candoormakh Creek, an increase in the proportion of flow discharging to Town

Creek, and aggravation of flood issues in Nabiac. Photographs 16 and 17 show evidence of the regrading works.

The potential exists not only to reverse the obstruction, but to divert an even larger proportion of the catchment along the Candoormakh Creek Road embankment and into Candoormakh Creek than would have historically occurred.

Analysis: Based on the above analysis, modelling of the 100 year flood was undertaken for three scenarios, accounting for a diversion of 30%, 50% and 70% of the Town Creek catchment away from Nabiac and into Candoormakh Creek. Modelling of the 50% diversion was also undertaken for the 20 and 5 year ARI events. The modelled impacts are summarised in Table 11. A map of the comparison locations is given on Figure 13.

Table 11: Town Creek Catchment Diversion – Peak Flood Level Impacts

ID	Creek	Location	5y ARI Peak Level (mAHD)	50% Diversion Impact (m)	20y ARI Peak Level (mAHD)	50% Diversion Impact (m)	100y ARI Peak Level (mAHD)	70% Diversion Impact (m)	50% Diversion Impact (m)	30% Diversion Impact (m)
1	Town	U/S Pacific Hwy	**7.27**	-0.34	**7.88**	-0.43	**8.16**	-0.74	-0.50	-0.28
2	Town	D/S Pacific Hwy	**7.18**	-0.23	**7.55**	-0.22	**7.66**	-0.19	-0.19	-0.09
3	Town	U/S Clarkson St	**7.18**	-0.23	**7.54**	-0.21	**7.65**	-0.18	-0.18	-0.09
4	Town	U/S Nabiac St	**7.17**	-0.23	**7.52**	-0.21	**7.62**	-0.17	-0.17	-0.08
5	Town	D/S Nabiac St 1	**7.10**	-0.18	**7.38**	-0.18	**7.47**	-0.15	-0.15	-0.07
6	Town	D/S Nabiac St 2	**7.09**	-0.17	**7.37**	-0.17	**7.46**	-0.15	-0.15	-0.07
7	Town	D/S Nabiac St 3	**7.08**	-0.17	**7.36**	-0.17	**7.45**	-0.15	-0.15	-0.07
8	Town	35m U/S Ferris Pl	**7.03**	-0.11	**7.22**	-0.11	**7.28**	-0.10	-0.10	-0.05
9	Town	35m D/S Ferris Pl	**6.18**	-0.21	**6.55**	-0.22	**6.70**	-0.21	-0.21	-0.10
10	Town	90m D/S Ferris Pl	**6.17**	-0.20	**6.51**	-0.20	**6.64**	-0.18	-0.18	-0.09
11	Town	230m D/S Ferris Pl	**6.05**	-0.13	**6.30**	-0.15	**6.45**	-0.16	-0.16	-0.08
12	-	Cnr Nabiac/Farrell	**7.44**	0.00	**7.48**	-0.02	**7.52**	-0.04	-0.04	-0.02
13	-	Cowper St	**6.68**	0.00	**6.71**	0.00	**6.75**	0.00	0.00	0.00
14	-	Cnr Hoskins/Stuart	**6.27**	0.00	**6.28**	0.00	**6.29**	0.00	0.00	0.00
15	Woosters	D/S Abbott St	**5.45**	0.00	**5.54**	0.00	**5.72**	0.00	0.00	0.00
16	Woosters	U/S Farnell St	**5.29**	0.00	**5.29**	0.00	**5.44**	-0.01	-0.01	-0.01
17	Woosters	D/S Cowper St	**3.90**	0.00	**3.95**	0.00	**4.17**	-0.01	-0.01	-0.01
18	Woosters	Stuart St	**2.97**	0.00	**3.21**	0.00	**3.50**	-0.01	-0.01	-0.01

The modelling results indicate that the flow diversion would result in a significant benefit, primarily to Taree LGA residents of Wallanbah Road upstream of the Pacific Highway, but also to residential and commercial properties in Nabiac. Peak flood levels for the 100 year ARI event would be reduced by an estimated 0.5 m for Wallanbah Road residents with a 50% catchment diversion, and by around 0.2 m near Clarkson and Nabiac Streets.

A detailed cost analysis for this measure has not been undertaken, primarily because floor level survey for the residential properties in the Taree LGA was unavailable, and this is where the primary benefit in terms of damages reduction would be realised. Despite these limitations, it is considered that the Benefit-Cost ratio is likely to be relatively high for this measure, and the suggested diversion works are recommended subject to further more detailed civil works investigation.

ACTIONS

A large component of the Candoormakh Creek Road catchment should be diverted into Candoormakh Creek, rather than going into Town Creek through Nabiac. Local re-grading and drainage works should be undertaken in the vicinity of the Wallanbah Road/Candoormakh Creek Road intersection to re-instate the existing flowpath, and where possible to increase the proportion of flow arriving at the Candoormakh Creek Road embankment that discharges northwards into Candoormakh Creek. This may be achieved by increasing the height of Candoormakh Creek Road at the low-points, which are currently subject to frequent overtopping. This would have the added advantage of improving access along this route during heavy rain.

The completion of this course of action will require a joint effort from Great Lakes and Taree Councils and Roads and Maritime Services.

6.3.5. Catchment Treatment

Catchment treatment modifies the runoff characteristics of the catchment to reduce the amount of runoff to downstream areas. For new development, this involves planning to maximise the amount of pervious area, maintaining natural channels where practical and the use of on-site detention (often referred to as Water Sensitive Urban Design or WSUD). For a rural catchment, this involves limiting deforestation or contour ploughing of hill slopes. These measures can reduce the volumes of storm water run-off in relatively small, frequent events, typically up to about 5 year ARI events. They have little effect in larger, less frequent events, above say a 20 ARI event. These measures can be effective on small catchments such as Town Creek, particularly if there is a significant new “green field” developments in upper catchment areas, but will generally have a negligible impact on large catchments such as the Wallamba River.

As a general concept, catchment treatment techniques and WSUD should be encouraged (e.g. on-site detention, limit on-site imperviousness for developments, controls on rural land use) along with water quality and other environmental controls as these approaches provide significant local drainage and non-flooding benefits. These approaches are generally implemented via development control policies.

ACTIONS

The area where benefits from catchment treatment measures are most likely to be effective is the Town Creek catchment upstream of the Pacific Highway, where Development Applications are in place for new residential subdivisions of land that is currently rural. This area is within the Taree LGA, and therefore Great Lakes Council has limited ability to enforce development controls on this area. However, it is recommended that catchment treatment measures are put in place for new "green fields" development, particularly in Town and Woosters Creek, to minimise adverse flood impacts (both in terms of quantity and quality of runoff) on Nabiac.

6.3.6. Retarding Basins, On-Site Detention

DESCRIPTION

Retarding basins are small-scale flood mitigation dams commonly used in residential catchments for the purposes of mitigating peak flows by retaining runoff from intense storms and releasing it at a relatively sustained rate. One of the major impediments in their use as a flood mitigation measure for existing development is the lack of suitable sites. For new "green fields" developments there is the opportunity to incorporate the retarding basins into site design which is not possible for existing development. Retarding basins can also provide significant water quality benefits, though in a heavily built up urban environment it is difficult to maintain these systems for this purpose.

The main issues associated with using detention basins for flood risk management are summarised below.

Size: In order to be effective at reducing peak flows and benefiting water quality the basin area must cover a reasonably high percentage of the upstream catchment. The larger the basin, the more effective it will be.

Benefit: Whilst any basin will provide some peak flow reduction and water quality benefit this must be balanced against the cost, and whether there are more cost effective methods. For example, it is generally acknowledged that public education and awareness and point source reduction provides the greatest benefit from a water quality perspective. The benefit for peak flow reduction is subject to the size of the basin and the outlet works. These are not easily defined at a concept stage, as detailed survey and design is required. Small basins generally provide the greatest peak flow reduction in small more frequent events, when the basin volume is a high percentage of the total flood volume. However, in these events there is often only minor above floor damage or significant hazard to mitigate. In large events, basins (unless very big) are largely ineffectual from both a water quality and peak flow reduction perspective. Also, for multi-peaked rainfall events the basin may provide some benefit in the initial peak but very little when the second or third peak arrives.

The use of a basin for dual purposes (water quality and peak flow reduction) generally means that a compromise of the benefits for each purpose has to be reached. This is because the water quality purpose is best achieved by containing all the frequent inflows. For flood mitigation purposes, these flows are generally not contained to allow the volume in the basin to be "empty" at the time of the peak inflow.

Loss of Land Use:

In a rural area (or some low-density urban areas) the use of land for basin construction is generally acceptable, particularly when the basin is implemented as part of a "green fields" subdivision.

Safety: This is one of the most important factors to be considered when constructing a basin in a residential area. Council will be changing an open space area with a low hazard potential during rainfall events to an area with a greater hazard. Apart from the risk of wall failure and consequently a sudden rush of floodwaters, there is the risk that people may drown or be swept into the basin. This can be negated by using fencing but this then precludes the use of the basin for other purposes. Generally basins deeper than around 1.2 m, or with side slopes steeper than 1V:6H are unacceptable as a person cannot wade out of them. The benefit of a reduction in hazard downstream must be balanced with the potential increase in hazard at the basin site. Constructing a basin places a significant potential liability on Council should it cause harm to persons in flood (or even non-flood) times.

Signs can be placed advising of the hazard, however in a legal environment it is difficult to argue that this abrogates Council's responsibilities. Also children, older residents and non-English speaking background residents may not understand the signs.

Retarding basins are unlikely to be a cost effective measure to negate existing creek flooding or overland flow problems in Nabiac. However all basins will provide some flow mitigation and water quality benefit. The benefit that can be achieved must be balanced against the loss of use of the land and concerns about Council's liability if construction of a basin increases the flood hazard in the area. As with catchment treatment measures (previous section), the principle benefit of detention basins is likely to be for any new "green fields" developments in the local creek catchment areas upstream of the Pacific Highway, for which there are Development Applications in place (in the Taree LGA), or for any major increase in development density within Nabiac itself (in Great Lakes LGA).

ACTIONS

Through development control policies, Council should encourage the use of retarding basins for development of new subdivision sites in the local creek catchment areas, to mitigate adverse flood impacts in Nabiac potentially resulting from such development.

6.4. Property Modification Measures

6.4.1. House Raising and Flood Proofing

DESCRIPTION

House raising has been widely used throughout NSW to reduce the risk of inundation above habitable floor levels. However it has limited application as it is not suitable for all building types. It is also more common in areas where there is a greater depth of inundation than at Nabiac, and raising the buildings allows creation of an underfloor garage or non-habitable room area.

House raising is suitable for most non-brick single storey buildings on piers and is particularly relevant to those situated in low hazard areas on the floodplain. The benefit of house raising is that it can eliminate inundation above the floor and consequently reduces the flood damages.

An alternative to house raising for buildings that cannot be raised is flood proofing or sealing of the entry points to the buildings. This measure has the advantage that it is generally less expensive than house raising and causes less social disruption. However this measure is really only suitable for commercial and industrial buildings where there are only limited entry points and aesthetic considerations are less of an issue. Based upon our experience we do not consider flood proofing a viable measure for residential buildings in Nabiac.

Table 12: Advantages and Disadvantages of House Raising

ISSUE	COMMENT
ADVANTAGES:	
Can be cost effective (benefit/cost ratio >1).	Generally the majority of suitable low lying buildings which would provide a B/C ratio of >1 have either already been raised or are not suitable (low economic value).
Nil maintenance cost.	May provide additional under floor usage.
Resident can still enjoy benefits of existing life style.	Residents do not have to move but will be inconvenienced during the course of work.
Grants are available.	Each application is assessed on its merits.
DISADVANTAGES:	
The benefit/cost ratio is small unless the building is frequently inundated.	The B/C ratio for raising a residential building by 0.3 m (assuming a cost of $60,000, and a lifetime of the works of 25 years) could be as high as 0.7 based on properties at Nabiac currently inundated by overland flow in the 5 year ARI, reducing to 0.35 for properties inundated in a 50 year ARI event or greater.
Grants only cover the basic costs of raising the structure.	Residents may have to provide their own funds to raise (say) pergolas or garages attached to the house. This can be a significant drawback for many residents.
Many buildings are not suitable.	Detailed inspection may preclude a number of buildings initially considered to be suitable (e.g. stone fireplaces).
Residents are “dislodged” for a period.	The residents may have to move for several weeks.
Low acceptance by residents.	In some locations there is a low acceptance by the residents. Generally where the building is frequently inundated the residents take up the offer. However, where the building is less frequently inundated (possibly never in the owner’s lifetime) the residents reject the offer.

DISCUSSION

There are a very small number of residential affected by above-floor inundation from mainstream flooding up to the 100 year ARI event, either from the creeks in town or the

Wallamba River. House raising could be a viable means of flood protection for these few properties assuming the buildings are of suitable construction.

There are several residential properties that are built with very low clearance above surrounding ground levels, or in some cases lower than surrounding ground levels and adjacent roadside swales (Photograph 18). Such houses are typically highly susceptible to flooding from shallow overland flow.

However a brief review of properties estimated to have over-floor flooding in the 100 year ARI event suggests that most are unable to be raised. Additionally the benefit/cost ratio is generally low unless the building is frequently inundated. The relative advantages and disadvantages of this measure are provided in Table 12.

Photograph 18: Examples of houses without signficant clearance of the ground floor level above surrounding areas

ACTIONS

Residents should be aware that house raising can occasionally be a cost effective solution for long term reduction of flood damages at residential properties, although not all types of house construction are amenable to raising. Applications for funding assistance for house-raising must be made on a case-by-case basis, and the benefit/cost ratio is unlikely to be very high for the majority of residential properties at Nabiac, in comparison to other areas in the state with higher flood damages.

6.4.2. Development Control Planning and Flood Planning Levels

DESCRIPTION

The strategic assessment of flood risk can prevent development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. It can also reduce the potential damage to new developments likely to be affected by flooding to acceptable levels. Development control planning includes both zoning and development controls.

The division of flood prone land into appropriate land use zones can be an effective and long term means of limiting danger to personal safety and flood damage to future developments. Zoning of flood prone land should be based on an objective assessment of land suitability and capability, flood risk, environmental and other factors. In many cases it is possible to develop flood prone lands without resulting in undue risk to life and property.

Development controls for Nabiac are included in a number of planning documents including the Local Environmental Plan (LEP) – (1996), Council's Flood Policy, and various localised Development Control Plans.

DISCUSSION

The LEP and Flood Plan are currently in the process of being updated by Council and the following issues need to be addressed when considering flood related development control policies.

- Ensure Adequate Access: Emergency access during times of flooding is not one of the key problems at Nabiac, as safe evacuation to high ground should generally be possible in times of flood, for both local creek flooding and Wallamba River flooding.
- Set Back from Waterways: A minimum setback for development from waterways and floodways should be considered.
- Fill (or excavation) in the Floodplain: Filling of land for development can result in it no longer being flood liable, however it can also affect flow patterns or even cause flood levels to rise. Filling for building pads in flood-liable areas (in-fill development) should therefore only be permitted if it does not affect local drainage issues or result in significant flood impacts. The cumulative effects of filling should be monitored (i.e. collected in a database) but are unlikely to present a major concern in the future.
- Building Materials: Some building materials are less susceptible to damage by floodwaters, or are easier to clean after a flood. By using such materials, flood damages can be minimised. In particular, marine grade timber that is not susceptible to failure after inundation should be required in flood-liable areas.
- Structural Soundness when Inundated: Floodwaters can impact upon the structural soundness of buildings in a number of ways relating to flow velocities, depths and associated debris loads. These should all be considered in relation to certification of the soundness of structures for the local hydraulic conditions.
- Fencing: Fences, whether solid or open, can impact upon flood behaviour by altering

flow paths. This impact will depend upon the type of fence and its location relative to the flow path. At Nabiac this is unlikely to be a significant issue for creek flooding but is of relevance for local catchment runoff and overland flow. Fences should not intrude into floodways or overland flow easements.

- Public Assets: It is essential that all public assets which may be damaged by floodwaters are located to minimise (or hopefully eliminate) such damage.
- Non-Residential and Special Use Properties: The flood related development requirements for all non-residential properties need to be clearly identified, including Special Use (hospitals, schools, halls, SES HQ).
- Land-use zoning: Refer to Section 6.2.4 for discussion.
- Climate Change: Should be addressed (refer to Section 5.3 for discussion).
- Flood Planning Levels: The FPL is used to define land subject to flood related development controls and is generally adopted as the minimum level to which floor levels in the flood affected areas must be built. The FPL includes a freeboard above the design flood level. It is common practice to set minimum floor levels for residential buildings as this reduces the frequency and extent of flood damages. Freeboards provide reasonable certainty that the reduced level of risk exposure selected (by deciding upon a particular event to provide flood protection for) is actually provided. It is common practice throughout NSW to use a FPL of the 100 year ARI event plus a 0.5 m freeboard. Other FPLs greater than the 100 year ARI such as the PMF may need to be considered where personal safety is a factor, such as evacuation planning or placement of critical infrastructure. **All residential properties, even those outside the flood extents estimated in the Flood Study, should have a FPL for habitable floor levels a minimum of 0.3 m above surrounding ground levels, to minimise the likelihood of flooding from local overland flow**. Consideration should also be given to specifying simplified FPLs for areas affected by local stormwater runoff (as identified on Figure 3B), and default FPLs for Commercial and Industrial development at the 100 year ARI level (no freeboard), with deviations from this default to be allowable on a merits-based approach. The different FPLs adopted by Council should be clearly listed in the Flood Policy.
- Wording on 149 Certificates: This should be reviewed every 2 years to ensure that the wording accurately reflects Council's intentions.
- Formalise Flood Policy: It is essential that Council develop a clear and unambiguous flood policy which is located in a single document.

ACTIONS

Development control planning can reduce the effects of flooding on future development by minimising flood damages and managing risk. In some areas where the FPL or other criteria can only be achieved at considerable additional cost, there is community resistance to implementing these measures. However at Nabiac these measures are unlikely to involve such resistance when applied to new development.

Development control plans should be reviewed in light of the considerations outlined above, particularly the setting of FPLs.

6.5. Response Modification Measures

6.5.1. Flood Warning and Evacuation Planning

DESCRIPTION

Flood warning and the implementation of evacuation procedures by the State Emergency Service (SES) are widely used throughout NSW to reduce flood damages and protect lives. The Bureau of Meteorology (BOM) is responsible for flood warnings on major river systems.

Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services. Adequate flood warning gives residents time to move goods and vehicles above the reach of floodwaters and to evacuate from the immediate area. The effectiveness of a flood warning scheme depends on:

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

DISCUSSION

The flood warning system currently in place for the Wallamba River is discussed in Section 3.7, however it should be noted that no warnings are available for Wallamba River flooding at Nabiac (only further downstream). There is no warning system in place for the local creek catchments. It is not possible to develop an effective warning system for the smaller creek catchments (Town, Woosters and Pipeclay) due to the relatively short response time from the start of the rain to the time of the flood peak (potentially less than 2 hours). Even for the Wallamba River, Nabiac is located in relatively upper parts of the catchment, and the lead time before flooding commences is likely to be shorter than the minimum standards required by the Bureau of Meteorology to implement a flood warning system.

This may change in the future with further development of more accurate radar based warning systems that can forecast where storms and the consequent flooding will occur. However due to the imprecise nature of predicting weather patterns it is unlikely that a highly accurate system that can provide sufficient warning will ever be possible for flash flooding of smaller catchments, or the upper portions of large river basins.

Due to the relatively fast rate of rise that is possible in the local creeks, it is possible for residents to be "caught completely unaware," particularly if heavy flood producing rainfall occurs at night. It will therefore not always be possible to prevent damages by moving items such as televisions (though many modern televisions are now wall mounted and immovable), rugs, clothing and cars.

It may be necessary for some residents in Nabiac to evacuate their homes during a major flood event. However it is unlikely that the depth of inundation will ever be such that above floor flood depths of greater than 1 m are experienced. Thus most residents would probably stay in their house and can escape the floodwaters by standing on tables etc. However some residents may wish to evacuate regardless or because they have some reason to leave the property (pick up children from school). The amount of time for evacuation depends on the available warning time.

Although Council monitors the situation during flood events the responsibility for preparing regional flood warning rests with the BOM. Based on this information the SES issues community level warnings. Council does not issue warnings but assists the SES with road closures and evacuations. The SES has a Local Flood Plan for the Great Lakes Council Area, the main features of which are:

- preparedness measures, conduct of response operations and the co-ordination of immediate recovery measures for flooding within the Council area (including Forster and Tuncurry),
- a guide to the content of evacuation warning messages and identifies sites to be used as evacuation centres (Nabiac showground is identified for Nabiac),
- the plan only considers evacuation up to the 100 year ARI flood level.

The main problems with all flood evacuations are:

- they must be carried out quickly and efficiently,
- they are hazardous for both the rescuers and the evacuees,
- residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers,
- evacuation routes may be cut some distance from their houses and people do not often appreciate the dangers of driving or walking through flood waters.

Due to the potentially fast rate of rise for local creek flooding it would be unlikely the SES would be able to initiate any major response effort until after the peak. For the Wallamba River there is a longer warning time available. However, a flood on the Wallamba River is likely to occur in conjunction with flooding at other nearby localities which will stretch the resources of the SES in the region. It is noted that there is a SES HQ in Nabiac.

As part of the consultation process through the Floodplain Management Committee, the SES indicated that their preferred methodology for management of the Wallamba River extreme flood risk would be to install an automatic river level gauge (with manual gauge boards) in the Wallamba River, at an accessible place upstream of the Pacific Highway at Nabiac. The installation of such a gauge would enable SES personnel to monitor the Wallamba River level at Nabiac in combination with telemetric rainfall in the upper catchment. Once the Wallamba River gauge reached a certain trigger level where there was a risk of breakout flows occurring through Nabiac, the village would be evacuated.

ACTIONS

A Local Flood Plan (Reference 8) for the whole Great Lakes Council area has been developed, but requires revision as some sections contain outdated information. The SES's primary role for local catchment flooding at Nabiac is likely to occur before (awareness program) and after the event (clean up) due to the limited response time available and likely demand on resources from other areas flooding concurrently. For large Wallamba River floods it may be necessary to evacuate residents, with priority areas determined from the FERP classifications in Figure 11 (Wallamba River flooding) and Figure 12 (local catchment flooding). The SES has indicated that a water level gauge should be installed in the Wallamba River upstream of the Pacific Highway at Nabiac, to provide sufficient information to make evacuation decisions.

The response of the community during an event is critical in reducing the flood damages and risk to life. Review of the Local Flood Plan should be undertaken by or in conjunction with the Nabiac SES, with a focus on preparedness and providing the community with information about “self-help” approaches for flood response.

6.5.2. Public Information and Raising Flood Awareness

DESCRIPTION

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

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

The above can be improved upon through implementation of an effective Council or SES run flood awareness program. The extent of the program can vary from year to year depending upon the circumstances.

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential risks of the situation. During a period of frequent flooding (as has recently occurred in Nabiac), the residents would probably have developed an unofficial warning network to effectively respond to imminent danger by raising goods, moving cars, lifting carpets, etc. Photographs and other non-replaceable items are generally put in safe places. Often residents in rural areas have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have “survived” previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner.

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

- frequency and impact of previous floods,
- history of residence,
- whether an effective public awareness program has been implemented.

It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and the level of awareness will diminish as the time since the last flood increases. A major hurdle is often convincing residents large floods will occur in the future. Some residents may oppose an awareness program because they consider it reduces the value of their property. However this should not hinder the continued need to inform and receive feedback from the community.

Notification on the Section 149 certificate is an approach to inform residents of the potential flood risk at their property. In this process it is recommended that properties potentially flooded by shallow overland flow be informed as well as those within the mapped flood extents identified along the main creek channels.

Residents in Nabiac typically have a reasonable awareness of flood issues, due to the relatively high number of recent flood events that have occurred resulting in overtopping of the main access roads to town, and flooding of the commercial areas on Town Creek. However, a key issue that requires constant reinforcement is to ensure that the community prioritises personal safety over other concerns during floods, and walking or driving through flood waters should be strongly discouraged.

A suitable Council wide flood awareness program should be implemented using appropriate elements from (Table 13), mainly focusing on aspects of personal safety during flash floods, and flood preparedness.

Table 13: Flood Awareness Methods

Method	Comment
Council website	Council should establish and maintain a section of Council's website where flood-related information, including flood study documents and reports, can be obtained.
Letter/Pamphlet from Council	These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of subsidies, changes to flood levels or any other relevant information.
School Project or Local Historical Society	This provides an excellent means of informing the younger generation about flooding. It may involve talks from various authorities and can be combined with topics relating to water quality, estuary management, etc.
Displays at Council Offices, Library, Schools, Shopping Centres, Local Fairs	This is an inexpensive way of informing the community and may be combined with related displays.
Historical Flood Markers or Depth Indicators on Roads	Signs or marks can be prominently displayed in parks, on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators on roads advise drivers of potential hazards.
Articles in Local Newspapers	Ongoing articles in the newspapers will ensure that the problem is not forgotten. Historical features and remembrance of the anniversary of past events make good copy.
Collection of Data from Future Floods	Collection of data assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible.
Types of Information Available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the Section 149 Certificate during the purchase process. Council do advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost.
Establishment of a Flood Affectation Database	A database would provide information on (for example) which houses require evacuation, which roads will be affected (or damaged) and cannot be used for rescue vehicles, which public structures will be affected (e.g. sewage pumps to be switched off, telephone or power cuts). This database should be reviewed after each flood event. It could be developed by various authorities (SES, Police, Council).
Flood Preparedness Program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program can assist the community to be adequately prepared. The SES would take a lead role in this.
Foster Community Ownership of the Problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. For example, Council should have a maintenance program to ensure that its drainage systems are regularly maintained. Residents have a responsibility to advise Council if they see a maintenance problem such as a blocked drain. This process can be linked to water quality or other water related issues.

ACTIONS

A flood awareness program should be implemented as part of the Floodplain Management Plan, with a focus on personal safety during flash flood events. Council's website should be updated to include Council's most recent flood information and reports.

6.6. Summary

The identified measures were assessed based on impacts on flood levels, reduction in property damage, feasibility, social impacts, environmental impacts, economic impacts and the long term performance given likely impacts of climate change. A score for each of the management options was determined using the criteria matrix described in Table 14 . The outcomes of this assessment are presented in Table 15.

Table 14: Evaluation Criteria for Flood Risk Mitigation Measures

Category	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefited	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straight-forward	Straight-forward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental and Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political/administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

Table 15: Summary Assessment of Identified Floodplain Management Measures

Measure	Score											
	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental and Ecological Benefits	Impacts on SES	Political/ administrative Issues	Long Term Performance	Risk to Life	TOTAL
FLOOD MODIFICATION MEASURES:												
Local Drainage Issues	1	-	-	1	1	1	0	0	0	1	0	4
Removal / Replacement of Structures and Blockage Prevention	3	2	2	2	1	1	0	0	0	2	1	14
Channel Modifications (Vegetation Clearing)	2	2	2	2	0	1	0	0	0	-1	1	9
Flowpath Diversion	3	3*	1	2	3	2	0	0	-1**	3	2	18
Catchment Treatment (for new development of greenfield sites)	0	0	1	1	1	1	1	0	0	1	0	6
Retarding Basins, On-Site Detention (new development of greenfield sites)	0	0	2	2	1	1	2	0	0	2	0	10
PROPERTY MODIFICATION MEASURES:												
House Raising and Flood Proofing	-	1	-2	-1	1	1	0	1	0	1	0	2
Development Control Planning and Flood Planning Levels	-	3	1	-1	2	2	0	1	0	3	0	11
RESPONSE MODIFICATION MEASURES:												
Flood Warning and Evacuation Planning	-	-	-	1	1	0	0	2	0	2	1	7
Public Information and Raising Flood Awareness	-	-	-	2	1	2	0	1	0	2	1	9

* Includes residential properties in Taree LGA

** Requires joint initiative by Taree and Great Lakes Councils, and Roads and Maritime Services

NOTE: where the impact of a measure is not readily quantifiable, or is highly variable as it depends on case-by-case details, a neutral (-) score is assigned.

6.7. Climate Change

The potential impact of increased design flood levels in the catchment due to climate change is discussed in Section 5.4. Modelling indicates that the potential change in peak flood levels from climate change would be greater in the lower portion closer to the Wallamba River where both sea level rise and rainfall increase would have an effect. However most of this impact is a result of the rainfall increase scenarios rather than sea level rise. Mapping of hazard and hydraulic categories for the 100 year ARI with sea level rise shows very little change for the current 100 year ARI conditions (compare Figure 3 with Figure 5, and Figure 7 with Figure 9).

As discussed in Section 5.3, projections of rainfall changes involve far more uncertainty than those for sea level rise, and there is additional uncertainty about whether additional rainfall would result in greater runoff for larger catchments like the Wallamba River, given the likelihood of generally drier catchment conditions.

There are no means of lessening the increase in greenhouse gases other than a world-wide reduction in their production.

ACTIONS

There is insufficient certainty surrounding rainfall increases from climate change to warrant changes to development control policies at Nabiac at this stage. Council should continue to monitor the available literature and reassess Council's Stormwater and Flooding DCPs as appropriate. At a minimum Council should obtain the most current information available from the Bureau of Meteorology, CSIRO and OEH every two years.

Some Councils in NSW have raised FPLs to account for the expected increase in flood level due to sea level rise in accordance with (Reference 14 and 17). This rise would be in addition to the 0.5 m freeboard. This issue should be canvassed at the Floodplain Risk Management Plan stage.

7. COMMUNITY ENGAGEMENT

A rigorous public consultation program was carried out as part of this study.

This included:

- review of submissions and questionnaires provided by residents as part of the Flood Study;
- interviews and site inspections with key respondents;
- floodplain management committee meetings,
- further community workshops to communicate possible risk management measures;
- public exhibition of study material.

The outcomes of the exhibition and consultation process have been incorporated into the recommendations of this Floodplain Risk Management Study and Plan.

7.1. Public Exhibition Process

Great Lakes Council adopts an integrated planning approach for floodplain management, in accordance with a Gateway Determination produced by NSW Department of Planning and Environment on 28 August 2014. This approach recognises the importance of including strategic planning considerations as part of the flood risk management process. Community engagement effort was therefore shared between Council's Design and Investigation Division and Strategic Planning Division. This approach provided a forum for the public to discuss a wider range of matters covering flood modelling, hazards and responses along with proposed strategic planning measures.

The Planning Proposal, Draft Great Lakes Development Control Plan (DCP) Amendments and Draft Nabiac Floodplain Risk Management Study were placed on public exhibition in accordance with the Gateway Determination, between 22 December 2014 and 30 January 2015 inclusive. During the public exhibition period Council officers organised official notifications in all local newspapers in December and January; public information sessions in Stroud, Nabiac, Tea Gardens, Pacific Palms and Forster, media releases and a notification in the January 2015 Council Communicator which was sent to 18,376 rate payers. The information session at Nabiac was held on Tuesday, 13 January 2015.

The hard copy documents were available at all Council District Offices and the Customer Service Centre in Forster during the public exhibition period and all information was available on the Council website. Unfortunately, in response to the public exhibition of the documents, no submissions were received. This is seen to be a result of widespread awareness and general acceptance of the options and results contained in the Study.

8. NABIAC FLOODPLAIN RISK MANAGEMENT PLAN

8.1. Introduction

The Nabiac Floodplain Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual (Reference 4) and the August 2010 Flood Risk Management Guide – Incorporating sea level rise benchmarks in flood risk assessment (Reference 18):

- *Is based on a comprehensive and detailed evaluation of factors that affect and are affected by the use of flood prone land;*
- *Represents the considered opinion of the local community on how to best manage its flood risk and its flood prone land; and*
- *Provides a long-term path for the future development of the community.*

The study is focused on the village of Nabiac, with a population of approximately 600, located on the Pacific Highway roughly 15 km north-west of Forster on the New South Wales Central Coast (Figure 1). The study area (Figure 2) includes the catchments of Town Creek, Woosters Creek and Pipeclay Creek in the vicinity of Nabiac, bounded by the Pacific Highway to the north and west, and bounded by the Wallamba River to the south. This area is within the Great Lakes Council Local Government Area (LGA), however the upper parts of these catchments to the immediate north are in the Taree Council LGA, with the boundary roughly delineated by the Pacific Highway.

Nabiac has a history of flooding problems, and in a recent community survey (Nabiac Flood Study - Reference 1), many residents reported instances of flooding. Flooding in Nabiac can occur from both the Wallamba River and from local catchment runoff (Town Creek, Woosters Creek and Pipeclay Creek), however the general consensus of the community is that the majority of flood issues are caused by flash flooding, particularly in Town Creek (which runs through the town centre) and Woosters Creek.

The local drainage system within the village is primarily grass-lined swales draining towards the natural creek channels. There a several crossings of each of the creeks, comprising bridges, box culverts, pipes and causeways.

The land usage within the study area is primarily rural and low density residential, with a concentration of commercial and light industrial properties downstream of the town centre. The upper catchment areas upstream of the Pacific Highway, and the Pipeclay Creek catchment to the east, primarily comprise rural properties.

The present review was initiated by Great Lakes Council to reassess flood risk management options and incorporate the NSW Government's sea level rise benchmarks, based on predictions by the Intergovernmental Panel on Climate Change (IPCC) and the CSIRO Technical Review for Australia, and also the potential increase in rainfall intensities due to climate change, and evaluate suitable adaptation measures.

8.2. Risk Management Measures Considered

A matrix of possible management measures was prepared and evaluated taking into account a range of parameters. This process eliminated a number of flood risk management measures (refer Section 6.2) including:

- Flood mitigation dams: - on the basis of high cost, large footprint, and environmental impact,
- Levees, floodgates and pumps on the basis that they are not effective mitigation measures,
- Voluntary purchase of flood affected buildings, as it is uneconomic and has a high social impact
- Rezoning of land is not practical in a rural community such as Nabiac,
- Flood insurance is unlikely to be taken up by residents due to the high annual premiums.

The full range of measures was evaluated in Section 6 and the outcomes are summarised in Table 16.

Table 16: Summary of Management Measures Investigated in Study

MEASURE	PURPOSE	COMMENT
FLOOD MODIFICATION:		
WORKS TO MINIMISE LOCAL DRAINAGE PROBLEMS (See 6.3.1)	To reduce the incidence of local runoff ponding in yards and streets.	Flooding in this manner does not usually enter buildings but it occurs frequently and causes significant inconvenience. In low-lying areas with little or no fall there is no easy or cheap solution. A community based approach should be introduced to monitor, identify and (possibly) resolve some problem areas.
REMOVAL AND REPLACEMENT OF STRUCTURES AND BLOCKAGE PREVENTION (See 6.3.2)	Will increase the hydraulic conveyance of the open channel system and reduce the likelihood of blockage.	These measures can reduce upstream flood levels and are likely to be cost effective.
CHANNEL MODIFICATIONS (See 6.3.3)	Clearing of the existing dense vegetation will increase the hydraulic capacity of Town Creek.	This measure can only be supported if there is a commitment from the local community (Landcare or such) to assist Council with the ongoing maintenance.
FLOWPATH DIVERSION (See 0)	To reduce the contributing catchment area and consequent peak flows in Town Creek by diversion into Candoormakh Creek.	The recent Pacific Highway upgrade works has diverted part of the upstream catchment into Town Creek. The original catchment area to Town Creek should be re-instated or if possible reduced further by relatively minor civil works within Taree LGA.
CATCHMENT TREATMENTS (See 6.3.5)	Reduce volume of runoff from catchment by maximising water retention and absorption, and minimising impervious surfaces such as roofs and roads.	These measures can be effective for future development in small catchments, to protect local creeks, and to improve water quality, but are not effective in reducing Wallamba River flood levels.

RETARDING BASINS, ON-SITE DETENTION (See 6.3.6)	Reduce peak flows by increasing upstream temporary floodpain storage capacity in basins.	These measures can be effective for future development in small catchments, to reduce downstream peak flows in local creeks, and to improve water quality, but are not effective in reducing Wallamba River flood levels.
PROPERTY MODIFICATION:		
HOUSE RAISING (See 6.4.1)	Prevent flooding of existing buildings by raising the floor level above the floodwaters.	All flood damages will not be prevented. Only suitable for non-brick buildings on piers. The cost is approximately $60,000 per house, but can vary considerably and is unlikely to be cost effective at Nabiac. Only suitable for a small number of buildings and not attractive to all residents. Nevertheless it should be investigated further.
FLOOD PROOFING (See 6.4.1)	Prevent flooding of existing buildings by sealing all the entry points.	Generally only suitable for brick, slab on ground buildings. Less viable for residential buildings.
DEVELOPMENT CONTROL PLANNING AND FLOOD PLANNING LEVELS (See 6.4.2)	S149 certificates should clearly inform owners and purchasers of risks, planning controls and policies that apply to the subject land.	Council should review the Flood Management Policy. Flood Planning Levels should be reviewed to consider inclusion of extreme events for critical public infrastructure and emergency management. Wording of flood-related information on the Section 149 Certificate should be reviewed and revised if necessary to bring it in line with the findings of this Flood Risk Management Plan.
RESPONSE MODIFICATION:		
FLOOD WARNING AND EVACUATION PLANNING (See 6.5.1)	Enable people to prepare and evacuate, to reduce damages to property and injury to persons.	System currently in place but it is based largely on regional catchment data. It is not possible to provide accurate flood warning on the small local creeks due to their short response time. Review of the Local Flood Plan will ensure that all up to date information is incorporated.
PUBLIC INFORMATION AND RAISING FLOOD AWARENESS (See 6.5.2)	Educate people to prepare themselves and their properties for floods, to minimise flood damages and reduce the risk.	A cheap and effective method but requires continued effort.

8.3. Floodplain Risk Management Measures in Plan

The recommended measures are described below (in no particular order within each priority group). The measures will be further refined and assessed by development of detailed local area adaptation plans for each foreshore management area.

HIGH Priority

1. **Reduce catchment area flowing to Town Creek in Nabiac, by undertaking civil works to divert flows into Candoormakh Creek, as occurred previously. (Section 6.3.4)**
   - **Cost:** Moderate
   - **Responsibility:** Council (Taree and Great Lakes) and Roads and Maritime Services

2. **Undertake upgrades of Nabiac Street pedestrian footbridge and Town Creek culverts at the end of Ferris Place, to match capacity of Town Creek culverts at Clarkson Street. As of late 2012 the Ferris Place culverts have already been upgraded by Council to have the same capacity as the Clarkson Street culverts).**
   - **Cost:** Moderate
   - **Responsibility:** Great Lakes Council

3. **Review and revise Flood Management Policy, and the wording on the Section 149 certificates, development restriction certificates and flood control lot certificates to incorporate revised flood planning levels.**
   - **Cost:** Low
   - **Responsibility:** Great Lakes Council

4. **Install an automatic river level recording gauge and manual gauge boards on the Wallamba River, upstream of the Pacific Highway at Nabiac. The gauge is required by the SES for the purposes of monitoring potential Wallamba River flow breakouts in extreme events, and for determining whether evacuation is required.**
   - **Cost:** Low
   - **Responsibility:** Great Lakes Council

MEDIUM Priority

1. **Undertake vegetation clearing works in Town Creek between Clarkson Street and Ferris Place. Obtain community commitment to maintain a clearing program.**
   - **Cost:** Moderate
   - **Responsibility:** Great Lakes Council and local residents.

2. **Undertake a review of the flood warning system for the Wallamba River and if necessary update.**
   - **Cost:** Low
   - **Responsibility:** Great Lakes Council and Bureau of Meteorology.

3. **Inform the SES of the outcomes of this Plan and the possible implications for flood evacuation. If necessary the SES should update the Local Flood Plan.**
   - **Cost:** Low
   - **Responsibility:** Great Lakes Council and State Emergency Services.

LOW Priority

1. **Establish a community flood awareness program with a focus on evacuation procedures and ensuring personal safety during floods.**
   - **Cost:** Low
   - **Responsibility:** Great Lakes Council and SES

2. **Review development control policies and if appropriate revise to encourage detention basins and catchment treatment for green-field development of local catchments upstream of Nabiac, particularly in Town Creek.**
    - **Cost:** Low
    - **Responsibility:** Great Lakes Council and Greater Taree City Council

3. **Evaluate whether a house raising scheme or similar will be supported by the community and a practical adaptation measure for flood affected properties and if so establish such a scheme.**
    - **Cost:** Low to evaluate. Approximately $60,000 to raise a non brick house, but highly variable
    - **Responsibility:** Great Lakes Council and local community

4. **Evaluate whether a flood proofing scheme for frequently inundated properties will be supported by the community if so establish such a scheme.**
    - **Cost:** Low to evaluate. Probably suitable only for commercial properties on a case by case basis.
    - **Responsibility:** Local business owners

5. **Ensure that ongoing local drainage problems are monitored and addressed.**
    - **Cost:** Moderate
    - **Responsibility:** Great Lakes Council and local residents

6. **Investigate the feasibility of upgrading Clarkson Street Bridge at Woosters Creek to provide enhanced flood immunity as part of future maintenance.**
    - **Cost:** High
    - **Responsibility:** Great Lakes Council and Roads and Maritime Services

9. ACKNOWLEDGEMENTS

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- Great Lakes Council;
- Office of Environment and Heritage;
- Nabiac SES unit;
- Bureau of Meteorology; and
- residents of Nabiac (particularly Bruce Weller and Kevin Griffis for their time and assistance).

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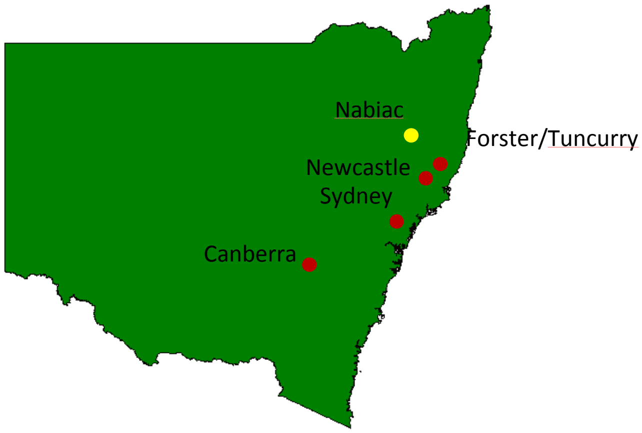
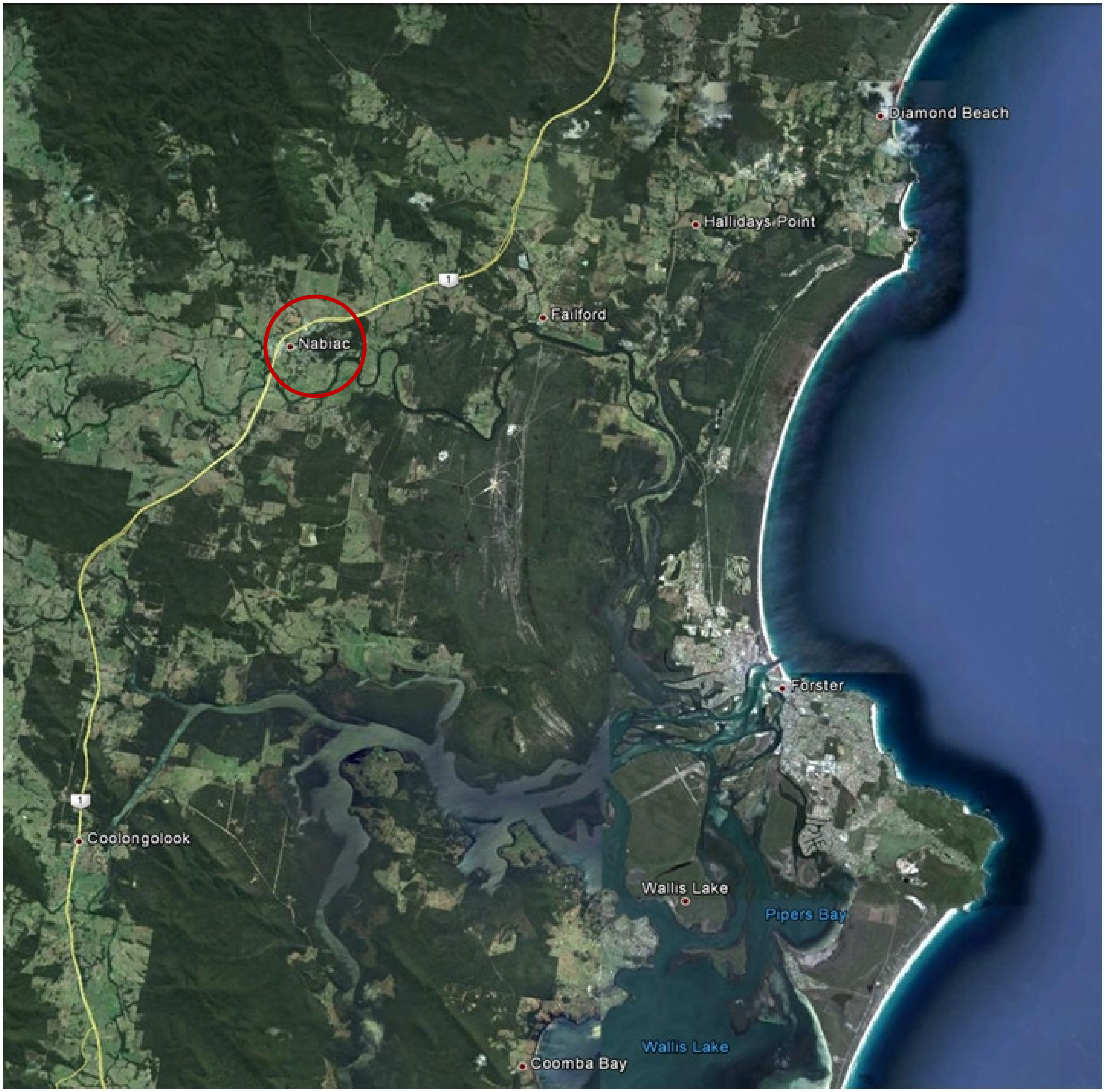
Figures

FIGURE 1
LOCALITY PLAN





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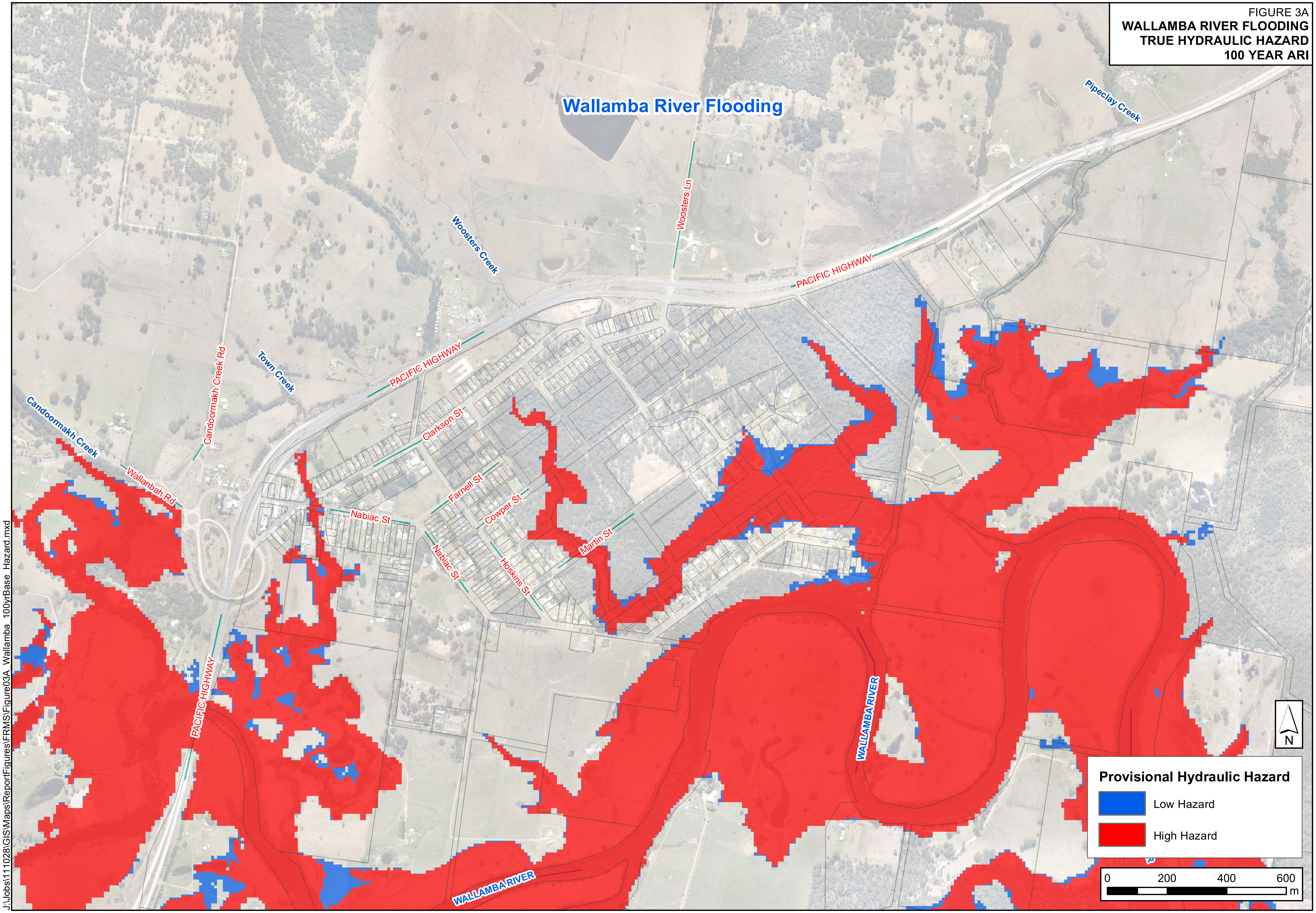

FIGURE 3A
WALLAMBA RIVER FLOODING
TRUE HYDRAULIC HAZARD
100 YEAR ARI

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Note 1: Properties in this area are subject to local overland flow. See report for Flood Planning Level guidance.

FIGURE 3B
LOCAL CATCHMENT FLOODING TRUE HYDRAULIC HAZARD 100 YEAR ARI

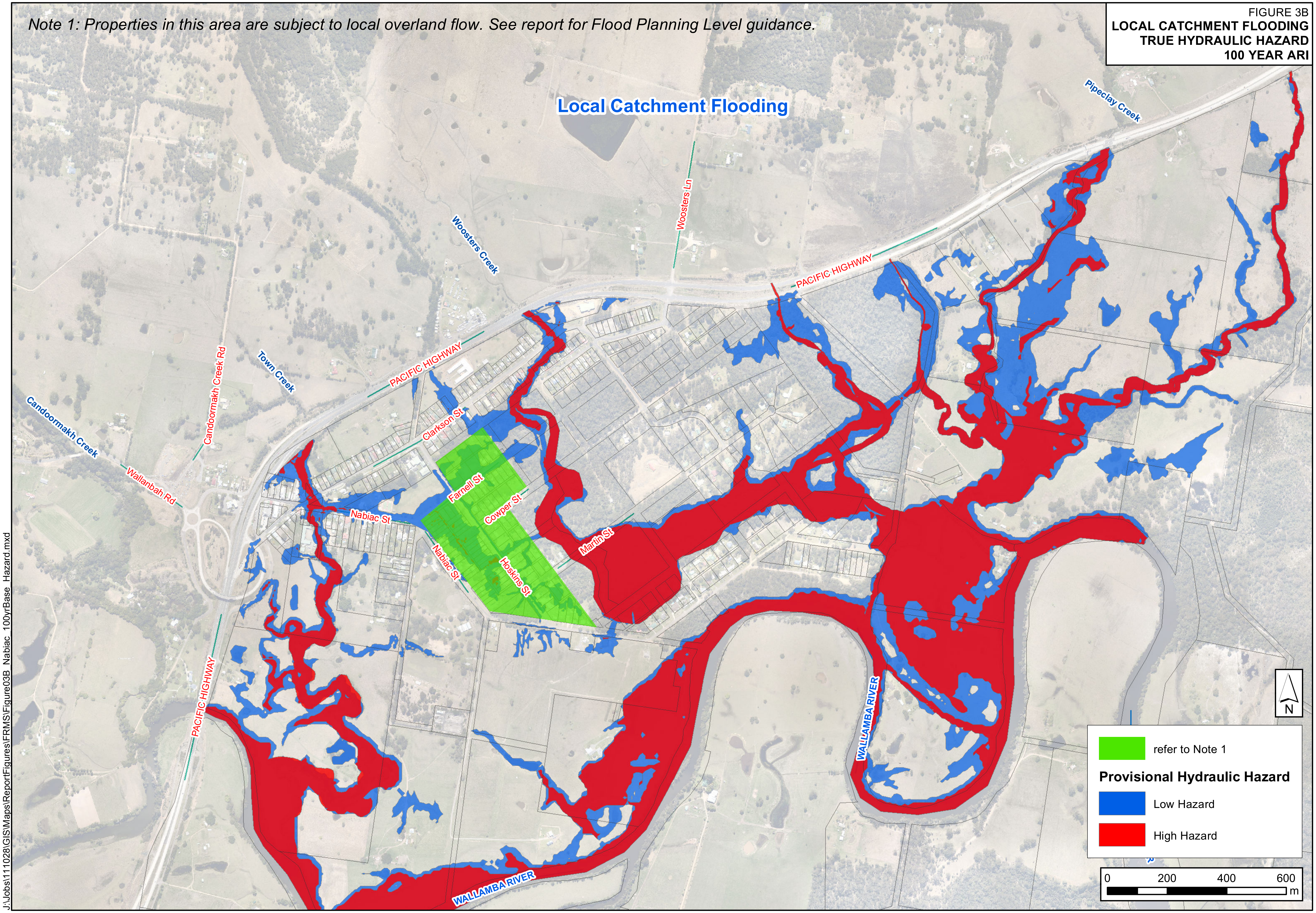

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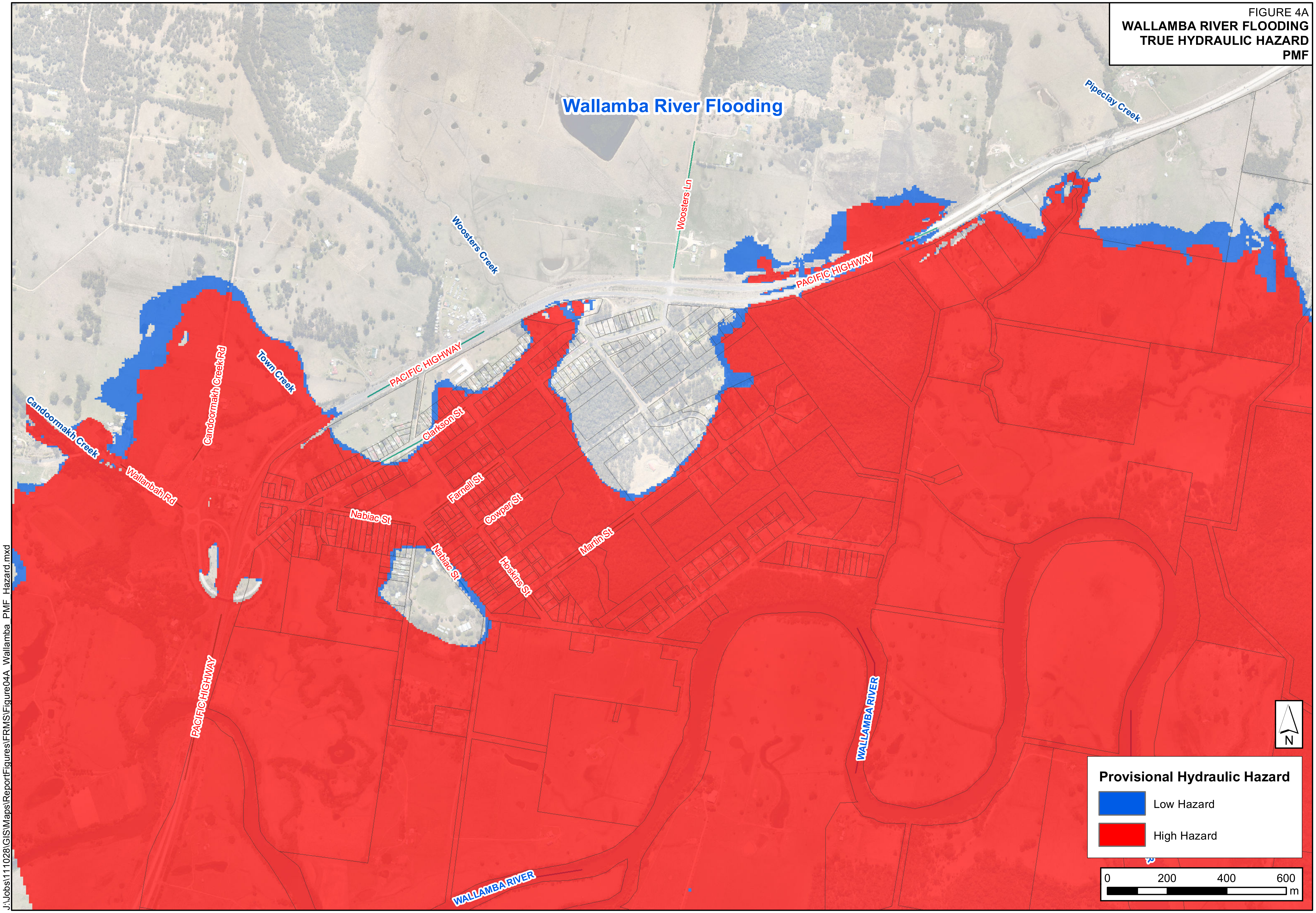
FIGURE 4A

WALLAMBA RIVER FLOODING
TRUE HYDRAULIC HAZARD
PMF



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Note 1: Properties in this area are subject to local overland flow. See report for Flood Planning Level guidance.

FIGURE 4B
LOCAL CATCHMENT FLOODING
TRUE HYDRAULIC HAZARD
PMF

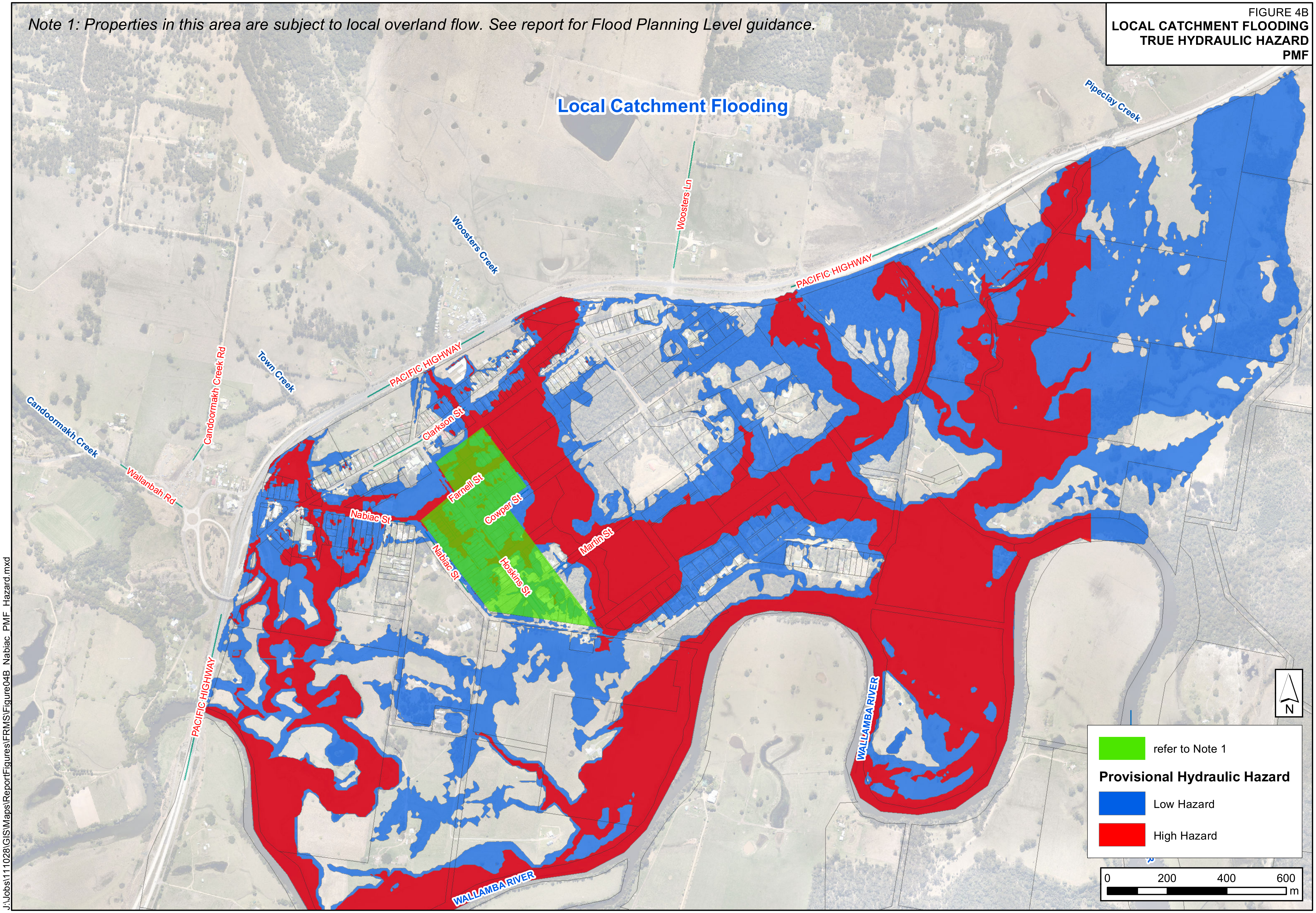

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FIGURE 5
WALLAMBA RIVER FLOODING
TRUE HYDRAULIC HAZARD
100 YEAR ARI +0.9m SEA LEVEL RISE

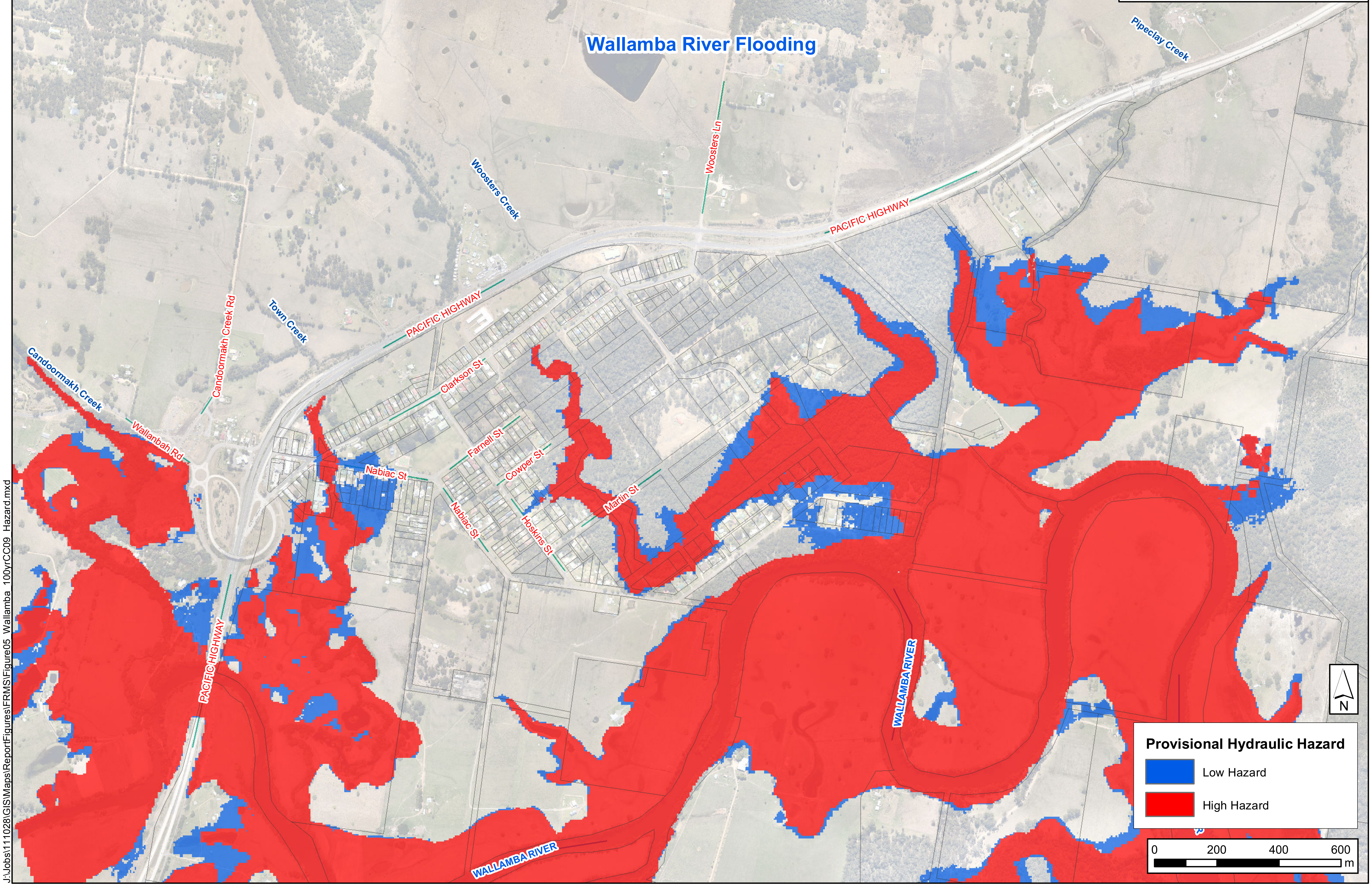

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FIGURE 6A
WALLAMBA RIVER FLOODING
TRUE HYDRAULIC HAZARD
100 YEAR ARI +30% RAIN+0.9m SEA LEVEL RISE

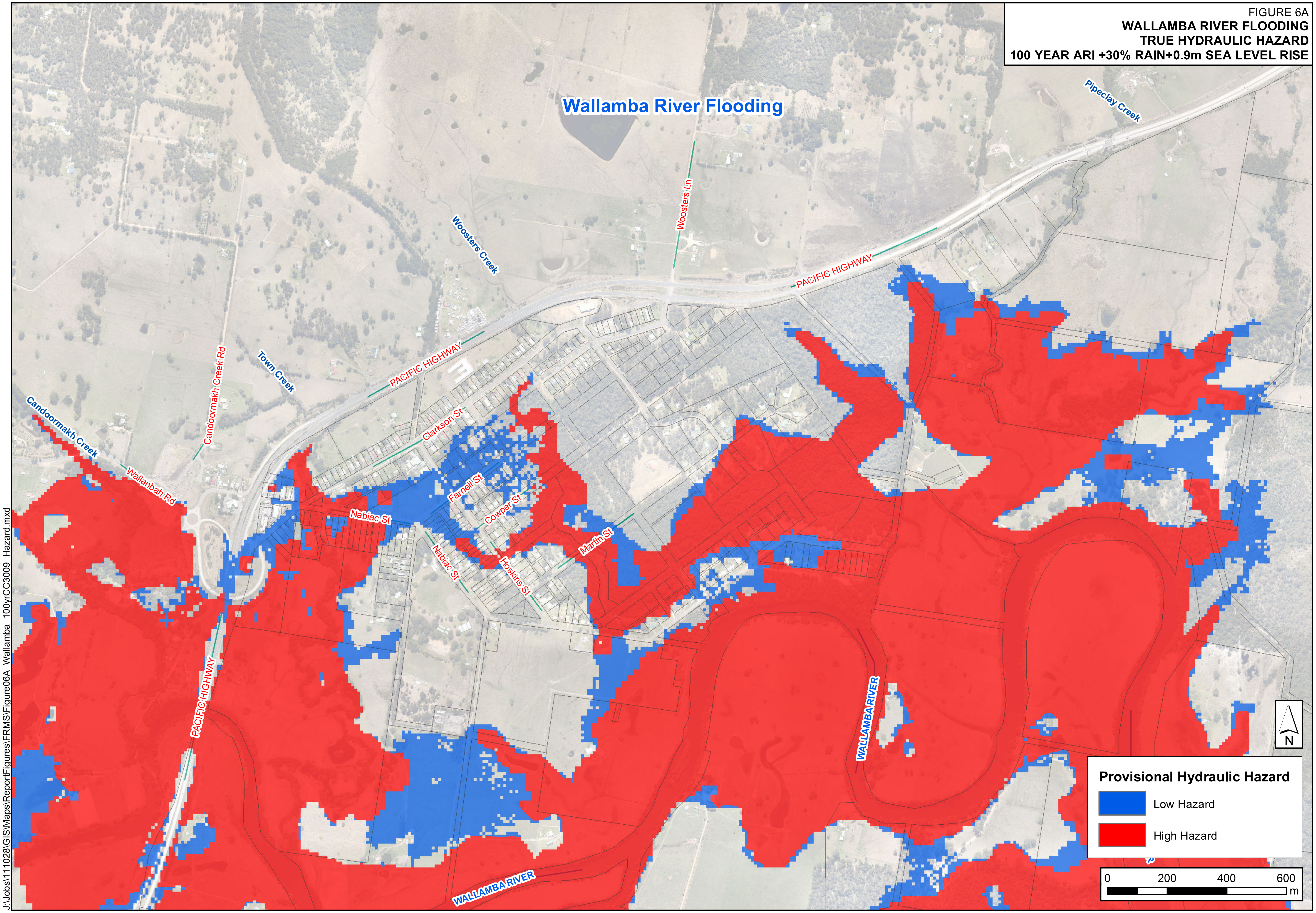

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FIGURE 6B

LOCAL CATCHMENT FLOODING
TRUE HYDRAULIC HAZARD
100 YEAR ARI +30% RAIN+0.9m SEA LEVEL RISE

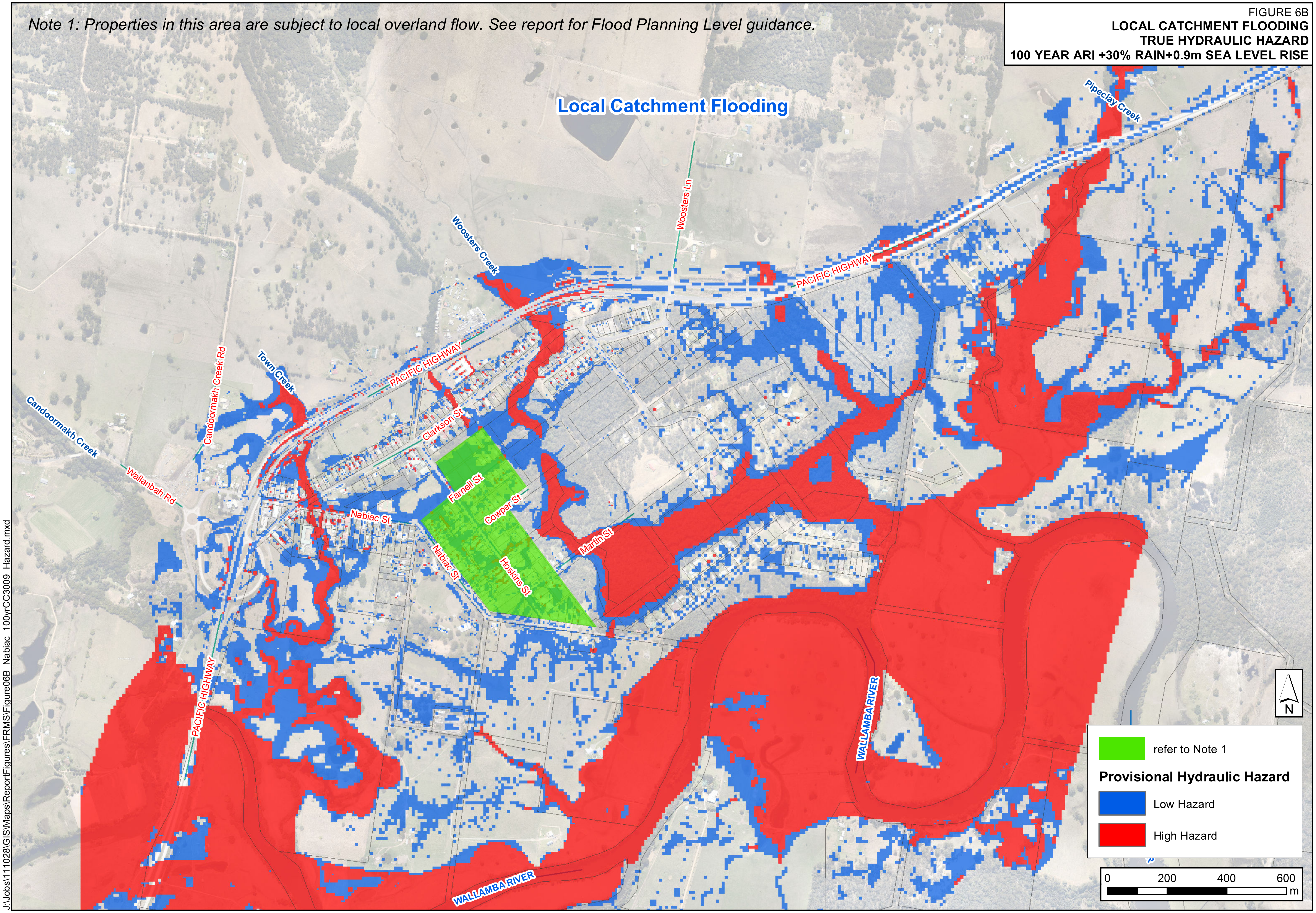

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FIGURE 7A
WALLAMBA RIVER FLOODING
HYDRAULIC CATEGORIZATION
100 YEAR ARI

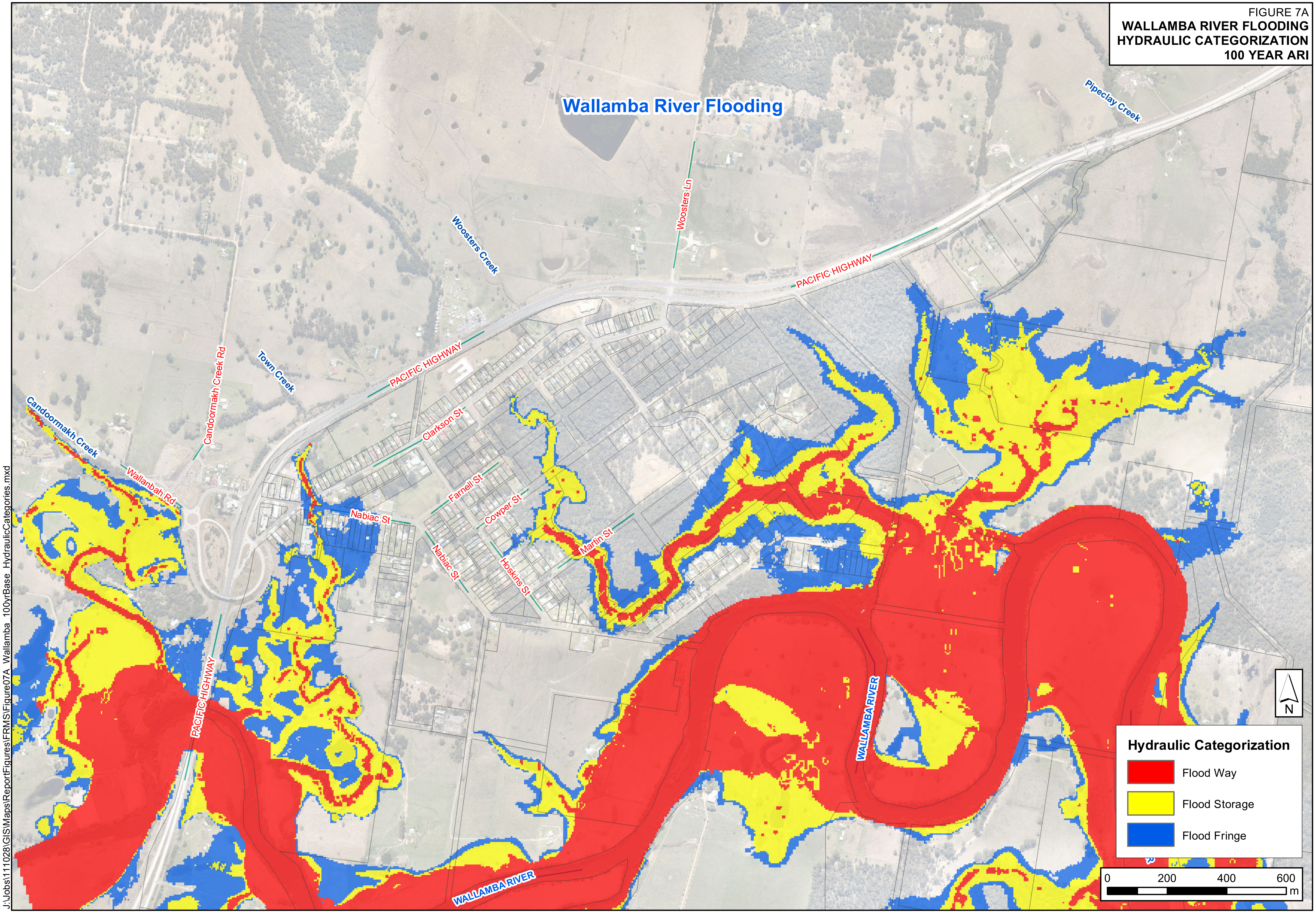

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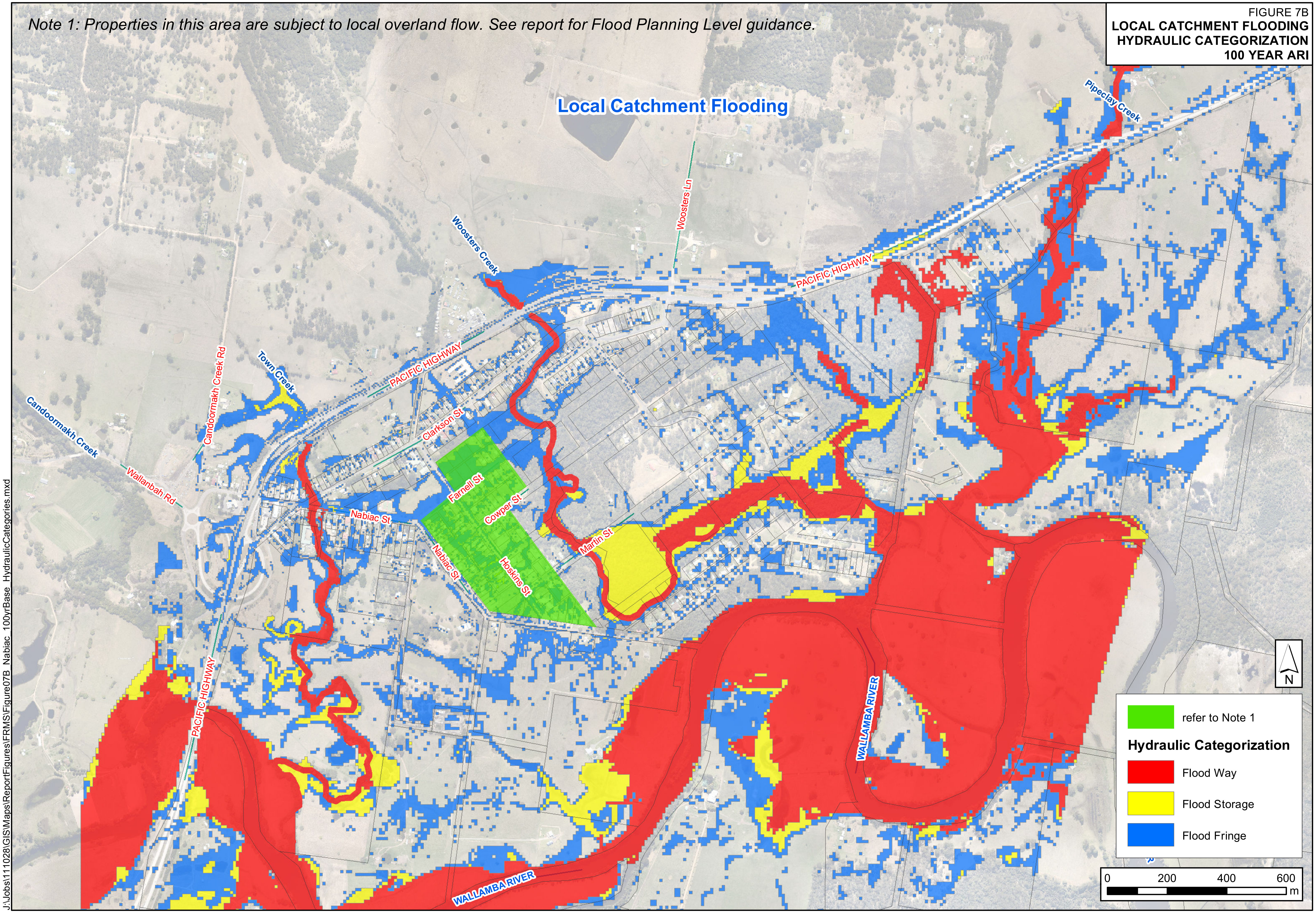
FIGURE 7B
LOCAL CATCHMENT FLOODING HYDRAULIC CATEGORIZATION 100 YEAR ARI

Note 1: Properties in this area are subject to local overland flow. See report for Flood Planning Level guidance.



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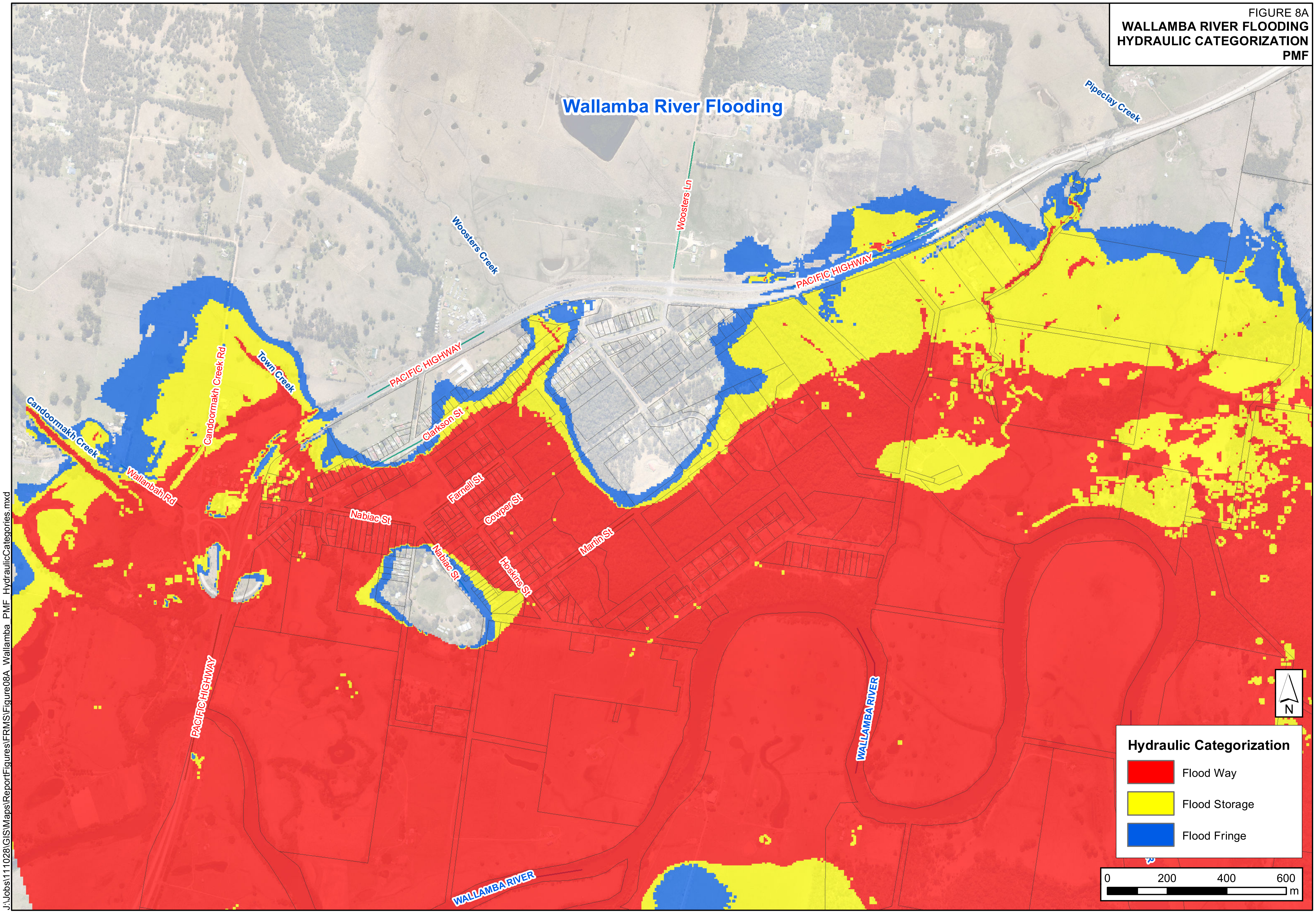

FIGURE 8A
WALLAMBA RIVER FLOODING
HYDRAULIC CATEGORIZATION
PMF
Wallamba River Flooding
Pipeclay Creek
Woosters Ln
Woosters Creek
PACIFIC HIGHWAY
Candoormakh Creek Rd
Town Creek
Candoormakh Creek
Wallanbah Rd
Clarkson St
Farnell St
Cowper St
Nabiac St
Hoskins St
Martin St
WALLAMBA RIVER
N
Hydraulic Categorization
Flood Way
Flood Storage
Flood Fringe
0
200
400
600
m
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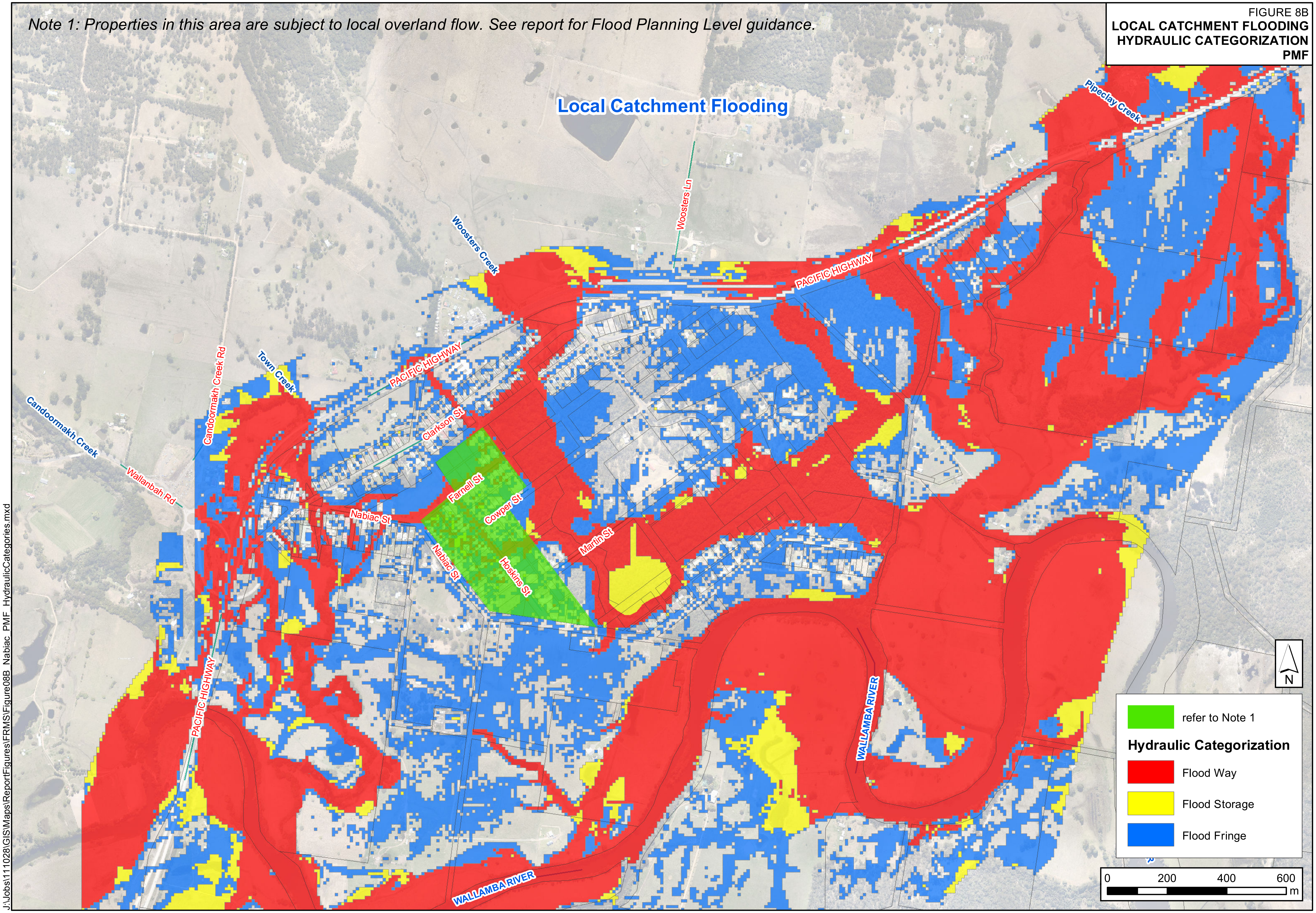

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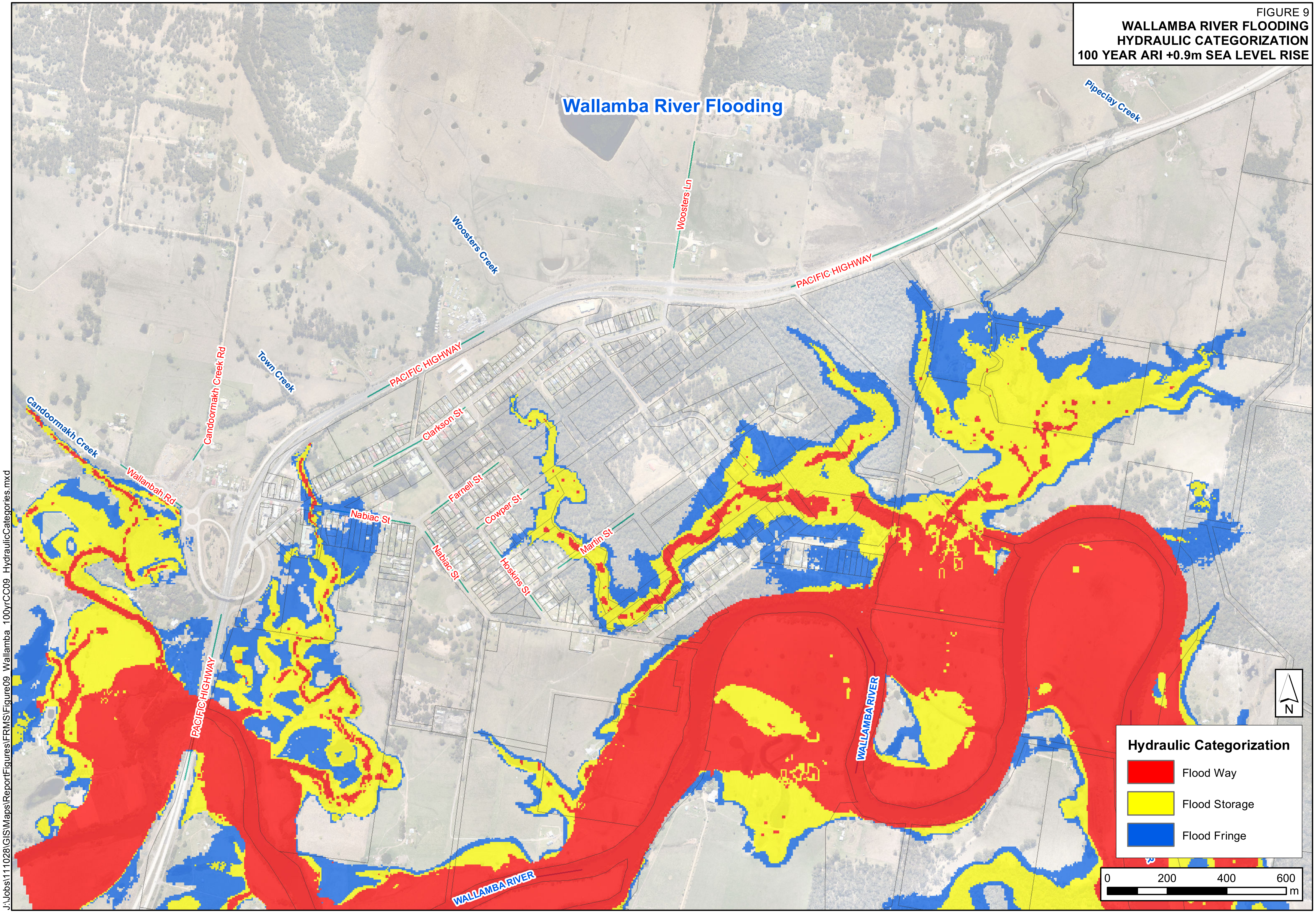
FIGURE 9
WALLAMBA RIVER FLOODING
HYDRAULIC CATEGORIZATION
100 YEAR ARI +0.9m SEA LEVEL RISE



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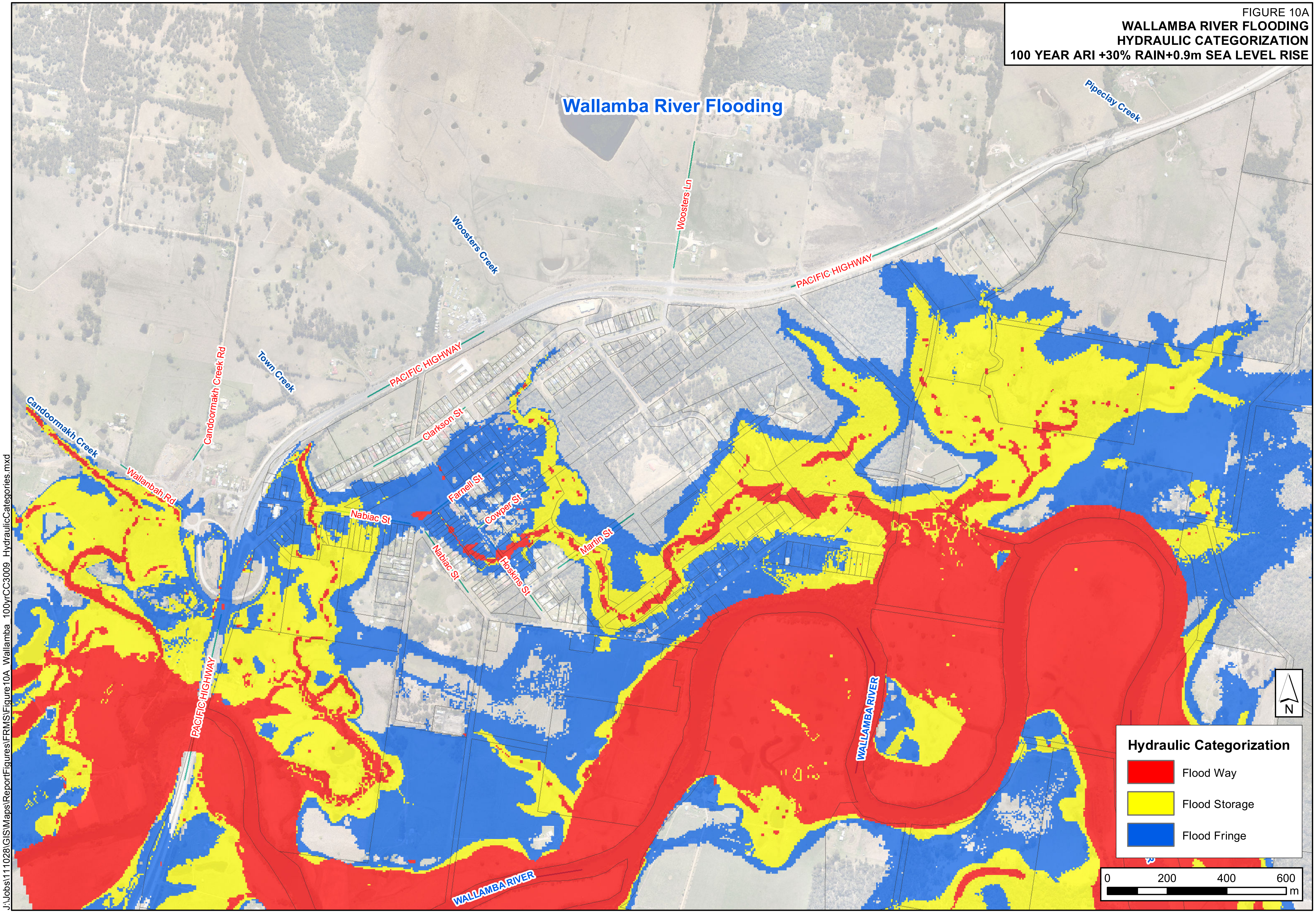
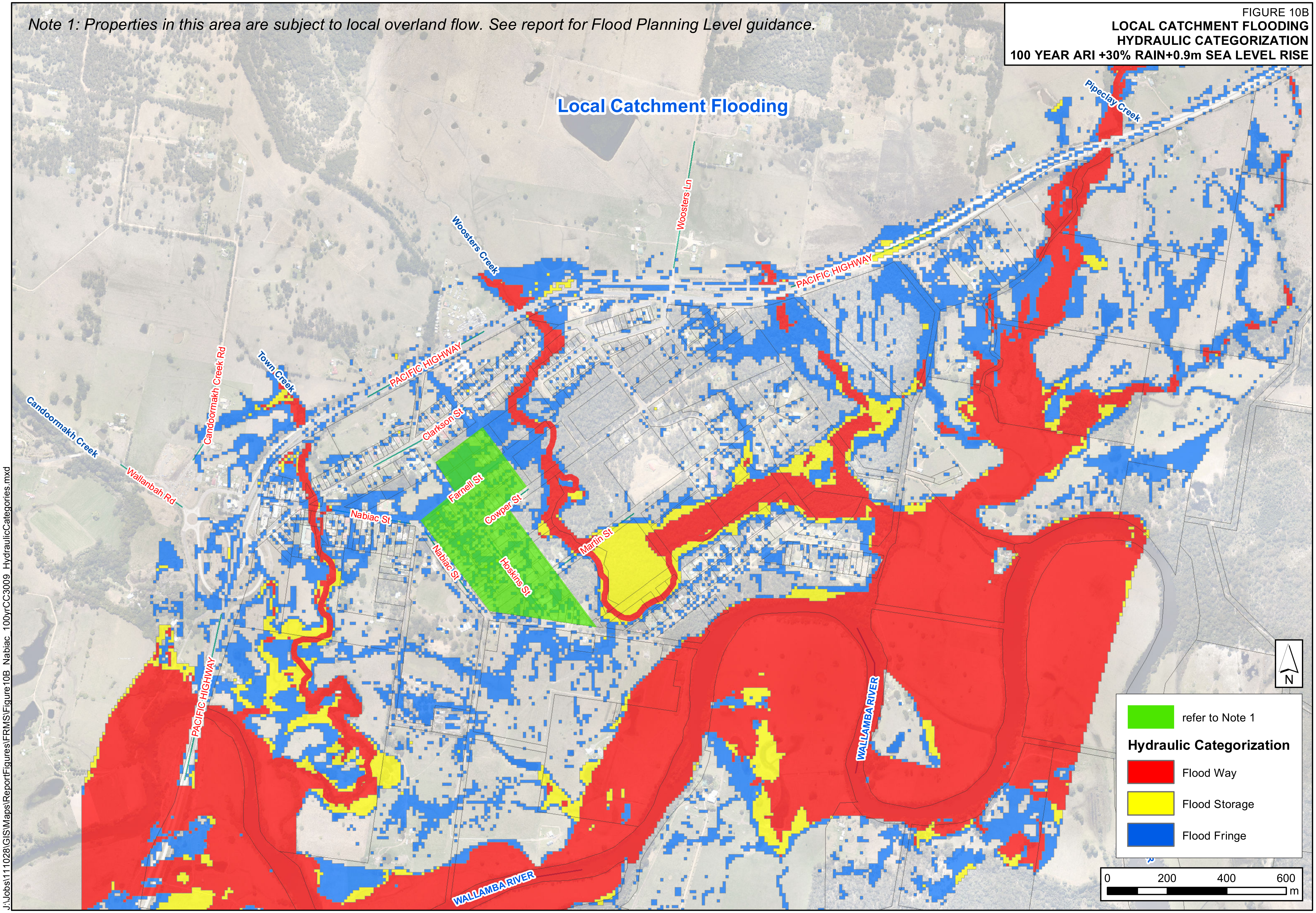


FIGURE 10A
WALLAMBA RIVER FLOODING
HYDRAULIC CATEGORIZATION
100 YEAR ARI +30% RAIN+0.9m SEA LEVEL RISE
Wallamba River Flooding
Pipeclay Creek
Woosters Ln
Woosters Creek
PACIFIC HIGHWAY
Candoormakh Creek Rd
Town Creek
Candoormakh Creek
Wallanbah Rd
Clarkson St
Farnell St
Cowper St
Nabiac St
Hoskins St
Martin St
WALLAMBA RIVER
N
Hydraulic Categorization
Flood Way
Flood Storage
Flood Fringe
0
200
400
600
m
J:\Jobs\111028\GIS\Maps\Report\Figures\FRMS\Figure10A_Wallamba_100yrCC3009_HydraulicCategories.mxd



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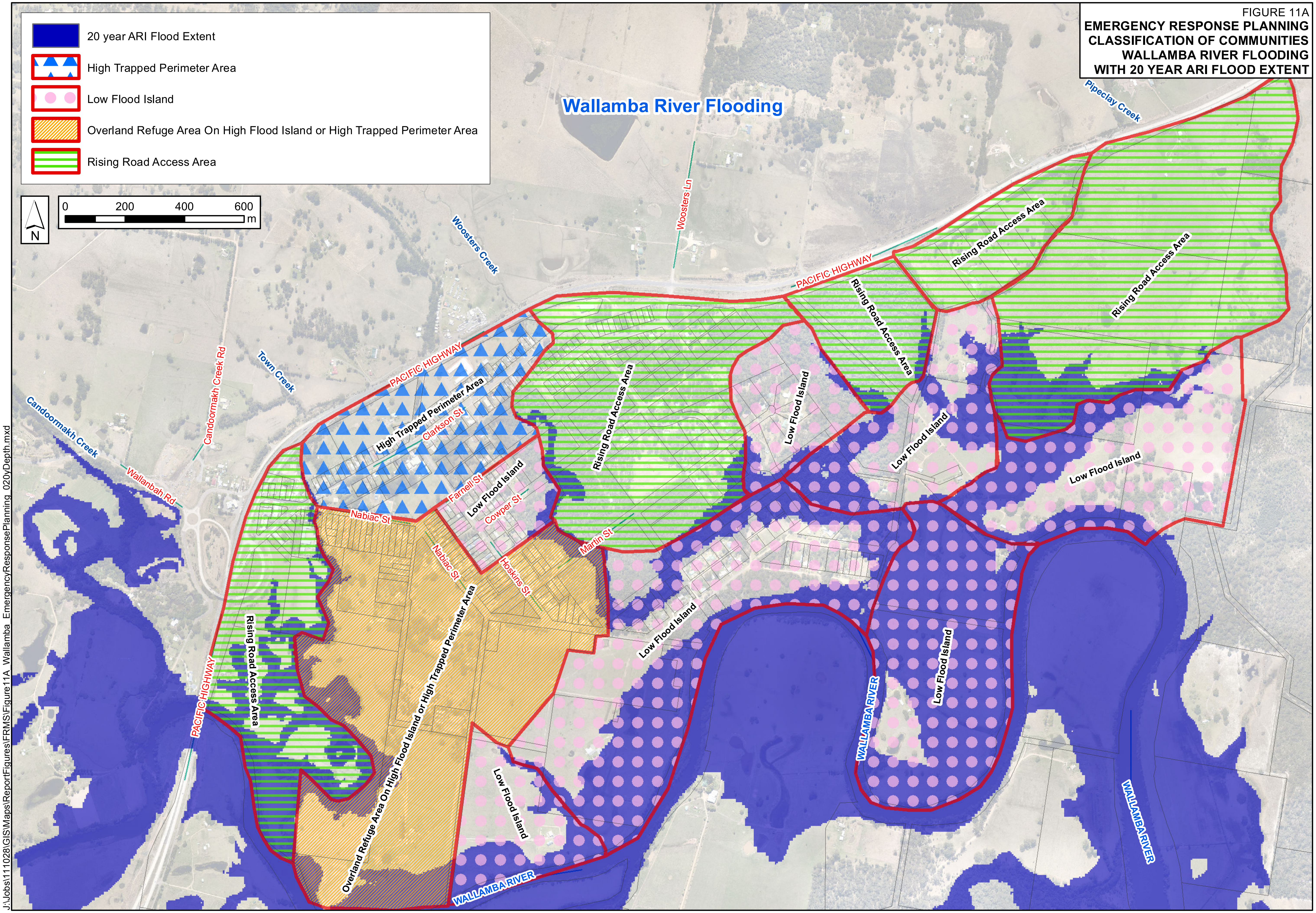
FIGURE 11A
EMERGENCY RESPONSE PLANNING
CLASSIFICATION OF COMMUNITIES
WALLAMBA RIVER FLOODING
WITH 20 YEAR ARI FLOOD EXTENT
20 year ARI Flood Extent
High Trapped Perimeter Area
Low Flood Island
Overland Refuge Area On High Flood Island or High Trapped Perimeter Area
Rising Road Access Area
N
0
200
400
600
m
Wallamba River Flooding
Pipeclay Creek
Woosters Ln
Woosters Creek
Town Creek
Candoormakh Creek Rd
Candoormakh Creek
Wallanbah Rd
PACIFIC HIGHWAY
High Trapped Perimeter Area
Clarkson St
Farnell St
Low Flood Island
Cowper St
Nabiac St
Hoskins St
Martin St
Rising Road Access Area
Overland Refuge Area On High Flood Island or High Trapped Perimeter Area
WALLAMBA RIVER
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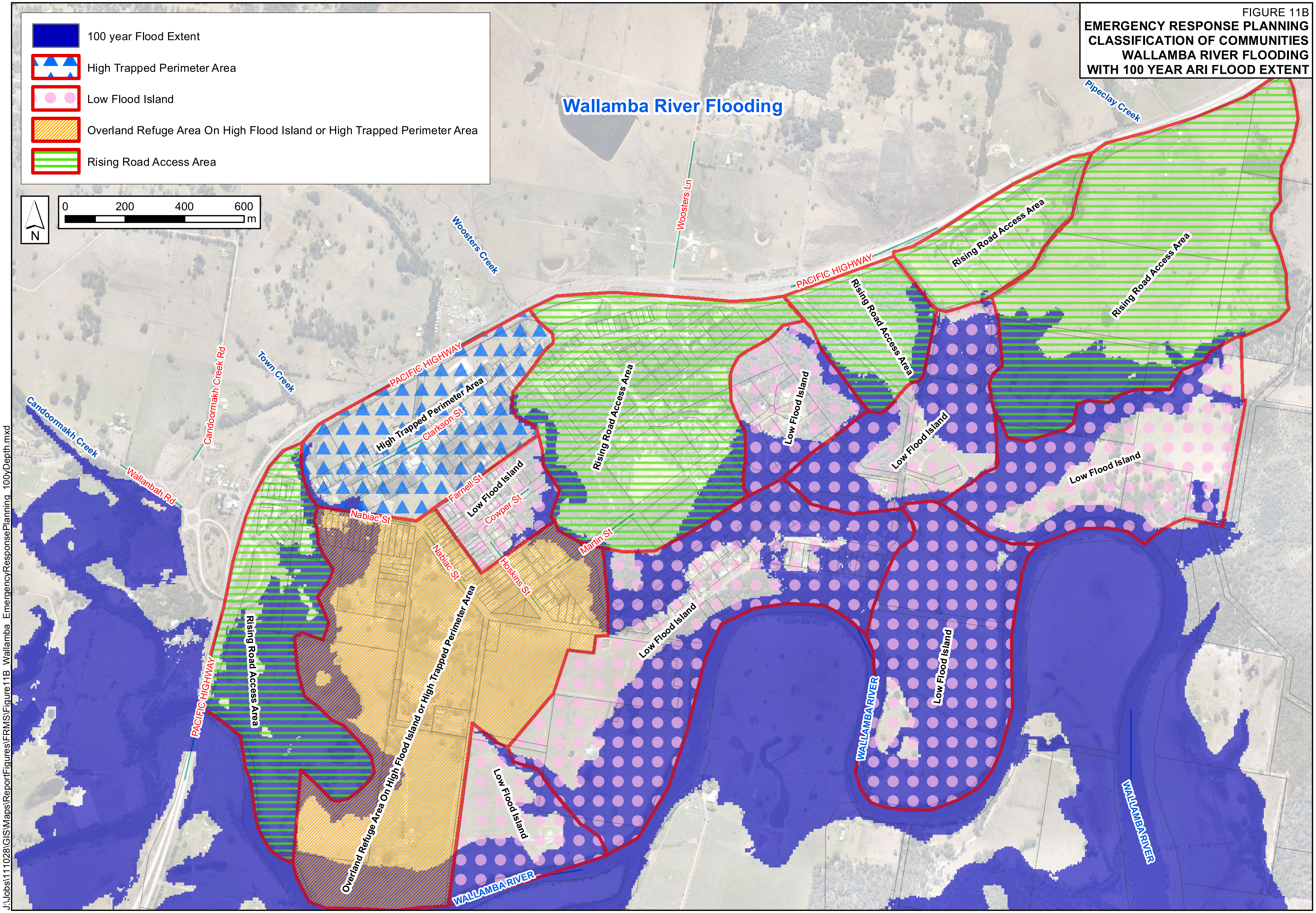

FIGURE 11B
EMERGENCY RESPONSE PLANNING
CLASSIFICATION OF COMMUNITIES
WALLAMBA RIVER FLOODING
WITH 100 YEAR ARI FLOOD EXTENT
100 year Flood Extent
High Trapped Perimeter Area
Low Flood Island
Overland Refuge Area On High Flood Island or High Trapped Perimeter Area
Rising Road Access Area
0
200
400
600
m
N
Wallamba River Flooding
Pipeclay Creek
Woosters Ln
Woosters Creek
PACIFIC HIGHWAY
Rising Road Access Area
Town Creek
Candoormakh Creek Rd
Candoormakh Creek
Wallanbah Rd
High Trapped Perimeter Area
Clarkson St
Low Flood Island
Farnell St
Cowper St
Nabiac St
Martin St
Hoskins St
Overland Refuge Area On High Flood Island or High Trapped Perimeter Area
WALLAMBA RIVER
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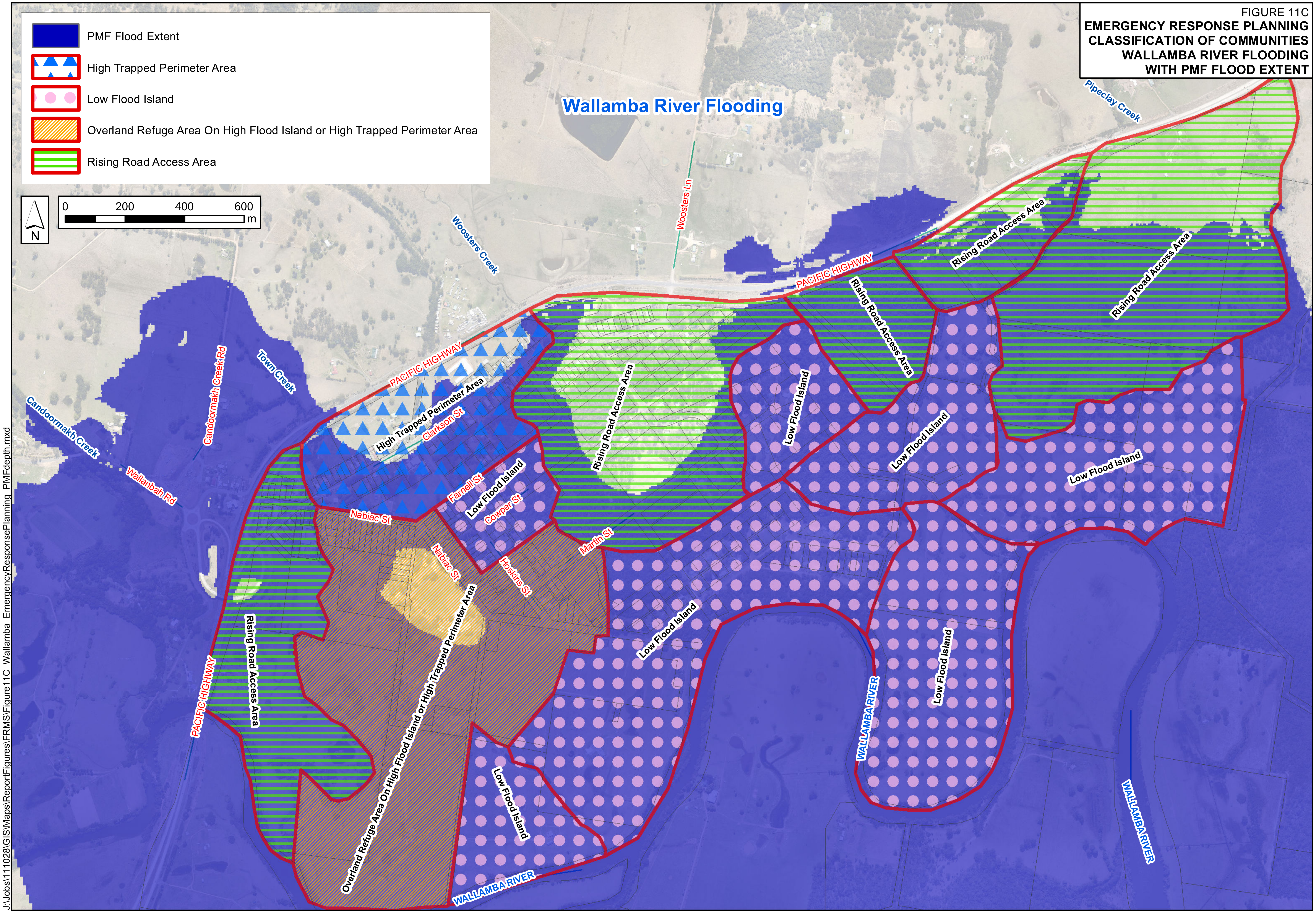
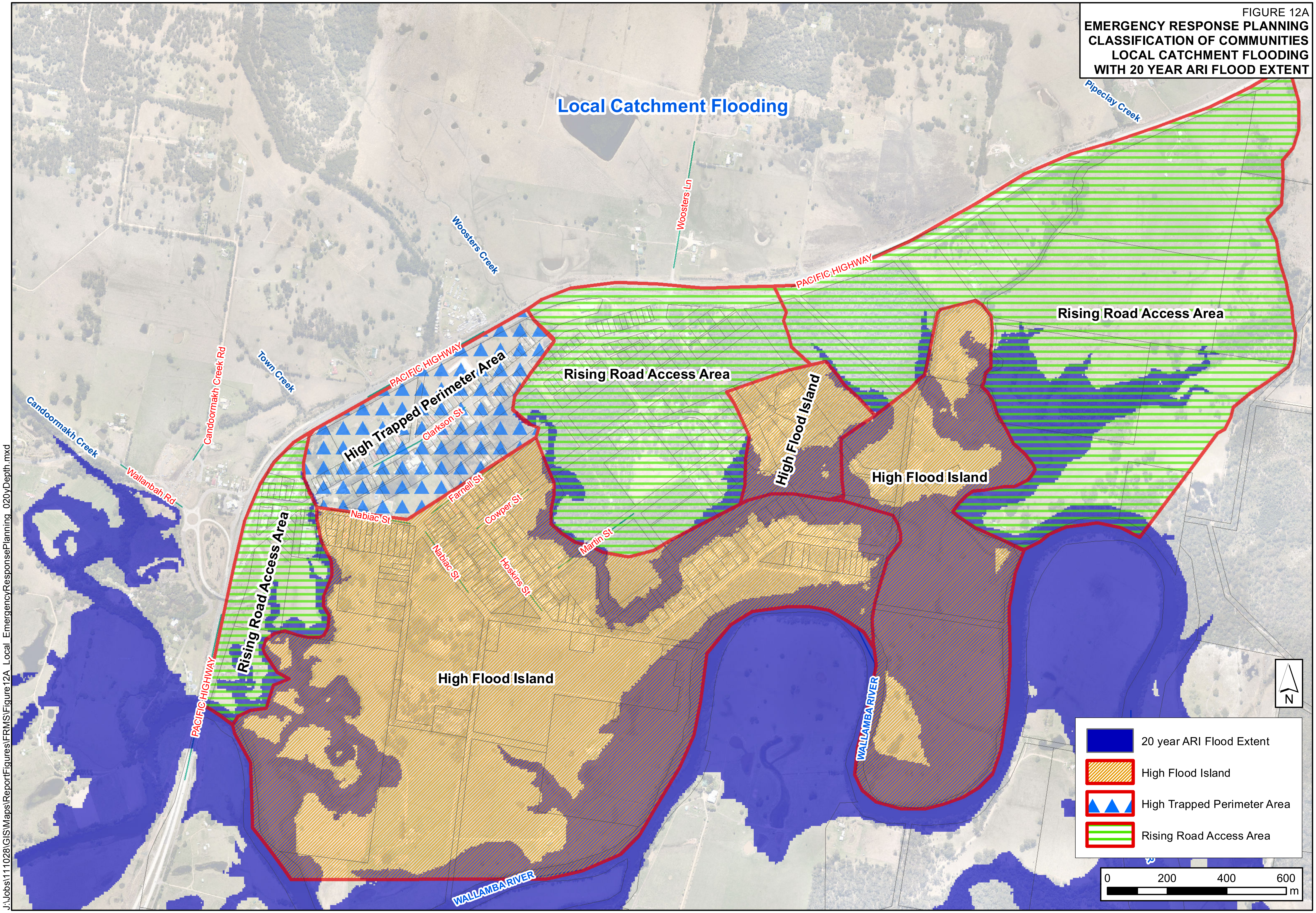


FIGURE 11C
EMERGENCY RESPONSE PLANNING
CLASSIFICATION OF COMMUNITIES
WALLAMBA RIVER FLOODING
WITH PMF FLOOD EXTENT
PMF Flood Extent
High Trapped Perimeter Area
Low Flood Island
Overland Refuge Area On High Flood Island or High Trapped Perimeter Area
Rising Road Access Area
0
200
400
600
m
N
Wallamba River Flooding
Pipeclay Creek
Woosters Ln
Woosters Creek
Town Creek
Candoormakh Creek Rd
Candoormakh Creek
Wallanbah Rd
PACIFIC HIGHWAY
High Trapped Perimeter Area
Clarkson St
Farnell St
Cowper St
Nabiac St
Hoskins St
Martin St
Rising Road Access Area
Low Flood Island
Overland Refuge Area On High Flood Island or High Trapped Perimeter Area
WALLAMBA RIVER

FIGURE 12A
EMERGENCY RESPONSE PLANNING CLASSIFICATION OF COMMUNITIES LOCAL CATCHMENT FLOODING WITH 20 YEAR ARI FLOOD EXTENT



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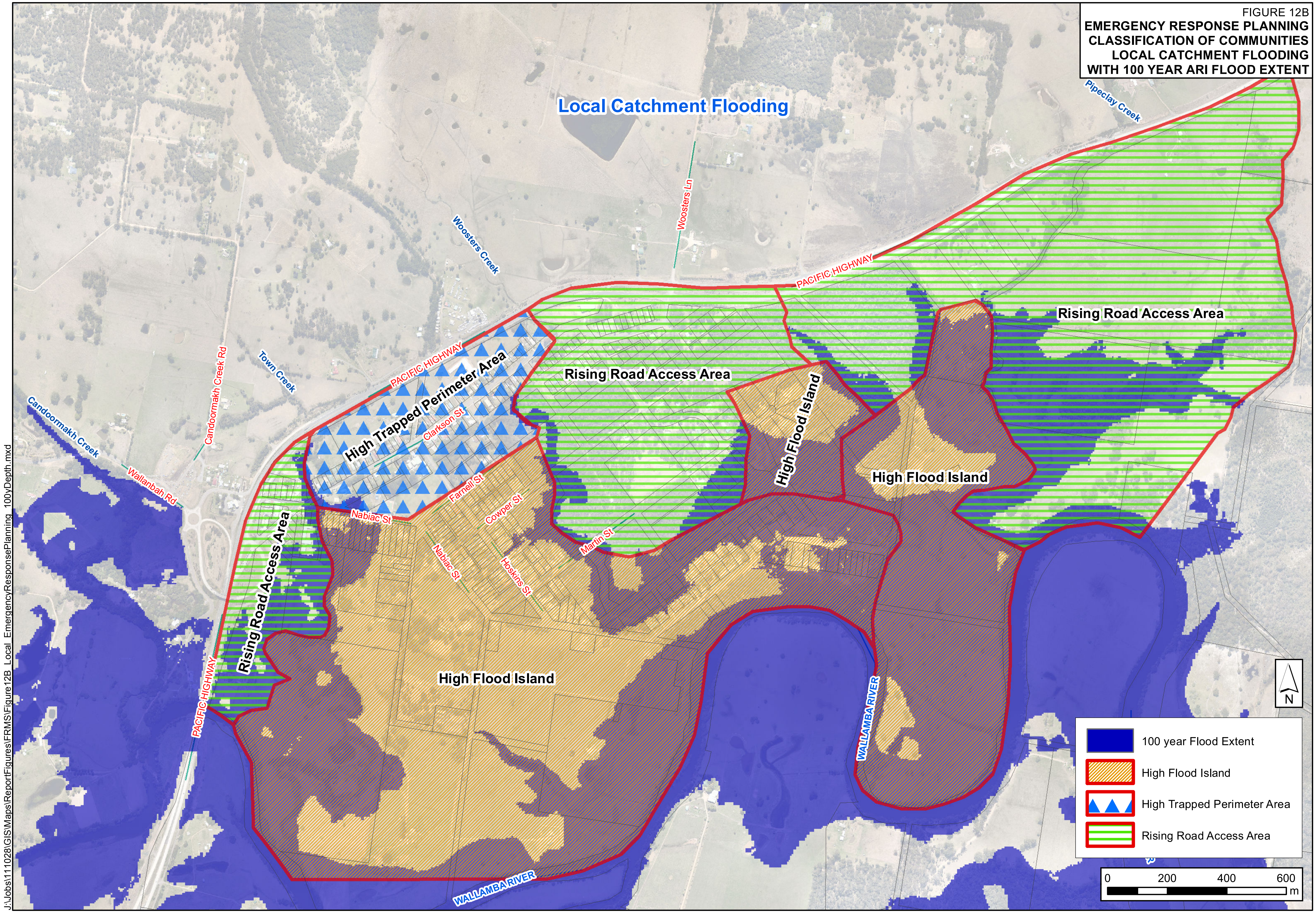

FIGURE 12B
EMERGENCY RESPONSE PLANNING
CLASSIFICATION OF COMMUNITIES
LOCAL CATCHMENT FLOODING
WITH 100 YEAR ARI FLOOD EXTENT
Local Catchment Flooding
Pipeclay Creek
Woosters Ln
Woosters Creek
Town Creek
Candoormakh Creek Rd
Candoormakh Creek
Wallanbah Rd
PACIFIC HIGHWAY
PACIFIC HIGHWAY
PACIFIC HIGHWAY
PACIFIC HIGHWAY
High Trapped Perimeter Area
Clarkson St
Rising Road Access Area
Rising Road Access Area
Rising Road Access Area
High Flood Island
High Flood Island
High Flood Island
Farnell St
Cowper St
Nabiac St
Nabiac St
Hoskins St
Martin St
WALLAMBA RIVER
WALLAMBA RIVER
N
100 year Flood Extent
High Flood Island
High Trapped Perimeter Area
Rising Road Access Area
0
200
400
600
m
J:\Jobs\111028\GIS\Maps\Report\Figures\FRMS\Figure12B_Local_EmergencyResponsePlanning_100yDepth.mxd

FIGURE 12C
EMERGENCY RESPONSE PLANNING CLASSIFICATION OF COMMUNITIES LOCAL CATCHMENT FLOODING WITH PMF FLOOD EXTENT

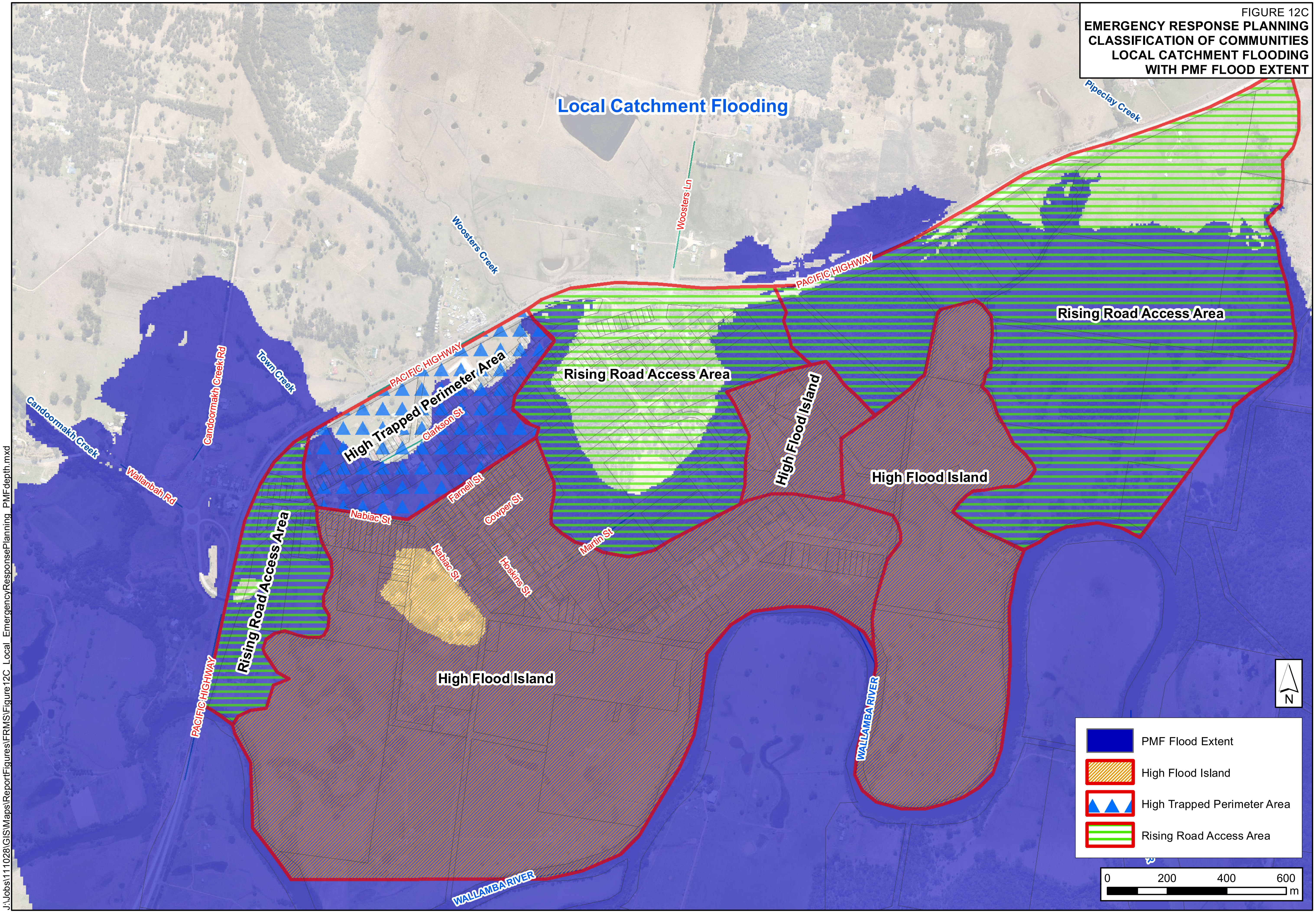

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FIGURE 13
PEAK FLOOD LEVEL COMPARISON LOCATIONS

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Great Lakes Local Environmental Plan 2012

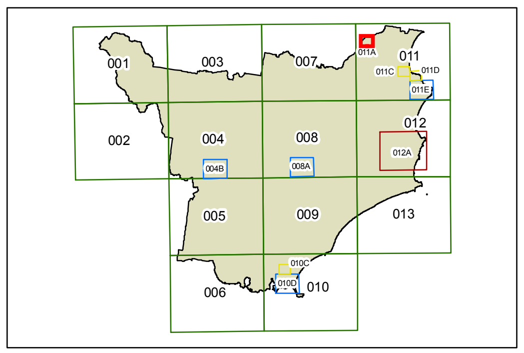
Land Zoning Map - Sheet LZN_011A

Zone

B1	Neighbourhood Centre
B2	Local Centre
B4	Mixed Use
B5	Business Development
E1	National Parks and Nature Reserves
E2	Environmental Conservation
E3	Environmental Management
E4	Environmental Living
IN1	General Industrial
IN2	Light Industrial
IN4	Working Waterfront
R2	Low Density Residential
R3	Medium Density Residential
R4	High Density Residential
R5	Large Lot Residential
RE1	Public Recreation
RE2	Private Recreation
RU2	Rural Landscape
RU3	Forestry
RU5	Village
SP2	Infrastructure
SP3	Tourist
W1	Natural Waterways
W2	Recreational Waterways

Cadastre

Cadastre 12/04/2010 © Land and Property Information (LPI)



N

0 200 400 Metres

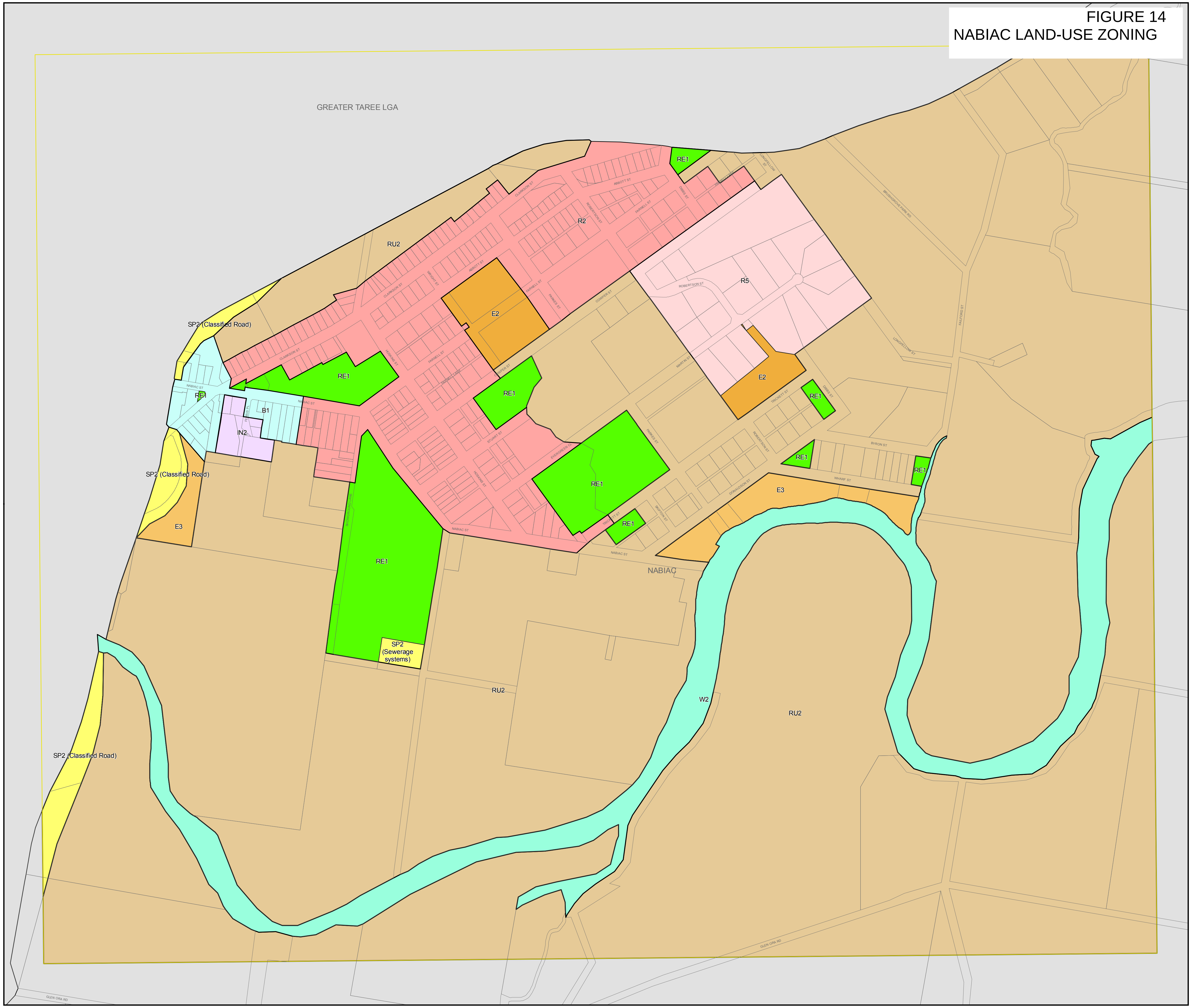
Scale:1:10,000 @ A3

Projection: GDA 1994 MGA Zone 56

Map identification number:

3400_COM_LZN_011A_010_20120413

FIGURE 14
NABIAC LAND-USE ZONING



Appendix A

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

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

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

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

	floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:
	$ the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
	$ water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or
	$ major overland flow paths through developed areas outside of defined drainage reserves; and/or
	$ the potential to affect a number of buildings along the major flow path.

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

	land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State=s rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to Awater level@. Both are measured with reference to a specified

	datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

Appendix C