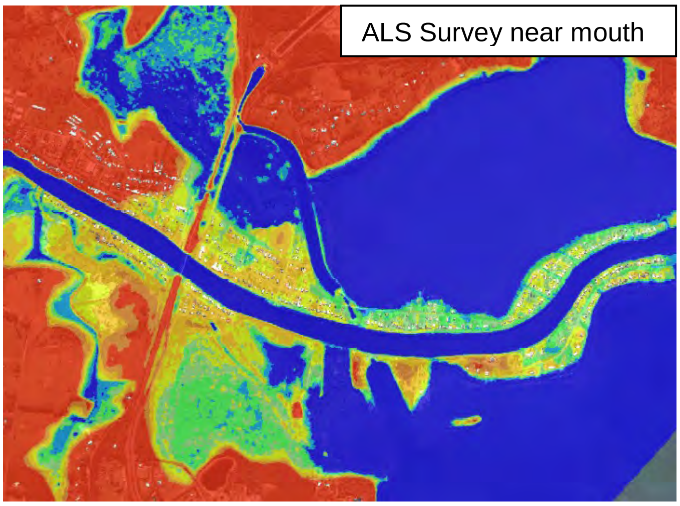
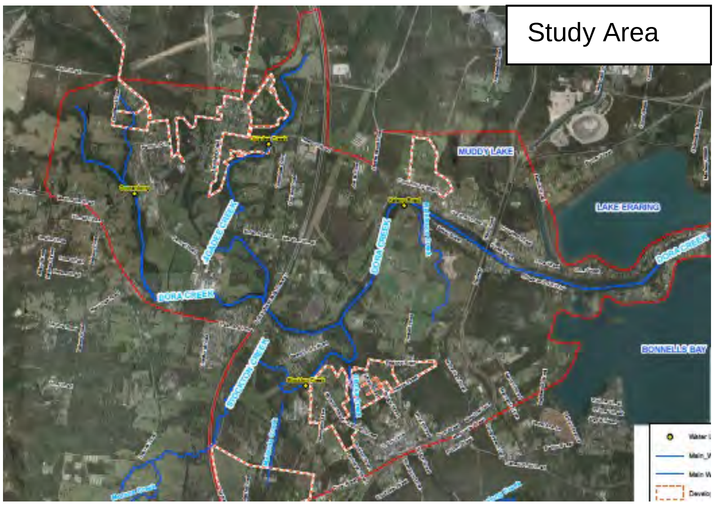
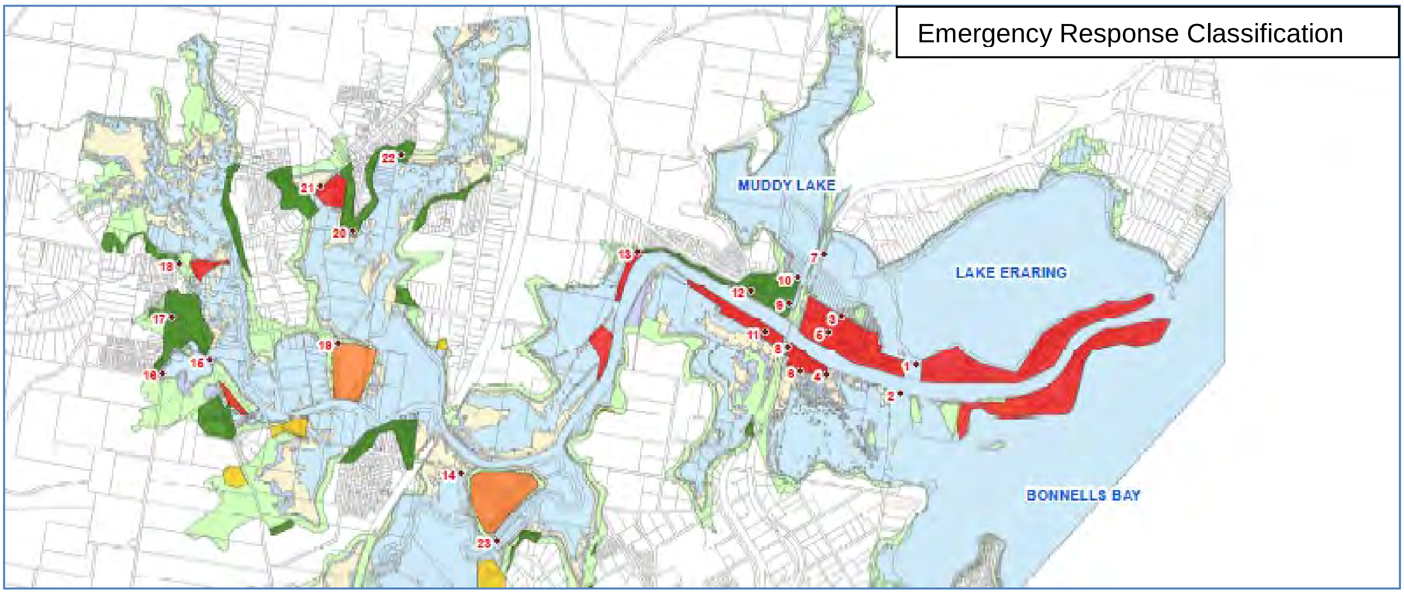
LAKE MACQUARIE CITY COUNCIL

DORA CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Final Report







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DORA CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT
MAY, 2015

Project Dora Creek Floodplain Risk Management Study and Plan	**Project Number** **113016**
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Date 5 May 2015	**Verified by**

Revision	Description	Date
1	Preliminary Draft Report	May 2014
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4	Final Report	5 May 2015

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
BoM	Bureau of Meteorology
CFERP	Community Flood Emergency Response Plan
DA	Development Application
DECC	Department of Environment and Climate Change
DECCW	Department of Environment, Climate Change and Water (now OEH)
DCP	Development Control Plan
EY	Exceedances per Year
FPL	Flood Planning Level
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
LEP	Local Environmental Plan
LGA	Local Government Area
m	metre
m^3/s	cubic metres per second
m AHD	metres above Australian Height Datum
MHL	Manly Hydraulics Laboratory
OEH	Office of Environment and Heritage
OSD	On Site Stormwater Detention
PMF	Probable Maximum Flood
PSD	Permissible Site Discharge
RMA	Unsteady Hydrodynamic Computer Model
SES	State Emergency Service
SSR	Site Storage Requirement
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software program (hydraulic computer model)
WBNM	Watershed Bounded Network Model (hydrologic computer model)
1D	One dimensional hydraulic computer model
2D	Two dimensional hydraulic computer model

FOREWORD

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

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

The flood management process in NSW has recently been up-dated to incorporate consideration of the effects of climate change, and particularly the effects of sea level rise, on mean water levels and on flood levels.

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

1. ***Flood Study***
   - determine the nature and extent of the flood problem.

2. ***Floodplain Risk Management Study***
   - evaluates management options for the floodplain in respect of both existing and proposed development.

3. ***Floodplain Risk Management Plan***
   - involves formal adoption by Council of a plan of management for the floodplain/foreshore.

4. ***Implementation of the Plan***
   - construction of flood mitigation works to protect existing development,
   - use of Local Environmental Plans, development and building controls to ensure new development is compatible with the flood hazard.

This Dora Creek Floodplain Risk Management Study and Plan involves a review of the previous 1992 Dora Creek Floodplain Management Study and the 1998 Dora Creek Floodplain Management Plan (References 2 and 3) and provides an updated document. This document has been prepared by consultant WMAwater for Lake Macquarie City Council and was undertaken following a review of the 1986 Dora Creek Flood Study (References 3). The results of this updated Dora Creek Flood Risk Management Study and Plan will provide the basis for the future management of flood liable land within the Dora Creek area.

1. DRAFT DORA CREEK FLOOD RISK MANAGEMENT PLAN

1.1. Introduction

The Dora Creek Flood Risk Management Plan has been prepared for Lake Macquarie City Council (Council) in accordance with the NSW *Floodplain Development Manual* (April 2005 - Reference 1) and the August 2010 *Flood Risk Management Guide – Incorporating sea level rise benchmarks in flood risk assessmen*t (Reference 4) and:.

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

The Dora Creek catchment is located on the western side of Lake Macquarie waterway, 30 km south-west of Newcastle and 120 km north of Sydney. Dora Creek has a catchment area of approximately 238 km^2 and is the largest catchment flowing into the Lake Macquarie waterway which has a total catchment of 648 km^2 (Figure 1).

The study area focuses on the existing township of Dora Creek and includes the townships of Cooranbong and Avondale, where new and planned rural and urban developments are proposed within the floodplain. The upper limit of the study area extends above Freemans Drive to Cooranbong and downstream to the confluence of Dora Creek with the Lake Macquarie waterway (Figure 1 and Figure 2).

There are three main tributaries within the catchment with Dora Creek being joined by Jigadee Creek at Cooranbong and then Stockton Creek before draining into Lake Macquarie waterway at Bonnells Bay and Lake Eraring.

Watercourses within the catchment area and above the tidal limit are narrow; Dora Creek is typically less than 15 m wide upstream of Freemans Drive. Below the tidal limit, the creeks become broader with Dora Creek varying from a width of 50m at the Sydney to Newcastle Freeway to 100m where it forms a delta into Lake Macquarie waterway. Upstream of the delta the Eraring Power station draws cooling water for steam condensation from Bonnells Bay, which passes under Dora Creek through a concrete tunnel and open canal.

1.2. Risk Management Measures Considered

A matrix of possible management measures was prepared and evaluated in this Flood Risk Management Study taking into account a range of parameters. This process eliminated a number of flood risk management measures (refer Section 5.2) including flood mitigation dams, retarding basins and voluntary purchase of all flood liable buildings. The use of on-site stormwater detention as a flood mitigation measure, as opposed to its use for mitigating the effects of urbanisation was also eliminated.

The full range of measures was evaluated in Section 5 and the outcomes are summarised in Table 1. Table 2 details the matrix scoring system and Table 3 provides the matrix results which ranks the management measures considered.

Community opinion on the full range of options has been canvassed during the public exhibition period in late 2014. however, it should be noted that these outcomes may change in the future and/or as an outcome of the proposed local area adaptation plans for sea level rise which was a recommendation of the June 2012 *Lake Macquarie Waterway Flood Risk Management Study and Plan* (Reference 9).

Table 1: Summary of Management Measures Investigated in Study

MEASURE	PURPOSE	COMMENT
FLOOD MODIFICATION:		
FLOOD MITIGATION DAMS, RETARDING BASINS (Section 5.2)	Reduce the peak flow from the catchment into Dora Creek and its tributaries by increasing the volume of flood storage in the catchment.	• Not considered further as have negligible impact on flooding in Dora Creek or its tributaries. • The size of storages required to make a difference to large creeks such as Dora Creek or Stockton Creek are very large, making them impractical on environmental, social and economic grounds.
ON-SITE DETENTION (Section 5.2)	Decrease effects of increased urbanisation.	• On-site detention or retarding basins are suitable measures to mitigate the potential increase in peak flow on downstream reaches as rural areas become urbanised. • Smaller on-site detention can help water quality and local drainage, but has little impact in Dora Creek or its tributaries.
LEVEE BANKS, FLOODGATES, AND PUMPS PREVENTING FLOODING AND PERMANENT INUNDATION (Section 5.3.1)	Prevent or reduce the frequency of flooding of protected areas. Prevent or delay permanent inundation from rising sea levels downstream of the railway line.	• Relatively expensive (several $million) for larger structures which are required to protect the "ribbon" type development along Dora Creek where the majority of floors likely to be inundated are located. • May cause local drainage problems and be unacceptable to the community due to restriction of waterfront access and views. • No specific sites have been investigated or identified at this time. A small local levee has been suggested at Doree Place but this does not reduce above floor inundation. • This may be an option to prevent inundation from sea level rise for properties downstream of the railway line. • A deflector levee at Kalang Road was identified in previous studies and reviewed herein. This levee would reduce peak velocities and provide some reduction in the potential for structural damage but

		the dis-benefits outweigh the benefits. • Levees will still be overtopped in major flood events and for this reason flood planning controls will still apply to areas protected by levees.
CHANNEL MODIFICATIONS (Section 5.3.2)	To increase the capacity of the channel and so reduce flood levels upstream.	• The hydraulic capacity of the channel and floodplain can be increased by straightening of the channel, widening or removal of vegetation along the banks. • However, such measures can often increase flood risk downstream. • These measures are costly to undertake and have significant environmental impacts and are thus rarely used.
PROVISION OF FLOODWAYS (Section 5.3.3)	To channel floodwaters away from affected areas and so reduce flood levels.	• The creation of floodways can provide an effective means of diverting floodwaters away from affected areas and thus reducing flood levels. • For the areas downstream of the railway line there are limited areas where a floodway could be created due to existing development and the power station channel. • An area on the south side immediately west of the channel (flow path 5 on Figure 5) could be cleared of shrub layer vegetation (largely weeds and not salt marsh or mangroves) to increase the hydraulic conveyance but the reduction in flood levels upstream are a maximum of 0.05m in the 1% AEP (1 in 100 year) event.
WORKS TO MINIMISE LOCAL DRAINAGE PROBLEMS (Section 5.3.4)	To reduce the incidence of local runoff ponding in yards and streets.	• Flooding in this manner does not usually enter buildings but it occurs frequently and causes inconvenience to residents. • In low-lying areas with minimal fall to the lake there is no easy or cost effective solution. Flap-gates on drains can reduce local flooding from elevated levels in Dora Creek. • A community-based approach should be introduced to monitor, identify and (possibly) resolve some problem areas.
PROPERTY MODIFICATION:		
VOLUNTARY HOUSE RAISING (Section 5.4.1)	Prevent flooding of existing buildings by raising the floor level above the floodwaters.	• All flood damages will not be prevented and only suitable for non-brick buildings on piers. • Costs approximately $70,000 per house but can vary considerably. • Only suitable for a small number of houses (generally with floor levels first inundated in the 10% AEP or smaller events) and not attractive to all residents. • Should be investigated further as, along with levees, house raising is one of the only measures

		to mitigate increased flood levels from sea level rise. • Not appropriate in areas where the land beneath buildings becomes permanently or frequently inundated. • Council should consider whether "slab on ground" construction is appropriate if there is the possibility that the house may require raising in the future.
FLOOD PROOFING (Section 5.4.2)	Prevent flooding of existing buildings by sealing all the entry points.	• Generally only suitable for brick, slab on ground buildings. • Less viable for residential buildings but should be considered for non residential buildings of slab on ground construction.
RE-BUILDING SUBSIDY (Section 5.4.1)	Provides an incentive to re-build at a higher level.	• Subject to availability of grant funding by OEH. • Mainly applicable for isolated, high hazard properties in flood liable areas. • No individual properties identified in the study.
VOLUNTARY PURCHASE OF INDIVIDUAL BUILDINGS (Section 5.4.3)	Purchase and removal of the most hazardous flood liable buildings to reduce risk to property and people.	• High cost per property. • Applicable for isolated, high hazard properties in flood liable areas. • None have been specifically identified in the study.
STRATEGIC PLANNING ISSUES (Section 5.4.4 & 5.4.5)	Reduce potential hazard and losses from flooding, tidal inundation, and permanent inundation by appropriate land use planning.	• Well-established processes are in place for dealing with land-use in flood hazard areas. • However, permanent inundation and changes in flood hazard over time, as a result of rising lake levels, are new issues and will require new responses. • Land use planning will have to consider the possibility that, without intervention, some low lying areas on Dora Creek may become unfit for habitation due to permanent inundation, loss of infrastructure and services, increased flood hazard, and loss of access • Protection measures (levees, filling etc), planned retreat, additional conditions on development, and changes in zoning are possible planning responses. • Local adaptation plans, are currently being undertaken by Council in close consultation with affected communities and would be an appropriate planning response at Dora Creek.
MODIFICATION TO THE S149 CERTIFICATE (Section 5.4.6)	S149 certificates should clearly inform owners and purchasers of risks, planning controls and policies that apply to the subject land.	• Council should review flood and permanent inundation related information on the Section 149 Certificate (2) to bring it in line with the findings of this Plan. • Council should make property information on flooding accessible on the internet.

MINIMISE THE RISK OF ELECTROCUTION (Section 5.4.7)	Design new electrical work, retro-fit existing electrical work, and educate residents, to prevent live wires going underwater in floods.	• New circuits in habitable dwellings are installed at or above the 1% AEP (1 in 100 year) flood level + 0.5m freeboard. • A risk and adaptation assessment to be undertaken to look at ways to encourage residents and authorities to retro-fit existing properties, with circuit breakers. • Use education and awareness campaigns to alert residents to the danger and suggest solutions.
REDUCE FAILURE OF SEWERAGE SYSTEM (Section 5.4.8)	Upgrade the sewerage system to reduce the likelihood of failure.	• Determine cause of past failures and resolve.
DETAILED REVIEW OF THE PROVISION AND MAINTENANCE OF SERVICES AND INFRASTRUCTURE ON FLOOD LIABLE LANDS DOWNSTREAM OF THE RAILWAY LINE WITH SEA LEVEL RISE (Sections 4.10 & 5.6.3)	Changes in relative lake level are predicted to reduce the asset life and increase maintenance costs of public infrastructure A detailed review will identify future infrastructure requirements, design standards and long term viability.	• Sea level rise will have a significant impact on the provision of services and infrastructure. • The impact needs to be evaluated and an assessment made of the long term viability of the provision and maintenance of both services and infrastructure. • It may be that some services and/or infrastructure cannot be supported in the long term and alternative strategies will need to be determined. • This assessment will primarily be concerned with the flood liable areas downstream of the railway line and for a sea level rise of up to 0.9m.
RESPONSE MODIFICATION:		
FLOOD WARNING (Section 5.5.1)	Enable people to prepare and evacuate, to reduce damages to property and injury to persons.	• System for Dora Creek catchment currently in place and is being updated in 2014 based on the results of the updated Flood Study. • The cost to improve the system is < $10,000 and will provide a high benefit/cost ratio.
FLOOD EMERGENCY MANAGEMENT (Section 5.5.2)	To ensure that evacuation can be undertaken in a safe and efficient manner.	• There is an existing SES Flood Plan for the Dora Creek catchment and a review of emergency management has been undertaken in the past. • The Plan should be updated in light of the present study. • The cost to improve the Plan is small and will provide a high benefit/cost ratio.
PUBLIC INFORMATION AND RAISING FLOOD AWARENESS (Section 5.5.3)	Educate people to prepare themselves and their properties for floods, to minimise flood damages and reduce the risk.	• A cheap and effective method but requires continued effort. • Variety of possible approaches. • SES and Council initiative produced a FloodSafe brochure for Dora Creek (www.ses.nsw.gov.au/content/documents/pdf/floodsafe/42156/doracreekfloodsafeguide). • Council is currently working with the community to prepare a Community Safety Plan •

OTHER MANAGEMENT MEASURES		
MINE SUBSIDENCE (Section 5.6.1)	The Mines Subsidence Board has indicated that parts of Lake Macquarie waterway are within, or may become within, a mine subsidence area.	• Current practice is to manage mining to prevent long wall extraction beneath foreshore areas. • The extent of these management areas needs to be reviewed with the relevant State agencies to make allowance for sea level rise. • If already mined areas are likely to experience continued subsidence, further detail from the Mines Subsidence Board is required to define the likely extent and an appropriate allowance, over and above the 0.5m freeboard, should be included in the flood development assessment process.
FLOOD INSURANCE (Section 5.6.2)	To spread the risk of individual financial loss across the whole community through insuring against flood damage.	• Does not reduce damage, but spreads the cost. • Flood insurance is available at a price for all residential properties and governments are currently considering universal or subsidised schemes. • Insurance against storm surge, tidal inundation, and permanent inundation from sea level rise is not available.
ADAPTATION TO SEA LEVEL RISE (Sections 4.10 & 5.6.3)	To reduce impacts of future flood events combined with higher ocean levels.	• Sea level rise will occur in the future and affect the lower reaches of Dora Creek • Adaptation for sea level rise through a local adaptation plan can address the adverse impacts

1.2.1. Relative Merits of Management Measures

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows) of the project over its life. It is a standard method for using the time value of money to compare the reduction in flood damages (benefit) with the capital and on going cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. A multi-variate decision matrix was developed for the Dora Creek area, allowing benefit/cost estimates, community involvement in determining social and other intangible values, and assessment of environmental impacts.

1.2.2. Management Matrix

The criteria assigned a value in the management matrix are:

- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- number of properties benefited by measure;
- technical feasibility (design considerations, construction constraints, long-term performance);
- community acceptance and social impacts;
- economic merits (capital and recurring costs versus reduction in flood damages);
- financial feasibility to fund the measure;
- environmental and ecological benefits;
- impacts on the State Emergency Services;
- political and/or administrative issues;
- long-term performance given the likely impacts of climate change and sea level rise,
- risk to life.

The colour coded scoring system for the above criteria is provided in Table 2 and largely relates to the impacts in a 1% AEP (1 in 100 year) event. Table 3 indicates the weighting assigned to each measure, however these may be adjusted in the light of community consultations and local conditions.

Table 2: Colour Coded Matrix Scoring System

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

Table 3: Matrix of Management Measures Investigated in Study (ordered by ranking)

Report Ref	OPTION	COMMENT	Impact on Flood Behaviour	Number of Properties Benefitted	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental\ Ecological Benefits	Impact on SES	Political / Admin Issues	Long Term Performance	Risk to Life	TOTAL	RANK
5.4.7	**Minimisation of risk of electrocution**	Reduction in risk to life during a flood due to electrocution	0	3	3	2	3	3	0	1	0	3	3	21	1
5.4.8	**Reduce failure of sewerage system**	Ensures sewerage working during floods	0	3	3	3	-1	0	3	1	2	3	3	20	2
5.5.1	**Improve flood warning**	Ensures maximum possible warning time is available to minimise damage and enable safe evacuation	0	3	1	3	3	3	0	1	0	3	3	20	2
5.5.3	**Undertake a flood awareness program**	Council and SES to provide information to residents.	0	3	3	2	2	2	0	3	0	2	2	19	4
5.6.1	**Include mine subsidence in flood related development controls**	Ensures mine subsidence will be considered when establishing floor level controls	0	3	1	1	3	3	0	0	0	3	3	17	5
5.5.2	**Flood emergency management**	Ensures optimal management of flooding when it occurs	0	0	1	2	2	2	0	3	0	2	3	15	6
5.4.4	**Limit extent of development into floodplain**	Ensures flood problem is not exacerbated	0	0	2	-1	3	3	0	0	-2	3	3	11	7
5.4.4 5.4.5	**Ensure adequate access during floods**	Reduces the risk to life	0	3	-2	3	1	-2	0	3	-1	3	3	11	7
5.4.6	**Modification of S 149 certificate**	Ensures up to date advice is provided to property owners	0	0	0	0	2	3	0	0	0	3	3	11	7
5.4.6	**Provide flood hazard information on the web**	Ensures property owners can quickly obtain accurate information	0	0	0	0	2	3	0	0	0	3	3	11	7
5.4.1	**House raising**	Available to all suitable flood prone homes	0	3	1	1	1	0	0	1	0	1	2	10	11
5.4.2	**Flood proofing for old and new development**	Generally for non-residential development such as commercial development which may have lower floor levels. Can be enforced through Council policies and development controls.	0	3	2	1	2	1	0	0	-1	1	1	10	11
5.6.2	**Flood Insurance**	Does not reduce flood damages but transforms the random sequence of losses into a regular series of payments	0	2	2	-2	1	1	0	0	-1	3	3	9	13
5.6.3	**Adaptation to sea level rise**	Control future development, mitigate impacts to existing developments and assess impact on provision of services and maintenance of infrastructure	2	3	-2	0	2	-3	0	1	-2	3	3	7	14
5.3.4	**Local drainage issues**	Improve drainage in local area	0	0	2	1	0	0	0	0	0	2	0	5	15
5.4.3	**Voluntary purchase**	Removal of properties from high hazard floodways is the only way to reduce flood risk to the occupants.	1	1	2	-1	-3	-1	0	1	-1	3	2	4	16
5.3.1	**New levee on Doree Place**	To reduce overbank inundation	0	2	1	3	-1	-2	0	0	-1	1	0	3	17

Report Ref	OPTION	COMMENT	Impact on Flood Behaviour	Number of Properties Benefitted	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental\ Ecological Benefits	Impact on SES	Political / Admin Issues	Long Term Performance	Risk to Life	TOTAL	RANK
5.4.5	**Rezoning of flood liable lands**	Ensures flood problem is not exacerbated	0	0	3	-3	0	0	0	0	-3	3	0	0	18
5.3.1	**Kalang Road diversion levee**	Measure considered previously to reduce velocities	0	3	-2	-1	-3	-3	0	1	0	2	1	-2	19
5.4.4	**On Site Detention**	Mitigate effects of urbanisation	0	0	-1	2	-1	0	0	0	0	-2	0	-2	19
5.4.4	**Filling in the floodplain.**	Raising flood prone ground to above the flood level to allow for development. Has implications on flood behaviour	-3	0	0	0	0	0	-2	1	-2	1	3	-2	19
5.3.2	**Dredging**	Reduce flood levels	3	3	-2	1	-3	-3	-3	0	-2	-3	0	-9	22
5.3.2	**Channel modifications**	Measures such as dredging, channelisation, vegetation removal or straightening to increase the hydraulic conveyance	3	3	-3	0	-3	-3	-3	0	-3	-3	0	-12	23
5.3.3	**Provision of floodways**	Create an efficient overland flowpath to divert floodwaters into the lake	1	3	-2	0	-3	-3	-3	0	-2	-3	0	-12	23

1.3. Flood Risk Management Measures in Plan

The recommended measures are described below (according to the ranking in Table 3). Several of the measures were also included in the 2012 Lake Macquarie Waterway Flood Risk Management Study and Plan (Reference 8).

The priority rating for implementation (High, Medium, Low) is based upon a qualitative assessment of the rankings in Table 3 (shown in brackets below) and the ease of implementation (availability of funds, responsibility etc.). Thus, a measure with a high rank in Table 3 will not necessarily be a high priority measure for implementation as for example, funds may not be available.

HIGH Priority

1. **(Rank 1) Review how the risk of electrocution during floods can be further minimised through additional controls, awareness programs or retro fitting of safety measures.**
    - **Cost:** low
    - **Responsibility:** Council
    - **Timeframe:** by the year 2017

2. **(Rank 2=) Undertake measures to reduce the likelihood of failure of the sewerage system during floods.**
    - **Cost:** unknown
    - **Responsibility:** Council and Hunter Water
    - **Timeframe:** by the year 2018

3. **(Rank 2=) Undertake a review of the flood warning system and update as necessary (currently underway in 2014/15).**
    - **Cost:** low - moderate
    - **Responsibility:** Council, Manly Hydraulics Laboratory and the Bureau of Meteorology
    - **Timeframe:** by the year 2015

4. **(Rank 4) Continue with on-going flood awareness programs.**
    - **Cost:** low
    - **Responsibility:** Council and SES
    - **Timeframe:** on-going

5. **(Rank 5) Assess the possible implications of mine subsidence in the area for flood related development controls.**
    - **Cost:** low
    - **Responsibility:** Council and Mines Subsidence Board
    - **Timeframe:** by the year 2018

Medium Priority

1. **(Rank 6) Inform the SES of the outcomes of this Plan and the possible implications for flood evacuation. As appropriate the SES should update their Flood Plan.**
    - **Cost:** low
    - **Responsibility:** Council and SES
    - **Timeframe:** by the year 2017

2. **(Rank 7=) Develop or amend the existing flood related development controls as detailed in this Study for the proposed development areas.**
    - **Cost:** minor
    - **Responsibility:** Council
    - **Timeframe:** by the year 2016

3. **(Rank 7=) Ensure adequate access during floods.**
    - **Cost:** will depend on works required
    - **Responsibility:** Council
    - **Timeframe:** by the year 2016

4. **(Rank 7=) Revise Section 149 certificates, development restriction certificates and flood control lot certificates to incorporate revised flood planning levels and a new permanent inundation planning level.**
    - **Cost:** low
    - **Responsibility:** Council
    - **Timeframe:** by the year 2015

5. **(Rank 7=) Make flood hazard information available on Council's web site.**
    - **Cost:** low
    - **Responsibility:** Council
    - **Timeframe:** by the year 2016

6. **(Rank 11=) Evaluate whether a house raising scheme or similar will be supported by the community and is a practical adaptation measure for sea level rise and if so establish such a scheme.**
    - **Cost:** low to evaluate. Approximately $70,000 to raise a non-brick house, but highly variable
    - **Responsibility:** Council and local community
    - **Timeframe:** by 2016

7. **(Rank 11=) Evaluate whether a flood proofing scheme or similar for non residential buildings will be supported by the community and is a practical adaptation measure for sea level rise and if so establish such a scheme.**
    - **Cost:** low to evaluate
    - **Responsibility:** Council and local community
    - **Timeframe:** by 2016

8. **(Rank 13) Ensure that the Insurance Council of Australia is informed of any available flood related information.**
    - **Cost:** low for Council
    - **Responsibility:** Council and Insurance Council of Australia
    - **Timeframe:** by 2016

9. **(Rank 14=) Undertake a detailed assessment (Local Area Adaptation Plan) for the foreshore area likely to be subject to sea level rise, in consultation with the community, of the implications and adaptation measures available to plan for and mitigate the effects of sea level rise (flooding and tidal inundation) as proposed in the Lake Macquarie Waterway Flood Risk Management Study and Plan.**
    - **Cost:** moderate
    - **Responsibility:** Council
    - **Timeframe:** aim to complete priority areas by the year 2020

10. **(Rank 14=) Review strategic land use planning to accommodate adaptation to changed flooding and inundation due to sea level rise. The review should include suitable development densities and types, possible need for retreat areas, future protection and adaptation of foreshore ecosystems, foreshore access and recreation, foreshore community facilities, and land required for infrastructure and protection works.**
    - **Cost:** moderate
    - **Responsibility:** Council and NSW Government
    - **Timeframe:** by the year 2017

11. **(Rank 14=) Undertake a detailed review of the provision and maintenance of services and infrastructure on flood liable lands downstream of the railway line with a 0.4m and 0.9m sea level rise.**
    - **Cost:** moderate
    - **Responsibility:** Council and other service providers
    - **Timeframe:** by the year 2017 and/or in conjunction with development of local area adaptation plans above

12. **(Rank 14=) Establish criteria to define what may make land “unsuitable” for current or proposed future use due to permanent inundation, and appropriate management response.**
    - **Cost:** moderate
    - **Responsibility:** Council
    - **Timeframe:** by the year 2017 and/or in conjunction with development of local area adaptation plans in above

13. **(Rank 14=) Develop or adopt financial models to prepare for future costs of possible protection works, infrastructure up-grades, relocations, and other adaptation options.**
    - **Cost:** moderate
    - **Responsibility:** Council and other service providers
    - **Timeframe:** by the year 2019

14. **(Rank 14=) Undertake a review of the suitability of slab on ground construction in the foreshore areas and whether other forms of building construction can be undertaken that would reduce flood hazard and/or allow future adaptation such as house raising.**
    - **Cost:** low - moderate
    - **Responsibility:** Council and NSW Government
    - **Timeframe:** by the year 2018

15. **(Rank 15) Ensure that ongoing local drainage problems are addressed, in accordance with Council's ability to fund such works.**
    - **Cost:** moderate
    - **Responsibility:** Council and local residents
    - **Timeframe:** ongoing

LOW Priority

1. **(Rank 16) Undertake a Voluntary Purchase Scheme**
    - **Cost:** significant
    - **Responsibility:** Council and OEH
    - **Timeframe:** may take many years

2. **(Rank 17) Construct the Doree Place levee at the same time as road works undertaken.**
    - **Cost: $50,000**
    - **Responsibility: Council**
    - **Timeframe: by the year 2025**

3. **(Rank 18) Rezone flood liable land to a more flood compatible usage.**
    - **Cost:** significant cost to existing land owners
    - **Responsibility:** Council, local residents
    - **Timeframe:** by the year 2030

4. **(Rank 19=) Construct a levee bank at Kalang Road to divert floodwaters away from the houses.**
    - **Cost:** over $1million
    - **Responsibility:** Council
    - **Timeframe:** by the year 2030

5. **(Rank 19=) Continue to implement an On Site Detention scheme to mitigate the increase in flows due to urbanisation.**
   - **Cost:** minor
   - **Responsibility:** Council
   - **Timeframe:** ongoing

2. INTRODUCTION

2.1. Background

The Dora Creek catchment is located on the western side of Lake Macquarie waterway, 30 km south-west of Newcastle and 120 km north of Sydney. Dora Creek has a catchment area of approximately 238 km^2 and is the largest catchment flowing into the Lake Macquarie waterway which has a total catchment of 648 km^2 (Figure 1 and Figure 2). The study area is shown on Figure 2 with the 2014 land use zones shown on Figure 3.

All parts of Dora Creek and its tributaries have experienced flooding in the past and Council has undertaken flood related studies in accordance with the NSW Government's 2005 Floodplain Development Manual (Reference 1). The current suite of studies supersede those previously undertaken.

2.2. Objectives

Council engaged WMAwater (formerly Webb, McKeown & Associates) to review the 1992 Dora Creek Floodplain Risk Management Study and 1998 Plan (References 2 and 3) in light of the NSW Government's benchmarks for sea level rise as well as guidelines for rainfall intensity increases (*Flood Risk Management Guide* – Reference 4 and *Floodplain Risk Management Guideline – Practical Consideration of Climate Change* – Reference 5).

The objectives of the Study are to identify and compare various management options, including an assessment of their social, economic and environmental impacts, together with opportunities to enhance the foreshore environments. The outcomes are provided in the Plan which has the primary aim to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk at this time and as a result of potential climate change. This review combines and updates the previous 1992 Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options (Reference 2) and 1998 Plan (Reference 3) into one document.

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

2.3. Floodplain Risk Management Process

2.3.1. Process

As described in the 2005 NSW Government's Floodplain Development Manual (Reference 1), the Floodplain Risk Management Process entails four sequential stages:

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

The 2015 Dora Creek Flood Study (Reference 6) has been undertaken in accordance with the first stage of the management process and involves a review of the 1986 Dora Creek Flood Study (Reference 7), to include the more recent data and incorporate the implications of climate change.

This document provides a review of the 1992 Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options and 1998 Plan (References 2 and 3) which constitutes the second and third stages in the process.

2.3.2. Terminology

Annual Exceedance Probability (AEP) is expressed using percentage probability. It expresses the probability that an event of a certain size or larger will occur in any one year, thus a 1% AEP event has a 1% chance of being equalled or exceeded in any one year. For events smaller than the 10% AEP (1 in 10 year) event however, an annualised exceedance probability can be misleading, especially where strong seasonality is experienced. Consequently, events more frequent than the 10% AEP (1 in 10 year) event are expressed as X Exceedances per Year (EY).

While AEP has long been used for larger events, the use of EY is to replace the use of Average Recurrence Interval or ARI, which has previously been used in smaller magnitude events. The use of ARI which indicates the long term average number of years between events, is now discouraged. It can incorrectly lead people to believe that because a 100-year ARI (1% AEP) event occurred last year it will not happen for another 99 years. For example there are several instances of 1% AEP (1 in 100 year) events occurring within a short period such as the 1949 and 1950 events at Kempsey, NSW.

The PMF is a term also used in describing floods. This is the Probable Maximum Flood that is likely to occur. It is related to the PMP, the Probable Maximum Precipitation.

This report has adopted the above approach and uses % AEP for all events greater than the 10% AEP (1 in 10 year) and EY for all events smaller and more frequent than this.

2.4. History of Flooding

Flooding within the Dora Creek and Cooranbong townships occurs following heavy rainfall where flows in excess of channel capacities results in overbank flooding. Within the lower reaches of Dora Creek, flooding may also be influenced by high water levels in Lake Macquarie waterway.

The dates of all known significant floods in the Dora Creek catchment are shown in Table 4.

Table 4: Significant Floods in the Dora Creek catchment

April 1927	February 1981
June 1949	April 1983
1953	1985
1962	1988
1963	June 1989
June 1974	February 1990
February 1975	August 1990
June 1975	April 1992
March 1977	June 2007
March 1978	

There are four water level gauges in the study area (Figure 2) that provide a historical record of flooding as well as extensive peak height records collected over the years by Council. Daily read and continuous rainfall (pluviometers) gauge provide a record of the historical rainfall producing flooding in the catchment. This information is described in detail in the 2015 Dora Creek Flood Study (Reference 6) and the design flood extents across the study area are shown on Figure 4.

The dates and approximate peak lake levels of all known significant floods in Lake Macquarie waterway are shown in Table 5. According to the 2012 Lake Macquarie Waterway Flood Study (Reference 8) the February 1990 and June 2007 long weekend events were both less than a 5% (1 in 20 year - 1.23 m AHD) AEP event in the Lake Macquarie waterway. It should be noted that the design magnitude of a historical flood will vary across a region. For example near Newcastle the June 2007 long weekend event exceeded a 1% (1 in 100 year - 1.50 m AHD in Lake Macquarie waterway) AEP event.

Table 5: Significant Flood Events on Lake Macquarie Waterway

Date (in order of severity)	Approximate Peak Lake Level (m AHD)
18 June 1949	1.25
April 1946	1.20
11 June 1930	1.10
9 June 2007	1.05
2 May 1964	1.00
4 February 1990	1.00
1953	0.90
1926/27	0.80
25 February 1981	0.80
May 1974	0.80
4 March 1977	0.70

Notes: Data obtained from the 2012 Lake Macquarie Flood Study - Reference 8.
Levels are an average of several recorded heights.
It is likely that several floods prior to 1970 may not have been recorded.

2.5. Council's Flood Policy

Council has had a development control policy for flood liable land for over 30 years. It has varied over those years in response to more information becoming available and as a reflection of NSW Government policy.

The policy as documented in the Council report of 6 April 1998 states:

- *habitable rooms to be a minimum 500 mm above the 1:100 year flood levels for still water conditions,*
- *non-habitable rooms to be at or above the 1:20 year flood level,*
- *commercial rooms to be a minimum 500 mm above the 1:100 year flood level,*
- *boat sheds to be constructed at the approved filling level if applicable, otherwise at the natural surface level,*
- *floors of industrial buildings to be constructed at or above the 1:100 year flood level,*

At particular locations, Council requires the applicant to provide a report from an appropriate Consulting Engineer, showing:

- *1:100 year flood levels allowing for the effects of wind/wave action, at the site of the proposed development,*
- *that the proposed development is capable of withstanding the effects of the wind/wave action associated with a 1:100 year flood.*

In 2008 Council applied new flood planning levels to these development criteria, for those properties subject to inundation from elevated water levels in Lake Macquarie waterway, to incorporate the predicted effects of sea level rise of 0.4m and 0.9m relative to the 1990 levels.

2.6. Related Issues

- The SES has prepared (April 1996) a comprehensive Local Flood Plan (a sub-plan of the Local Disaster Plan).
- Council's Sea Level Rise Policy and interim development assessment procedure has been applied to new developments since 2008 with no significant objection from developers or legal challenges.
- Council's Section 149 Certificate advises landowners if Council has a policy that imposes a development control on the Lot by reason of the likelihood of flooding. Since mid-2009, this includes consideration of the future effect of flooding and tidal inundation on properties exposed to elevated water levels in Lake Macquarie waterway. This notice is placed on all foreshore lots where any part of the land is below the 3 m AHD contour.
- Council is not aware of any quantitative flood damage data or complaints with respect to wind/wave activity.
- Council will provide (for a fee) a Flood Certificate (for catchment floods) and a Flood/Tidal Certificate (lake foreshore properties up to 3 m AHD). This certificate provides flood information including Council's flood planning level requirements, a survey of the existing buildings and grounds and whether existing buildings comply with Council's present floor height policies.
- Council will provide (for a fee) a Flood Control Land Certificate advising whether complying development may be undertaken under the Exempt and Complying Development Codes State Environmental Planning Policy.

In the past Council has issued Flood Awareness leaflets. Currently definitive flood information is only provided to landowners via the Flood Certificate and Flood/Tidal Certificate.

2.7. Previous Studies

A number of previous flood related studies have been undertaken within the Dora Creek catchment; many of which are relevant to this study. The following sections provide a review of these studies and identifies key points relevant to this study. The studies range from detailed drainage studies to management studies, the most relevant are:

- 1986 Dora Creek Flood Study, PWD (Reference 7);
- 1991 Dora Creek Floodplain Management Study – Hydraulic Analysis of Subdivision Options, PWD (Reference 10);
- 1992 Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options, PWD (Reference 2);
- 1994 Dora Creek, Kalang Road: Two Dimensional Study and Preliminary Design of a Flood Deflector, Patterson Britton & Partners (Reference 13);
- 1998 Dora Creek Floodplain Management Plan, DLWC (Reference 3);
- 2000 Dora Creek Floodwatch System Development and Operation, MHL (Reference 11);
- 2007 Development of a Local Response Plan for Dora Creek, SES (Reference 12);
- 2012 Lake Macquarie Waterway Floodplain Risk Management Study and Plan,

WMAwater (Reference 9);
- 2015 Dora Creek Flood Study, WMAwater (Reference 6).

Most of the previous studies above that relate to determining design flood levels have been summarised in the 2015 Dora Creek Flood Study, (Reference 6). Those which have not, or are of particular importance to this management study are detailed below.

The past studies have all generally focused on similar floodplain management measures and these are summarised on Figure 5.

2.7.1. 1991 Dora Creek Floodplain Management Study – Hydraulic Analysis of Subdivision Options (Reference 10)

This study was commissioned by Council to investigate the hydraulic impacts and estimate damage costs resulting from various development options to assist Council in determining subdivision options within the floodplain of Lower Dora Creek.

This study revised 1% AEP (1 in 100 year) design discharges from the 1986 Dora Creek Flood Study (Reference 7), based on the 1987 edition of Australian Rainfall and Runoff. Existing flood behaviour was defined using a MIKE 11 hydraulic model. The impact of the revised 1% AEP (1 in 100 year) flood on existing development at the time of the study within the Lower Dora Creek floodplain area was summarised as:

- up to 180 houses and 11 commercial properties would be inundated above floor level by floodwaters;
- up to 120 houses could be in an area of high hazard; and
- up to 90 houses are in areas where structural damage could occur to houses of inappropriate construction.

The study estimated the total potential annual average flood damage to be $111,880 ($1991) with a potential annual average damage of $315 per property ($1991).

The study identified the most hazardous environment in the study area was located close to Dora Creek along Kalang Road, with light framed houses being potentially liable to structural damage due to the combination of high inundation depths and velocities.

Once existing flood liability was established, a number of development options were assessed and their impact on flood levels and flood damages are summarised in Table 6.

Table 6: Impact of Development Options Considered in the 1991 Dora Creek Floodplain Management Study – Hydraulic Analysis of Subdivision Options (Reference 10)

No.	Description	Maximum Impact on Flood Levels (m)	Change in Potential AAD ($1991)
1	Fully infilling floodplains at Kalang Road, Minnie Street (excluding existing floodway), Baker Street, Dora Street and Stingaree Point Drive	0.04 – 0.12	$19,644
2	Infilling of only half the floodplain areas defined in Option 1	0.02 – 0.06	$7,916
3	Fully infilling floodplains at Baker Street, Minnie Street (excluding the existing floodway), Dora Street and Stingaree Point Drive	0.04 – 0.12	$18,723
4	Infilling of only half the floodplain areas defined in Option 3	0.02 – 0.06	$8,819

2.7.2. 1992 Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options (Reference 2)

In this study the design discharges and hydraulic modelling undertaken as part of the 1991 Floodplain Management Study (Reference 10) were adopted in order to investigate several flood mitigation options. Council proposed the following structural and non-structural flood mitigation options for investigation:

A. Lowering of the Dora Creek bank opposite Kalang Road at “Miracle Haven”;
B. Dredging of Dora Creek and assessment of the long term effects on flood levels;
C. Provision of a diversion channel to the lake;
D. Review Council controls on development at Kalang Road;
E. A voluntary purchase scheme for properties in Kalang Road;
F. Provision of a flood free access roadway from Baker Street to Moira Park Road, along the western side of the Great Northern Railway;
G. Provision of a diversion levee upstream of Kalang Road to direct overbank flood flow back into Dora Creek;
H. Implementation of a flood warning system, and
I. A voluntary house raising scheme for suitable timber and fibro houses.

The study found that Option F, G, H and I provided a better hydraulic solution for reducing flood hazard and damage and recommended that Council should develop suitable planning and building controls.

2.7.3. 1994 Dora Creek, Kalang Road: Two Dimensional Study and Preliminary Design of a Flood Deflector Levee (Reference 13)

Following the findings of the 1992 Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options (Reference 2) Council commissioned investigations into the hydraulic implications of constructing an earth fill deflector levee immediately upstream of Kalang Road, Dora Creek. The objective of the levee was to reduce flood velocities in the vicinity of the houses along Kalang Road.

Patterson Britton & Partners established a two dimensional finite element model 123DFE (a version of RMA) in lower Dora Creek. This hydraulic model was used to assess three deflector levee options:

1. Locating the levee so that it bisected the wetlands to the south-west of Kalang Road. The eastern tip was directed at right angles to the main channel;
2. Curving the eastern tip of the levee so that the deflected flow could enter the main channel more tangentially with the body of the levee to be constructed around the wetland area;
3. Modification of Option 2 above so that the main arm of the levee was modified so as to align flows more parallel to those in Dora Creek.

Results of each levee option assessed in Reference 13 are presented in Table 7. None of the options were found to reduce flood depths along Kalang Road; however all of the options produced a reduction in flood velocities.

Table 7: Comparison of Levee Options (Table 4.1 in Reference 13)

Option	No levee	Option 1 Levee	Option 2 Levee	Option 3 Levee
Downstream Velocities (m/s)				
• Typical velocity along Kalang Road	0.6-0.8	<0.1	0.1-0.2	0.1
• Typical velocity near most upstream house	0.6-0.8	0.6	0.2	0.4
• Typical velocity in main channel adjacent to levee	1.9	2.5	2.4	2.3
• Typical velocity at opposite bank of channel adjacent to levee	2.0	2.8	2.5	2.4
Formation of Eddy off Levee Tip	NA	Yes	No	Yes
Upstream Water Levels (m AHD)				
• 300 m upstream of levee (farmhouse # 1)	3.22	3.41	3.31	3.29
• 600 m upstream of levee (farmhouse #2)	3.29	3.44	3.34	3.33

A key concern with all levee options was the increase in flood levels upstream. A preliminary design of the deflector levee was undertaken with an estimated cost of $590,000 ($1994 or $1,032,000 in $2014). Protection to a 5% AEP (1 in 20 year) flood level was costed as $500,000 ($1994 or $875,000 in $2014).

Subsequent studies by Umwelt Australia in 2004-2005 reported on the outcomes of a community consultation program. The outcome of which was that the deflector levee proposal should not be continued due to negative environmental and social impacts, and negative community response to the proposal. It is understood that since 2005 no further work on this proposal has been undertaken.

2.7.4. 1998 Dora Creek Floodplain Management Plan (Reference 3)

The 1998 Floodplain Management Plan (Reference 3) assessed and recommended options considered in the 1992 Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options (Reference 2) for adoption by Council. These options were intended to protect existing development from flooding and to ensure that any new development would be reasonably protected from flooding and would not have major adverse impacts on existing development.

Structural options considered included:

- dredging of Dora Creek;
- a diversion channel to Lake Macquarie waterway; and
- a diversion levee upstream of Kalang Road.

Dredging and the channel diversion were not recommended due to the low benefit-cost ratio, however the diversion levee was found to have merit because it would reduce flood velocities and hazard to existing development in the Kalang Road area (a benefit/cost ratio was not provided).

Non-structural options considered included:

- flood warning and evacuation planning;
- an alternative road access for evacuation of the Baker Street area;
- voluntary purchase of properties in Kalang Road;
- voluntary house raising;
- planning and development controls.

A voluntary purchase scheme for Kalang Road was considered to not be cost effective and unlikely to achieve acceptance by residents of the area. The other non-structural measures were considered to have merit.

The Plan assessed areas with potential for future development within the floodplain, including subdivision. Some of the key outcomes are listed below:

- options which involve intensive residential development along both sides of the creek would lead to significant flood level increases;
- subdivision of areas east of the main north railway to a minimum lot size of 700 m^2 would be likely to cause only small increases in flood level provided there are appropriate controls to limit obstructions to overland flow paths;
- any proposals to change the use of non-urban land to the south side of Dora Creek and east of the railway would need to be assessed by specific studies;
- further subdivision of residential areas west of the railway line was prohibited;
- non-urban areas south of Baker Street and west of Kalang Road function as flood storage areas and any proposals to change the use of these areas would need to be assessed by specific studies.

A flood warning system was recommended and would use pre-determined relationships between catchment rainfall and flood levels at Dora Creek to issue flood alerts. The warning system would provide the SES and Council personnel predictions of flood behaviour during actual events.

The study recommended that a sounding survey within Dora Creek be continued and that if future siltation is found to increase flood levels compared to existing conditions, a detailed study of sediment transport and remedial options should be undertaken.

The key measures proposed by the Floodplain Management Plan are listed in Table 8 along with implementation costs.

Table 8: Key Measures Recommended in the 1998 Dora Creek Floodplain Management Plan (Reference 3)

Key Measure	Estimated Cost ($1998)
Flood forecasting system feasibility study	$20,000
Flood awareness and public education program	$10,000
Flood access roadway from Baker Street	$200,000
Diversion levee upstream of Kalang Road	$700,000
Voluntary house raising	$1,080,000
Amend floodway designations on map	-
Amend S149 Planning Certificates	-
Amend Local Environmental Plan	-
Prepare Development Control Plan for Flooding	-
TOTAL	**$2,010,000**

2.7.5. 2000 Dora Creek Floodwatch System Development and Operation (Reference 11)

One of the strategies recommended in the 1998 Floodplain Management Plan (Reference 3) was the implementation of a flood warning system for Dora Creek. Manly Hydraulics Laboratory (MHL) was commissioned by Council to implement a flood warning system for Dora Creek similar to the ones installed at Narrabeen and Manly Lagoons in Sydney.

The Floodwatch system included the following components:

- real time data acquisition and presentation;
- flood level simulations of actual and predicted rainfall, and;
- alarm facilities.

The existing real time data sources included five water level recorders, three rainfall gauges as well as ocean tide and wave data. The report recommended that funding of these be continued.

The Floodwatch system uses real-time rainfall, water level and ocean tide data as input into a numerical model used to predict water levels for the next 12 hours. A hydrologic model

(WBNM) was set up for the Dora Creek catchment and used to calculate lake and creek water levels. The model was verified using rainfall and water level data from the July 1988, February 1990, August 1990, August 1998 and July 1999 storm events.

The Floodwatch model automatically scans data recorders at 6:00 am each day and runs the model. The model may be manually run at any time. The system was set up to issue automatic alarms when nominated threshold levels are exceeded.

The report recommended that the Floodwatch model could be improved by additional calibration and also by:

- improvement of the Lake Macquarie waterway flood model via improved hydrologic modelling of the areas outside of the Dora Creek catchment;
- more rainfall and water level stations to realise uncertainty of spatial rainfall distribution;
- production of rating curves for Stockton and Cooranbong sites to allow a self calibrating model;
- recalibrate model with data from future storms;
- improvement of the Kalang Road hydraulic model;
- development of optimising techniques for self-calibration.

2.7.6. 2007 Development of a Local Response Plan for Dora Creek (Reference 12)

In 2007 the NSW State Flood Plan was under revision and resulted in the commission of this investigation into the flood threat within the Cooranbong operational area, specifically the Dora Creek floodplain.

The study used Figure L1 of the Floodplain Development Manual (Reference 1) in order to determine the depths at which vehicles would become unstable. As the 1986 Dora Creek Flood Study (Reference 7) and the 1991 Dora Creek Floodplain Risk Management Study - Hydraulic Analysis of Subdivision Options (Reference 10) did not record velocities of Dora Creek as a function of height and location, velocity estimates were made. Results are reproduced in Table 9 with H_R being the road height, H_{UV} being the depth at which vehicles would become unstable and H_{RUV} is the water height when vehicles become unsafe.

Table 9: Vehicular Safety Adjacent to Dora Creek and Stockton Creek (Table 5 in Reference 12)

Location	H_R - Road height (m AHD)	H_{UV} - depth at which vehicles unstable (m)	H_{RUV} - water level when vehicles unstable (m AHD)
Baker Street under Dora Creek Railway Bridge	0.70	0.10	0.80
Evacuation Road Entrance	1.15	0.30	1.45
Kalang Road	1.20	0.10	1.30

Flow and water level results from the 1986 Dora Creek Flood Study (Reference 7) and the 1991 Dora Creek Floodplain Risk Management Study - Hydraulic Analysis of Subdivision Options (Reference 10) were used to derive a rating curve under the Dora Creek railway bridge and the flow corresponding to each critical water level estimated along with an approximate time of inundation.

The report outlined an emergency response plan for flood evacuation, with an estimated time for evacuation of 2.5 hours at Baker Street.

2.7.7. 2012 Lake Macquarie Waterway Flood Risk Management Study and Plan (Reference 9)

Council engaged WMAwater to review the 2000 Lake Macquarie Flood Risk Management Study and 2001 Plan in light of the NSW Government's benchmarks for sea level rise as well as guidelines for rainfall intensity increases. The study made several recommendations for climate change adaptation and these include:

- Undertake a detailed assessment (Local Area Adaptation Plans) for each foreshore management area, in consultation with each affected community, of the implications and adaptation measures available to plan for and mitigate the effects of sea level rise (flooding and tidal inundation);
- Undertake a detailed review of the provision and maintenance of services and infrastructure in the foreshore areas with a 0.4m and 0.9m sea level rise;
- Establish criteria to define when land becomes "unsuitable" for current or proposed future use due to permanent inundation;
- Review the wording on the Section 149 certificates, development restriction certificates and flood control lot certificates to incorporate revised flood planning levels and new permanent inundation planning level;
- Review strategic land use planning to accommodate adaptation to changed flooding and inundation due to sea level rise. The review should include suitable development densities and types, possible need for retreat areas, future protection and adaptation of foreshore ecosystems, foreshore access and recreation, foreshore community facilities, and land required for infrastructure and protection works;
- Develop or adopt financial models to prepare for future costs of possible protection works, infrastructure up-grades, relocations, and other adaptation options;
- Undertake a review of the suitability of slab on ground construction in the foreshore areas and whether other forms of building construction can be undertaken that would reduce flood hazard and/or allow future adaptation such as house raising;
- Review Council's policy "Caravan Parks on Flood Prone Lands Surrounding Lake Macquarie Waterway (2005)" for caravan and cabin parks in the foreshore area;
- Evaluate whether a house raising scheme or similar will be supported by the community and is a practical adaptation measure for sea level rise and if so establish such as scheme.

These above recommendations are currently being implemented as part of the 2012 Lake Macquarie Waterway Flood Plan and were therefore not covered in the current study.

Other recommendations of the study include:

- Assess the possible implication of mine subsidence in the area for flood related development controls;
- Undertake a review of the flood warning system and if necessary update;
- Inform the SES of the outcomes of this Plan and the possible implications for flood evacuation. If necessary the SES should update their Flood Plan;
- Ensure that ongoing local drainage problems are monitored and addressed, in accordance with Council's ability to fund such works;
- Monitor any changes to the sedimentation and erosion regime in the Swansea channel.

Of these, review of the flood warning system, mine subsidence and the assessment of flood evacuation are relevant to the current Dora Creek Floodplain Management Study.

2.7.8. 2015 Dora Creek Flood Study (Reference 6)

The 2015 Dora Creek Flood Study (Reference 6) provides the most up to date information on design flood behaviour. This report was undertaken to update the previous 1986 Dora Creek Flood Study (Reference 7).

The main reasons for updating the hydraulic modelling approach were as follows:

- use of a two-dimensional (2D) hydraulic model rather than the one dimensional (1D) model used previously;
- availability of detailed bathymetric data of lower Dora Creek to better describe the bed of the channel rather than the use of cross sections used in previous studies;
- availability of Airborne Laser Scanning (ALS) or LiDAR survey that provides a very accurate definition of the topography of the floodplain;
- detailed field survey of the major river crossings;
- field survey of the channels that could not be picked up by ALS;
- incorporation of data for the February 1990, and June 2007 long weekend events in the calibration process;
- to assess the potential impacts of climate change.

The adopted approach was to establish a TUFLOW 1D/2D hydraulic model based on the available bathymetric and ALS survey with inflows from a WBNM hydrologic model. A calibration/verification was undertaken to the March 1977, February 1981, June 1989, February 1990, June 2007 long weekend and February 2013 events by matching the model results to the gauged water level / flow data as well as to the recorded peak levels. Design flood analysis using the calibrated WBNM/TUFLOW models was verified against flood frequency analysis at the Jigadee Creek gauge.

Sensitivity analysis and blockage assessments were undertaken to assess the effects of varying key model parameters. In addition analysis of the effects of a sea level rise elevating the adopted design water levels in Lake Macquarie waterway and an increase in design rainfall intensities were undertaken.

2.8. Summary of Floodplain Management Measures Considered in Previous Studies

Flood mitigation measures from the following reports were considered and the recommended options are summarised in Table 10:

- 1992 Dora Creek Floodplain Management Study (Reference 2);
- 1994 Dora Creek, Kalang Road Study (Reference 13);
- 1998 Dora Creek Floodplain Management Plan (Reference 3);
- 2000 Dora Creek Floodwatch System Study (Reference 11);
- 2007 Development of a Local Response Plan for Dora Creek (Reference 12);
- 2012 Lake Macquarie Waterway Floodplain Risk Management Study and Plan (Reference 9).

Table 10: Floodplain Management Measures Considered in Previous Studies

Option	Have the works been undertaken?	Reference
Lowering of the Dora Creek bank opposite Kalang Road at "Miracle Haven"	No	Reference 2
Dredging of Dora Creek and assessment of the long term effects on flood levels	No dredging undertaken	Reference 2
Provision of a diversion channel to the lake	No	Reference 2
Review present Council controls on development at Kalang Road	Yes	Reference 2
Voluntary purchase scheme for properties in Kalang Road	Scheme initiated but no houses purchased	Reference 2
Provision of a flood free access roadway from Baker Street to Moira Park Road along the western side of the Great Northern Railway	Completed in May 2005 by Council	Reference 2 Reference 3
Provision of a diversion levee upstream of Kalang Road to direct overbank flood flow back into Dora Creek	No due to negative environmental and social issues.	Reference 2 Reference 3 Reference 13
Flood warning system	Dora Creek Floodwatch has been operating since October 2001 and further review of it is currently underway by MHL.	Reference 2 Reference 3 Reference 9
A voluntary house raising scheme for timber and fibro houses	Two houses raised in 2004 and program suspended due to lack of funding from NSW Government.	Reference 2 Reference 3
Sounding survey within Dora Creek be continued to assess levels of sedimentation	Recent bathymetric survey undertaken 2010 - 2012 but no review of sedimentation.	Reference 3
Flood awareness and public education program	Implemented in 2001 with continued work on flood awareness including: public workshops; community door knocks and a meeting of the Dora Creek Flood Safety Focus Group with Council and SES in 2013. The Sustainable Neighbourhood	Reference 3

Option	Have the works been undertaken?	Reference
	group is actively working on climate change and flood awareness activities.	
Amend floodway designations on Council's maps	Amended in DCP1 in March 2004 and revised as part of the 2015 Dora Creek Flood Study (Reference 6)	Reference 3
Amend S149 Planning Certificates	Yes in 1998 and will be revised based on outcomes of the present study	Reference 3 Reference 9
Amend Local Environmental Plan	Implemented in 2004 LEP and current revision of LEP in progress	Reference 3
Prepare Development Control Plan for Flooding	Implemented in DCP1 in March 2004	Reference 3
Inform the SES of the outcomes of the Plan and the possible implications for flood evacuation.	Yes	Reference 9 Reference 11 Reference 12

3. STUDY AREA

3.1. Land Use

Dora Creek is part of the Lake Macquarie waterway catchment within the Lake Macquarie local government area (LGA). Some key features of the Lake Macquarie LGA (www.lakemac.com.au) are:

- it is one of the fastest growing cities in the Hunter, and one of the largest cities in New South Wales;
- Lake Macquarie's population was estimated as 201,000 in March 2011;
- Lake Macquarie is the Hunter region's largest city, accounting for 37% of the Lower Hunter population;
- Lake Macquarie is the fourth most populous city in NSW, and the eighth most populous city in Australia;
- The population of Lake Macquarie is expected to grow by 60,000 to 70,000 people over the next 25 years, which will create a demand for 36,500 new dwellings;
- The percentage of population aged 55+ will increase from 29% to 39% of the total population over the next 20 years.

The land use (within the study area) comprises the full range of planning zones listed in the Lake Macquarie Local Environmental Plan 2014 (refer Figure 3).

A summary of the number of properties within the above land use zones and having some part of their property within the 2015 Dora Creek Flood Study (Reference 6) PMF and 1% AEP (1 in 100 year) and 1% AEP (1 in 100 year) High hazard extent is shown in Table 11. The High hazard definition is described in Section 4.3 and is based on the depth and velocity of the floodwaters. The remainder of the 1% AEP (1 in 100 year) floodplain is Low hazard.

Table 11: Number of Properties within Study Area in each Land Use Zone

Categories	No. in PMF	% in PMF	No. in 1% AEP (1 in 100 year)	% in 1% AEP (1 in 100 year)	No. in 1% AEP (1 in 100 year) High hazard	%. in 1% AEP (1 in 100 year) High hazard
Commercial	0	0%	0	0%	0	0%
Mixed Use	14	1%	14	1%	13	1%
Business	12	1%	3	0%	2	0%
National Parks and Environment	260	12%	240	15%	215	16%
Industrial	18	1%	14	1%	13	1%
Residential	1362	65%	941	60%	733	56%
Recreation	51	2%	51	3%	49	4%
Rural	291	14%	228	15%	214	16%
Tourist	0	0%	0	0%	0	0%
Others	89	4%	69	4%	68	5%
Total	2097		1560		1307	

The majority of use based on the number of properties and not land area is Residential (65% in the PMF). However based on land area the non-urban zones cover the larger land area.

3.2. Building Floors

Council provided a database of all buildings with surveyed floor levels located within the Dora Creek flood affected areas (Table 12). This database was an amalgamation of floors surveyed previously (approximately the year 2000) and as part of the present study (2013). The database was then extended to include all properties with a building on it that was likely to be inundated above floor level in the 1% AEP (1 in 100 year) event. Thus approximately 40 building floors in the database were estimated from available data as surveyed floor levels were not available.

Table 12: Surveyed Building Floors Located within Study Area

Dora St east of cooling channel	Stingaree Pt Dr east of cooling channel	Doree Pl & Douglass St area	Cowell Street	Baker Street	Newport Road area	Kalang Road	Stockton Creek	Upstream M1	TOTAL
134	75	130	58	89	54	45	20	78	683

The database provides a reasonable estimate of the number of floors inundated in the 1% AEP (1 in 100 year) but understates the number of floors inundated in greater events. The properties containing the building floors in the database are shown on Figure 6.

The adopted floor level was assumed to be the lowest habitable or commercial/industrial floor level. For two storey residential properties it is sometimes unclear whether the ground floor has been approved for habitation or not and thus the information in the database should be checked if this is of specific interest.

A single level is used as the basis of estimating external damages (yard, garage, vehicle damages). This level is typically the garage floor level but if this level was not available it was estimated from the available information. It should be noted that there may be lower areas of the property which will be inundated in a smaller event than the garage floor level.

3.3. Regional Development Strategy

The Lower Hunter Regional Strategy, released by the NSW Department of Planning in October 2006, is a strategy that guides planning in the five local government areas of Lake Macquarie, Newcastle, Port Stephens, Maitland, and Cessnock for the period 2006 to 2031 and is reviewed every 5 years. A summary of this strategy is provided in Table 13.

Table 13: Lower Hunter Regional Strategy

Area	Additional People	New Homes	New Jobs	Regional Centres	
Lower Hunter	160,000	115,000	66,000	6 major regional centres, 1 regional city	
Lake Macquarie	60,000	36,000	12,200	3 major regional centres, 6 main town centres, 2 renewal corridors	
Dwelling Capacity Projections					
Area	**Centres and Corridors**	**Urban Infill**	**Total Infill**	**New Release**	**Total Dwellings**
Lake Macquarie	14,000	7,000	21,000	15,000	36,000
Total for the Lower Hunter	32,000	16,000	48,000	69,200	117,200
Lake Macquarie as a % of the Lower Hunter	44%	44%	44%	22%	31%

The strategy highlights the risk of flooding and states that "*Future urban development will not be located in areas of high risk from natural hazards, including sea level rise, coastal recession, rising water table and flooding".*

Despite this statement, the pressure to accommodate an additional 36,000 new dwellings in the Council LGA by the year 2031 may mean that areas at future risk of flooding are considered for development. Any proposals in these areas must therefore carefully consider the impacts of future flooding.

3.4. Community Consultation

A rigorous community consultation program was included as part of the study which included:

- a questionnaire sent out in April 2013;
- various floodplain management committee meetings attended by representatives from Dora Creek;
- public exhibition of the Draft Reports from 1 September 2014 to 31 October 2014 which included:
    - a Community Newsletter (Appendix D);
    - a public meeting held in Dora Creek on 20 September 2014;
    - the opportunity for residents to liaise with Council staff and the Consultant;
    - written feedback from the community. This was summarised in a spread-sheet and each individual comment addressed.

4. EXISTING FLOOD ENVIRONMENT

4.1. Flood Behaviour

Flooding within Dora Creek may occur as a result of a combination of factors including:

- flooding within the Lake Macquarie waterway;
- rainfall over the Dora Creek catchment and its tributaries; and/or
- permanent and tidal inundation as a result of rising sea and lake levels.

4.2. Hydraulic Classification

The 2005 NSW Government's Floodplain Development Manual (Reference 1) defines three hydraulic categories which could be applied to the study area, namely floodway, flood storage or flood fringe.

Floodways
"those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels".

***Flood storage* areas**
"*those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.*".

Flood fringe
"the remaining area of flood prone land after floodway and flood storage areas have been defined".

There is no precise definition of flood storage and flood fringe or accepted approach to differentiate between the two areas. In the 2015 Dora Creek Flood Study (Reference 6) hydraulic categorisation was defined according to the following approach, namely:

Floodway = *Velocity * Depth > 0.25m^2/s AND Velocity > 0.25m/s OR Velocity > 1m/s*

The remainder of the floodplain outside of the Floodway becomes either Flood Storage or Flood Fringe. In this study Flood Storage was defined as the land outside the Floodway if the depth is greater than 1m and Flood Fringe if the depth is less than 1m.

4.3. Flood Hazard Classification

The 2005 NSW Government's Floodplain Development Manual (Reference 1) determines the *provisional flood hazard* categorisation of an area based on the combination of the depth and velocity of floodwaters on the land. Provisional flood hazard was defined in the 2015 Dora Creek Flood Study (Reference 6), however, to assess the full flood hazard all adverse effects of flooding have to be considered. As well as considering the provisional (hydraulic) hazard it also incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production. As with provisional (hydraulic) hazard, land is classified as either *low* or *high* hazard for a range of flood events.

The classification is qualitative based on a number of factors as listed in Table 14.

Table 14: Hazard Classification

Criteria	Weight (1)	Comment
Size of the Flood	High	In the 0.2EY event there is considerable overbank inundation that would cause significant hardship and inconvenience to many residents. In larger floods the extent of inundation and affectation are increased significantly inundating large parts of the study area.
Flood Awareness of the Community	Medium to High	Residents have experienced a number of floods recently including the February 1990 and June 2007 long weekend events and the majority of the community will have a medium to high level of awareness of the impacts of large flood events.
Depth and Velocity of Floodwaters	Medium	Properties within Kalang Road and Baker Street experience high depths and velocities which may potentially cause structural damage to buildings and pose a significant risk to life.
Effective Warning and Evacuation Times	Medium	Potentially less than 6 hours, however will vary between storm events. There is a small likelihood that residents would be caught completely unaware however an SES Flood Plan is in place to evacuate residents in the worst affected areas such as Baker Street as well as the Floodwatch local flood warning system.
Evacuation Difficulties	High	For the majority of residents evacuation by road should not be undertaken unless prior to overbank inundation.
Rate of Rise of Floodwaters	High	The rate of rise of floodwaters in Dora Creek is reasonably fast as the catchment is roughly divided into three converging creeks (Jigadee, Stockton and Dora). Flood peaks on each creek may occur at different times or in unison and the rate of rise and severity of an individual event will not always be predictable from the total rainfall at a given location.
Duration of Flooding	Low to Medium	The duration of inundation will depend on whether flooding of Dora Creek occurs in conjunction with flooding of the Lake Macquarie waterway or not. For the majority of past large events (1990 and 2007) flooding of both systems has occurred simultaneously. If flooding occurs in the lake, floodwaters may be near their peak for over 12 hours. This extended duration is unlikely to add significantly to the damages but will increase the risk to life and will add considerably to the level of inconvenience and the recovery time. Permanent inundation due to sea level rise is of indefinite duration.
Effective Flood Access	High	Low flood islands occur downstream of the railway line near the foreshores of Dora Creek. A large number of properties become isolated in frequent events (0.2EY).
Additional concerns such as bank erosion, debris, wind wave action, sewage overflows	High	The upstream catchment is very steep and heavily vegetated and may cause erosion or scouring of the channel. Debris may be a factor and may come into contact with buildings or residents particularly in areas of high depths and velocity near the main waterways. Wave action (from wind or vehicle action) and sewage overflows are contributory factors.

Criteria	Weight (1)	Comment
Provision of Services	Medium	In a large flood it is likely that services will be cut (sewer and possibly others). There is also the likelihood that the storm may affect power and telephones. Permanent inundation from sea level rise may lead to permanent loss of services.

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

Based on the above assessment the flood hazard will increase to HIGH for all properties downstream of the railway line near the Dora Creek foreshore where there are evacuation and access issues in frequent events.

In floods greater than the 1% AEP (1 in 100 year) the hazard will increase as the depths and velocities increase. For the majority of areas, the flood levels will increase quickly, and as such, residents will have limited warning time (say less than 6 hours) to evacuate to higher ground.

An additional consideration is now required for areas that become permanently inundated as a result of sea level rise. Whilst it is not a catastrophic event, it presents a high hazard to property and infrastructure over time.

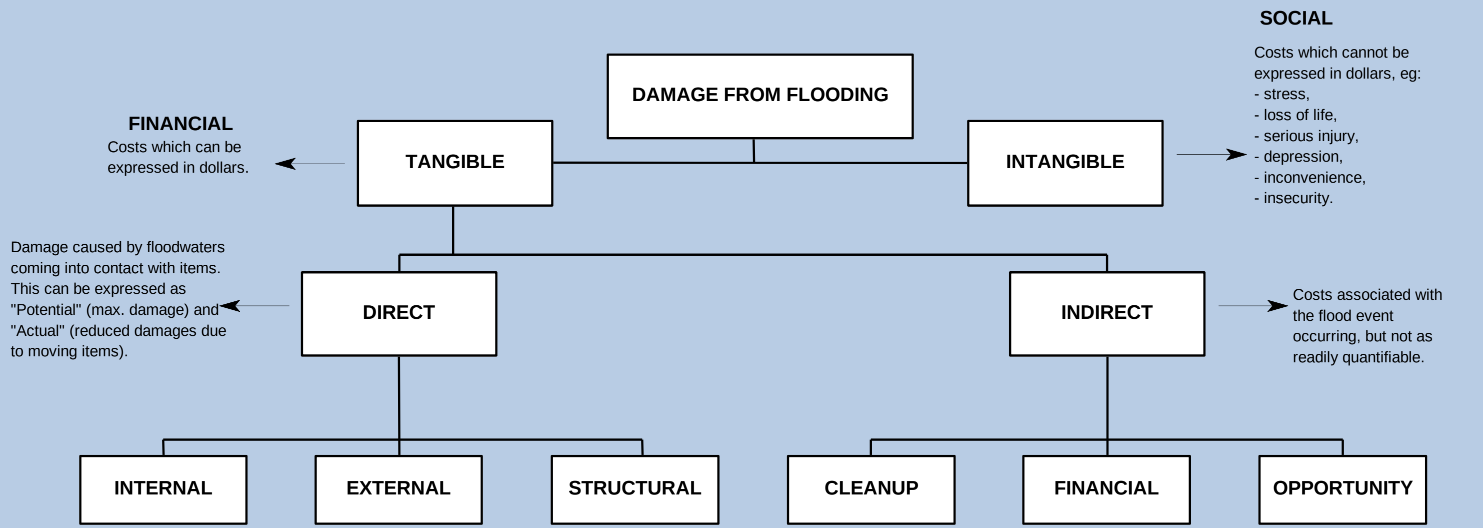
4.4. Flood Risk and the Social Impacts of Flooding

The costs of flood damages (a summary of the types of flood damages is shown on Table 15) and the extent of the disruption to the community depend upon many factors including:

- the magnitude (depth, velocity and duration) of the flood,
- land use and susceptibility to damages,
- awareness of the community to flooding,
- effective warning time,
- the availability of an evacuation plan or damage minimisation program,
- physical factors such as erosion of the creek foreshore, failure of services (sewerage), flood borne debris, sedimentation and wind/wave runup, and
- the types of asset and infrastructure affected.

In order to quantify the effect of inundation on the existing development, a floor level database was provided by Council for use in this study. This database was originally developed over 10 years ago with some updating by Council as part of the present study.

Table 15: Flood Damages Categories (excluding damages/losses from permanent inundation)



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

As the focus of this Flood Risk Management Study and Plan is on residential properties, given the relatively small number of non-residential properties identified a detailed assessment of the type and nature of flood damages for these non-residential properties was not undertaken.

Flood damages can be defined as being “tangible” or intangible”. Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value.

4.4.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories, direct and indirect damages. Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or a reduction in their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood including the cost of temporary accommodation, loss of wages by employees etc.

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

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

A flood damages assessment was undertaken for existing development in the study area and is summarised on Figure 7, Table 16 and Table 17. Table 16 groups the properties into nine areas and the key points are:

- In the 1% AEP (1 in 100 year) Dora Street east of the cooling channel exhibits the largest number of flood liable buildings. This is followed by Doree Place, Baker Street, Newport Road and Kalang Road. A slightly lower number is exhibited in the area upstream of the M1 Pacific Motorway (previously the F3 Freeway) and Stingaree Point Drive, Cowell Street and Stockton Creek exhibit the fewest number;
- In the 10% AEP (1 in 10 year) event Baker Street and Kalang Road exhibit the largest number of above floor inundated buildings;
- In the 0.2 EY (1 in 5 year) event 19 building floors are inundated, 75 in a 5% AEP event, 154 in a 1% AEP (1 in 100 year) event and to 596 in the PMF.

Table 16: Summary of Building Floors Inundated

Event	Dora St east of cooling channel	Stingaree Pt Dr east of cooling channel	Doree Pl & Douglass St area	Cowell Street	Baker Street	Newport Road area	Kalang Road	Stockton Creek	Upstream M1	TOTAL
0.2EY (1 in 5 year)	2	0	0	0	8	1	7	0	1	19
10% AEP (1 in 10 year)	3	1	1	0	14	3	9	0	2	33
5% AEP (1 in 20 year)	24	3	10	2	16	8	9	1	2	75
2% AEP (1in 50 year)	29	3	14	2	20	14	15	2	5	104
1% AEP (1 in 100 year)	41	5	21	8	24	17	19	5	14	154
0.5% AEP (1 in 200 year)	53	9	30	12	28	20	20	6	29	207
0.2% AEP (1 in 500 year)	70	10	55	18	33	24	22	8	38	278
PMF	125	65	125	45	71	48	42	14	61	596

A key point to note is that the design floods assume a constant tailwater level in Lake Macquarie waterway. For the 5% AEP (1 in 20 year) to the 0.2% AEP (1 in 500 year) events in Dora Creek this was taken as the 5% AEP (1 in 20 year) level of 1.23 m AHD in Lake Macquarie waterway. For the 0.2 EY (1 in 5 year) and 10% AEP (1 in 10 year) the constant level was assumed as the peak of the same design event in Lake Macquarie waterway, namely 0.82 and 0.94 m AHD respectively. The February 1990 and June 2007 long weekend events both reached approximately 1.0 m AHD in Lake Macquarie waterway.

The damages were calculated with use of a number of height/damage curves (that is, curves which relate the depth of water above the floor with tangible damages) which were developed based on guidelines provided by DECCW (now Office of Environment and Heritage). Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred. All buildings were assumed to be single storey residential premises. Those dwellings raised more than 0.5 m above ground use the standard high-set curve whilst all others use this low-set curve. For the calculation of AAD at Dora Creek it was assumed that there are no flood damages in the 1 EY (1 in 1 year) event.

Flood damages for the properties with floor level data are presented below in Table 17. From this it can be seen that nearly 50% of the AAD is contributed to by flooding events up to and including the 10% AEP (1 in 10 year) event. The AAD is in the order of $ 1.4 million relating to an average annual cost of flood damages to flood affected properties of $ 2,100.

Table 17: Summary of Tangible Flood Damages

Event	No. Properties Affected	No. Building Floors Inundated	Total Damages for Event	Ave. Damage Per Flood Affected Property	% Contribution to AAD
PMF	666	596	$ 58,221,800	$ 87,400	6%
0.2% AEP (1 in 500 year)	623	278	$ 20,729,000	$ 33,300	4%
0.5% AEP (1 in 200 year)	610	207	$ 15,863,500	$ 26,000	5%
1% AEP (1 in 100 year)	599	154	$ 11,839,800	$ 19,800	7%
2% AEP (1 in 50 year)	578	104	$ 8,608,100	$ 14,900	16%
5% AEP (1 in 20 year)	528	75	$ 5,988,700	$ 11,300	17%
10% AEP (1 in 10 year)	419	33	$ 3,230,500	$ 7,700	18%
0.2 EY (1 in 5 year)	317	19	$ 1,821,200	$ 5,700	23%
Average Annual Damages (AAD)			**$ 1,391,200**	**$ 2,100**	**100%**

Note: The remaining 5% contribution to AAD occurs in events greater than the 1 EY but smaller than the 0.2 EY event.

It should be noted that it is likely that some building floors will not have been identified in the database or may have been re-developed since the time of the survey however the damages assessment does provide an overall indication of the cost of flooding in Dora Creek.

Figure 4 indicates the spatial extent of inundation in the various design events and Figure 7 indicates the event which first inundates the lowest building floor on the property.

4.4.2. Intangible Flood Damages

The intangible damages associated with flooding are inherently more difficult to estimate. In addition to the direct and indirect damages discussed above, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors including the size of flood, the individuals affected, community preparedness, etc. However, it is important that the consideration of intangible damages is included when considering the impacts of flooding on a community. An overview of the types of intangible damages likely to occur within the study area is discussed below.

Isolation

Isolation (the ability to freely exit and enter your house) during flood events will become a significant factor for local residents. There is also a high level of community support and spirit, which can to some extent negate the effects of isolation and can certainly assist in a flood (as happened in the June 2007 long weekend event). However, isolation is of significant concern if a medical emergency arises during a flood, there is a need to pick up food or people or for other reasons. This is a significant factor in Dora Creek along the river banks where there is a long distance to travel to high ground and the roads become inundated relatively early in a flood.

Population Demographics

Analysis of the 2011 Census data indicates that there are some particular features of the population demographics of the community in the study area that might contribute to additional intangible damages, particularly community resilience.

These include age and income population characteristics. The population in some of the suburbs in the study area most vulnerable to floods and inundation from sea level rise and storms attributable to the impact of climate change are slightly older than the Lake Macquarie City average. For example, while the median age of the population of Lake Macquarie is 41 years old, the median age of the population in Dora Creek it is 47 years old, Morisset is 55 years old, Cooranbong is 40 years old, Martinsville is 48 years old and Mandalong is 38 years old. The median age of people in New South Wales is 38 years.

Furthermore, the percentage of the population over 65 years in Dora Creek is 24%, Morisset is 39%, Cooranbong is 21%, Martinsville is 15% and Mandalong is 14% compared to the Lake Macquarie median of 18% (the NSW median is 15%).

While some households in some vulnerable communities enjoy high incomes, many people living in vulnerable foreshore communities are living on incomes that are significantly lower than the Lake Macquarie average.

Unemployment levels in these communities are generally slightly higher than the Lake Macquarie median, with unemployment level in Dora Creek being 5.5% and Morisset being 9.7% compared to the Lake Macquarie median of 5.3% (the NSW median is 5.9%).

The age, income and unemployment statistics indicate the possibility of lower resilience of these vulnerable foreshore communities to adapt to change and respond in an emergency, therefore requiring local adaptation plans that acknowledge and respond to specific local challenges. Well-developed emergency preparedness, response and recovery programs are also required.

Stress

In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and its associated damage. The extent of the stress depends on the individual. To some extent, this does not appear to be a significant issue within the study area as a number of residents experienced both the February 1990 and June 2007 long weekend events and this issue has not become apparent in post flood surveys. The increasing hazard due to climate changes and rising sea levels is likely to add to community and individual stress, as it makes future events even more difficult to predict, and planning for the future even more uncertain.

Risk to Life and Injury
During any flood event there is the potential for injury as well as loss of life.

4.5. Impacts of Flooding on Public Infrastructure

Public sector (non-building) damages include:

- recreational/tourist facilities,
- water and sewerage supply,
- gas supply,
- telephone supply,
- electricity supply including transmission poles/lines, sub-stations and underground cables,
- roads and bridges including traffic lights/signs, and
- costs to employ the emergency services and assist in cleaning up.

Costs to Council from flooding typically comprise;

- clean-up costs;
- erosion and siltation;
- unblocking or repairing damaged drainage infrastructure;
- removing fallen trees;
- inundation of Council buildings;
- direct damage to roads, bridges and culverts;
- removing vehicles washed away;
- clean up assistance to ratepayers;
- increases in insurance premiums;
- closures of streets;
- loss of working life of road pavements; and
- operational costs in the lead up to and during flood events.

Damages to the public sector infrastructure can contribute a significant proportion of the total flood costs. There are no accurate estimates of the amount of previous damages to the public sector in previous floods in the Council LGA.

Fixed infrastructure such as roads and sewer are particularly vulnerable to permanent and tidal inundation as lake levels rise with predicted sea level increases. Infrastructure in low-lying areas close to the lake foreshore can expect to experience increased corrosion, rising groundwater levels, and more frequent tidal inundation. This will increase maintenance and service costs, and may lead to long-term failure of some assets unless they are re-designed or relocated. The future risk, and cost, to infrastructure needs to be investigated in more detail as local Area Adaptation Plans are prepared for vulnerable foreshore communities.

4.6. Impacts of Flooding on Commercial and Industrial Activities

Commercial and industrial activities will also be adversely affected by flooding and are vulnerable to permanent and tidal inundation as lake levels rise with predicted sea level increases. The magnitude of the damages will likely be less than for the residential community as there are much fewer buildings susceptible to flooding. A rigorous study of these impacts has not been undertaken but it is also likely that as re-development occurs (many commercial premises have a much shorter lifespan than houses) measures to mitigate the impacts of flooding and climate change can be incorporated into the building design. This issue would need to be examined on a case by case basis and/or in future planning studies.

4.7. Environmental Impacts of Flooding

Flooding is a natural phenomenon that has been a critical element in the formation of the present topography. Thus erosion, sedimentation and other impacts from flooding should be viewed as part of the natural ecosystem processes. It is only when these effects impact on man-made elements that they are of concern, and similarly, when development impacts or exacerbates these processes.

4.8. Flood Awareness and Flood Warning

The flood awareness of the community and the available flood warning time are important factors in reducing the likely flood damages. Based on experience in other areas and discussions with local residents and others it is likely that the flood awareness of the community is medium to high for the following reasons:

- the Floodwatch flood warning system based upon rainfall and river gauges;
- the residents will be aware of the water actually rising across their yards (unless at night) and heavy rain in their neighbourhood; and
- residents are generally aware that flooding occurs in the study area. Residents who have been in the area for a few years will have experienced minor flooding events (and possibly even the February 1990 and June 2007 long weekend events) and will be aware that larger events may occur causing more severe inundation.

The extent or success of self employed damage mitigation measures by the residents during the February 1990 and June 2007 long weekend events is unknown.

4.9. Flood Emergency Response Classification

To assist in the planning and implementation of response strategies, the SES in conjunction with OEH (formerly DECCW) has developed guidelines to classify communities according to the impact that flooding has upon them. Flood affected communities are considered to be those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue.

Based on the guidelines, communities are classified as either, Flood Islands, Road Access Areas, Overland Access Areas, Trapped Perimeter Areas or Indirectly Affected Areas (refer Table 18). From this classification an indication of the emergency response required can be determined.

Table 18: Emergency Response Classification of Communities

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Areas with Overland Escape Routes	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapped Perimeter	Yes	Possibly	Possibly
Indirectly Affected Areas	Possibly	Possibly	Possibly

The guideline was applied for the study area and the community was classified as indicated on Figure 9.

4.10. Climate Change

4.10.1. Background

The 2005 Floodplain Development Manual (Reference 1) requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change on flood behaviour. The 2015 Dora Creek Flood Study (Reference 6 - Section 8.2) provides a short history of NSW Government policy on the assessment of climate change. The most current advice is that in October 2012 the NSW Government indicated that the 2009 Sea Level Rise Policy is no longer NSW Government policy and advised Councils to adopt their own sea level rise projections based on competent and credible scientific advice. Council, along with most NSW Coastal Councils, adopted the benchmarks from the old NSW Sea Level Rise Policy Statement. This is based on current scientific advice, supported by a review by the NSW Chief Scientist and Engineer in April 2012.

These levels are a projected rise in average sea level from 1990 of 0.4 metres by the year 2050, and by 0.9 metres by the year 2100. However, it should be noted that climate change and sea level rise due to man-made or natural processes will continue beyond 2100.

There is no NSW Government Policy on increases in rainfall intensity due to climate change, the 2015 Dora Creek Flood Study (Reference 6) included a test for the sensitivity of flood levels to rainfall increases due to climate change across the following range:

Increase in peak rainfall and storm volume:

low level rainfall increase = 10%;

medium level rainfall increase = 20%;

high level rainfall increase = 30%.

The high levels of uncertainty about future changes to rainfall patterns at a catchment level means these scenarios are indicative rather than predictive. It is generally acknowledged that a 30% rainfall increase is probably overly conservative. Within 2 years there is likely to be more definitive advice on rainfall increase and how it should be accommodated in flood related planning.

4.10.2. Results

An assessment of a 0.4m and 0.9m sea level rise and an increase in the design rainfall intensities was undertaken. The results for the 1% AEP (1 in 100 year) event at various locations are provided in Table 19 and Table 20. Results for the 0.2 EY (1 in 5 year), 5% (1 in 20 year) and 1% AEP (1 in 100 year) events for the two sea level rise scenarios are shown in Appendix B.

Table 19: Results of Climate Change Analysis – 1% AEP (1 in 100 year) Levels (m)

Creek	Name	Peak Flood Level 1% AEP (1 in 100 year) (m AHD)	Difference (m)				
			Rain +10%	Rain +20%	Rain +30%	Sea level rise 0.4m	Sea level rise 0.9m
Jigadee	U/S Newports Rd	6.2	0.09	0.17	0.25	-	-
Jigadee	D/S Newports Rd	3.0	0.09	0.17	0.25	-	-
Jigadee	Jigadee gauge	5.8	0.09	0.18	0.27	-	-
Stockton	U/S Freemans Dr	3.9	0.23	0.45	0.66	0.03	0.09
Stockton	Morisset gauge	3.8	0.22	0.43	0.64	0.02	0.08
Dora	U/S Cooranbong Rd	5.9	0.11	0.22	0.33	-	-
Dora	Cooranbong gauge	5.7	0.12	0.24	0.36	-	-
Dora	Junction Jigadee Ck	4.3	0.24	0.47	0.67	0.02	0.07
Dora	D/S M1 Motorway	4.0	0.22	0.43	0.62	0.03	0.08
Dora	Junction Stockton Ck	3.7	0.24	0.46	0.66	0.03	0.10
Dora	Kalang Rd gauge	3.0	0.22	0.41	0.58	0.04	0.14
Dora	U/S Railway	2.4	0.12	0.23	0.33	0.04	0.17
Dora	D/S Railway	2.3	0.10	0.19	0.27	0.03	0.16

Note: A change in flood level of less than 0.01 m is considered negligible and marked as "-"

Table 20: Results of Climate Change Analysis – 1% AEP (1 in 100 year) Flows (m^3/s)

Creek	Name	Peak Flood Flow 1% AEP (1 in 100 year) (m^3/s)	Difference (m)				
			Rain +10%	Rain +20%	Rain +30%	SLR 0.4m	SLR 0.9m
Jigadee	Newports Road	332	12%	24%	37%	0%	0%
Stockton	Freemans Drive	393	8%	16%	26%	0%	0%
Dora	Cooranbong Road	552	12%	24%	36%	0%	0%
Dora	M1 Motorway	856	12%	25%	38%	0%	1%
Dora	Railway Bridge	1187	14%	28%	42%	2%	5%

The results in Table 19 indicate that a 10% rainfall intensity increase will raise flood levels by 0.1 to 0.2m, thus a 30% increase will raise levels by up to 0.7m.

The figures in Appendix B showing the effects of sea level rise indicate that:

- a 0.4m increase will largely result in a maximum increase of up to 0.2m upstream of the railway line in the 0.2 EY (1 in 5 year) and the 5% (1 in 20 year) events. In the 1% AEP (1 in 100 year) event the maximum increase upstream of the railway line reduces to less than 0.1m;
- a 0.9m increase will largely result in a maximum increase of up to a 0.5m increase upstream of the railway line in the 0.2 EY (1 in 5 year) and the 5% (1 in 20 year) events. In the 1% AEP (1 in 100 year) event the maximum increase upstream of the railway line reduces to less than 0.2m.

The implications for sea level on rise on tangible flood damages were assessed with the results shown in Table 21 and Table 22. Sea level rise will cause the number of building floors inundated to increase significantly, particularly in the smaller events such as the 0.2 EY (1 in 5 year) event where an additional 12 properties could become inundated above floor level with a 0.4m sea level rise.

Table 21: Summary of Increase in Building Floors Inundated due to Sea Level Rise

	Existing	Sea Level Rise 0.4 m			Sea Level Rise 0.9 m		
Event	Building Floors Inundated	Building Floors Inundated	Increase	Increase (%)	Building Floors Inundated	Increase	Increase (%)
PMF	596	602	6	1.0%	616	20	3%
0.2% AEP (1 in 500 year)	278	329	51	18%	412	134	48%
0.5% AEP (1 in 200 year)	207	270	63	30%	381	174	84%
1% AEP (1 in 100 year)	154	220	66	43%	351	197	128%
2% AEP (1 in 50 year)	104	182	78	75%	324	220	212%
5% AEP (1 in 20 year)	75	149	74	99%	310	235	313%
10% AEP (1 in 10 year)	33	67	34	103%	194	161	488%
0.2 EY (1 in 5 year)	19	31	12	63%	142	123	647%

As sea level rise will significantly increase the number of building floors inundated so will it increase the tangible flood damages. Increases in total flood damages would occur in all flood events however the most significant rise occurs in smaller events. For example with a 0.9m rise, flood damages in a 0.2 EY (1 in 5 year) event increase by 647% from the current day scenario compared to 128% in a 1% AEP (1 in 100 year) event. The contribution of each event to the AAD increases for the smaller flood events and reduces for larger events, thus in the future, the contribution of smaller flood events to AAD will increase further. Table 22 indicates that AAD will increase by a total of nearly $ 1.06 million with a 0.4m rise (a 77% increase) and will increase by $ 5.7 million with a 0.9m rise (a 143% increase).

Table 22: Summary of Tangible Flood Damages - Sea Level Rise Year of 0.4m and 0.9m

Sea Level Rise 0.4 m				Increase from Existing	
Event	Total Damages for Event	Ave. Damage Per Flood Affected Property	% Contribution to AAD	Total Damages for Event	Ave. Damage Per Flood Affected Property
PMF	$61,746,100	$ 92,600	**3.5%**	$3,524,300	$5,200
0.2% AEP (1 in 500 year)	$24,588,700	$ 38,900	**2.7%**	$3,859,700	$5,600
0.5% AEP (1 in 200 year)	$19,743,800	$ 31,700	**3.6%**	$3,880,300	$5,700
1% AEP (1 in 100 year)	$16,097,800	$ 26,300	**6%**	$4,258,000	$6,500
2% AEP (1 in 50 year)	$13,355,300	$ 22,300	**15%**	$4,747,200	$7,400
5% AEP (1 in 20 year)	$11,072,000	$ 19,500	**17%**	$5,083,300	$8,200
10% AEP (1 in 10 year)	$ 5,195,300	$ 10,500	**17%**	$1,964,800	$2,800
0.2 EY (1 in 5 year)	$ 3,179,300	$ 7,500	**26%**	$1,358,100	$1,800
Average Annual Damages (AAD)	**$ 2,457,800**	**$ 3.700**	**100%***	**Increase in AAD $ 1,066,600**	**$ 1,600**

Sea Level Rise 0.9 m				Increase from Existing	
Event	Total Damages for Event	Ave. Damage Per Flood Affected Property	% Contribution to AAD	Total Damages for Event	Ave. Damage Per Flood Affected Property
PMF	$67,171,900	$ 100,700	**1.4%**	$ 8,950,100	$ 13,300
0.2% AEP (1 in 500 year)	$31,752,600	$ 49,800	**1.3%**	$ 11,023,600	$ 16,500
0.5% AEP (1 in 200 year)	$29,070,100	$ 46,000	**2%**	$ 13,206,600	$ 20,000
1% AEP (1 in 100 year)	$26,650,400	$ 42,800	**4%**	$ 14,810,600	$ 23,000
2% AEP (1 in 50 year)	$24,351,700	$ 39,700	**10%**	$ 15,743,600	$ 24,800
5% AEP (1 in 20 year)	$22,826,300	$ 38,600	**13%**	$ 16,837,600	$ 27,300
10% AEP (1 in 10 year)	$13,628,000	$ 24,300	**17%**	$ 10,397,500	$ 16,600
0.2 EY (1 in 5 year)	$10,547,400	$ 19,200	**33%**	$ 8,726,200	$ 13,500
Average Annual Damages (AAD)	**$7,137,400**	**$ 10,700**	**100%**	**Increase in AAD $5,746,200**	**$ 8,600**

5. RISK MANAGEMENT MEASURES

5.1. General

The 2005 NSW Government's Floodplain Development Manual (Reference 1) separates risk management measures into three broad categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity and redirection of flow paths) and include flood mitigation dams, retarding basins and levees. At Dora Creek this would also include any works that modify bridges or waterway structures.

Property modification measures modify land use and development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), strategic planning (such as land use zoning), building regulations (such as flood-related development controls), or voluntary purchase.

Response modification measures modify the community's response to flood hazard by educating flood affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

5.2. Measures Not Considered Further

It was apparent that after a preliminary matrix assessment that a number of risk management measures that would not reduce current flooding and were therefore not worthy of further consideration. These are summarised in Table 23.

Table 23: Risk Management Measures Not Considered Further

Measure	Impact				
	Reduction in Flood Level	Social Effect	Environmental Impact	Cost to Implement	Benefit/ Cost Ratio
FLOOD MODIFICATION MEASURES					
Flood mitigation dams	Yes	Nil	Very High	Very High	Low
Retarding basins	Very small	Some	Variable	Medium	Low
On site stormwater detention	Nil	Minor	Nil	High per property	Low
PROPERTY MODIFICATION MEASURES					
Voluntary purchase of all buildings inundated in the PMF	Nil	High	Nil	High per building	Probably Low

Flood mitigation dams within the catchment are not viable on economic, social and environmental grounds for reducing levels in Dora Creek. Construction of retarding basins (say up to 50,000 m^3) and the use of on-site stormwater detention (OSD) or retention systems are increasingly being used in developing catchments. These measures are appropriate for use in controlling flooding in small catchments or to mitigate the effects of increased runoff caused by development but would not have a significant impact on flood levels within Dora Creek. Further detail on the use of OSD to manage the increase in flows from urbanisation is provided in Section 5.4.4.

Voluntary purchase of all flood liable buildings is not viable due to the extremely high cost.

5.3. Flood Modification Measures

Flood modification involves changing the behaviour of the flood itself, by reducing flood levels or velocities, or excluding floodwaters from areas under threat. This includes:

- dams;
- retarding basins;
- on site stormwater detention (OSD);
- levees, flood gates, pumps;
- channel modifications;
- provision of floodways;
- local drainage issues.

Discussion on each of these measures, except for dams, retarding basins and OSD (as a flood mitigation measure), is provided in the following sections.

5.3.1. Levees, Flood Gates and Pumps

DESCRIPTION

Levees are built to exclude previously inundated areas of the floodplain from flooding or inundation from the lake up to a certain design event. They are commonly used on large river systems (e.g. Hunter and Macleay Rivers) but can also be found on small creeks in urban areas.

Flood gates allow local runoff to be drained from an area (say an area protected by a levee) when the external water level is low, but when the river or lake is elevated, the gates prevent floodwaters from the river entering the area (they are commonly installed on drainage systems within a levee area).

Pumps are generally also associated with levee designs. They are installed to remove local runoff behind levees when flood gates are closed or if there are no flood gates.

Unless designed for the PMF, levees will be overtopped. When overtopping occurs, the rapid inundation may produce a situation of greater hazard than exists today. This may be further exacerbated if the community is under the false sense of security that the levee has “solved” the flood problem (as happened with Hurricane Katrina in New Orleans, USA in August 2005).

DISCUSSION

Constructing a levee system requires detailed planning and high costs (this includes the levee and any drains, gates or pumps associated with its function) but one advantage is a relatively low on-going maintenance cost compared to other measures such as dredging, although the levee system needs to be inspected on a regular basis for erosion or failure. In addition there needs to be some maintenance for grass cutting and vegetation trimming though generally these works are undertaken for aesthetic reasons. The annual cost of inspections for erosion or failure will generally be small (often less than $10,000 per annum per levee). However this amount can vary considerably depending upon the complexity and size of the structure.

Whilst the levee system may protect a large number of buildings from being inundated in a rare flood event, many levees have a low to medium benefit cost ratio as there are few building floors inundated (and so being able to be protected) in the more frequent floods. However with sea level rise the benefit cost ratio will increase and levees may become more economically viable or even become the only means of protecting existing developments. At Dora Creek there are a relatively large number of building floors inundated in the frequent events which increase the benefit cost ratio.

Pumps have been suggested as a means of addressing the “internal drainage” problem which may occur behind levees but are not widely used in levee situations in NSW. Some of the drawbacks of employing pumps are:

- high capital cost. In many instances two sets of pumps are installed in case one set is being repaired or maintained when the flood occurs;
- high maintenance cost. The pumps have to be regularly maintained and tested by trained personnel;
- relatively high risk of failure. Experience in other areas has shown that as the pumps are used only infrequently there is a relatively high risk of failure due to:
    - inadequate maintenance of the pumps causing seals or valves to deteriorate;
    - power cuts caused by the storm;
    - failure of the device which activates the pumps.

The pumps are only required to operate for a short time (several hours) possibly once or twice a year. If they fail to start or fail during the event there is practically no likelihood that service personnel will be able to restart them prior to the peak level being reached. An alternative to pumps is to install additional flap gated culverts and these can be more cost effective though also can fail (mainly due to vandalism or vegetation “jamming” the mouth open).

Table 24 provides a summary of the key issues to be considered with levee construction.

Table 24: Key Features of Levee Systems

ISSUE	COMMENT
ADVANTAGES:	
"Environmentally Sensitive Measure"	A well-designed vegetated earthen embankment set back far enough from the riverbank to retain foreshore access, and that does not interrupt local drainage, can have minimal environmental impact providing that the natural wetland hydrology is not affected. However, in many locations it is hard to meet all these criteria, and it will become increasingly difficult as lake levels rise and permanently inundate low lying areas.
Protects a large number of buildings.	A levee system could protect a large number of buildings (over 100) from being inundated up to the 1% AEP (1 in 100 year) or even larger flood event.
Can provide a high level of protection	At Lake Macquarie waterway and the lower parts of Dora Creek it is possible to protect to the PMF (2.8 m AHD with a 0.4m sea level rise in Lake Macquarie waterway) as this event is only 1.3 m greater than the 1% AEP level. However at many other locations along Dora Creek this is not possible due to the large height difference between the design events.
Low maintenance cost.	A levee system needs to be inspected annually for erosion or failure. In addition there is ongoing weekly or monthly maintenance (grass cutting, vegetation trimming). The annual cost of inspections for erosion or failure (of say flood gates) will generally be small (say less than $10,000 per annum per levee). However this amount can vary considerably depending upon the complexity and size of the structure.
DISADVANTAGES:	
Visually obtrusive to residents.	Residents enjoy living on the river bank of Dora and Stockton Creeks because of the visual attraction of the water and a (say) 2.0 m high embankment will significantly affect their vista. Anything which reduces the vista is unlikely to be accepted by the majority of residents. A freeboard of usually 0.5 m to 1 m should be added to the design flood level of the levee (level of protection afforded by the levee) to account for wave action, slumping of the levee or other local effects.
High cost	The cost to import fill, compact and construct an earthen levee is dependent on the availability of good quality fill and the associated transport costs, these will vary depending upon the locality. However, generally it is the land take and associated costs (possible services re-location and access) which add considerably to the cost. For these reasons no detailed costings have been undertaken at this stage. It is likely that levees will cost several million dollars depending upon their size and location but may be the only viable mitigation measure to protect against sea level rise.
Medium benefit cost ratio	Whilst the levee system may protect a large number of buildings from being inundated in a (say) 1% AEP (1 in 100 year) event it is likely to have medium benefit cost ratio as there are fewer buildings floors inundated (and so being able to be protected) in the more frequent floods (less than a 10% AEP (1 in 10 year) event). However with sea level rise the benefit cost ratio will increase and it may become economically viable.
Local runoff from within the "protected area" or upstream may cause inundation.	The ponding of local runoff from within the "protected area" may produce levels similar to that from the lake itself. At present local runoff already causes problems in several areas. Constructing a levee will compound this problem. It can be addressed by the installation of pumps or flap valves on pipes but these add to the cost and the risk of failure. This is a particular problem in areas on creek mouths and deltas, such as at Dora Creek as floodwaters from the catchment may get behind the foreshore levee.
May create a false sense of security.	Unless the levee system is constructed to above the PMF level it will be overtopped. When this occurs the damages are likely to be higher as the population will be much less flood aware (as happened in New Orleans, USA in August 2005).
Relaxation of flood related planning controls.	Most residents consider that following construction of a levee the existing flood related planning controls (minimum floor level, structural integrity certificate) should be relaxed. However, many experts consider that this should not be the case unless the levee is built to the PMF level and

ISSUE	COMMENT
	the risk of failure is nil. The general opinion is that a levee should reduce flood damages to existing development but should not be used as a means of protecting new buildings through a reduction in existing standards.
Restricted access to the water.	Access to the water for boating and other activities requiring easy access will be restricted. This can be addressed by (expensive) re-design of entry points.
Increase in flood levels elsewhere	Levees by their very nature prevent inundation of part of the floodplain. The floodwaters that previously entered the protected area must now travel elsewhere and in so doing increase flows and flood levels elsewhere. The increase in level depends upon whether the area to be leveed was a flood storage area with no or little cross flow or the area was an area of active flow, termed a floodway. This is a significant issue at Dora Creek where floodwaters flow across the banks on either side of Dora Creek downstream of the railway line. Constructing a levee in these areas would eliminate the cross flow and so increase flood levels elsewhere.

Kalang Road Diversion Levee

A flood diversion levee near Kalang Road was first proposed in the 1992 Dora Creek Floodplain Management Study (Reference 2) and a detailed assessment was undertaken in the 1994 Kalang Road Study (Reference 13). These two studies determined that the developments in the study area exposed to the most hazard were located along Kalang Road. Any houses of inappropriate construction could be liable to structural damage due to a combination of high inundation depths and velocities and the purpose of the levee was to reduce flood velocities and hence the hazard in the area.

Hydraulic modelling of the diversion levee in these studies indicated that it had very little impact on peak flood levels; however local velocities were significantly reduced. A summary of flood depths and velocities near buildings within Kalang Road properties is shown in Table 25 (taken from Reference 13).

Table 25: Flood Behaviour within Kalang Road properties (from 1994 Kalang Road Study Reference 13)

Event	Existing				With Diversion Levee			
	Peak Depth (m)		Peak Velocity (m/s)		Peak Depth (m)		Peak Velocity (m/s)	
10% AEP (1 in 10 year) Event	0.5 – 1.6	(front)	0.0 – 1.1	(front)	0.5 – 1.6	(front)	0.0 – 1.1	(front)
	0.4 – 1.3	(rear)	0.0 – 0.6	(rear)	0.3 – 1.3	(rear)	0.0 – 0.3	(rear)
1% AEP (1 in 100 year) Event	1.1 – 2.4	(front)	0.1 – 1.7	(front)	1.1 – 2.3	(front)	0.0 – 1.3	(front)
	0.4 – 1.3	(rear)	0.0 – 0.6	(rear)	1.0 – 2.0	(rear)	0.0 – 0.4	(rear)

On average the diversion levee reduced velocities at the rear of buildings on the Dora Creek side by 0.1m/s in the 10% AEP (1 in 10 year) event and 0.3m/s in the 1% AEP (1 in 100 year) event. At the front of buildings on the Kalang Road side peak velocities were reduced on average by 0.1m/s in the 10% AEP (1 in 10 year) event and 0.4m/s in the 1% AEP (1 in 100 year) event.

The cost to construct the levee was detailed in the 1994 Kalang Road Study (Reference 13) and these costs have been adjusted using the CPI (December 2013 versus December 1993) and reproduced in Table 26.

Table 26: Estimated Levee Cost (based on Appendix A in Reference 13 adjusted for CPI)

Item	Cost
Levee Works	$ 321,000
Reno Mattress	$ 250,000
Rock Gabion	$ 97,000
Levee Drainage	$ 25,000
Wetlands Drainage	$ 47,000
TOTAL COST	**$ 740,000**

There have been no reported instances of significant structural damage within Kalang Road area as a result of past floods.

The effects of constructing a diversion bank with a crest at 3.2 m AHD as suggested previously was investigated using the TUFLOW hydraulic model for the 10% (1 in 10 year) and 1% AEP (1 in 100 year) events. The results are shown on Figure 10 and indicate that whilst there is some reduction in velocity the reduction is not large enough to eliminate the hazard and thus the works cannot be justified.

There are a few examples of diversion levees in NSW (Maitland, Georges River) but most levees are constructed to divert flood waters away from areas (as at Lismore, Grafton and many inland towns) rather than to reduce velocities. The Picnic Point / Carinya Road on the Georges River is an example of a levee system constructed to reduce peak velocities rather than reduce flood levels.

The benefit cost ratio of the Kalang Road diversion levee is impossible to accurately estimate. No data is available to estimate when buildings are likely to fail in floods and the reasons for failure. Do they fail because of high velocities or for some other reason such as a timber house floats off its piers or a pier fails due to debris loading? There are few recent examples of houses being washed away in floods in NSW, though it did happen in the January 2011 south east Queensland floods. This has occurred in the past in NSW (notably Mt Pleasant Street, Maitland in February 1955) and frequently in floods during early white settlement (Gundagai - 1852) where most houses were of timber construction on piers and thus could float. Today buildings are constructed to much higher standards than in the past and many of those on Kalang Road are of brick construction.

Construction of a diversion levee at Kalang Road would reduce velocities and so reduce the likelihood of buildings being damaged by high velocities. There are approximately 40 residential buildings that might benefit from such a levee at Kalang Road, however the greatest benefit would likely be to the buildings at the most upstream point along Kalang Road. Also, even if a diversion levee was constructed there is no certainty that this would protect all of the buildings along Kalang Road. This measure is not considered a high priority measure as it provides minimal reduction in flood levels and thus minimal reduction in residential damages due to inundation or inconvenience. Whilst it will reduce the damage potential due to high velocities it will not eliminate this risk and will not significantly reduce the risk to life element as the depths of floodwaters are not affected.

Consultation undertaken previously has indicated that residents do not support construction of this levee. However this reaction from local residents to levee construction is not unusual.

New Levees to Protect Existing Developments

It is possible to construct levees around some of the flood affected buildings in the study area, however on balance the disadvantages significantly outweigh the benefits (Table 24). This situation is typical of many flood liable areas in NSW where it is possible to construct levees to provide protection but for economic, social (access and views), hydraulic (raised flood levels) and sometimes environmental considerations other measures are the preferred management strategy.

For the areas downstream of the railway line construction of levees would significantly impact on resident's aesthetic and physical access to Dora Creek which are the main reasons residents choose to live in the area. A levee would also significantly restrict the passage of floodwaters across the land and thus increase flood levels upstream.

For the Baker Street, Newport Road and Kalang Road properties a levee would impose similar aesthetic and physical access to Dora Creek impacts as for the properties downstream of the railway line.

For the Stockton Creek and upstream of the M1 properties the main issue is likely to be the fact that the buildings are widely scattered and thus it is impractical to construct a levee to protect them.

Whilst levees may not be the optimal measure at present they do provide the only means to protect low lying areas adjoining Dora Creek if sea levels rise as projected. A rise in the "average" lake level will mean that some low lying areas will become permanently inundated and other areas more frequently affected by overbank inundation. Levees may then have to be considered for these areas.

Suggested Levee along Doree Place

Local residents have suggested that recent developments (still on-going in 2014) on previously vacant land at 3 Dora Street and 1a and 3 Douglass Street have eliminated what residents consider is a floodway from Dora Street to Douglass Street. Hydraulic modelling was undertaken to evaluate the impacts and the results indicate that in a 0.2 EY (1 in 5 year) flood levels rise by up to 0.05m in the local area. This occurs because Dora Street at this location is lower than the land to the east (refer Figure 8) and thus there are limited flow paths out of this area through downstream properties. In the 1% AEP (1 in 100 year) event the closure of this flow path is of much less importance as floodwaters inundate the entire area and there are more available flow paths. It should be noted that any filling, construction of houses or additional fencing in this area will have similar impacts. Thus replacement of a wooden paling fence by a colorbond fence would increase flood levels.

Residents have suggested that the loss of this flow path could be compensated by construction of a levee along the river bank parallel to Doree Place. This would have the effect of preventing inundation in the more frequent events. The key levels and relevant information near the intersection of Doree Place and Wamsley Street are:

- the lowest level of river bank is 1.5 m AHD and the highest level near the eastern end of Doree Place is 1.9 m AHD. Thus the maximum level of protection is approximately 2 m AHD;
- there are many recorded historical peak flood levels for several events in this area ranging from 1.5 to 1.9 m AHD. The June 2007 long weekend event reached approximately 1.9 m AHD, February 1990 approximately 1.8 m AHD (slightly lower) and June 1989 approximately 1.6 m AHD;
- the 1% AEP (1 in 100 year) design flood level is 2.2 m AHD, the 5% AEP (1 in 20 year) is 2.0 m AHD; the 10% AEP (1 in 10 year) is 1.8 m AHD and the 0.2 EY (1 in 5 year) is 1.7 m AHD. However it should be noted that there is a gradient of approximately 0.2 m along Doree Place;
- Table 16 indicates that above floor inundation first occurs in this area in a 10% AEP (1 in 10 year) event with a single building inundated with nine additional building floors inundated in the 5% AEP (1 in 20 year) and 21 in the 1% AEP (1 in 100 year).

The impact of constructing a levee parallel to Doree Place to effectively eliminate floodwaters from entering the area from Dora Creek, except for local runoff and flows from Muddy Lake which may still inundate the area, was evaluated and this reduces flood levels by up to 0.05m in the 0.2 EY (1 in 5 year) event. No increase in flood level occurred elsewhere. This levee would therefore provide some benefit in events up until overtopping of the entire river bank occurs, however this must be balanced against the following:

- there is minimal reduction in AAD as only one building is inundated above floor in events up to the 10% AEP (1 in 10 year);
- inundation of the area will still occur from local runoff and from Muddy Lake;
- the cost of construction will depend upon whether road works at the Wamsley Street intersection can be undertaken in conjunction with other necessary road works. The cost to construct an earthen bank along the river will be approximately $50,000;
- it is unlikely that state or federal funding will be available for this measure as it provides minimal benefit in reducing above floor inundation;
- levees all require a freeboard which is generally 0.5m to 1m above the design level. As this levee is only a maximum of 0.5m high, in theory according to design levee practice the attributable benefit will be minimal.

SUMMARY

A review of the flood liable areas in the study area indicates that there are no areas where a levee system provides a viable socially acceptable measure to protect existing buildings.

A diversion levee at Kalang Road, or at any other location will reduce peak flood velocities but construction of such a levee cannot be justified based on the relatively small risk of houses being washed away or structurally damaged in events up to the 1% AEP (1 in 100 year). In larger events than the 1 % AEP (1 in 100 year) it is likely that some houses will be damaged or even swept away if of timber construction as has occurred in large floods (Maitland in 1955, southern Queensland in 2011) but this is a rare occurrence.

The suggested levee parallel to Doree Place should only be considered if it can be undertaken for minimal cost and general acceptance by the community.

5.3.2. Channel Modifications

DESCRIPTION

Channel modifications are usually undertaken to either increase the capacity of the channel and/or improve the conveyance of floodwaters which in turn will reduce peak levels. Channel modification includes a range of measures from straightening, concrete lining, removal of structures limiting the hydraulic capacity of the river, dredging and vegetation clearing. In some instances 'naturalising' the channel upstream can reduce peak levels downstream by slowing flows (but likely increasing flood levels upstream). Dora Creek is largely in its natural state except from clearing of vegetation on the banks and construction (opened in 1982) of the coal fired Eraring power station cooling water supply canal which passes under Dora Creek near its mouth.

DISCUSSION

Vegetation Clearing, Straightening, Concrete Lining

The creeks can be made more efficient carriers of floodwaters by clearing the river bank vegetation, straightening the course of the channel or making the bed smoother. These approaches do achieve a reduction in flood level as well as a narrowing of the floodplain and for this reason were widely used in the past in many urban areas of Sydney, Newcastle, Cessnock and other regional centres. However these management measures are only applicable for small creek systems, as wider than approximately 10m wide incurs significant cost. Today these measures are very rarely undertaken because of the high quality society places on the environmental aspects of a natural creek system. Due to the width of the creeks and the environmental considerations these measures are not appropriate.

Dredging

Dredging involves removal of the bed of creeks and disposal of the material elsewhere. In this way the capacity of the creek is increased and in this way the flood levels upstream are reduced. Dredging is today predominantly undertaken for navigation purposes but this approach cannot be supported on Dora Creek. Many residents in flood liable areas along rivers or creeks in NSW expect that dredging should be undertaken to reduce flood levels. Whilst this has been undertaken in the past, the philosophy today is that it is an unsustainable practice and thus not acceptable if undertaken solely for flood mitigation purposes. The following issues need to be resolved before dredging can be supported:

- can the excavated material be suitably disposed of?
- will dredging result in significant environmental damage to the creek?
- is dredging sustainable?
- is dredging economically viable?

On Dora Creek the excavated material may be able to be satisfactorily disposed of if it is not contaminated, however it should not be used to fill already flood liable areas as this would defeat the purpose of increasing the creek and floodplain volume by removal of material. Thus one of the key issues that needs to be resolved is where can the spoil be deposited and associated with this is what will be the costs of removal and disposal? An Environmental Impact Statement would be required to investigate this issue.

The loss of fish habitat and associated environmental damage caused by dredging the bed of a river is significant but in time the riverine ecosystem will recover. There may also be some environmental harm to the receiving site for the spoil.

The most significant issue with any form of dredging is that it is not effective over the long term. Rivers and creeks are dynamic systems and are continually responding to the runoff regime. There are monthly, seasonal and decadal variations in the regime which means that the rivers / creeks are continually in a state of flux. Sediment is continually being fed into the system from catchment runoff and the watercourse responds through erosion and sedimentation in the area downstream. If sediment is excavated the flow velocities are reduced as there is a larger waterway area. The creek responds to this by increasing the rate of sedimentation in the dredged areas. In time any dredged area will fill in and thus require on-going dredging.

The 1992 Dora Creek Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options (Reference 2) reviewed the likely infilling rate and considered that 35,000 m^3 of sediment would be deposited each year within the two suggested areas of dredging (refer Figure 5). The report indicated that an effective life of dredging could be as short as 10 years. Dredging is therefore not a sustainable measure and will require on-going dredging to achieve the full flood mitigation benefit. Of issue is whether infilling will occur more rapidly during an actual flood and so the expected benefit may not be achieved when the peak of the flood occurs. Also the flood mitigation benefit will be at its maximum immediately after dredging but will diminish over time as infilling occurs. If the flood occurs after considerable infilling has occurred the benefit will be much reduced.

The financial viability of dredging is dependent upon the cost (initial and on-going) and the expected benefit in terms of reduced flood levels and resulting flood damages. The 1992 Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options (Reference 2) indicated that removal of 240,000 m^3 of sediment would lower flood levels by up to 0.26 m at Kalang Road. In lower Dora Creek removal of 190,000 m^3 would result in a reduction in levels of 0.12 m. The cost of these measures was $ 3.6 million and $ 2.9 million respectively in $1992. In the present study two dredging scenarios were evaluated assuming approximately 200,000 m^3 was removed from each of the same areas. The results are provided in Appendix C for the 10% AEP (1in 10 year), 5% AEP (1 in 20 year) and 1% AEP (1 in 100 year) events. An indicative cost for dredging these two areas would be over $ 5 million for each area with a similar on-going maintenance cost every 10 years.

For the dredging near Kalang Road and upstream of the railway line there is a maximum decrease in level of up to 0.2 m in the 1% AEP (1 in 100 year) event (refer Appendix C). However there is also a minor (up to 0.1m) increase in level downstream. This occurs as the dredging reduces flood levels upstream and thus the temporary floodplain storage which results in a slight increase in peak flow and thus levels downstream. The maximum benefit of this dredging is largely on rural lands where there are few buildings inundated above floor level (Figure 6). However a significant number of dwellings are affected by increases in peak flood levels and two dwellings are newly flooded above floor in a 10% AEP event (see Table 27), as a result of the dredging in this area and for this reason dredging at this location cannot be supported.

For the dredging downstream of the railway line there is up to a 0.2m reduction in flood levels in a 1% AEP (1 in 100 year) event with only a minor increase in peak levels downstream which is largely isolated to the Dora Creek channel itself. A number or properties are benefited being no longer flooded above floor (see Table 27).

Table 27: Summary of Change in Building Floors Inundated due to Dredging

	Existing	Dredging upstream of the railway line			Dredging downstream of the railway line		
Event	Buildings Inundated	Buildings Inundated	Change	Increase (%)	Buildings Inundated	Change	Increase (%)
1% AEP (1 in 100 year)	154	154	0	0%	135	-19	-12%
5% AEP (1 in 20 year)	75	75	0	0%	65	-10	-13%
10% AEP (1 in 10 year)	33	35	2	6%	29	-4	-12%

The AAD for each dredging scenario was assessed. The dredging near Kalang Road and upstream of the railway line increased AAD by approximately 1%, while the dredging downstream of the railway line reduces AAD by approximately 12%. Based on an assumed cost of $ 5 million every ten years, over a 50-year period total costs would be in the order of $ 25 million (today's $ value). This gives a benefit/cost (B/C) ratio in the order of 0.18 which is considerably low. A B/C ratio below one, means that the cost of the option far outweighs the benefits and is therefore not economically feasible. For this reason and the other environmental issues, dredging as a measure for flood mitigation is not recommended.

SUMMARY

Channel modifications are rarely a viable floodplain management measure to reduce upstream flood levels. Dredging the same areas as indicated on Figure 5 by 200,000 m^3 each was evaluated with the results for dredging upstream of the railway line not providing any benefit in terms of AAD. Dredging downstream of the railway line does provide reduction in AAD but this must be balanced against the costs and adverse impacts of dredging and was shown to have a low B/C ratio.

In conclusion dredging for flood mitigation purposes is not recommended due to:

- the high cost of dredging ($5 million every 10 years);
- potential increase in downstream flooding in some instances;
- the likely environmental impacts;
- this measure is not sustainable;
- the high cost of disposal of the dredged material;
- limited hydraulic benefit (i.e. reduction in flood levels) and thus an indicative benefit cost ratio of less than one for the dredging downstream of the railway line.

5.3.3. Provision of Floodways

DESCRIPTION

Artificial floodways are constructed to funnel floodwaters efficiently to the outlet and in so doing reduce flood levels. Natural floodways are locations where overland flows are concentrated. Previous studies (Reference 3) have indicated the following floodways (refer Figure 5):

1. construction of a diversion channel from opposite Kalang Road to the south of Baker Street, under the railway line / Macquarie Street and into Bonnells Bay;
2. the presence of a natural floodway on the north side upstream of the railway line leading to the opening under the rail line, approximately 700m north of Dora Creek, and then into Muddy Lake;
3. the presence of a constructed floodway on the north side immediately downstream of the entry of the cooling waters channel into Dora Creek;
4. the presence of a constructed floodway on the south side immediately upstream of the entry of the cooling waters channel into Bonnells Bay;
5. the presence of a small constructed floodway on the south side immediately downstream of the entry of the cooling waters channel into Bonnells Bay.

Figure 8 provides a map of the ground levels downstream of Kalang Road and indicates the low lying areas where floodwaters will predominantly flow. There is no precise quantitative definition of a floodway (refer Section 4.2) and they are identified in flood studies to indicate areas where development should be avoided due to velocity, depth or a combination of both as blocking them will significantly increase flood levels upstream. However there is no quantitative definition of the term “significantly” (is it a 0.01m, 0.1m or a 0.5m increase) or how much blockage could occur in a floodway. Generally the blockage is assumed to be by man-made developments such as buildings or filling, however it could also be interpreted as blockage by excessive vegetation growth.

DISCUSSION

Floodway 1: The 1992 Dora Creek Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options (Reference 2) indicated that a diversion channel from opposite Kalang Road 100 metres wide would reduce flood levels by up to 0.54 m. This measure is not practical for a number of reasons including:

- the cost to purchase land;
- the cost to pass under the railway line and Macquarie Street;
- the excavation costs;

- the likely high environmental impacts, including that this may cause Dora Creek to erode this channel in a major flood.

More realistic alignments to enable floodwaters to reach the lake more efficiently are either across the land to the south or north of Dora Creek and downstream of the railway line. To the north the alignment is restricted by houses along Dora Street and the channel taking the cooling waters to Eraring power station.

Whilst Floodways 2 to 5 have been identified in past flood studies (Figure 5) the precise status of these flow paths is unclear and this is discussed below.

Floodway 2 upstream of the railway line is of limited value as the critical restriction is the bridge under the railway line. This opening is already fed by a significant catchment from upstream and improving the flow path from Dora Creek would provide no significant benefit.

Floodway 3 is an unformed floodway on the north side immediately upstream of the entry of the cooling waters channel into Bonnells Bay. Part of this land is heavily vegetated but there is also a 20m wide cleared area partially obstructed by a building. This land is owned by the power station. Clearing this floodway would only provide a minor reduction in flood levels upstream due to the relatively narrow width available.

Floodway 4 is approximately 150m wide and was created when the cooling water channel was constructed in 1977 (left side of Photo 1). A concrete roadway was also formed on Stingaree Point Drive to limit damage by floodwaters to the road. The road is at approximately 0.6 to 0.8 m AHD whilst the floodway downstream is generally lower than 0.6 m AHD (refer Figure 8).

Photo 1: Construction of Power Station Cooling Water Channel, circa 1977 (source unknown)

In 1977 all vegetation was cleared from this floodway but it is unclear why this occurred. It is not clear if this was to act as a permanent or temporary measure during construction or if it was cleared for other construction purposes. Also, it is not clear if there was a requirement on any party to maintain the floodway in a cleared state.

Clearing of the shrub layer of vegetation on the isthmus of Dora Creek will reduce flood levels upstream by increasing the capacity of the overland flow paths taking flood waters into the lake. Floodway 4 is the floodway most likely to be able to provide the greatest benefit in reducing in flood levels as:

- it is the widest;
- it is already at a low level and thus takes a significant amount of floodwaters under present conditions;
- whilst the existing vegetation is of ecological value it has only formed since 1977;
- the land is owned by Council and free of any existing development;
- the road on Stingaree Point Drive has a concrete surface and thus to some extent is protected from erosion by floodwaters compared to a bitumen surface.

The hydraulic capacity of the floodway could be improved by either lowering the concrete roadway or reducing the vegetation cover downstream. The land south of Stingaree Point Drive is already at a very low level (below 0.6 m AHD) though Stingaree Point Drive itself is slightly higher at approximately 0.6 to 0.8 m AHD. A gabion wall, approximately 0.6m high has been constructed on the southern boundary of this area. Removal of this wall was modelled and the results indicated that this would produce nil reduction in flood level due to the large distance between the gabion and the creek.

Lowering the road would mean that it becomes inundated more frequently, increasing water depths and risk to life to drive through in a flood. This would be unacceptable to the residents who live further downstream on the south side as this is their only access route. To create a floodway at this location by excavation to lower ground levels would therefore require construction of a road bridge. If excavation is undertaken there is also the risk that during a flood there would be erosion on this alignment and creation of a new outlet to the lake which would introduce further problems.

Lowering the land or clearing the vegetation would have significant environmental impacts. The main issues with undertaking this work are:

- initial cost to cut and dispose of all existing vegetation (indicative estimate of $50,000);
- ongoing annual cost to maintain the floodway clear of vegetation (indicative estimate of $10,000 per annum);
- loss of significant vegetation community and habitat for fauna;
- likely increase in erosion potential on the cleared land.

Preliminary hydraulic modelling was undertaken to assess the effect of removal of the vegetation and this indicated that the 1% AEP (1 in 100 year) flood levels would be lowered by a maximum of 0.05 m. A coarse preliminary assessment of the reduction in AAD was undertaken and this indicated that the ADD could be reduced by approximately $90,000.

Floodway 5 is less well defined than Floodway 4 and retains natural vegetation. This floodway could also be cleared of all vegetation, or partially if only the shrub layer was cleared in a similar manner to Floodway 4. However works on Floodway 4 would be preferable as any reduction in flood level from Floodway 4 would have a greater benefit on the main communities on the north and south side as they are closer to the floodway.

Other Floodway Issues

Local residents have regularly raised the issue of former culverts to carry floodwater from Dora Creek at the northern railway embankment that conveyed water down Douglass Street into Muddy Lake. It is unclear why these culverts were removed but there was obviously some specific reason. Constructing new culverts under a railway line would cost over $1,000,000 depending upon the size and number of them. These culverts would reduce flood levels upstream but increase them slightly downstream thus providing no net benefit.

Residents have suggested additional openings under the railway line to reduce flood levels upstream. Whilst these would achieve this objective they would disadvantage land owners on the downstream side where outflows from the openings occur. However the main issue with this option is the high cost to excavate under a railway line and the relatively small hydraulic advantage as only small culverts could be installed.

SUMMARY

Creation of floodways or increasing the hydraulic conveyance of them will reduce flood levels upstream with no adverse effect downstream as floodwaters enter the Lake Macquarie waterway. There are several key issues with this measure, including:

- the decrease in flood levels is relatively small;
- the change in risk to life and other intangible damages such as inconvenience, worry, duration of access cut and others is minimal;
- the loss of vegetation and habitat is significant with some protected under the NSW Threatened Species Conservation Act and the NSW Fisheries Act;
- there is an ongoing cost to maintain the floodways clear of significant vegetation;
- there is the potential that the works may increase the erosion potential or possibly result in Dora Creek forming a new flow path in the next flood.

5.3.4. Local Drainage Issues

DESCRIPTION

Local stormwater flooding is probably the flooding mechanism which is most widely identified by the community as being of concern, the only exception being where the residents actually experienced the February 1990 or the June 2007 long weekend events. Local flooding occurs within the study area due to the relatively flat grades, especially in the lower parts of the catchment.

DISCUSSION

Local flooding results from rainfall over the local catchment being unable to quickly drain away. Generally it only occurs after 50mm of rain in an hour or two and will not cause above floor inundation. In the past there has been ponding in the roadway but this has been significantly reduced with installation of kerb and guttering. Ponding in yards still occurs and may take several days to drain away. It is likely to be associated with high water table conditions and is exacerbated when elevated water levels occur in the Lake Macquarie waterway simultaneously or if the drainage system is restricted by debris, silt or vegetation.

This issue is known to occur between the railway line and Awaba Road on the north side.

Upgrading the sub-surface system to improve the road to lake stormwater drainage system would improve the situation. Flap gates on culverts might also prevent back flow from Dora Creek and should be investigated further. Installation of agricultural drains in private yards would assist in reducing the incidence of local flooding. Debris (litter, vegetation) in the piped system is not considered to be a major contributing factor according to Council officers.

As the benefits of the works are largely intangible (reduction in inconvenience) it is difficult to justify these works on economic grounds. The costs to provide mitigation measures would depend on the exact nature of the works. Funding for these works would generally not be provided under the NSW State Government's flood mitigation funding program.

SUMMARY

Local flooding is a significant issue for many residents but preliminary investigation indicates that there is no viable economic solution due to the low relief of the area. One approach would be to more closely identify the worst affected areas and provide a newsletter suggesting how residents could minimise the impacts of nuisance flooding themselves. Council should seek assistance from local residents to identify the problem areas and how they might be addressed. Once identified, inspections should be undertaken and maintenance works scheduled accordingly via service requests, as and where required.

5.4. Property Modification Measures

5.4.1. Voluntary House Raising

DESCRIPTION

House raising has been widely used throughout NSW to eliminate or significantly reduce flooding of habitable floors. However it has limited application as it is not suitable for all building types. It is more common in areas where there is a greater depth of flooding and raising the houses allows creation of an underfloor garage or non-habitable area (though it is essential that this underfloor area and its contents will not incur flood damages, as if it is infilled this may negate the benefits of house raising). House raising is not a suitable option for properties that are affected by permanent inundation as, while the building may be above lake flood levels, the land and infrastructure will be affected by the rising waters.

Several homes in the study area have been raised in the past for flooding reasons. Certainly many new houses have been constructed as two storey buildings with the ground floor for a garage and the habitable floor on the upper level.

DISCUSSION

House raising is suitable for most non-brick single storey houses on piers and is particularly relevant to those situated adjacent to Dora Creek. The benefit of house raising is that it eliminates flooding to the height of the floor and consequently reduces the flood damages. It should be noted that larger floods than the design flood (used to establish the minimum floor level) will inundate the house floor. It also provides a “safe refuge” during a flood, assuming that the building is suitably designed for the water and debris loading. However the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during a medical emergency, or larger floods than the design flood occurs.

Funding from OEH and the local Council has been available for house raising in NSW in the past and has been widely undertaken in rural areas (Macleay River floodplain) and urban areas (Fairfield and Liverpool). However OEH funding is now only available where a detailed assessment has been undertaken and it may be that Council funding cannot be provided and thus the home owner would need to contribute part of the costs. An indicative cost to raise a house is $70,000 though this can vary considerably depending on the specific details of the house. Home raising was the traditional method of eliminating tangible flood damages but is less prevalent today in NSW as:

- the majority of suitable buildings have already been raised,
- the houses that can be raised are nearing the end of their useful life,
- house styles and requirements (ensuites, cabling, air conditioning) means that the timber piered homes are less attractive than in the past,
- most households indicate that they would prefer to use the funding to construct a new house,
- re-building rather than renovations are becoming more cost effective. In many suburbs in Sydney 30 year old brick homes are being demolished as the cost per m^2 to renovate is up to twice the per m^2 cost of re-building. Thus if 50% of the house is to be renovated it is cheaper to re-build.

Subsidised house raising has been available in Lake Macquarie for more than 30 years, but only about 20 owners have used the scheme, and none in the last 10+ years. This option is unattractive to home owners, and subsidies from the NSW Government are difficult to obtain. Council records indicate that two houses in the study area have had their floors raised in 2004 but none since.

A house raising/re-building subsidy scheme has been considered whereby the home owner can put the payment towards the cost of a replacement house constructed in a flood-compatible way rather than raising the existing building. Such a scheme has been promoted in other flood prone communities in NSW where there are large numbers of houses that could be raised but many owners wish to re build and/or consider it more cost effective. This scheme would provide a financial incentive to undertake house raising or re-building works and would be available to all house owners whose house is flood liable.

Slab-on-ground construction is probably the current most common method of housing construction. A significant issue with this mode of construction is that the building floor is generally not much higher than the ground level, thus there is a risk with overland flow or shallow depths of flooding that some above-floor flooding will occur. House raising has been undertaken for slab on ground houses in the past (Fairfield) but is unlikely to be financially viable.

The house raising potential within the study area cannot be accurately assessed as there is only limited information in the floor level database for many houses.

Seventy five houses in the area downstream of the railway line are identified as being flooded above floor in the 1% AEP event. An indicative B/C ratio was established assuming that these 75 houses would all be raised to the 1% AEP flood level plus 0.5 m. Assuming a cost of $ 70,000 per house, the B/C over a 50 year period would be in the order of 1.5, which shows that house raising could potentially be of benefit. The B/C ratio will vary from house to house, depending on the depth of flooding occurring, the type of construction of the existing dwelling and the cost to raise the building.

SUMMARY

For some of the currently flood affected buildings within the study area house raising is a viable means of flood protection, however the costs may prohibit implementation.

In addition a house re-building subsidy scheme should be initiated in order to provide an incentive to all house owners whose house floor is flood liable. There should be further consultation with the community on their willingness to participate.

5.4.2. Flood Proofing

DESCRIPTION

Flood proofing is not a suitable option for properties that are affected by permanent inundation as, while the building may be protected from lake flood levels, the land and infrastructure will be affected by the rising waters.

DISCUSSION

An alternative to house raising for buildings that are not compatible, is flood proofing or sealing off the entry points to the building. This measure has the advantage that it is generally less expensive than house raising and causes less social disruption. However this measure is really only suitable for commercial and industrial buildings where there are only limited entry points and aesthetic considerations are less of an issue. Also there are issues of compliance and maintenance. For all property types, flood compatible building or renovating techniques should be employed for extensions or renovations where appropriate. Guidelines are provided in a booklet *"Reducing Vulnerability to Flood Damage"* prepared in 2006 for the Hawkesbury-Nepean Floodplain Management Steering Committee (Reference 14) as well as a 2013 report for Council titled *"A Report on Development Guidelines for Resilient Housing for Lake Macquarie"* (Reference 15).

Flood proofing is generally not funded through government grants and would therefore have to be self funded.

SUMMARY
For some of the currently flood affected non residential buildings within the study area flood proofing is a viable means of flood protection, however the costs may prohibit implementation.

5.4.3. Voluntary Purchase

DESCRIPTION
Voluntary purchase involves the acquisition of flood affected residential properties (particularly those frequently inundated in high hazard areas) and demolition of the residence to remove it from the floodplain. Generally the land is returned to open space.

Voluntary purchase is mainly implemented in high hazard areas as a means of removing isolated or remaining buildings and thus freeing both residents and potential rescuers from the danger and cost of future floods. It may also help to restore the hydraulic capacity of the floodplain.

DISCUSSION
As indicated in Section 5.2 voluntary purchase of all existing buildings inundated in the PMF cannot be justified on economic grounds.

Voluntary purchase has no environmental impacts although the economic cost and social impacts can be high. Many residents do not accept voluntary purchase because it would have significant impact on their community and way of life. Among these concerns are:

- it can be difficult to establish a market value that is acceptable to both the State Valuation Office and the resident;
- in many cases residents may not wish to move for a reasonable purchase price;
- progressive removal of properties may impose stress on the social fabric of an area;
- it may take several years before funding becomes available and in that time it is difficult for the owners to sell their properties privately as they would likely have to advise potential purchase of the voluntary purchase scheme.

However voluntary purchase is the only means of removing houses from the floodplain that present a regular and significant risk to life and flood damages that cannot be protected by other means.

SUMMARY
There are several houses located within or very close to high hazard floodways. These properties experience relatively frequent inundation of their building floor and could be considered for voluntary purchase. However, Council does not have funds available for

voluntary purchase of properties and funds would have to be made available from the State or Federal Governments. Experience in other areas, such as Maitland, is that it is unlikely that many owners would take up the offer.

5.4.4. Strategic Planning Issues

DESCRIPTION

Current land use zones are provided on Figure 3 and identified within the flood liable areas on Table 11. The division of flood prone land into appropriate land use zones can be an effective and long term means of limiting danger to personal safety and flood damage to future developments. Zoning of flood prone land should be based on an objective assessment of land suitability and capability, flood risk, environmental and other factors. In many cases, it is possible to develop flood prone lands without resulting in undue risk to life and property.

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

There are several flood liable areas in NSW where past floods have caused relocation to higher ground (Terara village to Nowra on the Shoalhaven River following the 1860 and 1970 floods) or the gradual decline of an area with limited potential for re-development (Horseshoe Bend at Maitland following the February 1955 flood).

DISCUSSION

Design flood mapping was undertaken as part of the 2015 Draft Dora Creek Flood Study (Reference 6) and is used by Council to identify properties subject to flood related development controls. The planning principle to be applied by Council is to limit development within floodways, in accordance with the requirements of the NSW Floodplain Development Manual (Reference 1) and the Construction of Buildings in Flood Hazard Areas Standard (Reference 16).

A significant issue at Dora Creek is the implications of sea level rise. It may be that some existing developed areas cannot be cost-effectively protected from future sea level rise. For these areas Council and the community will need to establish some form of re-development strategy. Each of these areas must be examined in detail through a local adaptation planning process.

DCP 2014 and the Dora Creek Precinct Area Plan

The current DCP 2014 includes a Dora Creek Precinct Area Plan (carried over from the 2004 DCP) that imposes specific development controls on some areas upstream of the railway bridge (Kalang Road and Baker Street), as well as downstream of the bridge. The Area Plan forms part of the DCP and translates flood study findings into development controls for Dora Creek. The current DCP provisions need to be revised to reflect the details of flood heights and extents in the new Study, as well as clarifying Council's position on the application of the DCP provisions in the commercial zone adjacent to Wamsley and Dora Streets. It is recommended that the Dora Creek Precinct Area Plan be reviewed and revised by Council to update controls (and maps) to restrict development within designated floodways (see Figure 58), prohibit development of Building Code of Australia Classes 1, 2, 3 4, 9a and 9c buildings in areas with flows in excess of 1.5 m/s, and clarify development controls for commercial and mixed use development,

Filling

Filling of the floodplain is generally not considered an acceptable means of permitting future development as it "destroys" the ecology of the area, disrupts flow behaviour, and affects local drainage. On the Dora Creek floodplain filling can raise flood levels by eliminating temporary floodplain storage and, in some cases, reduce the hydraulic conveyance. This is of particular importance in the areas downstream of the railway line as blocking these flow paths would impact on other floodplain users.

In flood fringe areas, where raising ground levels will not have a significant adverse impact on flood behaviour, managed filling could be adopted to ensure that there are no adverse impacts on surrounding flood levels, local drainage issues are not exacerbated and services (roads, sewer, water) can be accommodated. However a separate detailed flood study using an appropriate hydraulic model would be required to justify any proposed filling. The cumulative effects of filling would also have to be considered in such a study. These effects are difficult to evaluate as this would require knowledge of the extent and location of further fill in the study area.

Limit the Extent of Development

Development could be restricted in that no new development would be allowed within a flood prone area, for example up to the 1% AEP (1 in 100 year) event. This is appropriate in areas designated as floodways. However, where areas are already developed this can lead to degeneration in an area and has social implications for current property owners. Alternatively, future development in flood liable areas could be restricted to the "lowest residential" zoning. Thus any development that will increase the present residential density would not be permitted. Thus dual occupancy, sub-division or increasing the site coverage (increasing the size of the building) would not be permitted. In affected areas already zoned for medium density residential or urban centres, this could mean "back-zoning" to a lower development density, which may have legal and financial ramifications for Council. Legislative and financial options for Council and property owners to help deal with these situations should be raised with the NSW and Australian Governments, as the problem will occur in all coastal LGAs. There is also the possibility of establishing "transferable development rights" or similar schemes to encourage voluntary changes to inappropriate property zonings.

Ensuring Adequate Evacuation

Within Dora Creek, even if house raising, construction of a levee or filling was undertaken, and the services issues resolved, there is still no flood free access to high ground in flood. Whilst in a medical emergency a helicopter or flood boat could access the area many residents will attempt to cross the floodwaters (collect children, leave house, obtain food). This represents a burden on the SES to "rescue" residents and a risk to life to the residents who cross floodwaters unprepared.

At present many locations do not have adequate flood access (refer Figure 9). The lack of adequate access may mean that some areas should not be further developed. Council has constructed a flood access route from Baker Street to Moira Park Road in 2005 (refer Table 10). However many residents still have to travel through floodwaters for a relatively long distance or leave prior to the bank overtopping. It is understood that the gates could not be opened in the June 2007 event. This issue should be re-evaluated by the SES in their Flood Plan.

Review of Proposed Areas for Development

Figure 2 and Figure 4 indicates the areas for proposed development. The majority of these areas are outside the 1% AEP (1 in 100 year) flood extent. However adjacent to Clacks Creek, Stockton Creek and Mallards Creek the perimeter of these areas may approach into the 1% AEP (1 in 100 year) floodplain. This also occurs in Jigadee Creek and upstream of Cooranbong on Dora Creek. The following guidelines are suggested:

- initially an assessment must be undertaken to determine what parts of the proposed development areas will encroach into the 1% AEP (1 in 100 year) floodplain and what development is proposed for these areas. It may be that open space or other flood compatible use is proposed;
- on site detention or retarding basins should be incorporated into the design to ensure that the capacity of the existing drainage system is not reduced (i.e. no increase in peak flow). For direct inflows into major creeks such as Stockton Creek, Dora Creek or Jigadee Creek areas where the increase in peak flow in the 1% AEP (1in 100 year) will be less than 0.5% do not require mitigation works.

On Site Stormwater Detention (OSD)

OSD is implemented to ensure that the peak flows emanating from a developed catchment are not increased above that under the "natural" catchment conditions. Development increases the peak rate of flow by changing pervious into impervious surfaces and by reducing the travel time of runoff by changing vegetation surfaces to hard stand or including pipes in the conveyance system. OSD acts by creating mini retarding basins in each property and so attenuates the developed peak flow back to the undeveloped peak.

All Sydney Councils implement some form of OSD otherwise the downstream floodplain users would receive increased peak flows and thus increased peak flood levels when new development occurs.

Section 5.2 indicated that the incorporation of OSD on new developments will not provide any benefit in reducing flood levels in Dora Creek. However for the small catchments contributing to Dora Creek urbanisation (construction of pipe drainage systems and changing pervious to impervious cover) will increase peak flows downstream. OSD is supported as a means of mitigating the impacts of this urbanisation increasing peak flows downstream. OSD would only be applied where there is a drainage system downstream that would be affected by the increase in flow. For example, a property directly discharging into Dora Creek would not require OSD as the effect of urbanisation of the property would have no impact on flood levels in Dora Creek.

OSD is governed by applying a site storage requirement (SSR) and a permissible site discharge (PSD) to each property. The SSR and PSD are determined from a catchment based study and are unique to a specific sized catchment and extent/location of development. For example in the upper part of an existing developed catchment OSD will ensure that the piped drainage system and properties immediately downstream do not receive increased peak flows from the proposed development. However in the lower part of the catchment, where the drainage system feeds into a lake or large river system, the increased rate of runoff from a new development may be beneficial as this means the runoff has disappeared before the upstream peak arrives. For this reason many Councils have a line below which no OSD is required.

It should be noted that only a small percentage of the Dora Creek catchment comprises urban development containing impervious ground cover and piped drainage systems. The bulk of this urban development is at the downstream part of Dora Creek. Consequently the existing extent of urbanisation will have made very little difference to the peak flood levels in Dora Creek within the study area, however along small creeks the impact will be greater.

SUMMARY

Strategic planning is the main approach for reducing flood damages to future developments. No detailed assessment has been undertaken for future development scenarios or the necessary public consultation to determine which strategy should be employed. It is recommended that this process be undertaken to develop an appropriate approach for the Dora Creek area taking into consideration the implications of sea level rise.

5.4.5. Rezoning

DESCRIPTION

Rezoning involves changing current land uses as defined in the LEP (Figure 3) to remove higher risk properties from the floodplain such as residential properties and to prevent further development which could be at flood risk.

DISCUSSION

While it seems “common sense” to prevent additional development in vulnerable areas this could, in effect, ‘freeze’ new development in all flood affected areas. This is contrary to the aim of the NSW Government’s 2005 Floodplain Development Manual (Reference 1) which seeks to allow new development in flood affected areas, provided the risk is adequately assessed and managed.

In general, it is likely to increase the risk to persons and property, if more buildings, infrastructure and people are located in flood hazard areas, particularly high hazard areas and areas vulnerable to permanent inundation. So, land in the defined flood hazard areas should not be re-zoned if it increases development intensity. Individual developments that increase development intensity within current zonings, should be assessed against the increased risk to persons and property resulting from the development. As far as possible the risk should be minimised through the use of appropriate measures and be within acceptable standards taking into account the history of development in the area. If the development is likely to produce unacceptable risks the application should be modified.

In some specific circumstances, rezoning of flood liable land for higher density development could encourage people to purchase and demolish existing flood liable property and redevelop the area in accordance with Council's design floor level policy. This strategy is difficult to implement, as generally the surrounding residents, who are not flood affected, consider that the quality of the area would be adversely affected by the increased building density. Furthermore the high cost to purchase the existing land and building is unlikely to make this measure financially attractive to developers. Additional concerns are the cost to provide and maintain on-going services as well as the likely lack of adequate flood access. Such proposals should be considered against, at least, the criteria of "no increase in risk compared to current risk" for the life of the development.

The wholesale rezoning of all flood liable lands is not appropriate, but this measure could be used on a local scale as a means of removing or improving flood liable buildings.

SUMMARY

Table 16 indicates that over 150 building floors within the Dora Creek area are flood liable in the 1% AEP event. In many cases these properties may experience hazardous conditions during floods with limited evacuation routes. It is considered that current land uses are largely appropriate as they are currently the lowest density residential available in the LEP although Council may wish to review land-use zones in the future in the light of climate change.

5.4.6. Modification to the s149 Certificates

DESCRIPTION

Councils issue planning certificates to potential purchasers under Section 149 of the Environmental Planning and Assessment Act of 1979. The function of these certificates is to inform purchasers of planning controls and policies that apply to the subject land. Planning certificates are an important source of information for prospective purchasers on whether there are flood related development controls on the land. They need to rely upon the information under both Section 149(2) and 149(5) in order to make an informed decision about the property. It should be noted that only Part 2 is compulsory when a house is purchased and thus the purchaser may be unaware of detail in Part 5 unless it is specifically requested. Under Part 2 Council is required to advise that there are development controls that relate to hazards such as flooding, bush fire and landslip.

The current wording shown on Section 149(2) and 149(5) certificates provides only limited details of the extent of flood and sea level rise effects.

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on the type of flooding, whether from major rivers or local overland flooding, and the extent of flooding (whether widespread or relatively confined). It is noted that Council had for many years issued a Flood Prone Advisory Letter which was been well received. This practice has been unavailable since approximately 2006. New technology allows the possibility of this information being made available through an on-line property inquiry.

It should be noted that the Section 149 certificate only relates to the subject land and not any building on the property. This can be confusing or misleading to some.

The information provided under Part 2 of the certificate is determined by legislation and unless specifically included by the Council provides no indication of the extent of inundation. Under Part 5 there is scope for providing this additional type of information. Residents in many areas have suggested that insurance companies, lending authorities or other organisations may disadvantage flood liable properties that have only a very small part of their property inundated by floodwaters. Some Councils have addressed this concern by adding information onto Part 5 to show the percentage of the property inundated as well as floor levels and other flood related information.

Flood related development controls (such as stipulation of a minimum floor level) are the most constructive measures for reducing flood damages to new residential dwellings. The 1% AEP (1 in 100 year) flood level has been adopted in NSW and in many other parts of the world as a "reasonable standard" for managing flood risk for residential developments, a higher standard is adopted for developments more vulnerable to flooding such as hospitals, electricity sub stations or “seniors” housing. A lower standard would mean residents suffer undue damage and risk to life whilst a higher standard means that the society is spending a lot of money in managing a risk which has a low chance of occurrence.

According to the 2005 Floodplain Development Manual (Reference 1) the *purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of a FPL is actually provided given the following factors*:

- uncertainties in estimates of flood levels,
- differences in water level because of “local factors”,
- increases due to wave action,
- the cumulative effect of subsequent infill development on existing zoned land, and
- climate change. This largely relates to rainfall increase as future sea level rise has been relatively accurately determined by the IPCC and should not be included within the 0.5m freeboard.

In a real flood some of these factors may reduce the flood level (local factors) or not apply at all (no wave action).

SUMMARY

It is recommended that Council consider revising the flood related information on the Section 149 Certificate. As Council information for 149 Certificates is obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its web-site.

5.4.7. Minimise the Risk of Electrocution

DESCRIPTION

Minimising the chance of electrocution by turning off the electricity supply during a flood should be ‘standard practice’ for residents and commercial owners during floods. The risk of electrocution can also be reduced by installing electrical circuits above, at least, the flood planning level (1% AEP (1 in 100 year) flood level + 0.5 m freeboard).

DISCUSSION

There is always the risk of electrocution in times of flood and whilst this has occurred elsewhere there is no record of injury or loss of life due to electrocution in the study area in the February 1990 or the June 2007 long weekend events. In order to reduce the risk of electrocution a flood education program should be undertaken in vulnerable communities, especially with older housing stock.

SUMMARY

There is a risk of electrocution during flooding within the study area which needs to be addressed. At a minimum flood education programs should encompass this issue, and there may be role for specific programs targeted at tradesmen, for example, to encourage safer installations.

All new developments and re-developments should have requirements to locate unsealed electrical circuits at least 0.5 m above the 1% AEP (1 in 100 year) flood level. Ways to encourage retro-fitting of older buildings should be investigated, which could range from requiring circuit breakers as a condition for any re-development approvals, offering incentives to encourage owners to up-grade, to considering mandatory retro-fitting requirements. A minimum aim should be to have all properties in flood hazard areas to, at least, be fitted with a circuit breaker.

5.4.8. Reduce Failure of Sewerage System

DESCRIPTION

Residents have indicated that in the June 2007 long weekend event, the sewerage system failed in some places. It is unclear the exact cause of the failure and whether it was directly or indirectly due to the rainfall event or inundation by floodwaters. This failure represents a significant health risk to residents who wade through floodwaters. Failure predominantly occurs due to power outages (fallen power lines) but in large events the pumping stations may be turned off due to the influx of flood waters into the sewerage system.

Failure of the sewerage system can mean that properties that are not inundated by floodwaters but are connected to a non working pump station are also affected. Whilst the volume of sewerage discharge is minimal compared to the volume of floodwaters it becomes a significant hazard as the floodwaters are relatively static with little mixing.

DISCUSSION

The failure of the sewerage system during floods should be addressed. Initially this would involve a preliminary investigation and review of how failures have occurred in the past during floods. This would then lead to a means to reduce the failures (more secure power supply or raise vents in yards). Properties with floor levels below the flood planning level will require careful consideration to see how this can be achieved.

SUMMARY

The failure of the sewerage system during floods is considered one of the most significant floodplain management issues affecting the community and must be addressed.

5.5. Response Modification Measures

5.5.1. Flood Warning

DESCRIPTION

It may be necessary for a number of residents to evacuate their homes during or following a major flood, such as the February 1990 and June 2007 long weekend events, though it is understood that many residents stayed in their homes (possibly moved goods and themselves to an upper floor or onto tables or such like).

The amount of time for evacuation depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

Flood warning and the implementation of evacuation procedures by the SES are widely used throughout NSW to reduce flood damages and protect lives. Adequate warning gives residents time to move goods and cars above the reach of floodwaters and to evacuate from the immediate area to high ground. The effectiveness of a flood warning scheme depends on:

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

For smaller catchments a Severe Weather Warning (SWW) is provided by the Bureau of Meteorology (BoM) but this is not specific to a particular catchment.

DISCUSSION

The BoM is responsible for flood warnings on major river systems such as Lake Macquarie waterway and the Hunter River. Flood warning systems are based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. This information is then provided to the SES who undertake evacuations or flood damage prevention measures (sand bagging or raising goods).

The benefit cost ratio of flood warning systems depends on the cost to install or upgrade an existing system and the benefits that accrue in terms of a reduction in tangible and intangible damages. The reduction in tangible damages is less important than the reduction in intangible damages (safe and easy evacuation to high ground). Also there is only a limited amount of tangible damage reduction that is possible as damage to the building fabric, carpets, cabinets and other fixed items cannot be mitigated. It is impossible to accurately assess the benefit cost ratio for improving the existing flood warning system for Dora Creek but all would agree that any additional warning time is beneficial in reducing the potential risk to life and ensuring a safe evacuation. A major feature of improving the system is that there are no adverse impacts that must typically be addressed with implementation of other management measures. In this regard all residents should be made aware of the types of warnings issued by the BoM (refer flood awareness in Section 5.5.3).

Flooding in the Dora Creek catchment occurs relatively quickly and residents may potentially be caught unaware. The depth of floodwater varies throughout the study area with Kalang Road properties the worst affected.

The 2015 Dora Creek Flood Study (Reference 6) examined a range of rainfall durations (2 to 72 hour) to determine the design storm duration which produces the highest levels in Dora Creek and concluded that the 36 hour was critical, although the 9 hour duration was only slightly lower. However, design storms are not necessarily representative of real storm events within the catchment and the degree of flooding in the lower reaches of Dora Creek will depend on factors such as:

- co-incidence of rainfall within the Dora Creek, Stockton Creek and Jigadee Creek;
- water levels within Lake Macquarie waterway; and
- storm movement and rainfall intensities across the catchment.

Rainfall and flood levels during the June 2007 long weekend event are shown on Figure 11 which indicates that the maximum warning time was probably only 12 hours but realistically as the peak rainfall occurred in the afternoon/evening of 8th June 2007, with the peak in the early hours of the following day, the available warning time would be probably only 3 to 6 hours, depending upon the alertness of the residents. Residents within areas such as Stingaree Point Drive reported that they were isolated for up to 24 hours.

The BoM already has a flood warning system for the Lake Macquarie waterway catchment and MHL operates and maintains Floodwatch (Section 2.7.5) for Dora Creek which is a specific flood warning system for Dora Creek. A review of the system is currently (2014/15) being undertaken to ensure that it will work successfully in all future events.

Council also part sponsors the Australian Early Warning Network emergency/severe weather alert service that has approximately 50 subscribers within the study area.

SUMMARY

The greatest improvement in the accuracy of any flood warning predictions generally only occurs following major flood events. It is imperative therefore that a post flood assessment report be prepared following each future flood event with particular emphasis on the adequacy and accuracy of the flood warning system. This post flood assessment has been undertaken for the June 2007 long weekend event by the BoM.

Council is currently investigating the feasibility of a City-Wide Integrated Flood Warning System. It is intended that the current Dora Creek flood warning system be upgraded as appropriate and integrated with the City Wide Flood Warning System. Improvements include upgrading a number of gauges to ALERT and accounting for flood data from recent flood events. Upgrading the Kalang Road water level gauge to ALERT is currently underway. The remaining network of gauges (e.g. Morisset and Mandalong) would benefit from ALERT upgrades to improve warning times". Improving the flood warning system is relatively inexpensive and is likely to have a high benefit/cost ratio. It has no apparent adverse environmental or social impacts. The new information and predictive modelling from the 2015 Dora Creek Flood Study (Reference 6) has already been provided to MHL to assist with their flood prediction and warning system.

5.5.2. Flood Emergency Management

DESCRIPTION

As mentioned above, it may be necessary for some residents to evacuate their homes in a major flood. This would be undertaken under the direction of the lead agency under the Displan, the SES. Some residents may choose to leave on their own accord based on flood information from the radio or other warnings, and may be assisted by local residents. The main problems with all flood evacuations are:

- they must be carried out quickly and efficiently,
- there can be confusion about ‘ordering’ evacuations, with rumours and well-meaning advice from other residents taking precedence over official directions which can only come from the lead agency, the SES
- they are hazardous for both rescuers and the evacuees,
- residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers, and
- people (residents and visitors) do not often appreciate the dangers of crossing floodwaters.

For this reason, the preparation of a Community Flood Emergency Response Plan (CFERP) helps to minimise the risk associated with evacuations by providing information regarding evacuation routes, refuge areas, what to do/not to do during floods etc. It is the role of the SES to develop a CFERP for vulnerable communities. Dora Creek is the only community in Lake Macquarie LGA with a local CFERP currently in place.

DISCUSSION

The SES has the skills and experience to undertake the necessary evacuations. A local area response plan has already been prepared for the community and the Baker Street flood evacuation route established (Section 2.7.6). Council has also worked with the community through various means to improve public safety and to reduce damages during times of flood.

In a flood emergency, the SES is assisted by other agencies such as the Department of Family and Community Services who establish and operate evacuation centres. The Local Emergency Management Committee supports the SES by coordinating response by emergency service providers.

A key part of any flood emergency is the recovery arrangements, a well thought out and carefully managed recovery will ensure that residents and the community are able to be "back on their feet" as quickly as possible. This phase is very important and requires input from many different authorities.

SUMMARY

The SES should ensure that the Local Emergency Response Plan for Dora Creek is up to date and includes feedback from the June 2007 long weekend event and the recommendations of this plan. This might include floor level and ground level details provided in this report and the 2015 Dora Creek Flood Study (Reference 6). In addition, any input from the local community (e.g. Council, rural fire service, and community representatives) is recommended to ensure that workable actions for the community are incorporated. Priority should be given to the implementation of this Plan once completed, which will continue to involve ongoing community education and awareness.

5.5.3. Public Information and Raising Flood Awareness

DESCRIPTION

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

Flood Awareness: How aware is the community to the threat of flooding? Has it been adequately informed and educated? How aware is the community of how this threat will be exacerbated with sea level rise?

Flood Preparedness: How prepared is the community to react to the threat of flooding? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?

Flood Evacuation: How prepared are the authorities and the residents to evacuate households to minimise damages and the potential risk to life during a flood? How will the evacuation be done, where will the evacuees be moved to?

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc. Photographs (of less importance with digital photography) and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have "survived" previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner. To some extent many of the above issues for Dora Creek have already been addressed by the community as a result of previous floods including the February 1990 and June 2007 long weekend events.

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

- *Frequency and impact of previous floods.* A major flood causing a high degree of flood damage in relatively recent times will increase flood awareness. If no floods have occurred, or there have been a number of small floods which cause little damage or inconvenience, then the level of flood awareness may be low. As a result of the June 2007 long weekend event, which caused significant damage, the community generally has a medium to high level of awareness at this time (it will decline as the time since the last flood increases and maybe increase as a result of community flood or climate change awareness programs).

- *History of residence*. Families who have owned properties for a long time will have established a considerable depth of knowledge regarding flooding and a high level of flood awareness. A community which consists predominantly of short lease rental homes will have a low level of flood awareness. It would appear that the majority of the residents have lived in the study area for several years and are therefore familiar with flooding. Also it is very likely that new residents will be aware from advice at the time of their property purchase (Section 149 certificate) or from neighbours after they move in. It is very unlikely that a new resident buying a house along the foreshore of Dora Creek will not be aware of the potential of flooding.

- *Whether an effective public awareness program has been implemented.* A comprehensive awareness program has been implemented in the past by Council and the SES, and there have been many articles in the national and local press.

For risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and level of awareness diminishes as the time since the last flood increases.

A major hurdle is often convincing residents that major floods (larger than the June 2007 long weekend event) will occur in the future. Many residents hold the false view that once they have experienced a large flood then another will not occur for a long time thereafter. This viewpoint is incorrect as a 1% AEP (1 in 100 year) event (or sometimes termed a 100 year ARI) has the same chance of occurring next year, regardless of the magnitude of the event that may have recently occurred. A similar analogy is after "tossing" a coin say 5 times and coming up with "heads" each time, the chance of "heads" on the next throw is still 50:50.

Some NSW Councils (Rockdale, Pittwater, Maitland) have initiated catchment-wide flood awareness strategies (for residential and commercial). For the study area only a residential strategy is recommended as there are few commercial areas in flood hazard areas. Council and the SES produced the Dora Creek *FloodSafe* Brochure and their websites: **(www.ses.nsw.gov.au/content/documents/pdf/floodsafe/42156/doracreekfloodsafeguide, http://www.lakemac.com.au/downloads/Dora%20Creek%20FloodSafe%20brochure.pdf)** also provide excellent information on flood awareness and other flood related and climate change information.

Council has also other comprehensive information on flood history, past studies, awareness, preparation, frequently asked questions and other related information included in **www.lakemac.com.au/environment/natural-disaster/flooding**.

SUMMARY

Based on feedback it would appear that the majority of residents within the study area have a medium to high level of flood awareness and preparedness. However this may not be the case for the "holiday" visitors.

As time passes since the last significant flood, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program that would include Floodsafe brochures as well as advice provided on the Council and SES websites. Council and the SES are both active in updating their flood information for Dora Creek and this should continue.

Table 28 provides examples of various flood awareness methods that can be employed.

Table 28: Flood Awareness Methods

Method	Comment
Letter/pamphlet from Council	These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive measure which can be effective if residents take the time to absorb and apply the suggestions. The pamphlet can inform residents of ongoing implementation of the Risk Management Plan, changes to flood levels, climate change or any other relevant information.
Council website	Council should continue to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding within the study area (and elsewhere in the LGA) as well as on issues such as climate change. It is recommended that Council's website continue to be updated as and when required.
Community Working Group	Council has already initiated a Community Working Group framework in late

Method	Comment
	2013 and this will provide a valuable two way conduit between the local residents and Council.
School project or local historical society	This provides an excellent means of informing the younger generation about flooding and climate change. It may involve talks from various authorities and can be combined with topics relating to water quality, floodplain management, etc.
Displays at caravan parks or similar	This is an inexpensive way of informing the tourist/holiday maker community and may be combined with related displays.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood and climate change issues are not forgotten. Historical features and remembrance of the anniversary of past events are interesting for local residents.
Collection of peak water level data from future floods	Collection of data (photographs) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible (as occurred successfully after the June 2007 long weekend event). This might also include establishment of peak water level marker poles and which house floors are inundated (refer flood database below).
Types of information available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 149 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all visitors who may rent for a period. Some Councils have conducted “briefing” sessions with real estate agents and conveyancers.
Establishment of a flood affectation effects database	A database would provide information on (say) which houses require evacuation, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event. It is already being developed as part of this present study. This database should be updated following each flood with input from the community.
Flood preparedness program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Develop approaches to foster community ownership of the problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example residents should be advised that they have a responsibility to advise Council if they see a problem such as debris blockage or such like. This process can be linked to water quality or other water related issues including estuary management. The specific approach can only be developed in consultation with the community.

The specific flood awareness measures that are implemented will need to be developed by Council taking into account the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed in consultation with affected communities.

5.6. Other Management Measures

5.6.1. Mine Subsidence in Flood Related Development Controls

Whilst this is not a measure to manage the flood problem it is an issue that must be addressed to ensure that reliable floor level controls are incorporated into Council's flood related policies.

The Mine Subsidence Board has indicated that parts of the study area are within a mine subsidence area. The magnitude of subsidence could be between 0.1 m and 0.6 m. Further detail is required to define the likely extent and magnitude of mine subsidence and an appropriate allowance, over and above the 0.5 m freeboard, should be included in the flood development assessment process. Mine subsidence may also influence which areas will be exposed to permanent inundation from sea level rises.

It is only the Mines Subsidence Board that can provide this information and it is generally only provided for individual properties rather than on a broadscale basis.

5.6.2. Flood Insurance

Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments. It is only in the last five years or so that flood insurance has become readily available for houses, although it was always available for some very large commercial and industrial properties. There are many issues with the premium for this type of insurance and how insurance companies evaluate the risk (for example an insurance company may base premiums on ground level or may choose to consider the actual floor level of the development). These issues are outside the scope of this present study and were assessed as part of the Commission of Inquiry into the South East Queensland floods of January 2011. Flood insurance at an individual property level is encouraged for affected land owners, but is not an appropriate risk management measure as it does not reduce flood damages.

Insurance companies will not cover damage from storm surge, but the 2013 Dora Creek Flood Study (Reference 6) shows that it is rainfall events in the Dora Creek catchment that causes flooding together with elevated levels in Lake Macquarie waterway.

Continued access to flood insurance in flood-affected areas is, in part, dependent on the current system of flood studies and risk management planning represented by this Dora Creek Flood Study and Risk Management Study and Plan. This planning must include consideration of the future risk from sea level rise and climate change.

5.6.3. Adaptation to Sea Level Rise

A recommendation of the 2012 Lake Macquarie Waterway Flood Risk Management Study and Plan (Reference 9) was to undertake local adaptation plans (refer Section 2.7.7) and a plan will be undertaken for the area. As part of the present study three possible development scenarios have been investigated in order to determine their hydraulic impacts. These scenarios are broad scale and assume either filling of the land or construction of a levee. The three scenarios are:

1. Filling of the residential land within the Sydney Road and Cowell Street area on the south bank;
2. Filling of all residential lands on the north side bounded by the railway line, the river bank and Douglass Street and extending eastwards to the power station inlet channel crossing Dora Street;

3. Filling of all residential lands on the north side as for 2) above plus extending to the eastern end of the peninsula.

The modelling was undertaken for the 1% AEP (1 in 100 year) event. No assessment was undertaken for the residential properties on the south side to the east of Cowell Street along Stingaree Point Drive as this would require some form of elevated roadway in order to provide access during floods.

The results indicate the following:

- **Scenario 1**: Flood levels rise by a maximum of 0.05m upstream of the railway line at Baker Street and on the opposite bank at Doree Place. Properties on Kalang Road will experience up to a 0.02m increase;
- **Scenario 2**: The flood impacts are similar to Scenario 1 with flood levels rising by a maximum of 0.05m on the opposite south bank at Cowell Street and upstream of the railway line at Baker Street. Properties on Kalang Road will experience up to a 0.02m increase;
- **Scenario 3:** Flood level increases rise to above 0.05m upstream of the railway line with up to a 0.05m increase at Kalang Road.

Whilst any increase in flood level is unacceptable the increases are relatively small but affect a large number of buildings. If the existing development is to be maintained in these areas and sea level rise occurs, consideration will have to be given to addressing this issue as well as possible impacts on the provision of services and infrastructure (roads, water, power etc.).

6. ACKNOWLEDGMENTS

Lake Macquarie City Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage. The assistance of the following in providing data and guidance to the study is gratefully acknowledged:

- Lake Macquarie City Council;
- NSW Office of Environment and Heritage;
- Hunter Water;
- Manly Hydraulics Laboratory;
- Council's Floodplain Management Committee;
- State Emergency Services;
- Residents of the study area.

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2. Public Works Department NSW
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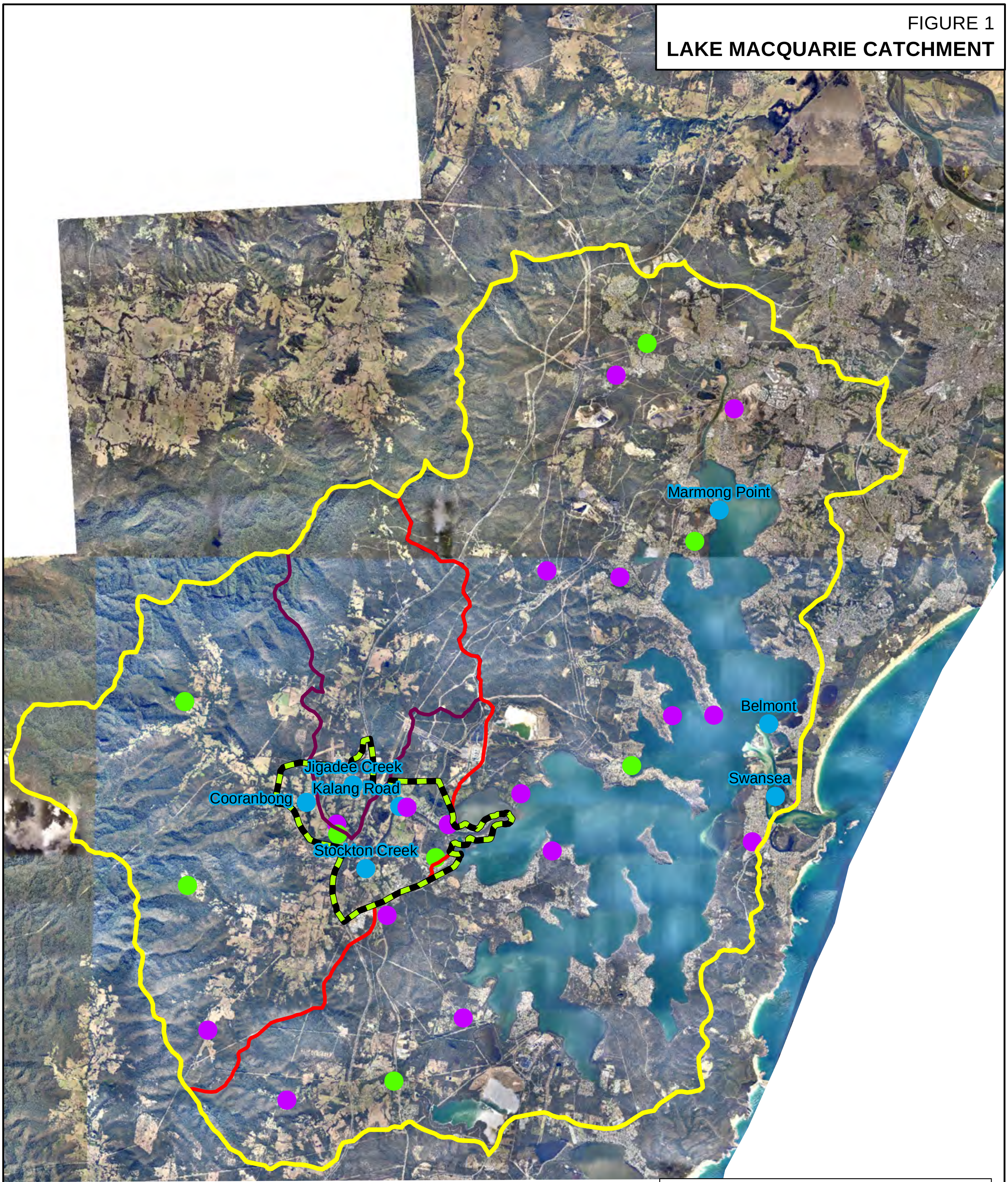
Version 2012.2

Figures

FIGURE 1
LAKE MACQUARIE CATCHMENT



NOTE:

1. Hunter Water operates approximately 15 pluviometers on the north east side of Lake Macquarie between Belmont and Wallsend. For clarity these gauges are not shown on this figure.

N

0 2.5 5 7.5 10 km

- Study Area
- Lake Macquarie Catchment
- Dora Creek Catchment
- Jigadee Creek Catchment
- Pluviometer
- Daily
- Water Level

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FIGURE 2
DORA CREEK STUDY AREA

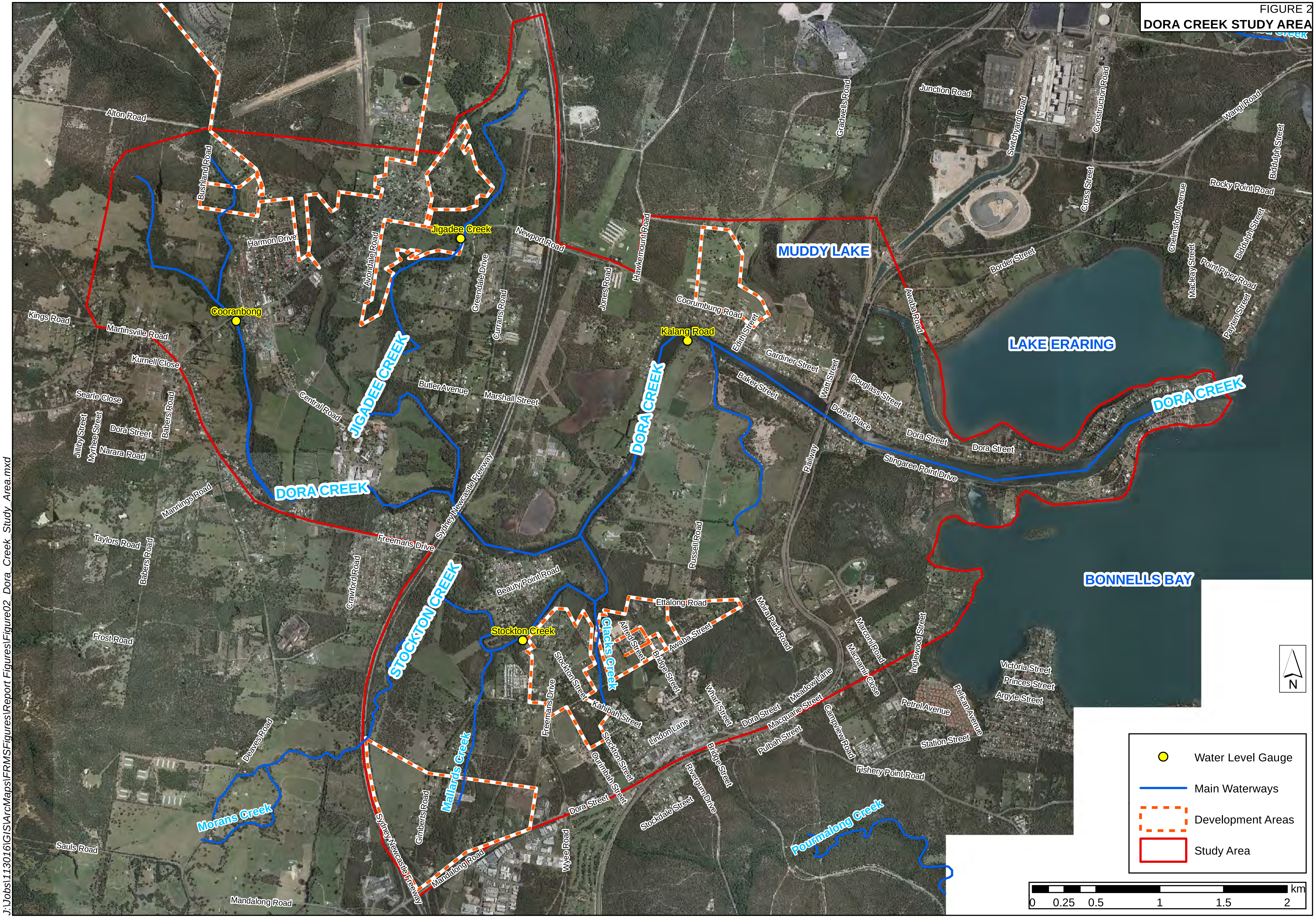

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FIGURE 3
LEP 2014 LAND USE ZONES

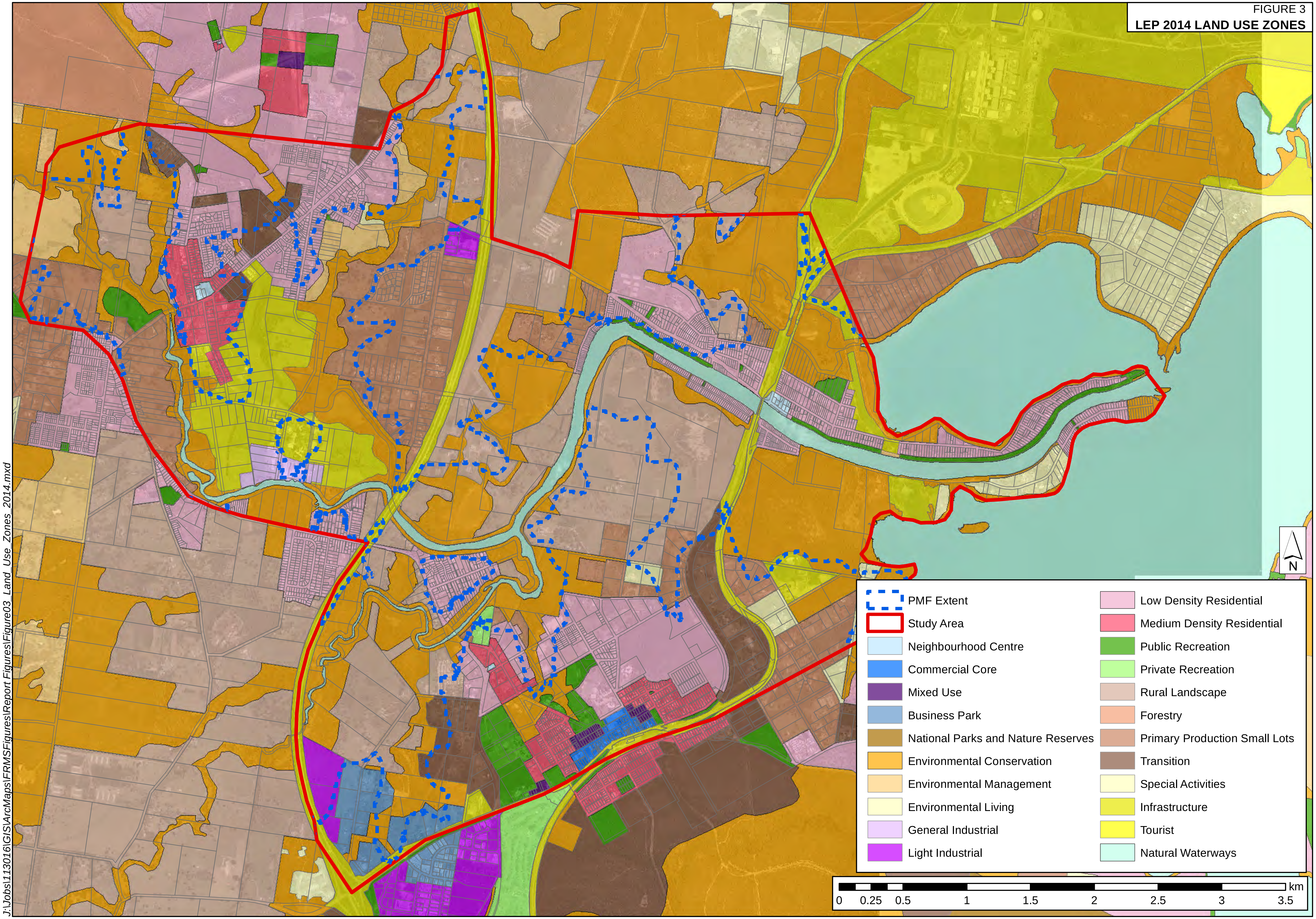


FIGURE 4
DESIGN FLOOD EXTENTS

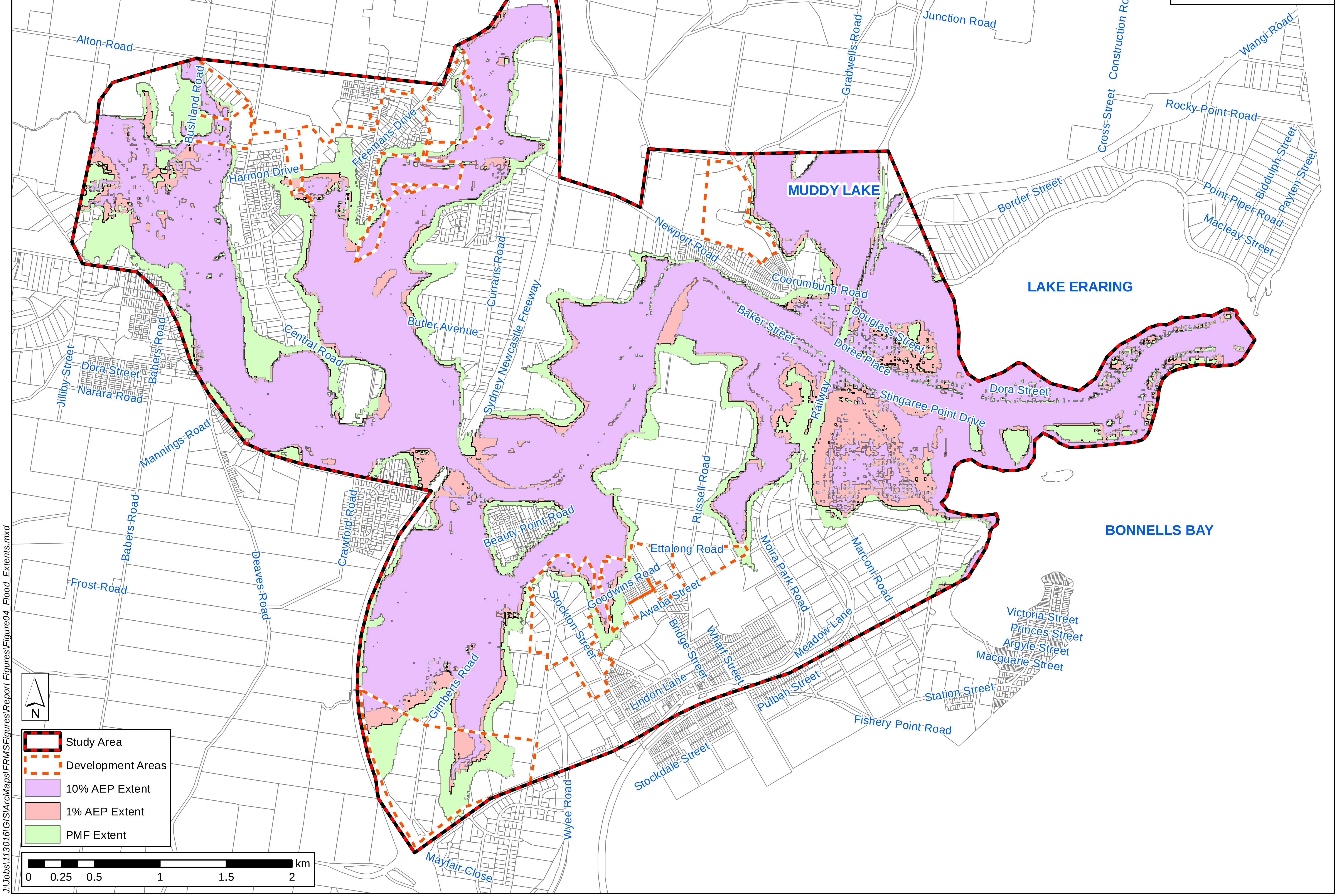
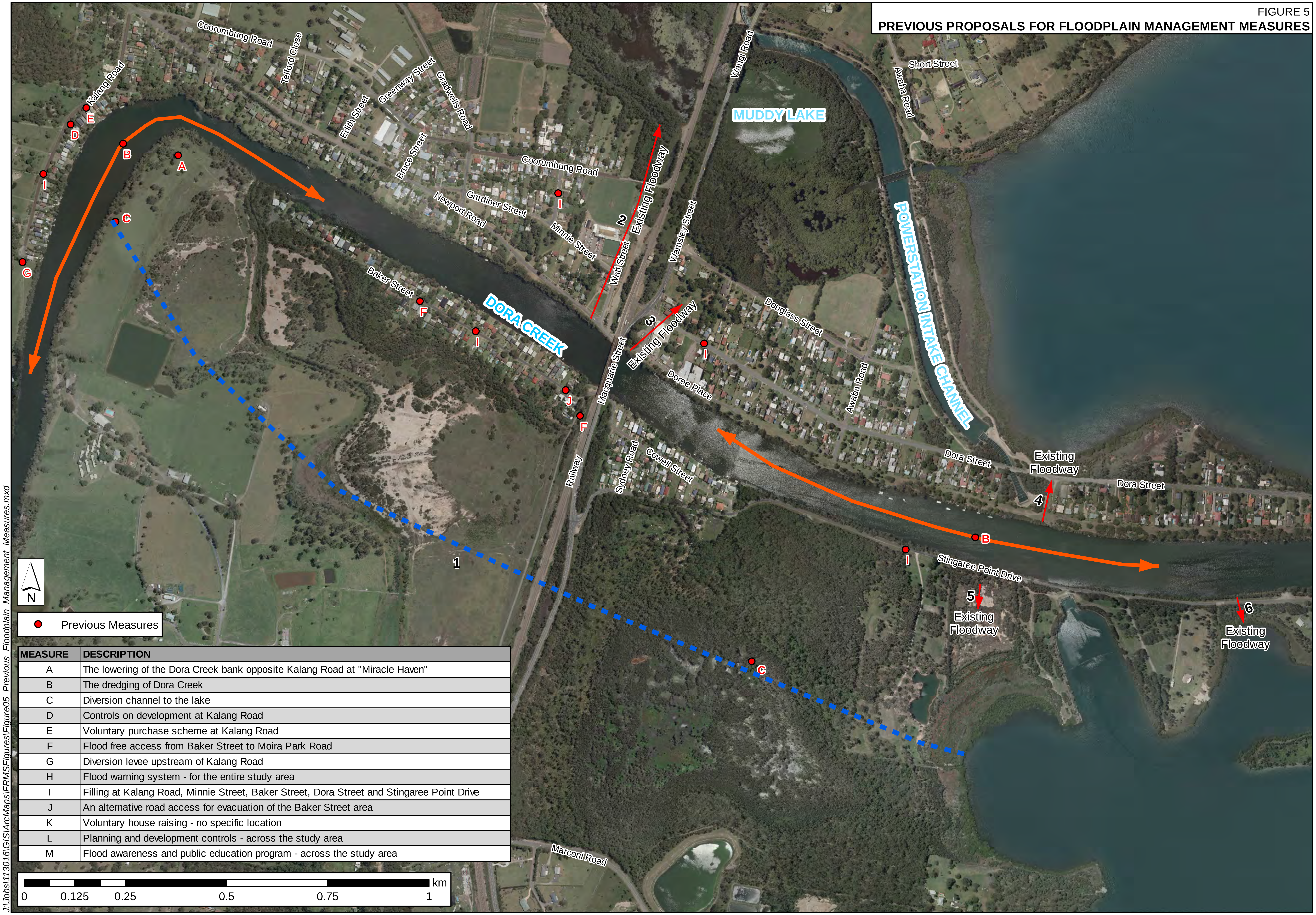


FIGURE 5

PREVIOUS PROPOSALS FOR FLOODPLAIN MANAGEMENT MEASURES



MEASURE	DESCRIPTION
A	The lowering of the Dora Creek bank opposite Kalang Road at "Miracle Haven"
B	The dredging of Dora Creek
C	Diversion channel to the lake
D	Controls on development at Kalang Road
E	Voluntary purchase scheme at Kalang Road
F	Flood free access from Baker Street to Moira Park Road
G	Diversion levee upstream of Kalang Road
H	Flood warning system - for the entire study area
I	Filling at Kalang Road, Minnie Street, Baker Street, Dora Street and Stingaree Point Drive
J	An alternative road access for evacuation of the Baker Street area
K	Voluntary house raising - no specific location
L	Planning and development controls - across the study area
M	Flood awareness and public education program - across the study area

FIGURE 6
SURVEYED BUILDING FLOORS

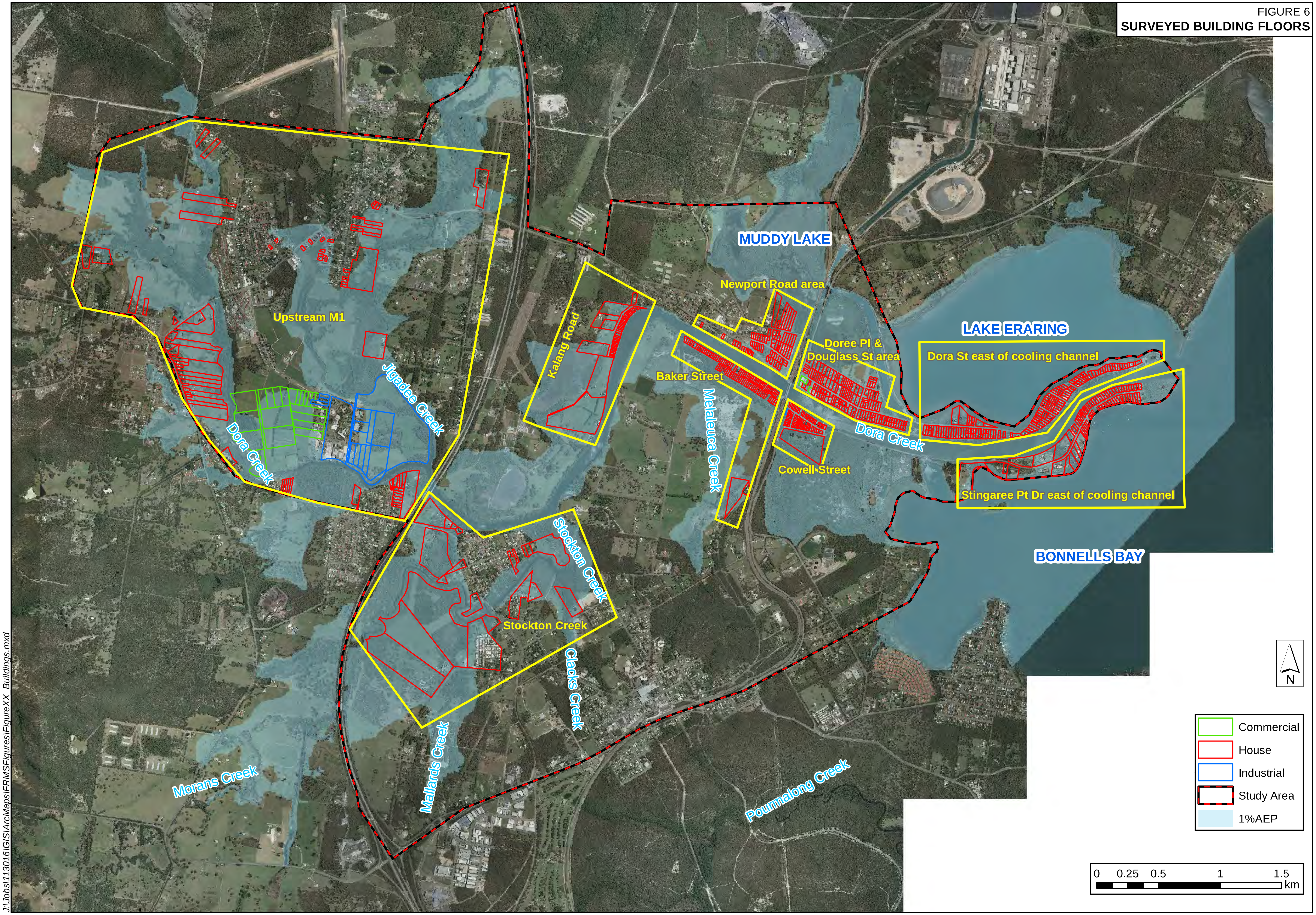
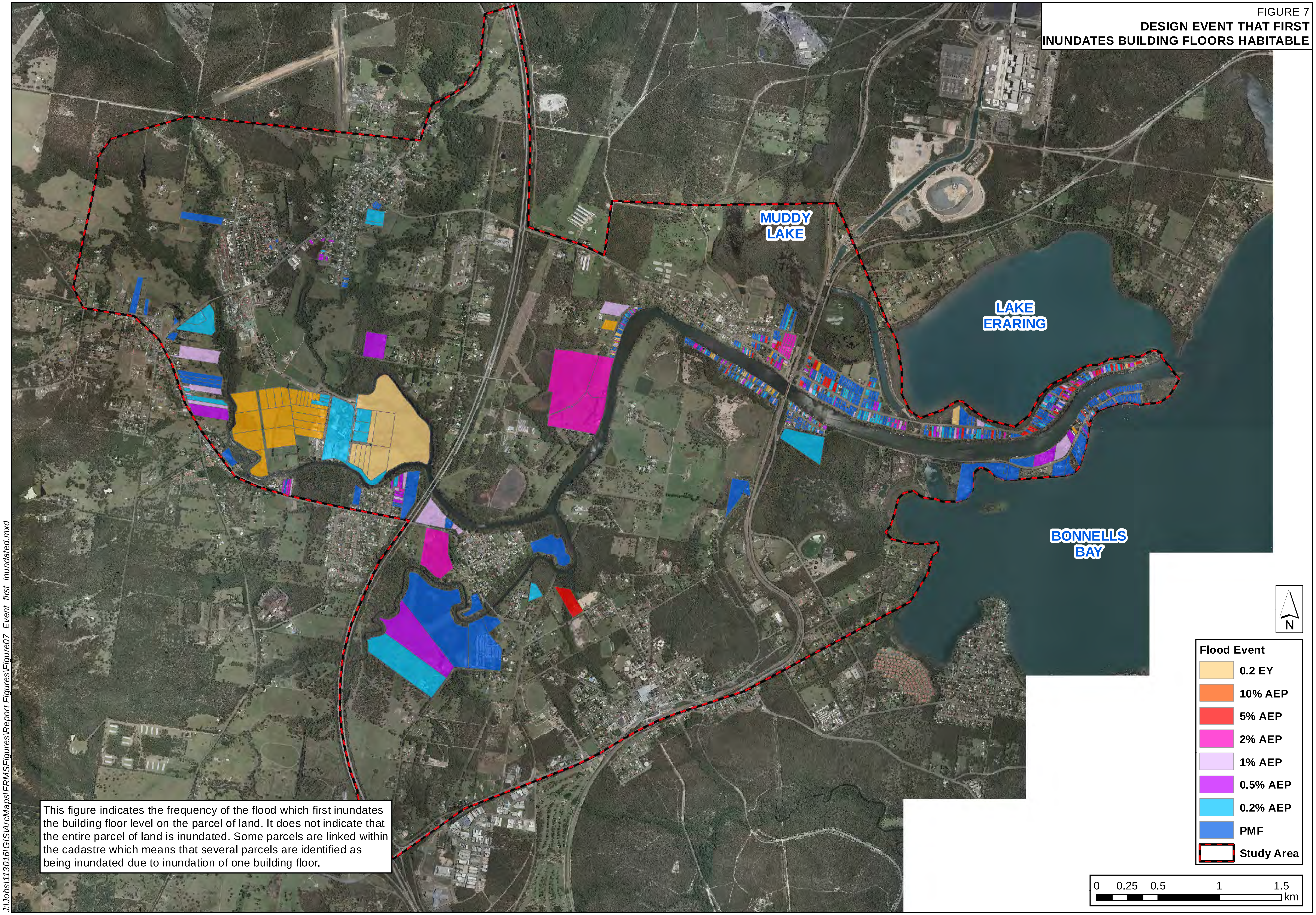


FIGURE 7

DESIGN EVENT THAT FIRST INUNDATES BUILDING FLOORS HABITABLE



This figure indicates the frequency of the flood which first inundates the building floor level on the parcel of land. It does not indicate that the entire parcel of land is inundated. Some parcels are linked within the cadastre which means that several parcels are identified as being inundated due to inundation of one building floor.

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FIGURE 8

ALS SURVEY DATA

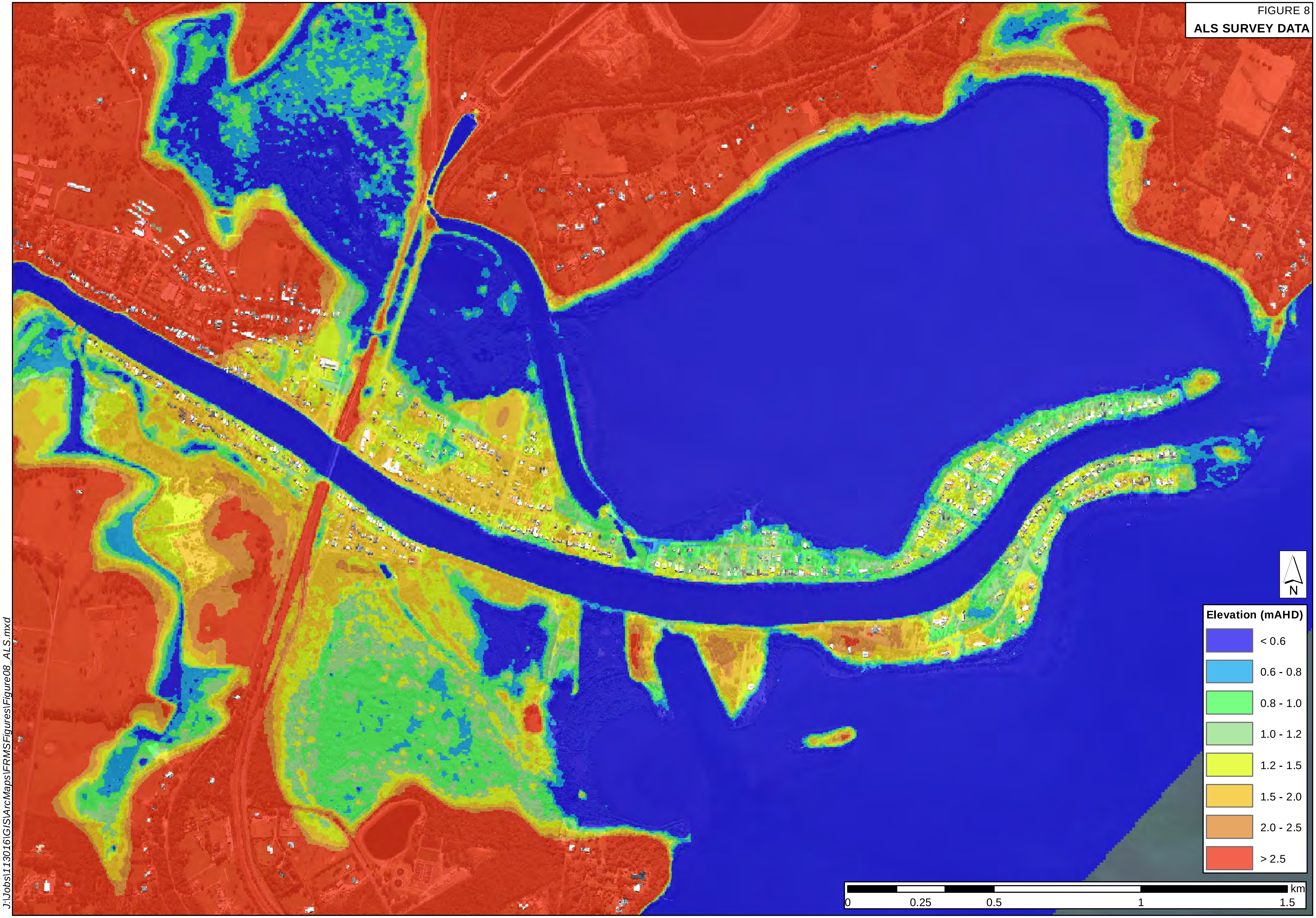

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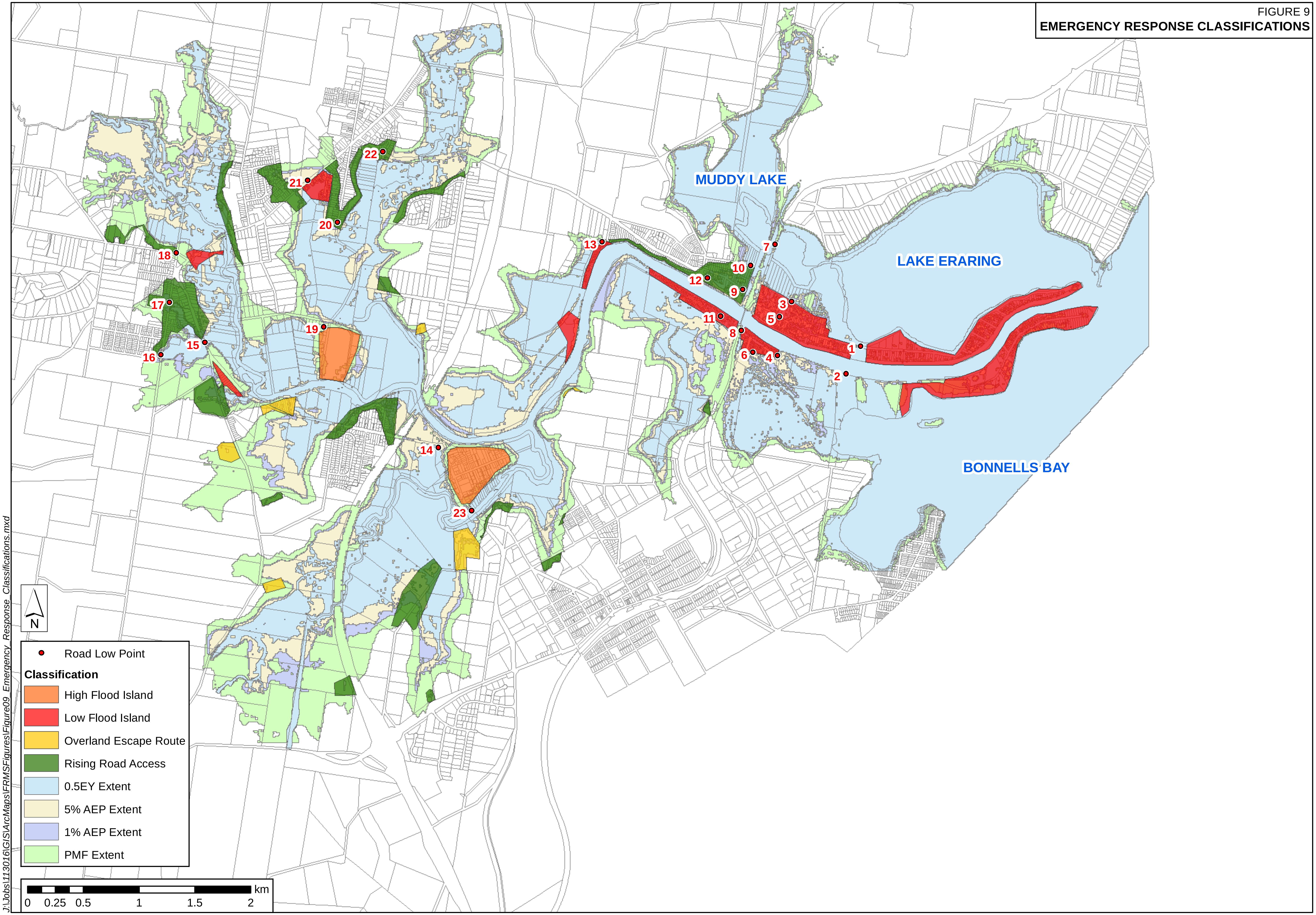
FIGURE 9

EMERGENCY RESPONSE CLASSIFICATIONS



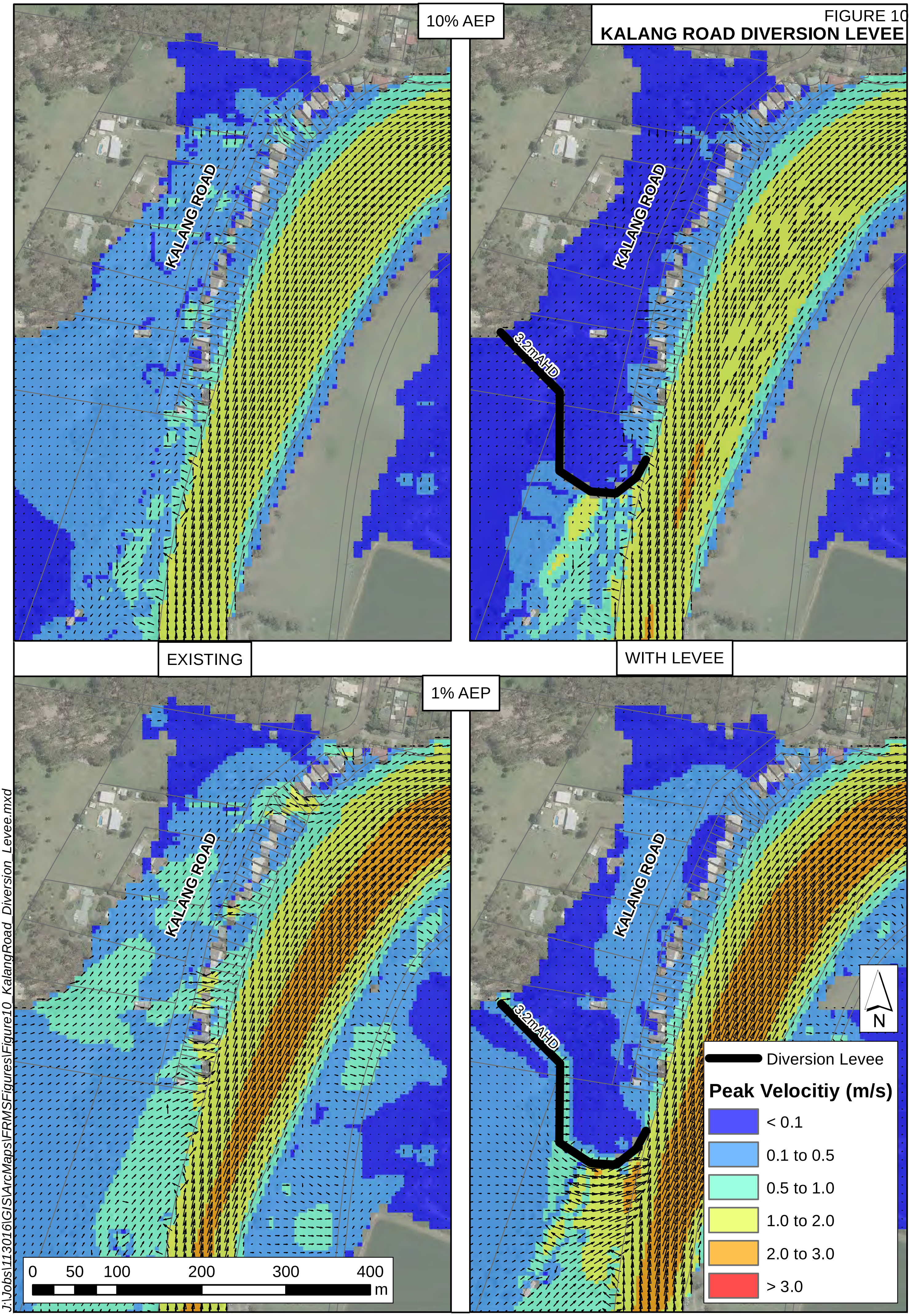


FIGURE 10
KALANG ROAD DIVERSION LEVEE
10% AEP
1% AEP
EXISTING
WITH LEVEE
KALANG ROAD
3.2mAHD
N
Diversion Levee
Peak Velocitiy (m/s)
< 0.1
0.1 to 0.5
0.5 to 1.0
1.0 to 2.0
2.0 to 3.0
> 3.0
0 50 100 200 300 400
m
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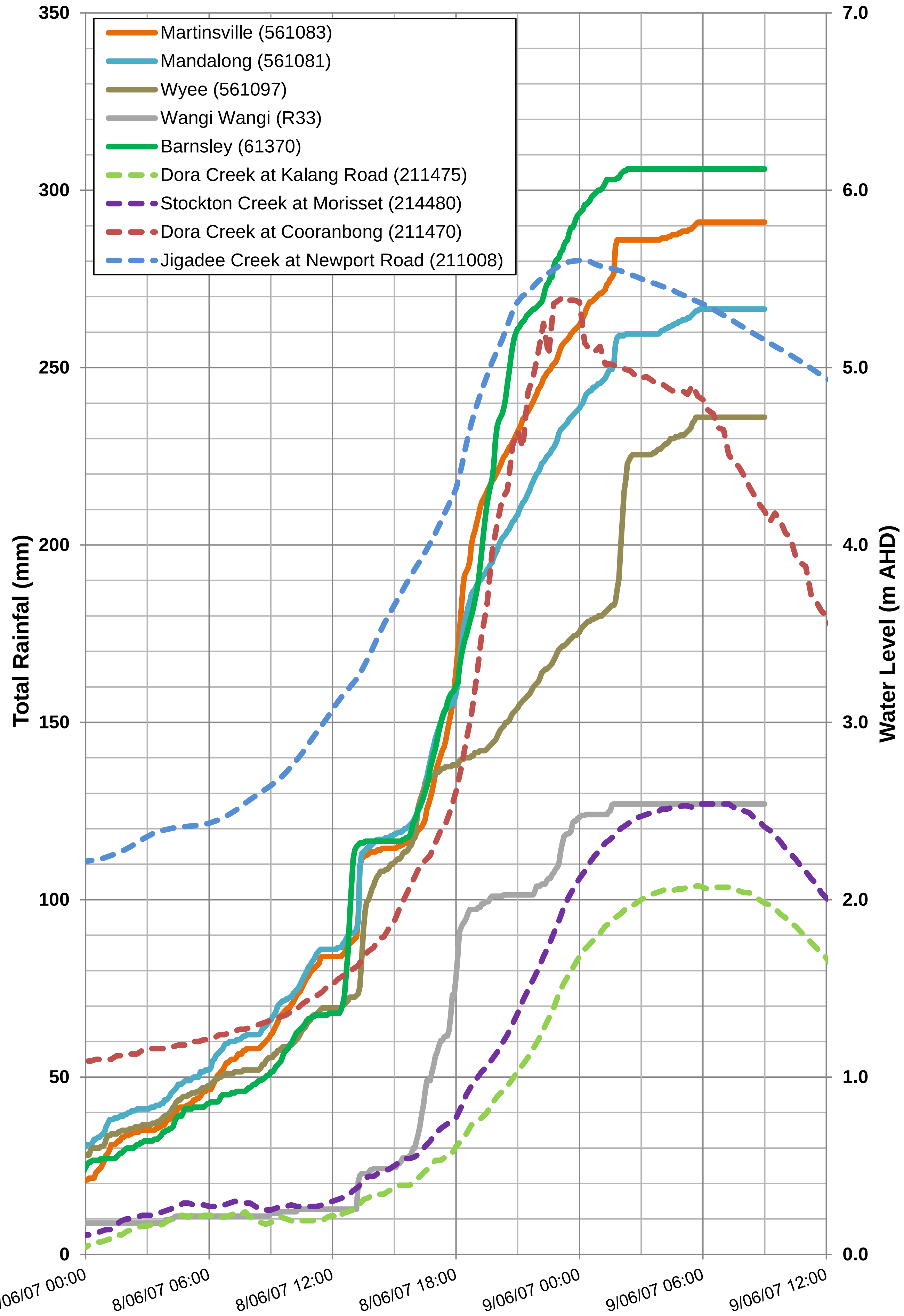
FIGURE 11
RAINFALL AND WATER LEVEL DATA
JUNE 2007 EVENT



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Appendix A

APPENDIX A: GLOSSARY OF TERMS

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, Government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions,

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

	to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the flood liable land concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the standard flood event in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the

	submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

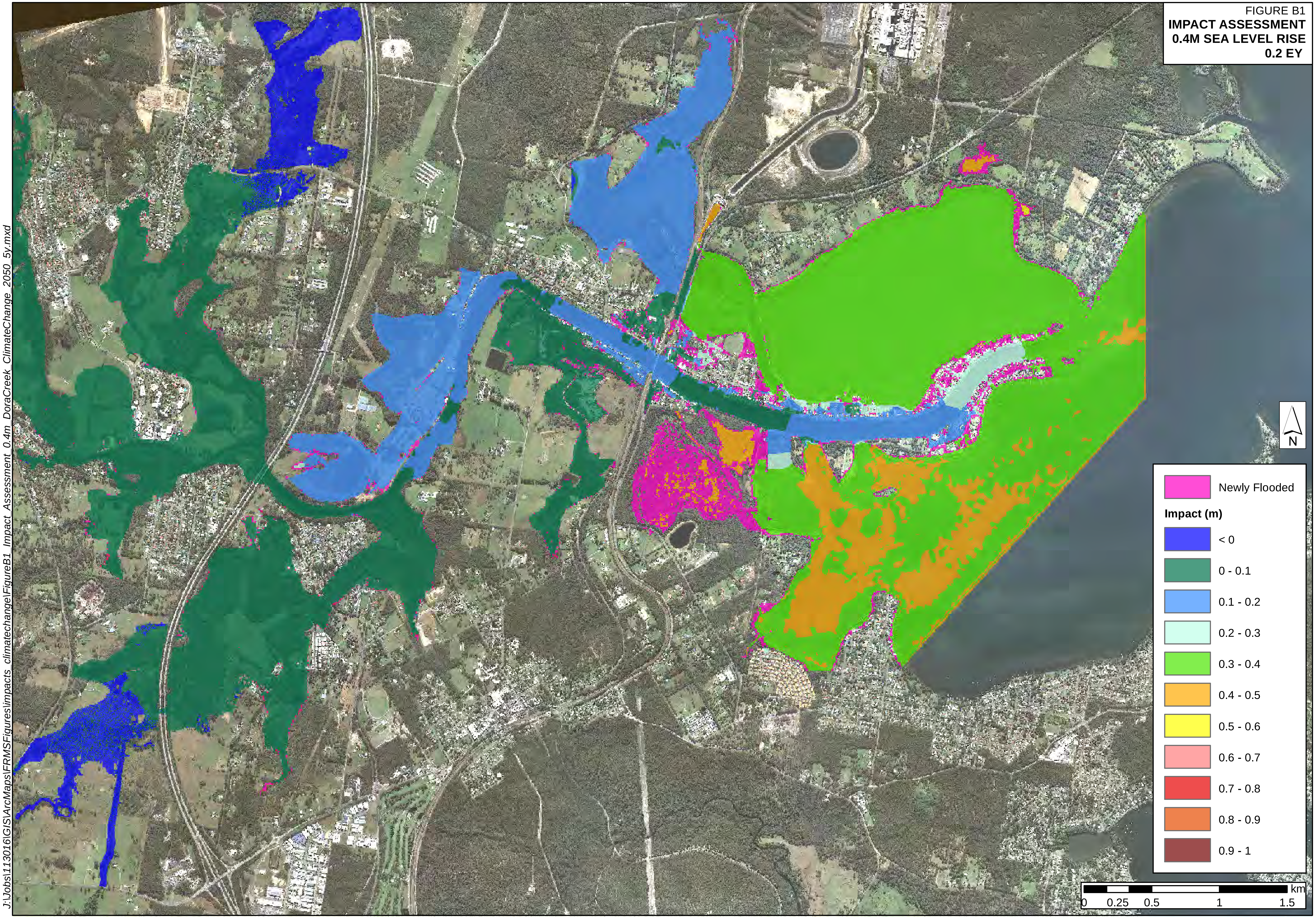

FIGURE B1
IMPACT ASSESSMENT
0.4M SEA LEVEL RISE
0.2 EY

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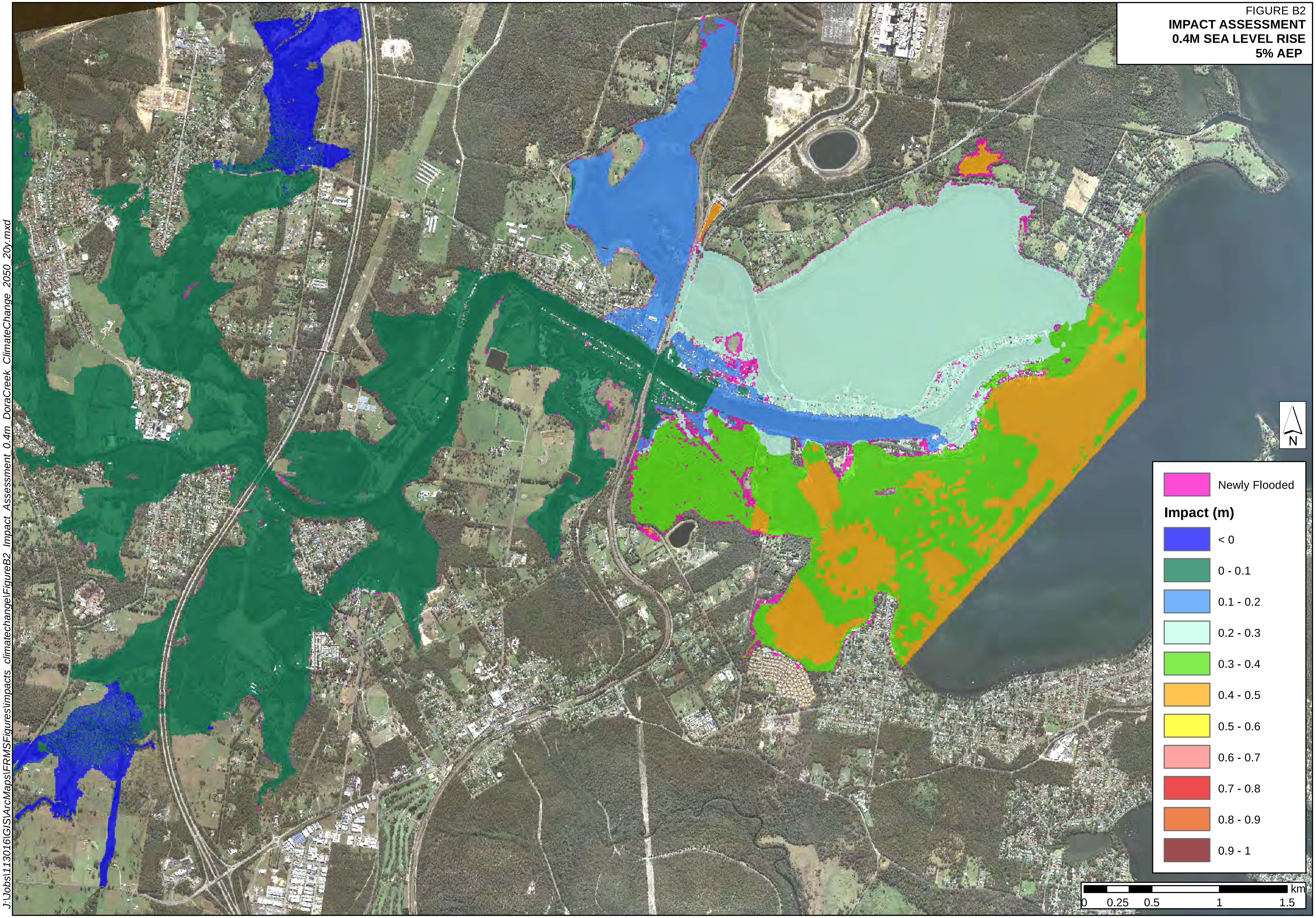

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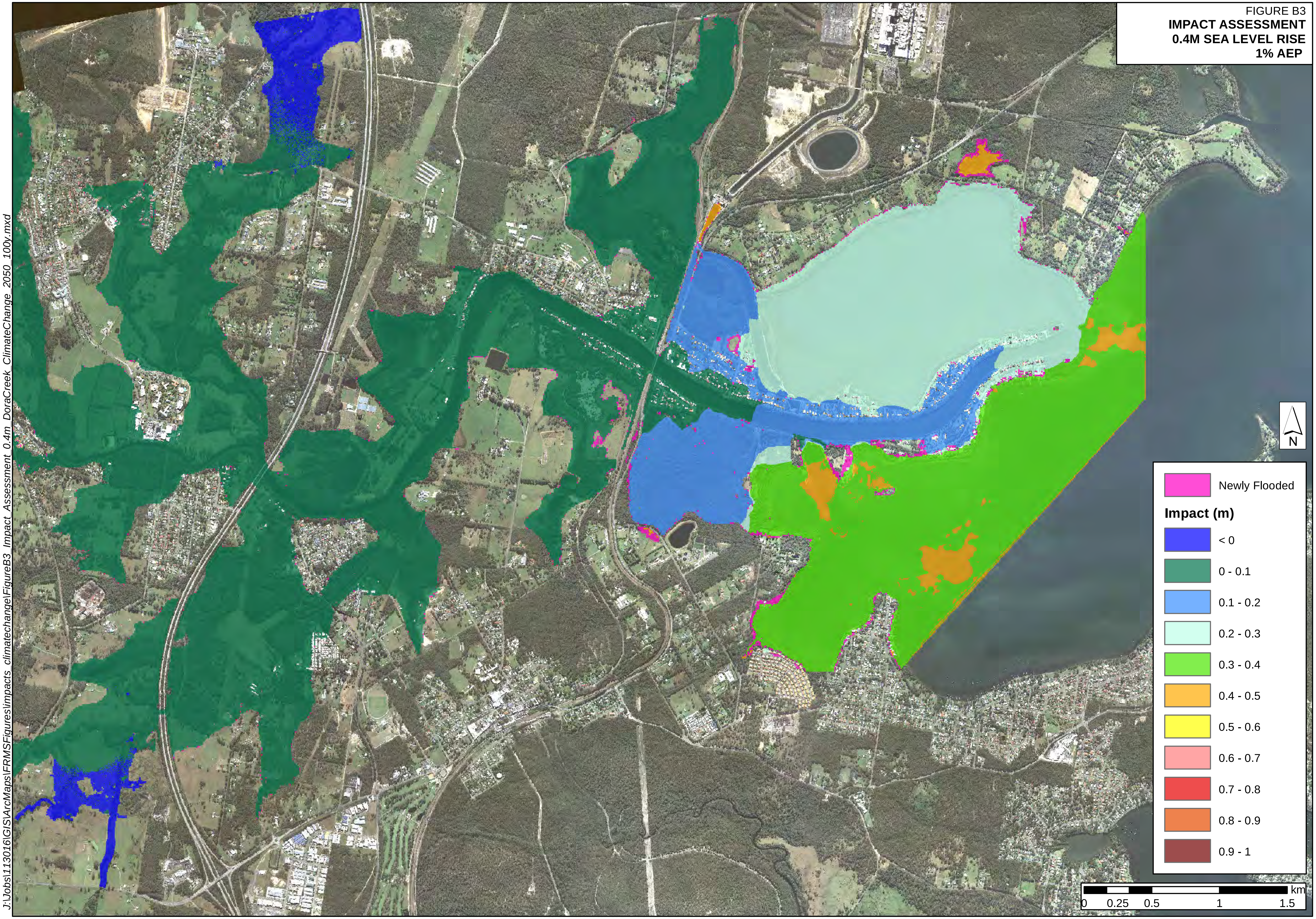
FIGURE B3
IMPACT ASSESSMENT
0.4M SEA LEVEL RISE
1% AEP



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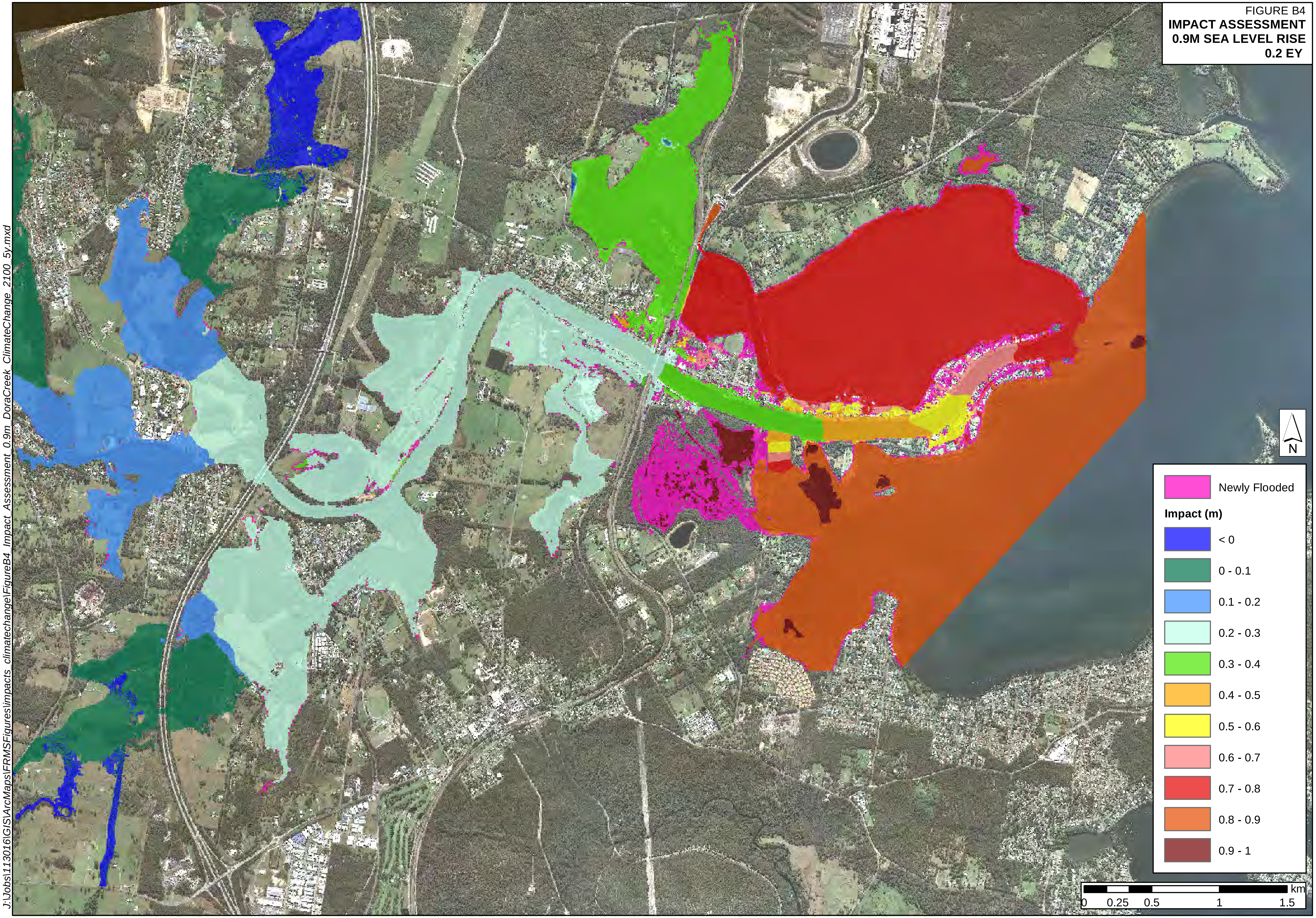
FIGURE B4
IMPACT ASSESSMENT
0.9M SEA LEVEL RISE
0.2 EY
N
Newly Flooded
Impact (m)
< 0
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1
km
0 0.25 0.5 1 1.5
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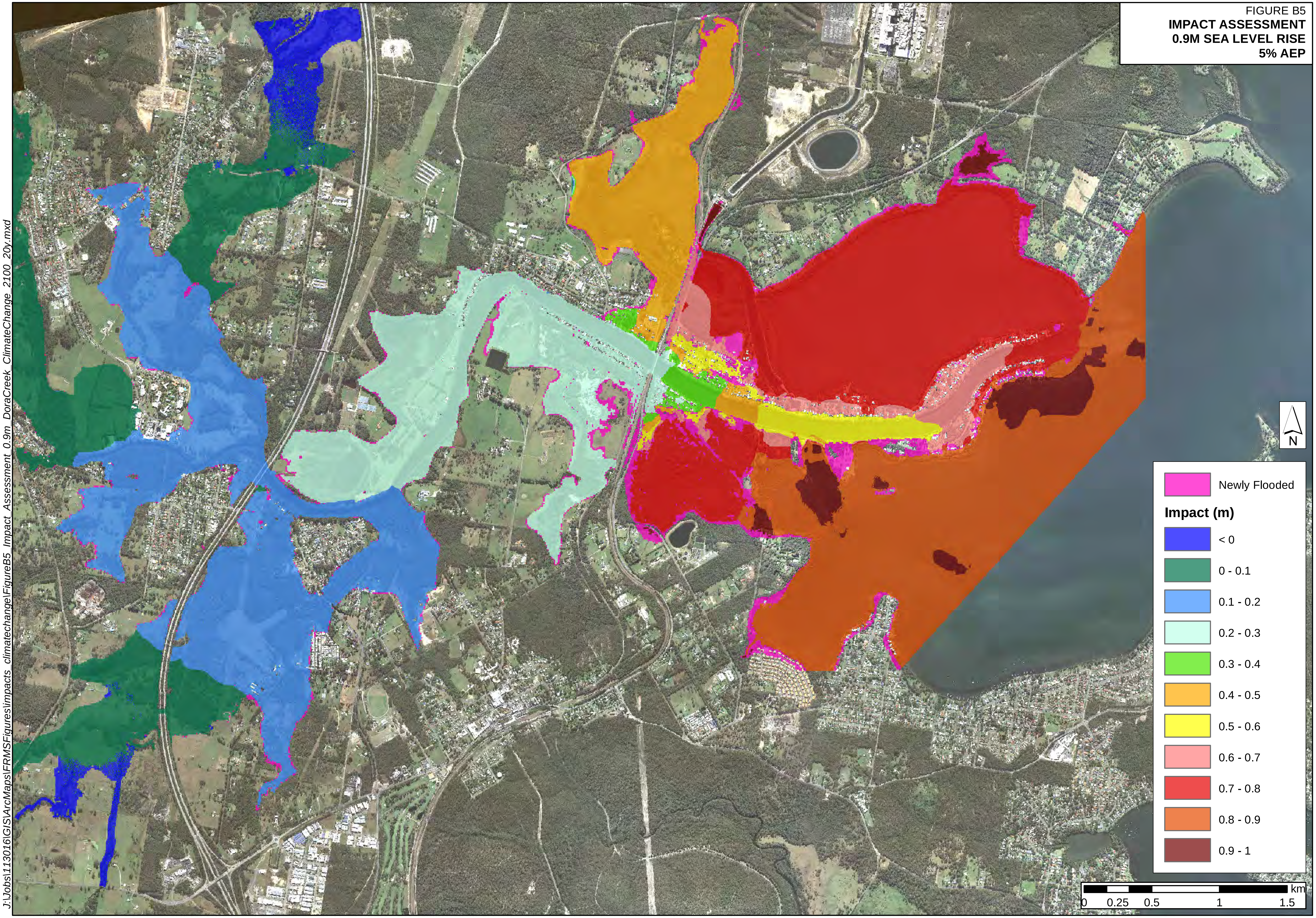

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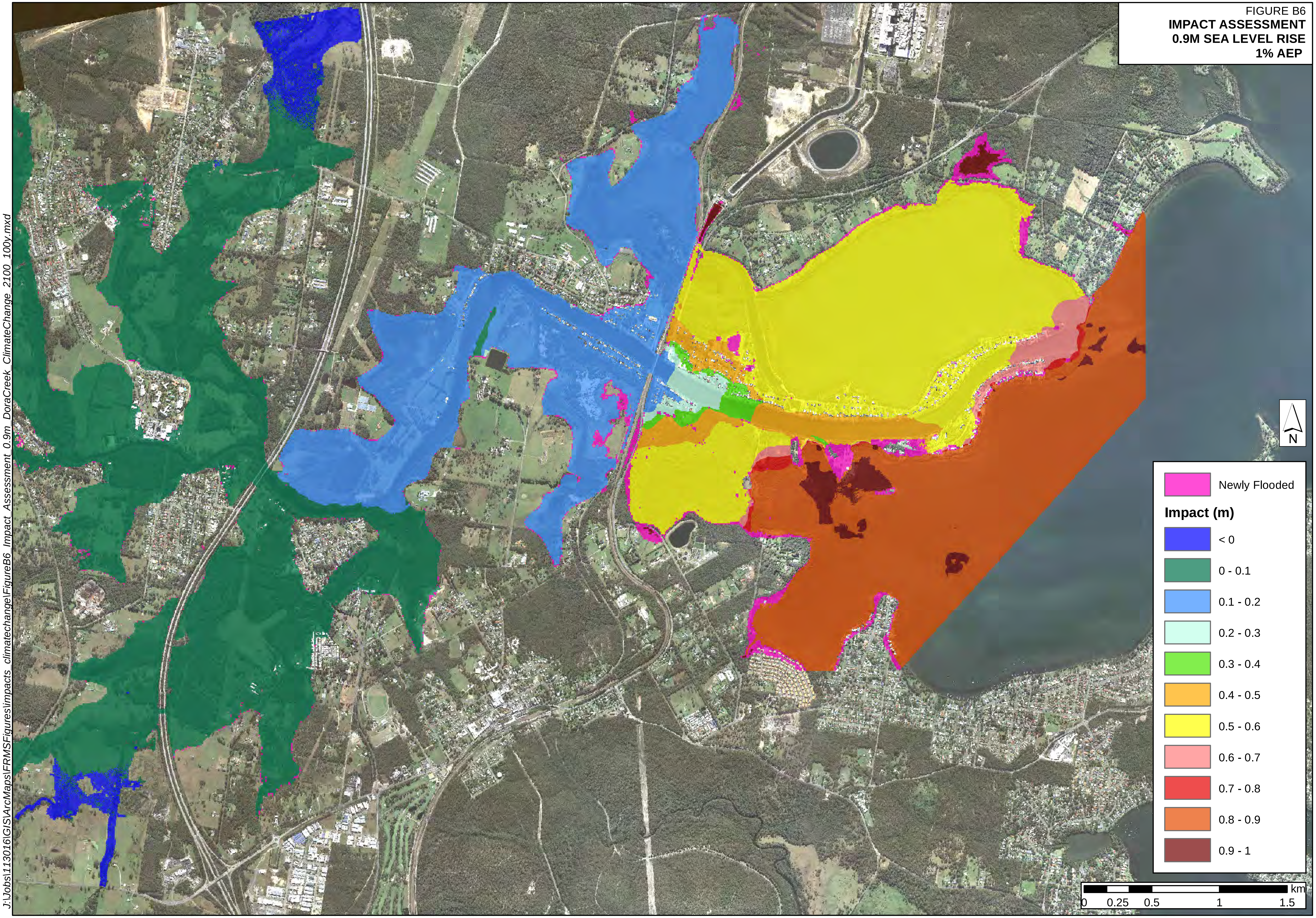
FIGURE B6
IMPACT ASSESSMENT
0.9M SEA LEVEL RISE
1% AEP
Newly Flooded
Impact (m)
< 0
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1
N
0 0.25 0.5 1 1.5 km
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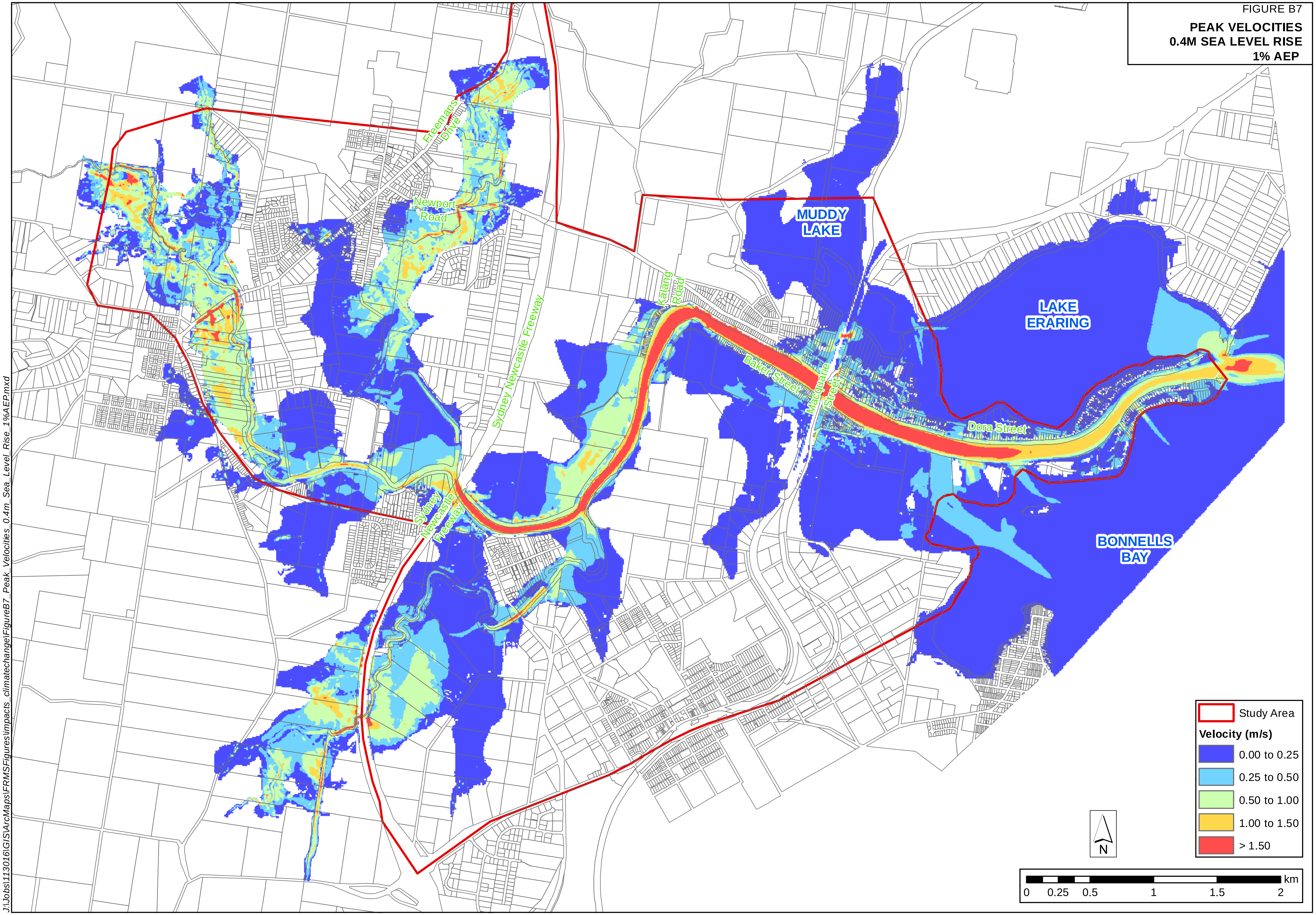
FIGURE B7
PEAK VELOCITIES
0.4M SEA LEVEL RISE
1% AEP
Freemans Drive
Newport Road
Sydney Newcastle Freeway
Kalang Road
Baker Street
Macquarie Street
Dora Street
MUDDY LAKE
LAKE ERARING
BONNELLS BAY
Study Area
Velocity (m/s)
0.00 to 0.25
0.25 to 0.50
0.50 to 1.00
1.00 to 1.50
> 1.50
N
0 0.25 0.5 1 1.5 2 km
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FIGURE B8

PEAK VELOCITIES
0.9M SEA LEVEL RISE
1% AEP

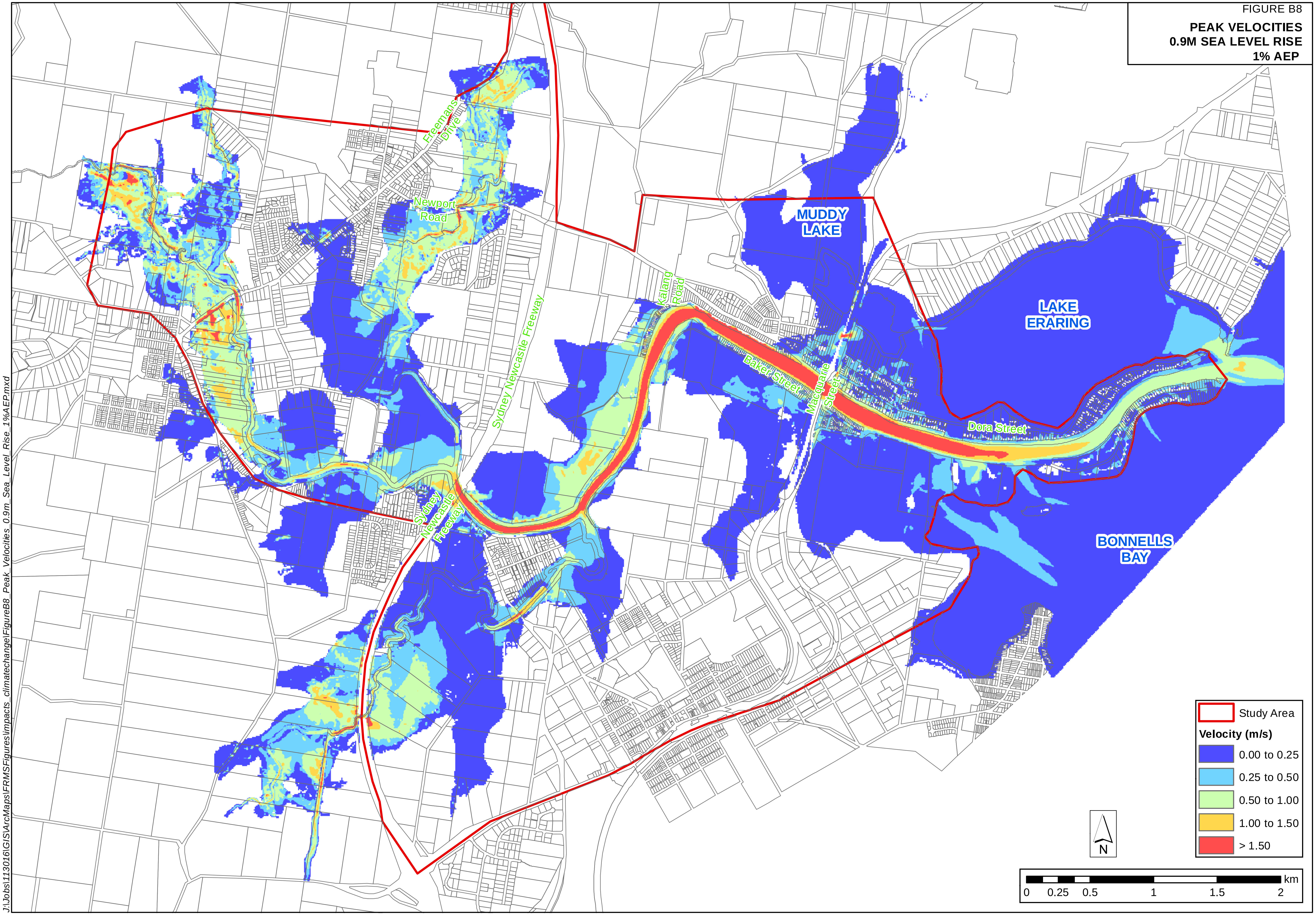

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FIGURE B9

INCREASE IN FLOOD EXTENTS 0.4M AND 0.9M SEA LEVEL RISE 5% AEP

FIGURE B10
INCREASE IN FLOOD EXTENTS
0.4M AND 0.9M SEA LEVEL RISE
1% AEP

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Appendix C

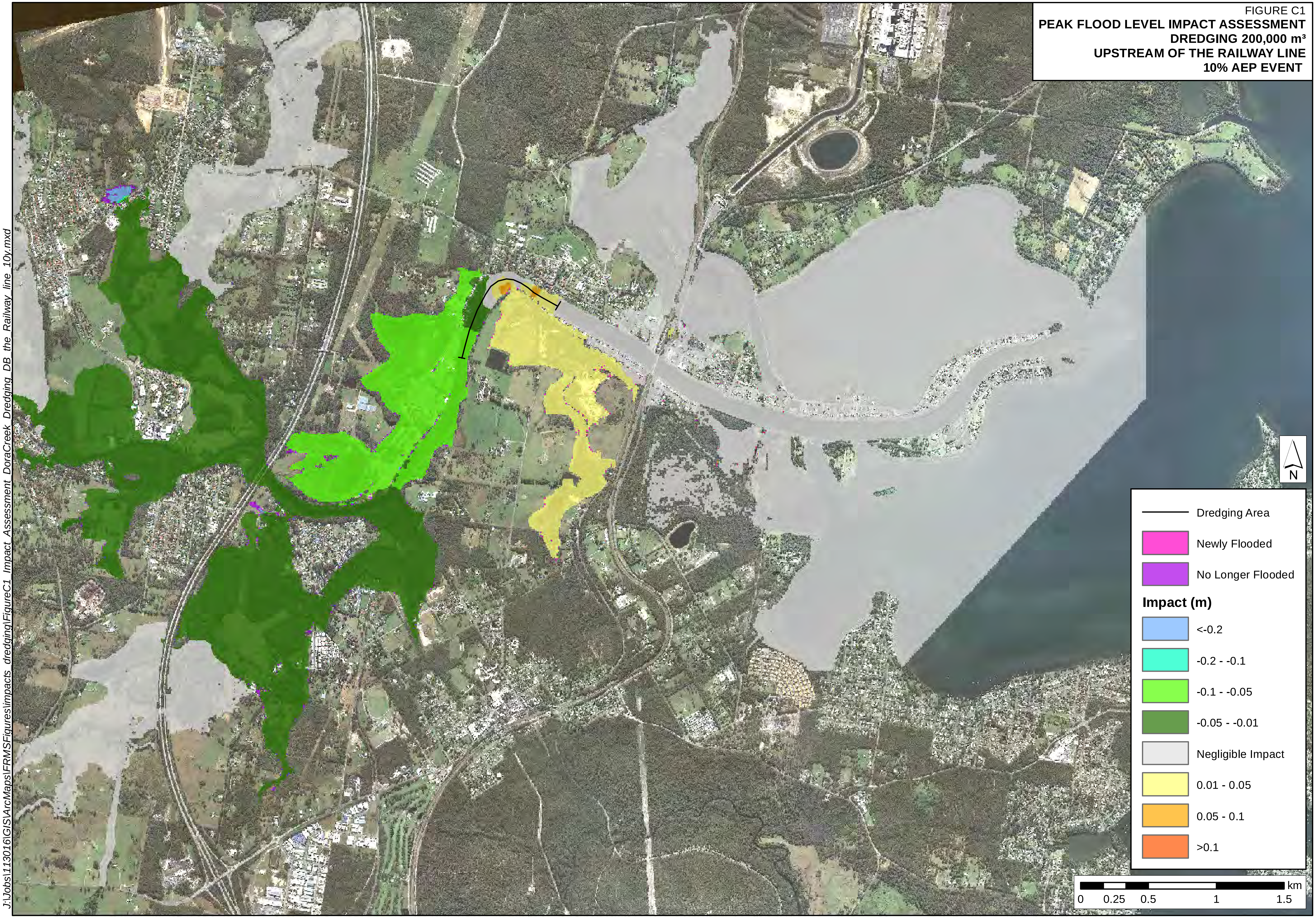
FIGURE C1
PEAK FLOOD LEVEL IMPACT ASSESSMENT
DREDGING 200,000 m³
UPSTREAM OF THE RAILWAY LINE
10% AEP EVENT
Dredging Area
Newly Flooded
No Longer Flooded
Impact (m)
<-0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Negligible Impact
0.01 - 0.05
0.05 - 0.1
>0.1
N
km
0 0.25 0.5 1 1.5
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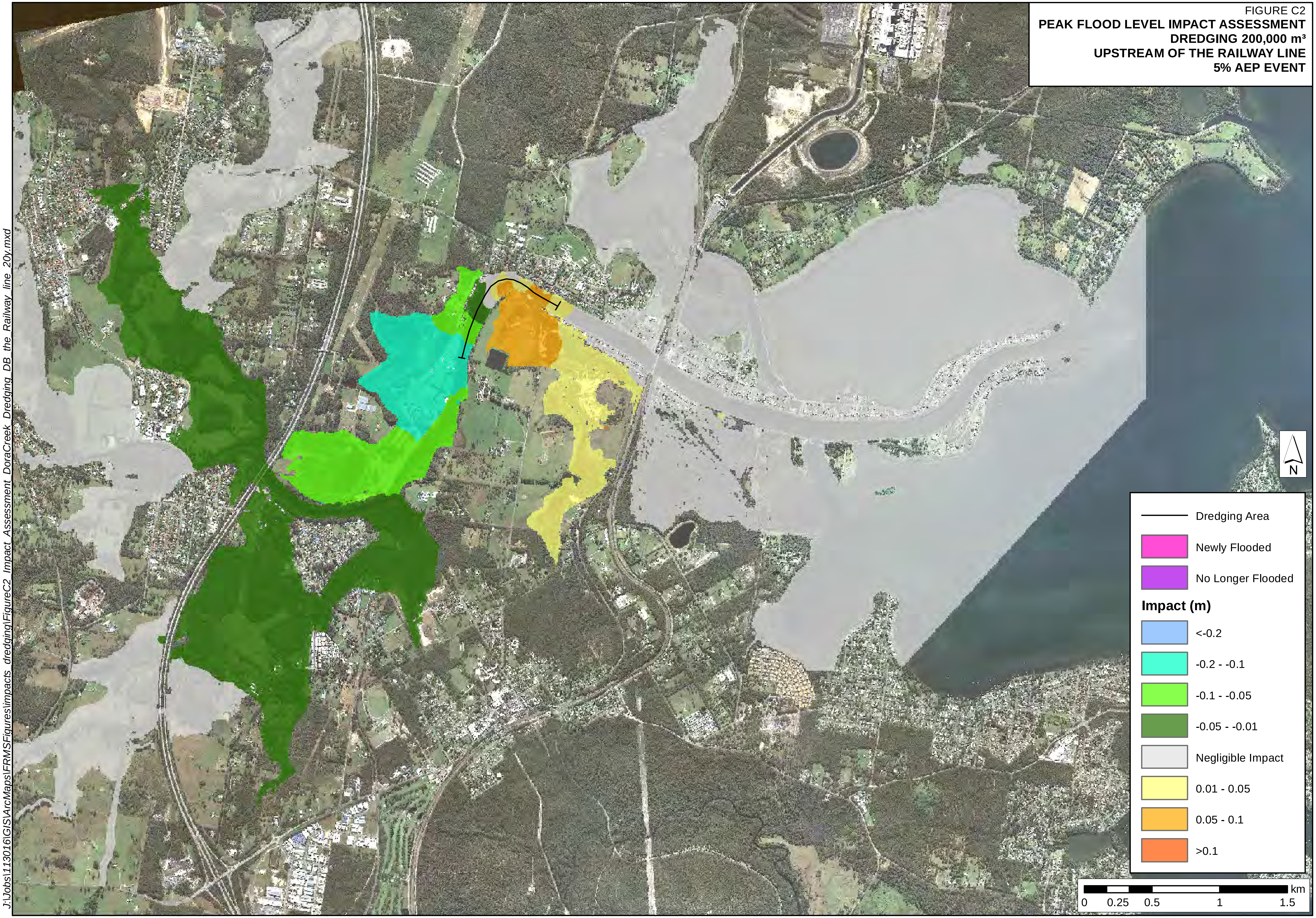

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FIGURE C3

PEAK FLOOD LEVEL IMPACT ASSESSMENT DREDGING 200,000 m³ UPSTREAM OF THE RAILWAY LINE 1% AEP EVENT

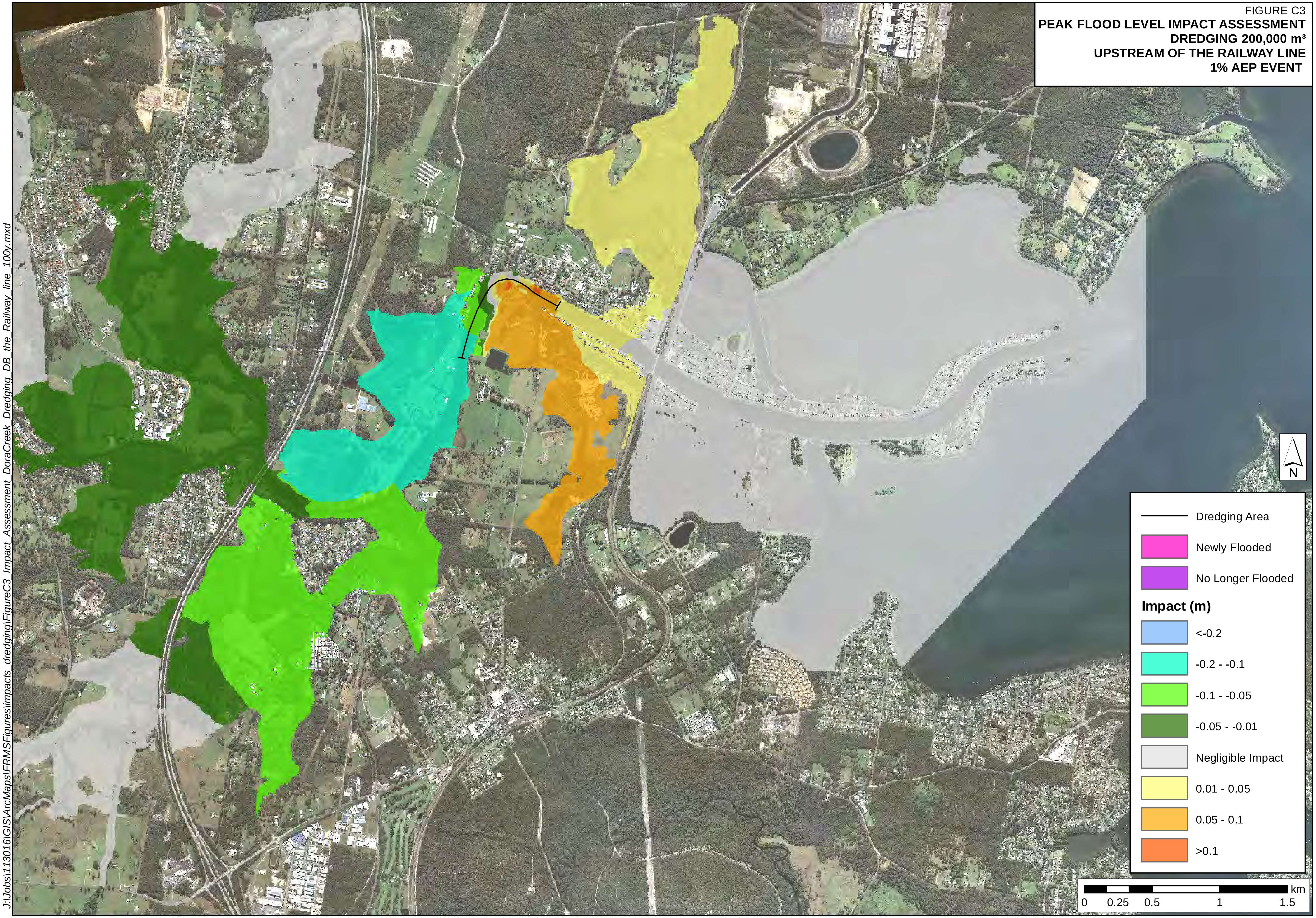

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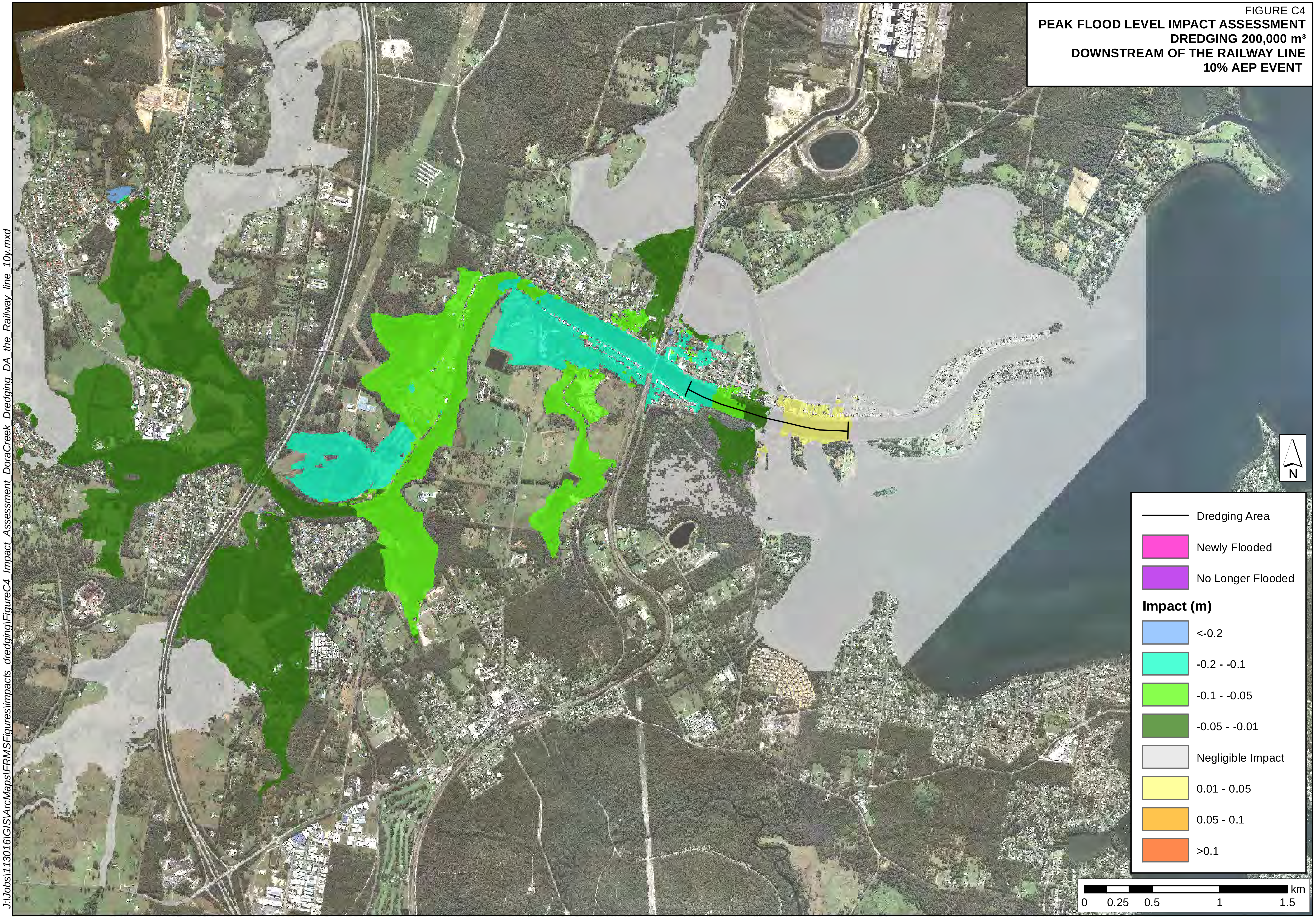
FIGURE C4
PEAK FLOOD LEVEL IMPACT ASSESSMENT
DREDGING 200,000 m³
DOWNSTREAM OF THE RAILWAY LINE
10% AEP EVENT



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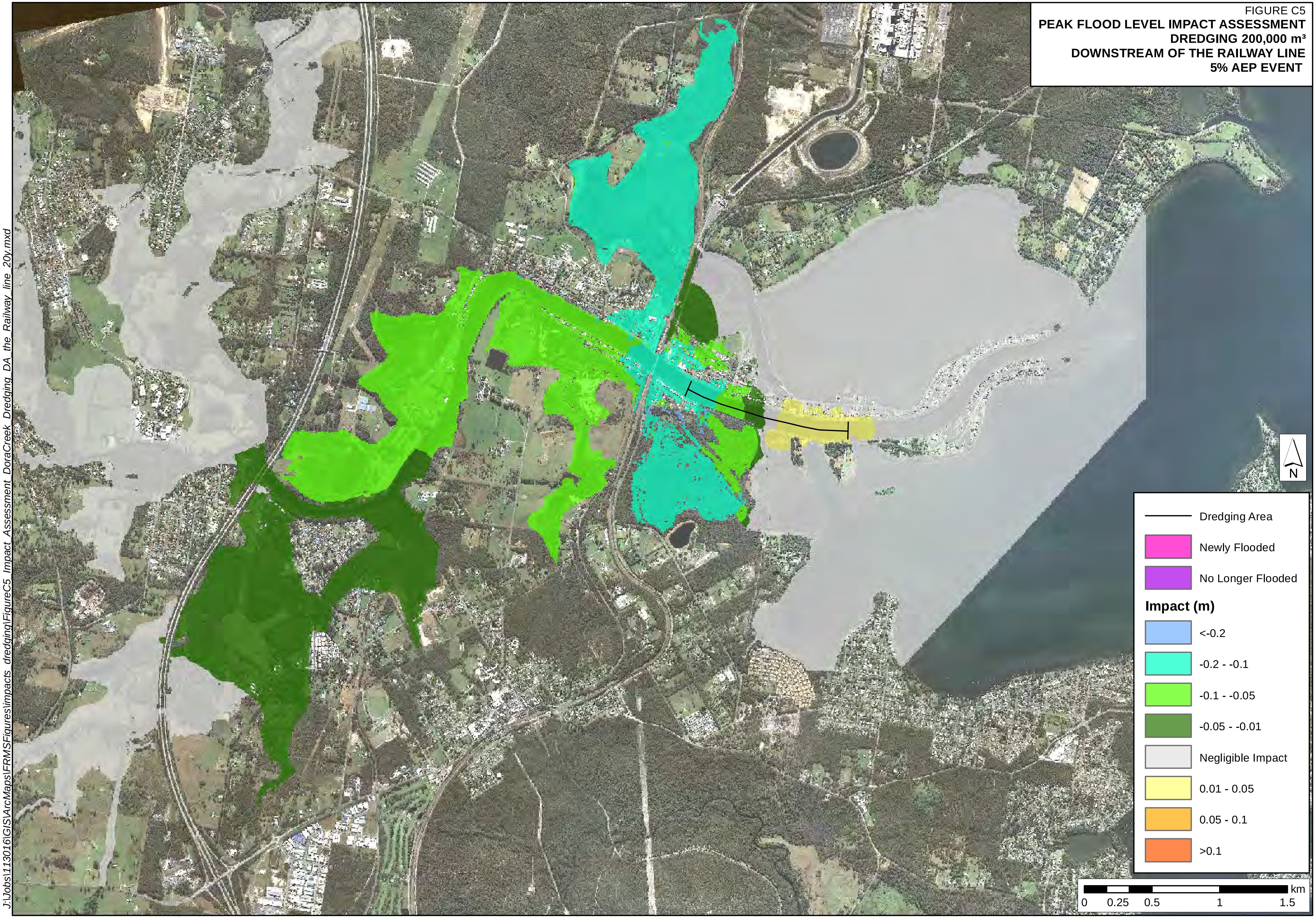

FIGURE C5
**PEAK FLOOD LEVEL IMPACT ASSESSMENT
DREDGING 200,000 m³
DOWNSTREAM OF THE RAILWAY LINE
5% AEP EVENT**

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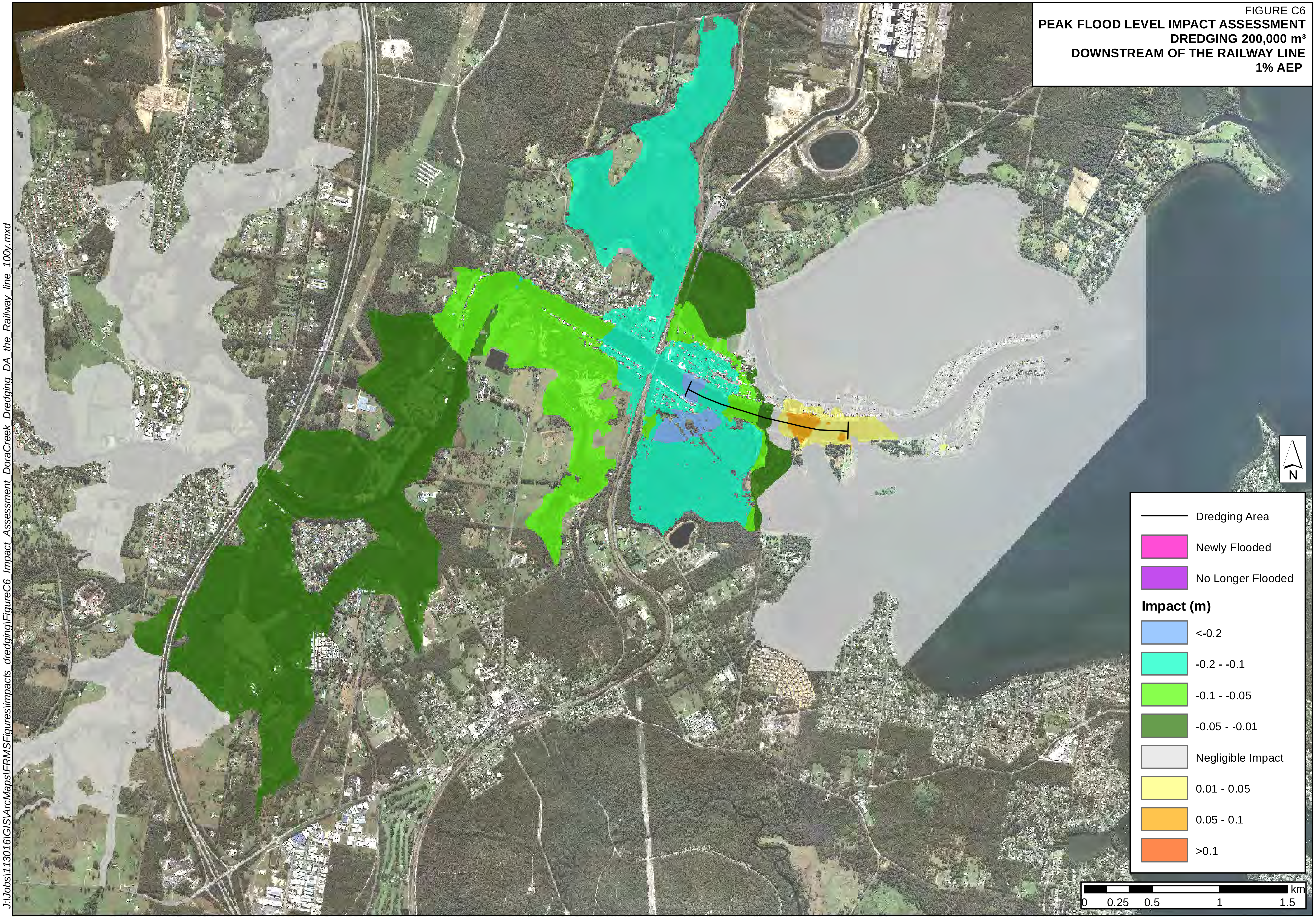
FIGURE C6

PEAK FLOOD LEVEL IMPACT ASSESSMENT DREDGING 200,000 m³ DOWNSTREAM OF THE RAILWAY LINE 1% AEP



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Appendix D

Have your say

Dora Creek Flood Study, Floodplain Risk Management Study and Floodplain Risk Management Plan

You are invited to have your say throughout September and October. Submit your feedback by Friday 31 October 2014.

Lake Macquarie City Council is committed to building more flood resilient communities across the City. This is the second newsletter for residents about understanding and managing flood risks in Dora Creek, and contains information about an upcoming community information session and how you can have your say.

Why is Council undertaking flood planning in Dora Creek?

Under NSW planning laws, councils are responsible for managing local flood planning.

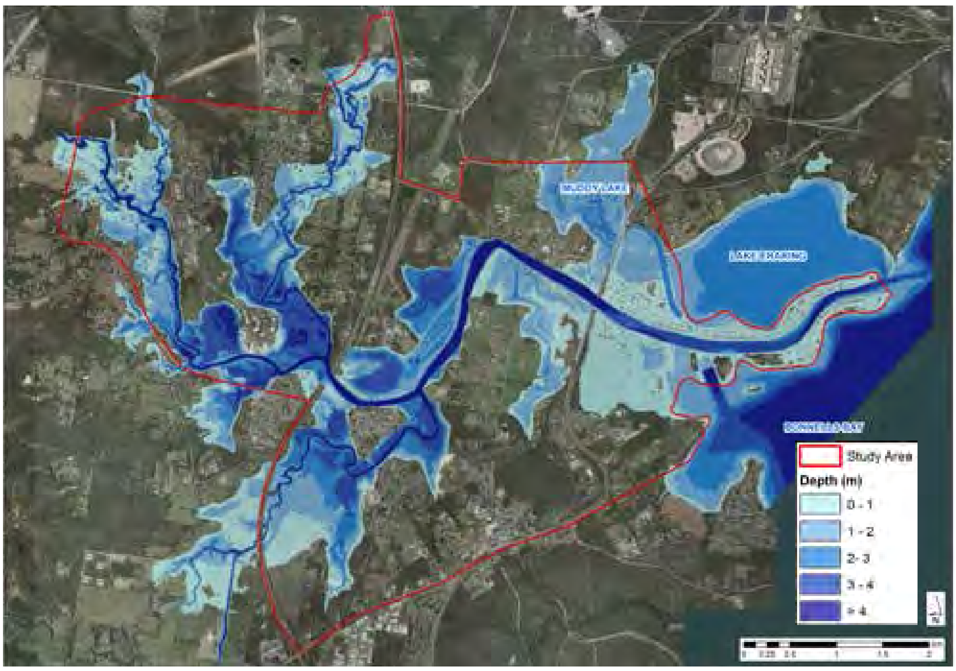
Council has prepared a comprehensive draft flood study, risk management study and risk management plan for the Dora Creek catchment, which defines the nature of flood risk in the area and provides recommendations for more effective flood management.

This assessment updates the previous 1986 Dora Creek Flood Study.

The floodplain risk management study builds on the flood study to identify a number of measures, which can be used to reduce flood risks in the catchment in the future such as:

- setting appropriate levels for development control;
- identifying works to reduce flooding; and
- raising community awareness of flooding issues so that they can take necessary precautions.

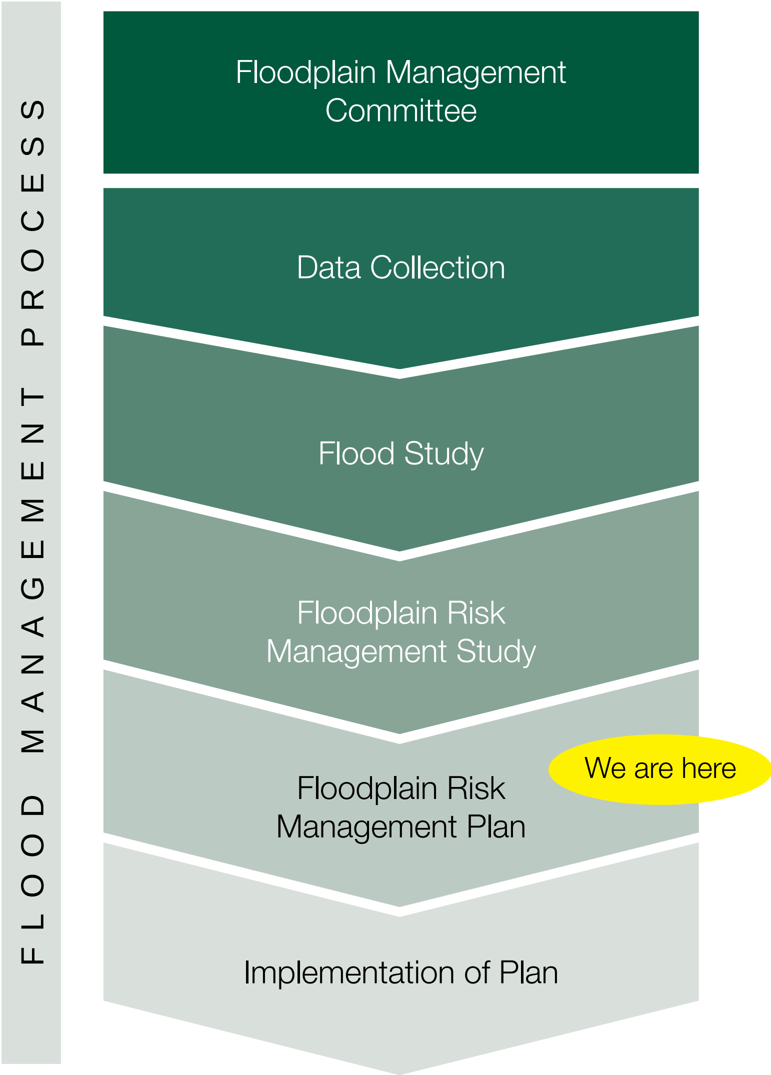
The floodplain risk management plan identifies which of the options considered in the risk management study are recommended for adoption by Council.



What has been completed so far?

During stage one, residents provided Council with their personal experiences of flooding such as photographs, flood marks and recorded observations. This process identified local concerns and values and helped Council understand how floods happen in the catchment.

From your feedback, we have a greater understanding of the flood behaviour in Dora Creek and have used this information to develop the draft Dora Creek Flood Study, Floodplain Risk Management Study and Floodplain Risk Management Plan.



Key findings

- The largest flood event recorded in Dora Creek occurred on March 1977, followed by the June 2007 long weekend, however larger events are possible
- Blockages within culverts and bridges have the potential to significantly impact the functioning and capacity of Dora Creek during flood events
- Up to 154 buildings are expected to be affected by over-floor flooding in a 1-in-100 year flood. This is 37 fewer buildings than were identified as affected in the previous (1986) Dora Creek Flood Study
- Most of these properties are on Dora Street, while a smaller proportion of affected properties are in Stingaree Point Drive and Cowell Street
- Flood modification options that have been considered to reduce the impact of flooding on properties include onsite detention, levees and floodways
- Property modification options such as development controls have been suggested to manage flood risk
- Flood response options suggested include an improved early warning system and education to raise awareness of flooding and encourage residents and visitors to prepare for flood emergencies.

Get involved and have your say ...

From 1 September to 31 October 2014, the draft Dora Creek Flood Study, Floodplain Risk Management Study and Floodplain Risk Management Plan are available to view at:

- Lake Macquarie City Council Administration Building, 126-138 Main Road, Speers Point
- Morisset Library, 39 Yambo St, Morisset
- Council's website, **www.lakemac.com.au** (open the link to the Draft Dora Creek Flood Study in the public notices and exhibition section)

Submissions

If you're affected by flooding in Dora Creek, your participation is encouraged.

Feedback can be sent to:

Lake Macquarie City Council
Box 1906 HRMC NSW 2310
or
email
council@lakemac.nsw.gov.au

Attend our community information session

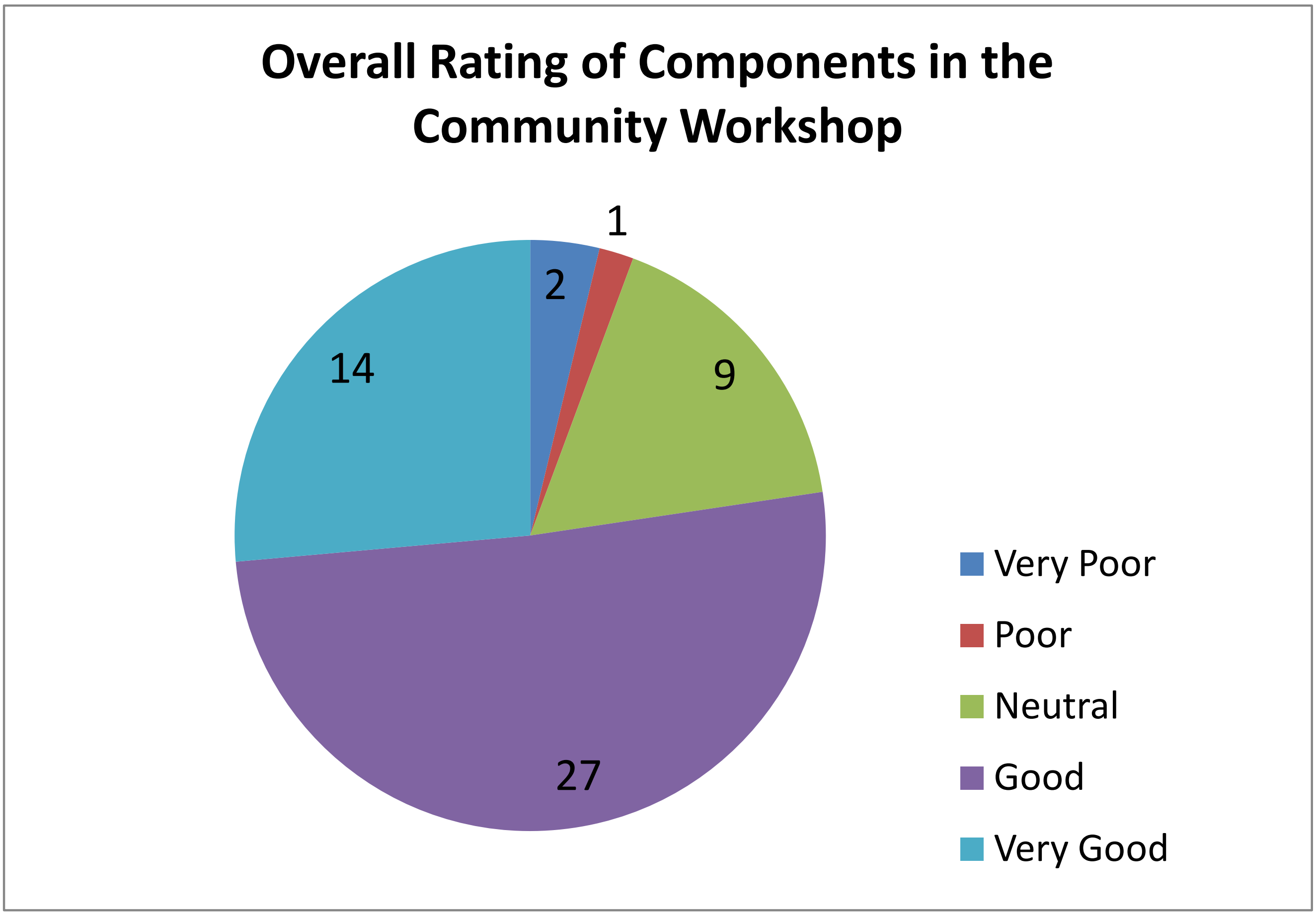
Saturday 20 September 2014

9am-12.30pm, with a formal presentation at 9:30am

Dora Creek Community Hall, Doree Place, Dora Creek

The information session will feature a presentation from the project team outlining the key findings and draft management options at 9:30am, with Council staff available before and after the presentation for you to meet, discuss the draft documents, ask questions and provide your feedback.

For further information please contact Councils' Customer Service Centre on 4921 0333


Overall Rating of Components in the Community Workshop
1
2
9
14
27
Very Poor
Poor
Neutral
Good
Very Good