



Narara Creek Floodplain Risk Management Study & Plan

Report

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HydroStorm Consulting
Golder Associates

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Foreword

The State Government's Flood Policy is directed towards providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Local Governments are responsible for the management of flood liable land under the Flood Policy. The State Government provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. In addition, the State Government's floodplain management grants program supports local government to manage flood risk. Assistance provided under this program is usually \$2 from the government for every \$1 provided by the Council.

Another State Government agency, the State Emergency Services, also assists Councils in managing the flood risk for local communities.

The Flood Policy advocates a flood risk management process based on the following sequential stages:

- | | |
|-------------------------------------|--|
| 1. Formation of a Committee | To oversee the flood risk management process. It is established by Council and includes community group representatives, State Government representatives and other relevant stakeholders. |
| 2. Data Collection | To facilitate flood risk management by collecting past data such as flood levels, rainfall records, land use, soil types etc. |
| 3. Flood Study | Determines the nature and extent of the existing flood behaviour in the floodplain. |
| 4. Floodplain Risk Management Study | Evaluates management options to manage flood risk in the floodplain. |
| 5. Floodplain Risk Management Plan | Preparation and formal adoption by Council of a management plan for the floodplain. |
| 6. Implementation of the Plan | Implementation of flood management options to protect existing development. Use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard. |

Data Collection and the Flood Study for Narara Creek catchment was completed in 2011 and subsequently revised in 2017. This report forms the fourth and fifth stages of the management process for the Narara Creek Floodplain and is based on the latest flood study results.

Following Council amalgamations under the State Government initiative, the Central Coast Council established an advisory committee known as the Catchment and Coast Committee – Brisbane Water and Gosford Lagoons. The role of this committee is to advise the Council on all matters relating to Council's responsibilities in relation to sustainable management of its coastal, estuarine, waterways, catchment and

flood liable areas. The Committee includes Councilors, Council Staff (non-voting) and representatives from the community.

Central Coast Council (former Gosford City Council) has prepared this document with financial assistance from the NSW Government through its 2012-13 Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage (now Department of Planning Industry and Environment).

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Executive Summary

Central Coast Council (Council) commissioned Golder Associates in association with HydroStorm Consulting to undertake a *Floodplain Risk Management Study* and prepare a *Floodplain Risk Management Plan* for the floodplain of Narara Creek and its tributaries. The *Floodplain Risk Management Study* follows a flood study (completed in 2013 and revised in July 2018 (Golder, 2018), which refined the understanding of complex flood behaviour of Narara Creek and its tributaries previously examined in separate studies for the tributary catchments. A *Floodplain Risk Management Plan* will draw upon the results of the assessment carried out for various floodplain management measures presented in the *Floodplain Risk Management Study*.

Study Objectives

The objectives of the Floodplain Risk Management Study are to:

- review Councils existing environmental planning policies and instruments.
- identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events.
- assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future.
- consider whether the proposed works and measures might produce adverse effects (environmental, social, economic or worsened flooding) in the floodplain and whether these effects could be reduced.
- examine the present flood management procedures, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's development and disaster planning requirements.
- examine ways in which the creek and floodplain environment may be enhanced by exploring the possibility of a strategy for vegetation planning that may create a valuable corridor of vegetation without having a detrimental effect on flooding.
- review the flood risk management measures identified in previous studies (refer Appendix E) or implemented as a management action of previous flood risk management plans. The review is required to ensure that those measures, which may have been suitable for flood behaviour established in the previous flood studies, may not be suitable for the flood behaviour established in the current flood study (Golder, 2018).

The Catchment

The Narara Creek catchment lies to the north of the Brisbane Water Estuary. Figure ES1 shows the extent of the catchment boundary and primary sub-catchments. The central and eastern parts of the catchment are densely populated with the primary land use being residential. Since the flood study review (Golder, 2018) a major residential development has occurred within the Narara Creek Catchment, at Research Road, Narara.

In the lower catchment, a major industrial area at West Gosford and a minor one at Glennie St West along with the commercial centres at Brookes Avenue, Wyoming and Lisarow are the primary sources of economic activity in the catchment.

The floodplain widens at the confluence of Brisbane Water Estuary, as the tidal limit extends approximately 5 km upstream of the Central Coast Highway, this significantly influences the flood behavior of the Narara Creek catchment.

The Central Coast Highway, The Pacific Highway, Manns Road, Showground Road and the Narara Valley Drive are the major roads through the catchment.

The Main Northern Railway also passes through the catchment with several stations servicing the area. In April 2015 Transport for NSW (TNSW) completed two passing loops between Gosford and Narara Stations so slow-moving freight trains on the Main North Line can wait while passenger services operate in a timely fashion. The effect of duplication of railway line on the floodplain has been examined further in this study.

Other major infrastructure/utilities in the catchment include the Gosford Hospital, North Gosford Private Hospital, Gosford Golf Club and the Racecourse/The Entertainment Grounds. Narara Valley High School along with several public schools also service this catchment. The critical infrastructure with respect to flood behaviour has been considered as part of emergency management.

The Narara Creek catchment (Figure ES1) has a total area of 46.7 km² and comprises seven major sub-catchments. The Review of the Narara Creek Flood Study (2018) has analysed flood behaviour for each individual tributary as well as the complex interaction at the tributary junctions. Understanding this flood behaviour is key to identifying effective flood risk mitigation options.

The Council has implemented some measures of a Rivercare Plan (Patterson Britton, 1997) in the catchment to improve the health of the waterways and to reduce the sediment load to Brisbane Water. The works carried out under this plan were primarily bank stabilisation works for various creeks in the catchment.

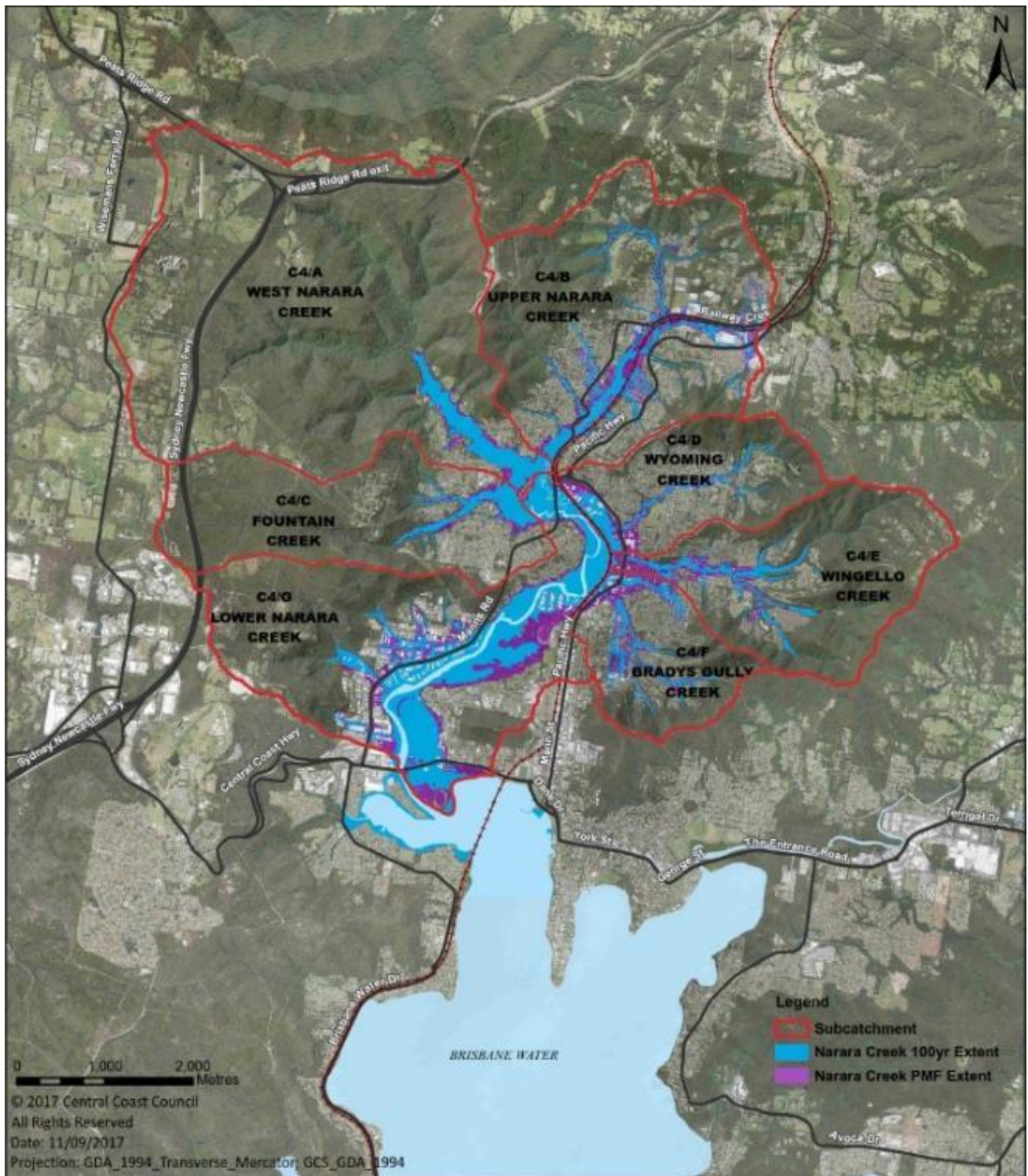


Figure ES1: Narara Creek Catchment

Flood Mechanisms and Behaviour

Narara Creek is the primary channel for conveyance of floodwaters through the catchment. Several large tributaries discharge into the main channel, which ultimately discharges to Fagans Bay in Brisbane Waters.

With the land use ranging from forest to highly urbanised areas within the catchment, the flood producing mechanisms are varied and complex. With concurrent flooding from various tributaries, the existing flood

behaviour in Narara Creek and the low-lying areas of various tributary catchments to a large extent is dependent on flood arrival times at various tributary junctions.

The upper reaches of various tributaries are independent of the 'backwater' influence of Narara Creek. However, the flood risk in general is low in the upper reaches and it is the lower reaches, where the flood behaviour is complex and a higher flood risk is manifested.

Storm Surge

Storm surge is an abnormal rise in seawater, typical during East Coast Low pressure systems, experienced periodically on the Central Coast and is measured as the height of the water above the normal predicted astronomical tide. A major event, which raised the Brisbane Water levels, occurred in 1974 (1% to 0.5% AEP) and more recently in 2015 (20% AEP).

The lower reaches of the study area are affected by flooding from Brisbane Water. The recent Brisbane Water Foreshore Floodplain Risk Management Study and Plan (Cardno 2015) has investigated this flooding and identified options for managing flood impacts. The reported 1% AEP flood level at the mouth of Narara Creek is 1.64 m AHD (Cardno, 2010). In the absence of creek flooding, the impact of Brisbane Water flooding would extend along Narara Creek to Carrington Street, Narara. On the other hand, the 1% AEP creek flooding (mainstream) is dominant along Narara Creek approximately to Garnet Adcock Memorial Park, downstream of Central Coast Highway bridge. Beyond this point, Brisbane Water flooding is dominant.

It is important to note that the previous flood studies undertaken in the early 1990s for various sub-catchments have potentially underestimated the flood levels along the lower Narara Creek. Those studies did not consider the combined impact of flooding in various sub-catchments nor any allowance was made for the sea level rise or increased rainfall intensity due to climate change. While analysing the major food event of 1992, a previous study (Kinhill, 1993) has reported that flood levels are potentially underestimated because of the lack of concurrent analysis of all the catchments.

The hydraulic modelling undertaken for the current study included all major structure and major drainage networks above 600 diameter pipes. While representative of flooding more broadly, the modelling was restricted to a grid size of 5m x 5m i.e. the smallest scale on which the flood behaviour is defined within the catchment. This definition of flood behaviour is far more detailed than produced in previous studies. All the major infrastructure, including bridges and culverts, were included in the model for the purposes of modelling flood management options and determining the flood planning area, including sensitivity analysis to climate change.

Mainstream Flooding

Mainstream flooding is associated with runoff generated from the catchment and then travelling through the major creek system within the catchment. Flooding starts when the capacity of the creek is exceeded. The creek gradient plays a major role in defining the floodplain. In the upper reaches of the study area, the gradient of various tributary creeks is steep, and the floodwaters are generally contained within a narrow floodplain. However, overland flow through the developed areas, along with the presence of street drainage, can have a significant impact away from the creek flooding.

In the middle reaches, where the tributaries join the Narara Creek, the flood arrival time from various tributaries plays an important role, as coincident arrival of floods from these tributaries can increase the flood hazard significantly.

In the lower reaches, near the Central Coast Highway, the floodplain widens significantly. The racecourse flood storage contributes significantly to the capacity of wide floodplain at this location and is of critical importance with respect to flood function. The lower parts of the catchment are also affected by coastal flooding. Elevated Fagans Bay levels can enhance the impact of the flooding from the catchment.

Overland Flooding

In addition to the flooding from the creeks, several areas in the catchment are affected by significant overland flow during flood events. The runoff in the catchment starts as the overland flooding and if street drainage is available, would enter the drainage system and would be carried to the nearby creek. However, if the street drainage is not available, or is under capacity, overland flow would occur on the street, and depending on the terrain may travel through the properties or down the street.

The industrial area in West Gosford is a prime example of this behaviour. Properties in this area, which lie west of Manns Road are affected by overland flooding due to the limited capacity of street drainage in this area.

Another significant factor in exacerbating the overland flooding is that the street drainage in the low-lying areas discharges into the nearby creeks, which are also likely to be in flooded conditions, thus limiting discharge from the street drainage.

Erosion

In addition to the direct risk from flooding, erosion and accretion of fluvial deposits due to sediment transport from the catchment or erosion of waterway banks affects the flood behaviour. Bank erosion also affects the stability of adjacent properties. The Council has already investigated a few affected properties along the Showground Road. Council prepared a Rivercare Plan (Patterson Britton, 1997) to improve creek stability in various parts of the study area. Under this program works have been carried out in various creeks such as the works carried out in lower reaches of Wyoming and Wingello Creeks. The Rivercare program was suspended during the process of Pacific Highway Upgrade concept design and community consultation. This program should be restarted to improve the conveyance and health of the creek systems.

Culvert Blockage

Culvert/Bridge blockage due to natural and anthropogenic debris has also occurred in the past in a major flood event. Private bridges in Brady Gully catchment were washed away and lodged at the culvert entrance downstream, causing flooding of the nearby properties. Natural debris such as uprooted vegetation, slumped creek banks etc., can also result in blockage of culverts.

These flood mechanisms both in isolation and in combination are the basis for floodplain management of this catchment. Sensitivity analysis has been completed within the flood study to gain an understanding of blockage on nearby properties.

The major areas of historical flooding in the Narara Creek catchment are highlighted in Figure ES4 & ES5.

Historic Flooding

Significant flooding events occurred within the Narara Creek catchment between October 1985 and February 1990, with flooding occurring mostly in the lower floodplain. During the 1985 event, 41 residences and 21 commercial /industrial premises were inundated above floor level (PWD Report No87045). The most

severely affected areas, where flood depths were up to one meter above the floor level, were in the Rowena Road and Showground Road areas.



Figure ES2: A Flooded Property at Showground Road Narara-14 October 1985

There was a significant flood event in February 1992, which resulted in widespread flooding across the upper and lower catchments. Subsequent analysis estimated that this event was slightly rarer than a 1% Annual Exceedance Probability (AEP) and it was generally agreed that it was the worst flood event on record (Patterson Britton, 1995).



Figure ES3: Gavenlock Oval Flood level mark 3 bricks under bottom of window – February 1992

The two historic events illustrated in Figures ES2 & ES3 highlight the severity of flooding that needs to be addressed in this floodplain risk management study. Figures ES4 and ES5 show the flood extent during the February 1992 flood event.

Several major floods in the past have been observed in the catchment. Historic flood levels recorded on Narara Creek at Showground Road are presented in the following table. The 1% AEP design flood for the present study is also presented in this table for comparison purposes.

Historical Flooding (AHD Range) Recorded on Narara Creek at Showground Road								1% AEP Design Flood Level (2018 Study)
Year	1949	1956	1974	1977	1978	1985	2007	
Height AHD (M)	3.0 to 4.1	2.9*	2.4 to 3.0	2.2 to 2.7	2.2 to 2.8	3.3 to 3.8	3.0*	3.90

* denotes adopted level

Years 1949 to 1985 - Source Lower Narara Creek Flood Study December 1988, Public Works Report 87045

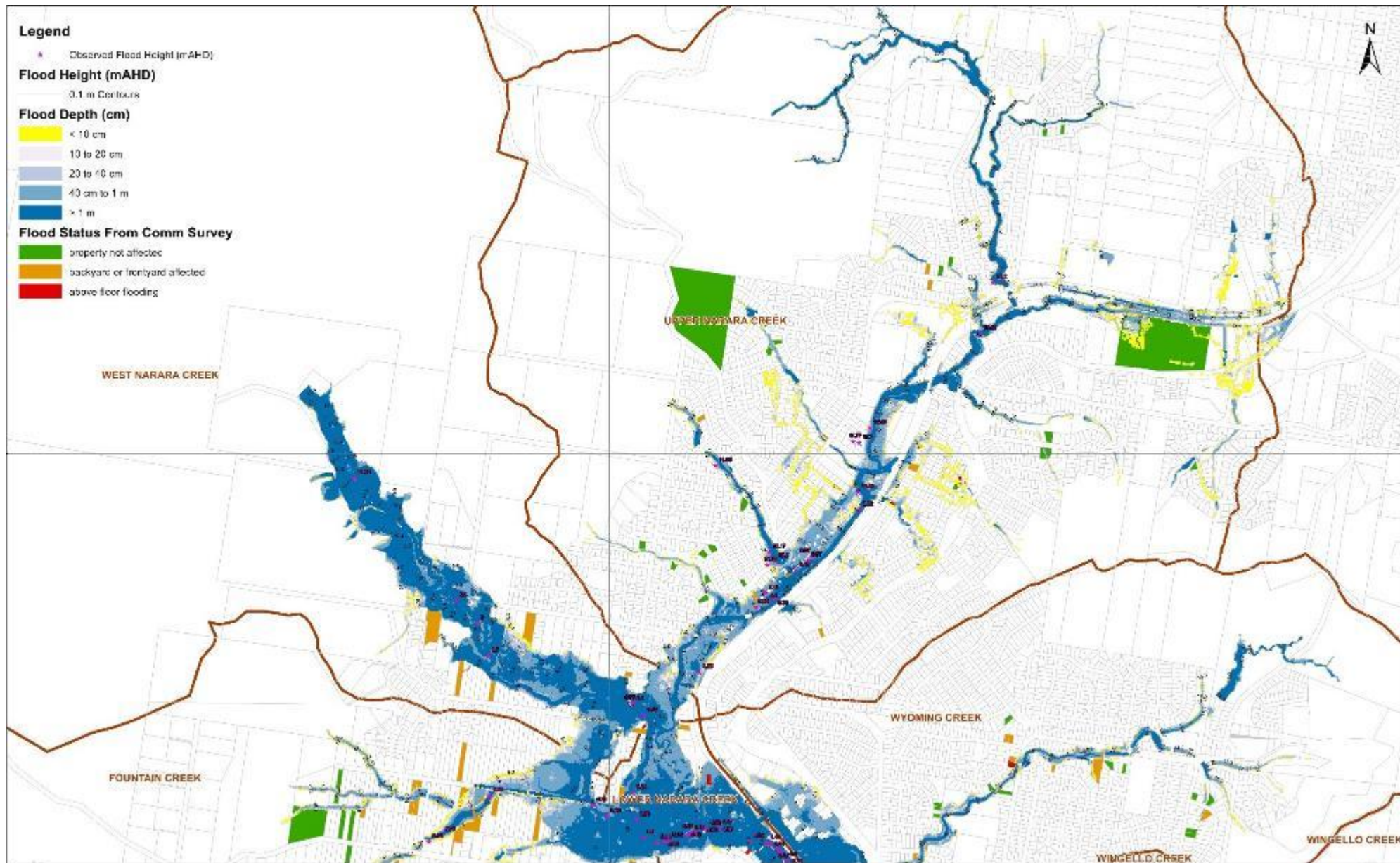


Figure ES4: Upper Narara Creek Peak Historical Flooding February 1992

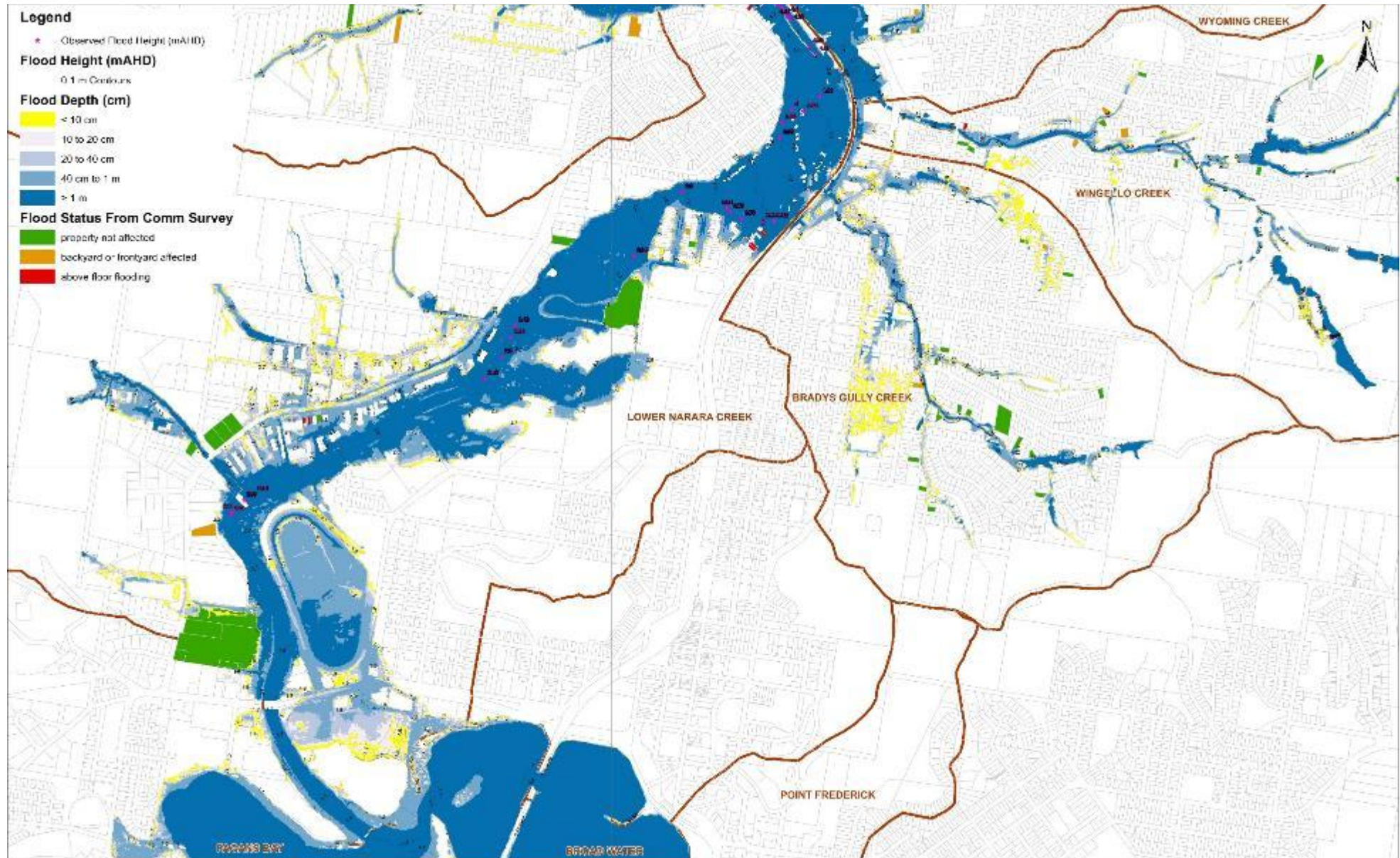


Figure ES5: Lower Narara Creek Peak Historical Flooding February 1992

Past Flood Mitigation Options

Following the major flood event in 1992, the Central Coast Council initiated a series of flood management studies that culminated in flood risk management plans for various creek systems in the study area. Several flood management options were investigated as part of those studies and a number of them have been implemented in the catchment. A sketch showing the implemented options is presented in Appendix B. The hydraulic model developed for the catchment has incorporated all those options.

All previous options were identified by studies undertaken for only a part of the larger Narara Creek catchment. Hydraulic assessment carried out in past studies for the options located in the upper reaches of the catchment, such as the Pecan Close Basin, is likely to be robust and the impact of the option would be relatively well defined. However, assessment of those options, which lie at or near the confluence with Narara Creek did not consider the dynamic flow behaviour with various flood arrival times from various parts of the larger catchment. Hence these options are likely to be assessed as less effective in the current study, where a whole-of-catchment modelling approach has been undertaken. As an example, the flood mitigation works undertaken on Wyoming Creek near Pacific Highway *appear to be less effective* than shown in the previous study (Floodplain Management Plan for Wyoming Creek, Kinhill, 1993).

It is noted that the options in the previous studies were assessed based on existing catchment conditions at that time. Generally, a separate assessment or reassessment of the previous options was not undertaken in the current study. The options that have been implemented in the study area were, however, included in the modelling and were considered to be a part of the existing conditions for the catchment.

The Lower Narara Creek Floodplain Management (1993) identified specific properties as high risk. Under the Voluntary Purchase (VP) program, and with assistance from the NSW Government's Floodplain Management Program, 39 properties in the Rowena Road / Showground Road area have been acquired over a period of approximately 20 years. The Plan was amended in February 2002 to include a further two properties in the voluntary purchase scheme, these properties have been reviewed as part of this study.

Impact of Transport Infrastructure Upgrade

The Pacific Highway upgrade through the catchment by TfNSW is a major infrastructure development within the floodplain.

As part of the adopted eastern route by TfNSW, it was necessary to close Carrington Street and investigate the option of a link road to connect Pandala Rd to Reeves Street.

This link road was deemed to provide traffic benefits and potentially provide a flood evacuation route for the local area. However, during community consultation by TfNSW, objections were raised by sections of the local community. Consequently, TfNSW removed this link road from the final option. The details of community consultation undertaken by the TfNSW are presented in Appendix F.

The link from Pandala Road to Reeves Street is an effective solution in terms of cost and flood risk management perspectives. It is recommended that the option for the provision of this link road be further explored, and the community re-engaged with the sole objective of highlighting the flood risk and the possible reduction of this risk for the area.

Flood Impacts and Damages

Floods have direct as well as indirect impacts on society. The direct impacts primarily include damage to properties and other financial impacts whereas indirect damages include social and psychological impacts on society. Consequently, some damages are tangible whereas others cannot be quantified.

The Narara Creek Flood Study Review (Golder, 2018) hereafter described as *The Flood Study* has provided the opportunity to assess the impact of the entire catchment in a single hydraulic model and hence the outcomes are considered more robust. The model is also able to accommodate three different types of flooding mechanisms in the catchment, namely overland flooding in the upper reaches of the catchment, fluvial flooding resulting from major waterways in the catchment and coastal flooding from Brisbane Waters. This Floodplain Risk Management Study considers the flood damages as a result of fluvial and overland flooding only. Damages assessment from coastal flooding have been estimated in the Brisbane Water Foreshore Floodplain Risk Management Study and Plan (Cardno, 2015).

Flood modelling indicates that flood impacts are widespread when various flooding mechanisms are considered. In a 1% AEP flood event, more than 650 properties are affected by above-floor flooding with an estimated flood damage of approximately \$70 million. The Average Annual Damage (AAD) for the study area is approximately \$24 million. The AAD is estimated from the probability of occurrence of flood events of different severity and the associated damages. It provides a long term average of flood damages in a catchment.

Table ES1 summarises the number of properties that would be flooded in different design flood events together with the tangible and intangible flood damage that is likely to occur in the study area.

Table ES1: Number of Flood Affected Properties and Associated Damages for Various Design Flood Events

Event	No of Houses Affected by Flooding	No of Houses with Over-Floor Flooding	Tangible Flood Damage	Intangible Costs (25% of Tangible Costs)	TOTAL
PMF	1673	1,560	\$162,143,164	\$40,535,791	\$202,678,955
500 Year ARI	949	781	\$67,545,307	\$16,886,327	\$84,431,634
200 Year ARI	949	781	\$62,200,622	\$15,550,155	\$77,750,777
100 Year ARI	861	664	\$56,466,705	\$14,116,676	\$70,583,381
50 Year ARI	792	585	\$50,226,874	\$12,556,718	\$62,783,592
20 Year ARI	721	527	\$44,847,713	\$11,211,928	\$56,059,641
10 Year ARI	657	482	\$40,504,378	\$10,126,094	\$50,630,472
5 Year ARI	562	416	\$34,641,868	\$8,660,467	\$43,302,335
2 Year ARI	187	166	\$13,141,528	\$3,285,382	\$16,426,910

The flood damage estimates have been derived for the state of the catchment circa 2009. Although the study area is almost fully developed as per the land zoning current at that time, any future changes in land zoning to intensify development can potentially have significant impact on the flood behaviour. The impact of re-zoning should be investigated on a catchment wide basis where cumulative impacts of all the possible/future land re-zonings are considered. Piecemeal assessment of development or rezoning should be avoided.

Flood Management Options

At project inception, the flood study results were presented to the Council's Coast and Flood Committee. Several flood management options were identified, and a preliminary list of flood management options was also presented in the meeting.

The identified options can be classified as:

- **Flood Modification (FM)** measures
- **Property Modification (PM)** measures
- **Emergency Response Modification (EM)** measures

Option identification and assessment is discussed in Section 9.

The **Flood Modification Options** identified for the study area and assessed were:

- West Gosford Industrial Area levee
- Raising the Siletta Road Basin storage level
- Racecourse storage area with accompanying levee
- Raising Central Coast Highway
- Creating detention basin in Brooks Avenue Industrial Area
- Filling of Caravan Park above the 1% AEP flood
- Upgrade of Narara Valley Drive Bridge

- Provision of a levee along the northern end of Koninderie Parade

The **Property Modification Options** identified for the study area and assessed were:

- Planning and development controls
- House Raising
- Voluntary Purchase
- On Site Detention Policy

The following **Emergency Response Modification** Options were found suitable for the study area:

- Revision of Central Coast Local Flood Plan (a sub-plan of DISPLAN)
- Information Transfer to SES by Council
- Public Awareness and Education by SES (FloodSafe Brochure for the study area)
- Public Awareness and Education by SES (Schools Package)
- Business Awareness and Education by SES
- Depth markers at major road crossings
- Flood Emergency Response Plan for Large Establishments
- Data Collection Strategies
- Flood Warning Systems
- Flood Mapping Information Council Website

The Council undertook an Early Warning Flood Forecasting Study (MHL, 2017) to explore the possibility of flood forecasting for the Narara Creek catchment. A flood forecasting tool (MHLFIT) was identified in the study as a suitable predictive flood tool. Following testing, the MHLFIT tool is now operational and currently in use by the Council and SES. The MHLFIT tool utilises the flood model results for forecasting flooding in the catchment based on the rainfall data from the local and regional rain and level gauges. This tool is specifically designed to assist SES and Council officers with predictive flood intelligence using real time data for flood forecasting in short duration catchments, such as Narara Creek.

Options Assessment

A preliminary assessment of the flood management options was undertaken and discussed in a meeting with the Council's Technical Sub-committee for the project. The options were assessed against the existing planning policies, possible effectiveness, community acceptability etc. before short-listing the options for further assessment.

The final assessment of options was carried out against a range of criteria, including technical, economic, environmental and social.

Hydraulic modelling was undertaken for several flood modification options. The results (refer Section 12) of this assessment were used to determine the reduction in flood damages as a result of the implementation of the options.

A detailed economic analysis was undertaken for those flood modification options for which hydraulic modelling was undertaken. Several property modification options (such as house raising and voluntary purchase programs) were also assessed for their economic feasibility. The economic assessment included a damages assessment and a benefit-cost ratio analysis.

A multi-criteria matrix assessment approach was adopted for the comparative assessment of all options identified using a similar approach to that recommended in the Floodplain Risk Management Manual (2023). This approach of assessing the merits of various options uses a subjective scoring system. The principal merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives “transparent” (i.e. various important factors are discussed and included in the analysis). However, this approach does not provide an absolute “right” answer as to what should be included in the Flood Risk Management Plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a preliminary score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criterion.

The following criteria were adopted for the matrix assessment:

- **Technical**
 - Likely Overall Hydraulic Improvement
- **Economic**
 - Capital and Operating Costs
 - Reduction in Risk to Property
- **Social**
 - Reduction in Social Disruption
 - Reduction in Risk to Life
- **Environmental**
 - Flow and Water Quality Objectives
 - Fauna/Flora
- **Community**
 - Community Support
- **Authority**
 - Council/Agency/SES Support
- **Policy/Legislation**
 - Compatible with Policies and Plans.

The score for each option is presented in this report (Section 15.3). Primarily, all options related to development control scored highly among all the options. Major flood modification options such as flood retarding basins are not feasible in the study area due to the developed nature of the catchment. The flood modifications therefore are of smaller magnitude and provide only localised benefits. However, those benefits are significant and can be adopted in the Flood Risk Management Plan. The Narara Valley Drive Bridge Upgrade along with the Koninderie Parade Levee and filling of Caravan Park are examples of the options that provide significant benefits, both tangible and non-tangible.

The final stage of the flood risk management process is to prepare a flood risk management plan for the study area. The findings of this report, including scoring of different options, would be taken into consideration while recommending various flood management options in the plan.

The draft Narara Creek Floodplain Risk Management Study and Plan would be placed on public exhibition to gather community feedback.

GLOSSARY

The terms presented in this glossary have been derived from the NSW Government Flood Risk Management Manual, Australian Institute of Disaster Resilience (supported by Australian Government Department of Home Affairs) and other common industry standards. Any ambiguity in the interpretation of these terms should be referred to the Council for clarification. The Council's interpretation of these terms shall be final and prevail over other interpretations.

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare, but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage	It is a long term average of flood damage in a catchment. It is estimated to be the likely damage every year from floods of various magnitudes. The damage corresponding to each magnitude of flooding is weighted by the percent chance of each being exceeded (damage caused by rare events is therefore weighted less). The sum of weighted damages represents the Average Annual Damage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the mainstream.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.

Critical Duration	Usually used with a storm event and specifies the storm duration that would produce highest flood levels at a particular location in the catchment
Cummulative Impacts	Any new development in a flood prone area can potentially have an adverse impact on flood behaviour. Cummulative impact refers to an impact that would occur if a development were repeated throughout the flood prone area in a catchment. As an example, filling of land in a single lot may not have a significant impact, but if such filling was carried out in each lot, the cummulative impact is likely to be significant
DEM	A Digital Elevation Model (DEM) is a representation of the bare ground (bare earth) topographic surface of the Earth excluding trees, buildings, and any other surface objects. DEMs are created from ground elevation data, which can be acquired through techniques such as photogrammetry, LiDAR, land surveying, etc.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. e.g. some roads may be designed to be overtopped in the 1 in 5 year or 20% AEP flood event.
Development	<p>Development has the same meaning as in Environmental Planning and Assessment Act 1979 and Environmental Planning and Assessment Amendment Act 2017. In general development is any of the following:</p> <ul style="list-style-type: none"> (a) the use of land, (b) the subdivision of land, (c) the erection of a building, (d) the carrying out of a work, (e) the demolition of a building or work, (f) any other act, matter or thing that may be controlled by an environmental planning instrument. <p>The Council LEP and DCP provide further definition of the development</p>
Defined Flood Event	Defined Flood Event (DFE) is the terminology as used in the Building Code of Australia (BCA) for the Central Coast Council LGA it is the 1% AEP Flood Event

Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Effective Evacuation Time	<p>Effective Evacuation Time is the time from the first warning of flooding by BOM or other sources to evacuation of the targeted community to a safe place. It includes time required for dissemination of warning (various means including door knocking), preparation of households to leave and driving via designated routes to a safe place. The Effective Evacuation Time should be greater than the arrival of flooding and cutting of evacuation routes.</p> <p>SES has produced technical guidelines for planned evacuation based on the Effective Evacuation Time.</p>
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
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 overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood Fringe Category	As per the Floodplain Development Manual, this hydraulic category represents the remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding. Also see definition under Hazard.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The mitigating measures which might be feasible for the management of a particular flood-prone area.

Flood planning area	Means a region within a polygon (defined by the flood study) that determines whether a parcel of land is classified as a flood control lot and thus subject to flood related development controls. The flood planning area is determined from several considerations, including flood behaviour and impact of climate change. For further details see Section 8.5 of the report.
Flood planning levels	Means the minimum floor level for a habitable building, generally calculated from the DFE or other flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection of flood planning level (FPL) is based on an understanding of the full range of flood behaviour and the associated flood risk. It also considers the social, economic, and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different floodplains. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs and include allowances for climate change where appropriate.
Flood Storages Category	As per the Floodplain Development Manual, this hydraulic category represents those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway Category	As per the Floodplain Development Manual, this hydraulic category represents those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.

Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hazard	<p>A source of potential harm or a situation with the potential to cause loss and pose a possible danger to personal safety. As per the Floodplain Development Manual, the flood hazard has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in Appendix L of the manual.</p> <p>The Australian Institute of Disaster Resilience Guideline 7-3, "Flood Hazard" (AIDR, 2017), has identified the following hazard categories, based on the velocity (V) and depth (D) of flow</p> <p>H1 – Generally safe for people, vehicles and buildings.</p> <p>H2 – Unsafe for small vehicles</p> <p>H3 – Unsafe for vehicles, children and elderly</p> <p>H4 – Unsafe for people and vehicles</p> <p>H5 – Unsafe for people and vehicles. Buildings require special engineering design and construction</p> <p>H6 – Unsafe for vehicles and people. All building types considered vulnerable to failure</p>
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Integrated Survey Grid (ISG)	ISG is a global co-ordinate system based on a Transverse Mercator Projection. The globe is divided into a number of zones, with the true origin at the intersection of the Central Meridian and the Equator.

LiDAR	<p>LiDAR stands for Light Detection and Ranging. It is a survey technique whereby a target is illuminated by a laser light and reflection from the target is recorded with a sensor. It is used to develop digital terrain models for the earth's surface.</p> <p>It is important to note that the survey captured by LiDAR is a snapshot in time and only valid for the date it is captured. The Narara Creek Flood Study Review (Golder, 2018) provides the details of LiDAR used in the assessment of flood behaviour and consequently in this study.</p>
Management plan	<p>A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.</p>
Mathematical/computer models	<p>The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.</p>
Probable Maximum Flood (PMF)	<p>The flood calculated to be the maximum that is likely to occur. The calculation is based on the procedures developed by the Bureau of Meteorology, as presented in the publication, <i>The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (BoM, 2003)</i>.</p>
Probability	<p>A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedence Probability. Australian Rainfall and Runoff provides the naming convention for expressing probability of occurrence of Design Floods.</p>
Risk	<p>Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.</p>
Runoff	<p>The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.</p>

Sea Level Rise	The predicted rise of sea levels in a future climate, which is affected by the increasing global temperatures. The Council has adopted a Climate Change Policy (CCP 2018), under which a Sea Level Rise policy is currently under preparation.
Significant Flood Effect	Means increasing the flood level for floods up to and including the Design Flood as specified in the Council DCP or Policy and/or changing the flood behaviour or flood category to the effect of increasing the flood hazard category to an unacceptable level. Also refer to cumulative effects.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

Narara Creek Floodplain Risk Management Study



Passive recreation following Voluntary Purchase of properties at Rowena Road



Hanlan Street Flooding – May 1998

1 Introduction

The Central Coast Council (The Council) manages flood risk in Central Coast Local Government Area (LGA). The Council has initiated several studies to prepare a comprehensive flood risk management plan for different catchments within the LGA. Narara Creek catchment is one of several catchments within the LGA that have a significant flood risk.

Residents of the Narara Creek catchment have experienced several major flooding events in the past, which have caused extensive damage to property and disruption to the community. Central Coast Council (former Gosford City Council) resolved to address the flooding issues in the Narara Creek Catchment and initiated this study to review the existing studies/plans and identify flood management options for effective management of the flood risk in the catchment.

The Council has commissioned Golder Associates and HydroStorm Consulting to undertake the Narara Creek Floodplain Risk Management Study and Plan (FRMSP) to identify, assess and compare various options for the management of flood risk within the Narara Creek floodplain.

The FRMSP has been undertaken for areas affected by mainstream flooding from the major creeks in the study area. Local overland flooding has not been considered in this study.

1.1 Study Context

Flood risk management in New South Wales is guided by the State Government's Flood Prone Land Policy. The primary objective of this Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods by utilising methods that strike a balance between social, economic, environmental and flood risk parameters. The policy encourages the merits-based approach for appropriate and sustainable use of the floodplains, employing ecologically beneficial methods wherever feasible.

The Flood Prone Land Policy emphasises the need for identifying flood management options to address the existing, future and continuing risk. This study has identified a mix of flood modification, property modification and flood response modification measures to achieve this objective.

For existing developed areas, the impacts of flooding may be reduced by flood mitigation works and measures, including on-going emergency management measures, the raising of houses where appropriate and by development controls. For areas proposed for development or redevelopment, the potential for flood losses may be contained by the application of ecologically sensitive planning and development controls.

The ultimate outcome of the Flood Prone Land Policy is the preparation and implementation of a Floodplain Risk Management Plan by Council. This study provides the foundation for preparing this plan. Community consultation is an important part of the process and this is undertaken via placing the draft report on public exhibition seeking community feedback.

NSW Government's Flood Prone Land Policy is enunciated in the Flood Risk Management Manual (2023). This study has been undertaken in accordance with this Manual. This manual presents the following stages in a typical floodplain risk management process:

- Formation of a floodplain risk management Committee
- Data Collection
- Flood Study

- **Floodplain Risk Management Study**
- **Floodplain Risk Management Plan**
- Implementation of Floodplain Risk Management Plan

This report presents the findings of the study for the highlighted and underlined stages in the above process.

Several floodplain management options were identified after review of the flood study results. A number of options were then selected for further investigation after discussion with the Council, DCCEEW and SES.

FINAL DRAFT

2 Study Area

Narara Creek is a tributary of Brisbane Water and is located to the north of the estuary, within the Central Coast LGA. The study area (Figure 1) includes the entire Narara Creek Catchment up to the confluence of Narara Creek with the Brisbane Water.

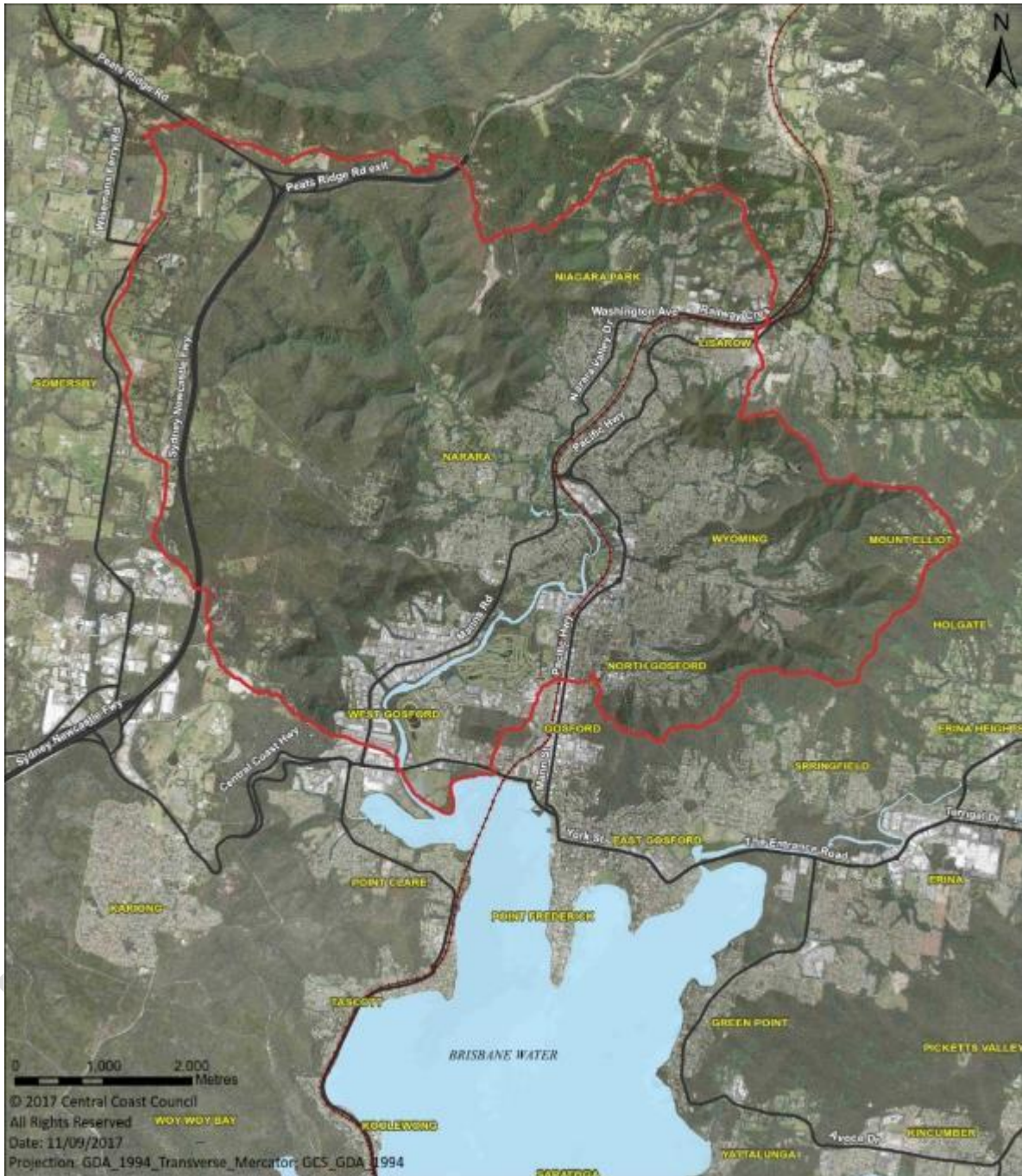


Figure 1. Narara Creek Floodplain Risk Management Study Area

2.1 Catchment

The floodplain of Narara Creek, which includes both fluvial and coastal floodplains, is very flat and close to sea level. The Narara Creek floodplain is bounded to the east, west and north by hilly and mountainous terrain. The tributaries arising from these hilly areas have narrow floodplains in the upper reaches but

widen significantly near the confluence with Narara Creek. Narara Creek discharges into Brisbane Water through a bridge of the Main Northern Railway.

Narara Creek is the primary channel for conveyance of floodwaters through the catchment. Several large tributaries discharge into the main channel, which ultimately discharges to Fagans Bay in Brisbane Water.

With the land use ranging from forest to highly urbanised areas within the catchment, the flood producing mechanisms are varied and complex. With flooding from various tributaries, the existing flood behaviour in Narara Creek and the low-lying areas of various tributary catchments to a large extent is dependent on flood arrival times at various tributary junctions.

The upper reaches of various tributaries are independent of the 'backwater' influence of the Narara Creek. However, the flood risk in general is low in the upper reaches and it is the lower reaches, where the flood behaviour is complex, that are subjected to a higher flood risk.

The Narara Creek Catchment has a total area of 46.7 km² and drains generally southward. Narara Creek discharges into Brisbane Water through a bridge of the Main Northern Railway, which has created an embayment in Brisbane Waters. There are also several local catchments that contribute runoff to Fagans Bay. To the east of the railway line, this area is referred to as the Broadwater before becoming Brisbane Water.

The Narara Creek system comprises seven major sub-catchments (Figure 2).

Each sub-catchment has been adopted as a flood management area and assigned a catchment identifier for easy reference throughout this report. These sub-catchments and their identifiers are:

- West Narara Creek (14.3 km²) – **C4/A**
- Upper Narara Creek (8.3 km²) – **C4/B**
- Fountain Creek (5.1 km²) – **C4/C**
- Wyoming Creek (3.1 km²) – **C4/D**
- Wingello Creek (4.9 km²) – **C4/E**
- Bradys Gully (2.6 km²) – **C4/F**
- Lower Narara (8.4 km²) – **C4/G**

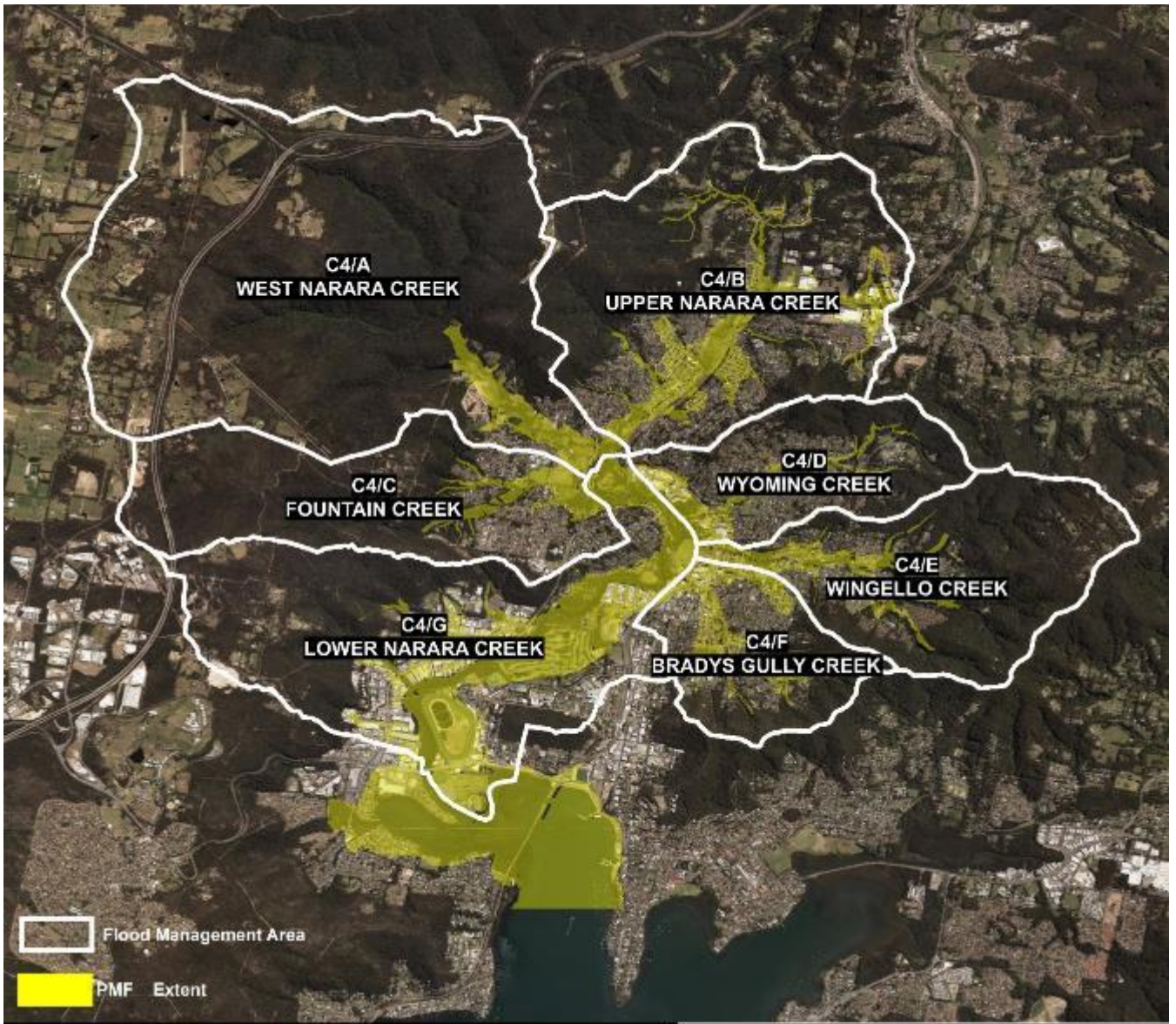


Figure 2. Narara Creek Major Sub-catchments

BOX 2.1 Catchments and Flooding Mechanisms

Three different types of flooding mechanisms exist in the catchment, namely overland flooding in the upper reaches of the catchment, fluvial flooding resulting from major waterways in the catchment and coastal flooding from Brisbane Water Estuary, which affects the lower parts of the catchment (tidal limit of Narara Creek is approximately 5.5 km from the Central Coast Highway along the creek, near the confluence with Fountain Creek). This study considers the impact of fluvial and overland flooding only for storm durations ranging from 30 mins to 9 hours.

Catchment flooding occurs over a much shorter duration in contrast to coastal storm surge which typically has a greater effective warning time (days) to prepare for the flood emergency.

Therefore, flood management options that improve flood emergency response are likely to be highly effective in reducing the flood risk including community education and flood management plans for individual establishments with large populations such as schools, aged care facilities etc. These are considered in more detailed within the study.

2.2 Land Use

Residential, commercial and industrial development occurs in the low-lying areas of the valley. The local catchments contributing directly to Fagans Bay are of similar nature. The areas surrounding upper reaches of various creeks are heavily forested.

Based upon the Central Coast Council LEP (2022) Land Zoning Maps, the breakdown of land use zoning across the catchment area comprises the following:

- C2 – Environmental Conservation
- C3 – Environmental Management
- C4 – Environmental Living
- DM – Deferred Matter
- E1 – Local Centre
- E3 – Productivity Support
- E4 – General Industrial
- R1 – General Residential
- R2 – Low Density Residential
- RE1 – Public Recreation
- RE2 – Private Recreation
- RU1 – Primary Production
- RU2 – Rural Landscape
- RU3 – Forestry
- SP2 – Infrastructure
- SP2 – Infrastructure (Health Services)
- SP2 – Infrastructure (Educational)
- SP2 – Infrastructure (Hospital)
- SP2 – Infrastructure (School/Church)
- SP2 – Infrastructure (Research Station)
- W2 – Recreational Waterways

Figure 3 presents the land uses within the Narara Creek catchment area.

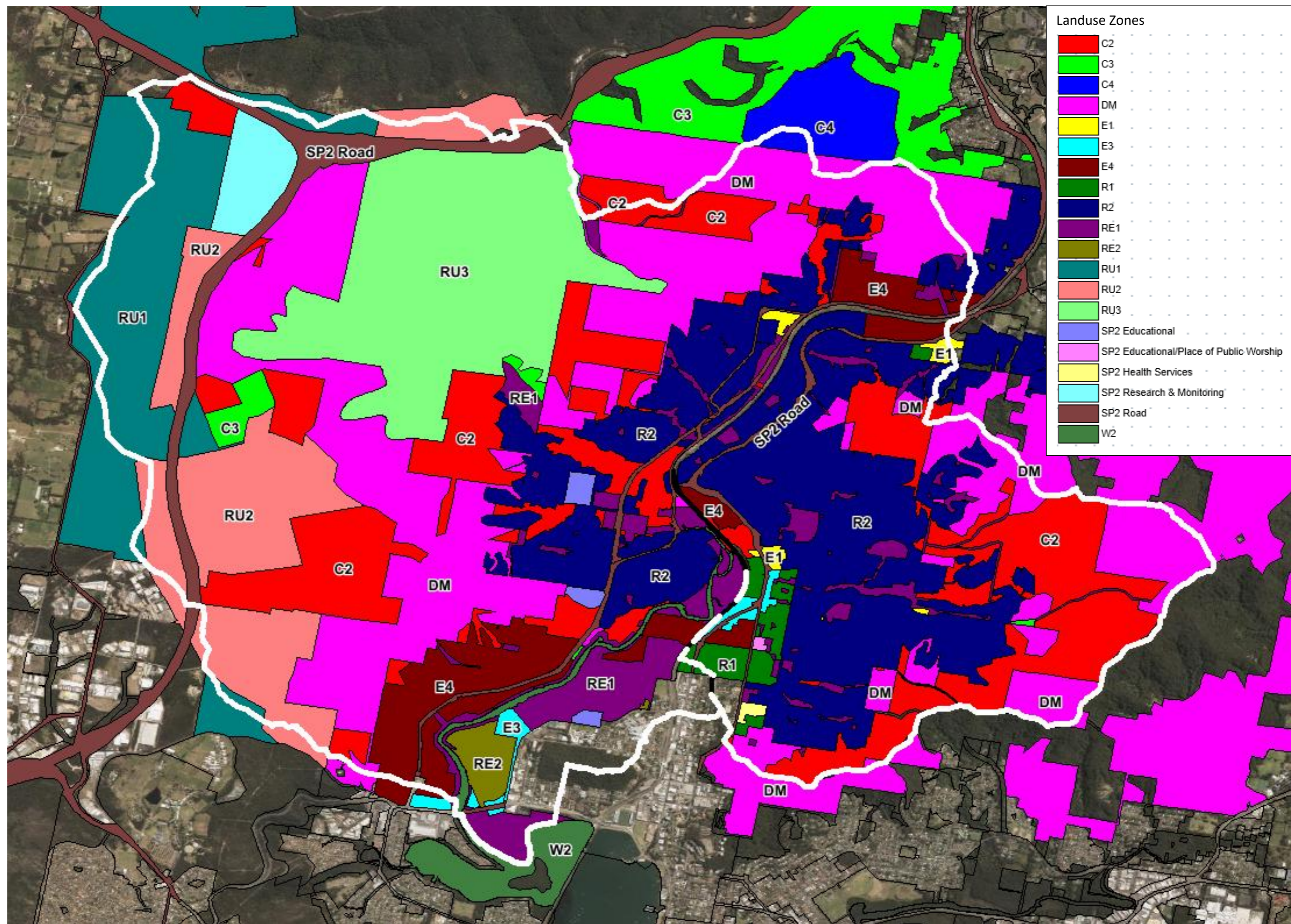


Figure 3. Land Zonings within the Narara Creek Catchment (Source: Central Coast Council LEP 2014)

Figure 4 presents the breakdown of different land uses in the study area.

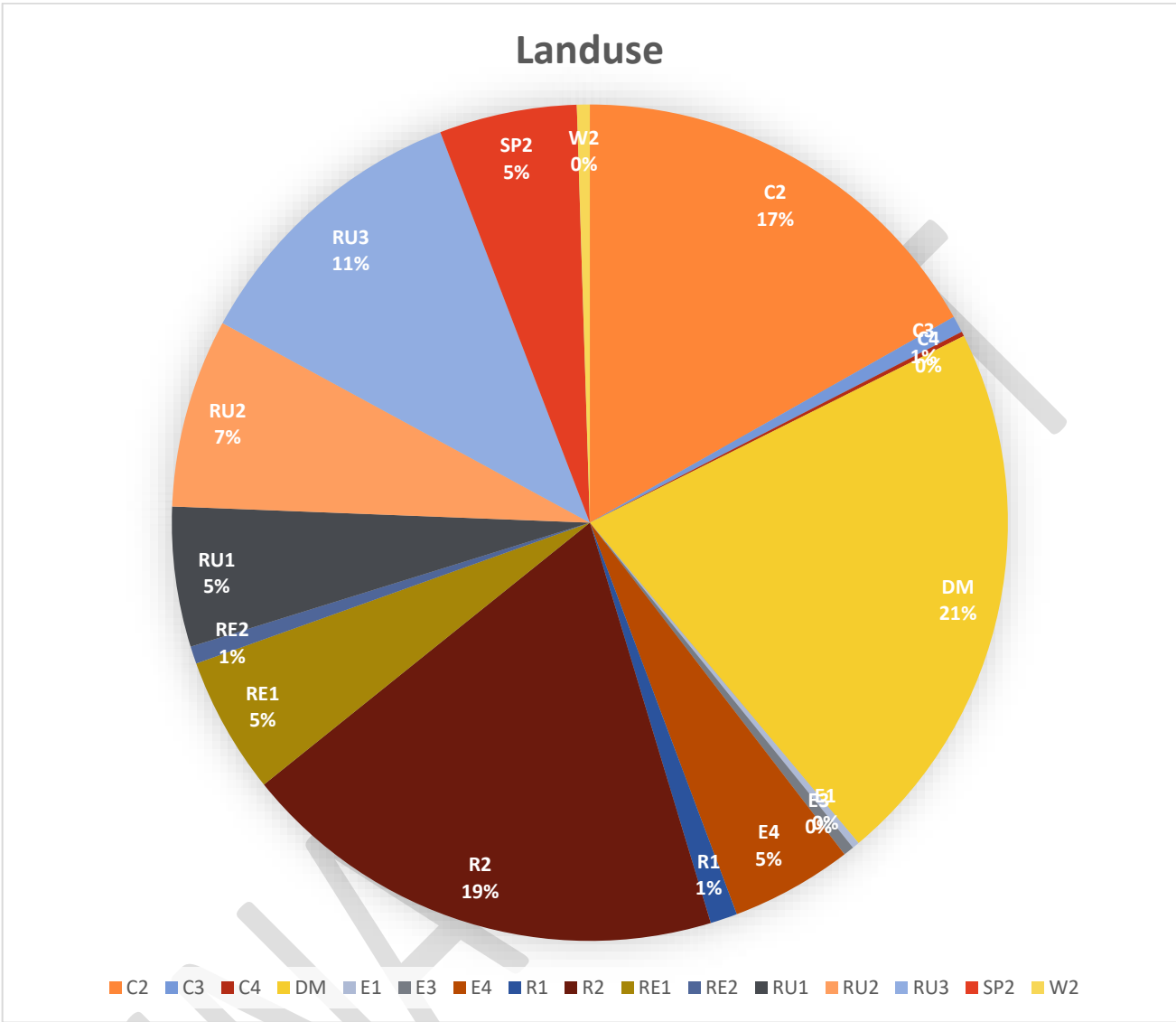


Figure 4. Landuse break down in the Study Area

The dominant zoning in the catchment area is Low Density Residential followed closely by Environmental Conservation, and then Public Recreation, Rural Landscape and Forest.

A few commercial and industrial properties in the study area have licenses for disposing of trade waste. These properties are shown in Figure 5.

BOX 2.2 Land Use

The majority land use in the catchment is rural/forest/open space/environmental conservation (approximately 56%). These areas contribute less runoff compared to developed part of the catchment. Any future development of these areas may exacerbate existing flooding in the catchment. Appropriate flood risk management measures are required for future planning of these areas.

The industrial/commercial areas have several trade waste licenses in the catchment (Figure 5). The trade waste from these businesses needs to be managed to avoid pollution of the waterways during flood events. Appropriate measures such as bunding etc. need to be provided to prevent spillage into the floodplain or from being washed away during the floods.

This study recommends a review of development controls to ensure pollution is managed during flood events. Options such as bunding with the capacity to withstand 1% AEP floods are likely to be suitable for this purpose.

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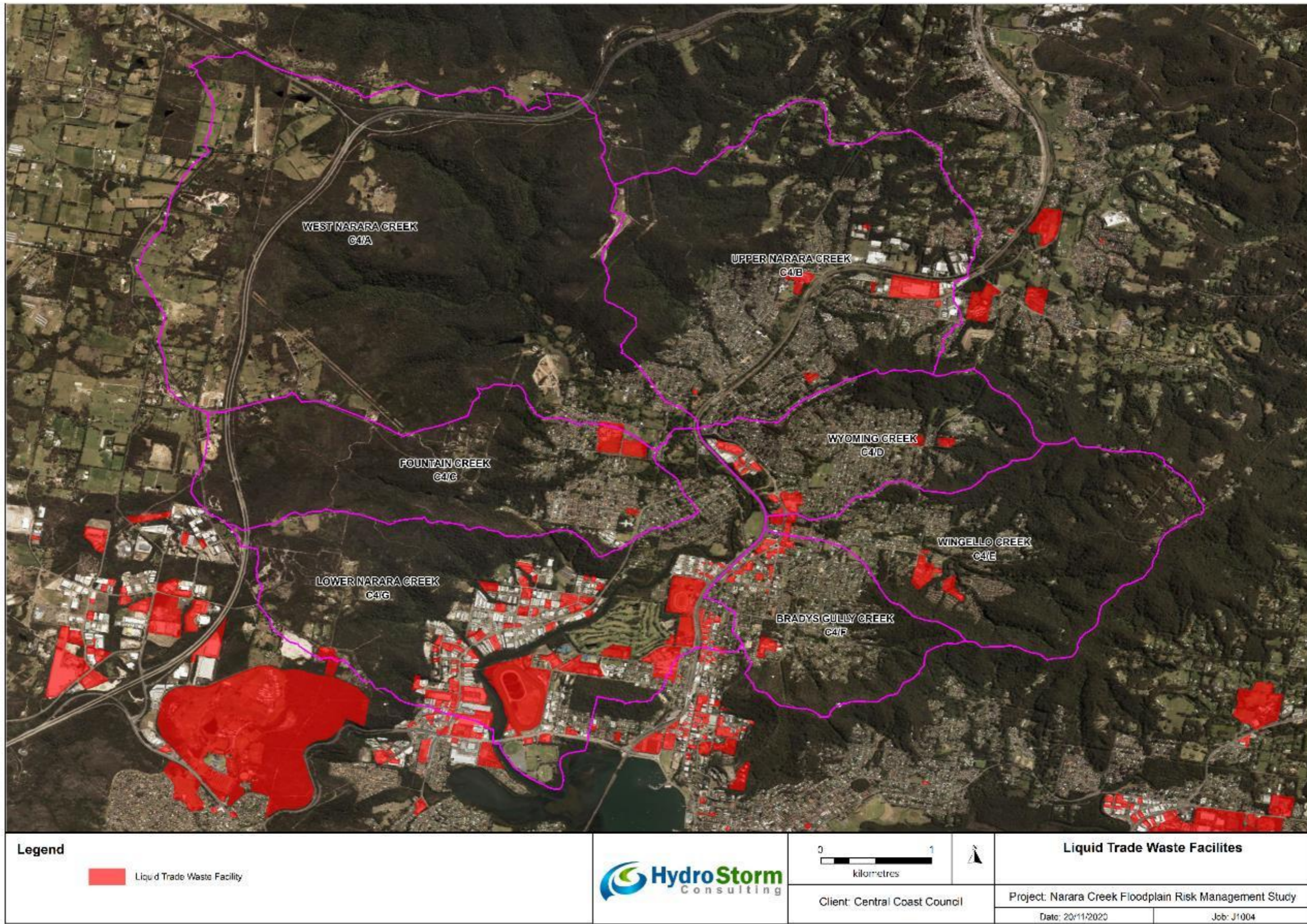


Figure 5. Trade Waste Industry in the Study Area

2.3 Transport and Access

The two main transport mediums for access to the Central Coast LGA are the road and railway. There are several major roads in the Narara Creek catchment area including Peats Ridge Road and the Sydney Newcastle Freeway which are situated in the west and north-west of the catchment. Manns Road and part of the Pacific Highway run through the middle part of the catchment in a north-east to south-west orientation. Both roadways run off the Central Coast Highway and act as main arterial roads for private, commercial and public transport accessing West Gosford, North Gosford and much of the northern and eastern suburbs of the Central Coast LGA. Both Manns Road and the Pacific Highway have sections which either cross or run directly adjacent to Narara Creek and as such are at risk from being affected by flooding from the Creek.

The Great Northern Railway line between Sydney and Newcastle runs through the study area. Both passenger and freight trains operate on this line and is the main public transport link between the Central Coast and Sydney. Most of the line is elevated, however it can potentially be impacted from localised flooding, causing disruption in the service.

BOX 2.3 Transport and Access

The extent of the Narara Creek floodplain has a significant impact on transport logistics, commuter transport and evacuation even during frequent flood events for the community within the catchment and also the broader community that regularly traverse this flood plain. Transport is identified as a key part of the Central Coast Council's Somersby to Erina Corridor Strategy Transport Assessment (Arup, Nov 2018). Key transport routes such as the Central Coast Highway that are impacted by flooding cause significant disruption to the community. To address this issue, this study examines potential flood mitigation measures including the effect of flooding when flood behaviour is altered.

2.4 Physical and Biological Environment

Based upon the Gosford Topographic and Orthophoto Map the floodplain of Narara Creek (the majority of which is considered to be coastal floodplain) is very flat and close to sea level. The Narara Creek floodplain is bounded to the east, west and north by hilly and mountainous terrain.

A number of tributary waterways drain into Narara Creek. These include a number of unnamed waterways as well as Fountain Creek, Bradys Gully, Wingello Creek and Wyoming Creek. Narara Creek drains into Broad Water which forms the northern extent of Brisbane Water.

BOX 2.4 Environmental Issues

Bank erosion is an issue at several locations in the catchment. Sediment loads are transferred along the waterways, causing blockages and impacting the health of the waterways. Bank erosion has also impacted a few houses built near the creek at the Showground Road.

2.5 Climate Change

Sea levels are expected to rise in a future climate. This is likely to increase coastal erosion and flooding that will affect communities living near the beaches and estuaries.

Higher temperatures, extreme weather events, such as floods and fire is likely to change the environment. Some hazards are correlated such as fires changing the runoff characteristics of a catchment and resulting in a different flow regime, with likely increase in peak discharges.

Adaptation to climate change is a challenging task and it is difficult to ascertain the complex interaction of environment, economics and communities to enable robust solutions for the future climate.

In July 2019 Central Coast Council adopted a Climate Change Policy thereby reaffirming its commitment to manage the future risks associated with the Sea level Rise and increased rainfall intensity. This study has incorporated Council's policy guidelines in assessing the flood risk for the study area.

The flood study (2018) identifies significant impacts of climate change through sensitivity analysis. Consideration of these impacts is a key outcome of this study. AR&R 2019 provides guidance for the climate projections and has been identified in Council's Climate Change Policy Action for implementation.

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BOX 2.5 Climate Change

Central Coast Council has adopted a Climate Change Policy in July 2019. One of the Policy Commitment Statements is to:

(D7) Incorporate climate change risks in strategic and infrastructure planning for the region to maximise local liveability through informed land use planning, development of planning controls and guidelines that facilitates regional urban growth, transport connectivity and utility services.

Under Policy Implementation actions, the CCP states that

The implementation of this Policy will be through Place Based Climate Change Action Plans that include but are not limited to issues relevant to sea level rise planning and ongoing adaptation; coastal and floods management; disaster resilience; biodiversity conservation; and emissions reduction. Figure 1 represents the framework to plan for climate change.



Figure 1: Framework for climate change planning

The Place Based approach means “consideration of a context specific approach to plan for places for people by involving the people in the decision-making process to maximise their connectivity to the place.”

The CCP requires consideration of sea level rise and flood management (increase in rainfall) for disaster resilience associated with the future climate. This study, which is a place based (Narara Creek Catchment), addresses the climate change impacts and incorporates those impacts in the flood planning for the area.

The risk management concept as applied to flooding is an appropriate tool for managing the future climate risk. The adopted Brisbane Water Floodplain Risk Management Plan (Cardno, 2015) provides the guidance for this FRM Study & Plan under the SSP 8.5 scenario.

2.6 Catchment and Creek Debris

Debris sources in urban catchments range from natural materials to anthropogenic, depending on the land use. Natural material such as vegetation of various sizes (tree, shrubs, twigs, grass cuttings etc.) are mobilised during a flood event and may cause blockage of flow generally at the entrance of various culverts and bridges in the floodplain. The forested areas of the Narara Creek catchment are likely to generate this type of debris and contribute to flow blockage and worsening of flood impacts.

A large quantity of sediment can also be mobilised from channel bed and side scouring, particularly from areas where creeks beds and banks are unstable. RiverCare works previously carried out at several locations in the Narara catchment have reduced the potential sediment loads that are usually deposited at the lower reaches of the creeks.

Anthropogenic debris generally observed in urban creeks include illegal waste dumps, waste bins, shopping trolleys etc. In large flood events, floating cars have also been observed as a major source of blockage in urban areas. All these types of debris can potentially be generated in a flood event in the Narara Creek catchment.

Any development proposed within the catchment that has the potential to mobilise debris with the potential to cause flood affectation should be considered very carefully. Flood modelling shows that Narara Creek is quite sensitivity to changes particularly at hydraulic structures.

BOX 2.6 Catchment Debris and Flooding

The potential of debris carried during the flood in waterways to block culverts and bridges along those waterways is significant. The amount of debris generated depends on the catchment characteristic and land use. Bank erosion can also play a role in mobilizing riparian vegetation as debris during flooding.

Catchment being forested, can generate significant vegetation debris and consequently result in blockage of culverts and bridges. Also, urbanised nature of the catchment suggest that anthropogenic debris is also highly likely. Pedestrian bridges, washed away in a major flood event in the past, have caused blockage in the downstream culverts in the Wyoming Creek catchment.

Control of debris production in the catchment and prevention of culvert blockage during flooding is generally an effective flood risk management measure. The Rivercare works undertaken by the Council have potentially reduced the vegetation debris originating from slumping creek banks during flood events. It is recommended that all major creeks in this catchment should be reviewed on completion of this FRMP together with annual operation expenditure.

Development approvals need to consider potential unforeseen consequences of car parking and the like where cars or other objects will float and cause blockages at major hydraulic structures such as bridges.

2.7 Brisbane Water Estuary

Brisbane Water is a shallow estuary which receives runoff from several creeks including Narara Creek. The estuary originates at the confluence with Narara Creek and extends approximately 18 km to its mouth at Broken Bay.

The Brisbane Water estuary and foreshores provide scenic value with areas of pristine vegetation. The Brisbane Water National Park to the west and Bouddi National Park to the east provide numerous vantage points to experience the landscape of the Brisbane Water estuary and its surrounds. In a recent survey of the estuary, over 100 bird species have been recorded. A number of those bird species along with some animal species are on the endangered list. The Brisbane Water estuary supports a significant oyster production industry.

Council completed The Brisbane Water Foreshore Flood Study (Cardno, 2013b), which provided a better understanding of the effects of storm surge generated primarily from "east coast lows" and the interaction with the local tributaries. However, the study relates primarily to potential floodwaters (storm surge) that rise up from the ocean (and into the estuary) and overtop seawalls and the foreshore.

BOX 2.7 Brisbane Water Estuary

Flooding behaviour around the Brisbane Water foreshore was investigated as part of the Brisbane Water Foreshore Flood Study (Cardno, 2013b). This study concluded that tidal / ocean flooding is dominant for the majority of the foreshore areas, i.e. severe ocean storms cause the highest water levels rather than catchment floods of the same average recurrence interval (ARI).

The exception was found to be within Fagans Bay, which is dominated by catchment flooding in less frequent events. This is due to large catchment flows from Narara Creek and the local hydraulic control (the northern railway bridge) which reduces the rate of discharge of catchment flows into the estuary. (Brisbane Water Foreshore Floodplain Risk Management Plan, Cardno ,2015)

Development of the lower sections of Narara Creek need to consider the sensitive nature of the estuary within Fagan Bay and the longer term interactions of tidal conditions and flood “ in flows “from Narara Creek.

3 Previous Studies

Several flood studies have been carried out in the Narara Creek catchment. These studies split Narara Creek into Upper and Lower sections and various tributaries Wyoming Creek, Wingello Creek and Bradys Gully, Narara Creek West of Hanlan St, Fountain Creek and Reeves Creek were treated as separate study areas without integration with the rest of the catchment. Accordingly, inconsistencies were identified when the results from separate studies were integrated into the latest flood study, titled "Review of the Narara Creek Flood Study (Golder, 2012). The flood study was subsequently updated in July 2018 by Golder Associates to address missing catchments and the inclusion of the Gosford Passing Loop rail infrastructure project undertaken by TfNSW.

The 2018 flood study consists of a whole-of-catchment approach and this was a primary objective when undertaking this update. Accordingly, a model of the whole Narara Creek catchment was developed.

In addition to flood studies, several floodplain management studies and floodplain risk management plans were prepared for various parts of the catchment. But, as noted above, a catchment wide approach was not taken due to limitations of the underlying flood study.

Various options considered in the flood management studies were taken into consideration in identifying various flood risk management options for the current study.

A summary of the previous management studies is presented in the following sections.

3.1 Floodplain Risk Management Studies

Flood Mitigation Investigations in the Narara Valley. Willing and Partners, 1979 – This report detailed hydrologic modelling of Narara Creek, Wyoming Creek and Wingello Creek using RATFL and RSWM. There was no hydraulic modelling undertaken in that investigation. Potential detention storage systems were assessed with respect to each of the Narara Creek, Wyoming Creek and Wingello Creek.

Lower Narara Creek Flood Study – Effect of Floodplain Filling. PWD, 1983 – This study examined the impact of floodplain filling on predicted flood levels in the CELLS model.

Review of Lower Narara Creek Floodplain Management Study. Kinhill, 1993 – This study updated an earlier update of a flood study conducted by PWD, 1988. This review was undertaken following severe flooding in February 1992 in the Lower Narara Creek study area which provided additional calibration data. The review also updated previously analysed management options. Management options included voluntary purchase, flood proofing of industrial properties and some houses, levee construction and channel improvement works. The hydrologic model, RORB, was retained for the flood study component of the analysis and the hydraulic model, CELLS, was also retained, however, it was noted that the model version had been upgraded. The extent of the hydraulic model was the same as the PWD, 1988 study.

Wingello Creek Flooding Investigation. Kinhill, 1993 – This report presents results of investigation of realignment options for Wingello Creek downstream of the Pacific Highway. The report presents details of a HEC-2 hydraulic model established to analyse this area. The area of study was below the Wingello Creek HEC-2 model and was not of sufficient resolution in the Lower Narara Creek CELLS model at the time.

Brooks Avenue Flooding Investigation. Kinhill, 1993 – This report presents an analysis of proposed realignment of Wyoming Creek and construction of a levee along Wyoming Creek to protect Brooks Avenue.

Floodplain Management Study for Narara Creek and Lower Narara Creek Tributaries West of Hanlan St. Kinhill, 1997 – This study assessed management options for Narara Creek and Fountain and Reeves Creek. Options included potential voluntary purchases, upgrade of hydraulic infrastructure and/or bridges, enlargement of conveyances, and installation of detention basins.

Flood Access Investigation for a Proposed High School, Narara. Kinhill, 1991 – This report identified potential access routes from the proposed high school site. This preliminary investigation examined potential for upgrade to culvert capacities, establishment of flood-free access routes and likely probability of occurrence of flooding during school hours.

Upper Narara Creek Floodplain Management Study. Patterson Britton and Partners, 1995 – This report presents potential structural and non-structural flood management options within the Upper Narara Creek area. As part of preparation of this study, a MIKE-11 model of the combined Upper and Lower Narara Creek system was prepared. Management options included bridge works (Deane St and Narara Valley Drive), channel modification, raising floor levels and bank stabilisation. Non-structural options included planning controls, acquisition of flood affected properties and evacuation planning.

Bradys Gully Blanche St Drainage Investigation. Webb McKeown and Associates, 1995 – A drainage analysis was undertaken in ILSAX, with hydraulic analysis in HEC-2 of the overland flow path downstream of the earthen dam above Blanche St. Cost-benefit analysis was undertaken of the culvert upgrade between Blanche St and Jarrett St as well as a new pipe upstream of Blanche St. A new drainage system option for North Crescent was also developed.

3.2 Floodplain Risk Management Plans

3.2.1 Lower Narara Creek Floodplain Management Plan. Kinhill, 1991

The plan presented a detailed review of options for thirteen general locations. These included Narara Creek floodway; West Gosford Industrial Area; Dwyer St Old Sewage Treatment Plant; Glennie St West Industrial Area; Rowena Road Protection Area; Showground Road Protection Area; Manns Road – Deane St Floodway; Brooks Avenue Flood Storage Area; and Wyoming and Wingello Creek Flood Storage Area. Management options included development control, stream modification, construction of berms/levees, potential voluntary purchase,

3.2.2 Floodplain Management Plan for Narara Creek and Lower Narara Creek Tributaries West of Hanlan St. Kinhill, 1997

The plan provides detailed discussion and estimated costing of each of the selected management options identified from the management study. These included raising Hanlan St and upgrade culvert capacity; construct a wet detention basin upstream of Hanlan St; creek realignment works; installation of a sediment trap; voluntary purchase; realignment and channel stabilisation works; wet detention basin for Fountain and Reeves Creek; removal of existing culvert on Carrington St; establishment of a causeway or bridge along Reeves St; upgrade of culvert capacity on Reeves St; and implementation of a development control plan for the catchment.

3.2.3 Floodplain Management Plan for Wingello Creek. Kinhill, 1993

The plan provides details of recommended options for Wingello Creek including costs. Options included replacement of low level bridge and adjustment of weir level; channel realignment; bank protection works; review of existing detention basin in Pecan Close; and a regular waterway maintenance program. Simulated flood contours, assuming all works are implemented, are also provided.

3.2.4 Floodplain Management Plan for Wyoming Creek. Kinhill, 1993

The plan provides a detailed description and estimated costs for various management options. Simulated flood contours, assuming all works are implemented, are also provided. Management options include increase in culvert capacity and channelization of creek; construction of energy dissipation structure; upgrade of bridge accesses to properties; bank protection works; inlet works and upgrade of culvert capacity; and implement a regular waterway maintenance program.

3.2.5 Floodplain Management Plan for Bradys Gully. Kinhill, 1993

The plan presents recommended management options for Bradys Gully including provisional costs. Simulated flood contours, assuming all works are implemented, are also provided. Management options include creek channelization; upgrade of culvert capacities; bank protection works; finalise channelization; upgrade pipe diameters; and implement a regular waterway maintenance program.

3.2.6 Upper Narara Creek Floodplain Management Plan. Patterson Britton and Partners, 1995

The plan presents recommended management options for the Upper Narara Creek area. Recommendations did not include acquisition of properties or floor level raising as these were considered uneconomic. Cost-benefit analysis was undertaken of the remaining options.

3.2.7 Update to Floodplain Management Study and Plan for Narara Creek and Lower Narara Creek West Tributaries West of Hanlan St. KBR, 2002

This letter updates two tables in the Floodplain Management Study based on review of details of a culvert under Hanlan St in the HEC-2 model.

3.3 Implemented Options

After the 1992 floods, the Council undertook a series of flood risk management studies and identified flood mitigation options in the catchment. A list of options (Appendix B), which were implemented in various sub-catchments is provided below:

- **Upper Narara Creek**
 - Silleta Road basin
 - channel improvement works – Koninderie Parade
 - levee bank – constructed upstream of Haggerty Close
- **West Narara Creek**
 - Hanlan St causeway upgraded
- **Reeves Creek**
 - culvert on Reeves St near Manns Road upgraded
- **Lower Narara Creek**
 - railway bridge blocked – Brookes Avenue
 - levee bank and detention basin – Brookes Avenue
 - channel widening, Showground Rd causeway and overflow channel
 - homes removed from Showground Round after voluntary purchase
 - creek realigned and new bridge on Showground Road

- homes removed after voluntary purchase and land lowered at Rowena Road
- floodway excavated – north of Glennie St West
- part of old sewage treatment pond removed
- **Wyoming Creek**
 - Chamberlain Road culvert
 - channel lining and rock chute construction below Alan Davidson Park
 - outlet realigned, new culverts under Pacific Highway
- **Wingello Creek**
 - channel and culvert upgrade to 1% downstream of Pacific Highway
 - outlet realignment at Willow Motel
 - Pecan Close retarding basin upgraded
 - weir and footbridge within former Reptile Park including channel works
 - channel works Warrawilla Road
- **Bradys Gully**
 - channel and Henry Parry Drive culverts upgraded to 1%
 - blocked Laycock St by 25%
 - channel and Kirkness Ave culvert upgraded to 1%
 - Jarrett St pipe drainage

The location plan provided by the Council of mitigation works that have occurred since the February 1992 event is presented in Appendix B.

A review of the previous flood management options suggests that the Voluntary Purchase of the properties along the Showground Road has been an effective option. Notwithstanding the cost of the option, Voluntary Purchase of properties with severe flood affectation remains an effective option in an urbanised flood prone area, such as the Narara Creek catchment. The option of voluntary purchase has been discussed further in the later sections of this report.

All previously recommended actions which have been implemented by Council have been included in this study. However, separate assessment of the effectiveness of these actions hasn't been undertaken.

3.4 Pacific Highway Upgrade – TfNSW EIS

Pacific Highway upgrade through Central Coast is part of NSW State infrastructure strategy to drive productivity and economic growth at a regional level. This upgrade is staged and Stage 4a (southern) and Stage 4 (northern) lie within the study area (See Appendix F for location).

TfNSW considered several route options for the upgrade. The preferred option was adopted after analysis and community consultation. The preferred option was modified in consideration of comments received during community and stakeholder consultation. The Central Coast Council was also a stakeholder in this process and provided comments on the preferred option. The final option layout along with excerpts from Community consultation report are presented in Appendix F.

Flood modelling was undertaken by TfNSW to assess the impact of various options and it was reported that *“Each option was also designed to have as least an impact as possible on the existing Narara Valley flood patterns.”* The flood models were not provided by TfNSW for consideration in this study.

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4 Narara Creek Floodplain

The floodplain for Narara Creek catchment was defined in the Review of the Narara Creek Flood Study (July, 2018), considering a whole-of-catchment approach, which was the primary objective when undertaking this update. Accordingly, a model of the whole Narara Creek catchment was created. A detailed analysis of the flood behaviour in the catchment was undertaken for various design flood events using a calibrated hydraulic model.

Design flood level, velocity and flow information was then developed for the Narara Creek floodplain, including provisional hazard categories as described in the Flood Risk Management Manual (2023).

To ensure that the FRMSP addresses current best practice, provisional hazard categories H1-H6 (AIDR, 2017) were also mapped (Figure 19, Figure 20 and Figure 21) as part of this FRMSP.

The 1% AEP flood extent for the Narara Creek catchment is presented in Figure 6 and Figure 7.

A summary of the design flood behaviour in various tributaries of the Narara Creek catchment is presented in the following sections.

4.1 Existing Flood Behaviour

Narara Creek is the primary channel for conveyance of floodwaters through the catchment. Several large tributaries discharge into the main channel, which ultimately discharges to Fagans Bay in Brisbane Waters.

With the land use ranging from forest to highly urbanised areas within the catchment, the flood producing mechanisms are varied and complex. With flooding from various tributaries, the existing flood behaviour in Narara Creek and the low-lying areas of various tributary catchments to a large extent is dependent on flood arrival times at the tributary junctions.

The upper reaches of various tributaries are independent of the 'backwater' influence of Narara Creek. However, the flood risk in general is low in the upper reaches and it is the lower reaches, where the flood behaviour is complex, that are subjected to a higher flood risk.

The Review of the Narara Creek Flood Study (Golder, 2018) has analysed flood behaviour for each individual tributary as well as the complex interaction at the tributary junctions. Understanding of this flood behaviour is key to identifying effective flood risk mitigation options.

Given that the time of concentration for flood flows varies throughout the catchment, design flood modelling was undertaken for various durations of each design flood event. For example, in the upper reaches of the catchment, where flow would exhibit a peak in a relatively short time, the critical design storm could be of the order of 30 minutes to an hour. In the lower reaches of the catchment, larger duration storms are more critical. Modelling was undertaken for storm durations ranging from 30 minutes to 18 hours to capture critical flow behaviour in various parts of the catchment.

The modelling indicated that the 2 hour and the 9 hour events were critical for most design flood events.

However, shorter durations in the upper catchments are also important as the impact can be as severe as longer durations within some sub-catchments. This study considers events of all durations and the maximum flood level is derived from all those events for each design flood i.e. an envelope approach was adopted where peak of peaks from various durations of a design event were derived.

Figure 6 and Figure 7 present the peak 1% AEP flood extent for the Narara Catchment under existing conditions, including the rail upgrade, which has been recently constructed by TfNSW.

The number of properties affected in various design flood events are provided in Table 1.

Table 1. Flood Affected Properties in a 1% AEP Event

Event (AEP)	No of Properties Affected by Flooding*	No of Properties with Over-Floor Flooding
PMF	1673	1,435
0.2%	915	578
0.5%	915	578
1%	794	435
2%	718	373
5%	636	343
10%	591	304
20%	518	255
50%	170	67

* *A property is considered flood affected even if a small part of the property is flooded*

Key locations for flood management (Figure 8) are areas subjected to major flooding with significant flood risk. These areas include:

- Properties along Koninderie Parade and surrounding areas
- Area between Deane Street and Reeves Streets
- Area at the confluence of Wyoming Creek and Wingello Creek with the Narara Creek, including Wyoming Caravan Park and Brooks Avenue Industrial area
- Properties along the northern end of the Showground Road
- Overland flooding in the West Gosford Industrial area
- Overland flooding around Gosford Hospital and further downstream
- The racecourse area (being a critical flood storage in the catchment)

The compendium of flood maps presented in the flood study (available on Council's website) provides details of the existing flood behaviour at the above locations and throughout the entire study area.

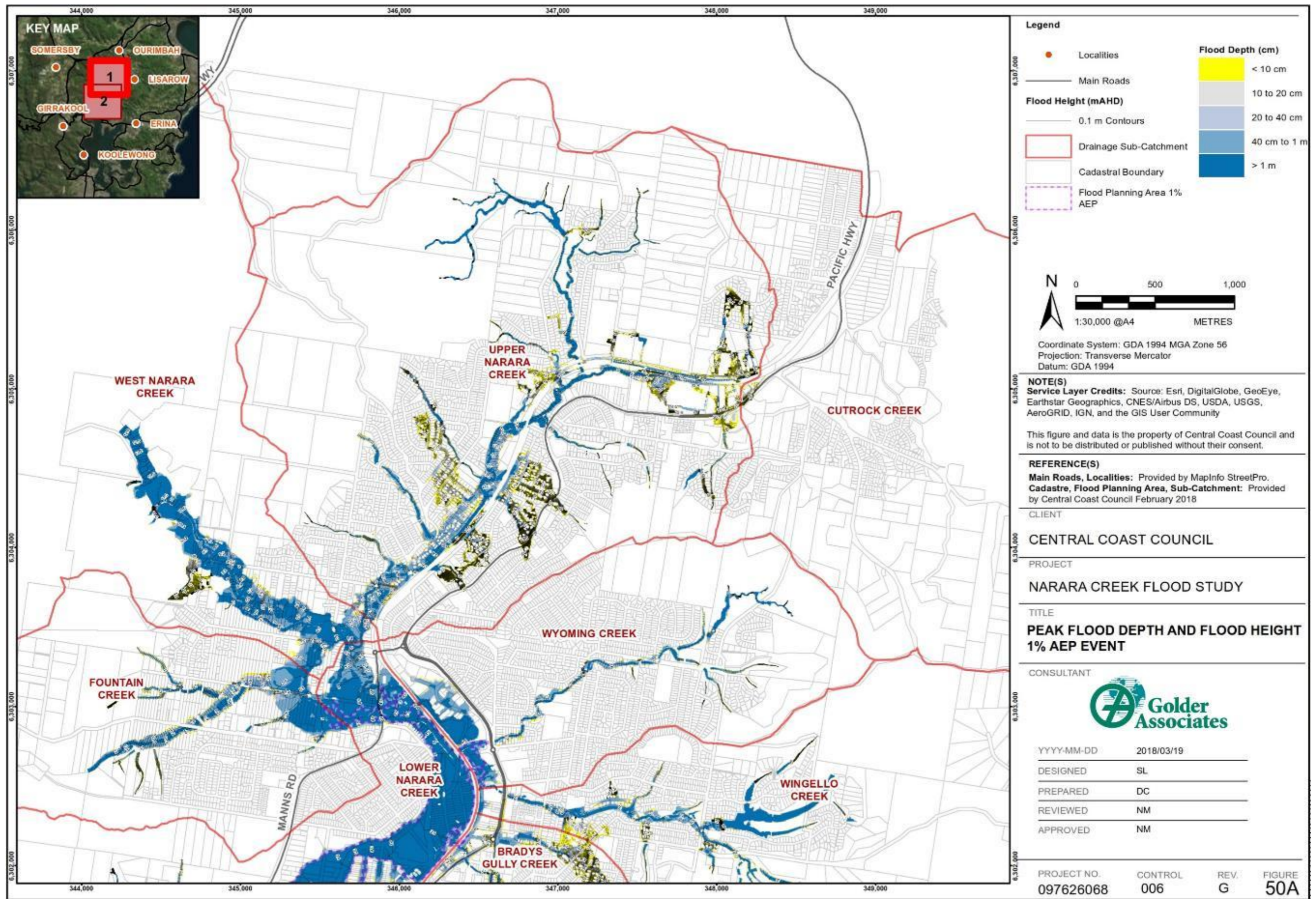


Figure 6. 1% AEP Flood Extent – Existing Conditions UPPER CATCHMENT

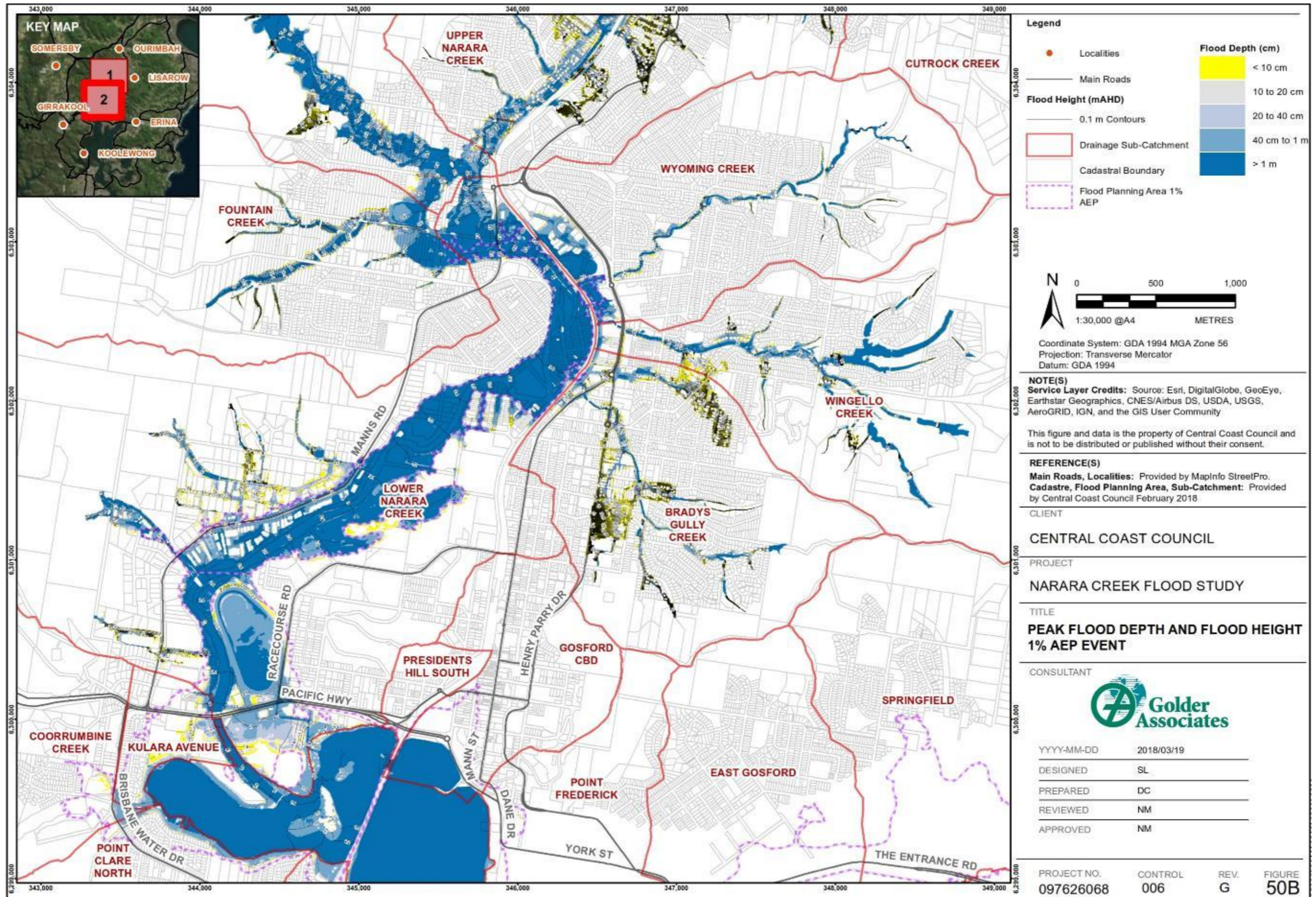


Figure 7. 1% AEP Flood Extent – Existing Conditions LOWER CATCHMENT

4.2 Flood Management Areas

Narara Creek catchment has been divided into seven Flood Management Areas (FMA), corresponding to the sub-catchments in the study area. The flood management measures have been identified and assessed in each management area, where feasible. Flood management measures, such as development controls, are common to all the FMAs.

Each FMA has been assigned an identifier, consistent with the convention adopted for other sub-catchments in the Central Coast LGA. These FMAs are:

Flood Management Area	Catchment Description	Catchment Area
C4/A	West Narara Creek	14.3 km ²
C4/B	Upper Narara Creek	8.3 km ²
C4/C	Fountain Creek	5.1 km ²
C4/D	Wyoming Creek	3.1 km ²
C4/E	Wingello Creek	4.9 km ²
C4/G	Brady's Gully	2.6 km ²
C4/F	Lower Narara Creek	8.4 km ²

To manage the economic consequences and risk to life associated with existing, future and continuing flood risk for occupation of flood prone land within the Narara Creek catchment, management measures have been identified. There are three broad categories of management measures, these being:

- **Flood Modification (FM) measures** – Flood modification measures are options aimed at preventing/avoiding or reducing the likelihood of flood risks. These options reduce the risk through modification of the flood behaviour within the catchment such as detention basins and levees.
- **Property Modification (PM) measures** – Property modification measures are focused on preventing /avoiding and reducing consequences of flood risks. Rather than necessarily modifying the flood behaviour, these options aim to modify properties (both existing and future) so there is a reduction in flood risk. Such as voluntary purchase, house raising, flood proofing of buildings and development controls.
- **Emergency Response Modification (EM) measures** – Emergency response modification measures aim to reduce the consequences of flood risk. These measures generally aim to modify the behaviour of people during flood events such as flood awareness and flood warning.

Key flood management issues (Figure 8) are discussed in the following sections of the report.

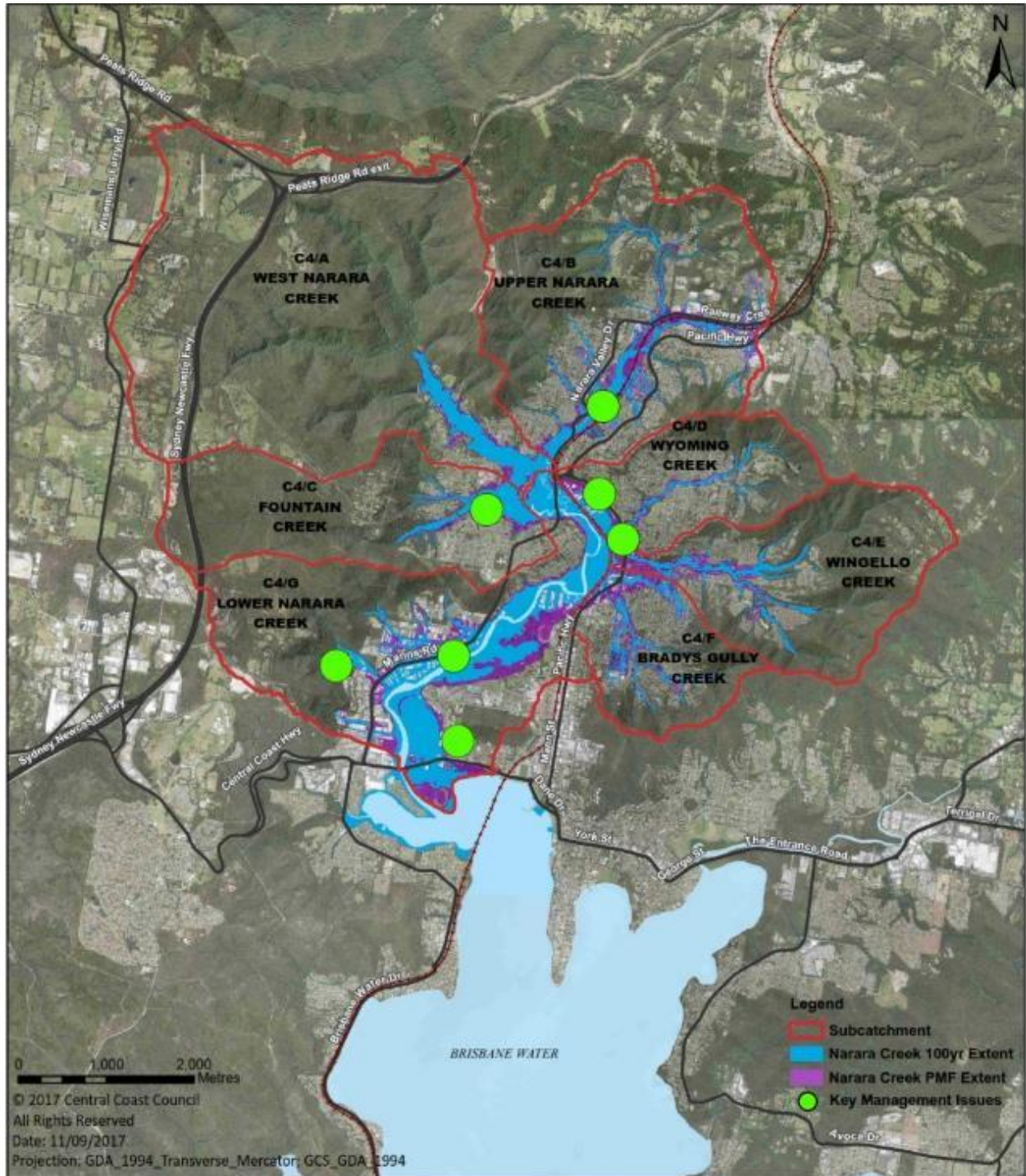


Figure 8. Flood Management Areas and Key Locations for Flood Management

4.2.1 West Narara Creek (C4/A)

The West Narara Creek Flood Management Area (FMA) extends from confluence with Narara Creek downstream of Hanlan Street to M1 Motorway in the west (Figure 9). The Narara Horticulture Dam is located in this FMA and is currently owned by Narara Ecovillage Co-operative Ltd. A large residential subdivision, Narara Ecovillage, has recently been completed near the dam.

The Narara Horticulture Dam presents a risk due to a potential dam-break and the ensuing flood. The dam owners have undertaken investigations and prepared a Dam Safety Monitoring & Surveillance Report and a

Dam Safety Emergency Action Plan to manage this risk. It is claimed by Narara Ecovillage that the dam is in good order and the risk of dam-break or flooding is assessed as low. On this basis, the NSW Dam Safety NSW (DS NSW) removed the Narara Horticultural Dam from the list of Prescribed Dams in July 2014. This removed any requirements for reporting to the DS NSW.

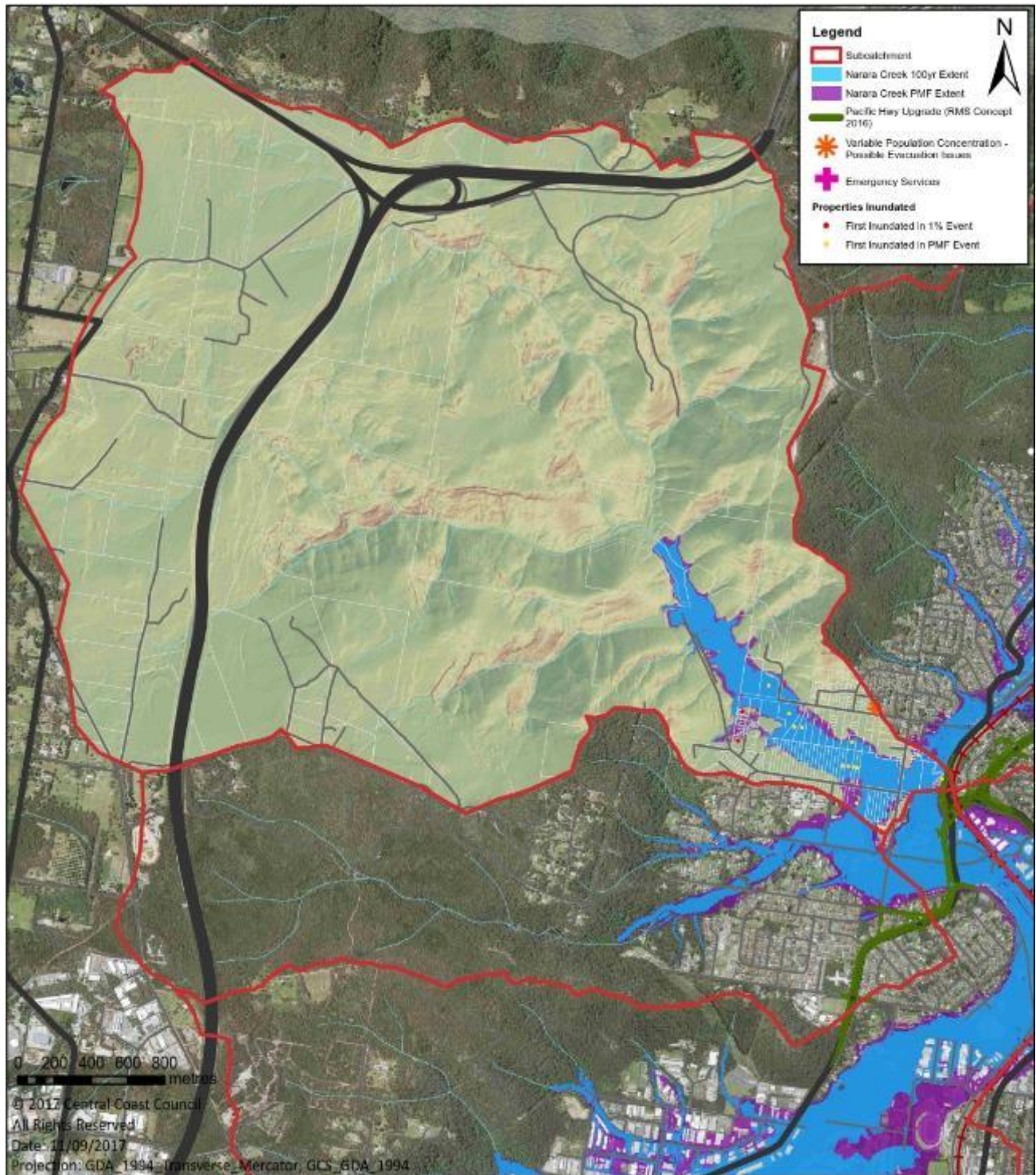


Figure 9. West Narara Creek FMA (C4/A) Layout

Previous Floodplain Management Plan – Lower Narara Creek Tributaries West of Hanlan Street (Kinhill Engineers Pty Ltd, 1997); Lower Narara Creek Floodplain Management Plan (Kinhill Engineers Pty Ltd 1991)

Several flood management options were identified in the above studies, as presented in Appendix E and reviewed in Section 11.6, Table 16. All options had a very low cost-benefit ratio but improved flood access, particularly in more frequent events. Although recommended in the plan, these options were not considered for implementation. The only option implemented was the upgrade of Hanlan Street culverts, which were designed to cater for a less than 1 year ARI event.

Modelling indicates West Narara Creek is out-of-bank in the 50% AEP event and above. Flood safe access is therefore a major issue in this FMA. For the existing developments, particularly the Narara Valley High School, and the recently completed Ecovillage, the residents would not have access to major roads during significant flooding, affecting flood emergency management in this area.

Channel works (Manns Road to Deane Street Floodway) were identified as a flood management option (NC12) in the Lower Narara Creek FRMP (1991) to increase the stream conveyance for Narara and Niagara Creeks, however this option was abandoned largely due to environmental concerns and replaced by a Rivercare Plan and general creek maintenance. This has not been re-considered in this FRMSP due to adverse environmental impacts.

The Australian Institute of Disaster Resilience (AIDR) has provided guidelines for assessing Flood Emergency Response Classification of a floodplain. According to these guidelines, large areas of this FMA would be classified as FIE (Flooded, Isolated and Elevated). The classification is based on a PMF event. The FIE classification represents a significant risk and needs to be addressed through appropriate flood management options.

The AIDR also provides guidance of effectively managing and limiting the growth of flood risk within the floodplain by categorizing the constraints to the Defined Flood Event (typically the 1%AEP). Flood Planning Constraint Categories (FPCC) can provide separation of areas based on suitability for more concentrated development or intensive land use. The AIDR suggests four FPCC (5). These categories could form the basis of a Development Control Plan for all FMA's.

5 Flood Planning Constraints Categories (AIDR, 2017)

FPCC	Constraint Subcategory
1	a) Floodway or flood storage area in the DFE
	b) Flood hazard H6 in DFE
2	a) Floodway in events larger than the DFE
	b) Flood hazard H5 in the DFE
	c) Emergency response (isolated and submerged areas)
	d) Emergency response (isolated but elevated areas)
	e) Flood hazard H6 in floods larger than the DFE
3	Remaining area below the DFE plus freeboard
4	Remaining area below the PMF or Extreme Flood

BOX 4.2.1 Addressing the Issues – West Narara Creek (C4/A)

Any new development along with the existing developments require effective planning and development controls to manage the flood risk. A large area of this FMA is flooded in a PMF event such that evacuation from this area is currently unavailable. Hanlan Street floods frequently and prevents flood evacuation even in small to moderate flood events.

Potential for further subdivisions due to permissible planning opportunities should be carefully considered with respect to evacuation as effective flood warning time in this area is very limited. Subdivisions that require filling to address flood risk will need to consider the cumulative impacts of the development for all flood events up to and including the PMF.

Flooding of Hanlan Street also restricts flood evacuation opportunities for the Upper Narara Creek FMA. The Narara Valley High School is also cut-off even in a minor flooding event which exposes itinerant visitors to flood risk during the morning and afternoon peak hours for the school. Flood management options include:

- Development controls to be reviewed, including consideration of FPCC
- Flood Risk awareness through education
- Flood alerts using sirens and predictive messaging
- A site-specific Flood Emergency Response Plan for the school and other large developments with significant flood risk
- Flood indicators with flashing lights at Hanlan and Fountains Road
- Visual messaging system (VMS), to be provided in consultation with TfNSW
- Predictive Early Warning Storm Forecast Networks established enabling preemptive flood warning initiated road closures
- Alternative evacuation route/s

The Narara Horticulture Dam also presents a risk due to potential dam-break and the consequent flooding. This dam used to be on the Prescribed Dams list as prepared by the Dam Safety NSW, however, currently is not on that. The dam owners, Narara Ecovillage Co-operative Ltd, have developed a Dam Safety Monitoring & Surveillance Report and a Dam Safety Emergency Action Plan and claim to undertake regular dam surveillance and maintenance. It is further claimed by Narara Ecovillage that the dam is in good order and the risk of dam-break or flooding is assessed as low. On this basis, the Dam Safety NSW (DS NSW) has removed the Narara Horticultural Dam from the Prescribed Dams list in July 2014. Consequently, the dam owner has no requirement for reporting to the DS NSW.

5.1.1 Upper Narara Creek (C4/B)

This part of the floodplain extends approximately from Deane Street to the northern end of the catchment (Figure 10). The primary flood affected area in this part of the floodplain include properties along Koninderie Parade. Significant out-of-bank flow occurs at this location in the 10% AEP design event with an overland flow path becoming active behind Koninderie Parade.

Narara Valley Drive is overtopped frequently with overtopping occurring even in the 50% AEP design event from overland flow arriving from the west of the road. The railway near Koninderie Parade is not overtopped up to approximately 0.5% AEP, the overtopping occurs in a PMF event. Flood events rarer than 0.5% AEP were not modelled and it is likely that those rarer events may result in overtopping at this location.

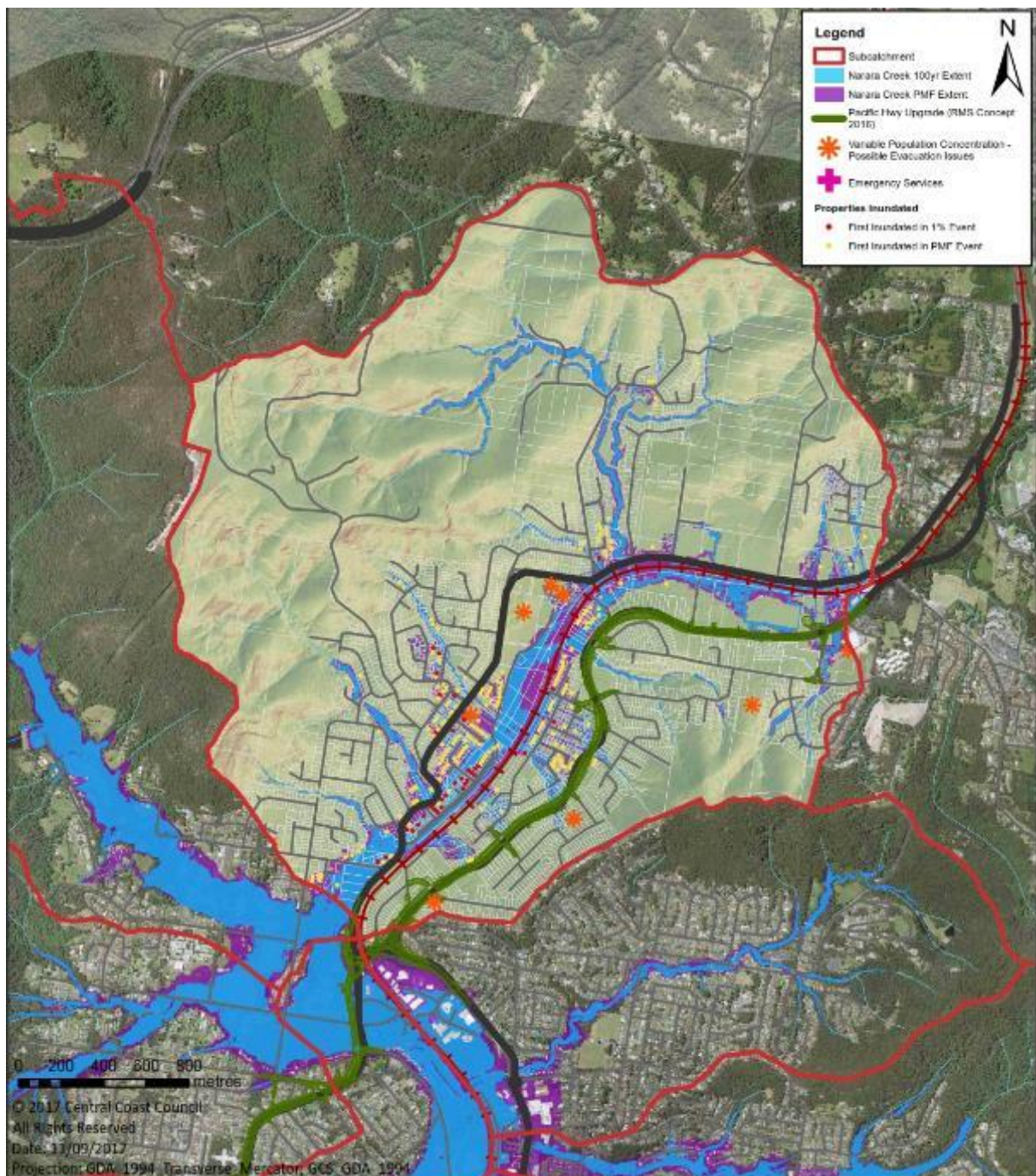


Figure 10. Upper Narara Creek Catchment (C4/B) Layout

Previous Floodplain Management Plan – Upper Narara Creek (Patterson Britton & Partners Pty Ltd, 1995); Lower Narara Creek Floodplain Management Plan (Kinhill Engineers Pty Ltd 1991)

Several flood management options were identified in the above studies, as presented in Appendix E and reviewed in Section 11.6, Table 16. The Upper Narara Creek FMP (Kinhill, 1991) key recommended flood mitigation measures were related to properties of Koninderie Parade area. Under the high priority actions of

the FMP, only the Koninderie Parade channel improvement and application of appropriate development controls has been implemented.

Properties affected in the 1992 flood event in Koninderie Parade had significant direct and indirect damages. Since no mitigation measures implemented have been determined as effective, the flood risk is still present.

These properties are still vulnerable and measures such as redevelopment to include safe refuge in place or voluntary purchase is considered in this study, refer flood mitigation modeling Section 12.3.1.

Some of the measures such as replacement of Narara Valley Drive culverts and levee construction in the reserve behind Koninderie Parade were reassessed in the current study.

An important recommendation of the FMP was to prepare a Flood Evacuation Plan for the Koninderie Parade Area and the areas west of the Deane Street crossing. This plan has not been prepared. Together with the flood evacuation planning of the West Narara Creek FMA and the Fountain Creek FMA, Koninderie Parade area needs to be included in a comprehensive flood evacuation planning for the entire region.

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BOX 4.2.2 Addressing the Issues – Upper Narara Creek (C4/B)

Catchment wise, this is the second largest FMA and drains the northern parts of the catchment. Properties along Koninderie Parade are severely affected in a major flood event. The vegetation growth in the creek also increases the chances of attaining higher flood levels if the floods occur in between the scheduled maintenance works.

Overland flow affects Narara Valley Drive. The local drainage has been improved based on the recommendations of a previous study including upgrading culverts and easements for secondary flows. However, the current study shows that the overland flow still affects the road.

Upstream of the northern end of Koninderie Parade, Narara Creek overflows, causing flooding of the Willari Ave playground. This flooding can potentially be prevented by the provision of a small levee at the location of creek overflow. This has been assessed in the current study (See Section 12.2)

Another option proposed previously was to upgrade the Narara Valley Drive culverts on Narara Creek to a free spanning bridge to improve conveyance and reduce the chances for blockage. This option along with a levee at the northern end of the Koninderie Parade can potentially reduce the flooding for the properties in that area. (See Section 12.3.1)

Additional undevelopable property downstream of the proposed upgrade may need to be acquired to address any negative impact by the construction of the levee.

Another potential option is to increase the flood holding capacity of Siletta Road basin, located in the upper reaches of the Narara Creek. However, steep terrain in the area prevents achieving significant increase in storage volumes.

Development controls along with other property modification measures are likely to be suitable for the Koninderie Parade area. Property modification measures may also be required to manage the flood risk in this area.

Other flood affectation in this FMA is due to overland flow in the residential area to the west of the railway corridor. Detailed local drainage studies would need to be undertaken to assess the flood risk and identify flood management solutions. As with other overland flow flooding areas in the catchment, there is an opportunity to review the basis of flood planning area control, with additional options for defining the flood planning area rather than the strict application of a fixed freeboard. The issue with the fixed freeboard application is that the flood planning area tends to cover an exaggerated area for flood planning purposes. Council has adopted different approaches for defining flood planning areas in the LGA.

5.1.2 Fountain Creek (C4/C)

The Fountain Creek catchment extends to Debenham Road in the west from its confluence with Narara Creek near Reeves Road intersection with Manns Road (Figure 11). The western tributary of Fountain Creek, accessed from Carrington Street and Reeves Road/Cross Street, is out-of-bank above the 50% AEP; however, model results indicate no residential properties are flood affected with above floor flooding up to the 0.2% AEP flood event.

At the upstream end of Cross Street, the natural floodplain has been filled and there are several access driveway bridges in this area. The level of service of these access bridges is quite low, generally less than 50% AEP.

Floodwaters in the upper reaches of this part of the floodplain are confined within the steep channels and out of bank flows are generally for rarer flood events.

There are two small dams known as Railway Dams in the upper reaches of the Fountain creek. These dams were built in the early 1900s to provide water for railway works in the area. These dams are owned and managed by Crown Lands and are subject to annual condition inspection by a dam safety consultant. Crown Lands coordinate repairs/defects identified in these inspections.

Previous Floodplain Management Plan – Lower Narara Creek Tributaries West of Hanlan Street (Kinhill Engineers Pty Ltd, 1997); Lower Narara Creek Floodplain Management Plan (Kinhill Engineers Pty Ltd 1991

Several flood management options were identified in the above studies, as presented in Appendix E and reviewed in Section 11.6, Table 16. Only a few options were implemented due to the low cost-benefit ratio. However, the majority of the options considered were beneficial in providing flood free access, particularly Reeves Street as it was planned to be linked to the freeway (now abandoned), more so for the frequent flood events. This study has identified that some of those previous recommendation that have not yet been implemented may form evacuation routes for the catchment (C4/C) area together with the adjacent catchment (C4/B).

Finally, an option was considered to extend the Pandala Road to Reeves Street through the Pandala Link Road as part of the Pacific Highway Upgrade project. This option involved acquisition of properties to create the connection between Pandala Road and Reeves Street. This option was presented to the community by the State Government's TfNSW through a public exhibition and information sessions held in September-October 2016. Approximately 400 responses were received from the community. A quarter of those responses objected to the construction of this Pandala Road Link. The major reasons for objection included property acquisition, increased traffic volume on Reeves Street and corresponding threat to the Reeves Street duck pond, school student safety and impact of future housing development. Based on this feedback, TfNSW removed this option from the design of Pacific Highway Upgrade (Appendix F).

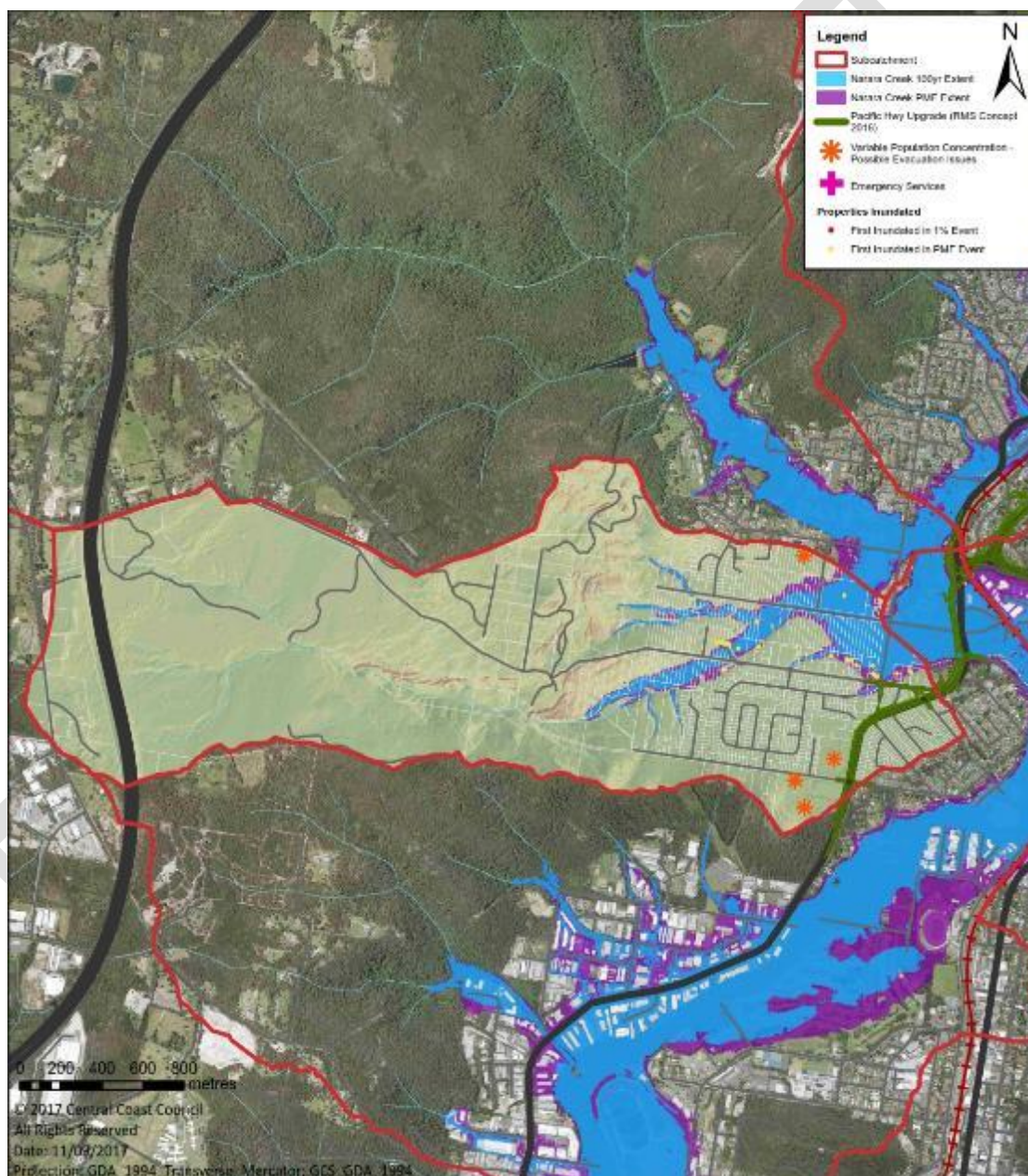


Figure 11. Fountain Creek Catchment (C4/C) Layout

BOX 4.2.3 Addressing the Issues – Fountain Creek (C4/C)

Only a small number of properties are affected by above floor flooding for various design flood events up to the 1% AEP event. However, inflows from Fountain Creek contributes to the major flooding at the confluence of Narara and West Narara Creeks.

Reeves Street has the potential to be part of an evacuation route for the Narara High School and the surrounding areas. However, this street is overtopped near the unformed Cross Street very frequently. An upgrade of the road and culvert at that location is required to establish Reeves Street as an evacuation route. In addition, the Cross Street connection to Carrington Road would need to be completed, including a bridge/culvert crossing for a local creek. This evacuation route would serve the local area, including the Narara Valley High School, Community Centre and the Narara Ecovillage.

Council is currently undertaking feasibility planning for this route and has included this in the forward works plan. Preliminary estimates suggest that the cost of this option is significant. However, flood evacuation is an important consideration for the Fountain Creek and the West Narara Creek catchments.

Application of development controls can be effective in managing the flood risk in this FMA.

Provision of a flood warning system comprising sirens can also be an effective tool in managing the flood risk in this FMA.

The Duck Pond, near the Pildara Street intersection of Reeves Street is a small detention basin and water quality improvement pond. This pond lies on a major overland flow path in this flood management area. Detailed flood behaviour of this pond was not investigated but is likely to provide flood management benefits in more frequent events, along with improving the stormwater quality from the upstream catchment. Detailed investigations would be required at the local scale to assess the flood management benefit of this pond.

5.1.3 Wyoming Creek (C4/D)

The Wyoming Creek catchment layout is shown in Figure 12. Wyoming Creek between Pacific Highway and Alan Davison Park is confined in-bank up to the 2% AEP event. The culvert at Pacific Highway has a level of service greater than the 0.2% AEP event. There are some residential properties adjacent to Wyoming Creek that are flood affected in the 1% AEP event and above. However, the highest flood risk is at the Wyoming caravan park where the flood depths can reach up to 1.2 m. Since it has a significant concentration of population and a limited time available to evacuate in a flood emergency, risk to life and property is significant.

Wyoming Creek is out-of-bank within Alan Davison Park in the 20% AEP event, however, is mostly confined within the creek reserve for all AEP events. The Gosford Loop study for railway upgrade by Transport NSW (Section 5.1.6) indicates that the upgrade works have increased the flood levels in the Alan Davidson Park up to 0.6 m. This indicates the sensitivity of the catchments and the effects of filling the floodplain.

The Day Street channel has a service level of about 2% AEP. Although the 50% AEP levels are above the concrete-lined portion of this channel, the available creek easement appears sufficient up to the 2% AEP event.

The Day Street culvert is overtopped in the 5% AEP event and above.

Above the Day Street culvert, Wyoming Creek is out-of-bank in the 50% AEP event and above, however, is confined within the creek reserve for essentially all AEP events except the PMF. Upstream of Chamberlain Road, Wyoming Creek is confined within the creek reserve up to the 0.2% AEP event. The Chamberlain Road culvert is overtopped in the 10% AEP design event and above. At Pangari Close, there is surface overland flow in events greater than 50% AEP. One property near the cul-de-sac is affected by above floor flooding for events greater than 20% AEP. The cul-de-sac is flooded to a depth of 1.3 metres for a duration of up to 1-2 hours.

The access bridge to the Aged Care Facility on Chamberlain Road near Malison Street is above the PMF. Further downstream, however, Chamberlain Road and Day Street are subject to inundation of up to 0.7 m in depth for a period of 2-3 hours at other locations. Evacuation from this area is still possible as alternate routes to regional roads are available in this FMA.

The culvert on Chamberlain Road at the intersection with Maya Street is overtopped in the 50% AEP event and above.

Previous Floodplain Management Plan for Wyoming Creek (Kinhill Engineers Pty Ltd, 1993)

Several flood management options were identified in the above studies, as presented in Appendix E and reviewed in Section 11.6, Table 16.

The plan primarily recommended floodway enhancement at several locations in the catchment. The plan also included Pacific Highway Chamberlain Road culvert upgrades. The Pacific Highway culvert upgrade prevents flooding of the highway up to a 1% AEP event.

The plan also recommended a regular creek maintenance program, as overgrown creeks would cause flood levels to rise and impact the surrounding properties.

Another important recommendation was related to the future development of the catchment, which required provision of stormwater detention facilities for the new developments.

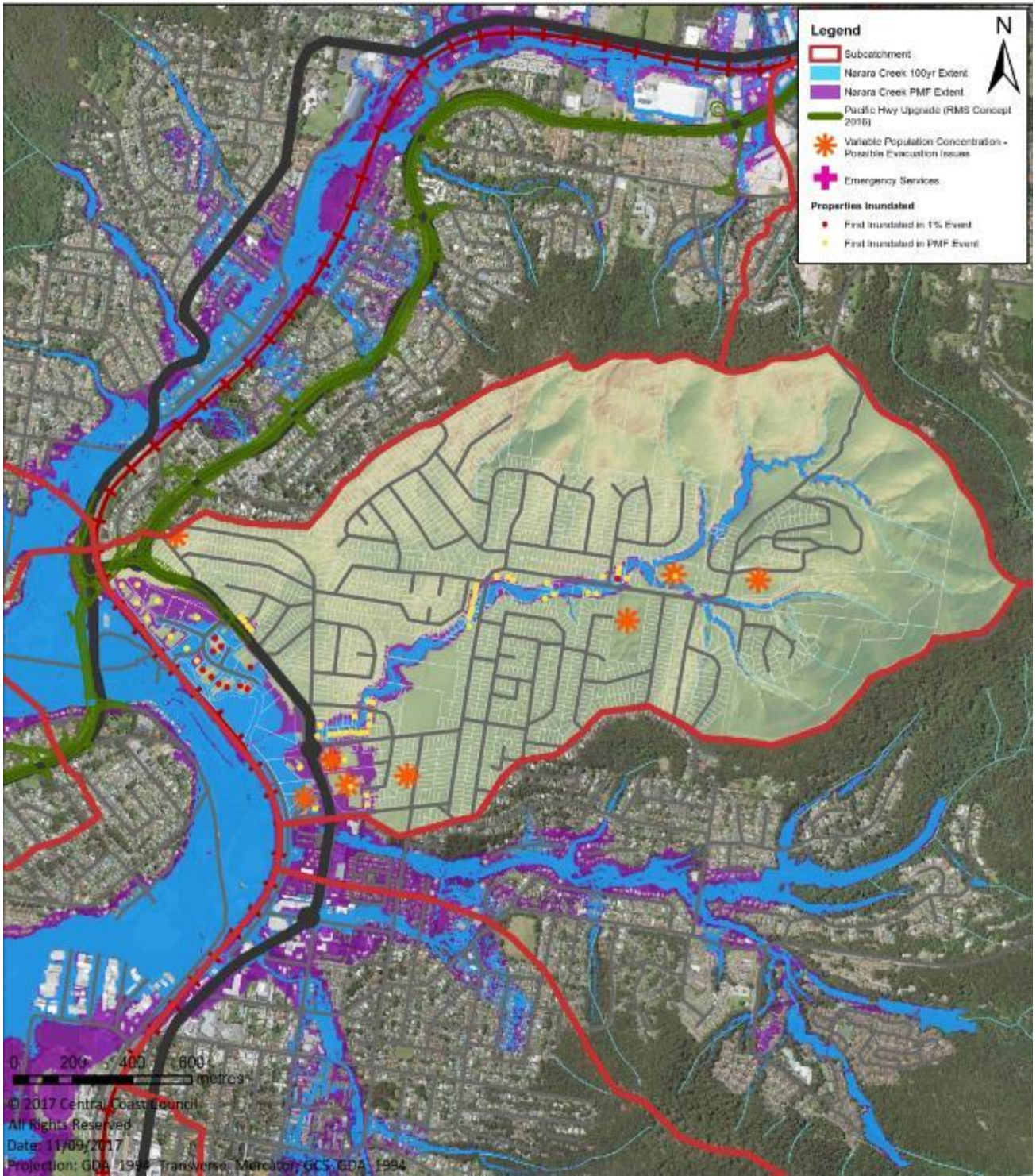


Figure 12. Wyoming Creek Catchment (C4/D) Layout

BOX 4.2.4 Addressing the Issues – Wyoming Creek (C4/D)

Wyoming Creek is confined within the creek reserve for majority of the area for the modelled design flood events. However, several road crossings are overtopped that can result in evacuation issues during a flood event. Effective warning tools could assist NSW Police and SES in road closures.

A small number of individual properties are affected by above floor flooding for various design flood events up to the 1% AEP event. Review of development controls with respect to H1-H6 hazard categories will ensure future development is assessed to minimise the flood risk.

The Brooks Avenue detention basin is not affected by flooding from Wyoming Creek except in a PMF event. However, this basin is flooded from the Narara Creek flooding and provides temporary storage for floodwaters. The basin discharges to Wyoming Creek via flood gates, which prevent flooding of the basin from Wyoming Creek. Regular maintenance of these flood gates is necessary for the expected flood mitigation benefit from the basin.

The Pacific Highway is affected by flooding from events greater than the 1% AEP event. However, the flooding duration is likely to be short. Overtopping flood depth and duration of flooding would need to be considered if the highway is to be used as an evacuation route.

To address the risk to life in the caravan park, this study undertook numerical modelling to gain an understanding of flood affectation to adjacent properties should the terrain be filled above the flood planning level (Section 12.5). Together with filling, an effective evacuation route would reduce the flood risk for the caravan park. Any rezoning or development should carefully consider evacuation routes to ensure no vehicles drive through a hazard category greater than H1.

For vulnerable developments like aged care facilities in addition to having habitable floors above the PMF, site-specific Flood Emergency Response Plan can be developed with the assistance of Council and SES to ensure greater resilience in times of flooding thereby reducing stress and providing clarity of thought in times of high anxiety.

Where other measures become unsuitable, properties that meet the specified criteria can be considered for Voluntary Purchase (Section 13.2) to eliminate the flood risk.

In general, application of development controls can be effective in managing the flood risk in this FMA. Understanding the cumulative impacts of new subdivision as it relates to the whole of the catchment and not in isolation should be a key consideration of development consent.

5.1.4 Wingello Creek (C4/E)

Wingello Creek catchment extends from Toomeys Road in the east to its confluence with Narara Creek near Pacific Highway and Kinnara Road intersection (Figure 13).

Wingello Creek is confined within the creek reserve for the majority of the area for the modelled design flood events. However, a few locations such as Roselands Avenue and Dalton Street are affected by flooding.

Lower Reach

Wingello Creek between the confluence with Narara Creek and Jarrett Street remains in-bank for all AEP events, except for the PMF. The Pacific Highway at this location has a level of service greater than the 1% AEP event.

Below Warawilla Road as well as below Jarrett Street, the currently creek reserve appears sufficient to confine up to the 0.2% AEP event. An exception is Roselands Avenue, where there is localised ponding due to the limited capacity of the pipe network.

The culvert at Jarrett Street, south of Adnamira Close, has a level of service of up to 20% AEP event.

Upper Reaches

Modelling indicates that the Pecan Close detention basin is overtopped in the 0.2% AEP event and above. The 'Declared Dam' status of the basin by Dam Safety NSW was reviewed by the former Gosford City Council commissioned a Dam Break Study and Flood Consequence Category Assessment (GHD, Nov 2017) for the basin. The study assessed the Flood Consequence Category of the basin based on both the Population at Risk (PAR) and Potential Loss of Life (PLL) values. Both the PAR and PLL assessments result in a Flood Consequence Category of "**Low**". The Sunny Day Consequence Category (SDCC) of the basin was assessed to be "**Very Low**". The outcomes of the Dam Break study were presented to Dam Safety NSW, which has approved Council's request to remove the Pecan Close basin from the 'Declared Dams' list. This change in basin status was gazetted on 5 August 2022.

The culvert at Maidens Brush Road has a level of service of 5% AEP. The Maidenbrush Road is also overtopped at several locations due to flooding from tributaries along the southern side of the creek. This can restrict the evacuation from the retirement village.

The majority of the retirement village is above the 1% AEP flood. However, a small number of properties in this facility, near the southern end of Kalawarra Road, are affected from flooding.

Previous Floodplain Management Plan for Wingello Creek (Kinhill Engineers Pty Ltd, 1993)

Several flood management options were identified in the above studies, as presented in Appendix E and reviewed in Section 11.6, Table 16.

This Plan identified that the majority of flows were contained within the banks of the channels however the Plan recommended a number of flood modification measures including instream works and erosion control. These works include channel and culvert upgrade to 1% AEP capacity downstream of Pacific Highway, outlet realignment at Willow Motor Inn downstream of Pacific Highway, Pecan Close retarding basin upgrade (as discussed above), weir and footbridge within former Reptile Park including channel works and channel works near Warrawilla Road.

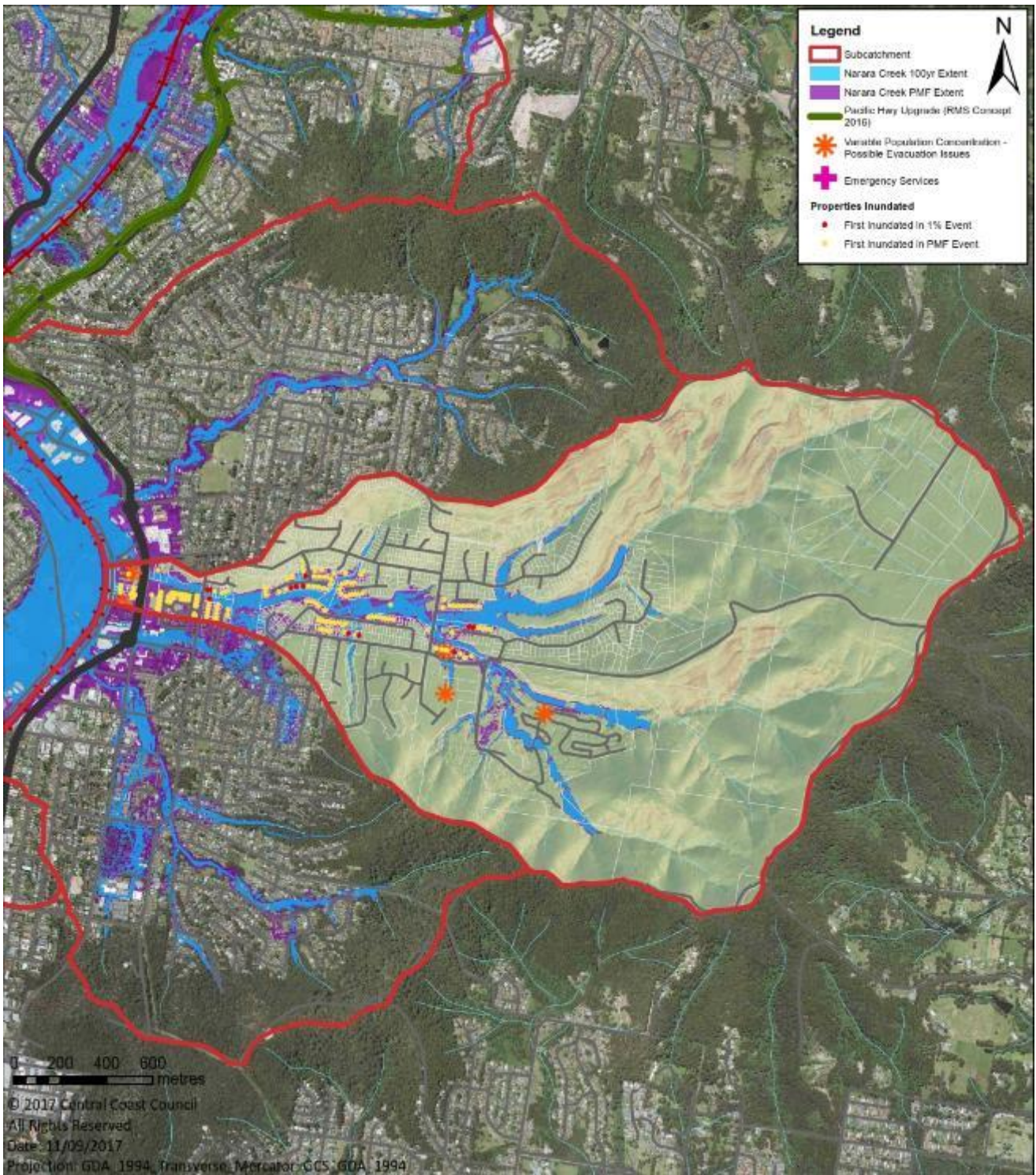


Figure 13. Wingello Creek Catchment (C4/E) Layout

BOX 4.2.5 Addressing the Issues – Wingello Creek (C4/E)

The Pecan Close basin, which was upgraded in 2007, provides significant storage of floodwaters. Council is the owner of this dam and is responsible for its maintenance and management. The basin, which was a 'Declared Dam' as per the Dam Safety NSW, was removed from the register of 'declared dams' following a Dam Break Study and Flood Consequence Category assessment for the basin was undertaken by the Council (GHD, Nov 2017). The study found that the basin has a low flood risk and consequently Dam Safety NSW approved Council's request to remove the Pecan Close basin from the register of 'Declared Dams'. This change in basin status was gazetted on 5 August 2022. The new status of the basin should be updated in SES operational plans.

A major development in the FMA is the retirement village, which is above the 1% AEP flood, except a few properties near the southern end of Kalawarra Road. Overtopping of Maidens Brush Road in a flood event can hinder evacuation from this retirement village. A site-specific Flood Emergency Response Plan prepared by the retirement village can help manage the risk of flooding.

The Pacific Highway is affected by flooding from events greater than the 1% AEP event. As such, the highway is not likely to be suitable for use as a local evacuation route at this location. However, the short duration of the flooding can potentially make this road available for any regional flood evacuation. The requirement of a regional flood evacuation route that spans several catchments in the Gosford area has been discussed in Section 14.1. Detailed analysis of such a route can be undertaken in a separate study.

The Roseland Avenue and the Dalton Street flooding can potentially benefit from upgrade of local drainage. A detailed local drainage study would be required to upgrade the drainage in these areas to further define and maintain secondary flow paths.

In the lower reaches of this FMA, cross-catchment flow from the Bradys Gully Creek in large flood events can result in a complex flood behaviour and may create issues for any future development of this area.

There is a limited scope to undertake any new major works. Application of development controls is likely to be effective in managing the flood risk in this FMA. Vacant land that has permissible development potential requires careful consideration of secondary flow paths and this should be reflected in development controls.

5.1.5 Bradys Gully (C4/F)

Bradys Gully is a tributary of Narara Creek and has a catchment area of 2.7 km². There are several tributaries of Bradys Gully that affect properties as an overland flow.

Lower Reach

The Bradys Gully catchment extends from the eastern end of the Bradys Gully Road in the east to the confluence with Narara Creek near the intersection of Akora Road with Pacific Highway.

Modelling indicates that Bradys Gully is in-bank up to the 2% AEP event below Henry Parry Drive to the Pacific Highway. Bradys Gully at the Pacific Highway is not overtopped until the 5% AEP event.

For design events greater than the 5% AEP, the constriction due to the Railway bridge, as well as tailwater effects of Narara Creek, lead to ponding immediately east of the railway line.

There is surface overland flow at the roundabout of Pacific Highway, Henry Parry Drive and Pemell Street in the 50% AEP event, however, is generally less than 10 to 20 cm until the 10% AEP event. There is ponding in Pemell St in all AEP events greater than 50%. This is due to the low hydraulic gradient between this location and the creek outlet under the Railway.

Upper Reach

The flooding is generally contained within the creek reserve in the upper reaches.

The capacity of the Our Lady of Rosary Primary School culvert is less than the 50% AEP event, however, the overland flow path between Glennie Street and Cary Street carries the floodwaters downstream, away from the school buildings, up to the 1% AEP. The car park on top of the culvert would be flooded. The school grounds fronting Carey Street would also be flooded. Above floor flooding is not likely.

Bradys Gully Creek between Glennie Street and Bradys Gully Road is contained in-bank for all AEPs events up to the PMF.

A tributary that passes through the Gosford Private Hospital, joins Bradys Gully Creek at Glennie Street. This tributary, above Glennie Street to Dwyer Street, has been piped. The capacity of that system appears to be less than the 50% AEP event, with surface overland flow occurring through the multi-unit housing complex down to Glennie Street.

There is overland flow through North Gosford Hospital; however, it is quite shallow up to the 10% AEP event.

There is a minor tributary of Bradys Gully that runs parallel to Bradys Gully Road which is now piped from below an earthen dam through to Blanche St and Jarrett St. This trunk line has recently been upgraded. Due to the shallow hydraulic gradient at the downstream end, that trunk line is subject to outlet control. Modelling suggests the capacity of the new drainage line is approximately 20% AEP event.

A tributary of Bradys Gully through Kirkness Avenue has capacity up to the 2% AEP event. Surface overland flow along Kirkness Avenue (where the natural watercourse has been piped) is generally less than 10 to 20 cm. Further upstream, the properties along Algwen Road are low lying and are affected by flooding from frequent events. In rarer events, the properties can be flooded to a significant depth (up to 1 m in a 1% AEP event).

Upstream of Bradys Gully Road, Bradys Gully Creek is confined in-bank up to Stachon Street to about the 1% AEP event. The level of service of the pipe running parallel to Stachon Street is less than the 50% AEP event and residents report regular issues with standing water due to overland flow.

A couple of low set properties at the northern end of Marangani Avenue have significant flood affectation. These properties start flooding in frequent flood events and can potentially flood to a depth greater than 1 m in a 1% AEP event, resulting in flooding of the ground floor. Similarly, a few properties on Yuroka Close also have significant flood affectation.

Flood hazards range between H1-H5 in channels and properties in and around the Maiden Brush Road. In particular, Carlson Avenue is subject up to an H5 hazard.

Previous Floodplain Management Plan for Wingello Creek (Kinhill Engineers Pty Ltd, 1993)

Several flood management options were identified in the above studies, as presented in Appendix E and reviewed in Section 11.6, Table 16.

Similar to the Wyoming and Wingello catchments, this plan (Kinhill,1993) identified that the majority of flows were contained within the banks of the channels. The Plan recommended a number of flood modification measures including instream works and erosion control.

The plan (Kinhill,1993) was confined to the defined creeks and did not include the Pemell Street to Maidens Brush Road area, which is shown to be affected by flooding (Golder, 2018) up to 1.3 m near the Pacific Highway roundabout and commercial premises. This is primarily due to the reason that the entire Narara catchment was not analysed using a single hydraulic model, and the cross-catchment flows that result in major flood events between the Bradys Gully and Wingello Creeks is not accounted for in individual models for each catchment.

In addition, residential properties are also affected in Pemell Street with 1% AEP flooding at or near existing floor levels, as discussed above.

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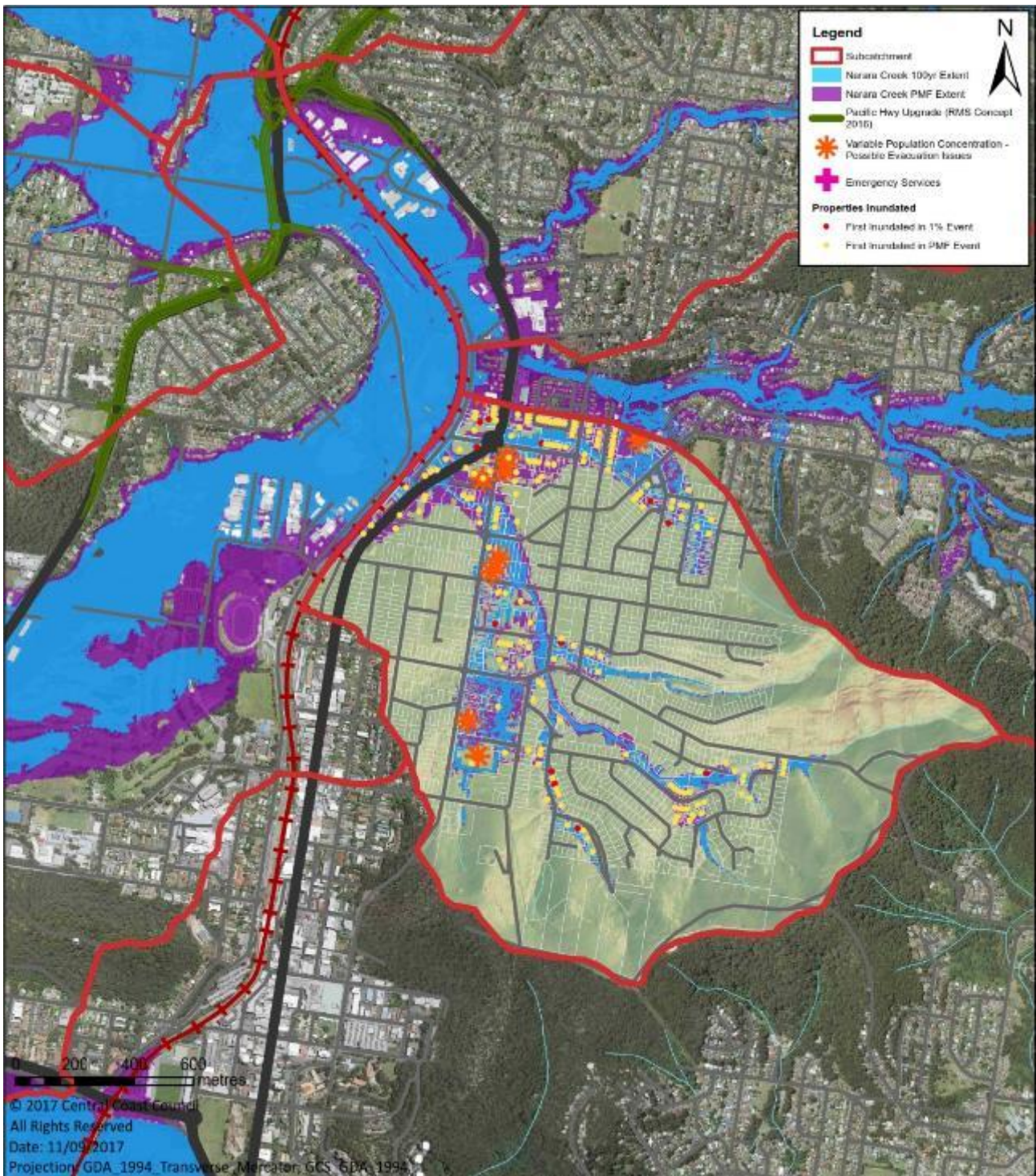


Figure 14. Bradys Gully Catchment (C4/F) Layout

BOX 4.1.7 Addressing the Issues – Bradys Gully Creek (C4/F)

Brady Gully Creek has several tributaries and each tributary has flood affected properties. Properties along Algwen Road, Marangani Ave, Yuroka Close, upstream of Blanche Street and Stachon Street are flood affected. However, majority of the creek flooding is confined to the creek reserve, even in the lower reaches of the catchment.

Our Lady of Rosary Primary School between Glennie Street and Carey Street is subject to flooding. In a major flood event, the school will be surrounded by floodwaters and create a significant risk for the school. The school should be advised of this risk and a site-specific Flood Emergency Response Plan should be prepared.

The Gosford Private hospital is also subjected to significant flooding. The local drainage within the hospital should be reviewed by the hospital and upgrade should be undertaken if required. A site-specific Flood Emergency Response Plan should be prepared by the hospital.

The area between Dwyer Street and Glennie Street is subjected to overland flow flooding. A detailed local drainage study can be undertaken to identify any upgrades that may reduce the flood risk. Additionally, any future development in this area should consider allowance for a dedicated overland flow path to minimise the flood risk.

Similarly, properties along Algwen Road may also benefit from a detailed local drainage study by identifying suitable upgrades.

The Pacific Highway is affected by flooding from events greater than the 1% AEP event. As such, the highway is not suitable for use as an evacuation route at this location. However, the short duration of the flooding can potentially make this road available for any regional flood evacuation.

The flood evacuation routes in general need to be identified LGA wide and then the local routes from the study area need to tie up with the regional routes.

Several works have been carried in this FMA in the past (Kinhill, 1993). These works include channel and culverts upgrade at Henry Parry Drive to 1% AEP capacity, channel and culvert upgrade at Kirkness Ave to 1% AEP event and Jarrett St pipe drainage

There is a limited scope to undertake any new major flood modification works. In general, application of development controls is likely to be effective in managing the flood risk in this FMA.

5.1.6 Lower Narara Creek (C4/G)

This management area extends from Fagans Bay to Manns Road bridge (Figure 15). The capacity of the Lower Narara Creek channel is approximately 10-20% AEP flood. However, flows break out near Showground Road and Glennie Street West industrial area in a 50% AEP event, which can potentially cause significant traffic gridlocks during peak hours. The properties at Showground Road near the Manns Road bridge are also frequently flooded with flood affectation starting at 50% AEP event.

The complex interaction of flow from Bradys Gully and Wingello Creek at the junction with Narara Creek results in flood behaviour which is determined by the timing of flood peak arrival at the junction. As an

example, peak flows from Bradys Gully and Wingello Creeks at the confluence with Narara Creek occur prior to peak flow of Narara Creek itself thereby allowing these tributaries to discharge. For Wingello Creek, the critical duration is 9 hours due to the Pecan Close detention basin; however, there is still significant discharge in the 2 hours design flood event from this catchment.

The flood behaviour near Carrington Street and Deane St is governed by flooding contributions from Fountain Creek and West Narara Creek. Of critical importance is overtopping of bridges in this area, which potentially cuts off the escape route during a flood emergency. The Carrington Street bridge is overtopped in the 20% AEP event. The Deane St bridge is overtopped in the 50% AEP event and above. Similarly, modelling indicates that the bridge at Manns Road is also overtopped in the 20% AEP and above.

It is also worth noting that the flood levels above 10% AEP in this area are impacted by the constriction caused by the Main Northern Railway across Fagans Bay.

There are several flood-affected areas with significant local flood risk. The industrial area at Glennie Street West is severely affected in a 1% AEP event, with almost all the properties affected by flooding in this event. Flooding of a few properties, along the Narara Creek banks start even in a 50% AEP event. Although channel improvement works have been undertaken in the past, this area is still severely affected. Flood emergency management measures, such as provision of flood alarms, appear to be a potential solution of risk management of this area. Other development controls, including management of hazardous materials, is required for this area.

39 properties along Showground Road and Rowena Road have been acquired under the Voluntary Purchase program by the Council. However, there are still a few properties that are flood affected near the Bellbowrie Avenue intersection. These properties are frequently flooded, with flooding starting in a 50% AEP event.

The West Gosford industrial areas flood affected from local runoff originating from the catchment to the west of the area. The local street drainage has a limited capacity, resulting in flood affectation even in a 50% AEP event. The redevelopment of the properties along Manns Road, on the bank of Narara Creek is being undertaken on a fill, which is above the 1% AEP flood level in Narara Creek. However, flooding arriving from the local catchment to the west affects these properties. A detailed local drainage investigation is required as a separate study to identify solutions for overland flow management.

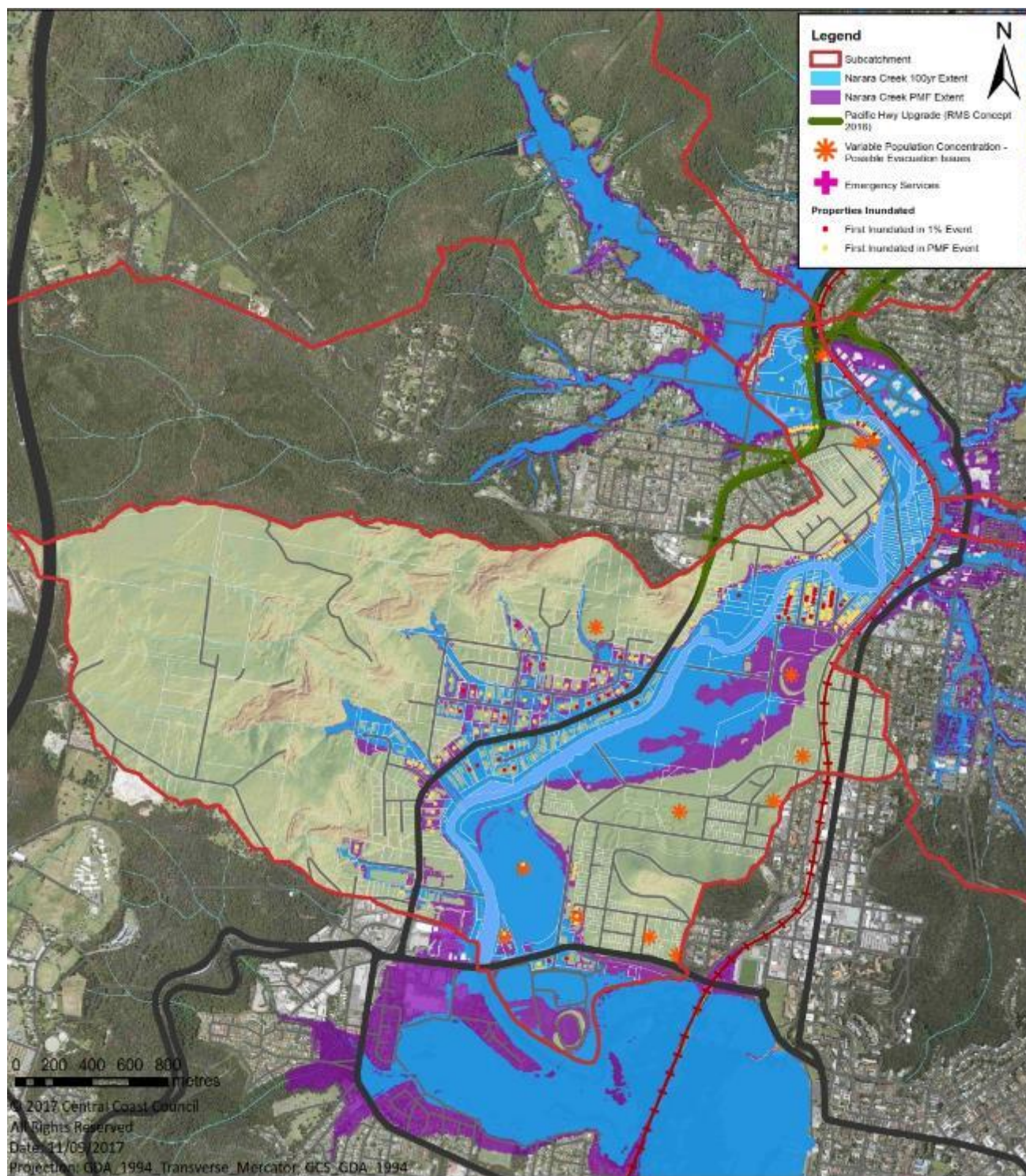


Figure 15. Lower Narrara Creek Catchment (C4/G) Layout

The lower reaches of Narara Creek are also impacted by flooding caused by ocean processes in Brisbane Water. The Brisbane Water Foreshore Flood Study (Cardno, 2013) provides details of this flood behaviour and highlights areas likely to be flooded within the Narara Creek catchment.

Rivercare works have also been planned by the Council for the section of the creek between Deane Street and Manns Road. These plans have been partly implemented and works were stopped when TfNSW started planning work on the Pacific Highway upgrade, since the initial plans would have impacted the Rivercare works. However, the approved alignment of the upgrade is now away from the Rivercare works, the Rivercare works can be re-initiated.

Previous Floodplain Management Plan for Lower Narara Creek (Kinhill Engineers Pty Ltd, 1991)

Several flood management options were identified in the above studies, as presented in Appendix E and reviewed in Section 11.6, Table 16.

Historically this FMA is the most flood affected area and presents a significant risk to life and property. The Council (former Gosford City Council) in implementation of the Floodplain Management Plan for Lower Narara Creek (FMPLNC,1991) addressed many of the community's concerns through voluntary purchase of residences and undertaking flood modification measures.

BOX 4.2.7 Addressing the Issues – Lower Narara Creek (C4/G)

The ad hoc filling of the Gosford Industrial Area adjacent to Narara Creek has likely created overland flow issues by blocking flow paths that drain this area to Narara Creek. In addition, the local road upgrade of Mann Street has a potential to further block these flow paths. A drainage Master Plan for the industrial area is required to ensure that the future filling does not increase the flood risk in this area.

Master planning would ensure better implementation in West Gosford and provide economic certainty. Further detailed study would be required to inform a Master Plan, including a detailed local study for drainage upgrade.

The Central Coast Highway is affected by flooding in frequent flood events, in particular near the Racecourse Road intersection. Any future upgrades of the Highway by TfNSW would provide an opportunity to reduce the frequency of flooding by improved drainage or raising of the Highway. Another option to manage flooding of the Highway is to build a small wall within the northern road reserve and utilise the racecourse flood storage to detain floodwaters in more frequent events.

The Wyoming Caravan Park is flood affected. The itinerant nature of its residents increases the flood risk, as the guest to the caravan park may not be familiar with the flood hazard. Filling was recommended (Option NC9.6) in the FMPLNC, 1991 in order to reduce risk at this caravan park. In order to gain an understanding of any affectation to other properties, this study has examined this option in more detail.

It is noted that Reconstruction Authority NSW is delivering a project to help make caravan and ski parks in the Hawkesbury-Nepean floodplain become more flood resilient. The project activities include developing park specific flood maps and assisting managers to understand how to interpret flood warnings for their site, and what actions to take to be prepared for, and better respond to, a flood. This project aims to help these parks better manage their flood risks now and into the future by having up-to-date flood emergency management plans and close working relationships with their local NSW SES units. Council may consider adopting this project for Wyoming caravan Park or other caravan parks in the LGA.

The racecourse along the Narara Creek provides essential flood storage during all flood events. Any future development of the racecourse should consider the impact of loss of storage on the surrounding areas.

BOX 4.2.7 Addressing the Issues – Lower Narara Creek (C4/G)...continued

Properties that meet criteria for Voluntary Purchase (Section 13.2) can be considered to eliminate the flood risk, where other measures become unsuitable. A property near Dell Road may be suitable for this purpose. Additionally, a small levee near Dell Road can prevent flooding of the properties from Narara Creek to the east. This can be undertaken in consultation with TfNSW planned upgrade for the Manns Road, which may benefit both objectives.

Previous development limits along Narara Creek were established (FMPLNC,1991) and are recommended to continue in this study. Specific development controls are required for properties along the banks where the 1%AEP is contained within the creek. The impact of shorter duration flooding should also be considered. However, there is significant flooding in events greater than the 1% AEP event, which need to be considered to ensure risk to life and damage to properties is addressed.

Development controls are also likely to play a significant role in the flood risk management for this FMA

In addition, flood emergency management measures, such as flood early warning systems including sirens, SMS messaging etc. for Rowena Road and the Glennie Street West industrial area would reduce the flood risk in this FMA.

The flood mitigation works undertaken in this FMA include levee to form the Brooks Ave detention basin, partial blocking of railway bridge for Brooks Ave detention basin, channel widening near the railway, Showground Rd causeway and overflow channel, Voluntary Purchase of homes along Showground Round, creek alignment and new bridge on Showground Road, Voluntary Purchase of homes and lowering of land at Rowena Road, excavation of floodway north of Glennie St West and part removal of old sewage treatment pond.

6 Impact on Community

6.1 True Flood Hazards

Floods can result in personal danger and generally cause damage to property. Flood hazard determines the impact of flooding on people and development in a floodplain. Effective flood risk management requires a detailed assessment of flood hazard to ensure that the existing flood risk is managed, and the future development of the floodplain is compatible with the flood hazard of a given area.

Flood hazard is not uniform across the floodplain. It also varies with time with progressive development of a floodplain and even during a flood event. Floodplain Development Manual provides the guidelines to categorize the flood hazard in a floodplain.

The provisional flood hazard, as defined in the flood study (Golder, 2018) is based on the hydraulic criteria derived from the flood depth and velocity. The true hazard is dependent on several other factors such as size of the flood, effective warning time etc., as discussed in the following sections.

6.1.1 Updated Hazard Guidelines

Australian Institute of Disaster Resilience (AIDR) has released updated guidelines (Handbook 7) for hazard classification (AEMI, 2014). These guidelines are currently the best practice in flood risk management in Australia and incorporate research work undertaken in Australia and overseas to define flood hazard based on the flood depth and velocity criteria. The primary difference between the Floodplain Development Manual (FDM) guidelines and those of AIDR is the number of hazard categories, with the later guidelines extending the number of categories to 6 (H1-H6) as opposed to three as proposed in the FDM. Both hazard definitions are presented in Appendix C.

The hazard categories based on FDM are presented in The Narara Creek Flood Study update and those based on AIDR Handbook 7 are presented in Figure 19.

The new flood hazard definition is used to define flood risk to the community by identifying the Flood Planning Constraint Categories (FPCC), as per AIDR Handbook 7. The hazard criteria for these FPCCs are provided in Section 4.2.1. The purpose of this categorization of the floodplain is to increase the flood resilience of the communities occupying various categories in the floodplain.

6.1.2 Additional Hazard Criteria

In addition to the hydraulic criteria, there are several other factors that determine the severity of the 'true' flood hazard at a given location in a floodplain. The Narara Creek Flood Study update (Golder, 2018) has prepared the provisional flood hazard categories based on the hydraulic considerations only, as per the FDM. In this study, several other factors have also been taken into consideration and the flood hazard maps revised where required. Various factors affecting the flood hazard and how they impact the Narara Creek catchment are discussed in the following sections:

6.1.2.1 Size of the flood

Small frequent floods have less impact on a community than the large, rarer floods. A range of flood events therefore need to be investigated for flood hazard. The size of the catchment and hence the magnitude of flood for even a more frequent flood event indicates that a relatively large segment of the community may be exposed to the flood hazard. In a 1% AEP event, the peak flow at Central Coast Highway is approximately

360 m³/s. This is a large flood and has the potential to cause extensive damage. Culvert blockages can result in significant re-distribution of flows and cause extensive damage.

This study has investigated flood hazard for the 20%, 5% and 1% AEP events together with the Probable Maximum Flood (PMF).

6.1.2.2 Effective Warning Time

Warning for an impending flood can reduce the flood hazard considerably. However, the warning should allow sufficient time to allow the community and the emergency services to undertake evacuation to be effective. Generally, a warning time of six hours is required at the minimum for evacuation purposes. In Narara Creek catchment, the flood peak near the downstream parts of the catchment would arrive in around six hours. However, significant flooding is likely to occur before the arrival of the flood peak, thus reducing the ability to evacuate. In upper parts of the catchment, the warning time is much smaller than six hours and therefore evacuation and consequently reduction in flood hazard is not feasible.

6.1.2.3 Flood Readiness

A community which is prepared for facing the flood threat is more likely to manage the impact of flooding both during and after floods. Although flood readiness is most useful where effective flood warning time is available, nevertheless, flood awareness can prepare the community even in flash flooding catchments like Narara Creek.

Flood readiness involves community education and a sustained campaign to highlight the risk of flooding to the community. Unfortunately, flood awareness campaigns are few and far between and generally do not have the desired impacts.

Flood readiness can be directly related to the frequency of flood impacts in a catchment. Where flooding is rare, the community loses the ability to manage floods effectively.

Based on the experience in other similar catchments, only a small proportion of the Narara Creek catchment community can be considered flood ready. Furthermore, the lack of extensive flood warning system reduces the benefit of flood readiness in the catchment. Hence, for the purpose of this study, the Narara Creek catchment community would not be considered ready for the floods.

6.1.2.4 Rate of Rise of Floodwaters

Narara Creek catchment has a significant rate of rise of floodwaters and consequently, potentially increases the flood hazard in the catchment. The rate of floodwater rise is different in different parts of the catchment. As an example, the floodwaters rise by approximately 0.2 m/hr near Central Coast Highway and approximately 0.7 m/hr near Carrington Street, Narara. This rate of floodwater rise is likely to reduce the effectiveness of any flood management measures during the flood event.

6.1.2.5 Depth and Velocity of Floodwaters

Impact of depth and velocity of floodwaters has been assessed in the preliminary hazard assessment. Flood depths greater than 1 m and flow velocity greater than 2 m/s can result in high hazard. Depths and velocities close to these values can still cause significant hazard, in particular near the community facilities which are more vulnerable such as aged care facilities and childcare centers etc. These considerations have informed the development of true hazard in the Narara Creek catchment.

6.1.2.6 Duration of Flooding

Excessive duration of flooding can be extremely stressful for the community, in particular where the properties are isolated during flooding. Flooding in Narara Creek catchment is of short duration, ranging

from approximately 3 hours in the upper parts and approximately 9 hours in the lower reaches of the catchment. Flood behaviour in the catchment shows that some properties in the catchment may be isolated during flooding. Although the duration of flooding is small, the isolation can create additional hazard for the residents of those properties. Understanding how long evacuation routes are interrupted (duration time) by flooding is critical for flood intelligence and SES operational flood plans.

6.1.2.7 Evacuation Problems

Issues related to evacuation of people and moveable property can result in additional damage and disruption to the community. Evacuation problems can result from several factors including:

- number of people requiring assistance
- the depth and velocity of floodwaters
- wading problems through floodwaters (uneven ground, fences, debris etc.)
- mobility of people (low mobility of children and aged)
- distance to flood-free ground
- inability to contact emergency agencies
- limited capacity of road to take additional traffic related to evacuation
- the time of day and weather conditions (difficult during night and wet weather)

In addition to the above, potentially low flood readiness of residents and availability of limited flood intelligence of the study area to SES can create significant evacuation difficulties. However, provision of flood intelligence developed in this study to SES would facilitate evacuation when required.

Narara Creek catchment presents significant evacuation difficulties, in particular in the middle reaches of the Narara Creek and hence this factor is one of the dominant factors in determining the true hazard for the Narara Creek floodplain.

6.1.2.8 Effective Flood Access

Safe access to and from the flood affected areas plays an important role in managing the flood risk by providing means for evacuation. Effective and safe access is a trafficable route that is open for sufficient time to allow evacuation of the people and their possessions. Access can be pedestrian or vehicular with the later being preferred for effectiveness.

Flood access needs to be tested for effectiveness in an extreme event such as the Probable Maximum Flood (PMF), however, it is not necessary to have the flood access trafficable for the PMF. Where feasible, PMF free access is desirable.

In the Narara Creek catchment, effective flood access can help reduce the flood risk generally for the middle reaches of the Narara Creek, where most of the evacuation difficulties lie.

6.1.2.9 Type of Development

The degree of hazard is also dependent on the type of development and the mobility of its occupant. The following factors related to a particular development will influence the hazard classification:

- The need for special evacuation needs (for developments such as aged care, childcare, school, hospitals, caravan parks etc.)
- Occupant awareness (occupants of caravan park, mobile homes, motels, hotels etc. may not be aware of the flood affectation of the site)
- Isolated residential development (difficult evacuation)

- Hazardous industries or storage areas (flooding of the facility can create public health risk or result in short/long term environmental damage)
- Potential for danger to personal safety and damage (mobile home and caravan parks can be damaged and may even endanger personal safety and property damage downstream if these dwellings float and travel downstream)
- Development over watercourses (can isolate part of the development and create evacuation difficulties. Pedestrian crossings over watercourses can be dislodged during flooding and result in blockage/damage during a flood events)

In addition to the 1% AEP event, vulnerable developments need assessment against the PMF to manage the risk to life.

6.1.3 Discussion on True Flood Hazard

Several factors such as the rate of rise of floodwaters, effective warning time, evacuation problems, effective flood access and flood readiness of the community in the study area would increase the severity of provisional flood hazard, as defined in the flood study (Golder, 2018). Other factors such as size of the flood (for lower catchment) and development types (aged care facilities, caravan parks etc.) can also increase the severity of hazard at a few locations within the study area. Some of the factors, such as duration of flooding will tend to decrease the provisional flood hazard.

All the above factors need to be considered in assessment of any existing or proposed development in the study area. Any future planning, including change in landuse would also need to consider these factors to manage the future flood risk. In particular, developments such as critical infrastructure and services, high intensity developments such as sub-division or block of units and vulnerable community/commercial facilities such as schools, childcare centres and aged care facilities would require consideration of full suite of hazard factors as discussed above.

Of all the factors that can modify the provisional flood hazard, evacuation problems play a major role, as several factors as discussed above contribute to the severity of evacuation difficulties. Based on this assumption, the true hazard is presented in Figure 16, Figure 17 and Figure 18 for the 5% AEP event, 1% AEP event and the PMF respectively. These figures identify additional areas that can be considered as high hazard, beyond the high hazard limits as per the provisional flood hazard definition.

In addition, any low hazard islands within the high hazard area should also be considered as high hazard.

As noted above, all other factors affecting the provisional flood hazard would need to be considered when assessing a development.

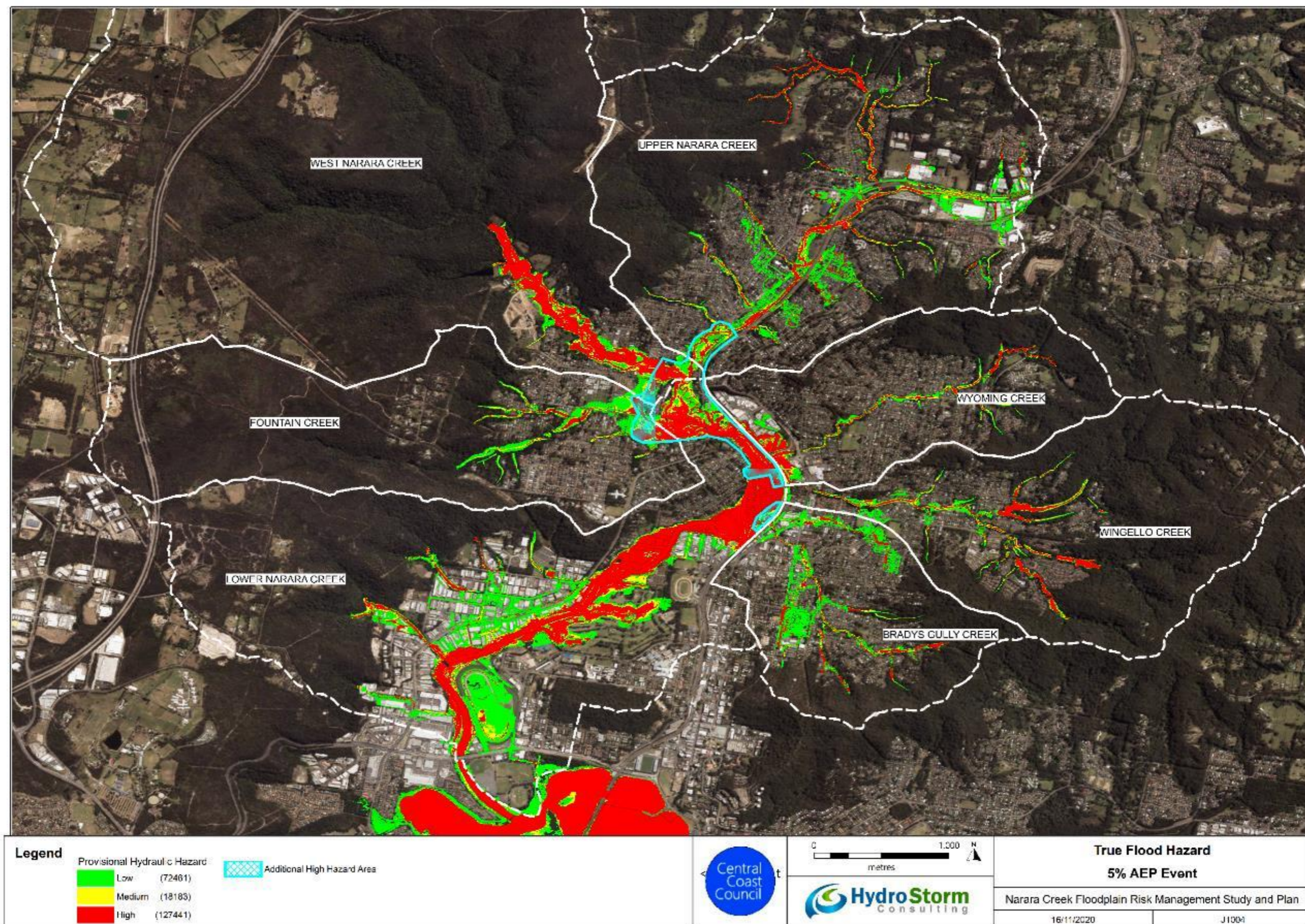


Figure 16. True Hazard – 5% AEP Event

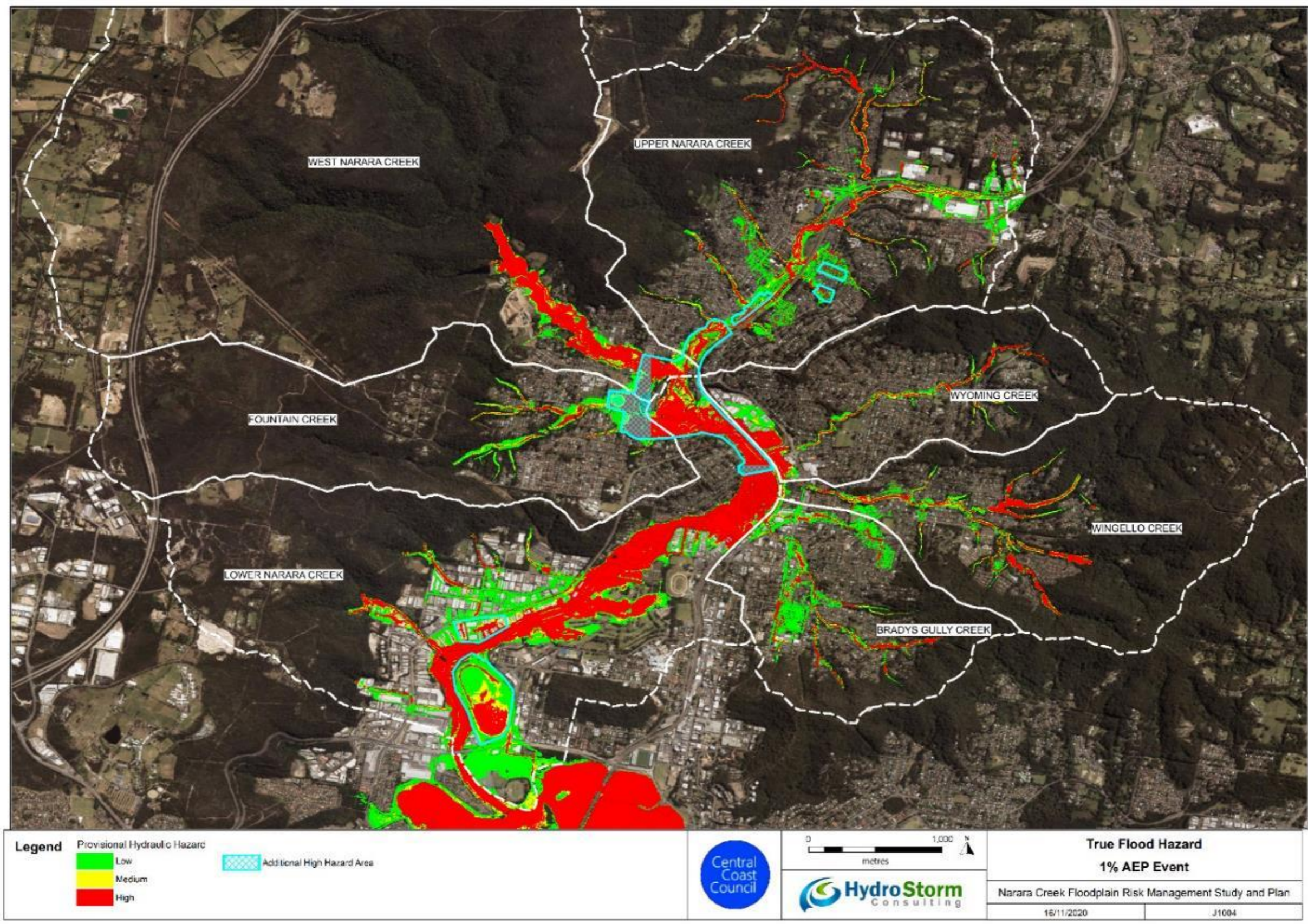


Figure 17. True Hazard – 1% AEP Event

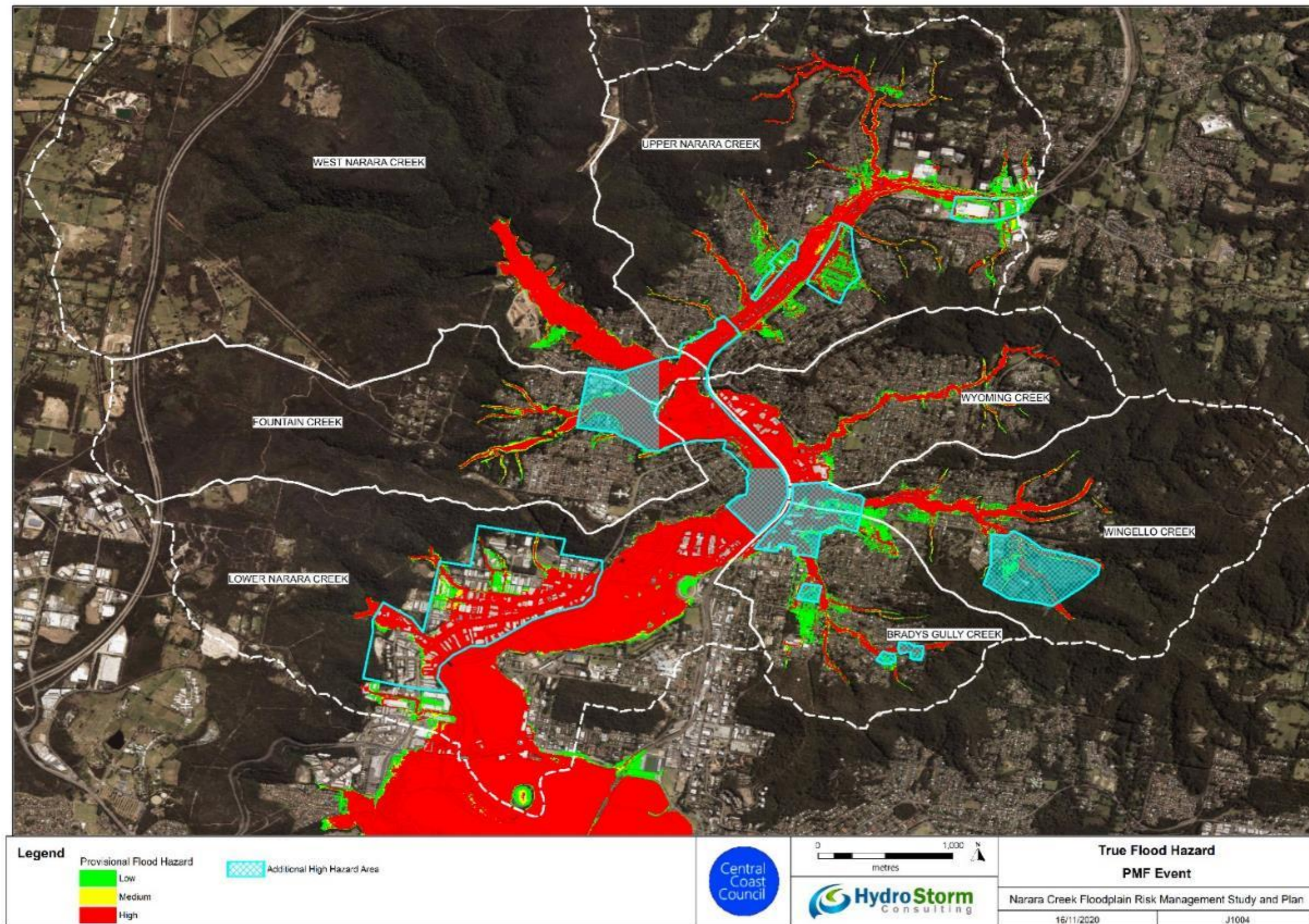


Figure 18. True Hazard – PMF Event

6.1.4 Additional Flood Hazard Maps

6.1.4.1 AIDR Guidelines

Australian Institute of Disaster Resilience (AIDR, 2017) has recently produced national guidelines for flood risk management. These guidelines have proposed methodology for flood hazard estimation based on vulnerability of the residents and various other elements of a floodplain. The new hazard definition is shown in Figure 19.

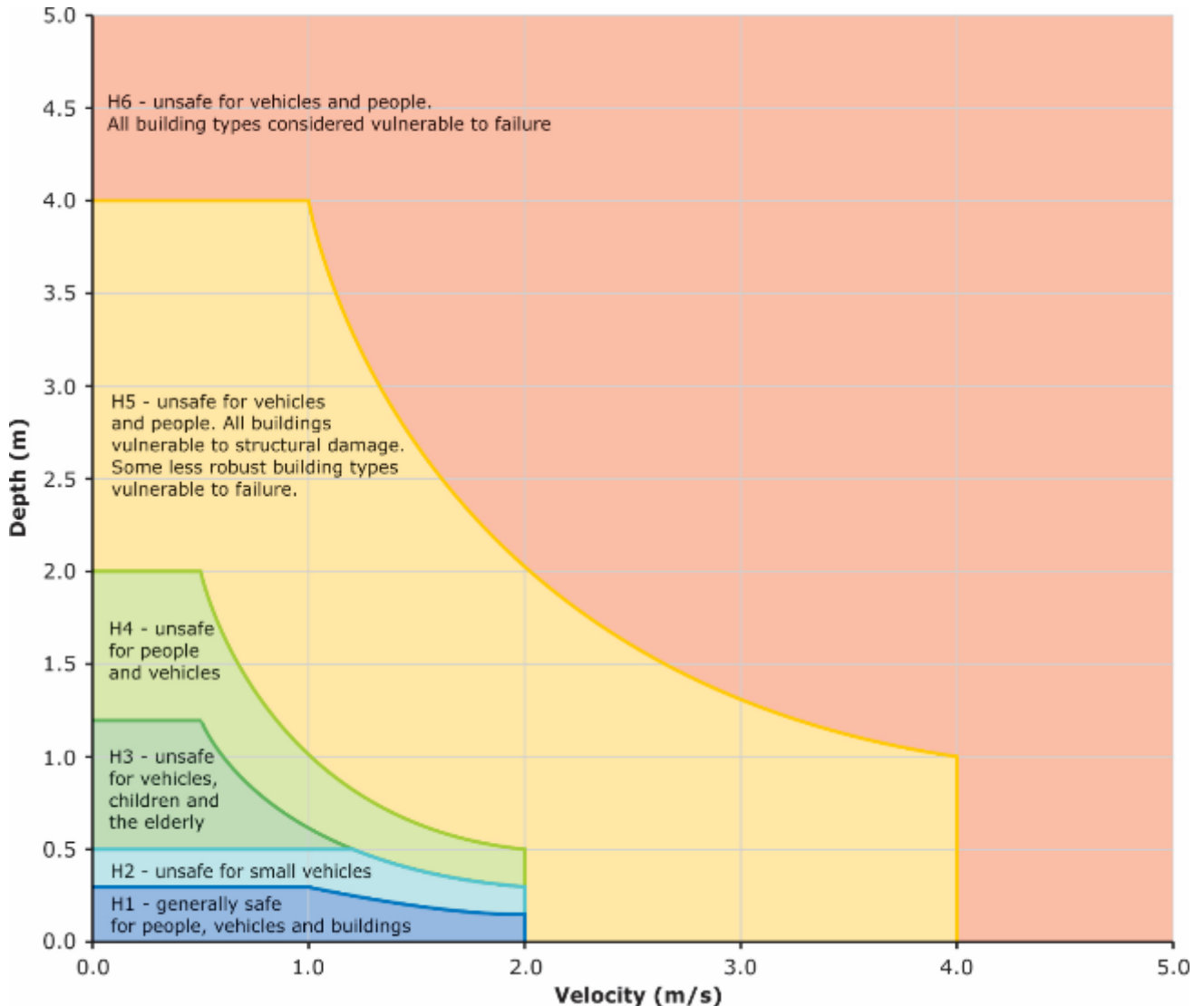


Figure 19. Flood Hazard Definition (AIDR, 2017)

Hydraulic modelling was undertaken to establish the new hazard definition for the study area. Figure 20 and Figure 21 show the new hazard for the 1% AEP event.

The new hazard definitions provide greater detail of vulnerability of life and property in a floodplain. It is also likely to be easily understood by the community at large. For the purpose of this floodplain risk management plan, Council will adopt this approach. This methodology replaces the traditional Low and High Hazard categorization (FDM, 2005) but not the intent of this categorisation.

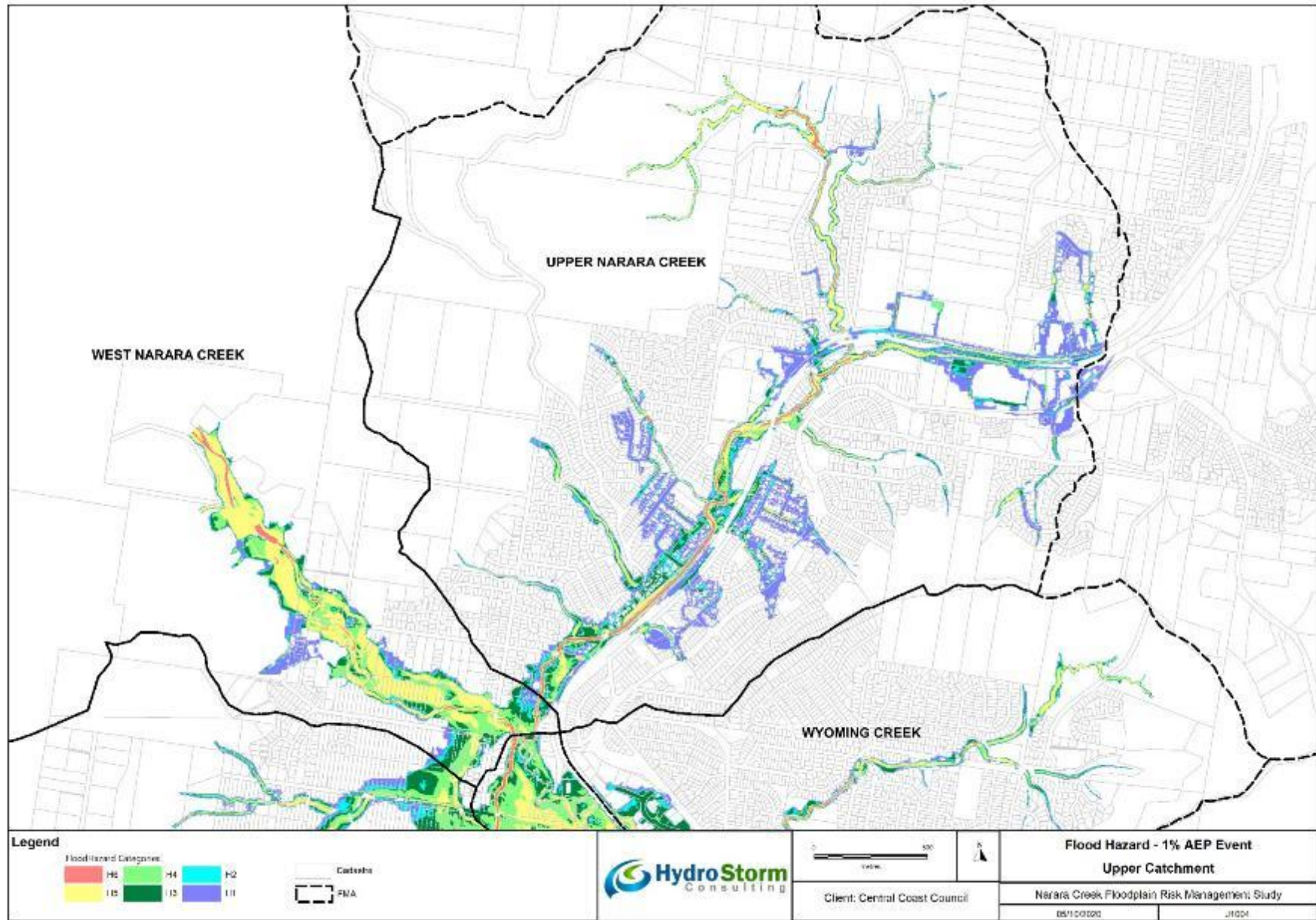


Figure 20. Flood Hazard H1-H6 – 1% AEP Event (Upper Catchment)

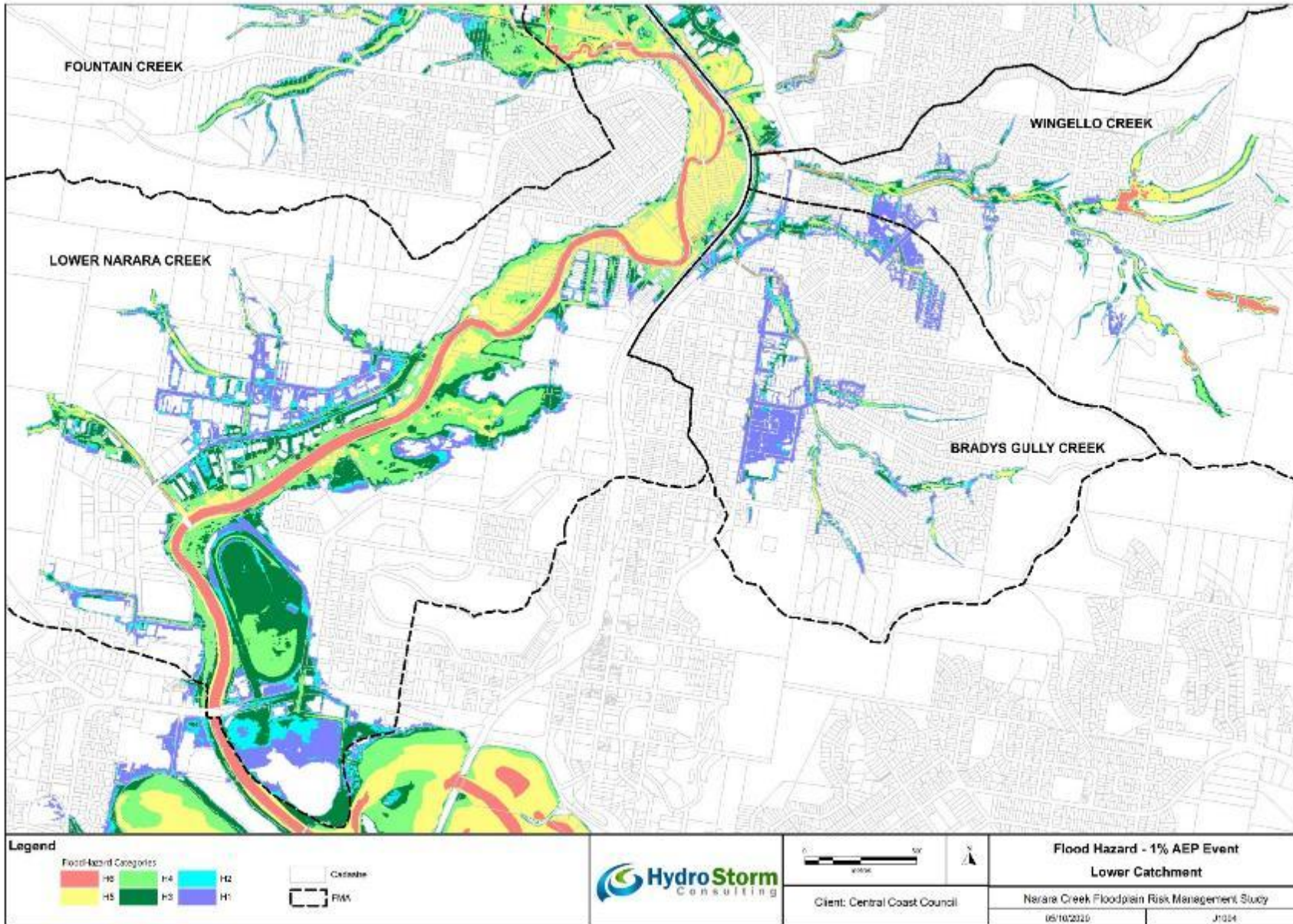


Figure 21. Flood Hazard H1-H6 – 1% AEP Event (Lower Catchment)

6.2 Flood Damages

Floods can cause extensive damages depending on the exposure of various parts of the floodplain to the flood hazard. Flood damage is also a function of land use, with developed areas suffering higher damages than those with low development.

Flood damages can generally be classified as tangible and intangible damages. The distinction between the two types of damages is that a cost estimate can be prepared for the tangible damages whereas this is not possible for the intangible damages.

The tangible damages include direct damages such as building contents, structural damage, vehicles etc. and indirect damages such as the clean-up costs after the floods.

The intangible damages include social impacts such as mental impacts on the flood affected community.

Table 2 summarises the flood damages that have been considered in this study.

Table 2. Types of Flood Damages

Damage Type		Damaged Items
Tangible	Direct	Building contents (internal)
		Structural (building repair and clean)
		External items (vehicles, sheds, outdoor furniture etc.)
	Indirect	Clean-up (immediate removal of debris and general clean up)
		Financial (loss of revenue, extra expenditure)
		Opportunity (non-provision of public services)
Intangible	Direct	Loss of life
		Environmental damage
		Health effects
	Indirect	Social – increased levels of insecurity, depression, stress
		General inconvenience in post-flood stage

Since it is not possible to estimate the cost of intangible damages a 25% increase over the tangible damages has been assumed to derive the total cost of the flood damage.

6.2.1 Floor Level and Property Survey

A detailed floor level and property survey was undertaken by the Council in 2015 and was updated subsequently with additional/missing information by February 2017. The survey was undertaken for more than 2000 properties in the Narara Creek floodplain and generally included all properties within the PMF flood extent. Appendix D provides floor level and relevant property details in the floodplain. This information is held with Council as it may be required for future studies or evacuation planning.

Understanding the relative height of floor levels to flood levels is critical for determining damages and therefore cost to benefit ratios for various flood management options that may reduce the flood levels. The floor levels are also used to provide flood intelligence mapping for the SES during storm events to ensure critical assets are deployed in a timely manner. For the individual owners of properties identified within the floodplain, the relationship between the floor level and the flood level can have a significant impact on the insurance premiums.

6.2.2 Damage Analysis

DCCEEW has prepared a standard model for calculating the flood damages. The model is based on a spreadsheet that incorporates design flood level data along with the flood damage curves for buildings. The damage curves can be modified for use in a given catchment. An important consideration in the DCCEEW model is the use of Protection Level, which is achieved by increasing the design flood levels to assess damage. The Protection Level is achieved by adding a freeboard to the design flood levels, assuming that the Protection Level provides the appropriate level for flood damage assessment. This study utilises the DCCEEW spreadsheet model for damage assessment and as such a 0.5m freeboard has been added to design flood levels for use in the damage model.

The flood damage assessment is based on a relationship between the depth of flooding on a property and the damage due to this flooding. This relationship is defined in so-called flood-damage curves. Although other factors such as duration of flooding and velocity of floodwaters can play a significant role in causing physical damage, there are no standard guidelines available to incorporate the impact of these factors in damage assessment.

If data is available, the flood damage curves can be prepared for the given catchment. However, such data is rarely available, and recourse has to be made to any available information in similar catchments. DCCEEW has undertaken an analysis of historic flood damages throughout the state and prepared representative damage curves, which have been adopted for this study.

Flood damages have been assessed for the existing catchment conditions and those flood management options that can provide an estimate of reduction in flood levels. These options only include flood modification options that have been modelled in this study. Other flood management options are likely to reduce flood damages, but it is not possible to estimate the monetary value of these options using the DCCEEW model.

It is noted that DCCEEW has recently updated the flood damage estimation model. The work undertaken for this study predates the release of the new model.

6.2.3 Flood Damage Estimation

Several factors are considered for estimating the flood damage in a floodplain. Various parameters used for flood damage estimation in the Narara Creek catchment are discussed in the following sections.

6.2.3.1 Residential Damage Curves

The DCCEEW guidelines for Residential Damage Curve were utilised for creating damage curves and then estimating the flood damages for residential areas of the catchment. The model accounts for three types of residential buildings:

- Single Storey, slab on ground
- Two Storey, slab on ground
- Single Storey, high-set.

The property survey undertaken by the Council provided the necessary details for the above types of properties.

An important aspect of the DCCEEW model is that the flood damages are incurred on a property prior to any over floor flooding. The damage curves estimated by the DCCEEW model allows for a damage of \$11,524 (November 2016 dollars) to the base of a house (0.5m below the floor level for slab on ground and 1.5m

below the floor level for high-set property type). The damage remains constant from the base of the house to the floor level of the house.

6.2.3.2 Average Weekly Earnings

The damage curves in the DCCEEW model are derived for late 2001 and need updating to reflect current dollar value for damages. These curves were updated to November 2016 dollars based on the Average Weekly Earnings in NSW, as recommended by DCCEEW. Average Weekly Earnings, according to DCCEEW, is a better guide than the inflation rate as measured by the Consumer Price Index (CPI), since AWE is a better representation of societal wealth and hence a suitable indirect measure of the value of a building and its contents.

The most recent data for AWE from the Australian Bureau of Statistics was for November 2016. Therefore, all ordinates in the residential flood damage curves were updated to the November 2016 dollars. In addition, all damage curves include GST as per DCCEEW recommendation.

While not specified, it has been assumed that the damage curves provided in the DCCEEW model were derived in November 2001, which has been used as the base year for comparison with the latest AWE values. The AWE shown in Table 3 provides the latest AWE values along with the base year. The latest AWE values were sourced from the Australian Bureau of Statistics website (www.abs.gov.au).

Table 3. AWE Statistics from 2001 and 2016

Date	AWE
November 2001	\$676.40
November 2016	\$1,164.60
Change	72%

Consequently, all ordinates on the damage curves were increased by 72%.

6.2.3.3 Other Parameters for Damage Estimation

Several additional parameters need to be incorporated in the DCCEEW damage model, such as floor area, level of flood awareness etc. The majority of the default parameters values as suggested by DCCEEW have been adopted.

A value of 240 m² was adopted as an estimate of the floor area for residential dwellings within the study area. The damage curves were adjusted for the Average Weekly Earnings factor as established by the damage model.

The Effective Warning Time has been assumed to be zero. A long Effective Warning Time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches). The adoption of zero warning time is because the response time of flood for the majority of the catchment is small i.e. the catchment is subjected to the so-called flash flooding.

It has been assumed that there are no post flood inflation costs. These inflation costs are generally experienced in regional areas, where re-construction resources are limited, and large floods can cause a strain on these resources.

The residential damage curves derived from the consideration of above parameters are shown in Figure 22. These damage curves were adopted for the current study.

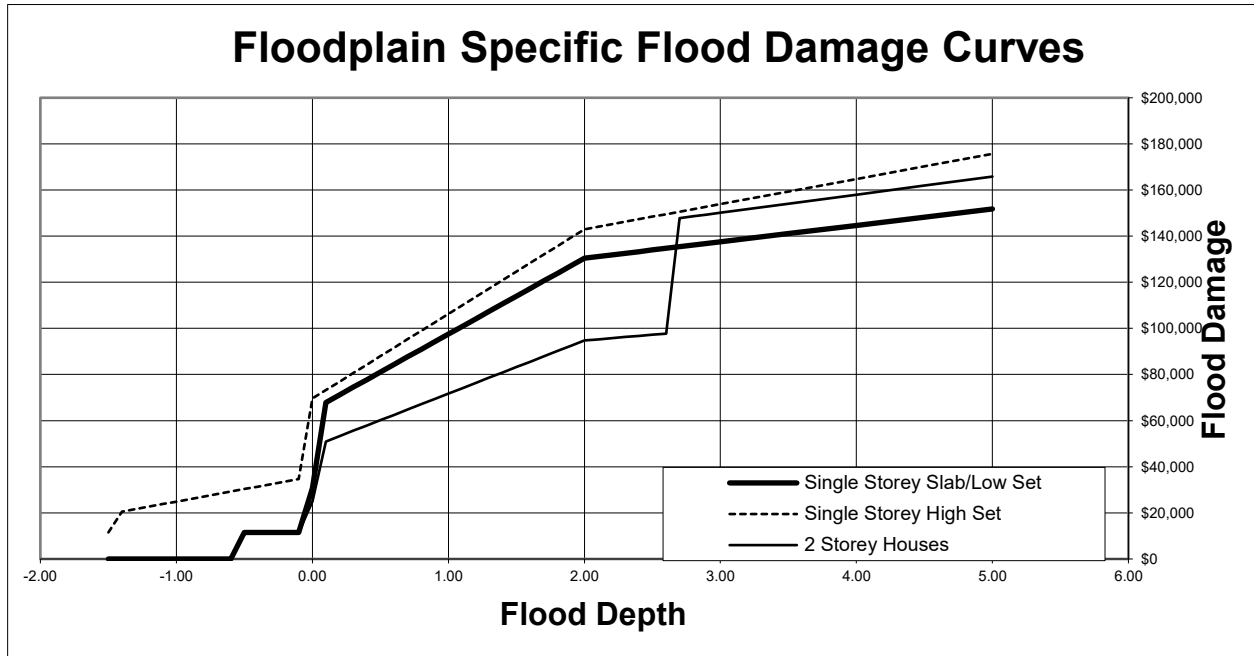


Figure 22. Adopted Flood Damage Curves

6.2.4 Flood Damage Estimates

The flood damages estimated by the DCCEEW model are presented in Table 4.

Table 4. Flood Damage Assessment Summary

Event (AEP)	No of Properties Affected by Flooding*	No of Properties with Over-Floor Flooding*	Tangible Flood Damage	Intangible Costs	TOTAL
PMF	1673	1,560	\$162,143,164	\$40,535,791	\$202,678,955
0.2%	949	781	\$67,545,307	\$16,886,327	\$84,431,634
0.5%	949	781	\$62,200,622	\$15,550,155	\$77,750,777
1%	861	664	\$56,466,705	\$14,116,676	\$70,583,381
2%	792	585	\$50,226,874	\$12,556,718	\$62,783,592
5%	721	527	\$44,847,713	\$11,211,928	\$56,059,641

Event (AEP)	No of Properties Affected by Flooding*	No of Properties with Over-Floor Flooding*	Tangible Flood Damage	Intangible Costs	TOTAL
10%	657	482	\$40,504,378	\$10,126,094	\$50,630,472
20%	562	416	\$34,641,868	\$8,660,467	\$43,302,335
50%	187	166	\$13,141,528	\$3,285,382	\$16,426,910

* The properties affected are based on a "Protection Level" of 0.5m. For properties affected without any protection level, see Table 1. For "Protection Level" see Section 6.2.5.1.

The total damage for each design event was plotted against the probability of the design event (Figure 23). In plotting these probability graphs, it was assumed that the flood damages occur up to the 100% (1EY, once every year) event and no damages occur for events frequent than this event.

The Average Annual Damage (AAD) was estimated by calculating the area under the damage-probability curve. The AAD for Narara Creek floodplain under existing conditions is estimated to be \$19.02 million.

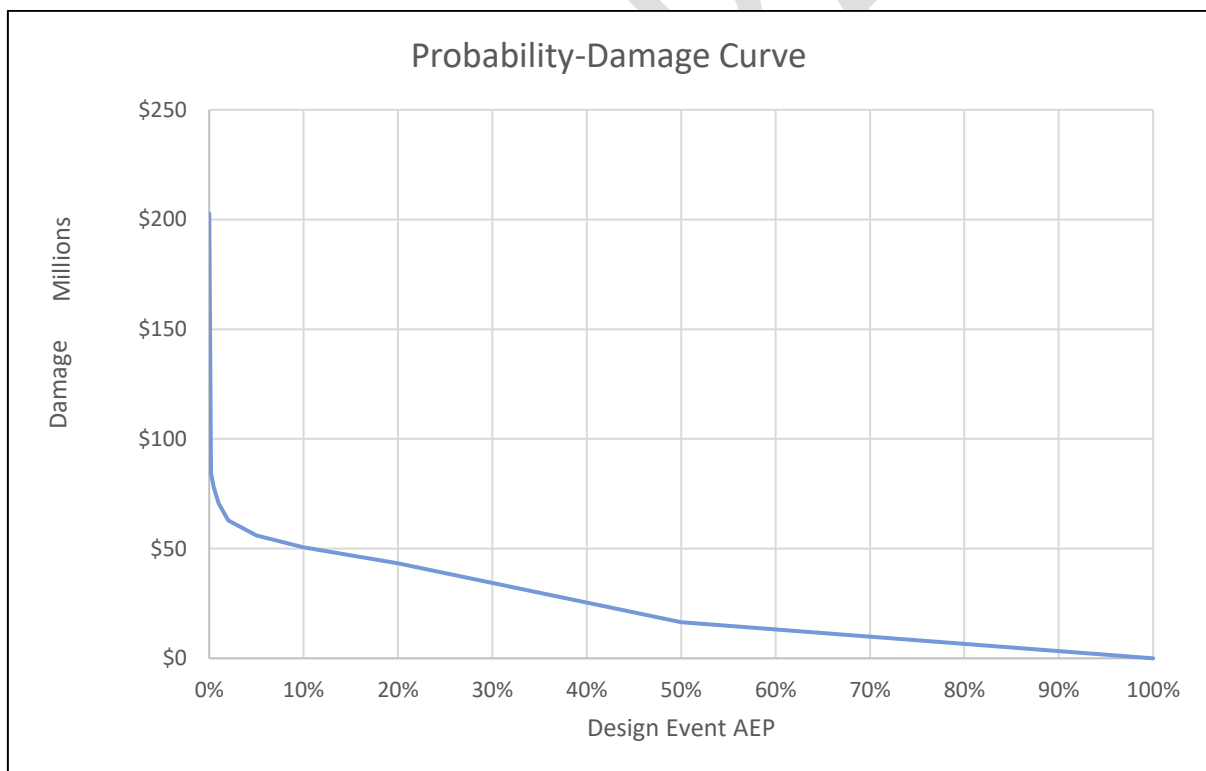


Figure 23. Probability-Damage Curve for Narara Creek Catchment

Table 5 provides incremental damages for various design flood events.

Table 5. AAD for Various Design Events

Design Increment	AAD (tangibles)	AAD (with intangibles)
up to 50% AEP	\$3,285,382	\$4,106,727

Design Increment	AAD (tangibles)	AAD (with intangibles)
50% to 20% AEP	\$7,167,509	\$8,959,387
20% to 10% AEP	\$3,757,312	\$4,696,640
10% to 5% AEP	\$2,133,802	\$2,667,253
5% to 2% AEP	\$1,426,119	\$1,782,649
2% to 1% AEP	\$533,468	\$666,835
1% to 0.5% AEP	\$296,668	\$370,835
0.5% to 0.2% AEP	\$194,619	\$243,274
0.2% AEP to PMF	\$228,540	\$285,675
Total Average Annual Damage	\$19,023,420	\$23,779,275

6.2.5 AAD Sensitivity

The AAD is based on several assumptions which can have a significant impact on its estimation. Two of the more important assumptions and its impact on AAD estimates is discussed below:

6.2.5.1 Protection Level

The flood damages have been estimated for the “Protection Level” rather than the floor level. The protection level is derived by adding the freeboard of 0.5m to the depth of flooding at a property, as per the DCCEEW guidelines. The rationale for the addition of freeboard is to allow for the uncertainty in the estimation of design flood depths. This process effectively increases the design flood levels by 0.5 m.

Application of 0.5 m freeboard to upper reaches of the catchment, where the flooding is mostly overland and is likely to be confined to the road reserves, is considered excessive. A more reasonable approach would be to apply a 0.3 m freeboard for these areas for flood damage estimation purposes. Application of 0.3 m freeboard results in an AAD of \$15.17 million.

If the protection level is completely removed, the AAD reduces to \$8.79 million.

Table 6 summarises the sensitivity of AAD to the protection level.

Table 6. Protection Level and AAD

Protection Level	AAD
0.5 m	\$19.02 million
0.3 m	\$15.17 million
0 m	\$8.79 million

It is also noted that with the reduction in protection level, the number of properties with above-floor flooding also reduces. In a 1% AEP event, the number of properties with above-floor flooding reduces from 664 to 435. In a 50% AEP event, the number of properties reduces from 166 to 67.

6.2.5.2 Design Floods for Flood Damage Estimation

Flood damages increase with the magnitude of flood in a catchment. However, most catchments have some capacity to carry frequent design flood events, with minimal or insignificant flood damages. The drainage design practice from late 1980 onwards has been to provide safe passage of design flows up to 20%-5% AEP events in the piped drainage and rarer events through the road or other reserves to minimise damages. This is the major/minor drainage design approach, which is currently the industry standard.

Analysis of pipe data for the study area indicates that almost 50% of the approximately 4000 pipes were constructed from 1990 onwards. It is, therefore, reasonable to expect that the drainage system design for 50% of the catchment would have followed the major/minor design approach.

The current flood study incorporates only pipes greater than 600 mm in diameter, which are generally located in the lower reaches of the catchments. In the upper reaches of the catchment, the pipe drainage is not included, and additionally the overland flow paths may not be well defined due to the nature of the hydraulic model. These assumptions are not likely to play a significant role in rarer floods such as the 1% AEP flood, however, can overestimate the flood affectation for more frequent events such as the 50% and the 20% AEP floods.

The flood damage estimation as described above requires identification of a design flood beyond which there are no flood damages. The above analysis assumes that damages would occur in all flood events up to the 100% AEP (1EY, once every year) event. Based on the above discussion of prevalent drainage systems (major/minor design) in the study area, this assumption is likely to overestimate the flood damage.

A sensitivity analysis for AAD was undertaken where the flood with no damage was moved up the scale from 100% AEP to 50% AEP and 20% AEP events. The results are presented in Table 7. These results are for 0.5 m protection level.

Table 7. Design Flood with no Damage and AAD

Design Flood with no Damage	AAD
100% AEP (1EY, once every year)	\$19.02 million
50% AEP	\$15.74 million
20% AEP	\$8.57 million

If the Protection Level is reduced to zero, the AAD with flood damages starting from the 20% AEP event is \$4.16 million. Thus the Protection Level and the damage initiating flood event has a significant impact on the calculation of AAD.

6.2.6 AAD Adopted for the Study

Among other factors, the AAD estimates for the existing conditions influence the effectiveness of flood management options. Establishing an appropriate AAD for the study area is therefore important. The sensitivity analysis for AAD for the two major assumptions shows significant variation in the AAD estimates.

However, such an analysis is generally not carried out in the flood risk management studies and the default criteria for the flood protection (0.5 m freeboard in this study) and the most frequent flood event modelled (50% AEP event in this study) is used in the damage analysis.

Given the above, it's recommended that the AAD of \$23.78 million (with intangible damages) be adopted for the purpose of this study. The other estimates of AAD would assist the Council in informed decision making regarding the flood risk management program within the Council.

6.3 Flooding of Roads

Several roads in the study area were overtopped during a flood event. Flood modelling was undertaken to assess the initiation of flooding and the duration of flooding during the 5% AEP, 1% AEP and the PMF events. More than a hundred locations were selected in the study area to derive this flood data. These locations are shown in Figure 24. The locations for reporting were selected based on the PMF flood extent. Hence a number of locations show no road overtopping in a more frequent flood event. The flood data is summarised in Table 8.

The model runs were undertaken for the 2 hour and the 9 hour duration and the data presented in Table 8 is the envelope of the two durations i.e. the first cutoff time was the earlier of the two durations and the duration of cutoff was the maximum of the two durations.

A road cutoff depth of 0.2m was used as a trigger for deriving this data. Flood depth greater than 0.2m can cause the vehicles to become unstable while driving through the floodwaters. Where no data is provided for a particular location, either the road is not overtopped or the cutoff flood depth of 0.2m is not reached.

Table 8. Flooding of Roads

Route Name	5% AEP		1% AEP		PMF	
	First Cut_Off Time	Duration Cut_Off	First Cut_Off Time	Duration Cut_Off	First Cut_Off Time	Duration Cut_Off
1	0.36	2.41	0.3	3.34	0.02	2.65
2	0.34	1.85	0.28	3.14	0	6
3	0.58	0.7	0.56	1.09	0.08	4.21
4					0.28	1.85
5	0.62	0.09	0.56	0.23	0.02	3.21
6	0.25	3.73	0.18	6.49	0.01	2.65
7					0.5	0.82
8	0.35	8.3	0.29	8.5	0.03	5.97
9	0.56	0.06	0.54	0.15	0	2.64
10	0.19	3.05	0.16	5.29	0.02	5.98
11	0.56	0.38	0.5	1	0.14	5.86
12						
13	0.68	0.05	0.6	0.19	0.15	1.65
14	1.02	1.14	0.86	1.59	0.28	2.38
15	0.56	10.13	0.48	10.57	0.16	5.84
16	0.64	1	0.58	1.52	0.2	5.7
17	0.43	0.27	0.38	0.4	0.02	2.89
18	0.41	10.88	0.36	11.09	0.06	5.94

Route Name	5% AEP		1% AEP		PMF	
	First Cut_Off Time	Duration Cut_Off	First Cut_Off Time	Duration Cut_Off	First Cut_Off Time	Duration Cut_Off
19	0.6	0.92	0.53	1.28	0.13	3.85
20	0.73	1.75	0.65	2.95	0.27	2.44
21						
22	0.62	0.15	0.59	0.22	0.03	2.65
23	0.58	0.34	0.5	0.51	0.05	2.91
24	0.43	2.01	0.38	2.94	0	6
25	0.59	0.19	0.56	0.27	0.03	2.45
26	0.5	1.38	0.44	1.81	0	2.56
27	0.31	2.54	0.25	3.79	0	2.46
28	0.34	0.53	0.28	1.2	0	2.33
29	0.3	8.61	0.23	8.78	0	2.76
30	0.53	0.17	0.38	0.26	0	2.63
31	0.43	1.14	0.37	1.54	0.03	2.46
32	0.38	3.88	0.32	6.45	0.01	5.99
33	0.66	0.34	0.6	0.78	0	2.44
34	0.39	1.61	0.33	2.56	0	6
35	0.41	0.96	0.36	1.41	0	3.89
36	0.43	8.24	0.38	8.54	0.1	5.9
37	0.56	1.59	0.5	2.65	0.15	5.85
38	0.6	0.58	0.51	1.04	0.2	2.51
39					0.63	5.37
40	0.61	1.24	0.56	1.82	0.11	5.89
41	0.8	2.26	0.72	4.46	0	5.33
42			1.06	0.29	0.38	2.26
43					0.54	1.87
44	0.4	8.12	0.34	8.38	0.03	5.97
45	0.99	1.17	0.84	1.7	0.36	2.91
46	0.82	2.39	0.72	4.56	0.31	5.69
47	1.33	1.11	0.64	1.82	0.15	5.85
48	1.32	4.03	1.1	5.29	0.49	3.68
49	1.2	4.95	1.04	6.24	0.48	5.52
50	0.96	7.01	0.79	8.1	0.27	5.11
51	5.23	1.04	0.78	1.9	0.33	3.13
52			5.63	0.23	0.36	2.96
53	0.81	3.9	0.73	5.5	0.1	5.9
54	1.79	1.73	1.49	2.54	0.46	3.54
55	1.85	1.73	1.52	2.62	0.53	3.88
56	1.69	2.64	1.36	4.41	0.58	4.2
57					0.27	2.66
58						
59	5.85	0.79	1.73	1.82	0.67	3.48
60			5.88	4.85	0.31	5.69

Route Name	5% AEP		1% AEP		PMF	
	First Cut_Off Time	Duration Cut_Off	First Cut_Off Time	Duration Cut_Off	First Cut_Off Time	Duration Cut_Off
61					0.94	2.53
62					0.24	5.76
63	0.33	4.72	0.27	6.35	0	3.88
64	0.35	3.26	0.29	5.62	0.01	3.71
65						
66					0.56	2.72
67					0.7	2.92
68					1.15	2.14
69					0.97	2.53
70			5.46	0.56	0.4	2.35
71			5.13	0.7	0.36	5.64
72	0.34	7.11	0.27	7.58	0.01	5.99
73			5.18	1.19	0.31	2.51
74			1.7	2.08	0.33	5.67
75	0.63	0.04	0.58	0.13	0.12	1.88
76	0.35	6.18	0.28	7.33	0	4.05
77	0.42	0.94	0.37	1.38	0.08	3.01
78	0.48	2.59	0.41	4.07	0	4.58
79	0.28	9.11	0.22	9.3	0.12	4.47
80	0.33	5.27	0.27	6.91	0	6
81	0.45	1.52	0.4	2.27	0.12	5.88
82	0.59	0.29	0.54	0.39	0.18	5.82
83					0.41	2.63
84	0.74	1.26	0.67	2.36	0.29	3.83
85	0.76	0.31	0.68	1.55	0.13	3.98
86	0.48	7.73	0.42	8.67	0	6
87					1.23	1.61
88					1.01	2.56
89	0.41	4.33	0.37	5.73	0.01	5.99
90					1.37	4.63
91	1.33	4.88	1.05	6.6	0.47	5.53
92	0.35	4.95	0.29	6.42	0	5.88
93	0.3	8.57	0.24	8.79	0	4.87
94	0.48	1.01	0.41	1.52	0.05	5.95
95			0.69	0.2	0.08	5.92
96			0.63	0.12	0	2.59
97	0.69	0.14	0.64	0.22	0.18	5.82
98			0.65	0.25	0.03	5.58
99	0.42	0.21	0.38	0.32	0.02	5.98
100					0.01	3.2
101	0.67	0.4	0.6	0.94	0.08	2.67
102	0.46	2.96	0.4	5.15	0.06	5.94

Route Name	5% AEP		1% AEP		PMF	
	First Cut_Off Time	Duration Cut_Off	First Cut_Off Time	Duration Cut_Off	First Cut_Off Time	Duration Cut_Off
103	6.59	0.64	2.66	2.7	0.27	5.25
104	0.52	9.19	0.44	9.29	0.12	5.88
105	0.4	8.91	0.34	9.58	0	6
106	1.12	2.73	0.95	3.82	0.31	5.69
107					0.49	4.85
108	0.58	0.22	0.56	0.49	0.02	2.55
109	0.63	6.19	0.58	7.24	0.19	5.81

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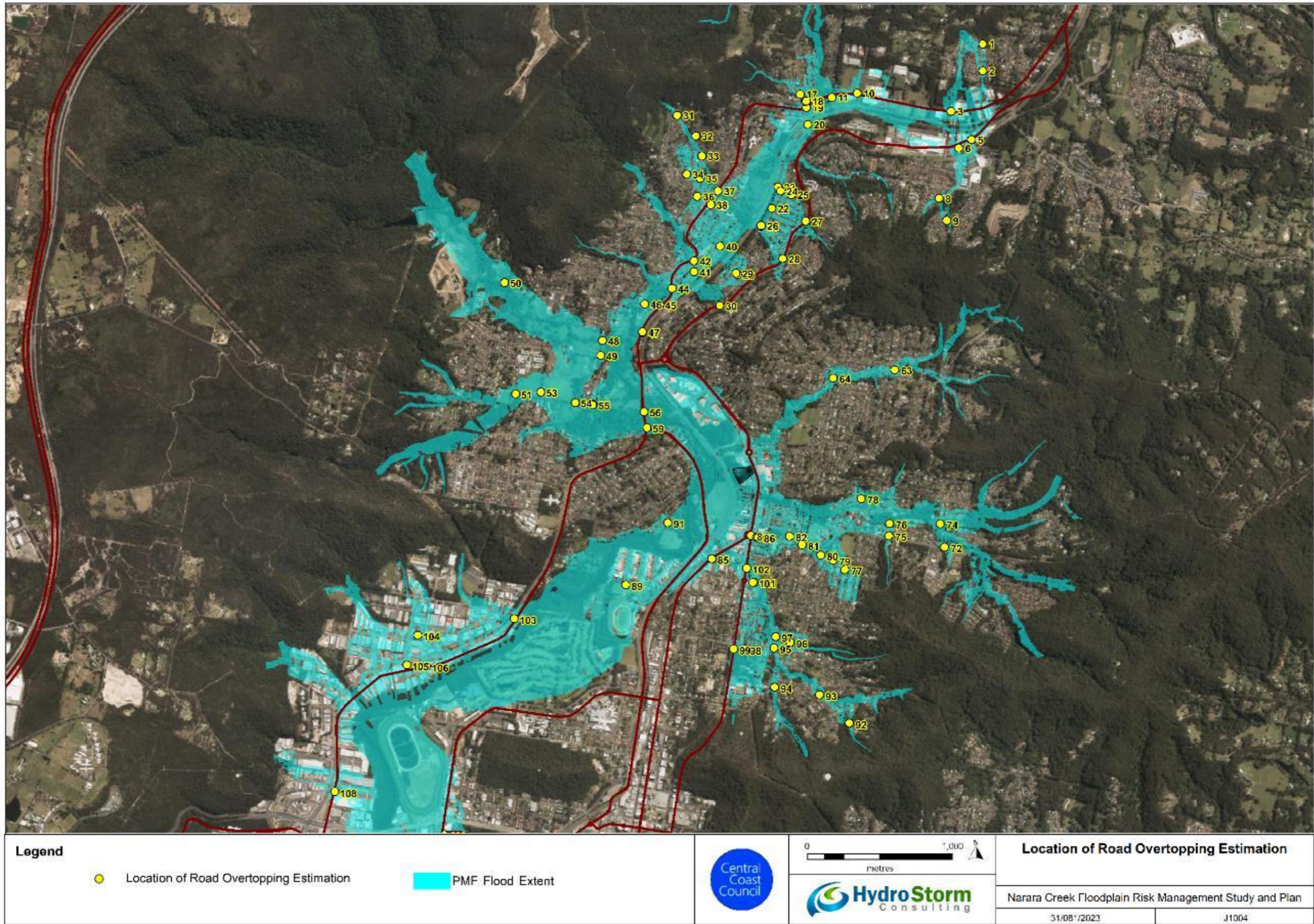


Figure 24. Flood Overtopping Road Locations

7 Planning and Development

The Central Coast Council was created from amalgamation of previous Gosford City Council and Wyong Shire Council. An amalgamated Local Environment Plan (LEP) for the two council areas has been adopted. The planning and development policies in the study area are governed by the Central Coast Local Environment Plan 2022 (LEP).

7.1 Central Coast Local Environment Plan

One of the aims of the Central Coast Local Environment Plan 2022 (LEP) is to

- (i) *To minimise risk to the community in areas subject to environmental hazards, including flooding, climate change and bush fires*

The LEP also aims to

- (a) *To encourage a range of housing, employment, recreation and services to meet the needs of existing and future residents of the Central Coast*
- (b) *To foster economic, environmental and social wellbeing so that the Central Coast continues to develop as a sustainable and prosperous place to live, work and visit*

The LEP clearly states the need for flood risk management in the study area keeping in view the economic, environmental and social wellbeing of the community. Any development in the floodplain needs to address the flood risk and ensure the wellbeing of the affected residents and the community at large.

The specific clauses for flood risk management include Clause 5.21 and 5.22 of the LEP. These clauses are:

5.21 Flood planning

(1) *The objectives of this clause are as follows—*

- (a) *to minimise the flood risk to life and property associated with the use of land,*
- (b) *to allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change,*
- (c) *to avoid adverse or cumulative impacts on flood behaviour and the environment,*
- (d) *to enable the safe occupation and efficient evacuation of people in the event of a flood.*

(2) *Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development—*

- (a) *is compatible with the flood function and behaviour on the land, and*
- (b) *will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and*
- (c) *will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and*
- (d) *incorporates appropriate measures to manage risk to life in the event of a flood, and*
- (e) *will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.*

(3) In deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters—

- (a) the impact of the development on projected changes to flood behaviour as a result of climate change,
- (b) the intended design and scale of buildings resulting from the development,
- (c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,
- (d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.

(4) A word or expression used in this clause has the same meaning as it has in the *Considering Flooding in Land Use Planning Guideline* unless it is otherwise defined in this clause.

(5) In this clause

Considering Flooding in Land Use Planning Guideline means the *Considering Flooding in Land Use Planning Guideline* published on the Department's website on 14 July 2021.

flood planning area has the same meaning as it has in the *Flood Risk Management Manual*.

Flood Risk Management Manual means the *Flood Risk Management Manual*, ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.

and

5.22 Special flood considerations

The Central Coast Council has adopted the 5.22 clause, which is as follows:

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

- (a) to enable the safe occupation and evacuation of people subject to flooding,
- (b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,
- (c) to avoid adverse or cumulative impacts on flood behaviour,
- (d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,
- (e) to avoid adverse effects of hazardous development on the environment during flood events.

(2) This clause applies to—

- (a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and
- (b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may—
 - (i) cause a particular risk to life, and
 - (ii) require the evacuation of people or other safety considerations.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority has considered whether the development—

- (a) will affect the safe occupation and efficient evacuation of people in the event of a flood, and
- (b) incorporates appropriate measures to manage risk to life in the event of a flood, and
- (c) will adversely affect the environment in the event of a flood.

(4) A word or expression used in this clause has the same meaning as it has in the *Considering Flooding in Land Use Planning Guideline* unless it is otherwise defined in this clause.

(5) In this clause

Considering Flooding in Land Use Planning Guideline—see clause 5.21(5).

flood planning area—see clause 5.21(5).

Flood Risk Management Manual—see clause 5.21(5).

probable maximum flood has the same meaning as in the *Flood Risk Management Manual*.

sensitive and hazardous development means development for the following purposes

- (a) boarding houses,
- (b) caravan parks,
- (c) correctional centres,
- (d) early education and care facilities,
- (e) eco-tourist facilities,
- (f) educational establishments,
- (g) emergency services facilities,
- (h) group homes,
- (i) hazardous industries,
- (j) hazardous storage establishments,
- (k) hospitals,
- (l) hostels,
- (m) information and education facilities,
- (n) respite day care centres,
- (o) seniors housing,
- (p) sewerage systems,
- (q) tourist and visitor accommodation,
- (r) water supply systems.

All flood risk planning in the study area is governed by the above clauses of the Central Coast LEP. The above LEP clauses were obtained from the NSW Government NSW Legislation website.

7.1.1 Current Land Use and Zoning

The current land use zoning in the study area is presented in Figure 25. The description of land use zones as per the LEP 2022 is presented in Table 9.

Table 9. Land use Zones in the Study Area

Zone Designation	Zone Description
C2	Environmental Conservation
C3	Environmental Management
C4	Environmental Living
DM	DEFERRED MATTER
E1	Local Centre
E3	Productivity Support
E4	General Industrial
R1	General Residential
R2	Low Density Residential
RE1	Public Recreation
RE2	Private Recreation
RU1	Primary Production
RU2	Rural Landscape
RU3	Forestry
SP2	Infrastructure
W2	Recreational Waterways

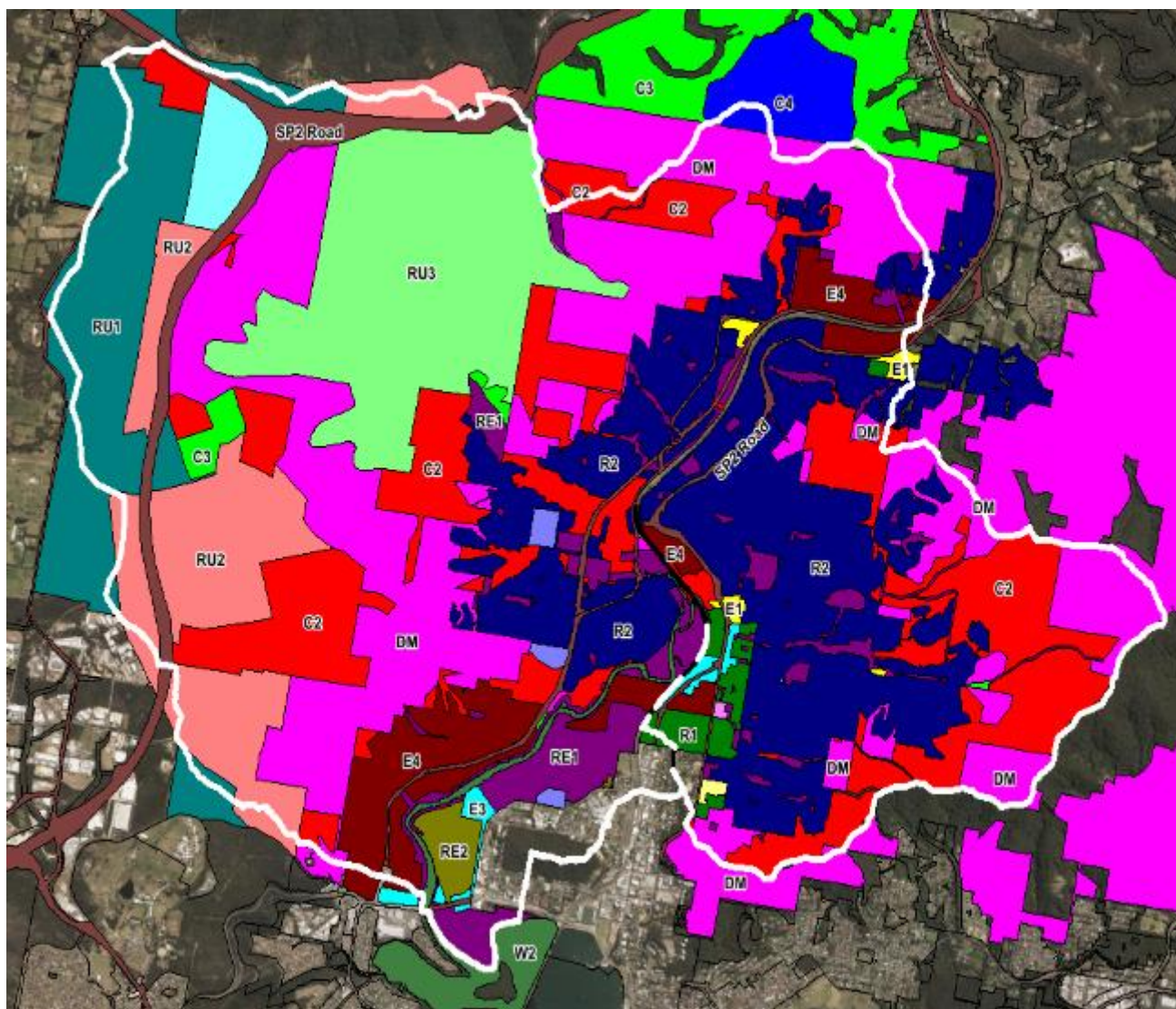


Figure 25. Land Use Zones

Any re-zoning of land within the study area should consider the impact of flooding. Intensification of development in the study area is likely to result in increased runoff, which can potentially have adverse impact at various locations in the catchment and cumulatively have impacts further downstream. This should be accomplished through a detailed flood impact study, which establishes the impact of the development on existing flood behaviour. Any infill development should also consider the cumulative impacts of such infill in other potential development areas. This is particularly relevant to the land marked as “Deferred Matter” in the LEP. The sensitivity analysis presented in the flood study (Golder, 2018) can be used to assess the impact of additional development.

7.2 Development Control Plan

The Central Coast Council has adopted a comprehensive Development Control Plan 2022 (DCP) to supplement the provisions of LEP 2022. However, the provisions of LEP 2022 prevail over the DCP 2022 in interpreting the development controls.

The Central Coast Council has adopted the provisions of the old DCP 2013 used by the Gosford City Council in DCP 2022 under Chapter 3.1 – Floodplain Management/Water Cycle Management. Part C of Chapter 3.1 is applicable to the study area.

The DCP incorporates flood risk management measures in a wider context of Water Cycle Management. This approach is able to manage flood risk in an environmentally sensitive manner and encourages the developer to incorporate flood risk management measures that could also benefit the environment.

The DCP provides guidelines for determining FPL for various development types in the study area. It requires that a flood study be undertaken for a development over a flood prone land to determine the impact of the development on the existing flood behaviour and to derive relevant flood controls for the development.

This study has provided details for determination of FPL for the study area, both for mainstream and overland flow flooding. It is recommended that the DCP considers the recommendations of this study in any future updates. In addition, several controls have been specified in this study related to flood control lots (A Flood Planning Matrix has been prepared). Some of these controls are already included in the current DCP. Any additional controls, as identified in this study, should also be incorporated in the DCP. Recommendations for appropriate allowances for climate change have also been examined.

7.2.1 Flood Emergency Response Planning

During flood emergency, the SES is expected to respond and evacuate the flood affected community. To facilitate the work of SES, preparation of a Flood Emergency Response Plan can also be incorporated in the flood study requirements for a significant development.

The current ADR guidelines provide classification of communities exposed to flood risk. The Flood Emergency Response Classification of Communities (FERCC) as per the Flood Risk Management Guideline EM01 of the Flood Risk Management Manual (2023) has been mapped for the study area and presented in Appendix I.

The following flood emergency response classifications have been provided in the ADR guideline:

- Flooded and Isolated (FI) - Areas that are isolated from community evacuation facilities (located on flood-free land) by floodwater and/ or impossible terrain as waters rise during a flood event up to and including the PMF. These areas are likely to lose electricity, gas, water, sewerage and telecommunications during a flood.
 - Submerged (FIS) - Where all the land in the isolated area will be fully submerged in a PMF after becoming isolated
 - Elevated (FIE) - Where there is a substantial amount of land in isolated areas elevated above the PMF
- Flooded with Exit Route (FE) - Areas that are not isolated in the PMF and have an exit route to community evacuation facilities (located on flood-free land).
 - Rising Road (FER) - Evacuation routes from the area follow roads that rise out of the floodplain
 - Overland scape (FEO) - Evacuation from the area relies upon overland escape routes that rise out of the floodplain
- Not flooded (N) - The area is not flooded in the PMF
 - Indirect Consequences (NIC) - Areas that are not flooded but may lose electricity, gas, water, sewerage, telecommunications and transport links due to flooding
 - Flood free - Areas that are not flood affected and are not affected by indirect consequences of flooding

The definition of submergence is not provided in the guidelines, however given the study area and the nature of flooding from the local creeks, it was assumed that a flood depth greater than 0.3m would be

considered as the critical depth for the identification of submerged properties. This depth relates to the safe limit for children wading through the floodwaters.

A significant indirect impact of the flooding is isolation of parts of the study area which are not subject to flooding. Such properties have been identified as indirectly affected (NIC) due to evacuation issues.

A detailed analysis of each property in the study area was undertaken to assign a suitable category of flood emergency response. The analysis was undertaken for the 5% AEP, 1% AEP and the PMF events.

The FERCC analysis shows that the FIS (Flooded, Isolated, Submerged) category is prevalent along the creek line of major overland flow paths developed during the flooding. With increasing frequency of the flood, the FIS category properties acquire the FIE (Flooded, Isolated, Elevated) category or FER (Flooded, Exit Route, Rising Road) category.

A number of areas have been identified to be NIC (Not flooded, Indirect Consequence) category, however, almost the entire study area that is not flood affected in a PMF can be classified to be in this category, as movement across or out of the study area is severely restricted due to the presence of several creek systems that cutoff the major or local roads. It is recommended that SES update its procedures and processes to include the information presented in the FERCC mapping.

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8 Flood Planning Level

8.1 General

The Flood Planning Level (FPL) is an important tool in managing the flood risk in a catchment. The FPL is generally derived from a suitable design flood level by adding a freeboard. The FPL alone does not provide enough protection against the flood risk as it does not ensure that the development is not located in high hazard area or a floodway and therefore does not address the issues of personal danger. The FPL therefore needs to be considered in conjunction with other appropriate land use controls and evacuation strategies.

8.2 Review of Flood Planning Level

A variety of factors need to be considered in determining an appropriate FPL. A discussion of these factors with recommendation for FPL for the study area is provided in the following sections.

8.2.1 Current Flood Planning Level

Historically, the design flood level used in NSW for this purpose is the 1% AEP event and the freeboard generally ranges from 0.3-0.5 m. Following this practice, the current flood planning in the study area is based on the 1% AEP flood levels derived from the Narara Creek Flood Study Review plus a 0.5 m freeboard. Council's DCP 2022 allows a lower freeboard of 0.3 m for non-habitable areas of a development, such as garages.

For certain developments such as critical infrastructure, aged care housing etc. and any other development that is deemed to create risk to life or causes flood evacuation issues, the LEP clause 5.22 and DCP2022 require that the Probable Maximum Flood level be considered as FPL. In addition, it requires all access roads and driveways, and external parking areas to be above the PMF to enable safe evacuation of the occupants or contents without having to cross floodwaters of any depth in all flood events.

The study area is affected by both catchment and Brisbane Water flooding. In the recently completed Brisbane Water Flood Risk Management Study, the recommended FPL for the Brisbane Water foreshore areas is

$$\text{FPL} = 100 \text{ year ARI DSWL} + \text{SLR (as defined in Council's policy)} + 0.5\text{m Freeboard}$$

where DSWL is the design still water level of the Brisbane Water and SLR is the sea level rise. The Brisbane Water study recommends that a progressively increasing SLR be adopted for FPL determination as the sea levels continue to rise in the future. The 1% AEP DSWL in West Gosford is reported to be 1.77 m AHD and with a freeboard of 0.5 m and assuming an SLR of 0.2m (commensurate with asset life, see Brisbane Water Flood Risk Management Study for details), the FPL for the study area affected by Brisbane Water flooding would be 2.47 m AHD.

The FPL for the area affected by Brisbane Waters would also be estimated with regard to Narara Creek flooding. It would be necessary to adopt the higher of the two FPLs for this area.

8.2.2 Choice of a Design Flood

As per the guidelines provided in the Floodplain Development Manual, the selection of a flood event for establishing an FPL is a matter of balancing two opposing objectives of community welfare and development as below

- The social, economic, environmental and cultural costs of restricting land use in the flood prone areas

- The social, economic, environmental and cultural benefits of reduction in the frequency, inconvenience, damage and danger to people caused by flooding

The above issues vary with location in the floodplain and between different types of development.

Experience of floodplain management in NSW indicates that a 1% AEP flood provides a suitable balance between the welfare and development objectives of a community. However, as stated above, certain critical or high vulnerability developments, such as aged care homes, schools etc. should be designed for the PMF event. This is particularly important in catchments with short response to flooding i.e. catchments subjected to “flash flooding”, as is the case with the Narara Creek catchment.

8.2.3 Likelihood of Flooding

Since the FPLs are derived from a design flood event, it is pertinent to consider the chance of a flood happening in an average lifetime (around 70 years). Table 10 has been reproduced from the Floodplain Development Manual (2005) to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Table 10. Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime

Likelihood of Occurrence in any year AEP (ARI)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
10% (1 in 10 year)	99.9	99.3
5% (1 in 20)	97	86
2% (1 in 50)	75	41
1% (1 in 100)	50	16
0.5% (1 in 200)	30	5

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

Note that there remains a 30% chance of exposure to at least one flood of a 0.5% (1 in 200 year) magnitude over a 70-year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development, as discussed above. In theory, the PMF cannot be exceeded, however, a rainfall event in Dubbo on 18 February 1984 exceeded the PMF estimates of that time. That rainfall event was used in deriving the current estimates of PMP for short duration storms.

8.2.4 Existing Level of Development

The study area is mostly developed, and the FPL used for development purposes in the past has been based on the 1% AEP flood level plus a freeboard of 0.5 m. Any re-development within the study area under a different FPL would be difficult to implement. However, the green-field sites and to some extent the brown-field development may present an opportunity to apply a different FPL depending on the flood risk along with the social, economic and environmental issues relevant to those areas.

8.2.5 Land Values and Social Equity

Land values are determined by a variety of factors including proximity to the creeks or other water courses. In the current home insurance market where the flood risk is being increasingly recognized for setting the insurance premiums, it is important that FPL is able to provide relief if a flood-affected site is re-developed.

The FPL should also not hinder the re-development of a flood-affected site as it would create social equity issues within the community.

8.2.6 Flood Readiness, Warning and Evacuation

The community in the study area has been exposed in recent years to a number of significant flood events (2015, 2021 AND 2022). However, experience in other floodplains shows that the state of readiness wanes with the passage of time and therefore is expected to be low in the study catchment in the long run. In addition to lack of flood readiness, the short flooding duration for the catchment reduces the potential for warning, response and evacuation during a flood event.

Under such conditions, adoption of a flood planning level that would reduce the flood risk could be an appropriate choice regarding these factors. Lack of warning increases the risk for more vulnerable developments such as aged care homes and hence adoption of a rarer flood event can be justified.

It is also important that the community is reminded of the possibility of floods rarer than those on which the FPL is based. Appropriate information for rarer floods (up to PMF) should be provided to the community in a suitable format.

8.2.7 Impact of Climate Change

According to Climate Council (Steffen et al, 2017), a 2°C rise in average global temperatures could result in a 10-30% increase in extreme downpours (Bao et al. 2017). In Australia, extreme rainfall events are projected, with high confidence, to increase in intensity, where extreme events are defined as the wettest day of the year and the wettest day in 20 years (CSIRO and BoM 2015; Bao et al. 2017; Figure 47). The tendency for an increase in intensity may be stronger for the larger, rarer events (current 1-in-20 year events) (Rafter and Abbs 2009) particularly at the sub-daily timescale (Westra et al. 2013).

Based on the available research the Department of Climate Change, Energy, the Environment and Water (DCCEEW) has prepared guidelines for incorporating the impact of climate change in flood risk assessment. These guidelines are related to potential increase in the rainfall intensity and Sea Level Rise (SLR) in the future climate.

The impact of SLR has already been incorporated in the FPL determination for the properties affected from the Brisbane Water flooding (Cardno, 2015). The impact of increased rainfall intensity also needs to be considered in determining the FPL.

As per the DCCEEW guidelines, modelling undertaken in the flood study (Golder, 2018) for an increase in design rainfall intensities by 10%, 20% and 30% indicates that the increase in flood levels height associated with

- 10% increase in rainfall intensity is 10 to 20 cm, except for Brookes Avenue detention basin where there is an increase of 30 cm.
- 20% increase in rainfall intensity is 30 to 40 cm along Narara Creek at Showground Road.
- 30% increase in rainfall intensity is 40 to 50 cm.

Analysis indicates a generally high sensitivity to an increase in rainfall intensity in the Narara Creek catchment, in particular along Narara Creek due to coincident runoff contribution from the contributing catchments.

It is pertinent to note that the impact of climate change on rainfall intensity (30% increase) results in an increase in flood levels, which is comparable to the current freeboard used for determining FPL.

8.3 Freeboard Selection

The freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. This consideration may result in the adopted FPL being higher than the PMF in some parts of the catchment. However, the FPL with appropriate freeboard should still be used in such cases given the purpose of freeboard is to provide a safety factor for a given design flood event.

The freeboard generally accounts for factors such as:

- changes in the catchment
- changes in the creek/channel vegetation
- accuracy of model inputs (e.g. accuracy of ground survey, accuracy of design rainfall inputs for the area)
- model sensitivity
- local flood behaviour (e.g. such as wave wash by passing cars/emergency vehicles),

The accuracy of ground survey used in the modelling is generally of the order of +/-0.15 to +/- 0.30 m. The model sensitivity was found to be the greatest for the inflows to the hydraulic model. An increase of inflows by 30% increased the flood levels by 0.35 m to 0.5 m for the 1% AEP event.

In addition to the above uncertainties, a potential local afflux of say 0.1 m due to local obstructions (not modelled) and local wave action of 0.1 m (truck wash etc.) would also add to the value of freeboard required for FPL purposes.

In the light of the above discussion, a freeboard of 0.5m is considered sufficient for properties affected by the catchment flooding where uncertainty in flow is up to 20%.

It should be noted that the latest version of AR&R specifically excludes the impact of climate change from the freeboard estimates. In Book 9, Chapter 3, Section 3.4.1 of AR&R, the following direction for the freeboard is provided:

“Freeboard should not be used to protect against measurable uncertainties, for example risk of blockage and climate change. If these risks are a concern for a given site, then they should be explicitly incorporated into the basic flood level estimates before freeboard is applied.”

8.4 Recommended Flood Planning Levels and Freeboards

From the discussion presented in the preceding sections, the 1% AEP event is a suitable design flood event (DFE) for determining the FPL. In addition, a freeboard of 0.5 m appears to be sufficient to account for the uncertainties in estimating the design flood event where uncertainty in flow is up to 20%.

A suitable FPL therefore would be the 1% AEP flood level plus a freeboard of 0.5m.

8.4.1 Climate Change and FPL

Climate change predictions suggest that the flood flows can potentially increase significantly with increase in rainfall intensities. Since the increased flows present additional flood risk, a component of climate change impact can be added to the design flood level in addition to the freeboard, to determine the FPL. The component of climate change would be dependent on the planning horizon of the proposed development and can be derived as discussed in Section 8.4.2.

The above approach would be consistent with that adopted in the Brisbane Water Foreshore Flood Risk Management Plan and hence the entire study area, which includes area under the influence of Brisbane Water flooding, would have the same approach applied for estimating the FPL.

Based on the above, consideration may be given in deriving the FPL as follows:

FPL = 1% AEP Design Flood Level + 0.5 m freeboard + increase in 1% AEP design flood level due to Climate Change

The derived FPL would be subject to the following conditions:

- where the adopted FPL is higher than the PMF, the FPL should be used
- FPL for critical infrastructure or highly vulnerable developments such as aged-care facilities should be set at a minimum of PMF. If the FPL, as calculated above, is higher than the PMF level, then the FPL should be used.

The FPL based on the traditional approach of adding a freeboard of 0.5m to the 1% AEP flood level can be adopted and consideration be given to adopting the FPL that contains a climate change component as discussed above.

The lower reaches of the study area are affected by projected Sea Level Rise (SLR) due to climate change. The Brisbane Water Foreshore Risk Management Study and Plan (Cardno, 2015) identify those areas and provide guidance for adopting a suitable FPL.

8.4.2 Estimating Increase in Design Flood Level due to Climate Change

The approach adopted in the Brisbane Water Foreshore Floodplain Risk Management Plan to apply a suitable Climate Change component for FPL determination based on the life of the asset, or the planning horizon, can also be adopted for the Narara Creek catchment.

Based on the DCCEE (previously DPIE/DPE) guidelines, the flood study (Golder, 2018) derived the increase in flood levels for the 1% AEP event for 10%, 20% and 30% increase in rainfall intensity, as part of the sensitivity analysis for future climate. For the purpose of deriving climate change component for FPL for different planning horizons, it is assumed that these rainfalls and corresponding flood level increases would occur in years 2020, 2050 and 2090 respectively. Depending on the planning horizon for the proposed development, the increase in 1% flood level corresponding to the planning horizon would be used for deriving the FPL. For example, if a development has a planning horizon up to 2050, the flood level increase associated with the 20% increase in rainfall intensity would be used for establishing the FPL for the development.

For critical infrastructure, it is recommended that a flood level increase corresponding to the 30% increase in rainfall is used in deriving the FPL.

It is noted that based on the latest estimates of climate change, as provided in **Error! Reference source not found.**, a smaller increase in rainfall intensity would be required as compared to the 10%, 20% and 30%

increases as analysed in the flood study. However, the current estimates are interim and might change in the near future, after more detailed analysis becomes available.

8.5 Flood Planning Area

As discussed above, the FPL is used as a tool to reduce the flood risk for the existing as well as any proposed developed in a floodplain. An important consideration in this regard is to define the area of the floodplain over which the FPL is applicable. This area is called the Flood Planning Area (FPA) and all properties lying within the FPA are deemed as Flood Control Lots, where further development controls are generally applied.

Generally, the FPA is defined by a virtual flood surface as defined by the FPL (i.e. the 1% AEP flood surface is raised by the freeboard). This definition of FPA has certain limitations, in particular, in the lower parts of a catchment where the raised flood surface can potentially extend beyond the PMF extent or even the catchment boundary.

A preliminary analysis was undertaken initially to define the FPA as discussed above. However, the extent of the FPA was beyond the PMF extent in the lower/flatter reaches of the catchment. To overcome this difficulty, a different approach was adopted to define the FPA. This approach, as discussed below, has also been adopted for other catchments in the Central Coast LGA.

Comparison of the flood extent for the 1% AEP design event + 30% increase in rainfall with the preliminary FPA as derived above, suggests that the two extents are similar in the upper reaches of the catchment. Therefore the 1% AEP event + 30% increase in rainfall intensity flood extent can act as a proxy for the FPA in the study area. This approach has been adopted for the current study. Figure 26 provides the FPA for the Narara Creek catchment.

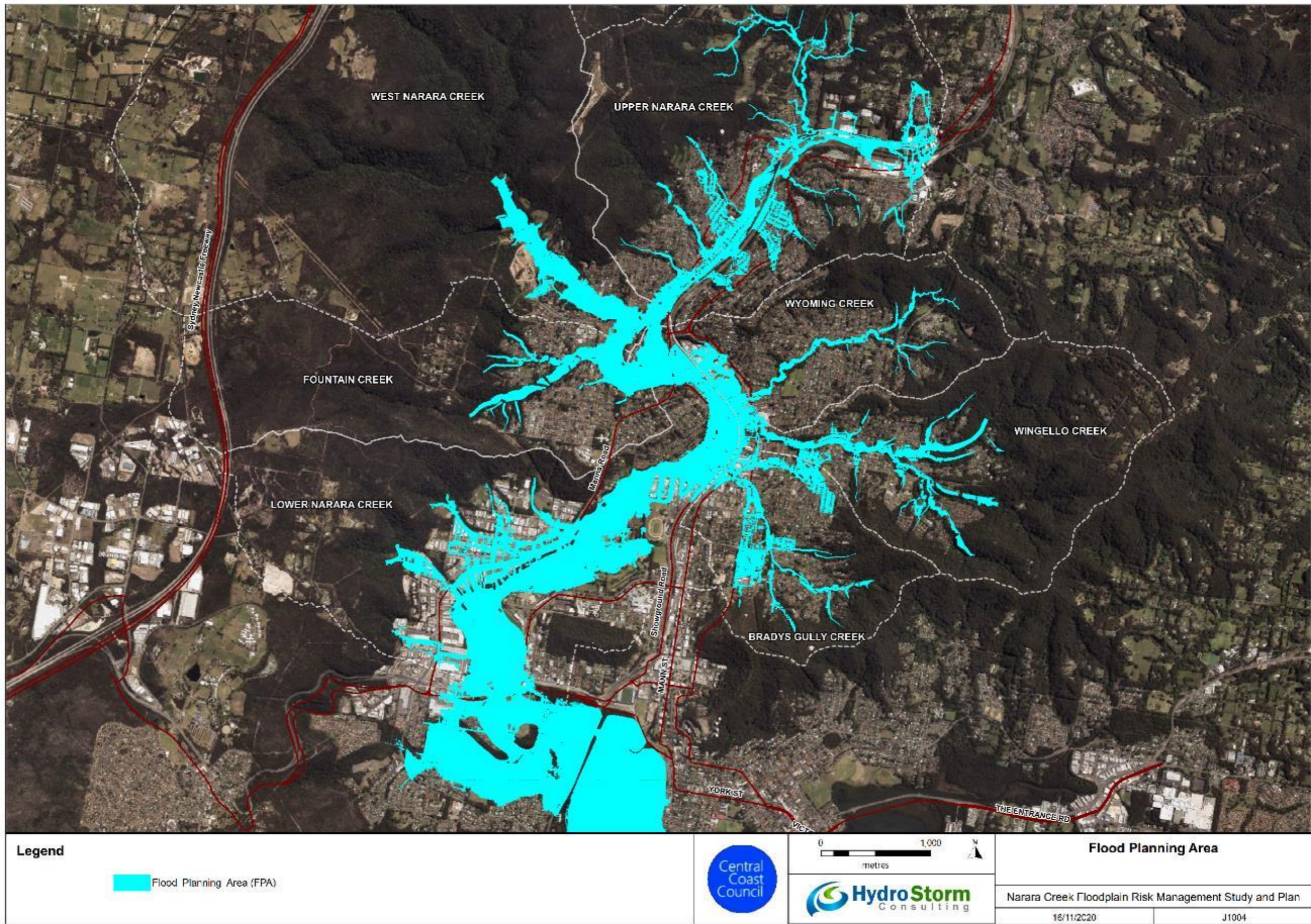


Figure 26. Flood Planning Area

9 Flood Emergency Planning

Flood emergency planning and implementing appropriate measures during a flood event is an effective way of managing the flood risk in the study area. Flood emergency management can reduce the costs of flooding and assist in managing the continuing and residual risk to the area.

The current flood emergency response planning tools for the study area are discussed below.

9.1 Hunter Central Coast District Disaster Plan (DISPLAN)

The NSW state emergency planning has produced the Hunter Central Coast Disaster Plan, which is applicable to the Gosford LGA. This plan defines the roles and responsibilities of various emergency combat agencies including the SES. However, this plan is currently under review for bringing in line with the new template and guidelines proposed when the State government changed the Emergency Management Districts to Emergency Management Regions.

This plan identifies riverine flooding, flash flooding and dam break flooding as a risk for the region. All these flooding scenarios are relevant to the study area.

9.2 Gosford City Flood Emergency Sub Plan (Local Flood Plan)

The latest version of Central Coast Flood Emergency Sub Plan was adopted by Council in September 2021. It is a sub plan of the Central Coast Emergency Management Plan. The Local Flood Plan has been prepared in accordance with the provisions of the State Emergency Service Act 1989 (NSW) and is authorised by the Local Emergency management Committee in accordance with the provisions of the State Emergency and Rescue Management Act 1989 (NSW).

The local flood plan covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the Gosford LGA.

The NSW SES Gosford Controller is responsible for dealing with floods as detailed in the State Flood Plan and ensure the preparedness, response and recovery aspects of the local flood plan are efficiently executed before, during and after a flood event.

The local flood plan includes flood emergency management measures required in the event of failure of previously prescribed dams, Narara Horticultural Dam and Pecan Close Retarding Basin, in the study area. These basins/dams have been de-prescribed and the Local Flood Plan should be updated with the new status of these basins/dams.

9.3 Evacuation

In flood emergency, suitable routes for evacuation should be available, that lead to either higher ground or designated evacuation centres in the study area or its surrounds. Effective evacuation therefore requires a safe evacuation route and an evacuation centre for temporary hosting of the evacuees.

9.3.1 Safe Refuge in Place

Timely evacuation of the residents is only feasible if the flood warning (usually from BOM) provides sufficient lead time. Given the steep rate of rise of floodwaters (flash flooding) with several roads cut-off in a short period after the onset of flooding, evacuation of residents would generally be not feasible. SES has determined that a minimum of 6 hours of lead time is required to safely evacuate a flood affected community. This lead time would not be available for the majority of flood events in the study area.

Thus, evacuation presents a significant decision making challenge for the SES and supporting agencies such as Council, as the decision to evacuate would need to be undertaken before even the onset of flooding. This is currently not feasible within the study area. Work, however, is currently underway by BOM (Flash Flood Advisory Resource, FLARE) to assist relevant organisations to develop flood warning systems for flash flooding. Evacuation may become feasible, if a functional warning system can be established through the BOM's FLARE processes.

In a major flood event, the residents of the study area are likely to stay indoor until the floodwaters have receded. This approach of avoiding flood risk, generally known as shelter-in-place, can be formally adopted as a measure for reducing the flood risk in the study area. This approach carries much lower risk than attempting to evacuate during or at the onset of flooding. However, there are risks involved in pursuing this approach as an option for flood management.

One of the major risks is that the residents would feel isolated for the period of flooding and can show irrational behaviour. Some residents become impatient and try to leave their homes, especially when there is a power outage, lack of comfort and sustenance, loss of amenities and lack of information about the ongoing flood. However, the isolation period is likely to be small, as the flooding would generally last for a few hours.

Another risk is that a resident may require medical attention. This would require the assistance of SES to undertake the evacuation to the nearest hospital.

There is also a risk of fire when residents are taking shelter in their homes. However, this risk is more prominent where the duration of shelter in place is for several hours. The duration of flooding for the majority of the study area would be in the range of 4-10 hours. Therefore, the fire risk during shelter in place is likely to be low.

Some of the measures that can be taken for minimising the risk associated with shelter in place include:

- ensuring that the development is structurally sound to withstand the impact of a PMF event
- provision of a second storey in the building for evacuation above the flood level
- providing updates to the residents about the ongoing flooding
- emergency help line to assist the residents with queries, including basic medical advice
- ensuring basic amenities during the emergency, such as toilets, lighting arrangement etc.

Shelter in place is an option for flood risk management and its merits-based use as a development control can potentially reduce the flood risk for the community. However, this option should be used as a last resort, only when the proposed development is able to demonstrate a safe shelter above the PMF, which is structurally sound and able to withstand the forces of floodwaters during a PMF event.

The shelter in place option should not be used for the new developments.

The Department of Planning, Housing and Infrastructure has recently released Shelter in Place guidelines. These guidelines should be used for the purpose of development control by the Council.

9.3.2 Evacuation Route

The study area would generally experience major flooding for short durations ranging from 3 to 9 hours. The roads/streets in the study area are likely to be flooded for generally 2-4 hours. Hence an orderly evacuation through the SES trained staff is not feasible. Most residents would stay indoors during the duration of flooding and face the flood hazard, if their property is flood affected. These flood-affected residents may

also try to escape the flooded areas and would require a suitable evacuation route to higher grounds or safe areas. It is noted that self-evacuation during a flood event carries a significant risk to life and should only be undertaken under the advice of SES. Knowledge of evacuation routes and the risks associated with self-evacuation should be part of the community education program.

A detailed review of the potential evacuation routes has been undertaken. Details of these potential routes is provided in Section 14.1.

9.3.3 Evacuation Centre

The Gosford Local Flood Plan specifies locations for evacuation during a flood emergency. The evacuation centres identified for the study area include:

- Narara Community Centre
- Niagara Park Stadium
- Gosford RSL Club

Whilst the Narara Community Centre and Niagara Park Stadium are located along the edge of the defined floodplain in the study area (PMF flood extent), the Gosford RSL Club lies within the floodplain and affected even in the 1% AEP flood extent. The other two evacuation centres are near the 1% AEP flood extent.

Given the proximity of the designated evacuation centres to the floodplain, the safety of the evacuees can be compromised. It is recommended that the suitability of these evacuation centres needs to be reassessed and the local flood plan updated. This would be accomplished when the flood intelligence data developed as part of the flood study is transferred to SES for operational purposes.

Various schools in the study area can be used as additional sites for evacuation purposes as a temporary shelter since the duration of flooding in the catchment is likely to be relatively short. In particular the Narara Valley High School may be considered for this purpose, as it would prevent parents from driving to and from school through flooded roads to reach their children at school.

9.4 State Emergency Services Operation

The NSW State Emergency Service (SES) is the combat authority for managing flood emergencies in the State. The roles and responsibilities of SES are defined in the NSW State Flood Plan, which is a subplan of the State Emergency Management Plan. The NSW SES Commissioner is required to ensure that all supporting emergency services and functional areas, organisations and officers mentioned in this plan are aware of their roles and responsibilities.

The study area is located within the footprint of the Gosford Unit of the Northern Zone of the of the State Emergency Service (SES). The Gosford SES maintains a Local Headquarters at Erina Works Depot, Pateman Road, Erina (this property is affected by flooding). The Operational Centre is also located in the Headquarters.

The Gosford SES unit is responsible for managing the flood emergency in the study area. The role of the SES in flash flood areas such as the Narara Creek floodplain is generally at the rescue and clean-up stage. Evacuation would generally be not feasible given the sudden onset of flooding. Preparing the community for dealing with flood emergency can significantly reduce the flood risk. SES can play a major role in this regard and develop community education programs in association with the Council to prepare the community for managing the flooding risk.

9.5 Flood Warning Systems

The Bureau of Meteorology issues a 'Flood Watch' along with the 'severe weather warning' or a 'severe thunderstorm warning' for the likely flood events and then a 'Flood Warning' when the flood is imminent. These warnings are relayed to the local SES, which disseminates this information to other relevant agencies such as Council, Police etc.

The flash flooding nature of the study area suggests that flood warnings that are relayed through BOM are not likely to provide sufficient time for orderly evacuation of the flood affected community. However, an automatic flood warning system such as a siren triggered by the flood level in a major creek, can alert the community to the impending flooding. Even this type of warning system is not likely to allow sufficient time for evacuation, however, can provide time for residents to react to this emergency, in particular during the night. Provided the community is educated about acting before and during the flooding, a significant reduction in flood risk can be achieved.

The council currently provides an SMS message service to residents who live on a low flood island around Tuggerah Street Lisarow. The only evacuation route for these residents is cut in frequent flood events and decision making is critical at the beginning of the storm event. This system could work more effectively within the Narara Creek Catchment provided that it is regularly tested and maintained annually.

The SES Flood Safe brochures provide the necessary guidance to deal with the flood emergency. For relatively large developments, such as schools, caravan parks, old age homes etc., a well-developed flood emergency response plan by the property owner can minimise the risk to life and property.

A flood warning system was installed by Council at Roweena Road basketball courts (Gavenlock Oval), near the bank of Narara Creek (Figure 27). It consisted of a water level detector and a siren, which sounded when the flood reached a critical level, indicating initiation of significant flooding. This system is no longer in use due to repeated vandalism and associated maintenance costs. It is recommended that this system should be made operational/upgraded and be maintained by the Council.

Former Gosford City Council completed a Storm & Flood Forecasting Study (MHL, 2017) which investigated the feasibility and options available for developing a cost-effective Early Warning Network Alert and Flood Forecasting System (EWNFFS). It identified the necessary tools and information that will assist decision makers in formulating an appropriate emergency response in a severe storm event.

Following the recommendations of the Flood Forecasting Study (MHL, 2017), the Council commissioned MHL to develop a Flood and Coastal Intelligence Tool, MHLFIT, that would provide a predictive tool for flood forecasting in the Narara Creek catchment. This tool has been prepared and provides Council the necessary flood intelligence to mobilise resources for minimizing the flood risk in the catchment. MHLFIT also enables SES local units and other flood intelligence officers to establish predictive flood messaging and help identify critical areas for operational deployment.

Other measures highlighted in the Flood Forecasting Study should also be implemented. These measures include maintenance and upgrade of infrastructure such as rainfall gauges and water level data loggers. Further details are available in the Flood Forecasting Study (MHL, 2017).



Figure 27. Flood Warning System at Roweena Road, Narara (Historic photo)

10 Community Consultation

An effective flood risk management program is underpinned by support from the local community. Dissemination of information throughout the flood risk management process and seeking community input at various stages of the process is critical in successful implementation of a flood management plan.

The Council has developed a community engagement strategy and will prepare a communication plan for the exhibition of this Floodplain Risk Management Study and Plan.

10.1 Community Survey

A community survey was undertaken during the preparation of the flood study. This survey sought to gain community's understanding of the flood issues in the study area. This survey was in the form of a questionnaire and answers to various questions in the survey provided an important insight into the flood risk perceived by the community.

The survey was mailed to 1,578 property owners within the study area. A total of 342 responses were received, which equates to a response rate of approximately 22%. Overall respondents reported a total of 495 locations where they had observed flooding or overland flows in the study area.

Details of the survey are presented in the Narara Creek Flood Study Review (Golder, 2018) (also available on Council's website). Details relevant to the current study are presented in the following sections.

10.1.1 Flood Modification Measures

Provision of flood modification measures were recommended by the majority of the respondents. The measures included creek enlargement, provision of flood basins, bridge/culvert enlargement, floodway construction and levees and flood walls.

The developed nature of the study area restricts the provision of major flood modification measures. Measures such as channel enhancement can provide local relief with adverse impacts downstream.

10.1.2 Development Controls

Almost all respondents to the question of application of development controls either wanted development to occur in the floodplain after application of development controls or no development to occur at all. This indicates an acute awareness of the role of development controls in managing the flood risk in the community. This awareness can be maintained by continuous community education.

10.1.3 Flood Warning

The majority of respondents have received flood warning from the local radio/television, with only a few receiving this information from other sources such as BOM etc. This process can be strengthened by ensuring that the local SES along with the Council's Local Emergency Management Officer are aware of this finding so that flood warnings can be put out through the most efficient channels.

As discussed above, the Council has recently developed a flood forecasting tool, MHLFIT, which would greatly facilitate mobilizing resources for flood risk management at the time of flood emergency. This tool can be accessed by SES as an effective mechanism to initiate and plan for flood events.

10.1.4 Flood Awareness

The majority of the respondents were aware of the flooding risk to their property except in Fountain Creek and Lower Narara Creek sub-catchments. Furthermore, the majority of those aware of flood risk thought that their property was not actually at risk of being flooded.

A sizeable minority is unaware of the flood risk and a targeted community education program can improve flood awareness among the community.

10.1.5 Community Education

The community was asked about various means to communicate the flood risk. Majority of the respondents preferred a direct method of receiving a letter from Council for flood related information. The emphasis was on continuing education rather than a one-off communication of the flood risk.

However, a number of residents also considered publication of flood maps on Council web sites to be sufficient for conveying the flood risk information to the community.

10.2 Floodplain Risk Management Committee

The Council has formed the Catchment to Coast Committee to oversee the work undertaken in the current study. The committee consists of members of the public, representative of DCCEEW and the Council staff. A technical sub-committee was formed prior to Council amalgamation to discuss the technical issues of the study. The members of this sub-committee include the representative of DCCEEW and the Council's flood risk management officer.

Several meetings were held with these committees throughout the study period and input from these meetings has been incorporated in the study outcomes.

10.3 Public Exhibition

The report will be publicly exhibited for a period of four weeks. Public comments will be considered for incorporation into the report before adoption by Council.

11 Floodplain Risk Management Options

11.1 General

Occupation of the floodplains comes with an inherent risk and identification and implementation of flood risk management options provide an opportunity to manage this risk. A better understanding and consequently an improved management of the flood risk can be achieved if the risk could be categorized as

- Existing flood risk – it is related to the existing developments on flood prone land. Such developments, by virtue of their location, are exposed to an 'existing' risk of flooding.
- Future flood risk – the future risk refers to future developments on flood prone land. The risk to such developments would not materialize until the developments occur. The future flood risk is also present due to the ongoing Climate Change.
- Residual/Continuing flood risk – this is the component of risk that would continue to exist even after the flood risk management options have been implemented. For example, an option designed for the 1% AEP event would have residual risk for rarer events such as 0.5% AEP event, which though rare, have a certain probability of occurring in the future.

The flood risk management strategies range from completely avoiding the risk at one end of the spectrum to accepting the risk at the other end. The alternative approaches to managing risk are outlined in Table 11 (after SCARM, 2000):

Table 11. Flood Risk Management Alternatives

Preventing/Avoiding risk	Not allowing development within the floodplain
Reducing likelihood of risk	Implementing structural measures to reduce risk. The potential for implementation of flood modification options is limited by economic, social and environmental constraints
Reducing consequences of risk	using development controls to floodproof buildings
Transferring risk	via insurance – likely to be costly given the current flood insurance options available
Financing risk	through natural disaster funding
Accepting risk	Not generally acceptable. Can also refer to the presence of continuing risk regardless of the options implemented. Flood emergency management measures may reduce this risk.

11.1.1 Floodplain Management Options

Recent work undertaken by Australian Institute of Disaster Resilience has established national guidelines for flood risk management (AIDR, 2017). These guidelines highlight the balancing act of occupation of floodplains and management of the associated risks. In addition, the Flood Risk Management Guideline MM01 of the Flood Risk Management Manual (2023) provides guidance for identifying flood risk management options.

The AIDR guidelines recommend various options for the management of existing, future and residual risk in a floodplain. These options may be developed at the regional, community or individual property level. Suitable treatment measures may include better land-use planning and development controls, improved information to inform emergency management planning, improved flood warning systems, more infrastructure to protect areas from flooding and better communication of flood risk to the community.

Table 12 and Table 13 provide details of the suitable options for various risk categories, both for existing and future developments.

Table 12. Generic Flood Management Options for Existing Developments

Development scale	Type of flood risk	Management measures*
Community or a specific area	Existing	Flood mitigation dams
		Retarding and detention basins
		Permanent levees
		Flow conveyance improvements
		Flood gates
		Temporary barriers
		Change in property zoning
	Residual	Flood prediction and warning
		Community-scale emergency response plans
		Evacuation arrangements
		Evacuation route upgrade
		Community flood readiness
		Community recovery plans
		Community recovery plans
Property	Existing	House raising
		House purchase
		Relocation of development
		Flood proofing of buildings
		Temporary measures
	Residual	Residual risk management options listed above augmented by appropriate property-based emergency management plans

Table 13. Generic Flood Management Options for Future Development

Development scale	Type of flood risk	Management measures
New development and redevelopment areas	Future	Zoning
		Development controls
		Building controls
	Residual	Flood prediction and warning
		Flood access and evacuation routes
		Emergency response arrangement for new areas
		Update of community-scale emergency management plans
		Development-scale flood awareness and readiness
Infill development within existing zoned areas	Future	Development controls
		Building controls
	Residual	Residual risk management options listed above augmented by appropriate property-based emergency management plans

*Management measures should include allowance for Climate Change impacts

11.2 Option Categories

The flood risk management measures can generally be classified as

- Flood Modification (FM) Measures – The flood modification options change the flood behaviour of the flood affected area such that the severity of flooding is reduced. Such options include detention basins, levees, filling of the floodplain, provision/enhancement of culvert/bridges etc.
- Property Modification (PM) Measures – The property modification options tend to modify the existing development such that the flood risk for the property and its residents is reduced. Development controls, flood proofing, house raising, voluntary purchase etc. are various property modification options
- Emergency Response Modification (EM) Measures – An effective response during a flood emergency can substantially reduce the flood risk. The emergency response modification options provide an opportunity to develop tools and establish procedures for managing the risk to the residents affected by flooding. Emergency response modification options include community flood awareness, flood warning systems, flood emergency response planning etc.

The above options have impact to a varying degree on a floodplain. A general assessment in this regard by AIDR is presented in Table 14.

Table 14. Typical Ability of Management Options to Reduce Flood Risk

Option Type	Existing Developed Areas			Future Development Area		
	Existing Risk		Residual Risk	Existing Risk		Residual Risk
	Safety	Damage	Safety	Safety	Damage	Safety
Measures to modify property						
Zoning and development control				High	High	Low ^a
Voluntary purchase	High	High	High			
Voluntary house raising	Low	Medium	Negative ^c			
Flood proofing of buildings	Low	Low				
Access during flood events	High	Low ^e	High	High	Low ^e	High
Measures to modify response						
Community flood awareness & readiness ^{b,d}	Low ^b	Low ^b	Low ^b	Low ^b	Low ^b	Low ^b
Flood predictions and warnings ^b	Medium ^b	Low ^b	Medium ^b	Medium ^b	Low ^b	Medium ^b
Emergency response planning for floods ^b	Medium ^b	Low ^e	High ^b	Medium ^b	Low ^e	High ^b
Measures to modify flood behaviour						
Levees	High	High	Negative ^c	High	High	Negative ^c
Detention/retarding basins	Medium	Medium	Negative ^c	Medium	Medium	Negative ^c
Flood mitigation dams	Medium	Medium		Medium	Medium	
Bypass flow conveyance	Medium	Medium		Medium	Medium	
Channel improvements	Medium	Medium		Medium	Medium	
Enhance environment						

a. Depends on consideration of emergency management issues and vulnerable development in land-use planning activities.

b. These options all rely on each other to be effective.

- c. Measures such as house raising and levees reduce risk to property but are known to have an adverse impact on perceived risk to life because people incorrectly assume that property protection measures have eliminated flood risk.
- d. There is little qualitative evidence showing community awareness and education campaigns are effective to reliably and perpetually reduce risk.
- e. Have no impact on structural damage. However, in some cases, where response times and conditions allow may permit some reduction in contents damage.

11.3 Implemented Floodplain Risk Management Options

A number of flood modification options were identified and recommended in previous studies. Several of these recommended options have been implemented in the study area. This study has included all the previously implemented options in the existing condition flood modelling for the study area and as such does not evaluate the performance of those options.

However, it's noted that in previous studies options were assessed using less detailed one-dimensional hydraulic (1D) models. Moreover, all the major sub-catchments were assessed individually and the impact of the option on the wider Narara Creek catchment was not assessed.

The current study uses a higher definition two-dimensional (2D) hydraulic model and can potentially demonstrate a different impact of the implemented option than that established in the previous study. One such example is the drainage enhancement across Koninderie Pde, which does not appear to provide the benefit established in the previous study.

11.3.1 Provision of Flood Retarding Basins

The Floodplain Management Study for Wyoming, Wingello and Brady's Gully Creeks (Kinhill, 1993) identified several locations in the upper reaches of these catchments for constructing detention basins. However, the modelling undertaken for that study indicated that provision of such basins in Wyoming Creek had little beneficial impact and hence were not recommended in the Floodplain Management Plan for these catchments.

Due to steep slopes in the upper reaches of the catchment, the basin wall heights need to be substantial to create significant storage for flood management purposes. This is difficult to achieve in the Narara Creek catchment. Furthermore, the basins would almost certainly be included on the prescribed list of Dam Safety NSW. This would require much stringent controls on design, management and maintenance of these structures.

11.4 Floodplain Management Areas

The study area covers several sub-catchments and historically a number of these sub-catchments have been subject of flood risk management study. To facilitate identification of various flood management options and achieve consistency with the previous studies, the following Flood Management Areas (FMAs) have been established for the purpose of this study. Figure 28 shows these management areas.

- C4/A – WEST NARARA CREEK
- C4/B – UPPER NARARA CREEK
- C4/C – FOUNTAIN CREEK
- C4/D – WYOMING CREEK
- C4/E – WINGELLO CREEK
- C4/F – BRADYS GULLY CREEK
- C4/G – LOWER NARARA CREEK

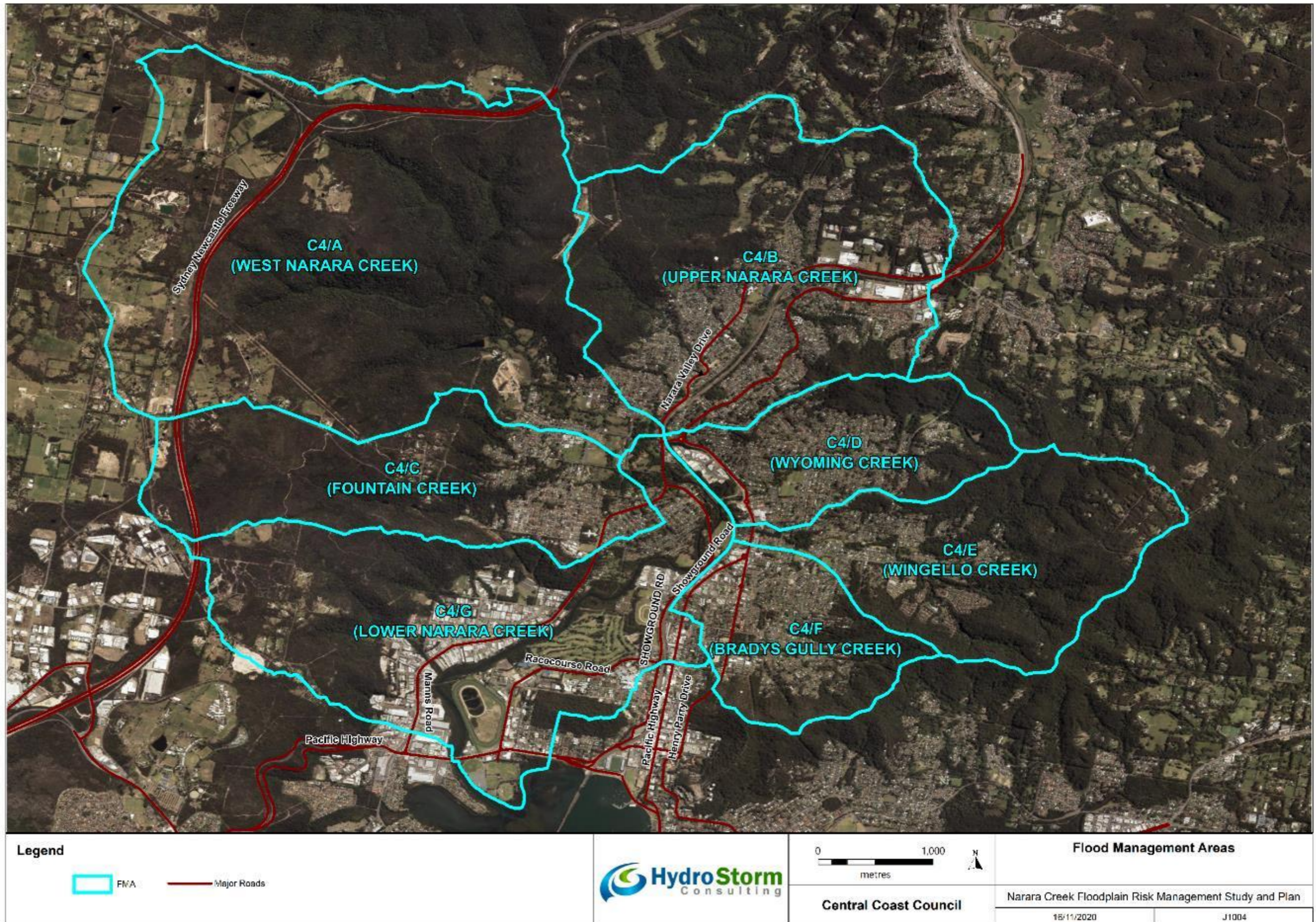


Figure 28. Flood Management Areas

11.5 Options Identified by Stakeholders

11.5.1 Options Identified by the Stakeholders

Various stakeholders including the local community suggested several options for flood management. These options are listed in Table 15.

Table 15. Flood Management Options by Community

Type of Option	Option Description
Flood Modification Options	<ul style="list-style-type: none"> - Creek enlargement - Culvert/bridge enhancement - Construction of floodways - Flood basins - Levees or flood walls
Property Modification Options	<ul style="list-style-type: none"> - Development Controls
Response Modification Options	<ul style="list-style-type: none"> - Flood warning - Community education

11.5.2 TfNSW Project and Council Recommendation

TfNSW has recently upgraded the Pacific Highway through the study area. Two routes for the upgrade were identified, one each along either side of the Narara Creek (eastern and western routes).

The western route was favoured by the Council as it provided several opportunities to minimise the flood risk in the study area. For this route, properties along Koninderie Parade would have been acquired, which is a major flooding hotspot in the study area. In addition, the escape route for the residents of West Narara Creek and Fountain Creek catchments would have been established by upgrading the local roads and connecting them to the upgraded highway.

However, after considering various factors including the community response for the two options, TfNSW adopted the eastern route.

11.6 Options Identified in the Current Study

Past studies have identified several flood risk management options, many of which have already been implemented by the Council. A summary of the options presented in various reports is provided in Appendix E.

In the current study, several additional floodplain risk management options were identified at the initial stages of the project. These options were presented to the technical sub-committee of Council's Floodplain Risk Management Committee. The preliminary options were refined in two rounds of discussion with the sub-committee.

The refined list of floodplain risk management options was assessed in detail. The following sections of the report provide details of option assessment, including flood modelling results for the flood modification options.

The list of options assessed in this study are presented in Table 16. A short assessment of the option along with the recommendation for adoption in the flood risk management plan is also included.

Figure 29 shows the location of the flood modification options investigated in this study.

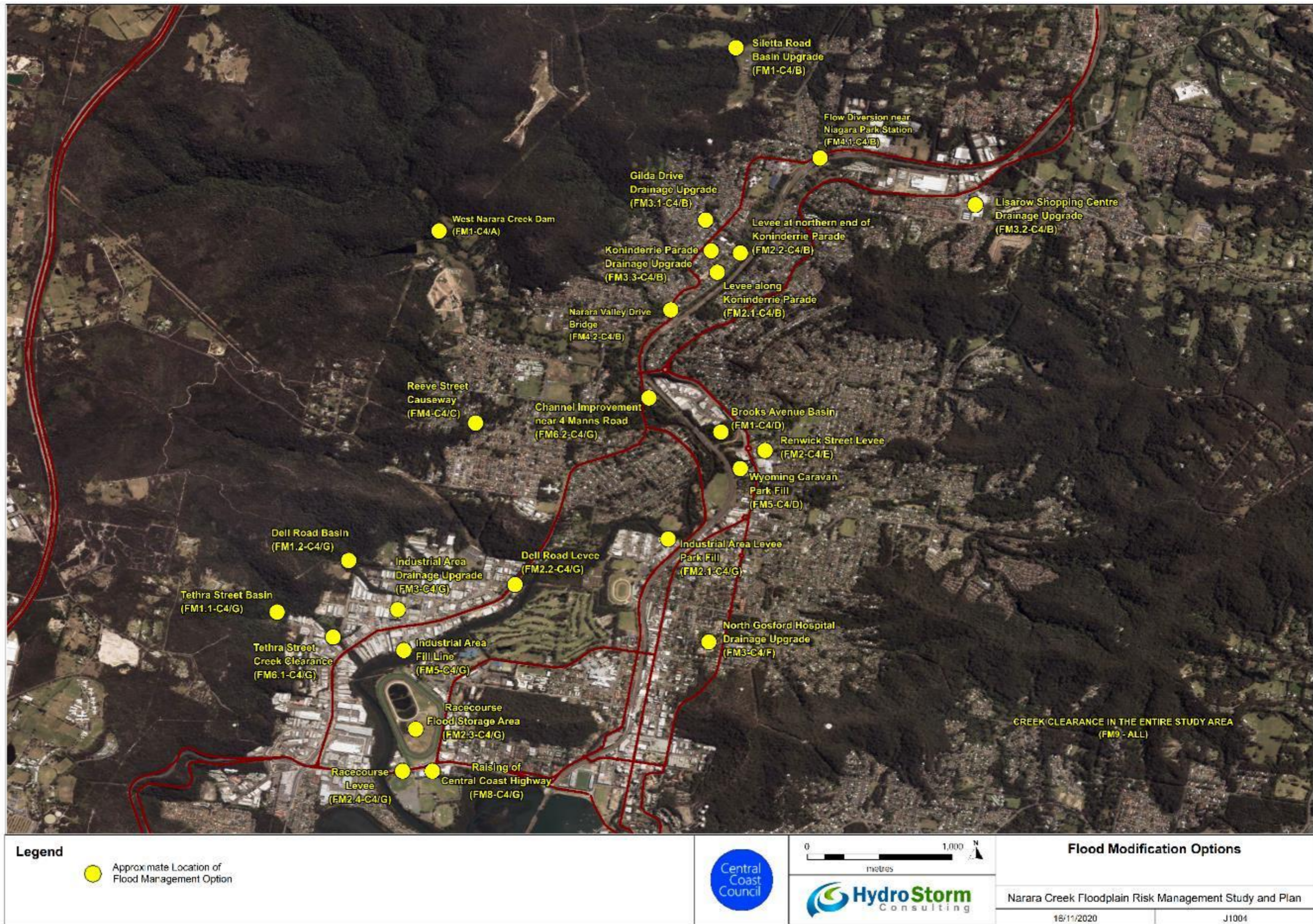


Figure 29. Flood Modification Options – Investigated for the Study

Table 16. List of Flood Risk Management Options

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
FLOOD MODIFICATION OPTIONS									
C4/A	FM1-C4/A	BASIN	West Narara Creek Dam	- Near the existing dam on Old Agricultural Experiment Station on the main West Narara Ck branch. A large scale sub-division, Ecovillage, has recently been developed nearby.	- Kinhill 1997 FRMS considered this option but for a smaller storage dam (crest at RL 12 m AHD). The study, however, found that such a dam would not significantly reduce the flood affectation downstream.	NO	NO After detailed review of the Kinhill report, further investigations were not carried out	Based on previous assessment by Kinhill, the option was not considered viable.	NO
				- If built to the same level as the existing dam (~ 17 m AHD), can potentially improve flooding downstream. However, the dam is likely to be High Hazard category dam				Since the development of this FRMSP the land of NSW Government Agricultural Research Station was sold and rezoned to accommodate an Ecovillage, which is now developed. The dam mentioned has now been removed from the prescribed dam schedule. Further discussion is provided in Section 4.2.1	
				- The proposed dam is likely to be a prescribed dam for the purposes of Dam Safety NSW, with higher maintenance costs					
C4/B	FM1-C4/B	BASIN	Siletta Road Basin Upgrade	- The wall of the basin could be raised to increase storage	NO	NO	YES	Flood modelling shows limited benefit. (Section 11.1)	NO
				- The valley upstream of the basin is steep and therefore may not result in significant increase in storage					

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
	FM2.1-C4/B	LEVEE	Levee along Koninderie Parade	- A levee along part of the street may be helpful. Levee along the full length of the street is not recommended due to likely downstream adverse effects near Deane St. With part length of the street, adverse impacts may be minimal.	Upper Narara Creek FRMP 1995 (Patt Britt) recommended maintaining the conveyance of the channel by desilting and vegetation removal through regular maintenance works. This was implemented	NO	YES	The levee may increase the capacity of the channel, however, likely to result in downstream impacts.	NO
				- Approximately 1 m high levee may be suitable				Can potentially create higher risk for properties at Koninderie Pde for less frequent events, where the levee is overtopped.	
				- Levee to start upstream of Koninderie Pde along the creek line				Part construction of a levee (OPTION FM2.2-C4/B) may be feasible in combination with other options.	
	FM2.2-C4/B	LEVEE	Levee at northern end of Koninderie Parade	A small levee along the creek may prevent flow through the proposed childcare precinct, near Willari Avenue – Combined with other options may provide additional downstream benefits. Can potentially be combined with Option FM4.2-C4/B	NO	NO	YES	The levee is provided along the creek bank, upstream of Koninderie Parade. Modelling indicates (Section 11.2) that It prevents overflow of creek and provides significant improvement.	YES
	FM3.1-C4/B	DRAINAGE UPGRADE	Gilda Drive Trunk Drainage Improvement - Upper Narara	- Significant overland flow due to limited drainage capacity	NO	NO	NO	Out of scope for the current study.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				- May also require creek clearance works			However, local high definition drainage study recommended for further investigations to a future stage	Drainage improvement can potentially provide local relief.	
				- Likely interaction with flooding on Koninderie Pde					
				- Detailed trunk drainage analysis will be a recommendation of this study as it is beyond the scope of current study.					
				- May not be effective near the creek due to backwater effects					
	FM3.2-C4/B	DRAINAGE UPGRADE	Lisarow Shopping Centre Drainage - Upper Narara	- The flow is confined to a narrow flow path upstream of the shopping centre; however, spreads further downstream and inundates the car park of the centre.	NO	YES	NO	The shopping centre presents a significant flood risk. A detailed drainage analysis for the local catchment is required to manage the flood risk, including the provision of effective flood evacuation in a PMF event.	YES
				- Detailed trunk drainage analysis can identify the required upgrade to the existing drainage to prevent flooding of the shopping centre.		Car park works carried out circa 2016. It is assumed that appropriate drainage has been provided			
	FM3.3-C4/B	DRAINAGE UPGRADE	Koninderie Pde Drainage Upgrade	Enhance local trunk drainage to minimise overland flow flooding from the west of Koninderie Pde	NO	NO	NO	Out of scope for the current study.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
	FM4.2-C4/B	CULVERT/ BRIDGE	Narara Valley Drive Road approaches and upgrade box culvert to clear span	Replace the existing four cell culvert with the bridge design provided in the Upper Narara Creek Floodplain Management Plan (1995). The proposed bridge has a road level above the 1:100 AEP flood level. Proposal will reduce upstream flood and facilitate evacuation.	Kinhill 1995	NO	YES	Modelling shows significant improvement (Section 11.3). Can be combined with Option FM2.2-C4/B.	YES
C4/C	FM4-C4/C	CULVERT/ BRIDGE	Reeves St Causeway	Upgrade road access to 1% AEP flood. Would require bridge or multi-cell culvert. Extensively requested in recent community survey. Can be part of flood evacuation route for the West Narara area.	Kinhill 1997 (Option FR7)	NO	YES	Can potentially provide flood free access for Narara High School. Suitable for flood evacuation strategy in the study area. Will address the issue highlighted by the residents	YES
C4/D	FM1-C4/D	BASIN	Brooks Avenue Detention Basin Review	- Preliminary review of this detention basin suggests that the flow entering the basin from Narara Creek, under the railway, impacts the industrial/commercial properties at Brooks Avenue. Blockage of the flow from Narara Creek can potentially benefit this area.	Proposed in Kinhill 1991 Study.	YES. But the railway underpass was only partially blocked and not fully blocked as proposed. Currently a bicycle path is provided through this underpass	YES	Modelling shows significant benefit to the Brooks Avenue industrial area by complete blockage of the underpass (Section 11.4) Bike path would need to be relocated if this option is implemented. Properties in Showground Road would need to be protected for likely flood impact.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				- Option to completely block the flow under the Railway underpass from Narara Ck to Brooks Avenue was modelled.				Wyoming Creek Maintenance Plan (ECMD3920007) requires review to ensure detention storage area is properly maintained to ensure fit for purpose operation	
	FM5-C4/D	FILLING	Wyoming Caravan Park filling	Raise the caravan park area above the 1:100 AEP flood level to assess impact	NO	NO	YES	The filling can be achieved only with impact (Section 11.5). Provides benefit by protecting the caravan park from 100 yr flooding but has impact on adjoining properties	NO
C4/E	FM2-C4/E	LEVEE	Renwick Street - Wyoming Creek	Wyoming Creek FRMS&P (Kinhill, 1993) identified upgrade of Pacific Highway culvert and creek works to reduce flooding in this area. Potential for reducing flood risk by removing flood affectation Levee might be a solution	YES	YES, but levee was not implemented	NO	Limited benefit. Likely to impact surrounding properties as identified in the Wyoming Creek FRMS&P (Kinhill 1993).	NO

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
C4/F	FM3-C4/F	DRAINAGE UPGRADE	North Gosford Hospital	Drainage improvement within the hospital site required. Hospital flood risk to be managed through Flood Emergency Response Plan for the hospital.	NO	NO	NO	The hospital administration is required to improve internal drainage and prepare Flood Emergency Response Plan.	NO
				Detention basin in the park between Burrabil Ave and Dwyer St (north/downstream of the hospital) may improve flooding north of Dwyer Street.				The detention basin between Burrabil Ave and Dwyer St not feasible due to existing landuse	
C4/G	FM1.1-C4/G	BASIN	Tathra Street Basin - West Gosford	- The basin would be in the land zoned 7a Environmental	NO	NO	This option can potentially be combined with FM6.1-C4/G	Modelling shows that the benefit is limited to a few properties (Section 11.6)	NO
				- May not be effective up to 1% AEP due to limited size					
	- Preliminary investigation suggests embankment level to be at 6 - 7 m AHD (2-3 m high embankment)								
C4/G	FM1.2-C4/G	BASIN	Dell Road Basin - West Gosford	- At the intersection of Dell and Nells Roads	NO	NO	YES	Modelling shows that the benefit is not significant (Section 11.6)	NO
				- Land zoning is 7a					

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				<ul style="list-style-type: none"> - May not be effective in major events due to smaller size - Preliminary investigation suggests embankment level to be 7 - 7.5 m AHD (2-3 m high embankment) - A better option than trunk drainage improvement as future sea level rise scenarios may diminish the benefits of trunk drainage improvements. 					
	FM2.1-C4/G	LEVEE	Levee protection for industrial area at Glennie St West	<ul style="list-style-type: none"> - The right bank of Narara Creek is much higher than the left bank looking downstream near Glennie Street West. A levee along the industrial area may be useful and may not have significant impacts downstream. 	<ul style="list-style-type: none"> - An option for this area whereby the area north to the Industrial area was lowered to create a high-level floodway (Kinhill 1991) has been implemented. 	NO	NO	Likely to have significant downstream impacts	

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				<ul style="list-style-type: none"> - If there is an impact on the right overbank downstream of the levee, the proposed levee can be supplemented with another levee at the impacted location. This would in turn may have an impact on the Golf Course, which may not be significant and may be acceptable. - The area is very flat, in particular along Bowen Cr, which is also an overland flow path 					
	FM2.2-C4/G	LEVEE	Levee protection for industrial area at end of Dell Road prevent overbank flooding from Narara Creek	Investigate the potential to raise the lower end of Dell Road and incorporate into any future upgrade with Transport fNSW.	NO	NO	NO	Not modelled in this study but is recommended for further investigations. There is an opportunity to buy property prior to Transport fNSW finalisation of Pacific Hwy Upgrade. Should this land become available for purchase council should consider purchasing this land and implementing this option	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
	FM3-C4/G	DRAINAGE UPGRADE	Industrial Area Drainage Improvement - West Gosford	- Floor levels for more than 60 properties in the industrial area are close to street level and are likely to flood, causing flood damage	NO	NO	NO	Out of scope for the current study.	YES
				- Trunk drainage improvement may be considered in this area			However, local high definition drainage studies recommended for further investigations at a future stage	Drainage improvement can potentially provide local relief.	
				- Detailed trunk drainage analysis is recommended				West Gosford Industrial area is impacted by the upgrade to the Pacific Highway by Transport fNSW. Any changes in the road level would adversely impact the flooding in this area. Council should advise Transport fNSW that detailed assessment of flooding is required.	
	FM5-C4/G	FILLING	West Gosford Industrial Area Fill Line	- Establish Fill line for industrial development along Narara Creek in West Gosford Industrial Area	NO	NO	YES	Fill line established for filling the land along the creek (Section 11.7)	NO

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
								Drainage corridors required through this fill area for flows arriving from west from the Industrial area.	
	FM6.1-C4/G	CHANNEL WORKS	Tathra Street Creek Clearance	<ul style="list-style-type: none"> - Creek has limited conveyance due to high vegetation growth in parts of the creek. - The creek also has eroding banks that contribute to sediment transport to Narara Creek and ultimately Brisbane Water - Creek works similar to Rivercare Works to improve conveyance can be undertaken - Rivercare type works can be undertaken to prevent excessive regrowth of vegetation 	This creek was highlighted for future assessment in the Kinhill 1991 FRMP.	NO	This option can potentially be combined with FM1.1-C4/G	Modelling shows that the benefit is limited to a few properties. However, it is important to clear and maintain the creek to improve flow behaviour. An additional benefit is to manage water quality of the Brisbane Water by preventing slumping of creek banks and transport of sediment to Brisbane Water.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				- Additional benefit is that sediment generation and transport can be reduced which is one of the objectives for the Brisbane Waters Management Plan. Thus, a combined flooding and water quality objective can be achieved					
	FM6.2-C4/G	CHANNEL WORKS	4 Manns Road (Narara Nursery)	Waterway enlargement can provide local benefit by reducing flood levels	Two floodways were proposed in the Kinhill 1991 to streamline the flow within the creek.	NO	NO	Local enhancement of a section of Narara creek is not likely to have a significant benefit.	NO
	FM2.3-C4/G	LEVEE	Preservation of Racecourse and Golf Course Flood Storage Areas	- Racecourse and golf course provide flood storage during significant flood event	This option was also considered in Kinhill 1991.	Yes, the DCP 2022 has provided the appropriate controls	YES	Loss of flood storage in these two areas due to development can potentially increase the flood risk for adjoining areas, including the Central Coast Highway.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				- Development controls have been retained in current DCP specific location schedules to manage the flood risk	Gosford Development Control Plan (2022) acknowledges the flood risk of this area. Chapter 5.15 has specific controls for Lot 4 DP 775631				
	FM2.4-C4/G	LEVEE	Racecourse Storage Area with Flood Barrier/Levee	Levee along Central Coast Highway and Racecourse Rd to create flood storage and reduce flooding of Central Coast Highway	NO	NO	YES	Modelling indicates that additional flood storage provided by levee reduces flooding on the Central Coast Highway (Section 11.8). However, it has significant impact upstream of the levee.	NO
				Flood barrier/Levee				An alternative to the above levee is a flood barrier within the road reserve of Racecourse Road. Approximately 0.6m high block wall can serve this purpose. This alternative has not been modelled.	
	FM8-C4/G	ROAD WORKS	Central Coast Highway raising	Raising Central Coast Highway above the 1% AEP flood level would also provide protection from longer term effects of climate change and tidal inundation	NO	NO	YES	Modelling shows that the Highway can be made flood free up to the 1%AEP flood (Section 11.9). Further detailed assessment by TfNSW of raising of Central Coast Highway to mitigate flooding impacts to this primary transport route will be required.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				An alternative option to achieve the same outcome is by provision of a flood barrier between the racecourse property and the road reserve. This option has not been evaluated. However, FM2.4-C4/G indicates that a levee would reduce the impact of flooding on the Central Coast Highway					NO
	FM9- ALL	Creek Maintenance	Floodway	Controlling creek vegetation in an ecological sensitive manner will enable a reduction of flood impact. Council has a dedicated Creek Maintenance officer that currently receives annual operational budget.	YES	YES	YES	Creek Maintenance is critical for key areas such as Wyoming, Wingello and Bradys Gully. Existing management operational plans need review to ensure creek maintenance is a permanent feature of the operational plan.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
PROPERTY MODIFICATION OPTIONS									
C4/B	PM1.1-C4/B	SPECIFIC DEVELOPMENT CONTROLS	Lisarow Shopping Centre	<ul style="list-style-type: none"> - Development controls in isolation or along with other measures provide a significant opportunity to reduce the flood risk. - Development controls related to evacuation planning would be required 	NO	NO	NO Latest development occurred circa 2016. It is assumed that appropriate drainage, as per Council standards, has been provided.	NO	NO

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
C4/B	PM1.2-C4/B	SPECIFIC DEVELOPMENT CONTROLS	Koninderie Parade	<ul style="list-style-type: none"> Properties along Koninderie Parade are among the worst flood affected areas in the catchment Development controls such as building to the flood planning level, providing safe evacuation etc. would reduce the flood risk 	NO	NO	YES	<ul style="list-style-type: none"> Development controls would include floor levels to flood planning level, flood compatible construction, safe evacuation or refuge in place. Proposed planning matrix (Appendix G) provides guidance on how this option could be implemented. 	YES
C4/B	PM2-C4/E	VOLUNTARY PURCHASE	Koninderie Parade	<ul style="list-style-type: none"> Properties along Koninderie Parade are among the worst flood affected areas in the catchment 	NO	NO	YES	<ul style="list-style-type: none"> A phased approach of flood risk management can be adopted. 	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				<ul style="list-style-type: none"> - Voluntary purchase is a potential solution for managing the flood risk. The acquired properties provide an opportunity to change the land use to a suitably flood compatible use. 				<ul style="list-style-type: none"> - The development controls become applicable in the short run, followed by the implementation of flood modification options and lastly the voluntary purchase option should be pursued. - These properties would be recommended to be assessed against other at risk properties in an LGA wide Policy 	
C4/E	PM2-C4/E	VOLUNTARY PURCHASE	Adnamira Close - Wingello Creek	<ul style="list-style-type: none"> - Possibility of a levee or VP due to significant flood impact 	NO	NO	NO	<ul style="list-style-type: none"> - Only back half of the properties affected. Development controls might be more suitable. 	NO

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
C4/G	PM1.1-C4/G	DEVELOPMENT CONTROLS	West Gosford Industrial Area	<ul style="list-style-type: none"> - Lack of local drainage capacity results in significant inundation of the area, with several properties with above floor flooding. - Development controls would provide immediate benefit to this area - Controls relevant to trade waste industries would also be required 	NO	NO	YES	<ul style="list-style-type: none"> - Development controls as per Council's current DCP - Section 12.1 provides details of the development controls - Detailed drainage studies are recommended in future for managing local overland flooding. A Drainage Master Plan would be prepared to identify the secondary flow paths 	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
	PM1.2-C4/G	DEVELOPMENT CONTROLS	Golf Course and Racecourse Storage Areas	<ul style="list-style-type: none"> - Development controls can provide significant benefits - Preserving the flood storage area and limiting the intensity of the development can be part of the development controls - A flood warning system may also be helpful in managing the flood risk. 	Gosford Development Control Plan (2022) acknowledges the flood risk of this area. Chapter 5.15 has specific controls for Lot 4 DP 775631	NO	YES	<ul style="list-style-type: none"> - Development controls as per Council's current DCP should be applied. - Specific control for this area includes evacuation planning during flood emergency and flood warning system - Section 12.1 provides details of the development controls 	YES
	PM1.3-C4/G	DEVELOPMENT CONTROLS	Glennie St West Industrial Area	<ul style="list-style-type: none"> - Development controls can be effective in managing the flood risk 	NO	NO	YES	<ul style="list-style-type: none"> - Development controls as per Council's current DCP should be applied, including safe refuge and a flood warning system 	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				<ul style="list-style-type: none"> - Safe refuge for extreme floods and a flood warning system can potentially reduce the flood risk 				<ul style="list-style-type: none"> - Section 12.1 provides details of the development controls 	
	PM2.1-C4/G	VOLUNTARY PURCHASE	VP of Industrial Properties at Glennie St West	VP of the industrial area properties may be a suitable solution, however, is not recommended as the industrial business activity is already limited in the Narara Valley and reduction in this activity may have social consequences	NO	NO	NO	Not suitable as economic activity is reduced in the study area.	NO
	PM2.2-C4/G	VOLUNTARY PURCHASE	Two properties in Narara	One of the properties has requested in the community survey that the house be demolished and rebuilt to FPL with Council's assistance.	A levee was discussed in Kinhill 1991, but VP was outcome. One of the properties was not part of the VP program.	NO	YES	Properties on Rowena Rd were acquired under VP, except two properties. In 2002, Council resolved to acquire these two properties.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
ALL	PM1-All	DEVELOPMENT CONTROLS	Common Development Controls for the entire study area	<ul style="list-style-type: none"> - Development controls in urbanised areas such as the study area is a highly effective tool in managing the flood risk - This study has identified the Flood Planning Area (FPA). All properties lying within the FPA are noted as Flood Control Lots, where the development controls apply - Common development controls include setting floor levels at Flood Planning Level, use of flood compatible materials, safe refuge or evacuation during a flood emergency 	Various recommendations in a piecemeal fashion	YES	YES	<ul style="list-style-type: none"> - Council's current DCP should be updated as per study recommendation - Section 12.1 provides details of the development control matrix for various developments in different hazard categories 	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
	PM2-All	VOLUNTARY PURCHASE	VP of various properties in the study area	<ul style="list-style-type: none"> - Voluntary Purchase (VP) of properties that are exposed to high flood risk can eliminate this risk. - The acquired properties provide an opportunity to change the land use to a suitably flood compatible use. 	YES, several properties along Showground and Rowena Rd were identified for VP	YES	YES	<ul style="list-style-type: none"> - Based on the current flood hazard definition (H1-H6), several new properties have been identified as potential candidates for VP. Details are presented in Section 12.2. - A council wide policy should be developed and the properties identified in this study should be considered along with properties recommended in other catchments and a priority list developed before acquisition of properties under that policy. 	YES
	PM3-All	HOUSE RAISING	Structural raising of the houses to minimise damage	Houses with above floor flooding can potentially be raised to reduce flood damages	NO	NO	YES	<ul style="list-style-type: none"> - Considering the limitations of house raising, this option is generally not feasible for the study area. However, as properties reach effective life and are redeveloped habitable floor levels could be set at PMF or Safe Refuge in Place can be provided. 	NO

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
	PM4-All	SHELTER IN PLACE	Shelter in flood affected property	<ul style="list-style-type: none"> - Limited flood warning time in the study area suggests that the residents are better off staying at home rather than drive/walk through flooded streets. - If appropriately designed, a flood affected property can be used as a shelter during a flood event 	NO	NO	YES	<ul style="list-style-type: none"> - Shelter in place is not a desirable option for flood risk management. However, can be used in a limited number of cases under a merits-based approach - Section 12.1 provides details of the development controls 	YES
ALL	PM5	Stormwater Drainage Network	Overland Flood Studies	<ul style="list-style-type: none"> - Several properties in the upper reaches of the catchment are affected by overland flow flooding 	NO	NO	NO	<ul style="list-style-type: none"> - A high definition flood modelling would be required for the local study areas. These flood studies should consider the latest version of AR&R. Any future updates of the Narara Creek Flood Study should also consider latest version of AR&R. Review of the flood study or this flood risk management study should generally be undertaken every five years. 	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				<ul style="list-style-type: none"> - Complete for each individual FMA overland flood studies at a level of detail that will identify deficiencies in the stormwater network 				<ul style="list-style-type: none"> - Out of scope for this study 	
ALL	PM6	SPECIFIC DEVELOPMENT CONTROLS	Hazardous Materials	<ul style="list-style-type: none"> - Hazardous waste industry can potentially result in environmental damage by releasing waste in a flood event - Advice on managing hazardous materials can be included in development controls for the industrial areas in the catchment, including the West Gosford Industrial Area. All trade waste industries to be included for the application of appropriate development controls - Detailed drainage investigations are required in future 	NO	Some aspects identified in DCP	YES	Include Hazardous waste considerations such as bunding to prevent inflows from flooding in a 1% AEP event or as specified by the relevant authority	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
EMERGENCY RESPONSE MODIFICATION OPTIONS									
C4/C	EM1-C4/C	FLOOD EVACUATION ROUTE	Narara Valley High School Evacuation Route Upgrade via Cross Street	<ul style="list-style-type: none"> - School buses have been observed to travel through flooded roads to transport students. This creates a significant risk to life which needs to be addressed - A safe route for buses could be west along Fountains Road then south at the fork with Research Rd, then onto Cross Street (not formed yet) and finally east along Reeves St, which leads to Manns Road. - For this route to operate, Cross Road needs to be formed and the causeway on Reeves St needs to be converted to a culvert/bridge crossing. - Provision of audible alert for the local residences and recreational areas 	<ul style="list-style-type: none"> - This option has been recommended in the Kinhill 1997, FRMP. 	NO	YES	<p>Evacuation route is recommended as the observed community behaviour (driving through flooded roads in this area) during the flood emergency has increased the flood risk.</p> <p>The cost of implementing this option as compared to EM1.2-C4/C is significantly high.</p>	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
C4/C	EM1.2-C4/C	FLOOD EVACUATION ROUTE	Pandala Route	Alternative evacuation route proposed by Transport fNSW but did not get community support however this could be a more cost-effective measure than Cross-Reeves Street Route and provides regular traffic routes when Carrington Street closes due to Pacific Highway upgrade	YES Transport for NSW	NO	YES	Evacuation route is recommended as community behaviour (driving through flooded roads in this area) during the flood emergency have increased the flood risk. This option has considerably less cost than the Cross-Street option (EM1-C4/C). A feasibility study should be undertaken to further assess this option.	YES
C4/G	EM1.3-C4/G	FLOOD EVACUATION ROUTE	Mann Street Alternate Route	<ul style="list-style-type: none"> - Mann Street West Gosford will not provide a flood free access. - Alternate route needs to be considered 	NO	NO	YES	An alternate route has been identified as discussed in Section 13.1.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
C4/G	EM1.4-C4/G	FLOOD EVACUATION ROUTE	Hanlan Street Route	- Rather than travelling south, Hanlan Street provides an evacuation route to the north. This route is suitable for properties located to the north of West Narara Creek crossing of Hanlan Street	NO	NO	YES	Evacuation from local flood affected area to the north via Hanlan Street. A trafficable bridge is required over a creek crossing in the north	YES
C4/G	EM2.1-C4/G	EMERGENCY WARNING SYSTEM	Rowena Road Area	The current operation/maintenance of siren/audible alert for the local residents, should be reviewed.	NO	NO	YES	An audible alert which is triggered through a water sensor at the creek bank is recommended or telemetry to existing stream gauges (Section 13.2).	YES
	EM2.2-C4/G	EMERGENCY WARNING SYSTEM	Glennie St West Industrial Area	Provision of audible alert for the local shop owners	NO	NO	YES		YES
	EM2.3-C4/G	EMERGENCY WARNING SYSTEM	West Gosford Area	Provision of audible alert for the Gosford Racecourse area	NO	NO	YES		A catchment wide approach should be adopted to provide flood warning systems

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
	EM2.4-C4/G	FLOOD EVACUATION ROUTE	Warning Sign Boards	Provision of electronic sign boards alerting the closure of road – Fountains Road Deane Street, Narara High School, Manns Rd near nursery, Racecourse Road	NO	NO	YES	Several locations have been identified for warning signs as discussed in Section 13.2.	YES
ALL	EM2-AII	EMERGENCY WARNING SYSTEM	Emergency Management Measures	<ul style="list-style-type: none"> - Training of SES and other Council Officers in its flood intelligence capabilities should be undertaken. - Weather/flood prediction service for the public, particularly those in Low Flood Islands - Update local Flood Subplan to include coordination with Transport NSW to initiate electronic messaging services 	NO	NO	YES	<p>Several flood emergency warning tools have been highlighted in this study, including location of flood depth markers.</p> <p>Training of SES and other Council Officers in its flood intelligence capabilities should be undertaken.</p>	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
								<p>A comprehensive program to develop flood emergency warning systems throughout the LGA should be considered in consultation with SES, as coordinated approach for managing a flood emergency is required during a flood, which may affect several catchments in the LGA.</p> <p>The hydrometric systems used for emergency management should be maintained by the Council.</p>	
ALL	EM3-AII	EMERGENCY PREPAREDNESS	Flood Intelligence for SES	<p>Flood data preparation for use by SES during emergency (road closures, available routes for evacuation etc.)</p> <p>Council has developed a tool for flood forecasting, MHLFIT, for a comprehensive LGA wide flood emergency management</p>	NO	NO	YES	Information provided to SES by Council. MHLFIT training in using predictive warning tool should be undertaken.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
	EM4-All	EMERGENCY PREPAREDNESS	Local Flood Plan	Update local flood plans with the new flood intelligence, including identification and location of shelters for the community to take refuge during flood emergency and evacuation routes	NO	NO	YES	Local flood plan to be updated by SES with new flood data, including evacuation routes and Flood Emergency Response Classification of communities	YES
	EM5-All	EMERGENCY PREPAREDNESS	Community Awareness	<ul style="list-style-type: none"> - Community awareness about flood risk, including knowledge about areas flooded, evacuation route, emergency shelters, emergency communication etc. - Employ Community Flood Educator to review and implement flood education and messaging 	NO	NO	YES	<ul style="list-style-type: none"> - A comprehensive community education program to be prepared by SES in association with the Council. - Review and revise the Central Coast Flood Education Strategy to provide ongoing recommendations to develop early warning alert system that will enable timely messaging and evacuation and inform and provide flood information to the affected residences and the wider community. 	

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
								- A full review of the Draft Central Coast Flood Education Strategy be undertaken to provide a strategic direction for implementing and resourcing flood education.	
	EM6-All	EMERGENCY PREPAREDNESS	Business Awareness	Local businesses to be made aware of the flood risk including knowledge about areas flooded, damage to machinery/goods, evacuation route, emergency shelters, emergency communication etc.	NO	NO	YES	A Business Safe brochure to be prepared by the SES. Information sessions to be held for various business communities	YES
	EM7-All	EMERGENCY WARNING SYSTEM	Flood Markers	Provide flood depth markers at various locations in the study area. Information about the flood markers and their significance of use while driving should be included in the flood education of the community	NO	NO	YES	Locations of flood markers have been identified (Section 13.7). To be installed by the Council, in coordination with TfNSW.	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
				Flood Audit of the properties to assess flood resilience and identifying flood management measures at a local scale					
	EM8-All	EMERGENCY PREPAREDNESS	Flood Emergency Response Plan	<p>Several large developments in the study area are flood affected. These developments include aged care establishments and hospital. A site specific flood emergency response plan is required for these large developments.</p> <p>Flood emergency response plans to be prepared in conjunction with options EM5-All and EM6-All</p>	NO	NO	YES	The study recommends preparation of Flood Emergency Response Plan for large establishments such as aged care facilities and hospitals	YES

FMA	Option Identifier	Option Type	Name	Short Description / Preliminary Review	Identified/Recommended in previous study	Implemented	Further Investigation* (this Study)	Option Assessment (this Study)	Further consideration for the Management Plan (this Study)
	EM9-All	EMERGENCY PREPAREDNESS	Data Collection	<p>Field data to be collected after flood events to assist in improving the flood definition in the catchment</p> <p>Continue use of the existing telemetry system along with data collection after an event</p>	NO	NO	YES	<p>Council should set up a program to collect flood related field data after a significant flood event</p> <p>The existing telemetry systems should be maintained and data obtained from telemetry should be processed and archived.</p>	YES

Detailed assessment of these options is provided in Chapter 12, 13 and 14.

12 Flood Modification Options

Flood modification can be affected by undertaking works in the catchment. Several flood modification options based on the following types of works were identified for the study area.

- Flood Retarding Basin – FM1
- Levee – FM2
- Drainage Upgrade – FM3
- Provision/Enhancement of Culvert/Bridge – FM4
- Floodplain Filling – FM5
- Channel Works – FM6
- Maintaining Flood Storage – FM7
- Road Works – FM8
- Creek Clearance – FM9

A unique identifier has been used for each flood modification option. The identifier reflects the flood management area and the type of option as per the above list. For example, option C4/G-FM1 is a flood modification (FM) option in the C4/G flood management area. Identifier 1 suggests that this option relates to a flood retarding basin.

Flood modelling was undertaken to assess the impact of those options. The impact assessment indicates the potential for the option to mitigate the flood impact. Several options result in minor adverse impacts while providing significant benefits. The options recommended for adoption in this study would need further investigation at the detailed design stage, including investigation for local measures to remove this adverse impact.

The modelling results are various options are presented in the following sections.

12.1 Siletta Road Basin Upgrade (FM1-C4/B)

A significant catchment contributes runoff to upper Narara Creek near Niagara Park. A flood retarding basin has been constructed near Siletta Road. Increasing the capacity of the basin by raising the dam wall can potentially provide additional flood mitigation for areas downstream of Niagara Park.

The flood retarding basin upgrade was incorporated in the model and a model run was undertaken for the 1% AEP event. The impact of the basin is shown in Figure 30.

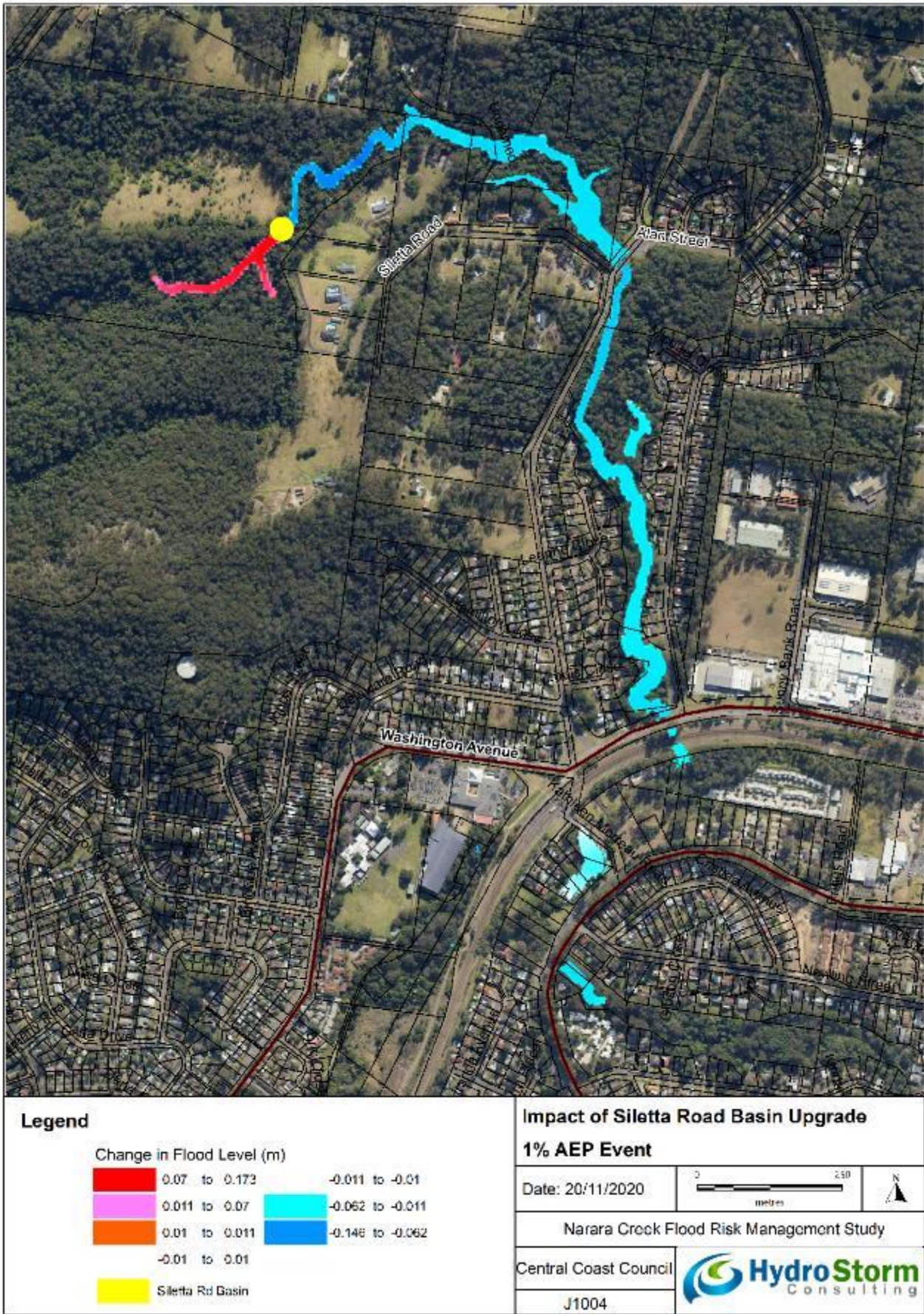


Figure 30. Impact of Siletta Road Basin (1% AEP Flood Event)

The results indicate that the beneficial impact of this option is limited to the in-bank flow or some rural properties downstream of the basin site.

This option was not further investigated due to limited potential for flood mitigation.

BOX 11.1 Siletta Road Basin Upgrade (FM1-C4/B)

Recommended for detailed assessment: NO

12.2 Levee at Northern End of Koninderie Parade (FM2.2-C4/B)

As discussed above, properties along Koninderie Parade are affected by flooding from Narara Creek. The creek overflow starts at the northern end of Koninderie Parade and occurs along the entire length of this road. The properties in this area are also affected by overland flow arriving from the catchment to the west.

Based on the above flood behaviour, a levee is proposed at the northern end of the Koninderie Parade to prevent overtopping at that location. Model run undertaken for the 1% AEP event shows beneficial impact as shown in Figure 31.

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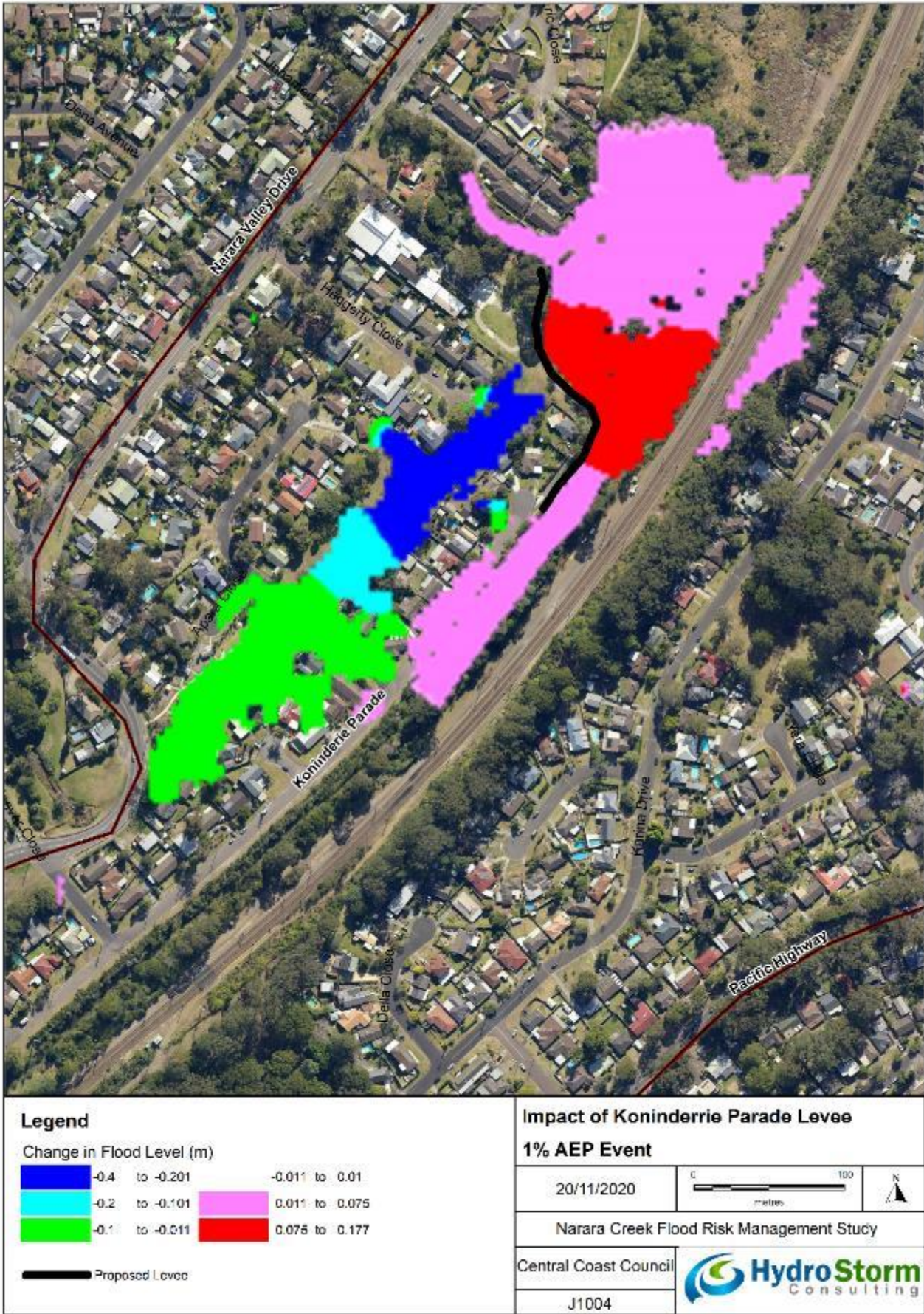


Figure 31. Impact of Koninderrie Parade Levee (1% AEP Flood Event)

This option results in lowering the flood levels by up to 0.4 m in the open space to the west of Koninderie Parade and up to 0.1m for some of the properties fronting Apará Close, Woorin Close and Willan Avenue.

There is also an increase of up to 0.18 m in the open space to the north of the Koninderie Parade. The land for this open space is owned by the Central Coast Council and is zoned RE1- Public Recreational, E2- Environmental Conservation and SP2- Infrastructure. The impact is contained within landuse that is not exposed to significant public risk and therefore any future development in this area can potentially occur while considering the higher flood levels due to this option.

BOX 11.2 Levee at Northern End of Koninderie Parade (FM2.2-C4/B)

Recommended for detailed assessment: YES

12.3 Narara Valley Drive Bridge Upgrade(FM4.2-C4/B)

The properties along Koninderie Parade are severely impacted by flooding from Narara Creek. An option to upgrade the Narara Valley Drive Bridge was identified by a previous study. This option was modelled for the 1% AEP event to assess the benefits of this option. Figure 32 shows the results of this option.

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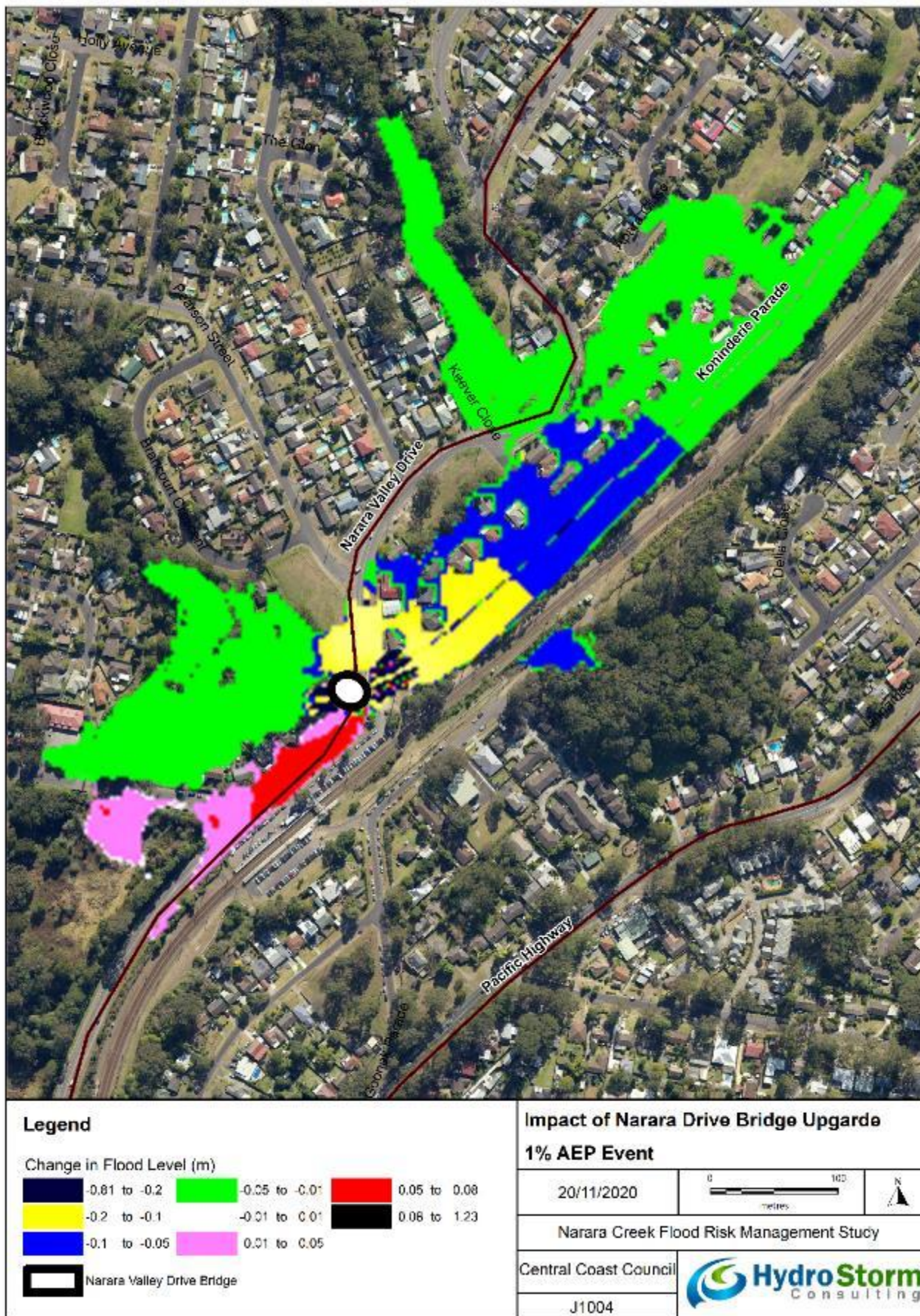


Figure 32. Impact of Narara Valley Drive Bridge Upgrade (1% AEP Flood Event)

This option reduces the flood levels from approximately 0.2 m near the bridge to 0.01 m further upstream to the limit of impact of this option.

There is a small increase in flood levels downstream of the bridge, along the railway. A net increase in the topography around the bridge due to a high road deck / weir forces some floodwater to that area. This is a minor impact and can potentially be managed at the stage of detailed design of the bridge.

The bridge not only provides greater capacity but also lowers the potential for debris blockage.

BOX 11.3 Narara Valley Drive Bridge Upgrade(FM4.2-C4/B)

Recommended for detailed assessment: YES

12.3.1 Combined Narara Valley Bridge and Koninderie Parade Levee Option

Both Narara Valley Drive Bridge upgrade and Koninderie Parade Levee options provide flood mitigation for the generally the same locality. Since the cost of providing Koninderie Parade levee is not likely to be significant, it can be combined with the upgrade of Narara Valley Drive Bridge. Figure 33 shows the combined benefit of the two options.

If the above option is not considered to be a viable management option, Voluntary Purchase of the properties should be considered in the longer term for managing the flood risk. As a short term solution, development controls, including provision of a safe refuge in place may be considered.

12.3.2 Provision of a flood detention basin upstream of Koninderie Parade Levee

The council owns the land u/s of the levee. An option was identified later in the study whereby this land can potentially be used as a detention basin to mitigate the adverse impact of this option in that area. This option is not fully assessed in this study but can be assessed at the implementation stage of the above combined option.

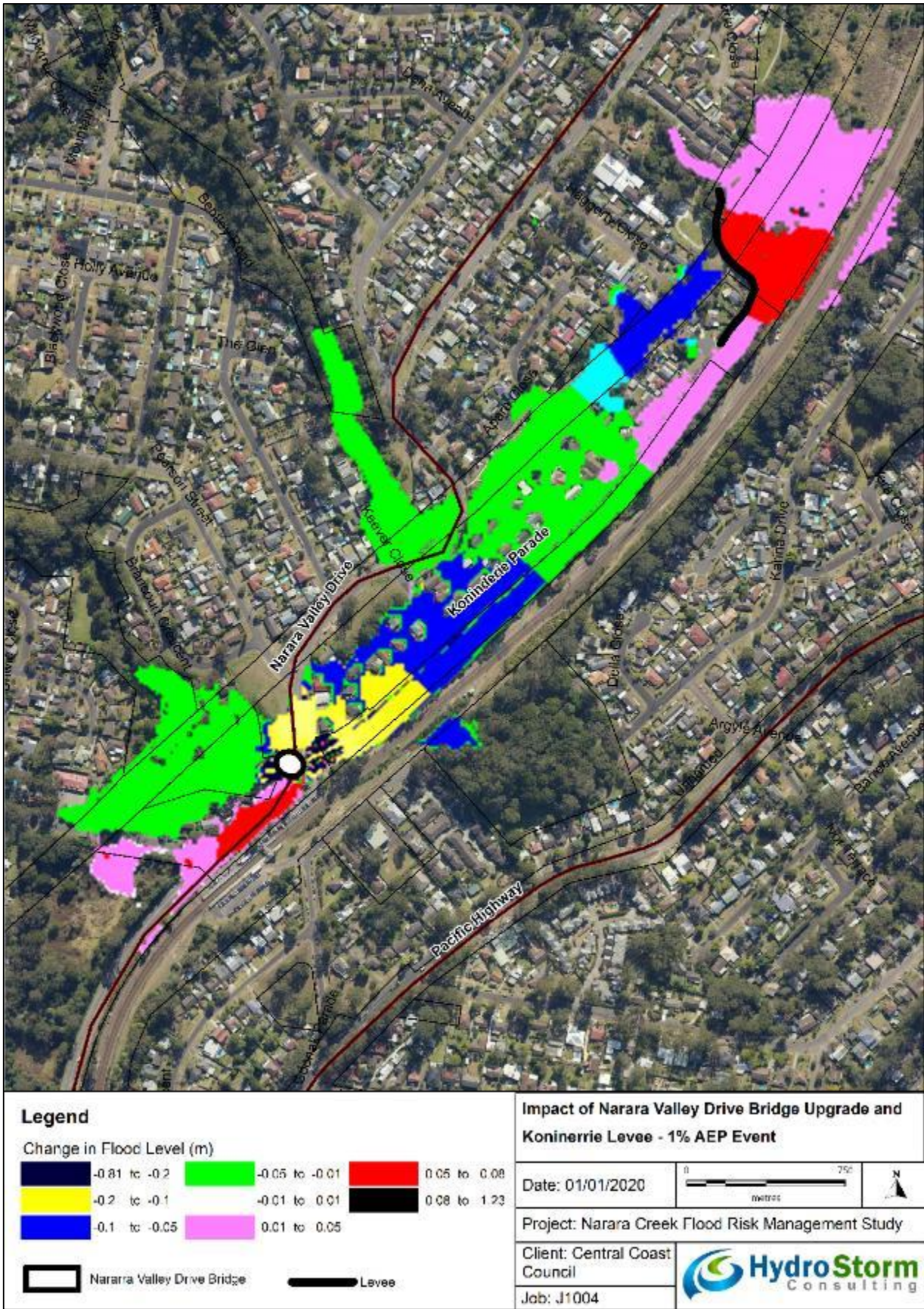


Figure 33. Combined Impact of Narara Valley Drive Bridge and Konindeferie Parade Levee (1% AEP Flood Event)

12.4 Brooks Avenue Detention Basin (FM1-C4/D)

The industrial area at Brooks Avenue is primarily affected from flooding from Narara Creek through an underpass under the Northern Railway. A study undertaken previously has recommended blockage of this underpass to reduce flooding of the industrial area from Narara Creek and provision of a levee along Wyoming Creek to prevent flooding from this creek. However, only the levee was constructed and one-way flood gates were installed to allow flow from industrial area into Wyoming Creek. The underpass is still present and currently used with a pedestrian/cycleway through the underpass.

Under this option, the underpass was blocked to create a flood retarding basin for the local catchment flows. The basin would store the floodwaters temporarily and discharge to Wyoming Creek under the existing levee through a one-way flood gate as discussed above. The option was modelled with 1% AEP flood event and the results are shown in Figure 34.

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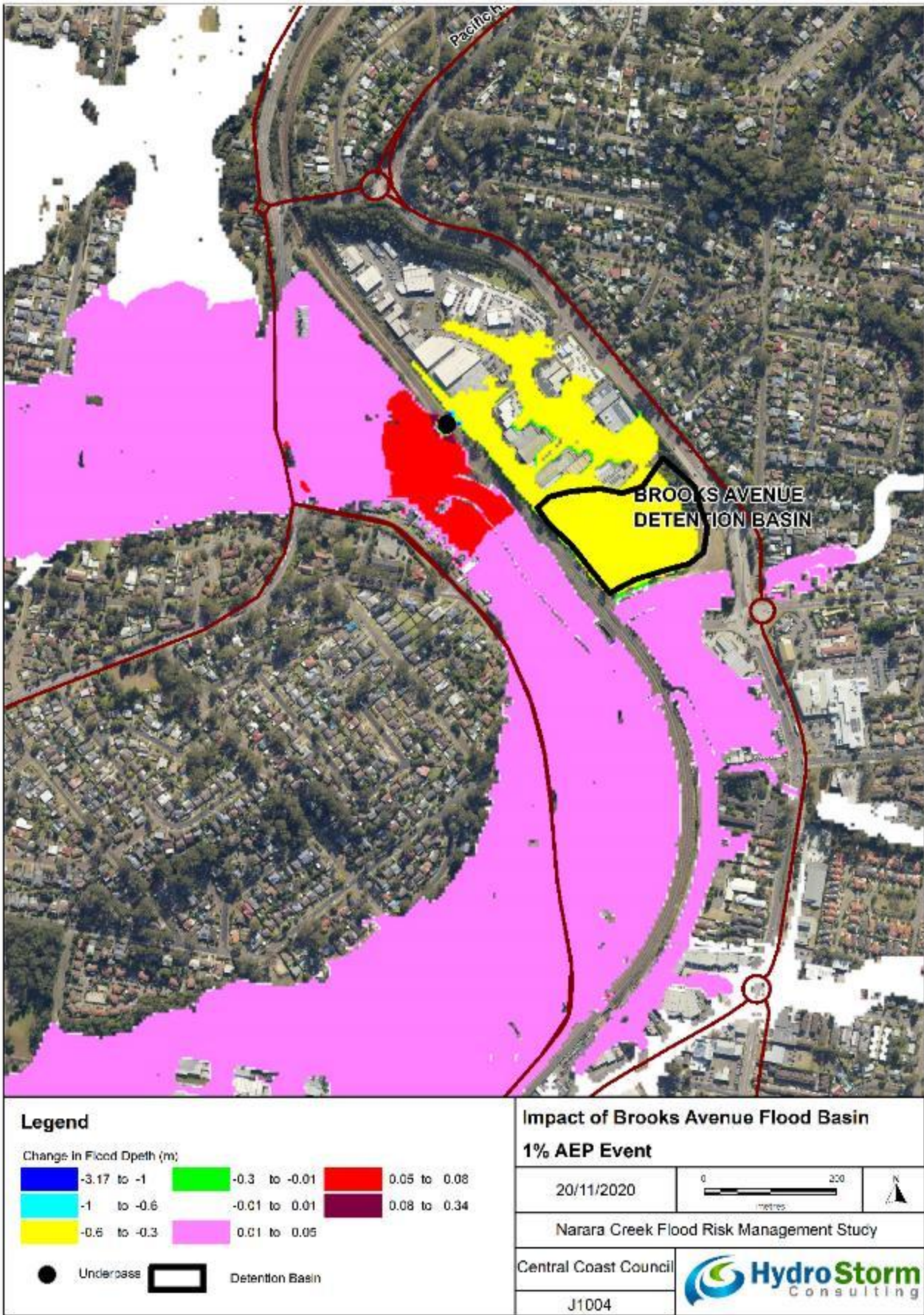


Figure 34. Impact of Brooks Avenue Detention Basin (1% AEP Flood Event)

The model results indicate that the 1% AEP flood levels would reduce by approximately 0.6 m in the industrial area. This is a significant reduction in flood levels and can potentially reduce damages to the properties in that area. However, there is an increase of up to 0.3 m in flood levels for several properties west of the underpass. The floor level of a few properties, which are currently above the 1% AEP flood, would be subject to above floor flooding under this option. In addition, the scouring potential in the backyard of these properties is likely to increase with this option. Further downstream, the flood levels increase up to 0.05 m along Narara Creek.

This option has the potential to reduce the flood risk in the Brooks Avenue Industrial area, however, a more detailed investigation is required where options to manage the adverse impact on the properties could be identified.

Since there is a significant benefit to the industrial area, other design flood events were also modelled for estimating the benefit/cost ratio.

Brooks Avenue detention basin flooding is regulated via floodgates, which open into Wyoming Creek. Regular maintenance of these flood gates is recommended for the expected flood mitigation benefit from the basin.

BOX 11.4 Brooks Avenue Detention Basin (FM1-C4/D)

Recommended for detailed assessment: YES

12.5 Caravan Park Filling (FM5-C4/D)

The caravan park in Wyoming on Pacific Highway is a popular lodging place. There is also an established business for the sale of caravans next to the park. The caravan park floods frequently along the western boundary and almost the entire park is flooded in a 1% AEP event.

The flood risk at the caravan park can potentially be managed by filling the caravan park to the 1% AEP flood level. The fill option was investigated, and initial modelling was undertaken for the 1% AEP design flood event. The impact of filling is shown in Figure 35.

The model results show that the filling of caravan park can provide benefit but the adjacent properties are affected, including impact on the railway. The property also has potential evacuation issues that would need to be addressed in any future development of the site.

This option is in a private land and therefore not suitable for Council to undertake works. Any future filling of the site should be accompanied by the assessment of cumulative impact of similar developments in the entire floodplain.

BOX 11.5 Caravan Park Filling (FM5-C4/D)

Recommended for detailed assessment: NO

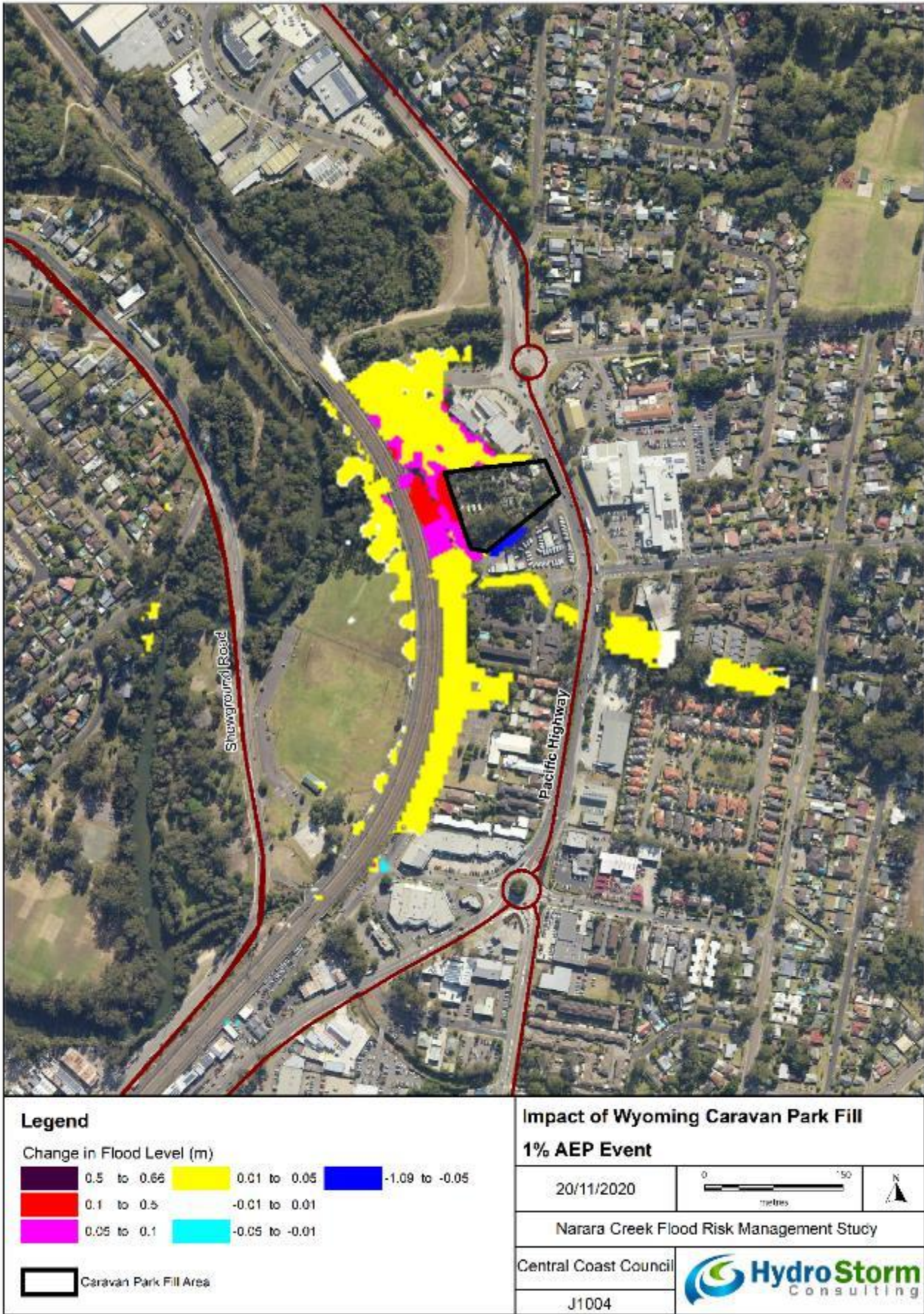


Figure 35. Impact of Caravan Park Filling (1% AEP Flood Event)

12.6 Tathra Street and Dell Street Basins (FM1.1-C4/G, FM1.2-C4/G & FM6.1-C4/G)

The West Gosford Industrial area is affected by flooding from runoff generated in the two local catchments to the west of this area. The two catchments contribute flow at the western end of Tathra Street and Dell Road. The local topography at these locations is such that a flood retarding basin can be provided for flood mitigation.

In addition, the creek that carries flow from Tathra Street to Narara Creek is overgrown and has limited flow capacity.

A flood mitigation consisting of flood retarding basins at Tathra Street and Dell Road along with improvement of creek conveyance (such as through RiverCare work that has been implemented in other creeks in the catchment) was modelled for the 1% AEP event. The improved conveyance of the creek was modelled by reducing the creek roughness. The impact of this option is shown in Figure 36.

The model results show only a minor improvement downstream of Tathra Street basin and no improvement downstream of Dell Road basin. Given the limited benefits, further investigations were not carried out into this option. However, option FM6.1-C4/G can be considered for implementation, since creek maintenance is likely to lower the flood levels locally, if the creek is cleared of excessive vegetation over its entire length, to the confluence with Narara Creek.

It is noted that the creek clearing activity in Tathra St aligns with areas of high biodiversity value, habitat areas for threatened species and predicts habits. Further investigation of this option requires consultation with appropriate Council teams on biodiversity impacts and receiving guidance on ensuring clearing is done in a sensitive manner.

BOX 11.6 Tathra Street and Dell Street Basins (FM1.1-C4/G, FM1.2-C4/G & FM6.1-C4/G)

Recommended for detailed assessment: NO

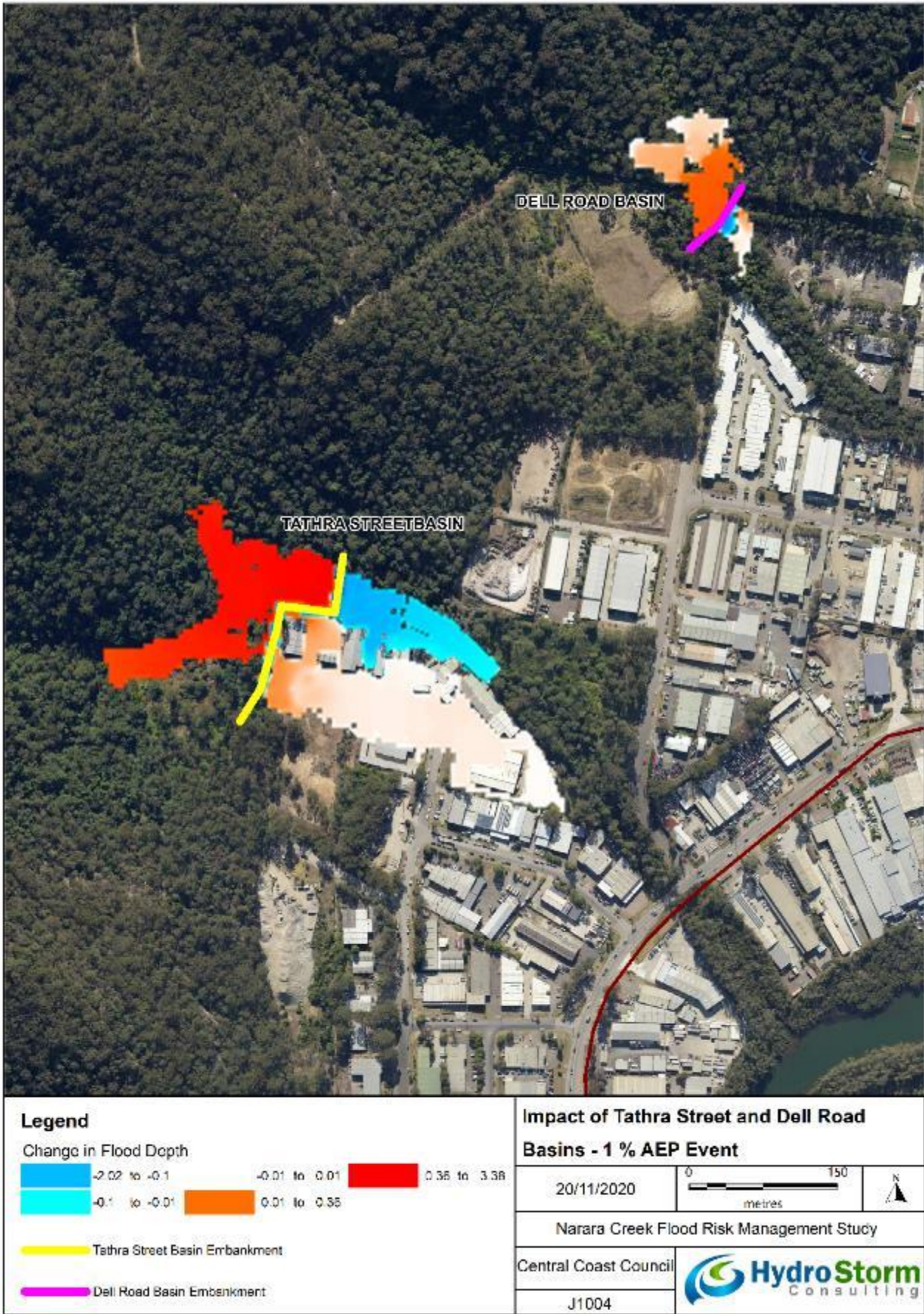


Figure 36. Impact of West Gosford Industrial Area Retarding Basins (1% AEP Flood Event)

12.7 West Gosford Industrial Area Fill Line (FM5-C4/G)

The West Gosford Industrial Area is a major economic hub within the Narara Creek catchment. In recent developments along Narara Creek, significant fill has been used to achieve the flood planning level. This option determines the impact of filling on the industrial properties along Narara Creek to prevent any future development from having any adverse impact on the surrounding properties.

The above option was modelled for the 1% AEP event. The impact of the option is shown in Figure 37.

The results indicate that the filling of the Narara Creek foreshore for industrial development would result in adverse impact on the existing industry to the west of Manns Road. This is due to the blockage of flow from west of Manns Road travelling to Narara Creek. It is recommended that future fill development in this area should allow for overland flow paths through the development to convey flow from west of Manns Road to Narara Creek.

12.7.1 Dell Road Levee

The area east of Dell Road intersection with Manns Road, near Narara Creek, is low lying and overbank flows at this location impact the West Gosford industrial area. A small levee at this location can potentially prevent this overbank flow. This option was identified as a corollary to the fill option and can be investigated further in the future.

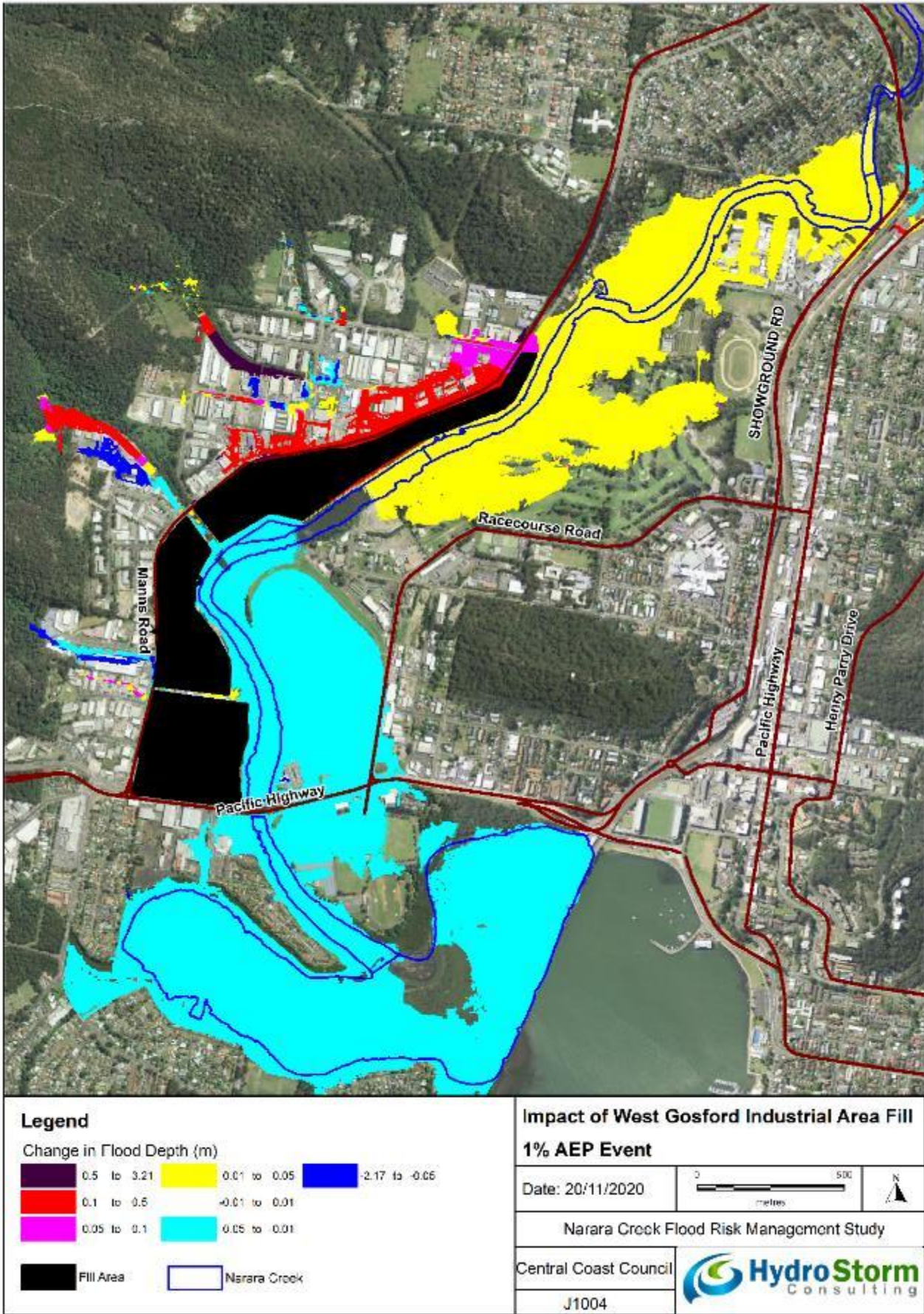


Figure 37. Impact of West Gosford Industrial Area Fill (1% AEP Flood Event)

12.8 Racecourse Flood Storage Area (FM2.4-C4/G)

The Racecourse in the lower catchment near the Central Coast Highway is an important storage area in major flood events. The 10% AEP event starts entering the racecourse and the 5% AEP event completely fills the racecourse. This area has been earmarked for future development including possible rezoning and hence the impact of flood storage on the proposed development needs to be considered. To facilitate this development, the floodwaters can be prevented from entering the racecourse from Narara Creek. However, this is likely to have a significant adverse impact on the surrounding properties. In addition, the flooding of the storage cannot be completely prevented as the runoff from the local catchment to the east can still enter the flood storage. The beneficial impact could be a reduction in flood levels along the Central Coast Highway.

To assess this option, a levee was modelled along the western boundary of the racecourse to prevent flooding from Narara Creek. Modelling was undertaken for the 1% AEP design flood event. The impact of the option is shown in Figure 38.

The model results indicate a significant adverse impact along Narara Creek, where a maximum increase of 0.36 m is likely to occur. The beneficial impact is within the racecourse where the flood levels can drop by a maximum of 0.55 m. This options also results in reducing flood levels on a small section of the Central Coast Highway by up to 0.4 m.

The modeling results also confirm previous Narara Creek FRMP that flood storage within the racecourse is important and any development should be considered very carefully to prevent any adverse impacts.

This option in its current form is not acceptable due to significant adverse impact. However, additional investigations can be carried out to refine this option such that the adverse impact of the option is reduced to an acceptable level. This may include relocating the levee within the racecourse to allow flow area for floodwaters along the western boundary of the racecourse.

Given the above analysis, this option was not considered further for the purpose of this study.

BOX 11.8 Racecourse Flood Storage Area (FM2.4-C4/G)

Recommended for detailed assessment: NO

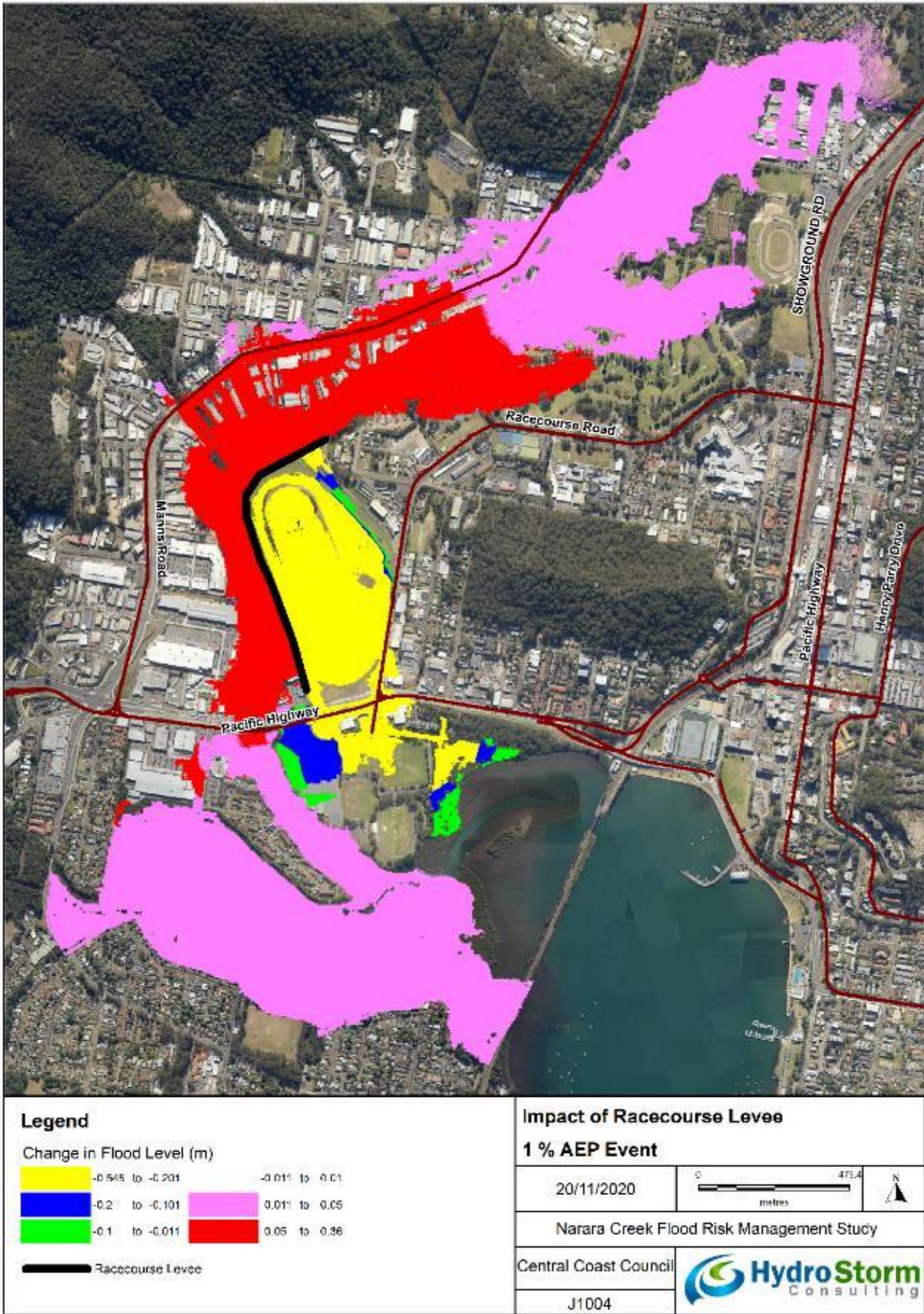


Figure 38. Impact of Racecourse Storage Area Removal (1% AEP Flood Event)

12.9 Central Coast Highway Raising (FM8-C4/G)

The Central Coast Highway is affected by flooding from Narara Creek, south of the racecourse and west of the Central Coast Highway Bridge on Narara Creek. For frequent events, up to 10% AEP, flooding of the highway is caused by the local catchment runoff and is limited to the intersection of Showground Road. For the 20% AEP event and greater the highway is flooded from the Narara Creek overflow through the racecourse area. An option was investigated to raise the level of the Central Coast Highway with provision of cross-drainage to reduce the depth of flooding on the highway.

The Coastal Highway was raised to 3 m AHD and a model run for the 1% AEP event undertaken. The impact of the option is shown in Figure 39.

The model results indicate that the Coastal Highway is not overtopped in a 1% AEP flood event. This is a significant improvement in flood behaviour as the Central Coast Highway can remain trafficable up to the 1% AEP event and consequently be part of an evacuation route during major flood events. However, the highway would be overtopped in a PMF.

The modelling also shows impact within the racecourse and along Narara Creek. More detailed investigation with cross-drainage is likely to remove this impact.

This option is to be undertaken by Transport for NSW (TfNSW). Further detailed assessment by TfNSW of raising of Central Coast Highway to mitigate flooding impacts to this primary transport route will be required.

BOX 11.9 Central Coast Highway Raising (FM8-C4/G)

Recommended for detailed assessment: YES

12.9.1 Flood Barrier along Central Coast Highway

A barrier with average height of 0.6 m and approximately 900 m in length can also be considered along the Central Coast Highway. This barrier would predominantly run along the edge of road reserve that continues around commercial development near Narara Creek. Whilst out of scope for this study, further detailed assessment of the feasibility of this flood barrier will be required with consideration of benefits and cost. The benefits would typically be for Adcock Park, with consideration of ongoing estuarine and tidal flooding impacts. The costs would include the capital cost and the potential catchment flooding impacts elsewhere.

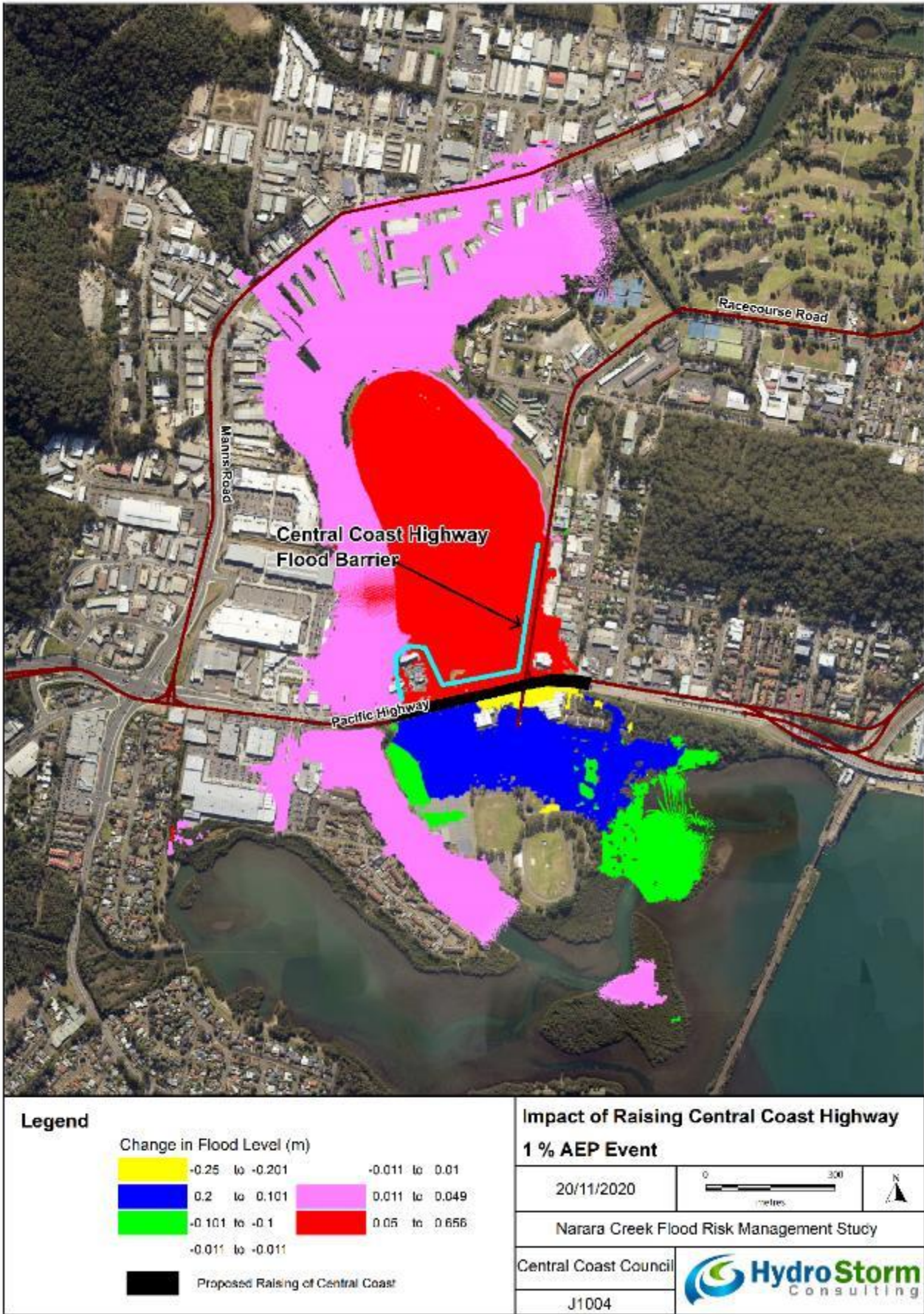


Figure 39. Impact of Raising Central Coast Highway (1% AEP Flood Event)

12.10 Creek Maintenance (FM9-ALL)

Overgrown vegetation in creeks can reduce the conveyance of floodwaters. The vegetation can also trap natural debris, resulting in degraded creek environment. Controlling creek vegetation in an ecological sensitive manner will enable a reduction of flood impact.

Creek Maintenance is critical for key areas such as Wyoming, Wingello and Bradys Gully. Council's management operational plans need to ensure creek maintenance is a permanent feature of the operational plan.

It is noted that the creek clearing activity may impact areas of high biodiversity value, habitat areas for threatened species and predict habitats. Consultation is required with appropriate Council teams on biodiversity impacts and guidance obtained for ensuring clearing is done in a sensitive manner.

12.11 Combined Option

The flood modification options have been assessed individually. If all of these options were implemented in the study area, the combined effect of these options can potentially have an unknown impact on the existing flood behaviour.

To assess the flood behaviour of combined options, a few options that provided significant benefits were assessed together. The combination of options included

- Koninderie Parade levee
- Narara Valley Drive bridge
- Brooks Avenue detention basin
- Raising of Central Coast Highway or the alternative flood barrier (Section 12.9.1)

Since all the above options have very localised impacts (beneficial and adverse), the combined effect of all these options does not have wider impacts over the study area. The above recommended options can therefore be implemented progressively without creating a catchment-wide impact.

The impact of the combined option on the 1% AEP existing flood is shown in Figure 40.

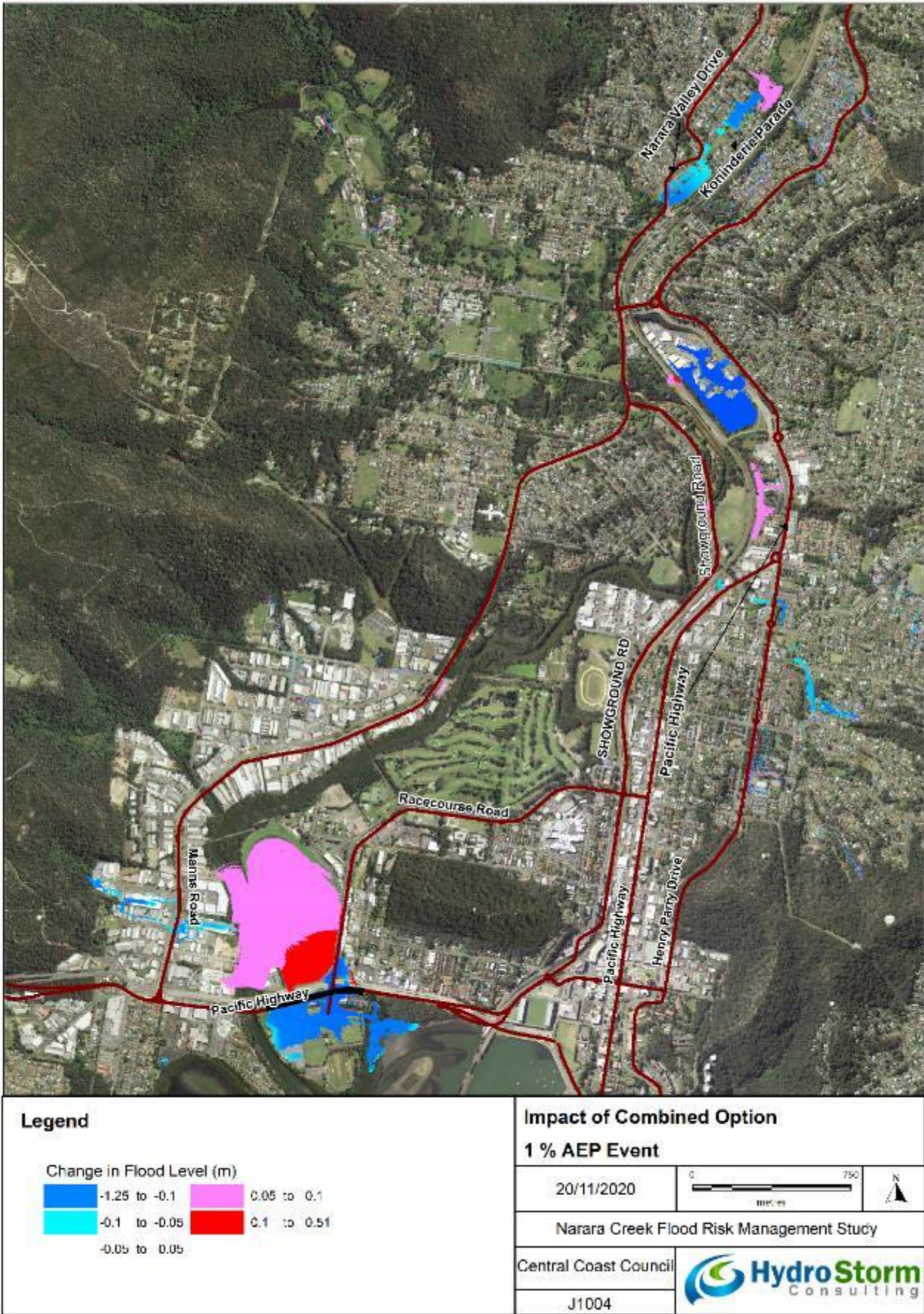


Figure 40. Impact of Super Option – 1% AEP Event

13 Property Modification Options

Several property modification options have been identified for the Narara Creek catchment. Some of these options are effective for the existing developments and others for the future development within the floodplain. The property modification options identified for the Narara Creek floodplain are:

- Planning and development controls (PM1)
- Voluntary Purchase (PM2)
- House Raising (PM3)
- Shelter in Place (PM4)
- Stormwater Drainage Upgrade (PM5)
- Management of Hazardous Material (PM6)

A discussion of each option is presented in the following sections.

13.1 Planning and Development Controls (PM1)

The Central Coast Council LEP (2022) clauses relevant to flood risk management are presented in Section 7.1 identifies the primary objectives to be achieved through flood risk management in the LGA. Based on these LEP clauses, the Council has developed a Development Control Plan (DCP) for managing flood risk in the LGA. The current DCP2022 provides several controls for flood risk management. A Flood Control Target Matrix is provided that specifies development controls for different types of developments. However, this matrix does not take into consideration the flood hazard associated with a particular development. Given the recent guidelines by Australian Rainfall and Runoff and Australian Institute of Disaster Reduction (Handbook 7 – Managing the Floodplain) and the Flood Prone Land Package planning guidelines by DCCEEW, the DCP can be improved for the following aspects related to flooding:

13.1.1 Planning Matrix

The LEP requires that the development needs to be compatible with the flood function of the site and will not adversely affect the safe occupation and efficient evacuation of people. A comprehensive planning matrix should be developed to account for the varying degree of flood risk in a floodplain. In this regard, the hazard categories H1-H6 can be utilised to define the flood planning precincts based on the level of flood risk. Within these precincts, various controls would be applicable to different types of developments. For example, a single residential development can potentially be subject to a different set of controls as compared to a childcare centre within the same flood planning precinct.

Based on the above criteria, a preliminary planning matrix has been prepared for review and further development. It is recommended that this preliminary planning matrix be further developed after review of flood risk in the other catchments and appropriate stakeholder consultation throughout the Council LGA. The preliminary planning matrix is presented in Appendix G.

13.1.2 Climate Change

The future climate can have a significant impact on the flooding behaviour in the study area. The flood study provides a detailed analysis of climate change impacts. The DCP can be improved by incorporating controls related to climate change.

It is also recommended that the continued revision and updating of these documents occur on an as-needed basis. A general review should be undertaken at least every five years.

The implementation of climate adaption planning will be through Place Based Climate Change Action Plans that include but are not limited to issues relevant to sea level rise planning and ongoing adaptation, coastal and floods management, disaster resilience, biodiversity conservation and emissions reduction.

13.1.3 Safe Refuge in Place

The effective flood warning time in the study area is generally insufficient for evacuation of the community during a flood emergency. The flood risk would significantly increase if the community self-evacuates without the assistance of SES. A safe refuge in place i.e. a flood-free place in a building on a property where the residents can move to during flood emergency, can potentially reduce the food risk. This is further discussed in Section 13.4, where the limitations of this flood risk management approach are also highlighted.

The Department of Planning, Housing and Infrastructure has recently released Shelter in Place guidelines. These guidelines should be used for the purpose of development control by the Council

13.1.4 Cumulative Impact

Continuous development in a catchment can have a significant impact on the flood behaviour. Developments in the upper reaches of the catchment which are outside the flood prone area, can potentially increase runoff by increasing the impervious area, thereby contributing to increase in the flood peaks.

The developments within the flood prone area can additionally alter the flood behaviour in a manner that is detrimental to the neighbouring environment. If these developments are allowed un-checked, a cumulative impact of such developments can have significant adverse impact in the flood prone area.

It is recommended that no filling be allowed without hydraulically equivalent compensatory cut and assessment of impacts. Filling individual sites in isolation, without consideration of the cumulative effects should not be permitted and any development that impacts land not in the immediate control of the developer is not approved. Filling should only be limited to areas categorized as Flood Fringe as filling of Flood Storage or Floodways are likely to have significant flood impacts.

In general, a cumulative development assessment should be undertaken by a developer, whereby the impact of similar developments in the entire floodplain is assessed. However, if it is demonstrated that the proposed development has nil impact in various design flood events, cumulative impact assessment is not required, since by definition, any number of developments with nil impact would not have any impact on the overall flood behaviour.

The impact assessment should be undertaken for the standard design flood events up to and including the PMF.

13.1.5 Hazardous Material Management

The study area has several industries that not only generate hazardous waste but are likely to store hazardous material on site. Figure 5 shows the location of the industries generating trade waste in the catchment. In a flood event, the hazardous material can be mobilised and introduced in the surrounding environment in an uncontrolled manner, potentially causing extensive environmental damage and creating public health risk. Appropriate management of these hazardous material is required to manage the risk to the environment and the community.

The LEP Clause 5.22, as discussed in Section 7.1, provides guidelines for managing the risk associated with trade waste industries. The Special Flood Consideration category for development control in these guidelines provides the recommendation to manage such facilities throughout the flood prone land (PMF extent) by specifying development controls for safe storage and discharge of hazardous materials. In this

regard, local measures such as bunding to exclude hazardous material storage areas would need to be included in the development controls. The flood planning level for such facilities could also be based on the PMF. Additionally, a site-specific flood management plan may be required for some of the hazardous industries.

13.2 Voluntary Purchase Program (PM2)

In high hazard areas of the floodplain an alternative to the construction of flood modification options is the use of voluntary purchase (VP) of flood affected properties. This option would free both residents and emergency service personnel from the hazard of future floods. This can be achieved by the purchase of properties and the removal/demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then need to be rezoned to flood compatible use, such as recreation or parkland or possibly redeveloped in a manner that is consistent with the flood hazard.

13.2.1 Guidelines for Voluntary Purchase

The Department of Climate Change, Energy, Environment and the Water (DCCEEW) has issued guidelines (2024) for voluntary purchase of properties that have been identified in the flood risk management plan for the study area. The guidelines specify that the properties being considered for VP should be located:

- Within high hazard areas where there is a significant risk to life for occupants and those who may have to evacuate or rescue them. However, a house in a location that is classed as high hazard on the basis of depth or provisional hazard alone would not be automatically eligible for VP. Hazard categorisation should be based on the true hazard assessment and consider a range of other factors that influence flood hazard as detailed in the Flood Risk Management Manual (2023).
- Within a floodway where the removal of the house may be part of a floodway clearance program. A floodway clearance program is aimed to reduce the impact of development on flood behaviour elsewhere in the floodplain and enable the floodway to more effectively perform its flow conveyance function.
- Within the footprint of a proposed flood mitigation measure or where a flood mitigation measure may result in a significant increase in flood risk to a house that cannot be protected. Eligibility will be considered as part of the detailed investigation and design for the works project. Funding the purchase of the property would be considered as part of the total works package which could include preconstruction activities.

Financial support for VP is provided only for the residential properties, which were constructed prior to 1986. Commercial or industrial properties are not supported by the VP scheme.

The proposed criteria to determine properties that are eligible for voluntary purchase includes:

- property located totally in the combined high hazard/floodway area for the 1% AEP flood.
- property access totally inundated by 1% AEP high hazard and/or floodway.
- occurrence of above floor flooding in the 5% AEP flood event, and
- economic value of damages is comparable to the property market value
- consider against other VP identified in other FRMP

Comparison against other VP options identified in various FRMP is an important criteria as the limited budget for undertaking this option would require prioritisation of all VP properties in the LGA. It is therefore recommended that an appropriate policy should be prepared and a VP register developed, ranking all VP in LGA against the above criteria or other additional criteria as deemed fit by the Council.

13.2.2 Interim Flood Risk Management

The VP option implementation is likely to be a long term process for the Council, primarily due to financial constraints. Since the properties identified for VP have a high risk of flooding, this risk in the interim period needs to be managed. Some of the options for managing the flood risk include:

- Safe refuge in place (discussed in Section 9.3.1)
- Habitable floor level above the PMF
- Structural enhancement of the property
- SES to have a register of VP properties, to act during the flood emergency
- A special notification issued to the resident of the property, highlighting the significant flood risk

A combination of the above options can also be used to manage the interim flood risk.

13.2.3 Potential VP Properties

Based on the above criteria, a preliminary investigation has identified several properties as potential for VP in Narara.

These properties are surrounded by hazard category H4 and H5 in a 1% AEP flood event. Both these hazard categories suggest that people and vehicles are unsafe in a 1% AEP event and hence evacuation is not feasible.

13.2.4 Koninderie Parade

The properties along Koninderie Parade are exposed to high flood risk in a major flood event. In a 1% AEP event, the hazard category is H5 and in a PMF event it becomes H6 (Figure 41) and the above-floor flooding is significant, ranging from 0.3m to 0.7m. The evacuation route for these properties is blocked during flooding and with the highest flood hazard category structural damage is also likely. The risk to life and property is therefore high.

Given the high level of flood risk for these properties, voluntary purchase is a potential option for flood risk management.

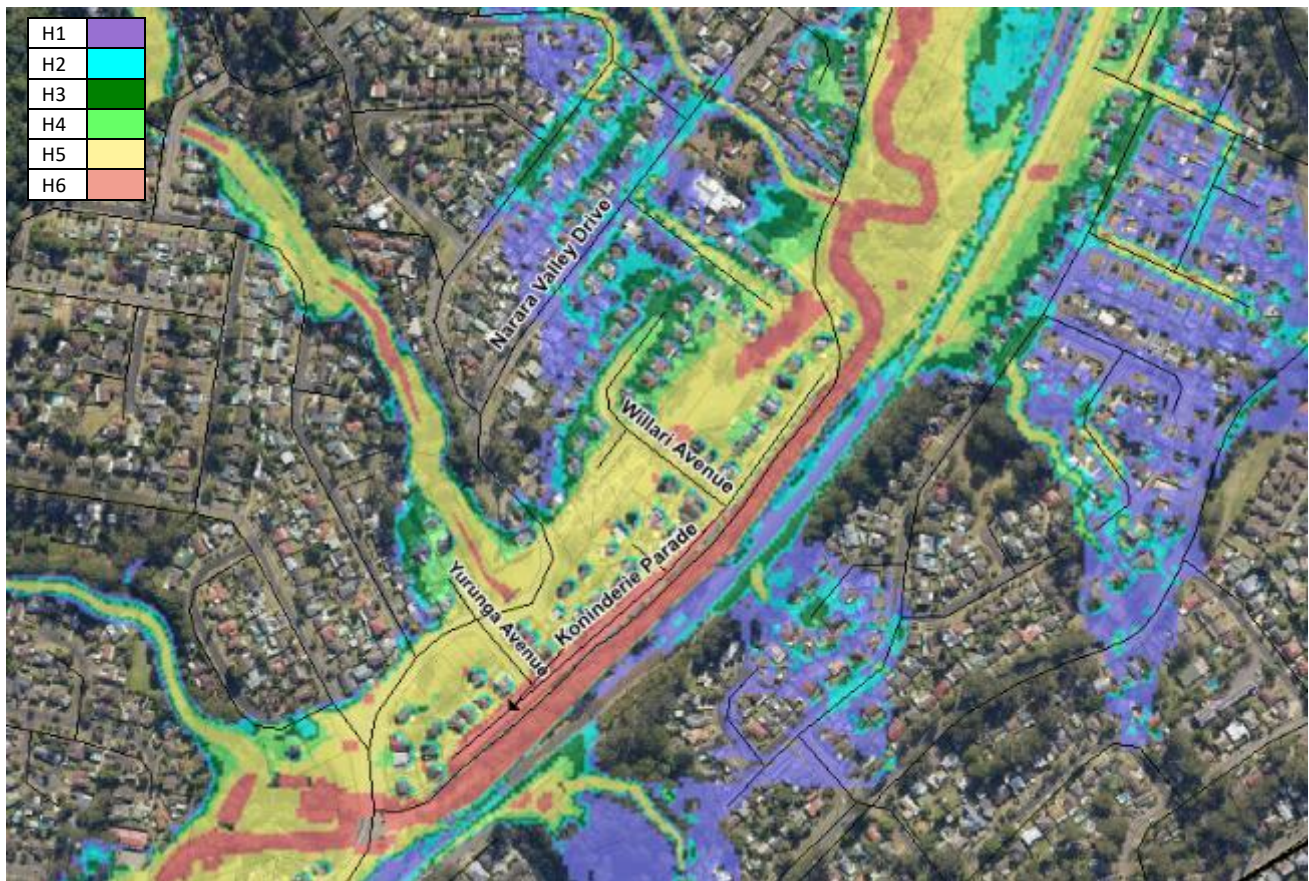


Figure 41. Koninderie Parade Flood Hazard - PMF

13.2.5 Summary for VP Option

A preliminary investigation has identified several properties as potential candidates for VP. Further investigation, including consultation with the owners and DCCEEW (for funding) is required to firm up the proposal for VP.

If mitigation measures (currently proposed or any identified in the future) result in reduction in flood risk for any of the above properties, they can be removed from the VP list after careful consideration.

13.2.6 LGA Wide Voluntary Purchase Program

The properties identified in this study for VP together with other properties throughout the LGA can be prioritized and a long-term program to buy these properties can be developed and implemented as the funding becomes available.

13.2.7 Previous Recommendation for Voluntary Purchase

In the Council meeting of 5 February 2002, the Lower Narara Creek Floodplain Management Plan(1993) was amended to include two properties in Narara in the Council's voluntary purchase program.

Review of current study data suggests that one of the properties would have an above floor flooding to a depth of 0.4m and the property would be subject to hazard category H4/H5 in a 1% AEP flood event.

The other property would have an above-floor flooding of 0.2m and would be subjected to H3/H4 hazard category.

Based on the above flood affectation of the property, these two properties can potentially be considered in a future Voluntary Purchase program.

13.2.8 Land Swap

An alternative to voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land in a non-flood prone area (e.g. an existing park) for the flood prone land with the appropriate transfer of park facilities to the acquired site. After voluntary purchase, the Council would then arrange for the demolition of the building and have the land rezoned to open space. The land swap approach may result in a significant saving on the land component of the voluntary purchase costs. However, it is understood that there are limited opportunities for land swap in the study area. If this option is pursued, the process is more involved compared to VP and would occur over a longer period.

13.3 House Raising Program (PM3)

There are more than 400 properties in the study area that are affected by above floor flooding in a 1% AEP event. House raising is a potential option to reduce the incidence of above floor flooding for at least some of these properties. In general, those properties for which the above floor flooding starts at more frequent events are considered suitable for the house raising option.

Whilst house raising is a potential option for flood risk management whereby the occurrence of flooding is reduced, there are several factors to be considered before such an option can be adopted. These factors include:

- only piered structures are considered suitable for house raising as cost of raising slab on ground structures is prohibitive or impractical
- only single storey structures are considered for house raising
- the potential for damage to items on a property other than the raised dwelling (such as gardens, sheds and their contents, garages, cars, etc.)
- unless a dwelling is raised above the level of the PMF, the potential for above floor flooding still exists (i.e. there will be a residual risk)
- evacuation may be required (e.g. medical emergency during a flood event) even if no above floor flooding occurs. This evacuation is likely to be hampered by floodwaters surrounding a property
- need to ensure the new footings and piers can withstand flood-related forces, house raising is generally only suitable for low hazard
- potential conflict with height restrictions imposed for a specific zone or locality within the local government area (for properties to be raised to a significant level, e.g. greater than 1m).

In summary, the following criteria were used to identify suitable properties for potential house raising:

- Pier on ground construction
- Single storey building
- Above floor flooding in frequent flood events (50% AEP)
- Not located in H3 hazard category or above (the building may sustain damage in a high hazard category)
- No evacuation issues

Considering the criterion of above-floor flooding, several properties were identified for house raising in the study area. These properties have been identified based on the information provided in the property survey. Further assessment would be required if this option is pursued by the Council. In addition, comparative assessment against other properties identified within the LGA would also be required for prioritisation purposes.

13.4 Shelter in Place (PM4)

In developed catchments, where alternative flood management options are not available, an appropriately designed property can be used as a shelter during a flood event. Such an option is only suitable where

evacuation is not possible due to lack of flood warning time due to 'flash' flooding nature of the catchment, such as the study catchment. The shelter in place option reduces the risk by preventing people from evacuating at the wrong time during a flood event, where they can get trapped or exposed to indeterminate flood hazard (hazard category H2 and above would make evacuation difficult).

This option should only be used where the existing development is replaced/modified with the same population density. The shelter in place structure should have suitable habitable floor area above the PMF level to provide refuge to the residents (Council has previously recommended 30 m² area for PMF refuge for a two-storey residential detached dwelling) and should be designed to withstand the forces associated with the PMF flow in and around the property, including inundation of the property.

It is noted that shelter in place should not be the leading solution for flood risk management as other suitable options for flood risk management should be considered before adoption of this option. This option has limitations as the occupants of the property may be without essential services such as water and electricity, and being isolated, may be denied access to emergency services such as medical evacuation. In addition, SES may have to provide additional resources to evacuate the occupants if any need arises.

This option, therefore, should be used as a last resort and should not be used for the new developments.

13.5 Stormwater Drainage Upgrade (PM5)

Several properties in the upper reaches of the catchment are affected by overland flow flooding. Detailed local drainage investigations are required as separate studies to identify solutions for overland flow management.

Overland flow flood studies for each individual FMA should be undertaken at a level of detail that will identify deficiencies in the stormwater network. A high definition flood modelling would be required for individual catchment management areas or for the entire study area. The future flood study should consider the latest version of AR&R. Review of the flood study should be undertaken every five years or when there is a significant changes in the contributing catchment.

13.6 Management of Hazardous Materials (PM6)

Hazardous waste industry can potentially result in environmental damage by releasing waste in a flood event. LEP Clause 5.22 provides guidelines for managing the risk associated with trade waste industries by specifying development controls for safe storage and discharge of hazardous materials.

Advice on managing hazardous materials can be included in development controls for the industrial areas in the catchment, including the West Gosford Industrial Area. Controls such as provision of bunding to prevent inflows from flooding in a 1% AEP event or as specified by the relevant authority, can be included in the development controls.

All trade waste industries to be included for the application of appropriate development controls. Detailed drainage investigations are required in future to identify the risk of inundation of the hazardous waste industry.

14 Emergency Response Modification Options

The objective of response modification options is to develop the ability of a flood affected community to respond effectively during a flood event. The response modification options also aim to enhance the capacity of emergency responders during a flood emergency. Options such as development of flood forecasting tools, creating flood awareness in public and preparing/updating flood emergency plans at a local level are required to create flood resilience.

The overarching document for flood emergency management is the NSW State Emergency Management Plan. This document provides guidance to a broad range of emergency management measures and should be used when considering planning measures. It also clearly establishes the role of the SES and the appropriate procedures for liaison with SES during an emergency.

Given the developed nature of the catchment, response modification options along with the property modification options are likely to play a primary role in managing the flood risk in the study area.

Several response modification options were identified for the study area and the following options are considered for the floodplain:

- Flood Evacuation Route (EM1)
- Emergency Warning Systems (EM2)
- Information Transfer to SES by Council (EM3)
- Revision of Central Coast Local Flood Plan by SES (a sub-plan of DISPLAN) (EM4)
- Public Awareness and Education by SES (FloodSafe brochure for local community, Schools Package for student awareness) (EM5)
- Business Awareness and Education by SES (EM6)
- Depth Markers at Major Road Crossings by SES (EM7)
- Flood Audit to Identify Vulnerable Properties (EM8)
- Flood Emergency Response Plan for Large Establishments (EM9)
- Data Collection Strategies (EM10)

14.1 Flood Evacuation Route (EM1)

The objective for flood evacuation is to manage the risk to life for the flood affected community. Evacuation is generally required during a flood event, however, in the event of large infrastructure damage, evacuation may be necessary even after a flood event, to shelter the community before the essential services and amenities are restored. Flood warning is critical in affecting any evacuation. Contrary to common perception, several hours of warning and preparation time is required to undertake an effective and orderly evacuation of a flood affected area.

The feasibility of evacuating a population from a flood prone area is generally established through the so-called Timeline Evacuation Model developed by the SES. This model is based on the principle of comparing the time required for evacuation with the time available for evacuation and can be represented as:

Surplus Time = Time Available – Time Required

Evacuation is only feasible if the time available is greater than the time required. The time available is generally from the time of sounding the warning to the time when the evacuation route is cut-off. The time required depends on several factors including

Warning Acceptance Factor – accounts for the delay between receiving an evacuation warning and acting upon it

Warning Lag Factor (WLF) – is an allowance for the time taken by occupants to prepare for evacuation

Travel Time (TT) – is defined as the number of hours taken for all of the evacuation vehicles to pass a point given the road capacity

Traffic Safety Factor (TSF) – is added to the travel time to account for any delays that occur along the evacuation route.

Consideration of above factors can amount to several hours of Time Required for evacuation. In the study area, the Time Required is very likely to exceed the Time Available for the entire catchment, which is likely to vary from several minutes to a few hours in various parts of the catchment.

Evacuation routes are required to be operational even in extreme flood events and therefore routes that are not affected in a PMF event are identified. However, in urban areas, where overland flooding is significant, identifying such a route is generally not possible. In the study area, no route is available that is flood-free in a PMF event. Despite this limitation, several routes have been identified that can potentially be used during a flood emergency in a large flood event. The SES should be made aware of this limitation of the identified flood evacuation routes.

Evacuation can be undertaken by the affected residents themselves or it can be facilitated by the SES. Where community is expected to self-evacuate, a clear flood-free route should be available either for pedestrian or traffic movement. Given the rapid rate of rise of floodwaters in the study area, vehicular evacuation is generally not feasible. The residents can potentially take shelter on higher ground as the duration of flooding is likely to be short. Evacuation to an area above the PMF level should be a major control for any future development in the study area. It is recommended that the evacuation issues be addressed for large developments including sub-divisions, rezoning, apartment buildings etc.

If evacuation is necessary such as due to medical reasons, SES would be called upon for this service. A dedicated flood evacuation route in the study area would assist SES for this purpose. Currently, work is underway to increase the flood warning time for flash flooding. The BOM is leading this effort and has created a knowledge database to assist Councils in developing a flood forecasting and warning system for catchments affected by flash flooding. If a flash flood warning system is established for the study area in future, dedicated evacuation routes would be required for orderly evacuation.

West Narara and Fountains Creek catchments are generally the most vulnerable areas with respect to flood evacuation. Several potential evacuation routes have been identified for these areas. These potential future evacuation routes may be feasible if upgrade works are undertaken.

14.1.1 Reeves Street Evacuation Route

The West Narara area has large flood affectation. Narara Valley High School (NVHS) access via Carrington St and Pandala Rd is frequently affected by flooding. School buses and parents driving to school have been observed to travel through flooded roads to transport students. This creates a significant risk to life which needs careful consideration and an effective solution.

A safe route for buses and a potential evacuation route for the local community is to travel west along Fountains Road which turns south at the fork with Research Rd, then onto Cross Street (not fully formed yet) and finally east along Reeves St, which leads to Manns Road. For this route to operate, Cross Street needs to

be formed and the causeway on Reeves St needs to be converted to a culvert/bridge crossing. In addition, the Reeves Street drainage would need upgrade at two other locations east of the causeway. This route is shown in Figure 42.

It is noted that this evacuation route is not flood free in all design flood events and would require significant road upgrades to be an effective flood evacuation route.

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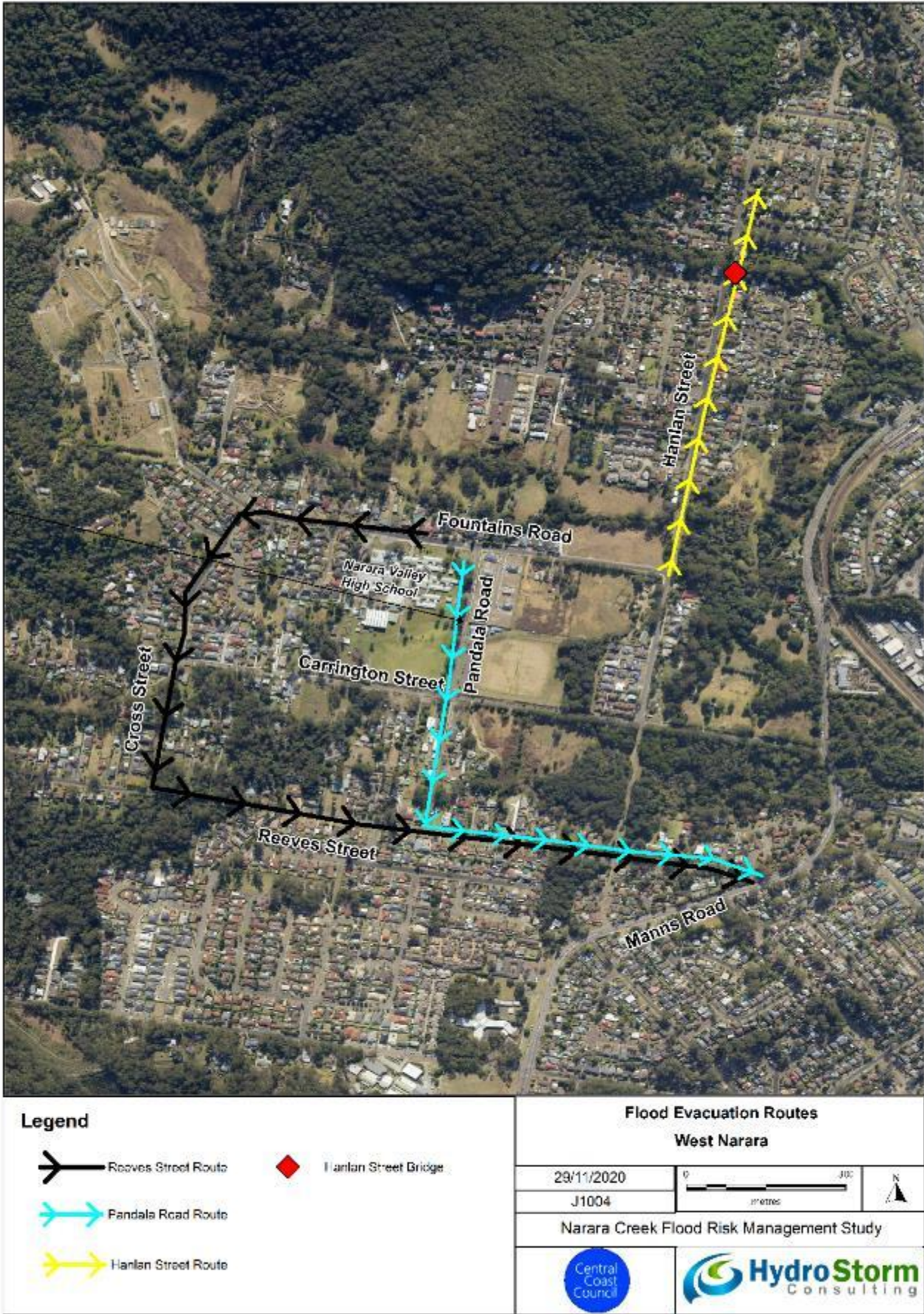


Figure 42. Potential Flood Evacuation Route for West Narara

14.1.2 Pandala Road Link Evacuation Route

The evacuation from the West Narara Creek catchment can occur through another potential route along Pandala Road, which would need to be extended beyond Carrington Street to Reeves Street, by acquiring two properties (Figure 42). This route was also proposed as part of the upgrade of Pacific Highway by Transport fNSW but met strong opposition from the local residents during the community consultation process.

Despite this opposition from the community, this route has the potential to provide flood evacuation, in particular for the Narara Valley High School.

It is noted that this evacuation route is not flood free in all design flood events and would require significant road upgrades to be an effective flood evacuation route.

14.1.3 Hanlan Street Evacuation Route

Currently, any evacuation by vehicle through Hanlan Street would travel south towards Carrington Street and then east along Carrington Street to Manns Road. This is however not feasible, given the high hazard flooding along this route. A possible route along Hanlan Street could be towards north where flood affectation is generally low hazard (Figure 42). This is currently not feasible because Hanlan Street does not provide vehicular access beyond Deane Street, where this street has only a pedestrian bridge connecting the two sides (currently closed). A vehicular bridge at this location would create a suitable evacuation route from the flood affected areas of West Narara Creek floodplain.

It is noted that this evacuation route is not flood free in all design flood events and would require significant road upgrades to be an effective flood evacuation route.

14.1.4 West Gosford Evacuation Route (Mann Street Alternate Route)

The industrial area of west Gosford is widely affected in a major flood event. Evacuation to Manns Road would be required from the local streets of the area for onward evacuation. The Dell Road exit to Manns Road is not feasible (unless flood modification option FM2.2 C4/G is implemented, see Table 16) as the Narara Creek overflows at this location, resulting in significant depth of flooding. The route shown in Figure 43 can potentially be used for evacuation for large flood events.

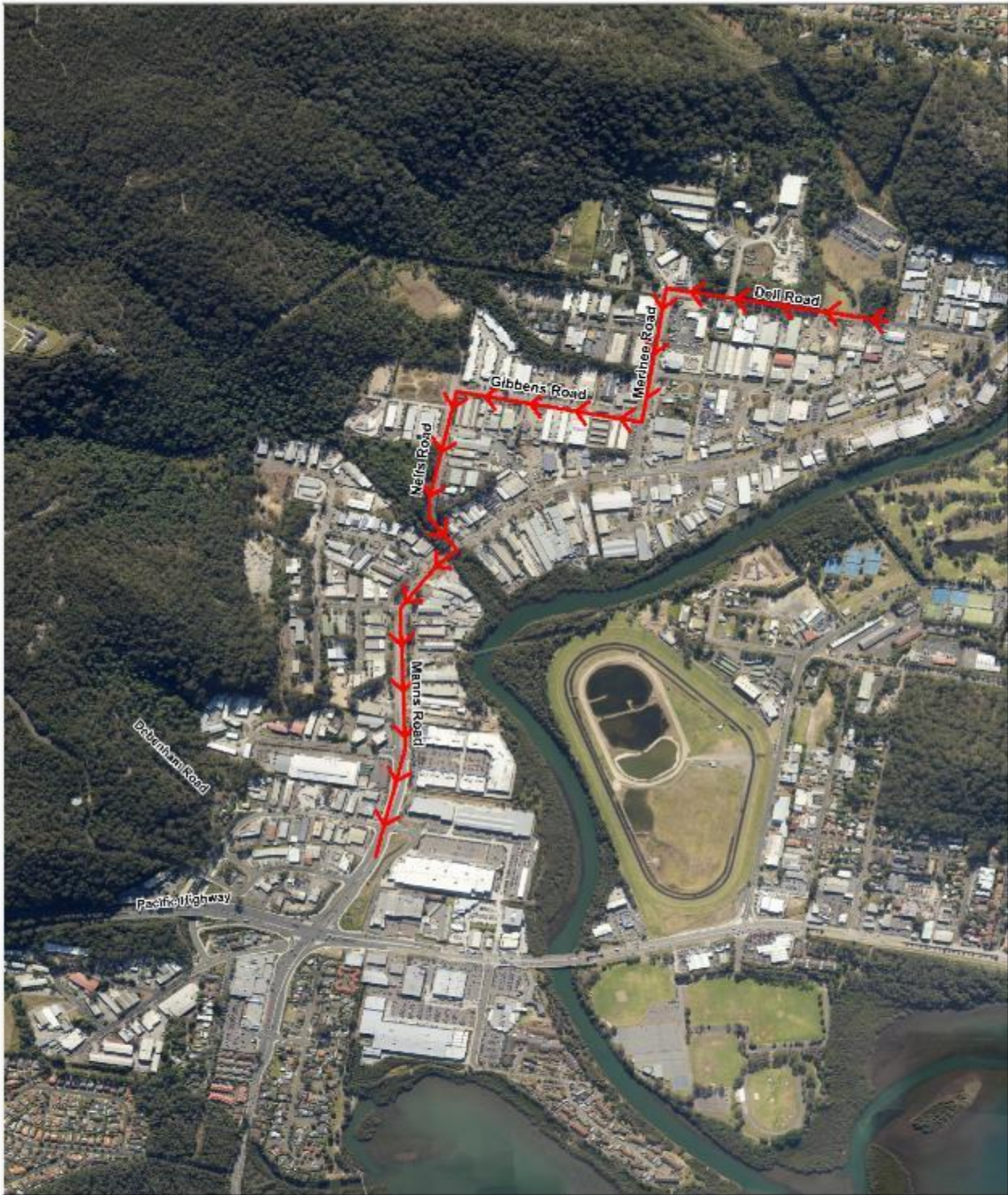
It is noted that this evacuation route is not flood free in all design flood events and would require significant road upgrades to be an effective flood evacuation route.

14.1.5 Mount Elliot Evacuation Route

The lower parts of the Wingello and Wyoming Creek are flood affected and evacuation from this area through road network towards the west and south may not be feasible due to significant flooding of those roads. The Maidenbrush Road heading east through Mount Elliot provides an opportunity for a flood evacuation route as shown in Figure 44. This route would join The Ridgeway that connects with Lisarow to the north.

It should be noted that this route is a dirt road that is generally severely rutted and hard to pass without a 4wd vehicle. Road works would need to be undertaken by the Council if this route is to be developed as an all-weather evacuation route.

It is noted that this evacuation route is not flood free in all design flood events and would require significant road upgrades to be an effective flood evacuation route.








Legend  Flood Evacuation Route	Dell Road Flood Evacuation Route West Gosford		
	29/11/2020		
	J1004	Narara Creek Flood Risk Management Study	
			

Figure 43. Potential Flood Evacuation Route for West Gosford

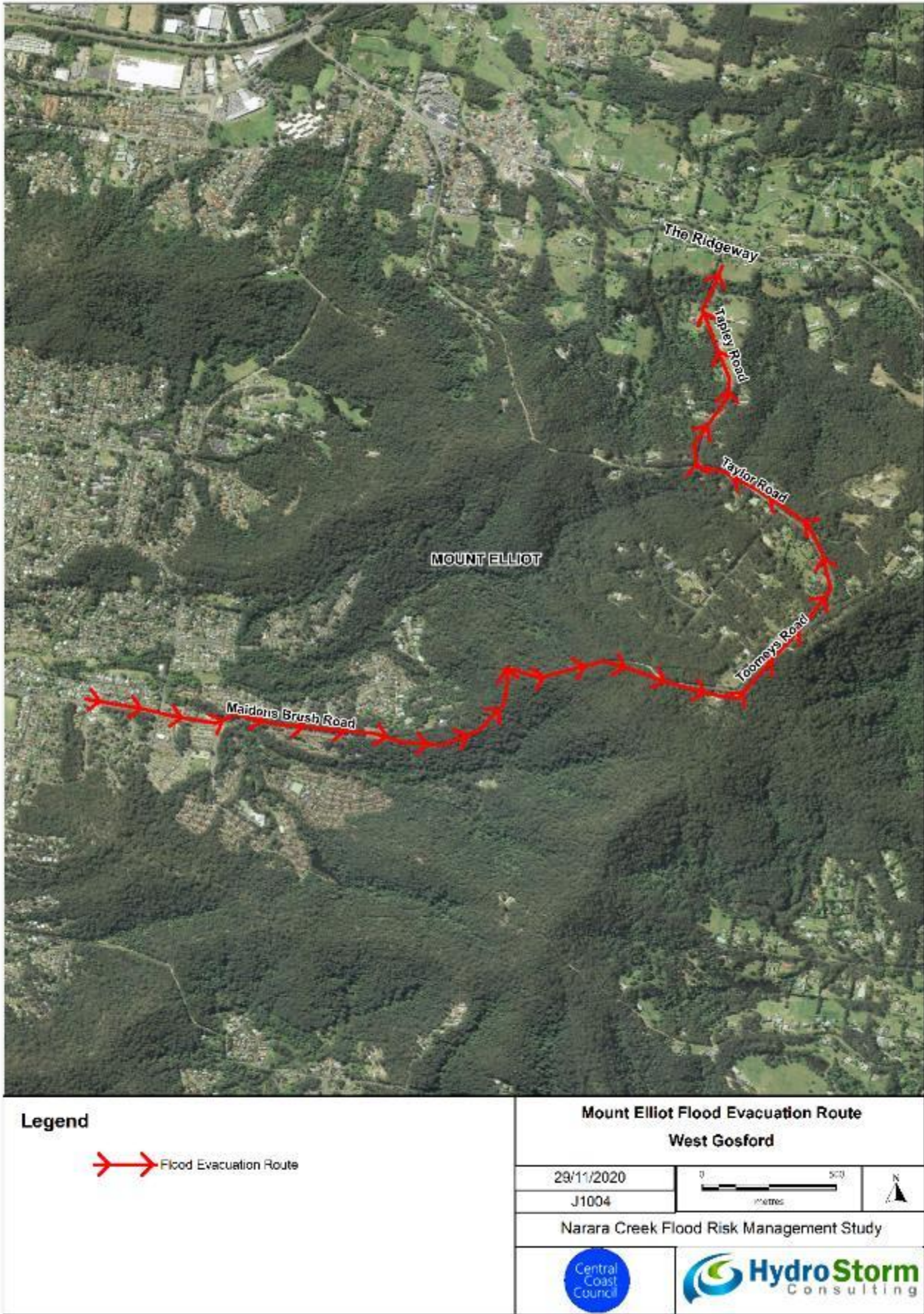


Figure 44. Potential Flood Evacuation Route for Wyoming

14.1.6 Development Assessment

Any large scale or sub-division development entails higher density of population with a corresponding increase in the flood risk. Along with other development controls, such developments should demonstrate a robust flood evacuation strategy to manage the risk to life. This would ensure that the emergency management resources can be utilised for managing the existing flood risk and additional resources are not required to service the community.

14.1.7 LGA Wide Evacuation Strategy

Considering flood evacuation in the study area in isolation from the rest of the LGA may not be an effective response, as concurrent flooding is likely in several catchments in the LGA during a major flood event. A comprehensive study for the entire LGA should be undertaken to establish evacuation routes that complement each other. In addition, the evacuation centres can be developed at suitable locations in the entire LGA.

14.2 Flood Emergency Warning Systems (EM2)

Installation of effective Flood Warning Systems (FWS) can play a significant role in managing the flood risk in the study area. A FWS has several component processes that need to be effective individually to produce an effective outcome. These components include flood monitoring and forecasting, interpretation of flood data, construction of flood warning message for the community, means of communicating the flood warning message, eliciting appropriate response from emergency management services (SES, police etc.) and review after the emergency period has passed.

One of the major issues highlighted in the 2011 Brisbane Floods was the effective communication of flood warning to the community. The Queensland Chief Scientist Report (QLD Govt., 2011) has highlighted this issue and provided the guidance presented in Figure 45.

	Informative	Accurate/trustworthiness	Timeliness	Audience reach	Varying audience capacities	Reliable/resilient	Little labour required	
Sirens/alarms	Works well for this aspect	Works well for this aspect	Works well for this aspect	Variable for this aspect	Works well for this aspect	Works well for this aspect	Works well for this aspect	<ul style="list-style-type: none"> Quick; reliable; limited information and reach, but becoming more versatile with voice and remote capabilities
Text message	Works well for this aspect	Works well for this aspect	Works well for this aspect	Variable for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Can reach wide audience very quickly; no power needed Less reliable for areas with poor mobile phone coverage
Automated telephone	Works well for this aspect	Works well for this aspect	Works well for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Landlines becoming less common; people often not at home/indoors
Radio message	Works well for this aspect	Limited use for this aspect	Works well for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Electricity not required; widest reach – home, work, travelling Variable accuracy; requires public to be listening
Television	Works well for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Electricity required; variable accuracy; limited reach; requires public to be listening
Websites/ social media	Works well for this aspect	Variable for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Quick dissemination; becoming very widespread; capacity for images Electricity/internet required; variable accuracy
Email	Works well for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Quick dissemination, but usually has to be actively accessed; power and telecommunication infrastructure needed; internet required
Speaker phone	Works well for this aspect	Works well for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Direct, specific communication Requires access to flooded area; difficult to hear
Doorknocking	Works well for this aspect	Works well for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Direct communication; chance to ask questions; high credibility Resource intensive; requires access to flooded area
Letterbox drop	Works well for this aspect	Works well for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Ability to reach almost all audiences, but may miss youth Slow; requires access to flooded area
Noticeboards	Works well for this aspect	Works well for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Useful for roads, infrastructure and location-specific information; can be controlled remotely
Print media	Works well for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Informative/detailed; ability to reach wide audience Time needed; variable accuracy
Word of mouth	Works well for this aspect	Variable for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	Limited use for this aspect	<ul style="list-style-type: none"> Uses info from multiple sources; persuasive Variable accuracy

Table 2. Pros and cons of different flood warning communication methods. Compiled by the Science, Engineering and Technology Panel.

Figure 45. Flood Warning Communication Methods (Queensland Chief Scientist Report, 2011)

Based on the Chief Scientist’s report, Sirens/alarms appear to be an effective mode of communication during a flood event. The limitation in terms of audience reach can be managed through appropriate design of these alarms, to ensure the sound of the alarm reaches the targeted audience. Other measures, such as text messages, use of radio/television etc. are also effective and can be adopted along with sirens/alarms.

Council had installed a siren based flood warning system at Roweena Rd, behind the basketball courts, on the bank of Narara Creek. This system is currently non-functional due to repeated vandalism and the associated maintenance costs. It consisted of a water level sensor and a siren. The siren works when the floodwaters reach the critical flood level, the sensor sends a signal to the siren, alerting the local community. This warning system should be reinstated and maintained by the Council.

Keeping in view the past use of siren based flood warning systems in the study area, three additional locations have been identified for this purpose. It is assumed that the sound from these sirens would provide appropriate coverage within the study area. The location of the proposed sirens is shown in Figure 46.

The Council completed a Storm and Flood Forecasting Study (MHL, 2017) for the southern parts of the Council (previously Gosford City Council LGA). As part of this study a Flood Intelligence Tool (FIT) has been developed for use in the LGA. This is a comprehensive tool which provides flood forecasting and emergency warning capabilities to the SES and the Council.

The Council currently provides an SMS message service to residents who live on a low flood island around Tuggerah Street Lisarow. The only evacuation route for these residents is cut in frequent events and decision making is critical at the beginning of the storm event. This system could potentially work effectively within the Narara Creek Catchment provided that it is regularly tested and maintained annually.

While flood warning messaging is a key element in effective communication, maintenance of stream gauges and telemetry is critical in providing a higher level of service. Allocating the annual budget within Council's operation plan will ensure gauges function prior, during and after the storm events.

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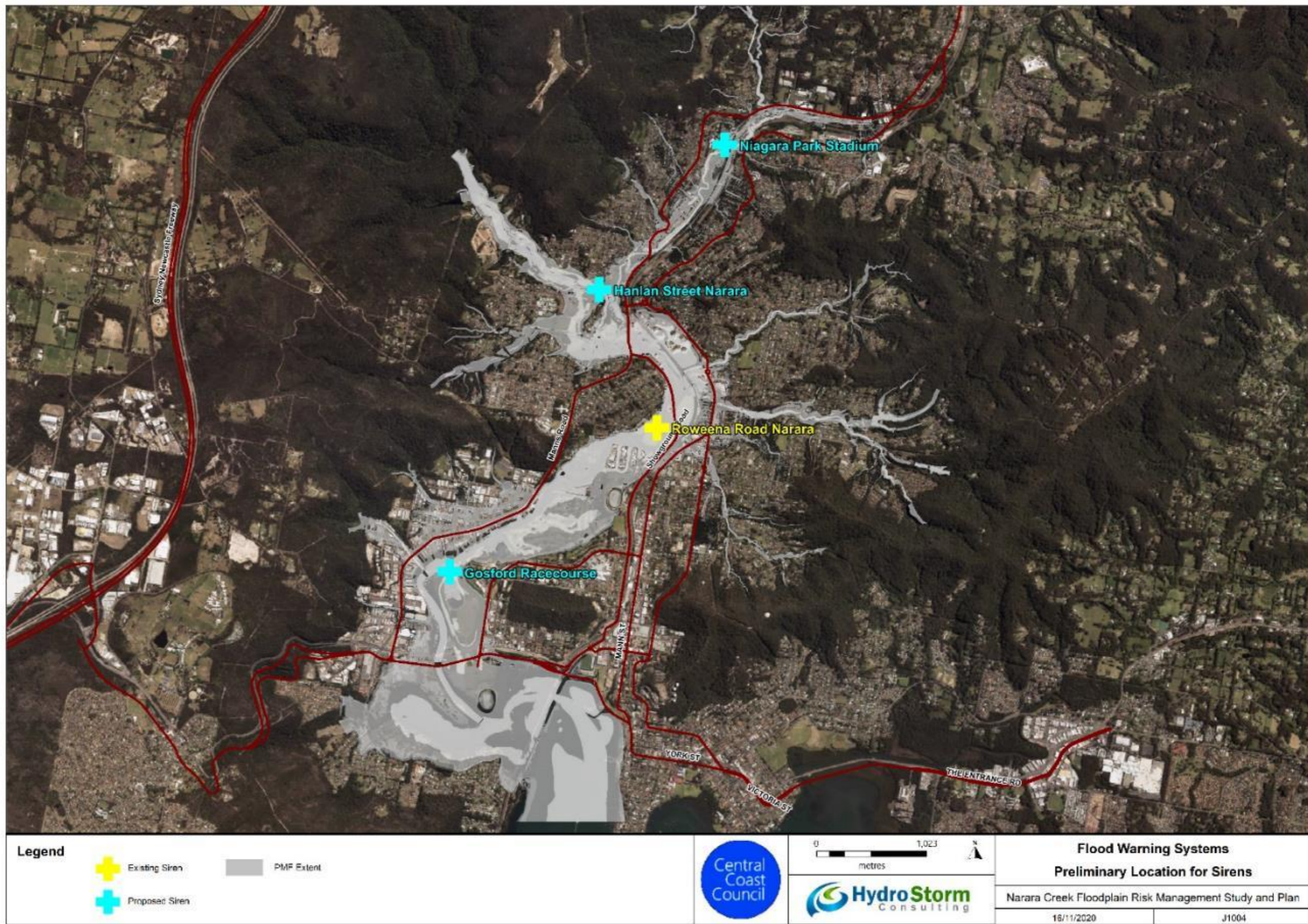


Figure 46. Flood Warning System – Potential Location of Flood Sirens

14.3 Information Transfer to SES by Council (EM3)

The findings of the flood study provide critical data source for the State Emergency Service. Information could be provided from the findings of the flood study in two forms:

- Electronic information (flood extent mapping and flood hazard mapping in geographic information system format).
- Laminated flood intelligence maps (hard copies of flood extent and hazard mapping) in laminated plan format for use in the operations centre to assist with directing teams to the most likely affected localities. This can also help to overcome any issues associated with power loss or difficulty with accessing information in an emergency.
- Upload all data to the SES flood data portal
- Training of Local SES Unit in the use of the Narara Catchment Flood Intelligence Tool (MHLFIT)

It is envisaged that all relevant flood study data, including flood maps and Flood Emergency response Classifications, would be provided to SES in an electronic format by the Council. It is recommended that the SES update its flood intelligence for the Narara Creek catchment.

14.4 Revision of Local Flood Plan by SES (EM4)

Based on the flood study data, the Local Flood Plan can be updated by the SES. In this regard, the list of evacuation centres needs to be updated as discussed in Section 9.

The flood study data can also provide guidance for evacuation routes that can be used during a flood emergency. A preliminary assessment suggests that several evacuation routes may be suitable within the catchment. Additional investigations along with the data provided in this study can be used to establish flood evacuation routes with appropriate road signage. This information can be shared with the local Police for assistance during flood evacuation.

14.5 Public Awareness and Education by Council and SES (EM5)

Flood awareness is an essential element of flood risk management for people residing in a floodplain. The affected community must be made aware, and need to remain aware, of their role in the overall floodplain management strategy for their area. This includes the defence of their property and their own evacuation if required. Given the short duration of flooding and the hazardous nature of a number of roads within the area, residents can potentially be encouraged to seek refuge via vertical evacuation, where possible.

Flood awareness is an ongoing issue and requires continuous effort of related organisations (e.g. Council and SES). The major factor determining the degree of awareness within the community is the frequency of moderate to large floods in the recent history of the area. The more recent and frequent the flooding, the greater the awareness. Maintaining an adequate level of flood awareness during the extended periods when flooding does not occur is a challenge for effective flood emergency planning.

A continuous awareness program needs to be enforced to ensure new residents are informed, the level of awareness within long-term residents is maintained, and to cater for changing circumstances of flood behaviour and new developments. An effective awareness program requires ongoing commitment.

The education campaign should be run every year and an appropriate budget should be allocated for this purpose. In the interim, as a minimum, following awareness campaigns may be considered for the floodplain:

- Information packages to be included in Council rates notices for all affected properties on a regular basis
- Development of a Schools Package from existing materials developed by the SES and distribution to the local schools

In addition, the meeting of local Community groups could be used to arrange flood awareness programs at regular intervals.

SES has prepared a general FloodSafe brochure, which is an effective means of ensuring that the community is able to access necessary information. This brochure is available on the SES website (www.ses.nsw.gov.au). Both SES and Council can promote this brochure and encourage the residents to review it for their safety. In addition, education initiatives by the Council would provide ongoing recommendations for all the LGA including;

- Development of early warning alert system that will enable timely messaging and evacuation
- Enable earlier shutdown of the vulnerable assets, such as sewer mains and/or sewer pump mains and prevent health hazard during flood events
- Inform and provide flood information to the affected residences and the wider community
- VMS messaging through TfNSW for major flood affected roads
- Training SES Volunteers in the application of MHLFIT Tool and predictive flood capabilities
- Annual Flood Warning Drill and maintenance of sirens

In addition, the following resources can be useful for the community

- *Hazards Near Me* application (app) developed by NSW Government
- *Floods Near Me* phone application (App) developed by MHL
- Flood Ready Guide by SES (currently under preparation)

Services to provide early warning systems for the public are increasingly becoming available through private businesses. Tailored flood warnings can be delivered to the public directly through smart phones, which can be particularly useful for the study area where the flood warning times are short. The Council along with SES can further investigate this option.

Another opportunity for community education is via the flood certificates (Section 10.7 certificates) issued by the Council. A flyer about flood risk management with general measures for managing the risk can be included with the flood certificate.

To facilitate community education and SES operations, vulnerable facilities and infrastructure along with the flood hazard (category H1 to H6) for the 1% AEP flood event in the study area is shown in Figure 47, Figure 48, Figure 49 and Figure 50 for the northern, eastern, western and the lower catchment.

A list of these facilities and infrastructure is provided in Appendix H.

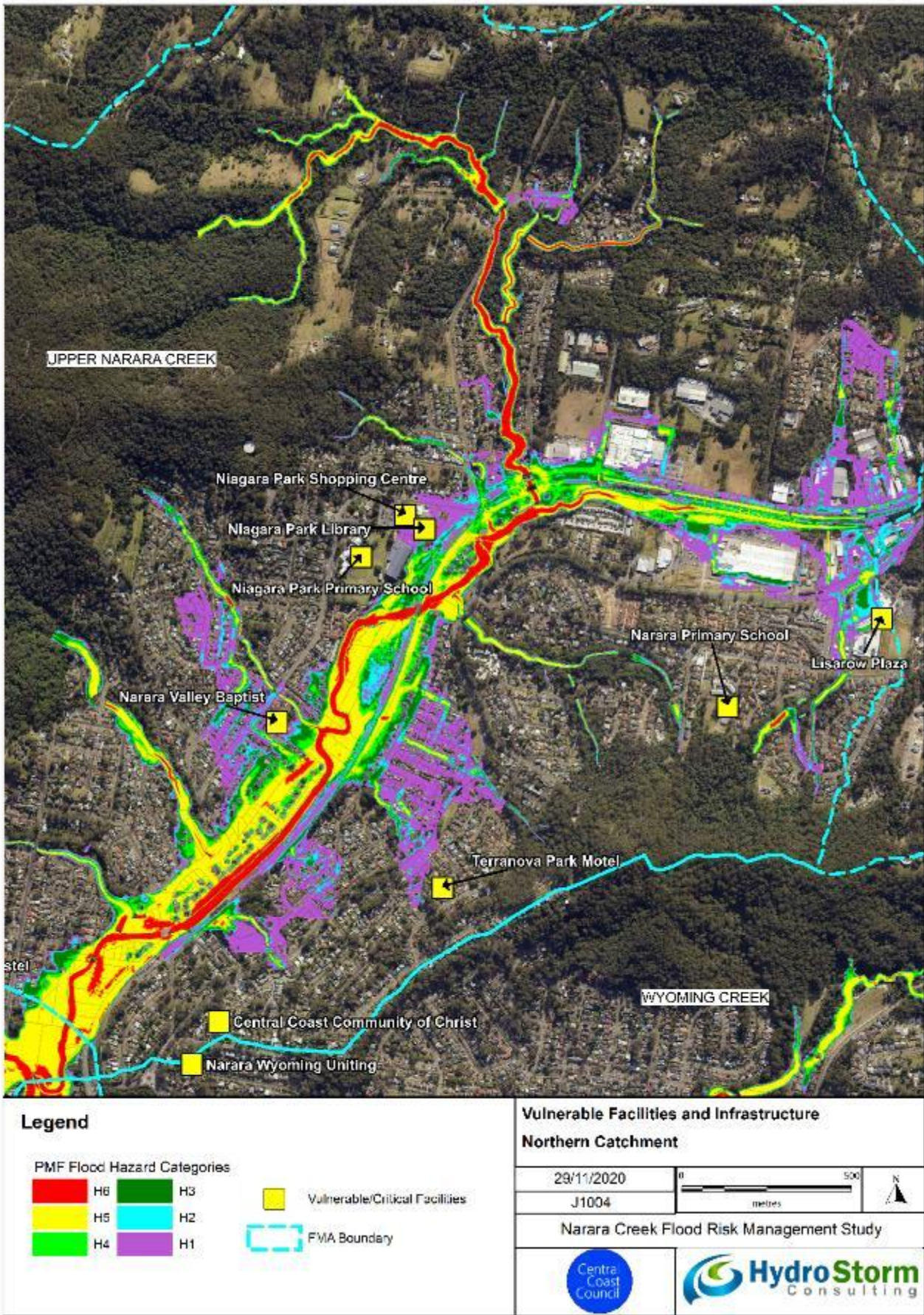


Figure 47. Vulnerable Facilities and Infrastructure – Northern Catchment

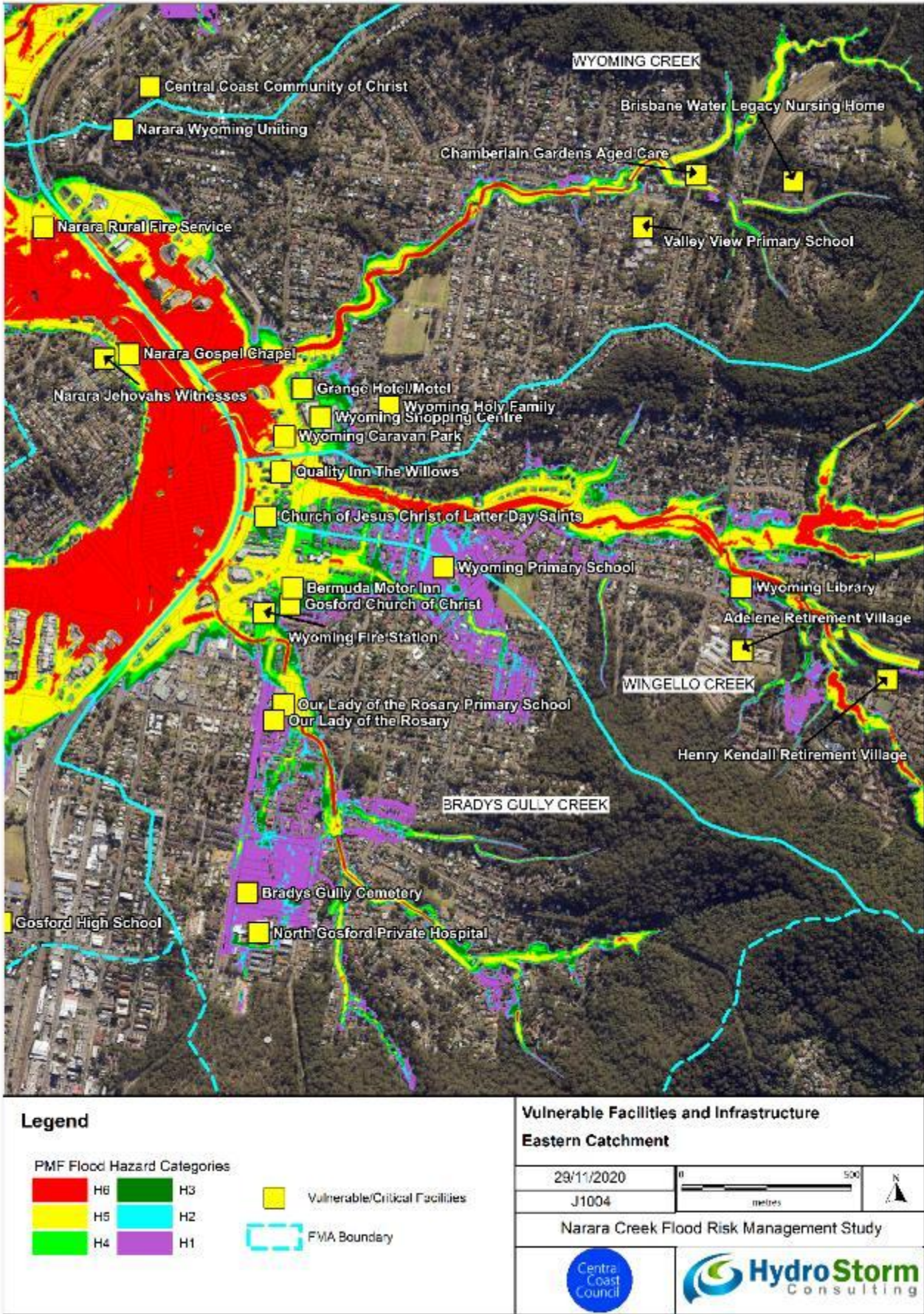


Figure 48. Vulnerable Facilities and Infrastructure – Eastern Catchment

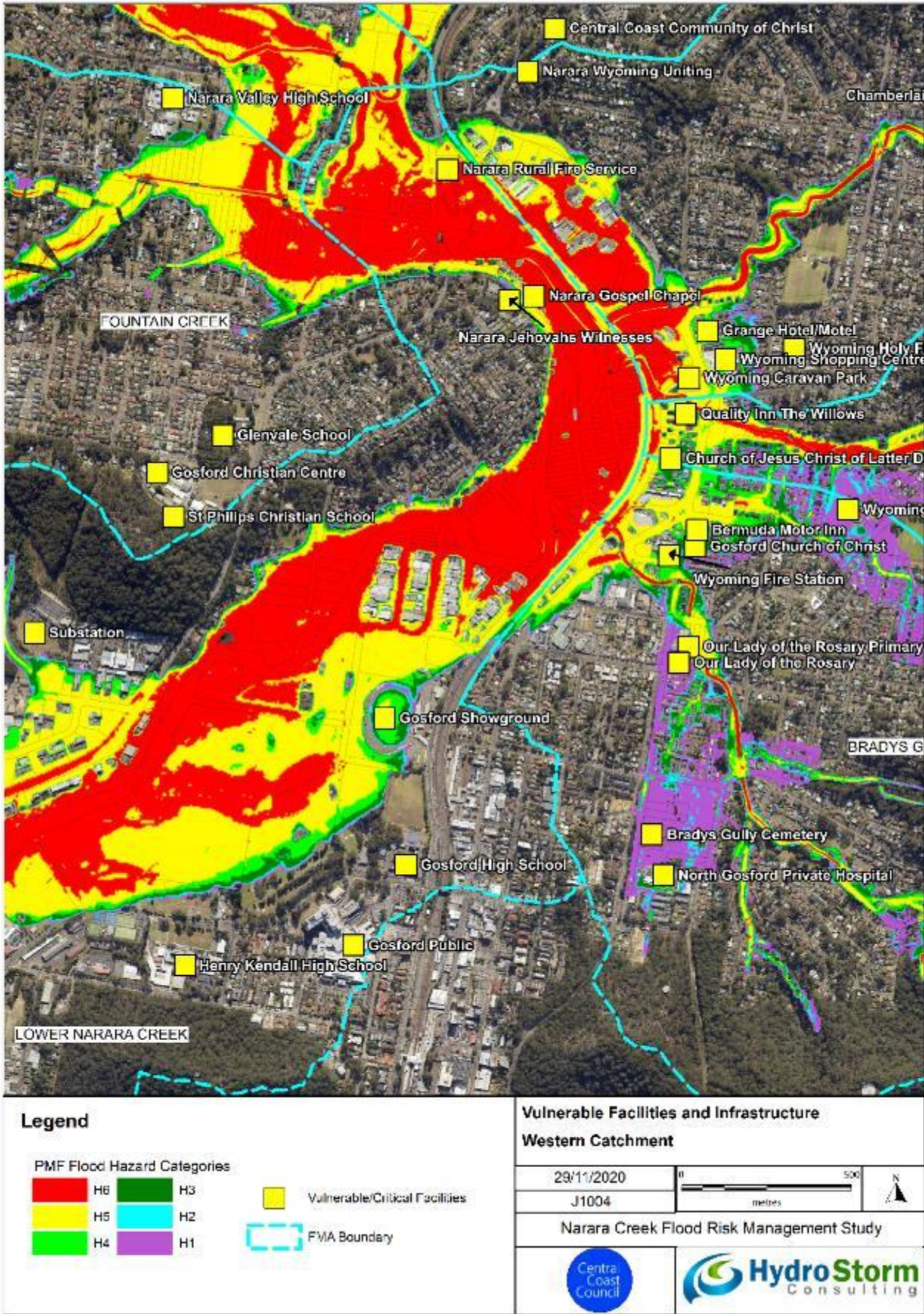


Figure 49. Vulnerable Facilities and Infrastructure – Western Catchment

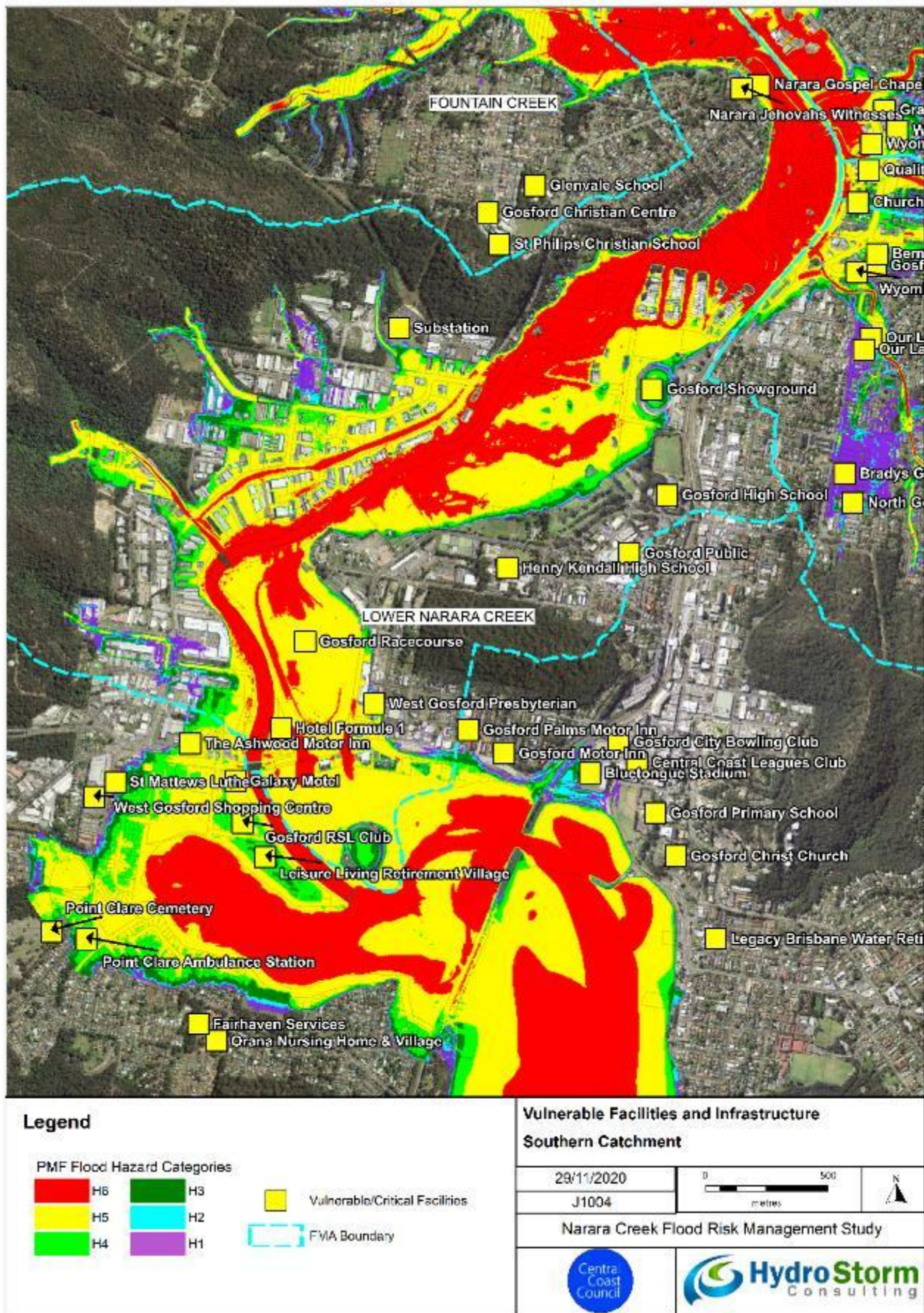


Figure 50. Vulnerable Facilities and Infrastructure – Lower Catchment

14.6 Business Awareness and Education by SES (EM6)

Local businesses to be made aware of the flood risk including knowledge about flooded areas, damage to machinery/goods, evacuation route, emergency shelters, emergency communication etc.

Several commercial/industrial properties in the study area are affected by flooding. SES has prepared a generic Business FloodSafe Toolkit and Plan for businesses. The flood affected businesses should be encouraged to adopt this brochure for their properties and prepare for the flood emergency to minimise losses and risk to their employees.

14.7 Depth Markers at Major Road Crossings by SES (EM7)

Flood depth markers provide guidance as to the depth of flooding at a specific location. Depth markers are commonly located on roads that are periodically inundated and present a traffic or pedestrian hazard. Being a permanent sign by the side of the road, flood markers can also be a continuous reminder of the flood hazard to the local residents. However, it is likely that the community would be reluctant to have these permanent signs in their neighbourhood, particularly for the nearby residents.

In addition to providing guidance to drivers and pedestrians on the depth hazard, the markers can also be used by roaming crews of the SES to provide updates on the nature of the changing flood threat in an area for a relatively large duration event.

A flood depth of 0.2-0.3 m can cause a small car to float. A flood depth marker is recommended to be installed at the following locations, where the flood depth is greater than 0.2 m in a 20% AEP event.

- Railway Crescent near Excelsior Street in Lisarow
- Washington Avenue near Alan Street in Niagara Park
- Alan Street near Siletta Road in Niagara Park
- Koninderie Parade near Yurunga Avenue in Narara
- Narara Valley Drive crossing of Narara creek in Narara
- Narara Valley Drive near the Narara train station
- Deane Street crossing of creek in Narara
- Hanlan Street crossing of creek in Narara
- Hanlan Street near the intersection of Fountain Road
- Carrington Street crossing of creek, west of Pandala Road intersection
- Carrington Street and Hanlan Street intersection
- Brookes Avenue at Frances Parkes Road intersection in Wyoming
- Brooks Avenue at Evan Close Intersection in Wyoming
- Showground Road near intersection with Maliwa Rd in Narara
- Showground Road near 124 Showground Road Gosford
- Caravan Park in Wyoming
- Warrawilla Road crossing of the creek in Wyoming
- Pacific Highway near Laycock Street intersection in Wyoming
- Pacific Highway, north of intersection with Pemell Street in Wyoming
- Maidenbrush Road, west of intersection with Henry Parry Drive in Wyoming
- Henry Parry Drive, north of intersection with Maidenbrush Road in Wyoming
- Stachon Street near 31 Stachon Street in North Gosford
- Bradys Gully Road crossing of the creek, near Jarrett St intersection in North Gosford
- Manns Road near intersection with Dells Rd in West Gosford

- Manns Road near Merinee Road intersection in West Gosford
- Pacific Highway near intersection with racecourse Road in West Gosford

The depth markers have been proposed for major roads in the study area, where the volume of traffic is likely to be significant.

It is noted that other roads in the study area can also be flooded at several other locations due to culvert blockage etc. The residents of the study area should be warned about this potential hazard through the community education program.

The proposed flood markers are shown in Figure 51.

It is noted that the Council has secured grant for installing flood depth markers at various locations around the LGA including Narara valley.

14.7.1 Flashing Lights

Depth markers are difficult to sight during the night. Flashing lights can be provided at all the locations of the depth markers specified above. These lights would be connected to a water sensor, which would turn the flashing lights on when the overtopping road depth reaches approximately 0.10m and then turn to red when the depth reaches 0.2m.

A pilot project can be carried out at a few major roads before rolling out to the all the recommended locations.

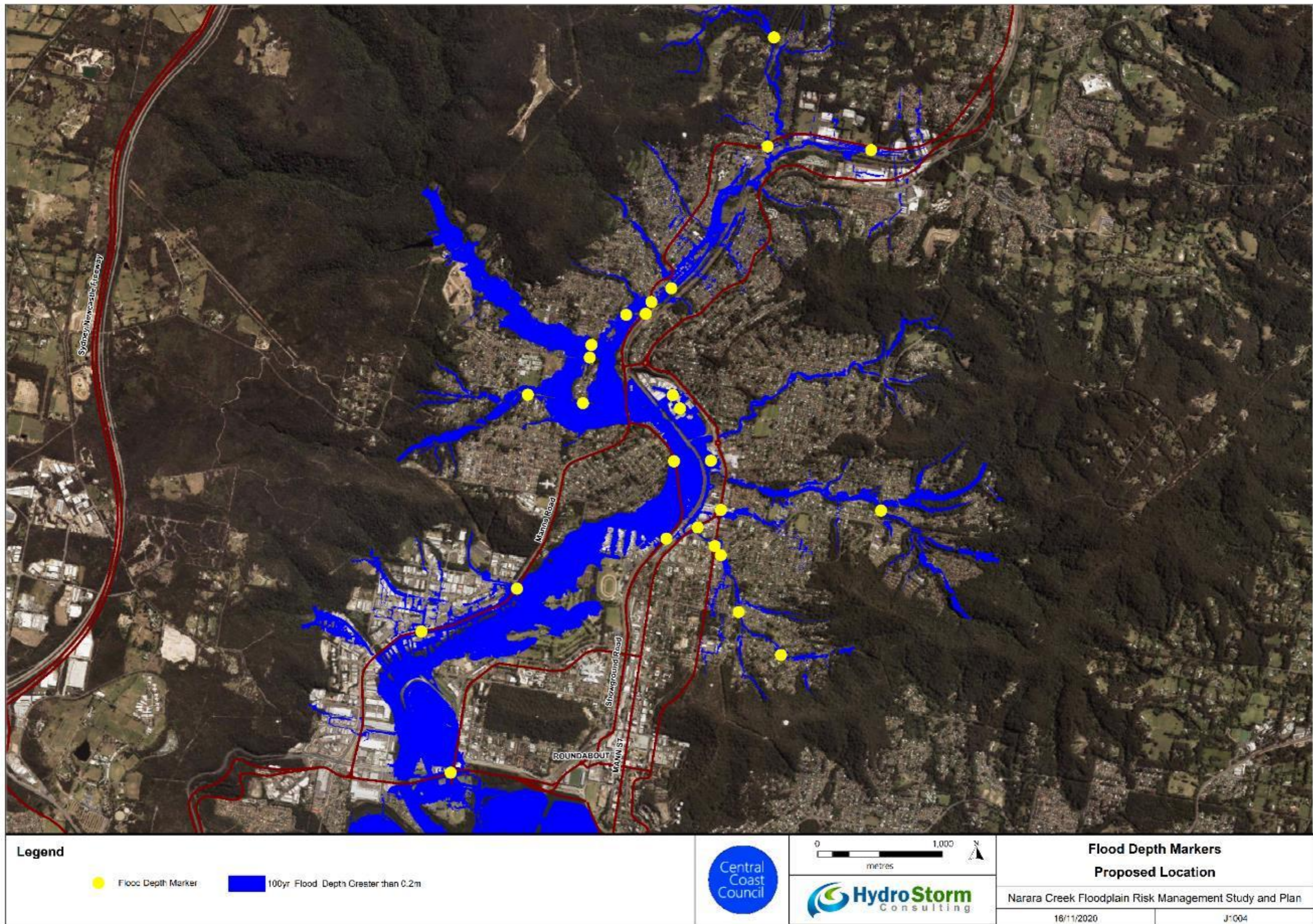


Figure 51. Potential Locations for Flood Depth Markers

14.8 Local Flood Emergency Response Plan for Large Facilities (EM8)

There are several large developments in the study area that accommodate a large number of temporary or permanent residents, which increases the vulnerability to flood hazard for these developments. These developments include aged care facilities, schools, caravan park, hospital, community centres etc. (see Figure 47 to Figure 50). Other large developments include commercial or industrial developments where loss of property can be significant due to flooding. Since it is difficult to implement flood modification measures in the study area due to the developed nature of the catchment, a Flood Emergency Response Plan (FERP) along with development controls can be a valuable tool in managing the flood risk for such large developments. A model large facility/development Local Flood Emergency Response Plan can be developed by the SES/Council to facilitate preparations of such plans in the study area or the wider LGA.

Flood behaviour has been defined for all these developments and based on this information a FERP should be developed by the owners of these developments. The FERP should inform the owners/managers of these developments of the site-specific actions that are required to manage the risk of flooding to the residents and the property. An important aspect of this plan is to identify evacuation routes for the residents, if available. Otherwise, an on-site refuge should be made available for the duration of flooding.

The Council should inform the owners of these vulnerable developments of the requirement to prepare a FERP for flood risk management.

14.9 Data Collection Strategies (EM9)

Floodplain Management is an ongoing process and involves collection of historic flood data, including rainfall and flow gauge data, that can be used in future review and update of the Floodplain Risk Management Plan. It is therefore imperative that data collection strategies are put in place for this vital component of the floodplain management process. This would involve the preparation of a flood data collection form and use of this form following a flood event.

Protocols and procedures should be in place regarding data collection. As part of this process, a questionnaire can be sent to the residents after the event to obtain details of the flooding. This community consultation process can also be used for community education purposes as well.

Council can consider combined funding for data collection strategies and the maintenance of telemetry systems, as the telemetry systems are a source of data collection in the study area. The need for data collection for a robust flood risk management program cannot be overemphasized and funding allocation for these activities should be a high priority for the Council.

15 Option Assessment

Flood modification options have been assessed through hydraulic modelling as discussed above. The economic benefit obtained from those options provides a basis for selecting suitable options for the Flood Risk Management Plan for the study area. In addition, the social and environmental impacts of various options are also assessed in a multi-criteria assessment approach, which provides a holistic value of each option and helps prioritisation process.

15.1 Economic Assessment of Flood Modification Options

The flood modifications options found to be promising in the initial modelling and preliminary assessment were further assessed by undertaking the detailed modelling for the full suite of design flood events. The flood damages for each of those options were calculated as discussed in Section 6.2.4. The economic analysis was undertaken by calculating the Net Present Value of the damages of each option and the base case for an option life of 50 years and a discount rate of 7%. The economic analysis is presented in Table 17.

Table 17. Economic Assessment of Flood Modification Options

#	Option	Design Life of Option	AAD	NPV of Damage	Cost of Option	Option benefit relative to the Base case	Benefit/Cost Ratio
1	Current Conditions - no Further Development	50	\$ 23,781,301	\$ 351,981,009	n/a	\$ -	n/a
2	Brooks Ave Detention Basin (FM1-C4/D)	50	\$ 23,747,206	\$ 351,476,364	\$ 800,000	\$ 504,645	0.63
3	Koninderie Pde Levee (FM2.2-C4/B)	50	\$ 23,202,185	\$ 343,409,655	\$ 1,000,000	\$ 8,571,354	8.57
4	NVD Bridge Upgrade (FM4.2-C4/B)	50	\$ 23,689,834	\$ 350,627,222	\$ 1,800,000	\$ 1,353,786	0.75

15.2 Multi-Criteria Assessment

A multi-criteria matrix assessment approach was adopted for the comparative assessment of all identified options using an approach recommended in the Flood Risk Management Manual and Flood Risk Management Guideline MM01 (2023). This approach to assessing the merits of various options uses a subjective scoring system. The principal merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives “transparent” (i.e. all the important factors are included in the analysis). However, this approach does not provide an absolute “right” answer as to what should be included in the Floodplain Risk Management Plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criterion.

15.2.1 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain as well as the community preferences.

The criteria adopted include:

- Technical Likely Overall Hydraulic Improvement
- Economic Capital and Operating Costs
Reduction in Risk to Property
- Social Reduction in Social Disruption
Reduction in Risk to Life
- Environmental Flow and Water Quality Objectives
Fauna/Flora
- Community Community Support
- Authority Council/Agency/SES Support
- Policy/Legislation Compatible with Policies and Plans

A brief description of the above criteria is presented below:

Likely Overall Hydraulic Improvement – Flood modification options generally result in decrease in the flood levels in the catchment. However, these options can potentially have an adverse impact further downstream

Capital and Operating Costs – Flood modification and property modification options generally have large capital and/or operating costs. Sourcing funds for higher cost options can be challenging for the Council

Reduction in Risk to Property – This is measured by the reduction in AAD for the property due to the implementation of the option

Reduction in Social Disruption – Flooding of an area causes disruption in the daily lives of the residents and effective flood management options tend to reduce this disruption. Sometimes implementation of an option can result in adverse community response and consequent social disruption

Reduction in Risk to Life – Risk to life cannot be eliminated in a floodplain (up to the PMF flood extent). However, flood management options would generally tend to reduce the risk to the life of the residents. Any option that increases risk to life is not considered suitable for floodplain management

Flow and Water Quality Objectives – The natural environment of the floodplain needs to be preserved or enhanced through the implementation of flood management options. The natural flow processes in the creek system should be maintained and the quality of the stormwater/floodwaters should be maintained as far as practical while considering flood management options

Fauna/Flora – Flood management options and in particular, flood modification options can potentially impact on the fauna/flora habitat or have an adverse impact on the local ecology

Community Support – Community support for a flood management option is gauged from the results of community survey. Where this information is not available, a reasonable assumption is made in assigning the score for this criterion

Council/Agency/SES Support – Most flood management options would be supported by the Council and other agencies including SES. However, the level of support would vary if there were funding constraints or less community support for the option

Compatible with Policies and Plans – For effective implementation of the flood management options, the existing Council/State policies should support the option. However, flood management options can potentially have conflicting objectives to the existing policies. E.g. the flood planning level may result in the height of the building that is restricted through other policy or development control.

The scoring system is shown in Table 18 for the above criteria.

Table 18. Scoring System for Option Assessment

CRITERIA	SCORE				
	-6 to -10	-1 to -5	0	1 to 5	6 to 10
Likely overall hydraulic improvement	Negative impact (> 0.2 m increase in peak flood level at any location)	Negative impact (> 0.1 m increase in average peak flood level at any location)	Negligible improvement or only local improvement	Flood level decrease (0.1 - 0.5 m decrease in peak average flood level across the floodplain)	Flood level decrease (>0.5 m decrease in peak average flood level across the floodplain)
Capital and Operating Costs	Extreme (e.g. >\$1 million)	High \$500,000 - \$1 million	Medium \$200,000 - \$500,000	Low \$50,000 - \$200,000	Low \$10,000 - \$50,000
Reduction in Risk to Property*	Major increase in AAD (> 25% of existing AAD)	Slight increase in AAD (up to 25% of existing AAD)	No Improvement	Slight decrease in AAD (up to 25% of existing AAD)	Major decrease in AAD (> 25% of existing AAD)
Reduction in Risk to Life**	-	-	No change in risk to life	Slight reduction of risk to life	Major reduction of risk to life
Reduction in Social Disruption	Major increase in social disruption	Slight increase in social disruption	No change to social disruption	Slight reduction of social disruption	Major reduction of social disruption

CRITERIA	SCORE				
	-6 to -10	-1 to -5	0	1 to 5	6 to 10
Compatible with Water Quality and Flow Objectives	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
Fauna/flora impact	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit
Community attitude	Strong disagreement	Disagreement	Neutral/no response	Support	Strong support
Council/state agency attitude	Strong disagreement	Disagreement	Neutral/no response	Support	Strong support
Compatible with Policies and Plans	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible

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

** Any option resulting in increase in risk to life would not be considered as a viable option.

15.3 Option Scores

Based on the criteria presented in Table 18, the scores for various recommended options (Table 16) are presented in Table 19. Application of score for several criteria is based on the overall knowledge of the study and past experience and as such has certain scope for modification.

In general, the property modification and response modification options score higher than the flood modification options. This is typical of a developed urban area, where significantly large flood modification options are generally not feasible. This implies that flood risk in the study area can be managed through less capital intensive measures.

The scoring of options provides the necessary tool to prioritise works in the study area and provides the basis for adoption of flood risk management options for planning purposes.

Table 19. Scoring for Flood Risk Management Options

Option Identifier	Options	Likely overall hydraulic improvement	Capital and Operating Costs	Reduction in Risk to Property	Reduction in Risk to Life	Reduction in Social Disruption	Compatible with Water Quality and Flow Objectives	Fauna/flora impact	Community attitude	Council/state agency attitude	Compatible with Policies and Plans	TOTAL SCORE
Flood Modification Options												
FM2.2-C4/B	Levee at northern end of Koninderie Parade	5	2	7	3	0	0	0	5	0	5	27
FM3.1-C4/B	Gilda Drive Trunk Drainage Improvement - Upper Narara	3	-5	3	1	7	2	-1	10	8	8	36
FM3.2-C4/B	Lisarow Shopping Centre Trunk drainage and Flood Emergency Response Plan	3	-7	5	2	9	5	-5	10	3	8	33
FM3.3-C4/B	Koninderie Pde Drainage Upgrade	3	-3	3	1	8	2	-1	10	8	8	39
FM4.2-C4/B	Narara Valley Drive road approaches and upgrade box culvert to clear span	4	-2	5	2	2	5	5	10	5	5	41
FM4-C4/C	Reeves Street Causeway	7	-10	5	3	5	-1	-1	5	5	3	21
FM1-C4/D	Brooks Avenue detention basin	5	0	5	2	2	5	0	8	0	5	32
FM2.2-C4/G	Levee protection for industrial area at end of Dell Road prevent overbank flooding from Narara Creek	5	3	7	5	2	0	0	7	3	8	40
FM3-C4/G	Industrial Area Drainage Improvement - West Gosford	3	-5	3	1	7	7	-1	10	5	10	40
FM6.1-C4/G	Tathra Street Creek Clearance	2	-2	1	0	4	3	3	10	10	8	39
FM2.3-C4/G	Preservation of Racecourse and Golf Course Flood Storage Areas	2	5	1	1	5	0	-2	0	3	2	17
FM8-C4/G	Central Coast Highway Raising	7	0	4	3	7	0	0	8	5	5	39
Property Modification Options												
PM1.2-C4/B	Koninderie Parade development controls	0	8	5	5	5	0	0	8	10	10	51
PM2-C4/E	Koninderie Parade voluntary purchase	0	-10	10	10	8	0	0	0	-5	0	13
PM1.1-C4/G	Development controls for West Gosford Industrial Area	0	10	5	5	5	0	0	8	10	10	53
PM1.2-C4/G	Development controls for Golf Course and Race Course Storage Areas	0	10	5	5	3	3	0	8	10	10	54
PM1.3-C4/G	Development controls for Glennie St West Industrial Area	0	10	5	5	0	0	0	8	10	10	48
PM2.2-C4/G	Voluntary purchase of two properties in Narara	0	-10	10	5	-2	0	0	8	-5	4	10
PM1-All	Planning and development controls for the entire study area	0	10	10	8	5	10	0	7	10	8	68
PM2-All	Voluntary Purchase in the study area	0	-10	10	10	0	0	0	-5	-5	5	5

Option Identifier	Options	Likely overall hydraulic improvement	Capital and Operating Costs	Reduction in Risk to Property	Reduction in Risk to Life	Reduction in Social Disruption	Compatible with Water Quality and Flow Objectives	Fauna/flora impact	Community attitude	Council/state agency attitude	Compatible with Policies and Plans	TOTAL SCORE
PM4-All	Shelter in Place in the study area	0	10	3	3	0	0	0	7	-5	-5	13
PM5-All	Overland Flood Studies in the study area	0	-3	7	5	8	0	0	8	8	8	41
PM6-All	Hazardous Materials management in the study area	0	10	0	7	0	10	10	7	7	7	58
Response Modification Options												
EM2.1-C4/G	Rowena Road Emergency Warning System	0	2	0	8	0	0	0	8	10	10	38
EM2.2-C4/G	Glennie St West Industrial Area Emergency Warning System	0	-3	0	8	0	0	0	10	10	10	35
EM2.3-C4/G	West Gosford Emergency Warning System	0	-3	0	8	0	0	0	10	5	10	30
EM2.4-C4/G	Electronic warning sign boards along major roads	0	5	2	8	0	0	0	3	5	10	33
EM2-All	Emergency management measures such as deployment of MHL Fit Flood Warning System	0	7	5	10	2	0	0	10	10	10	54
EM3-All	Flood Intelligence for SES	0	10	0	6	5	0	0	5	10	10	46
EM4-All	Revision of Central Coast Local Flood Plan by SES (a sub-plan of DISPLAN)	0	8	2	8	7	0	0	7	10	10	52
EM5-All	Public Awareness and Education by Council/SES	0	7	3	5	5	0	0	9	10	10	49
EM6-All	Business Awareness and Education by Council/SES	0	7	5	5	5	0	0	8	10	10	50
EM7-All	Flood depth markers at major road crossings	0	8	0	9	0	0	0	7	10	10	44
EM8-All	Flood Emergency Response Plan for Large Facilities	0	8	2	9	5	0	0	10	10	10	54
EM9-All	Data Collection Strategies	0	8	0	0	0	0	0	10	10	10	38

Part 2 - Narara Creek Floodplain Risk Management Plan



Carrington Street flooding – March 2002

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16 Floodplain Risk Management Plan

The Narara Creek Floodplain Risk Management Plan (FRMP) draws upon the results of the assessment carried out for various floodplain management measures presented in the Narara Creek Floodplain Risk Management Study (FRMSP). The FRMP will direct the future management of flood prone land in the Narara Creek catchment with an emphasis on educating the community about the flood risk and its consequences to facilitate informed decision making in case of a flood emergency and to appreciate the flood controls that the Council would rely on making the community flood resilient.

The Narara Creek FRMSP has presented the flood risk options in detail after a comprehensive review of the existing flood behaviour in the Narara Creek catchment. Several flood modification, property modification and flood emergency response modification options have been identified and assessed.

The flood risk management plan brings together all the options and recommendations and provides a planning tool for implementing various options.

The key findings of the FRMSP are that the existing flood risk across the study area can be managed to an acceptable level primarily through the implementation of development controls and emergency response measures, although several flood modification measures have also been found to be effective. The potential for increased flood risk as a result of climate change was also identified to be significant for the study area. This risk can be managed by making an allowance in the flood planning level of the study area. Measures have been recommended in this plan to improve flood planning through property modification and response modification options.

16.1 Floodplain Risk Management Plan Objectives

The primary objectives of preparing the Narara Creek FRMP are to:

- Provide a practical framework and implementation plan for managing existing, future and continuing flood risk within the study area;
- Consider the impact of future climate on flood risk management in the study area, based on Council's Climate Change policy;
- Formulate a cost effective Plan for the study area based on the findings of the Floodplain Risk Management Study;
- Provide a priority program for implementation of the recommended works and measures in accordance with Flood Risk Management Manual (2023);
- Ensure that intergenerational equity is maintained through achieving a balance between reducing flood vulnerability for the current and future generation, without overly burdening the current generation with costs and avoiding the transfer of costs or risk to future generations;
- Disseminate the outcomes of the Plan to state agencies including those directly impacted by the decisions identified e.g. police and emergency services; and
- Provide for the management of flood risks to public assets (such as services and utilities) and private property.

17 Floodplain Risk Management Actions

The floodplain risk management options were analysed using a multi-criteria matrix as part of the FRMSP and those identified to be the most effective in reducing the flood risk have been selected for inclusion as management actions in this FRMP. The assessment of options included evaluation regarding the social and environmental benefits accruing from various options.

17.1 Implementation of Floodplain Risk Management Actions

In order to achieve the implementation of relevant management actions, a program of implementation has been developed. An indicative estimate of capital and recurring cost has been made and timeline for implementation (immediate or staged) and priority for implementation (high, medium or low) has been established. An approximate timeframe for 'immediate' implementation of an option is 0-5 years and that for the 'staged' is 5-10 years.

With respect to immediate implementation, the option needs to be implemented in the short term if funding and resources permit. The feasibility of the option is also high and additional investigations for implementation are minimal. The staged implementation would require additional investigations, feasibility studies or further development of the strategy before implementation. The implementation time is usually from short to medium term.

Prioritization not only relies on the option ranking but also the ease with which a certain option can be implemented. Generally, options in the top third rankings are considered high priority, the middle third the medium priority and the remaining the low priority.

The list of recommended actions with implementation recommendations is presented in Table 20.

Table 20. List of Floodplain Risk Management Actions

Option Identifier	Options	Rank	Indicative Cost		Implementation Time frame	Priority	Implementing Agency
			Capital	Recurring			
PM1-All	Planning and development controls for the entire study area	1	\$50,000	N/A	Immediate	High	Council
PM6-All	Hazardous Materials management in the study area	2	Included in PM1-All	N/A	Immediate	High	Landowner
PM1.2-C4/G	Development controls for Golf Course and Race Course Storage Areas	3	Included in PM1-All	N/A	Immediate	High	Council
EM2-All	Emergency management measures such as deployment of MHL Fit Flood Warning System	3	\$80,000	\$2,000	Immediate	High	Council/SES
EM8-All	Flood Emergency Response Plan for Large Facilities	3	to be undertaken by the development	N/A	Immediate	High	Council/SES
PM1.1-C4/G	Development controls for West Gosford Industrial Area	6	Included in PM1-All	N/A	Immediate	High	Council
EM4-All	Revision of Central Coast Local Flood Plan by SES (a sub-plan of DISPLAN)	7	\$20,000	N/A	Immediate	High	SES
PM1.2-C4/B	Koninderie Parade development controls	8	Included in PM1-All	N/A	Immediate	High	Council
EM6-All	Business Awareness and Education by Council/SES	9	\$20,000	N/A	Immediate	High	SES/Council
EM5-All	Public Awareness and Education by Council/SES	10	\$80,000	\$20,000	Immediate	High	SES/Council
PM1.3-C4/G	Development controls for Glennie St West Industrial Area	11	Included in PM1-All	N/A	Immediate	High	Council

Option Identifier	Options	Rank	Indicative Cost		Implementation Time frame	Priority	Implementing Agency
			Capital	Recurring			
EM3-All	Flood Intelligence for SES	12	\$10,000	N/A	Immediate	High	Council/SES
EM7-All	Flood depth markers at major road crossings	13	\$100,000	\$2,000	Immediate	Medium	Council
FM4.2-C4/B	Narara Valley Drive road approaches and upgrade box culvert to clear span	14	\$1,800,000	\$1,000	Staged	Medium	Council
PM5-All	Overland Flood Studies in the study area	14	\$150,000 per study (approx.)	N/A	Immediate	Medium	Council
FM2.2-C4/G	Levee protection for industrial area at end of Dell Road prevent overbank flooding from Narara Creek	16	\$1,000,000	\$2,000	Staged	Medium	Council
FM3-C4/G	Industrial Area Drainage Improvement - West Gosford	16	\$2,500,000	\$3,000	Staged	Medium	Council
FM3.3-C4/B	Koninderie Pde Drainage Upgrade	18	\$375,000	\$1,000	Staged	Medium	Council
FM6.1-C4/G	Tathra Street Creek Clearance	18	\$50,000	\$2,000	Immediate	Medium	Landowner/ Council
FM8-C4/G	Central Coast Highway Raising	18	by TfNSW	by TfNSW	Staged	Medium	TfNSW
EM2.1-C4/G	Rowena Road Emergency Warning System	20	\$30,000	\$1,000	Immediate	Medium	Council
EM9-All	Data Collection Strategies	20	\$10,000	\$80,000	Immediate	Medium	Council
FM3.1-C4/B	Gilda Drive Trunk Drainage Improvement - Upper Narara	22	\$1,250,000	\$2,000	Staged	Medium	Council
EM2.2-C4/G	Glennie St West Industrial Area Emergency Warning System	23	\$80,000	\$1,000	Immediate	Low	Council
FM3.2-C4/B	Lisarow Shopping Centre Trunk drainage and Flood Emergency Response Plan	24	\$750,000	\$1,000	Staged	Low	Landowner

Option Identifier	Options	Rank	Indicative Cost		Implementation Time frame	Priority	Implementing Agency
			Capital	Recurring			
EM2.4-C4/G	Electronic warning sign boards along major roads	24	\$600,000	\$5,000	Immediate	Low	State Govt/ Council
FM1-C4/D	Brooks Avenue detention basin	26	\$800,000	\$2,000	Staged	Low	Council
EM2.3-C4/G	West Gosford Emergency Warning System	27	\$80,000	\$1,000	Immediate	Low	Council
FM2.2-C4/B	Levee at northern end of Koninderie Parade	28	\$1,000,000	\$2,000	Staged	Low	Council
FM4-C4/C	Reeves Street Causeway	29	\$4,340,000	\$3,000	Staged	Low	Council
FM2.3-C4/G	Preservation of Racecourse and Golf Course Flood Storage Areas	30	N/A	N/A	Immediate	Low	Council
PM2-C4/E	Koninderie Parade voluntary purchase	31	\$2,500,000	N/A	Staged	Low	Council
PM4-All	Shelter in Place in the study area	31	N/A	N/A	Immediate	Low	Council
PM2.2-C4/G	Voluntary purchase of two properties in Narara	33	\$2,500,000	N/A	Immediate	Low	State Govt/ Council
PM2-All	Voluntary Purchase in the study area	34	\$7,500,000	N/A	Immediate	Low	Council

A number of options related to property modification and response modification options have been assigned an “Immediate” timeframe. This implies that the work on these options should commence at the earliest available opportunity.

17.2 Option Implementation

The flood management options identified in this plan are recommended for implementation as per the suggested timeframe and prioritisation. Delay in implementing these options would increase the cost of flooding to the community in the coming years. The climate change impacts would also add to the flood risk and increase the cost of flooding, both in tangible and intangible damages.

Several emergency management and property modification options are generally easy to implement with low costs. The implementation of these options should start as early as possible after the adoption of this plan.

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