Transport
for NSW

M1 Pacific Motorway extension to Raymond Terrace Flood Design Report

3 April 2025

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Acknowledgement of Country

Transport for NSW acknowledges the Wonnarua, Worimi and Awabakal, Traditional Custodians of the land on which the M1 Pacific Motorway Extension to Raymond Terrace project is located. We pay our respects to Awabakal, Wonnarua and Worimi Elders past and present and celebrate the diversity of Aboriginal people and their ongoing culture and connections to the lands and waters of NSW. Many of the transport routes we use today – from rail lines, to roads, to water crossings – follow the traditional Songlines, trade routes and ceremonial paths in Country that our nation's First Peoples followed for tens of thousands of years. Transport for NSW is committed to honouring Aboriginal peoples' cultural and spiritual connections to the land, waters and seas and their rich contribution to society.

I. Revisions and Distribution

Draft issues of this document are identified as etc. Upon initial issue this will be changed to a sequential number commencing at Version 0. Revision numbers will continue at Rev. 1, 2 etc.

The controlled master version of this document is available for distribution as appropriate and maintained on the document management system being used on the project, available to all project workers. All circulated hard copies of this document are deemed to be uncontrolled.

Author	WMAwater
Date	3 April 2025
Version	3.3
Reference	Flood Design Report
Division	XX

II. List of Tables

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V. Definitions and abbreviations

Definitions and abbreviations to be applied to the Document Title are listed below.

Term/Abbreviation	Definition
M12RT	M1 Pacific Motorway extension to Raymond Terrace (the overall project)
AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DECC	Department of Environment and Climate Change (now DCCEEW)
DNR	Department of Natural Resources (now DCCEEW)
DPE	Department of Planning and Environment (now DCCEEW)
DTM	Digital Terrain Model
EIS	Environmental Impact Statement
EPI	Environmental Planning Instrument
GIS	Geographic Information System
IFD	Intensity, Frequency and Duration (Rainfall)
mAHD	meters above Australian Height Datum
OEH	Office of Environment and Heritage (now DCCEEW)
PMF	Probable Maximum Flood
Transport	Transport for New South Wales
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)
AEP	Annual Exceedance Probability

VI. Adopted Terminology

Australian Rainfall and Runoff (ARR, ed Ball et al, 2019) recommends terminology that is not misleading to the public and stakeholders. Therefore, the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example, there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2019 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore, the term Exceedances per Year (EY) is recommended. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example, an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore, an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
Extreme	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

VII. Executive Summary

BACKGROUND

Transport for New South Wales (Transport) is constructing the M1 Pacific Motorway extension to Raymond Terrace (the Project). The Project will connect the existing M1 Pacific Motorway at Black Hill and the Pacific Highway at Raymond Terrace within the City of Newcastle and Port Stephens Council local government areas (LGAs). The Project location is shown in Figure 1.

PURPOSE OF THIS REPORT

The updated flood model developed for the current Project and documented in this report addresses the requirements of the Ministers Condition of Approval E36. The extent of the model on the Hunter, Williams and Paterson Rivers is such that the afflux impacts of the Project are contained within the model extent. The updated flood model is considered appropriate for assessment of the impacts of the Project on the full range of flood behaviour and characteristics as it reproduces flood behaviour and represents the spatial variability of rainfall.

This report documents the existing flood behaviour within the study area without the Project. It also documents the flood behaviour and impacts from the Project.

EXISTING FLOOD BEHAVIOUR

Flooding of the Project area is generated by both river dominated events (from the Hunter and Williams River) and local catchment dominated events. In the lower reaches of the Hunter Valley the ocean level also influences flooding.

As there are two distinct flood mechanisms that cause flooding on the Hunter Valley, two cases were modelled to reflect these types of events. These include:

- Hunter River dominated flows,
- Williams River dominated flows.

Due to the extensive size of the Hunter Valley Catchment, most floods are caused by runoff from specific parts of the catchment. A notable exception of this is the February 1955 event which affected the entire Hunter region (i.e. total catchment flood) and caused significant widespread flooding. Some floods have been particularly influenced by contributions from the Williams catchment. Other major mainstream floods in the catchment were recorded in 1893, 1930, 1951 and 1990.

More recently, significant flooding has occurred within the catchment in May 2005, June 2007, April 2015 and January 2016. The June 2007 event is one of the largest flooding events affecting large proportions of the catchment including Raymond Terrace, Maitland and Newcastle.

Flooding within the study area has been modelled for existing (without Project) events ranging from 20% AEP to 1 % AEP (refer to Figure 11 to Figure 50). In the upstream areas of the study area, the Hunter River flows east and joins with Paterson River (at Morpeth) before joining the Williams River and flowing south at Raymond Terrace. The Hunter River then flows through the Project area and flows southeast to discharge at the Pacific Ocean.

UPDATED FLOOD MODEL

A new hydrologic model has been developed of the Hunter River catchment in response to the Project's Conditions of Approval. The M1 Pacific Motorway extension to Raymond Terrace updated flood model has been developed and updated to address the full extent of the existing flood behaviour within the study area without the Project, the flood behaviour with the Project and the impacts of the Project. The updated model was modified to represent the terrain and waterway structures developed as part of the detailed design for the Project.

DESIGN CRITERIA

Impacts from the Project have been assessed against criteria outlined in the Conditions of Approval for M1 Pacific Motorway Extension to Raymond Terrace (SSI 7319) (Department of Planning and Environment, 2022). The following quantitative design limits (QDL) have been applied to flood events including 1%, 5%, 10% and 20% AEP (Conditions of Approval E33):

a) a maximum increase in inundation time of one hour or 10% whichever is greater;
b) a maximum increase of 10 mm in above-floor inundation to habitable rooms where floor levels are currently inundated;
c) no above-floor inundation of habitable rooms which are currently not inundated in the 1% AEP flood event;
d) a maximum increase of 50 mm in inundation of land zoned as residential, industrial or commercial;
e) a maximum increase of 100 mm in inundation of land zoned as rural, primary production, environment zone or public recreation;
f) no significant increase in the flood hazard or risk to life; and

g) maximum relative increase in velocity of 10%, where the resulting velocity is greater than 1.0 m/s, unless adequate scour protection measures are implemented and/or the velocity increases do not exacerbate erosion as demonstrated through site-specific risk of scour or geomorphological assessments.

Conditions of approval E33 b and c relate to buildings floor levels while the remaining conditions relate to lots. Details of the application of these to the Project are described in Sections 4 and 5.

IMPACT ASSESSMENT

Impact of the Project on flood characteristics is determined by comparing the existing conditions (without the Project) scenario with the Project scenario. In the 1% AEP event, flood levels increase by up to 60mm upstream as a result of the Project. Larger impacts occur within the Project corridor (Transport land). Immediately upstream of the Hunter River bridges impacts in the 1% AEP are between 5 and 20 mm. Typically, on the floodplain upstream of the Project impacts are in the order of 15 to 20 mm for the 1% AEP event. Impacts greater than 10mm extend up to Osterley along Hunter River and to just north of Seaham Weir along Williams River.

The increase in peak flood velocity is generally less than 10% in areas where the Project has velocities greater than 1 m/s. Locations where the change in velocity exceeds this are typically located near or within the Project boundary, where there are significant topography modifications (for example the introduction of infrastructure such as abutments and piers). Site specific risk assessment of erosion resulting from velocity increase/ exceedances has been undertaken for locations outside the project boundary. This assessment found that the lots with velocity increases above the QDL are capable of withstanding the marginally higher velocities and site treatments are therefore not required.

Comparison of the peak flood hazards shows that the Project has minimal impact to the hazard classification and that there are no significant areas where flood hazard has increased. Impacts above the QDLs generally occur at lots along the edge of the flood extent.

The quantitative design limits were assessed at a total of 9211 floor levels and all lots within the model extent. The following tables summarise the impacts and exceedances.

Table 1: Summary of Impacts of all buildings (including habitable buildings, uncategorised buildings and non-habitable buildings)

	20% AEP	10% AEP	5% AEP	1% AEP
Flooded above floor in existing conditions	181	1245	1759	2760
Flooded above floor with Project	181	1246	1761	2763
Above floor afflux greater than 10 mm with Project	4	56	184	1041
Newly flooded buildings in 1% AEP with Project	N/A	N/A	N/A	3

Table 2: Summary of Lots exceeding QDLs

AEP	Impact Exceedance		Inundation Exceedance	Velocity Exceedance	Total Number of lots subject to a QDL Exceedance
	50mm	100mm			
20% AEP	8	15	190	5	194
10% AEP	6	5	274	6	278
5% AEP	6	3	200	10	204
1% AEP	18	4	467	12	474

CONCLUSIONS

The M1 Pacific Motorway extension to Raymond Terrace updated flood model developed for Project and documented in this report is considered appropriate for use in meeting the Ministers Condition of Approval E36. The extent of the model on the Hunter, Williams and Paterson Rivers is sufficient that the afflux impacts of the M1 to Raymond Terrace Project are contained within the model extent. The M1 Pacific Motorway extension to Raymond Terrace updated flood model is considered appropriate for assessment of the impacts of the Project on the full range of flood behaviour and characteristics. The Project was assessed against the quantitative design limits (refer to Section 4). Overall, the Project was found to be above the quantitative design limits at 1,044 buildings and 474 lots for the 1% AEP event. Overall, the exceedances are considered minor in nature. Transport will consult with all impacted landowners and receivers to further communicate and discuss specific Project flood impacts.

Table of Contents

1. Introduction

1.1. Project overview

The M1 Pacific Motorway extension to Raymond Terrace (referred to within this document as the Project) will connect the existing M1 Pacific Motorway at Black Hill and the Pacific Highway at Raymond Terrace within the City of Newcastle and Port Stephens Council local government areas (LGAs). The Project will provide a critical link in the National Land Transport Network, particularly for the coastal Sydney to Brisbane corridor.

The Project will include the following key features:

- A 15-kilometre motorway comprised of a four-lane divided road (two lanes in each direction)
- Motorway access from the existing road network via four new interchanges at:
    - Black Hill: connection to the M1 Pacific Motorway
    - Tarro: connection and upgrade (six lanes) to the New England Highway between John Renshaw Drive and the existing Tarro interchange at Anderson Drive
    - Tomago: connection to the Pacific Highway and Old Punt Road
    - Raymond Terrace: connection to the Pacific Highway.
- A 2.6-kilometre viaduct over the Hunter River flood plain including new bridge crossings over the Hunter River, the Main North Rail Line, and the New England Highway
- Bridge structures over local waterways at Tarro and Raymond Terrace, and an overpass for Masonite Road in Heatherbrae
- Connections and modifications to the adjoining local road network
- Traffic management facilities and features
- Roadside furniture including safety barriers, signage, fauna fencing and crossings and street lighting.
- Adjustment of waterways, including Purgatory Creek at Tarro and a tributary of Viney Creek
- Environmental management measures including surface water quality control measures
- Adjustment, protection and/or relocation of existing utilities
- Walking and cycling considerations, allowing for existing and proposed cycleway route access
- Permanent and temporary property adjustments and property access refinements
- Construction activities, including the establishment and use of temporary ancillary facilities, temporary access tracks, haul roads, batching plants, temporary wharves, soil treatment and environmental controls.

Appendix A contains a number of design plans and conceptual views which shows the location of the Project and its key features.

1.2. Key Project features affecting flooding

The key features of the project that affect flood behaviour are the:

- bridge piers,
- embankments,
- abutments,
- culverts, and
- access tracks.

The Project consists of:

- The main 2.54 km Hunter River bridge
- 10 other bridges
- 29 sets of new culverts

The main feature of the project affecting flooding is the 2.54-kilometre viaduct (BR05) over the Hunter River and floodplain, the Main North Rail Line, and the New England Highway. The viaduct has a total of 76 piers that are spaced about 33.9m apart and pier column diameters between 1.3 and 1.7m. The western floodplain of the Hunter River includes 54 piers and is around 1.8 km in length.

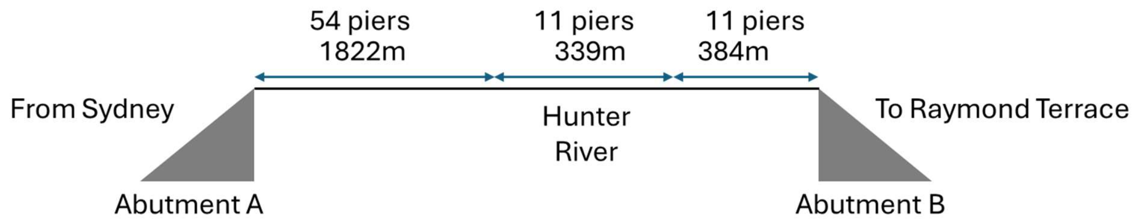

Diagram 1: Main viaduct (BR05) over Hunter River and its floodplain.

The other key Project features affecting flooding is the 171.5m bridge over Windeyers Creek (BR11). The flooding in this area is mainly dominated by regional flooding in the Hunter River. This bridge consists of 5 piers with 1.25m column diameters. Appendix A includes plans of the Project.

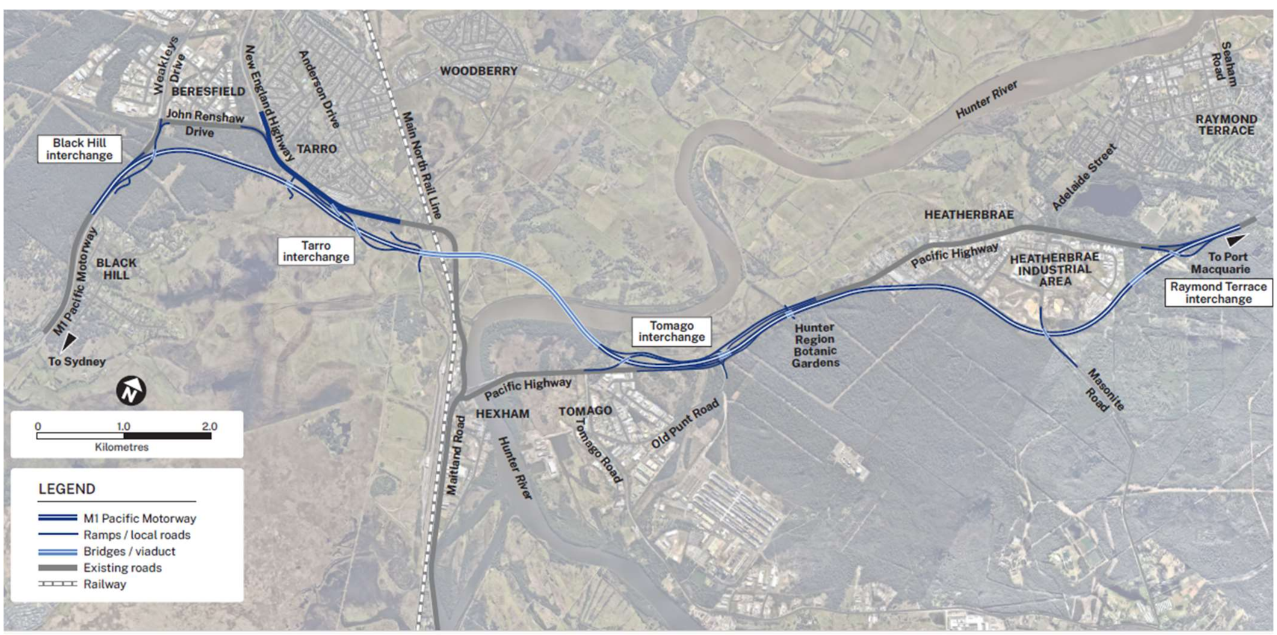

Diagram 2: Project alignment with key features

1.3. Relevant Conditions of Approval

The Project is classified as Critical State Significant Infrastructure (CSSI). The Conditions of Approval for the Project issued by the Minister of Planning contain the following conditions relating to flood modelling:

Number	Condition	Addressed
E33	The CSSI must be designed and operated to limit impacts on flooding characteristics in areas outside the Project boundary during flood events up to and including the 1% AEP flood event, in accordance with the following Quantitative Design Limits (QDLs): (a) a maximum increase in inundation time of one hour or 10% whichever is greater; (b) a maximum increase of 10 mm in above-floor inundation to habitable rooms where floor levels are currently inundated; (c) no above-floor inundation of habitable rooms which are currently not inundated in the 1% AEP flood event; (d) a maximum increase of 50 mm in inundation of land zoned as residential, industrial or commercial; (e) a maximum increase of 100 mm in inundation of land zoned as rural, primary production, environment zone or public recreation; (f) no significant increase in the flood hazard or risk to life; (g) maximum relative increase in velocity of 10%, where the resulting velocity is greater than 1.0 m/s, unless adequate scour protection measures are implemented and/or the velocity increases do not exacerbate erosion as demonstrated through site-specific risk of scour or geomorphological assessments.	Refer to Section 4
E36	Updated flood modelling must be undertaken for a range of flood events (including the 20%, 10%, 5% AEP and 1% AEP) for the CSSI and include the upstream direction along the Hunter River, Paterson River and Williams River to define the full extent of afflux levels. The updated assessment must be consistent with the *Australian Rainfall and Runoff – A Guide to Flood Estimation* (GeoScience Australia, 2019). ***Note:*** *The intent of this condition is to ensure the modelling and results of the CSSI are updated to include the Paterson River and Williams River to understand the full extent of the CSSI's afflux impacts.*	The M1 Pacific Motorway extension to Raymond Terrace updated flood model was developed for the Project which extended upstream of the previous modelling on the Hunter River, Paterson River and Williams River such that the afflux is contained within the new model extents. Refer to Section 2 and 3.
E37	The results of the updated flood modelling must be detailed in a **Flood Design Report**. The Report must be reviewed and endorsed by a suitably qualified and experienced hydrologist, who is independent of the CSSI's design and construction and the persons/organisation who prepared the **Flood Design Report**.	This report constitutes the Flood Design Report. This report has been reviewed by an independent suitably qualified and experienced hydrologist.
E38	The **Flood Design Report** must be submitted to the Planning Secretary for information within 6 months from the commencement of construction. The independent reviewer's endorsement must be submitted with the report.	This report.

1.4. Purpose of this report

The updated flood model developed as part of the current Project (referred to as the M1 Pacific Motorway extension to Raymond Terrace updated flood model) and documented in this report aims to address the requirements of the Ministers Condition of Approval E36. The EIS flood model has been extended and enhanced such that the extent of the M1 Pacific Motorway extension to Raymond Terrace updated flood model on the Hunter, Williams and Paterson Rivers is sufficient that the afflux impacts of the M1 to Raymond Terrace Project are contained within the model extent. The M1 Pacific Motorway extension to Raymond Terrace updated flood model is considered appropriate for assessment of the impacts of the Project on the full range of flood behaviour and characteristics and has been adopted for the design of the Project.

Hydrologic and hydraulic modelling has been undertaken to determine the existing flood behaviour which is suitable for assessing the impact of the Project on flood behaviour and the impact of flooding on the Project (bridges and culverts). This report documents the existing flood behaviour within the study area without the Project, the flood behaviour with the Project and the impacts of the Project.

In undertaking the flood modelling consideration is given to the relevant standards and guidelines:

- *NSW Floodplain Development Manual* (NSW Gov, 2005)
- *Environmental Planning and Assessment Amendment Act 2017 and associated Directions issued under section 117*
- *Practical Consideration of Climate Change – Flood risk management guideline* (DECC, 2007)
- *Australian Rainfall and Runoff* (1987 and 2019) (Pilgrim, 1987 and Ball et al, 2019) and *Australian Rainfall and Runoff Revision Project 15: Two dimensional modelling of Rural and Urban Floodplains guidelines* (IEAust, 2012)
- *Managing the floodplain: a guide to best practice in flood risk management in Australia* (AIDR, 2017).

1.5. Structure of this report

The structure of this report is as follows:

- Section 1 - Introduction
- Section 2 – Study Area and Existing Environment
- Section 3 – Updated Flood Modelling
- Section 4 – Design Criteria
- Section 5 – Results
- Section 6 – Conclusions
- Section 7 – References
- Figures 1 to 94
- Appendix A – Project Plans
- Glossary

2. Study Area and Existing Environment

2.1. Study Area

The Hunter Valley is located in northern NSW on the east coast of Australia. It is one of the largest valleys in NSW and covers a total area of approximately 21,450 km^2. The catchment is delineated by the Mount Royal Range to the east, where it rises in the Barrington Tops at an elevation of approximately 1,500 meters above mean sea level. The western boundary is formed by the Great Dividing Range, encompassing the Goulburn River and its tributaries. A southern lateral spur extends eastward to the Myall Range, enclosing the headwaters of Wollombi Brook and Wallis Creek. The upper catchment is characterised by steep terrain with sparse timber cover, transitioning to hilly, open, and undulating foothills descending towards the Hunter and Goulburn Rivers.

The Hunter River at and below Maitland, is characterized by flatter terrain, expansive floodplains, and widespread agricultural activities such as vineyards, dairy farming, and crop cultivation. Human activities like land clearing, urbanization, and infrastructure development significantly impact the lower catchment area. The Lower Hunter Flood Mitigation Scheme, which began in the 1980's, includes a number of major flood mitigation works throughout the lower reaches of the Hunter Valley. This includes levees, controlled floodways, flood storage areas and floodgates.

The flood study area has been identified to assess the potential adverse impacts to flooding from the Project and covers waterways located in floodplain areas of the Hunter River, Paterson River and Williams River that surround the Project (refer to Figure 1). The study area has been expanded from the EIS to ensure the full extent of impacts of the Project are captured.

The Project is located downstream of the junction of the Hunter River and Williams River and upstream of Hexham. The floodplain model area has a total of 473 km^2 and extends from the mouth of the Hunter River, west of the Project along the Hunter River to Oakhampton and north along Williams River to East Seaham. To the east, the study area extends to Grahamstown Dam and Williamtown.

The flood study area includes parts of the Port Stephens Local Government Area, Maitland Local Government Area, and City of Newcastle Local Government Area. The existing Environmental Planning Instrument (EPI) Land Zoning for the study area was obtained from the Department of Planning, Housing and Infrastructure and is shown in Figure 2. This was used to inform comparison with the conditions of approval for the Project.

2.2. Flood History and mechanisms

As discussed in the 1994 Flood Study (NSW Public Works Department, 1994) there are three distinct flood mechanisms that cause flooding in the lower Hunter Valley. This includes:

- Hunter River dominated events.
- Williams River dominated events
- Local catchment flow events

Hunter River dominated events occur when there is significant rainfall upstream in the Hunter River catchment. This type of flooding is typically caused by inland depression rainfall which results in increased river flows and elevated water levels in the downstream i.e. at Raymond Terrace. Due to the extensive upstream Hunter River catchment area (21,000km^2 to Raymond Terrace), these types of floods are usually very large and affect extensive areas of the catchment. In the lower reaches around the Project, large Hunter River dominated flooding can results in the back up flooding in the lower Williams River floodplain. An example of this type of flooding is the February 1955, one the most severe floods in the Hunter River's history. According to the 1994 Flood Study, it was estimated to be 0.2% AEP event upstream at Maitland (on the Hunter River), while little flow was recorded upstream in the Williams River (at Glen Martin Gauge) on the day of peak flooding. Flooding was experienced in the lower Williams catchment due to back up flooding from the Hunter River.

The second mechanism is Williams River dominated flooding resulting in heavy rainfall in the Williams River catchment. These events are usually caused by low pressure coastal systems (east coast lows). These flood events are more common but due to the smaller Williams catchment, they tend to be smaller than Hunter dominated floods. An example of this type of flooding is the April 2015 flood. A combination of Hunter and Willams River flooding can occur also occur, which can be particularly detrimental at Raymond Terrace where both rivers meet. An example of this is flooding occurred in March 1893, where heavy rainfall in Williams River and Lower Hunter River caused significant flooding. Under such conditions, it is likely that there will be little time difference between peak flow in the Williams River at Raymond Terrace and peak Hunter River flood levels. According to the 1994 Flood Study, the 1893 flood flow at Maitland was approximately 6% AEP but levels in Williams Catchment estimated to be in 1% AEP. The high flood levels experienced at Raymond Terrace were likely dominated by the Williams River catchment.

Although the majority of historic flood records available for riverine flooding (Williams or Hunter), it is recognised that runoff from local catchments can pose a significant flood risk, particularly when they coincide with major riverine flood events. This type of flooding occurs when sudden intense rainfall occurs which overwhelms the drainage systems cause overland flows e.g. May 2005.

2.3. Topographic Data

There is a considerable amount of topographic data available for the study area. However, the accuracy and suitability of these existing datasets for use in the present study varies. This includes hydrosurvey and Airborne Laser Scanning.

Hydrosurvey of the Hunter River collected in 2005 was available from Department of Planning and Environment and is shown in Figure 4. Flood events have occurred since this survey which may have impacted the riverbed however no more recent survey is available for comparison.

Airborne Laser Scanning (ALS) ground levels and their resulting 1 m resolution digital elevation model (DEM) were provided for the study area. The ALS collection was undertaken in 2012, 2013, and 2014. Spatial accuracy of the ALS in the horizontal and vertical directions was reported as 0.8m and 0.3m, respectively.

Topographic data used in the hydraulic model for this study were sourced from the previous hydraulic models outlined in Section 2.4. For a number of locations where the survey was poor, and recent adjacent development had taken place, updated survey data from these recent developments was used. The topographic information available for this study area was used to infill the small gap between models on the Hunter River, validate topographic information in the hydraulic models and in fine tuning the sub-catchments layout.

2.4. Floor Level Database

A number of floor level databases are available for the study area. A combined floor level database was compiled from the following sources:

- Floor level surveys undertaken by Port Stephens Council, Newcastle City Council, City of Maitland as part of the NSW flood program,
- Drive-by floor level estimates and

- Estimations based on LiDAR data plus 0.3 m (to allow for a step).

The compiled database contained 9211 floor levels of buildings. The floor level survey points are shown in Figure 5. The floor levels were used to compare against the conditions of approval. Additionally, WMAwater conducted a field trip to the study area to validate the existing dataset and to estimate floor levels of new buildings.

2.5. Hydraulic Models History

A number of two-dimensional hydraulic models are available for the Hunter River. Due to the size of the floodplain and historical computational limitations, no previously compiled, single, two-dimensional model of the Hunter River is available.

The following models cover the area to the full extent where the Project may potentially result in flood impacts (e.g. afflux):

- *M1 to Raymond Terrace hydraulic model* (Jacobs, 2022): which extends the mouth of the Hunter River to Green Rocks. This model was developed in the EIS and concept design stage.
- *Green Rocks to Branxton Model* (WMAwater, 2011): which was developed for Maitland City Council and extends from Green Rocks to Branxton.
- *Williams River Model (BMT WBM, 2009)*: which was developed for Port Stephens Council and includes the lower Hunter region and extends north to Dungog. This model has three domains:
    - *Upper Williams River model*
    - *Lower Williams River model*
    - *Lower Hunter model*

The hydraulic model extent for each previous study is shown in Diagram 3. Elements of these models have been used to form the basis of the M1 Pacific Motorway extension to Raymond Terrace updated flood model which has been adopted to assess the impacts of the Project.

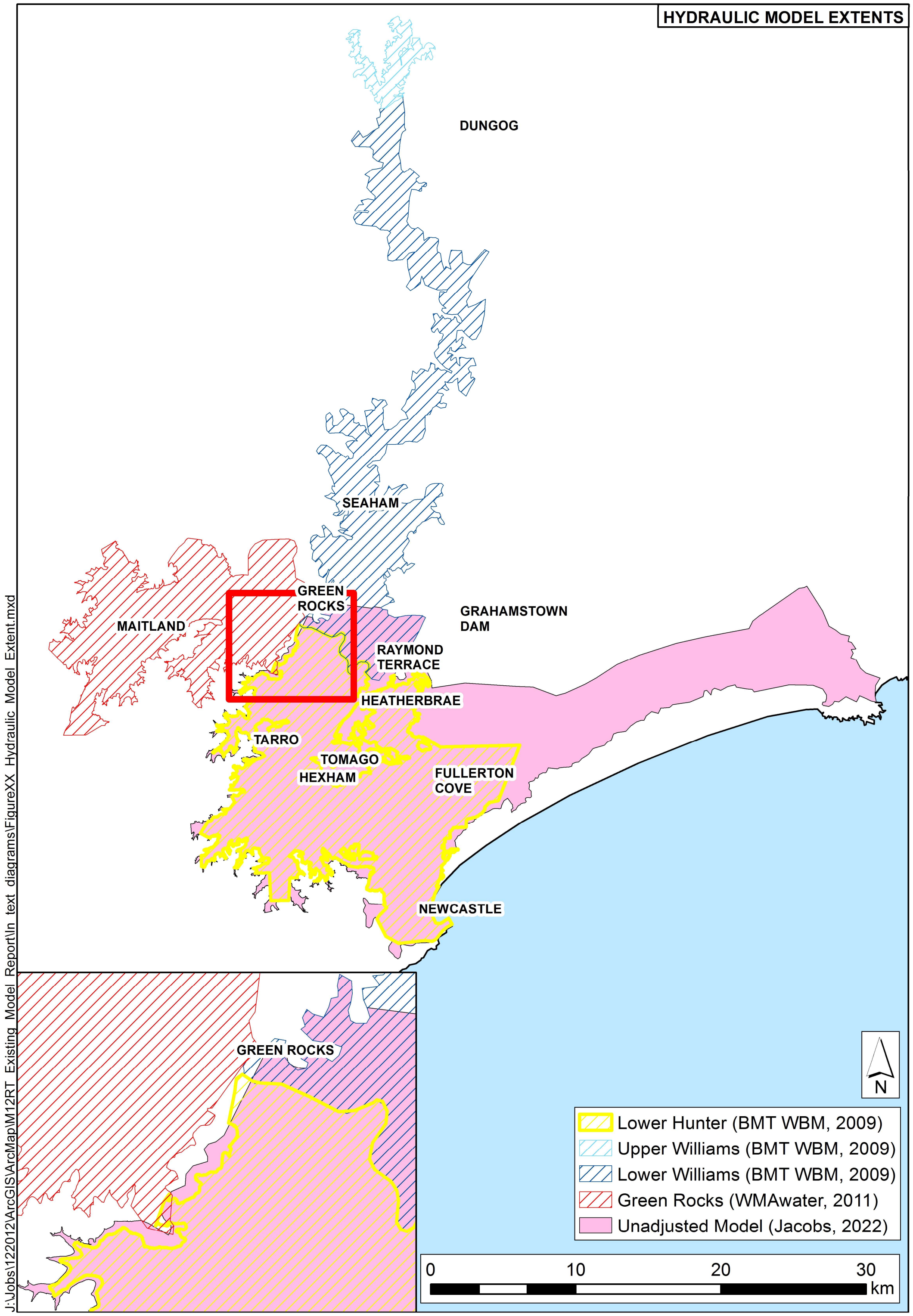

Diagram 3: Previous Model - Hydraulic Model Extent

3. Updated Flood Modelling

3.1. Development of the Model – Overview

This section summarises the development of the M1 Pacific Motorway extension to Raymond Terrace updated flood model. The methodology used to develop the flood model for the study is in accordance with ARR 2019 and best practice documents (discussed in Section 1). While the model may be suitable for a range of other uses other than impact assessment of the Project, as it reproduces flood frequency at Raymond Terrace, is based on calibrated Council flood models, is consistent with the latest ARR recommended design estimation methodology and considers the dominate flood mechanisms, it should be validated against historic flood events and other flow gauges further upstream before used for any other purpose.

3.1.1. Hydrologic Model

A hydrologic model of the entire Hunter River catchment was established as part of the study using the Watershed Bounded Network Model (WBNM) (Boyd et al, 2007). The parameters adopted for this study were based on those recommended in ARR 2019 (Ball et al, 2019) and previous experience. A total of 391 sub-catchments were established to represent the catchment (Figure 6).

Hunter River dominated and Williams River dominated events were generated. Hydrographs extracted from the hydrological model were used as inflows (flow vs time) for the hydraulic model. The selected temporal patterns for the Hunter River and Williams River dominated events are discussed in Section 3.3.

3.1.2. Hydraulic Model

A significant update was required to develop the M1 Pacific Motorway extension to Raymond Terrace flood model to define the full extent of afflux due to the Project.

The hydraulic model was developed using TUFLOW, a finite volume model commonly used for flood modelling in Australia. The latest version of the software (2023-03-AA) was used which has enabled increased event simulation times and allows the model terrain to be varied from 20m to 5m. This allows higher resolution representation of the terrain to be used where needed such as along road upgrade corridors. The model extent is based on the combination of three previous models as described in Section 2 and shown on Diagram 3. The combined model extent is shown on Figure 8. Model inflows were derived from the hydrologic model. A time varying tidal boundary was adopted as the downstream ocean boundary. Existing culverts and bridges were represented in the model.

3.2. Representation of the Project

The hydraulic model for the existing condition was modified to represent the Project. This included changing the existing condition terrain in the hydraulic TUFLOW model to represent the new road embankments as well as adding new culverts and bridges (as flow constrictions). The road design was initially developed for the two project stages:

- Stage 1 Black Hill to Tomago (BH2T)
- Stage 2 Heatherbrae Bypass (HB)

The designs for the two project stages were then combined to represent the final combined design. Design elements and hydraulic design parameters such as the road embankment and surface, form loss, roughness, culvert configuration and sizing were preserved from the files for each stage. However, model files which related to how the design elements connected to the broader hydraulic TUFLOW model were refined to improve stability and to be compatible with the M1 Pacific Motorway extension to Raymond Terrace updated flood model.

The quadtree zone allowed the Project embankments to be represented by a 5m by 5m cell size while keeping locations outside of the Project area coarser (20m by 20m cell size). This allowed the model run time to be practical for the Project design while providing suitable detail in critical areas. The quadtree extent is shown on Figure 9.

The bridges of the Project were represented by layered flow constrictions. The main bridge/viaduct which crosses the Hunter River was represented by a series of separate layered flow constriction shapes. In the Project scenario, each of these shapes had different blockage and form loss coefficients applied to take into account:

- Different pier design along the bridge (i.e. spacing and pier diameter)
- Varying skew of the bridge in comparison to the flow direction of the Hunter River.

Appendix A presents drawings of the viaduct and the Project.

3.3. Events Modelled

Design event flood surfaces were produced by enveloping the results of Hunter and Williams River dominated event runs for each AEP. Table 3 presents the adopted event durations which produced the highest peak flow at Hexham. The temporal patterns that represent how rainfall occurs over time were based on observed historic events in accordance with ARR 2019. Each event was run both with and without the Project.

Table 3: Design Event Surface Events

Design Event Surface	Hunter River Dominated	Williams River Dominated
20% AEP	48 hr	24 hr
10% AEP	72 hr	30 hr
5% AEP	96 hr	30 hr
1% AEP	72 hr	30 hr

3.4. Validation of the Model

The models used to form the basis of the M1 Pacific Motorway extension to Raymond Terrace updated flood model were calibrated to a number of observed flood events. A number of methods were used to verify the M1 Pacific Motorway extension to Raymond Terrace updated flood model was representing observed flood behaviour. This included comparison of design flood levels to flood frequency estimates at Raymond Terrace and previously modelled levels at Raymond Terrace and Hexham. Design flood surfaces were also compared to those from the EIS. An independent model was established to compare the head loss at the Hunter River crossing to that produced by the TUFLOW model.

4. Existing Flood Behaviour

Flooding within the study has been modelled for existing (without Project) events ranging from 20% AEP to 1 % AEP (refer to Figure 11 to Figure 50). In the upstream areas of the study area, the Hunter River flows east and joins with Paterson River (at Morpeth) before joining the Williams River and flowing south at Raymond Terrace. The Hunter River then flows through the Project area and flows southeast to discharge at the Pacific Ocean.

Downstream of Green Rocks there are broad floodplains characterized by flat terrain and low flow velocities (<1 m/s). Flood depths in most of these areas are greater than >0.5 m. There are floodplains within the study area at Millers Forest, Hexham Swamp, downstream of Grahamstown Dam, Nelson Plains.

The Maitland area is mostly flat with wide floodplains. As the Hunter River passes between Duckenfield and Osterley, the floodplain narrows. The narrowing of the floodplain increases velocity to 2 m/s and flood levels drop across the contraction.

There are levee embankments along both sides of the Hunter River from Duckenfield to Raymond Terrace and from Raymond Terrace to the Project. In the 20% AEP event (Figure 11 and Figure 12) and rarer, the embankment is breached at Duckenfield and flows travel south and inundate the floodplain at Millers Forest. Flow velocity exceeding, approximately 3.4 m/s in the Hunter River near Duckenfield causes breakouts from the main river channel to occur.

The terrain in the lower reaches of the Williams River is flatter. There are levees along both sides of Williams River. In the 20% AEP event (Figure 11 and Figure 12) the levee is partially overtopped. The Williams River breaks out near Seaham Boat Ramp where there is a bend in the river. In events 10% AEP (Figure 13 and Figure 14) and rarer, the levee is overtopped.

Windeyers Creek and Grahamstown Drain flow to the west. Three kilometres downstream of Raymond Terrace they join the Hunter River just north of the Project site. In events up to the 1% AEP, the flood extent is fairly contained within the farmland and vegetated areas. Masonite Road is overtopped in the 5% AEP and rarer events (Figure 15 and Figure 16).

Purgatory Creek, located just south of Tarro, flows to the east where it joins Hunter River during more frequent events (20% AEP and smaller). During bigger events the flow direction of Purgatory Creek is reversed. Water coming from further upstream of the Hunter River pushes water into the creek reversing the flow direction towards Hexham Swamp.

4.1. Flood Levels and Depths

Peak Flood Levels for the 20%, 10%, 5% and 1% AEP events for the existing (without Project) case are presented in Figure 11 to Figure 18 and are shown for key points of interest (POI) in Table 4. The locations of the POIs are shown in Figure 1. Flood levels at POIs have been provided as a general overview of flood levels and may not capture the complete range of flood levels within the catchment.

Table 4: Existing Peak Flood Levels at POI

POI	Description	Existing Peak Flood Level (mAHD)			
		20% AEP	10% AEP	5% AEP	1% AEP
1	Hunter Wetlands	0.72	1.11	2.00	3.81
2	Hexham Swamp	0.74	1.14	2.00	3.85
3	Hexham Train Support Facility	0.97	1.15	2.00	3.93
4	Raymond Terrace at Williams St	2.22	2.74	3.27	4.82
5	Woodlands Close	1.46	1.53	2.00	3.94
6	Main North Rail	1.81	2.34	2.88	4.43
7	Oakfield Road	1.81	2.38	2.93	4.49
8	Western Woodbury Park	2.02	2.63	3.17	4.74
9	Heatherbrae (eastern banks)	1.15	2.49	3.03	4.59
10	Hunter River at Millers Forest	2.07	2.69	3.22	4.77
11	Port Stephens Street	2.16	2.70	3.22	4.79
12	Upstream Hunter River	3.99	4.09	4.16	5.08
13	Tomago Road Intersection	1.94	2.11	2.64	4.11
14	Hunter Botanic Garden	-	-	-	-
15	WWTP	-	-	-	4.75
16	Upstream Williams River	2.59	2.86	3.38	4.88
17	Fitzgerald Bridge	2.31	2.81	3.32	4.84
18	Hexham Bridge	1.28	1.79	2.33	4.00
19	Hunter River at M12RT	1.40	2.25	2.82	4.37
20	Woodlands Close	1.35	1.42	2.00	3.94
21	Masonite Road	4.26	4.25	4.27	4.75
22	Grahamstown Drain	2.21	2.65	3.17	4.75
23	Windeyer’s Creek	2.17	2.65	3.17	4.75

*Note: Dash (-) indicates no flooding

Peak flood depths are presented in Figure 20 to Figure 26 and summarized in Table 5. In the 1% AEP event (Figure 25 and Figure 26), flood depths along the Project alignment exceed 3 m from Tarro to Tomago. In the 1% AEP event, peak flood depths in the Hunter River channel at the Project crossing exceed 10 m. Millers Forest, west of the Hunter River upstream of the Project, experiences flood depths in existing conditions ranging from 3.5 to 4.5 m. South of the interchange of New England Highway and Anderson Drive, the flood depths are approximately 3.5 m. At Heatherbrae where the Project crosses Windeyers Creek and Grahamstown Drain, the flood depths range from 2 to 3 m.

Table 5: Existing peak flood depth at POI

POI	Description	Peak flood depth (m)			
		20% AEP	10% AEP	5% AEP	1% AEP
1	Hunter Wetlands	0.52	0.91	1.80	3.61
2	Hexham Swamp	0.67	1.07	1.92	3.78
3	Hexham Train Support Facility	0.19	0.37	1.22	3.15
4	Raymond Terrace at Williams St	5.89	6.42	6.95	8.50
5	Woodlands Close	0.36	0.44	0.91	2.85
6	Main North Rail	0.19	0.33	0.53	2.07
7	Oakfield Road	0.98	1.55	2.10	3.66
8	Western Woodbury Park	1.19	1.79	2.33	3.90
9	Heatherbrae (eastern banks)	0.84	2.18	2.72	4.28
10	Hunter River at Millers Forest	0.55	1.16	1.69	3.25
11	Port Stephens Street	0.38	0.92	1.45	3.02
12	Upstream Hunter River	8.07	8.17	8.24	9.16
13	Tomago Road Intersection	0.10	0.26	0.80	2.27
14	Hunter Botanic Garden	-	-	-	-
15	WWTP	-	-	-	1.31
16	Upstream Williams River	7.09	7.36	7.88	9.38
17	Fitzgerald Bridge	3.27	3.77	4.28	5.79
18	Hexham Bridge	7.26	7.77	8.31	9.99
19	Hunter River at M12RT	5.61	6.47	7.04	8.58
20	Woodlands Close	0.29	0.36	0.94	2.88
21	Masonite Road	0.22	0.21	0.23	0.71
22	Grahamstown Drain	1.68	2.12	2.65	4.22
23	Windeyer's Creek	0.88	1.35	1.88	3.46

4.2. Velocities

Peak velocities within the study area for the 20% AEP to 1% AEP are presented in Figure 27 to Figure 34. The study area is mostly flat terrain with wide floodplains subject to low peak flood velocities.

In the 1% AEP event (Figure 33 and Figure 34), between Raymond Terrace and Hexham, peak flood velocities are typically between 1.5 to 2 m/s in the Hunter River. At the Project crossing of the Hunter River, peak flood velocities are greater than 2 m/s in the channel (reaching up to 2.6 m/s at the downstream bend) and 1.2 m/s in the floodplain. The floodplain around Millers Forest experiences low flood velocity (<1 m/s). At Heatherbrae where the Project crosses Windeyers Creek and Grahamstown Drain, the flood velocities are less than 0.5 m/s.

4.3. Flood Hazard

Hazard classification plays an important role in informing floodplain risk management. It reflects the likely impact of flooding on development and people, providing a measure of potential risk to life and property damage, from a flood event. Hydraulic hazard is typically determined by considering the depth and velocity of floodwaters. In recent years, flood hazard classification has been updated to account for new data and research. Flood hazard categories have been updated based on research investigating the consequences when people, vehicles and buildings are impacted by floodwaters. Research has been undertaken to assess the hazard to people, vehicles and buildings based on flood depth and velocity and the effect of both when considered together.

Hydraulic hazard categories have been determined for the study area in accordance with the NSW Flood Risk Management Manual (NSW Government, 2023) and its accompanying guideline FB03 – Flood Hazard.

The accompanying guideline FB03 contains information relating to the categorisation of flood hazard. A summary of this categorisation is provided in Diagram 4.

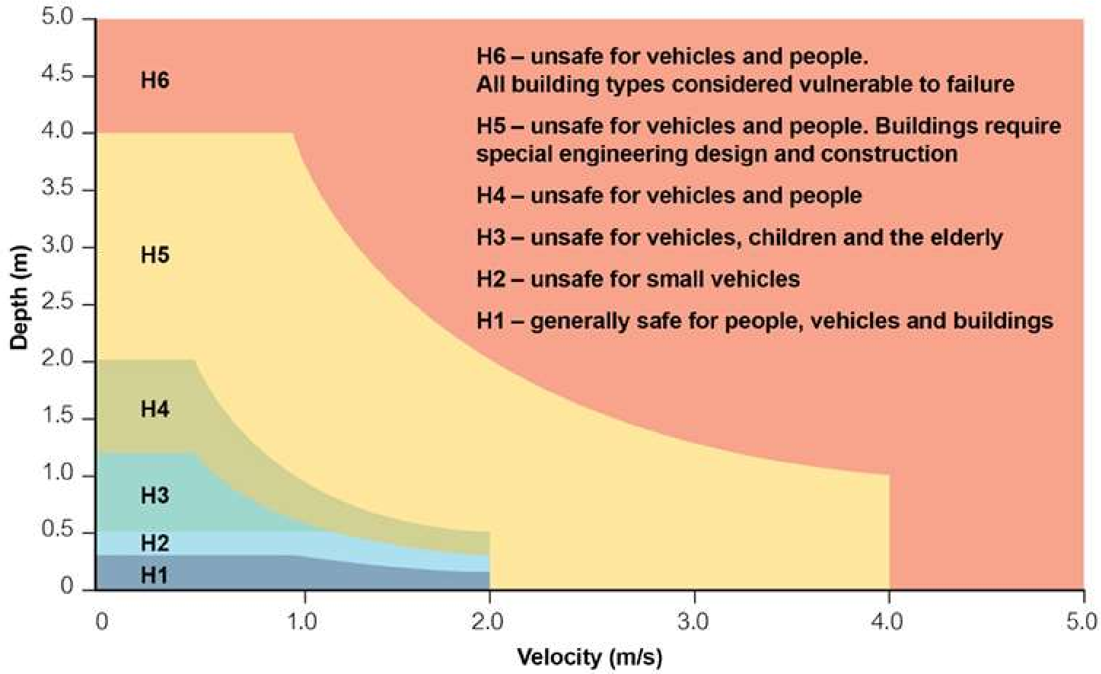

Diagram 4: Hazard classification diagram (Source: AIDR,2017)

The hazard classification of the existing (without Project) case is presented in Figure 35 to Figure 42 for 20%, 10%, 5% and 1% AEP events. In the 1% AEP event (Figure 41), the hazard classification along the Project alignment is H5 (Unsafe for all people and all vehicles. Buildings require special engineering design and construction) or H6 (Unsafe for people or vehicles. All building types considered vulnerable to failure) from Tarro to Tomago. At Heatherbrae, along the Project alignment hazard classifications are typically H5.

In the 10% AEP (Figure 37 and Figure 38), flood hazard in most areas upstream Raymond Terrace and the area around Hexham are classified as H5 or H6 which is defined as being unsafe for vehicles and people. Impacts downstream of Hexham are dominantly classified as unsafe for vehicles, children and the elderly (H3).

4.4. Duration of Inundation

The length of time each location is subject to floodwaters (inundation) is calculated by the flood model. This is referred to as the duration of inundation. The duration of inundation determines how long a location is "wet" during an event. Duration of inundation is an important metric as it indicates:

- how long a road may be cut,
- how early recovery can commerce after an event, and
- how long pasture may be inundated and therefore the potential for pasture die-off.

The duration of inundation for flood depths above ground in the existing case model is presented in Figure 43 to Figure 50.

At the end of the model simulation for all flood events (at time 500 hours), which is 389 hours after the main rain burst for a 1% AEP flood event, there are still areas subject to inundation in the model extent and majority of low-lying areas in the floodplain remain inundated. Diagram 6 and Diagram 7 (Section 6) presents an example hydrograph of the flood levels within low-lying areas in a 1% AEP flood event. The hydrographs show that the flood levels have stabilised and therefore, it was considered impractical to run the hydraulic model for extended simulation times, as it is expected processes at a finer scale than the model resolution such as infiltration and local drainage should be considered.

5. Design Criteria

5.1. Quantitative Design Limits

The Project Conditions of Approval for M1 Pacific Motorway Extension to Raymond Terrace (SSI 7319) (Department of Planning and Environment, 2022) include criteria for design and operation of the Project to limit impacts. The following quantitative design limits (QDL) apply to flood events up to and including 1% AEP (Section E33 of Conditions of Approval):

a) maximum increase in inundation time of one hour or 10% whichever is greater;

b) a maximum increase of 10 mm in above-floor inundation to habitable rooms where floor levels are currently inundated;

c) no above-floor inundation of habitable rooms which are currently not inundated in the 1% AEP flood event;

d) a maximum increase of 50 mm in inundation of land zoned as residential, industrial or commercial;

e) a maximum increase of 100 mm in inundation of land zoned as rural, primary production, environment zone or public recreation;

f) no significant increase in the flood hazard or risk to life; and

g) maximum relative increase in velocity of 10%, where the resulting velocity is greater than 1.0 m/s, unless adequate scour protection measures are implemented and/or the velocity increases do not exacerbate erosion as demonstrated through site-specific risk of scour or geomorphological assessments.

E33 b and c relate to buildings floor levels while the remaining conditions relate to lots.

5.1.1. Habitable floor levels

A habitable room is defined in the Conditions of Approval for M1 Pacific Motorway Extension to Raymond Terrace (SSI 7319) (Department of Planning and Environment, 2022) and relate to a number of conditions. It is defined as:

> As defined in the Floodplain Development Manual (DIPNR, 2005):
>
> *"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 and commercial situation: an area used for office or to store valuable possessions susceptible to flood damage in the event of a flood."*

Where the property is subject to flood planning conditions, the habitable floor level is set to the flood planning level.

Furthermore, Section E35 of the Conditions of Approval states that:

> *"Where floor level survey data is not available from Council(s), the Proponent must undertake floor level surveys of all potentially flood affected buildings where the QDLs set out in Condition E33 (b), (c), (d) and (e) are unlikely to be met, to confirm afflux limits. Where floor level survey data is not available or has not been surveyed, the existing ground level is to be adopted as the floor level."*

A floor level database has been compiled for the full extent of the flood model area. This database focuses on capturing, among other things, the primary floor level of each property.

Buildings in the floor level database that are impacted by the Project (i.e. a flood level increase due to the Project) were categorised based on whether the building is considered to be habitable. Categorisation was undertaken by Transport and WMAwater using a combination of aerial imagery, publicly available photographs of the property and targeted site inspections. Buildings not impacted by the Project were not subject to detailed assessment and therefore were not categorised.

For buildings in the floor level database that are impacted by the Project but categorised as undetermined, a conservative approach was taken and a QDL exceedance was assumed, and the property owner will be consulted.

The number of buildings in each category is summarised in Table 6.

Table 6: Building type summary

Habitable	Number of Buildings
Yes	479
No	712
Undetermined	179
Not categorised	7,841

5.1.2. Land Zoning

A number of the quantitative design limits refer to the various land zone types. The latest available Environmental Planning Instrument (EPI) Land Zoning was obtained from DPHI. The EPI Land Zoning classes were categorised to correspond with the land zones referred to in the Conditions of Approval. The resulting categorisation is summarised in Figure 3. A subset of Land Zoning Class was classified as Other and was assumed to have the same restrictions as the Residential, Industrial, or Commercial zones in the Conditions of Approval. The EPI Land Zones as presented in Figure 2 and Figure 3 present the land zones categorised according to the Conditions of Approval.

Table 7: Categorised EPI Land Zones

Conditions of Approval Category	EPI Land Zoning Class	EPI Land Zoning Code
Residential, Industrial, or Commercial	Business Park	B7
	Local Centre	E1
	Commercial Centre	E2
	Productivity Support	E3
	General Industrial	E4
	Heavy Industrial	E5
	General Industrial	IN1
	General Residential	R1
	Low Density Residential	R2
	Medium Density Residential	R3
	High Density Residential	R4

	Large Lot Residential	R5
Rural, Primary Production, Environment Zone, or Public Recreation	National Parks and Nature Reserves	C1
	Environmental Conservation	C2
	Environmental Management	C3
	Environmental Living	C4
	Public Recreation	RE1
	Private Recreation	RE2
	Primary Production	RU1
	Rural Landscape	RU2
	Forestry	RU3
	Village	RU5
Other	Complex Area	CA
	Mixed Use	MU1
	Special Activities	SP1
	Infrastructure	SP2
	Tourist	SP3
	Unzoned Land	UL
	Natural Waterways	W1
	Recreational Waterways	W2

5.2. Material Impact Considerations

In addition to Transport obligations to consult with affected landowners where project flood impacts exceed the QDLs (a), (b), (c) and (d) outlined in CoA E33, CoA E34 requires Transport to seek agreement from landowners on alternative flood levels, or mitigation measures as agreed with property owners where there is material impact.

CoA E42 also requires the establishment of the Independent Flood Impact Assessment Panel (IFIAP) to provide expert advice and make recommendations to address impacts where agreements with landowners cannot be obtained. The IFIAP is guided by a Terms of Reference developed by Transport with the guidance of flooding specialists and approved by the Planning Secretary under CoA E43. These approved Terms of Reference have been published and are available on the Project website.

The terms of reference provide some greater clarity on material impact. It defines matters that will be taken into consideration during consultation with affected landowners. An extract from the Terms of Reference developed to guide the consideration of material impact is outlined below.

Members of IFIAP have discussed and agreed an approach to the consideration of “Material Impact” where a property is impacted by CoA E33 QDL (a) to (e). Whether impacts are considered materially significant would be a site-specific merit-based assessment and take into consideration a range of factors. Typically, these factors might include:

- *Depth and duration of existing inundation for flood events up to 1%*
- *Duration and extent of project caused inundation, with consideration of existing land use and/or zoning, and duration and extent of existing flood inundation*
- *Project caused afflux resulting in new, above floor inundation of habitable floors greater than 10mm*
- *Project caused afflux resulting in increased above floor inundation of habitable floors greater*

than 30mm

- *Project caused afflux resulting in increased above floor inundation of floors of sensitive infrastructure >50mm (e.g. emergency service, electricity substations, water treatment plants)*
- *For flood impact of properties that exceed QDL (a), (d) and (e), material impact may be triggered when the area of impact is increased by >400m2 or more than 5% of a lot size where the lot size is greater than 8000 square meters. Where multiple adjoining lots have the same owner, the overall property impacts will be considered.*

6. Impact Assessment

Typically, a major bridge crossing is expected to increase flood levels upstream of the bridge and decrease flood levels downstream of the bridge. The downstream impacts typically do not stretch far downstream. On a large flat floodplain, the impacts can stretch upstream a considerable distance. The QDLs defined in Section 5.1 set the limits for design and operation of the Project and are addressed in the following sections. Impacts of the Project on flood characteristics are determined by comparing the existing conditions with the Project scenario.

For example, flood level impacts are calculated as the flood levels with the Project minus flood levels for existing conditions (without the Project). A negative number represents a decrease in flood levels due to the Project. A positive number represents an increase in flood levels due to the Project. An increase of 10mm (0.01m) is recognised as the practical limit of mapping of flood level impacts (Babister and Barton (Ed), 2012). Therefore, impacts within 10mm (0.01m) is considered minimal.

6.1. Flood Levels and Flood Level Impacts

Figure 51 to Figure 58 present the peak flood levels with the Project in the 20%, 5%, 10% and 1% AEP events. Table 8 describes the existing (without Project) and with Project flood levels and the difference between them at points of interest locations. Figure 59 to Figure 66 present the flood level impact maps for the Project.

In the 1% AEP event, flood levels increase by up to 0.06 m upstream of the Project (Figure 65 and Figure 66). Larger impacts occur within the Project corridor (Transport land). Immediately upstream of the Hunter River bridges, impacts in the 1% AEP are between 0.005 and 0.02 m. Typically, on the floodplain upstream of the Project impacts are in the order of 0.02m for the 1% AEP event. Impacts greater than 0.01m extend just north of Seaham Weir (along Williams River) and up to Osterley (along Hunter River). At the Tarro Interchange, flood levels increase locally by up to 0.09m in the road corridor due to the Project. At the Tomago Interchange with Old Punt Road, the flood levels increase by up to 0.055m in the 1% AEP. At the Masonite Road crossing, flood levels in a 1% AEP on surrounding rural properties are predicted to increase by up to 0.019m.

Upstream of the Project, flood levels increase by up to 0.016m within the Hunter River in the 20% AEP (Figure 60). These flood level increases extend up to Heatherbrae. To the north of the site, in the area between the Hunter River and the Pacific Highway, flood levels increase by up to 0.028 m. At the Tarro interchange, flood levels increase by up 0.39 m within the road corridor. At the Masonite Road crossing, levels decrease by up 0.3 m. In the 10% AEP, the impacts extend upstream of the Project to the floodplains in Woodberry, Tomago and Heatherbrae as well as in Windeyers Creek and Grahamstown Drain. The flood level increases in these areas are generally up to 0.012m (Figure 62).

As part of the Project the existing Pacific Highway is raised near the Hunter Region Botanic Gardens. In frequent events (20% AEP, 10% AEP, 5% AEP) floodwaters overtop the existing Pacific Highway to inundate the area east of Pacific Highway (near Hunter Region Botanic Gardens) in the existing scenario (without the Project). With the Project, this area of the Pacific Highway reduces the overtopping causing a reduction of flood level.

Table 8: Peak flood levels at Points of Interest

Key locations	Description	Existing Peak Flood Level (mAHD)				Peak Flood Level with Project (mAHD)				Change in Peak Flood Levels (m)			
		20% AEP	10% AEP	5% AEP	1% AEP	20% AEP	10% AEP	5% AEP	1% AEP	20% AEP	10% AEP	5% AEP	1% AEP
1	Hunter Wetlands	0.72	1.11	2.00	3.81	0.72	1.12	1.99	3.80	0.001	0.003	-0.003	-0.011
2	Hexham Swamp	0.74	1.14	2.00	3.85	0.74	1.14	1.99	3.84	-0.002	0.003	-0.003	-0.012
3	Hexham Train Support Facility	0.97	1.15	2.00	3.93	0.97	1.16	2.00	3.92	0.002	0.005	-0.002	-0.003
4	Raymond Terrace at Williams St	2.21	2.74	3.27	4.82	2.22	2.75	3.28	4.84	0.007	0.009	0.009	0.017
5	1 Woodlands Close	1.46	1.53	2.00	3.94	1.46	1.54	2.01	3.98	0.000	0.006	0.003	0.045
6	Main North Rail	1.81	2.34	2.88	4.43	1.80	2.35	2.89	4.45	-0.008	0.011	0.009	0.020
7	Oakfield Road	1.81	2.38	2.93	4.49	1.80	2.39	2.94	4.51	-0.007	0.012	0.010	0.020
8	Western Woodbury	2.02	2.63	3.17	4.74	2.02	2.64	3.18	4.76	-0.007	0.010	0.010	0.018
9	Heatherbrae (eastern bank)	1.15	2.49	3.03	4.59	1.18	2.50	3.04	4.61	0.028	0.015	0.013	0.023
10	Hunter River In Millers Forest	2.07	2.69	3.22	4.77	2.06	2.70	3.23	4.79	-0.004	0.009	0.009	0.018
11	Port Stephens Street	2.16	2.70	3.22	4.79	2.16	2.71	3.23	4.81	0.007	0.009	0.009	0.017
12	Upstream Hunter River	3.99	4.09	4.16	5.08	3.99	4.09	4.16	5.09	0.000	0.000	0.000	0.012
13	Tomago Road Intersection	1.94	2.11	2.64	4.11	1.94	2.11	2.63	4.10	0.000	0.001	-0.007	-0.010
14	Hunter Botanic Garden	-	-	-	-	-	-	-	-	-	-	-	-
15	WWTP	-	-	-	4.75	-	-	-	4.77	-	-	-	0.018
16	Upstream Williams River	2.59	2.86	3.38	4.88	2.60	2.87	3.38	4.90	0.003	0.009	0.007	0.016
17	Fitzgerald Bridge	2.31	2.81	3.32	4.84	2.31	2.82	3.33	4.85	0.006	0.009	0.008	0.017

18	Hexham Bridge	1.28	1.79	2.33	4.00	1.28	1.79	2.33	4.00	0.000	0.000	0.000	-0.002
19	Hunter River At M12RT	1.40	2.25	2.82	4.37	1.41	2.27	2.83	4.38	0.010	0.013	0.007	0.015
20	Woodlands Close	1.35	1.42	2.00	3.94	1.37	1.46	2.00	3.98	0.023	0.044	0.001	0.043
21	Masonite Road	4.26	4.25	4.27	4.75	4.17	4.15	4.17	4.77	-0.092	-0.094	-0.093	0.017
22	Grahamstown Drain	2.21	2.65	3.17	4.75	2.21	2.66	3.18	4.77	0.000	0.012	0.007	0.018
23	Windeyer's Creek	2.17	2.65	3.17	4.75	2.18	2.66	3.18	4.77	0.008	0.011	0.005	0.018

*Note: Dash (-) indicates no flooding. Levels are reported to two decimal points, impacts reported to three, which might lead to some rounding anomalies.

6.2. Velocity

Comparisons of existing conditions and with Project, peak flood velocities in the vicinity of the Project are shown in Figure 67 to Figure 70 for the 20% AEP to 1% AEP event. These comparisons show that the Project produces minimal differences in velocity for events up to the 1% AEP.

In general, the increase in peak flood velocity is less than 10% in areas where the Project has velocities greater than 2 m/s. Locations where the change in velocity exceeds this are typically located near or within the Project boundary, where there are significant topography modifications (for example the introduction of infrastructure such as abutments and piers). In general, the Project has minimal impacts (<0.1 m/s difference) on maximum peak flood velocities. Table 9 presents a comparison of the peak flood velocity in the Hunter River at the Project.

Table 9: Peak Velocity in Hunter River

AEP	Peak velocity in Hunter River for existing case (m/s)	Peak velocity in Hunter River for the with Project scenario (m/s)
20%	1.87	1.87
10%	2.49	2.48
5%	2.54	2.54
1%	2.83	2.84

6.3. Hazard

Comparisons of the existing and with Project scenario flood hazard classifications in the vicinity of the Project are shown in Figure 71 to Figure 74 for the 20% AEP to 1% AEP event. Comparison of the peak flood hazards shows that the Project has minimal impact to the hazard classification and that there are no significant areas where flood hazard has increased. However, there are small areas where it incrementally changes by 1 category. For example, in the 20% AEP, small areas near the Hunter Region Botanic Gardens decrease from Category H4 to H3.

6.4. Duration of Inundation

Changes in duration of inundation from the existing scenario to the Project scenario are shown in Figure 75 to Figure 78 for the 20% AEP to 1% AEP event. The duration of inundation changes with AEP due to the different chosen critical durations and temporal patterns for the events inundating the floodplain at different times during the event. The duration of inundation typically only changes in close proximity to the Project. The pier alignment and size of the Project infrastructure on the floodplain are designed to minimise as much as possible the obstruction to the flow. The flood level hydrographs are plotted for two locations on the floodplain (Diagram 5) and are presented in Diagram 6 and Diagram 7 for a 1% AEP event. While in the floodplain north of the Project (Diagram 6), the peak flood level has increased in the Project scenario, there are minimal impacts to the duration of inundation. The floodplain south of the Project (Diagram 7) is not affected by either peak water level change or change in duration of inundation.

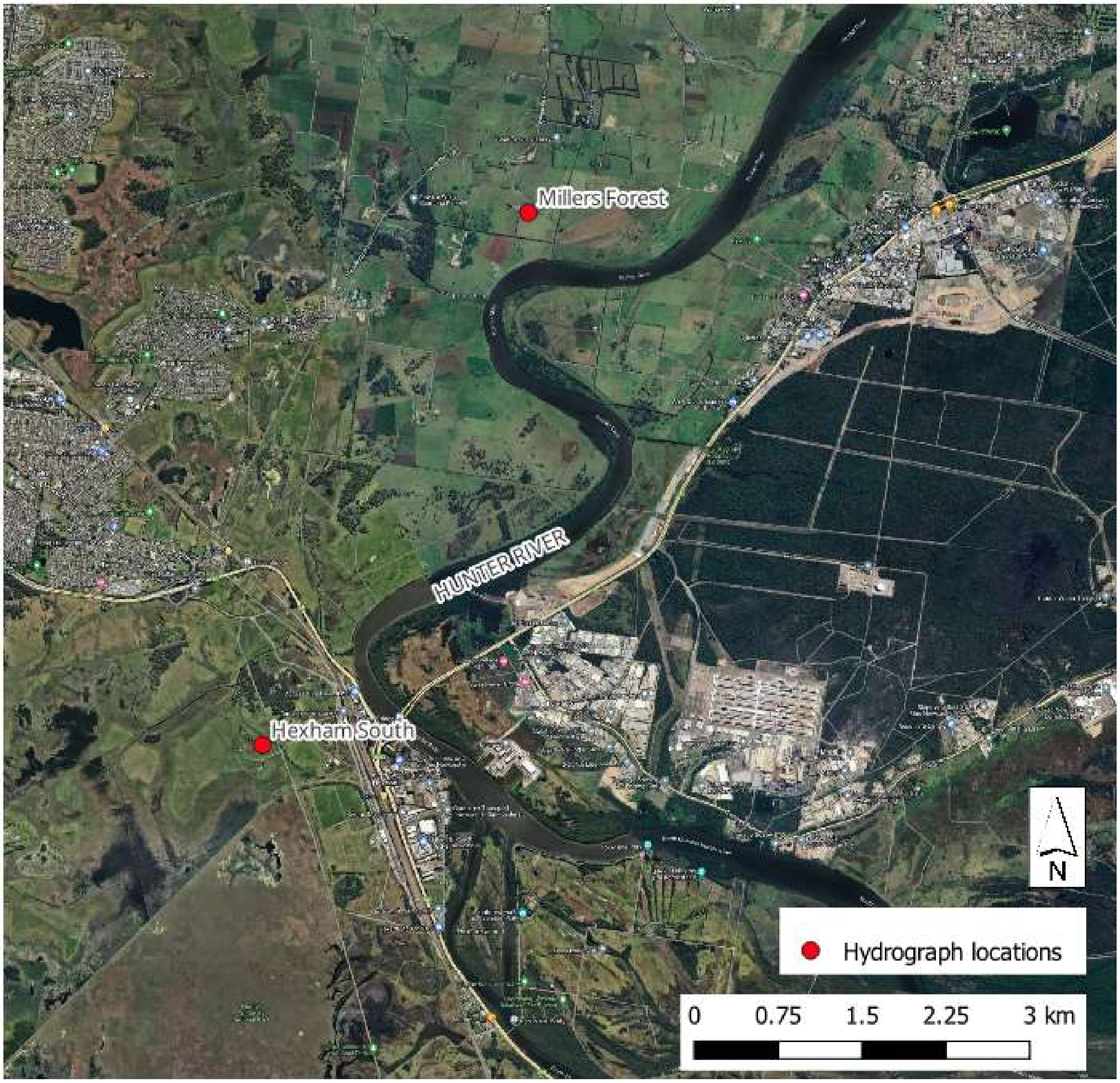

Diagram 5: Location of presented hydrographs

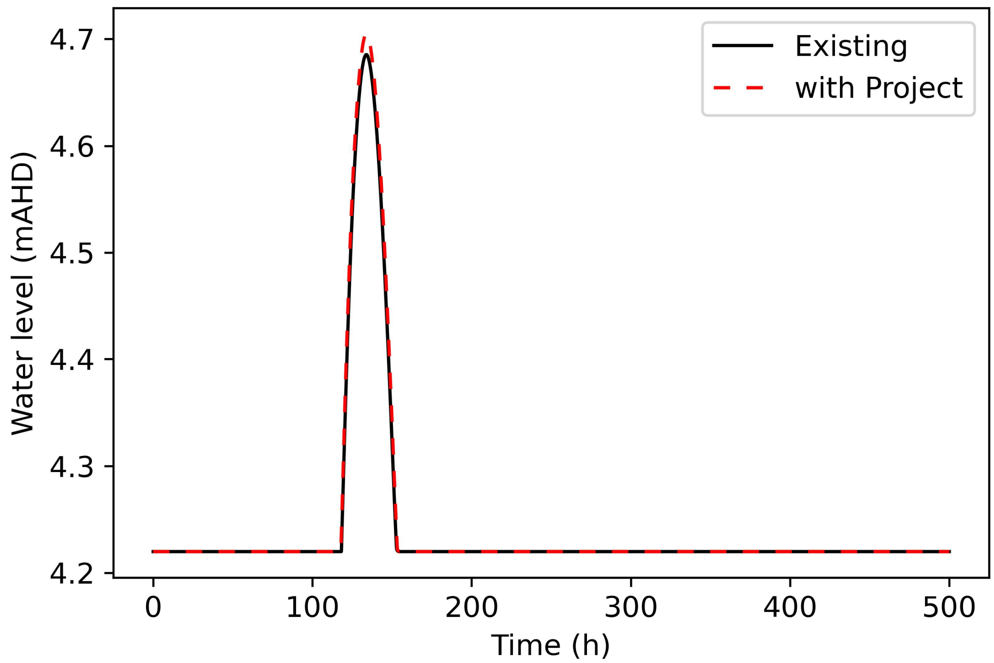

Diagram 6: Flood level hydrograph of the 1% AEP event in the floodplain at Millers Forest north of the Project

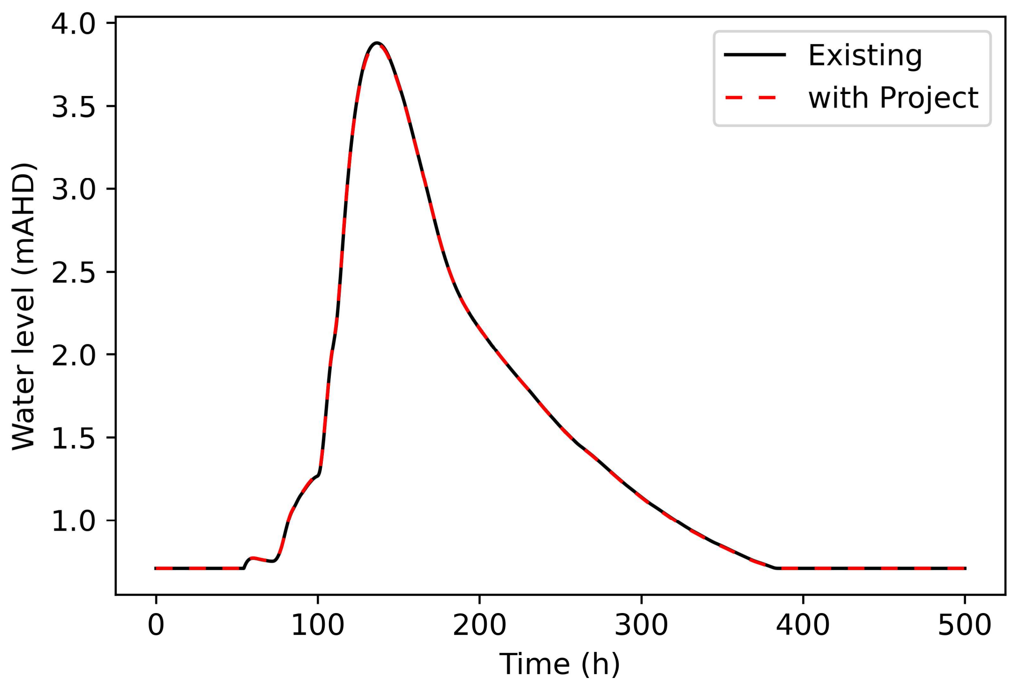

Diagram 7: Flood level hydrograph of the 1% AEP event in the floodplain at Hexham south of the Project

6.5. Quantitative Design Limit Comparison

6.5.1. Floor levels

The Minister's Conditions of Approval (DPE, 2022) for the Project define the Quantitative Design Limits (QDLs) for design and operation of the Project. Section E33b relates to floor levels and states that

"a maximum increase of 10 mm in above-floor inundation to habitable rooms where floor levels are currently inundated"

Habitable rooms and associated floor levels are defined as per Section 5.1.1

Section E33c defines additional design limits for the 1% AEP event:

"no above-floor inundation of habitable rooms which are currently not inundated in the 1% AEP flood event."

Buildings assessed as habitable within the floor level database have been assessed for this criterion and Table 10 presents the number of habitable buildings with impacts above the QDLs listed in Condition of Approval E33b and/or E33c. Of the 479 buildings categorised as habitable within the study area, 302 have above floor afflux greater than 10 mm and one habitable building is newly flooded above habitable floor level due to the Project. The highest afflux impact at a residential building above floor level is about 23mm (with above floor flood depths increasing from 1.91m in the existing case to 1.933m with the Project for the 1% AEP event).

Table 11 presents the buildings categorised as 'Undetermined' with impacts above the QDLs listed in CoA E33b and/or E33c. Of the 179 buildings categorised as 'Undetermined', 113 of these have above floor afflux greater than 10 mm and none of these are newly flooded above floor level due to the Project.

Table 12 presents the number of all buildings with impacts above the QDLs listed in CoA E33b and/or E33c. Table 12 shows that the majority of these buildings which exceeded the QDLs were categorised as not habitable (628 buildings exceeding the QDLs). There were no non-categorised buildings which exceeded the QDLs. Figure 79 to Figure 82 show the buildings in the floor level database which were modelled to exceed the QDLs. In the 1% AEP event, the majority of properties that are impacted above the QDLs are located:

- On the edge of the floodplain at Tarro, Woodberry, Beresfield
- West of the existing Pacific Highway at Heatherbrae
- On the western floodplain of the Hunter River between the Project and Millers Forest
- Along the riverbank in and just upstream of Raymond Terrace along the Hunter River and the Williams River

Overall, the number of properties affected has been reduced from the EIS concept design. This is a result of a number of design refinement and pier configuration changes to the Hunter River bridge.

Table 10: Inundation of habitable buildings

	20% AEP	10% AEP	5% AEP	1% AEP
Flooded above floor in existing scenario	13	134	292	398
Flooded above floor in with Project scenario	13	133	293	399
Above floor afflux greater than 10 mm	0	7	103	302
Newly flooded habitable rooms in 1% AEP	N/A	N/A	N/A	1

Table 11: Inundation of buildings categorised as 'Undetermined'

	20% AEP	10% AEP	5% AEP	1% AEP
Flooded above floor in existing scenario	16	72	114	168
Flooded above floor in with Project scenario	16	72	114	168
Above floor afflux greater than 10 mm	0	1	3	113

Newly flooded habitable rooms in 1% AEP	N/A	N/A	N/A	0

Table 12: Inundation of all buildings (including habitable, not habitable and undetermined buildings)

	20% AEP	10% AEP	5% AEP	1% AEP
Flooded above floor in existing scenario	181	1245	1759	2760
Flooded above floor in with Project scenario	181	1246	1761	2763
Above floor afflux greater than 10 mm	4	56	184	1041
Newly flooded buildings in 1% AEP	N/A	N/A	N/A	3

6.5.2. Lots

6.5.2.1. Inundation time

The Minister's Conditions of Approval (DPE, 2022) for the Project defines inundation time Quantitative Design Limits (QDLs) in Section E33a):

"a maximum increase in inundation time of one hour or 10% whichever is greater".

Inundation duration exceeding the QDLs occurs in the following locations (as shown in Figure 91 to Figure 94):

- around the Tarro interchange particularly in the 20% and 10% AEP.
- Upstream of the Project to the north-east of Windeyers Creek
- East of the Hunter River and the Project around Hunter Botanical Gardens, particularly in the 1% AEP.

In the 1% AEP, the QDL for duration of inundation (a maximum increase of one hour or 10%, whichever greater) is exceeded in 467 lots. Impacts above the QDLs generally occur at lots along the edge of the flood extent and are often characteristic of the model rather than an actual impact. For example, the choice of model grid cell size or the depth above which a grid cell is assumed wet, would impact the duration of inundation in the edge of the flood extent. Therefore, it would be reasonable to filter out small areas (in the order of few model grid cells) in the duration of inundation results.

6.5.2.2. Flood level impacts

The Minister's Conditions of Approval (DPE, 2022) for the Project Section E33d requires that:

"a maximum increase of 50 mm in inundation of land zoned as residential, industrial or commercial."

Land zoning for the model area is shown on Figure 2. Figure 3 depicts the clustered zoning types used for this assessment. A total area of 128.2 km^2 has been zoned as residential, industrial, or commercial (or other) and 81.4 ha (0.781km^2) of this area has peak flood level increases greater than 50 mm in the 1% AEP event. The maximum increase in flood level due to the Project in land zoned residential, industrial or commercial, or other is up to 203 mm at Tomago.

The Minister's Conditions of Approval (DPE, 2022) for the Project stipulates in the Quantitative Design Limits (QDLs) (Section E33e) that:

"a maximum increase of 100 mm in inundation of land zoned as rural, primary production, environment zone or public recreation."

A total area of 344.8 km^2 has been zoned as rural, primary production, environment zone or public recreation and 0.81 ha (0.008 km^2) of this area has peak flood levels increases greater than 100 mm in the 1% AEP event. The maximum increase in flood levels due to the Project in these land zones, is up to 718 mm just south of Tarro, largely contained within the project boundary with some impact extending into a Hunter Water access corridor.

In the 1% AEP, an increase of flood levels of more than 100 mm in land zoned as rural, primary production, environmental zone, or public recreation or more than 50 mm in land zones as residential, industrial or commercial, occurs at 22 lots.

6.5.2.3. Velocity

The Minister's Conditions of Approval (DPE, 2022) for the Project defines the Quantitative Design Limits (QDLs) relating to velocity as (E33 g):

"maximum relative increase in velocity of 10%, where the resulting velocity is greater than 1.0 m/s, unless adequate scour protection measures are implemented and/or the velocity increases do not exacerbate erosion as demonstrated through site-specific risk of scour or geomorphological assessments."

In the 1% AEP, a maximum increase in velocity of 10% with a resulting velocity greater than 1m/s occurs at 12 lots. These exceedances typically occur in locations near or within the Project boundary, where there are significant topography modifications. Examples of this include the introduction of infrastructure such as abutments and piers.

Velocities in the order of 2 m/s are generally required for scour to occur on well grassed areas.

Site specific risk assessment of erosion resulting from velocity increase / exceedances has been undertaken for locations outside the Project boundary. This has concluded that the locations with exceedances are generally very small areas within larger rural lots. The landform of impacted sites includes flat topography (0-2%) and well grassed ground covering or engineered (road) surfaces. Due to these factors the impacted areas have been assessed as capable of withstanding the marginally higher velocities and site treatments are therefore considered not required.

6.5.2.4. Hazard

The Minister's Conditions of Approval (DPE, 2022) for the Project defines in the Quantitative Design Limits (QDLs) (Section E33f) for flood hazard as:

"no significant increase in the flood hazard or risk to life."

Minor changes to flood hazard occur largely in isolated areas of the model where they are on the edge between hazard categories and a minor change in either depth or velocity shifts the hazard to a different category. For example, this occurs around the Hunter Botanic Gardens, to the east of the Project. The changes in flood hazard are not considered significant.

6.5.2.5. Summary of lot impact

A total of 474 lots with the Project have flood behaviour that is above the QDLs for at least one of the categories in the 1 % AEP event. In the 5 % AEP, 10 % AEP, and 20 % AEP a total of 204, 278, and 194 lots respectively exceed the QDLs. A total of 742 lots are impacted above the QDLs in one of the categories in one of the events from 20% to 1% AEP.

Table 13: Summary of lots with exceedance of QDLs from the Project

AEP	Flood Level Impact	Inundation	Velocity	Total
20% AEP	23	190	5	194
10% AEP	11	274	6	278
5% AEP	9	200	10	204
1% AEP	22	467	12	474

6.6. Impact of the Project on other infrastructure

6.6.1.1. Impacts on road infrastructure

There are several existing roads near the Project which would form the evacuation and emergency access routes from areas that are flood prone. Analysis of the hazard classification was undertaken in accordance with *The NSW Floodplain Development manual, Managing the floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017) and Book 6, Chapter 7 of ARR 2019 (Ball et al, 2019). H2 classified areas are considered unsafe for small vehicles and therefore H2 provides an indication of the change in risk to life along evacuation routes. A classification of H2 corresponds to a flood depth of 0.3 m and low flood velocity.

The hazard classification of major roads and evacuation routes within the extent of the model area has been completed by point sampling the hazard classification from the hydraulic model outputs along the road at an increment of 10 m. For each major road, Table 14 presents the length of road where the hazard classification is H2 or greater without the Project. It also provides the difference in length of road affected (presented in brackets) with the Project.

Table 14: Length of road (m) with Hazard Classification of H2 and greater for existing scenario and change in length for the with Project scenario

Road	20% AEP	10% AEP	5% AEP	1% AEP
Cabbage Tree Road	40(-)	120 (-)	630 (-)	630 (-)
Maitland Road	390 (-)	590(-)	1310 (-)	10920 (-20)
New England Highway	50 (-)	170 (-)	840 (-)	2530 (+150)
Pacific Highway	1360 (-)	2950 (+20)	4070 (-230)	9720 (-2510)
Raymond Terrace Road	3420 (-)	5870 (-)	6400 (+10)	7350 (-)
Seaham Road	2440 (-)	3850 (-)	4120 (-)	4210 (-)
Tomago Road	40 (-)	60 (-)	120 (-)	710 (-)

* Value in brackets show the increase in length of road with hazard classification of H2 and greater in the Project scenario. Positive numbers represent an increase in distance. Negative numbers represent a reduction in distance.

As shown in Table 14, the Project has two minor increases in length of road impacted (i.e. 20 m in 10% AEP and 10 m in 5% AEP) and a number of minor reductions. The minor changes are not considered to change the overall flood affectation of the roads within the model extent. Note changes less than 20 m may not be represented due to the modelling constraints but are unlikely to affect road serviceability.

As shown in Table 14 the length of Pacific Highway classified as considered unsafe for small vehicles (H2) or greater is reduced by 2.51 km in the 1% AEP. This reduction is mainly located along Pacific Highway between Tomago and Heatherbrae, where the existing Pacific Highway is upgraded as part of this Project.

The duration that major roads are inundated with and without the Project are presented in Table 15. Most roads are inundated long after peak of the event. In all cases the existing situation is maintained or improved. Inundation here is defined as water above road elevation. Especially in smaller events changes tend to be shorter than one hour (Figure 66).

Table 15: Duration of inundation of major roads (hours)

Roads	20 % AEP	10 % AEP	5 % AEP	1 % AEP
Seaham Road	418 (-)	442 (-)	434 (-)	455 (-)
Raymond Terrace Road	399 (-)	402 (-)	390 (-)	455 (-)
William Bailey Road	(-)	(-)	332 (-)	399 (-)
King Street	(-)	(-)	329 (-)	397 (-)
Hunter Street	357 (-)	374 (-)	338 (-)	385 (-)
Thomas Street	(-)	(-)	(-)	(-)

Pacific Highway	495 (-)	490 (-)	456 (-)	497 (-)
Tomago Road	456 (-)	445 (-)	449 (-)	457 (-)
New England Highway	497 (-3)	496 (-16)	457 (-2)	499 (-4)
Maitland Road	357 (-)	371 (-)	358 (-)	407 (-)
Cabbage Tree Road	434 (-)	340 (-)	349 (-)	372 (-)
Nelsons Bay Road	(-)	(-)	(-)	(-)

* Value in brackets show the change in inundation time due the Project. Positive numbers are an increase in duration with the Project. Negative numbers represent a reduction in duration with the Project.

6.6.1.2. Impacts on rail infrastructure

There are a number of railway lines within the study area. The Intercity Train Network which connects Sydney with the Hunter Valley runs through the study area and intersects the Project at Tarro.

In the existing scenario, the rail line is not overtopped between Tarro and Thornton for events up to 20% AEP (Figure 20). In the 10% AEP, the rail line between Beresfield and Tarro is overtopped by up to 0.29 m (Figure 22). In the 10% AEP, the Project increases the flood levels by 11 mm at the railway line. In current conditions, the railway line is overtopped by up to 2.4 m in the 1% AEP event (Figure 26). With the Project in place, in the 1% AEP event, peak flood levels at the railway line increase by up to 20 mm between Beresfield and Tarro (Figure 66). While there is some increase in peak flood level at the railway line, there are no changes to the length of railway track overtopped.

There are commercial railway lines which run parallel to the Intercity Train Network. The depot for these railway lines is located north of the Hexham Train Station (west of Hexham Bridge). As these railway lines are parallel to the Intercity Train Network, they experience similar impacts. The Hunter Valley Corridor which includes rail infrastructure at Kooragang Island and Port Waratah is located more than 10 km downstream of the Project. The Project will have minimal impact on these structures.

6.6.1.3. Impacts on Raymond Terrace Levee

Raymond Terrace is located near the confluence of the Hunter and Williams River and was constructed as part of the Lower Hunter Flood Mitigation Scheme. The Raymond Terrace Levee protects the central business district and southern residential precincts in Raymond Terrace from flooding from both the Hunter and Williams River. Diagram 8 presents the alignment of the Raymond Terrace Levee.

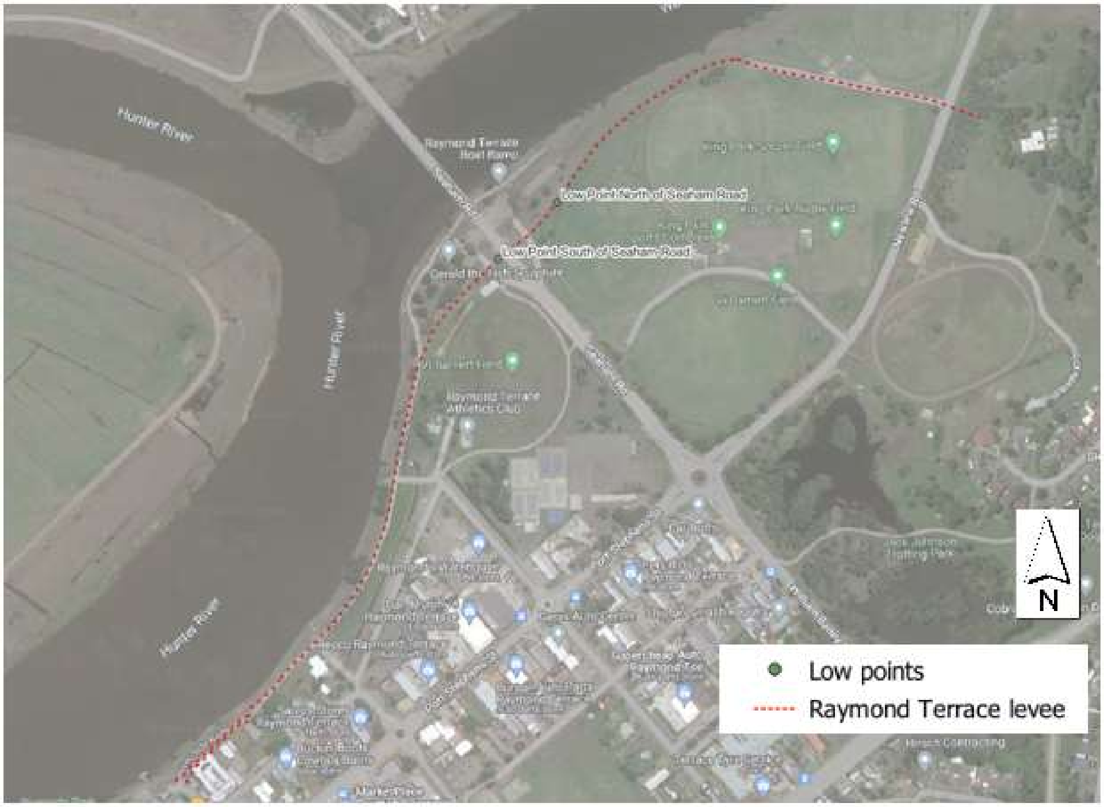

Diagram 8: Alignment of Raymond Terrace Levee

South of Seaham Road, Raymond Terrace Levee typically has a minimum crest level of 3.2 m AHD. There is a low point of 2.97 m AHD at Terrace Park located just south of Seaham Road. North of Seaham Road, the minimum crest level is 3.15 m AHD in The Jack Collins Oval.

Table 16 presents the peak flood levels at the low points of Raymond Terrace Levee under existing conditions and the impacts as a result of the Project. In existing conditions, the Raymond Terrace Levee is not overtopped in more frequent events (20% AEP and 10% AEP). The levee begins to overtop in a 5% AEP at the low point south of Seaham Road. In rarer events (0.5% AEP), the levee is completely overtopped.

In the 1% AEP event, the flood levels increased by 17 mm North of Seaham Road due to the Project. The Project results in a minimal change to the overtopping frequency. Diagram 9 presents the stage frequency curve of flood levels near the low point of the Raymond Terrace Levee. Given that the low point of the Levee is at 2.97 m AHD, the Raymond Terrace Levee begins to overtop at approximately an event of 8% AEP.

Table 16: Peak flood levels along Raymond Terrace Levee from the Project

Location (Levee Low Point m AHD)	Existing Flood Levels (m AHD)				Flood Levels Impacts (m)			
	20% AEP	10% AEP	5% AEP	1% AEP	20% AEP	10% AEP	5% AEP	1% AEP
South of Seaham Road (2.97 m AHD)	-	-	3.322	4.836	-	-	0.011	0.017

North of Seaham Road (3.15 m AHD)	-	-	3.321	4.840	-	-	0.011	0.017

* Dash (-) indicates that the levee is not overtopped.

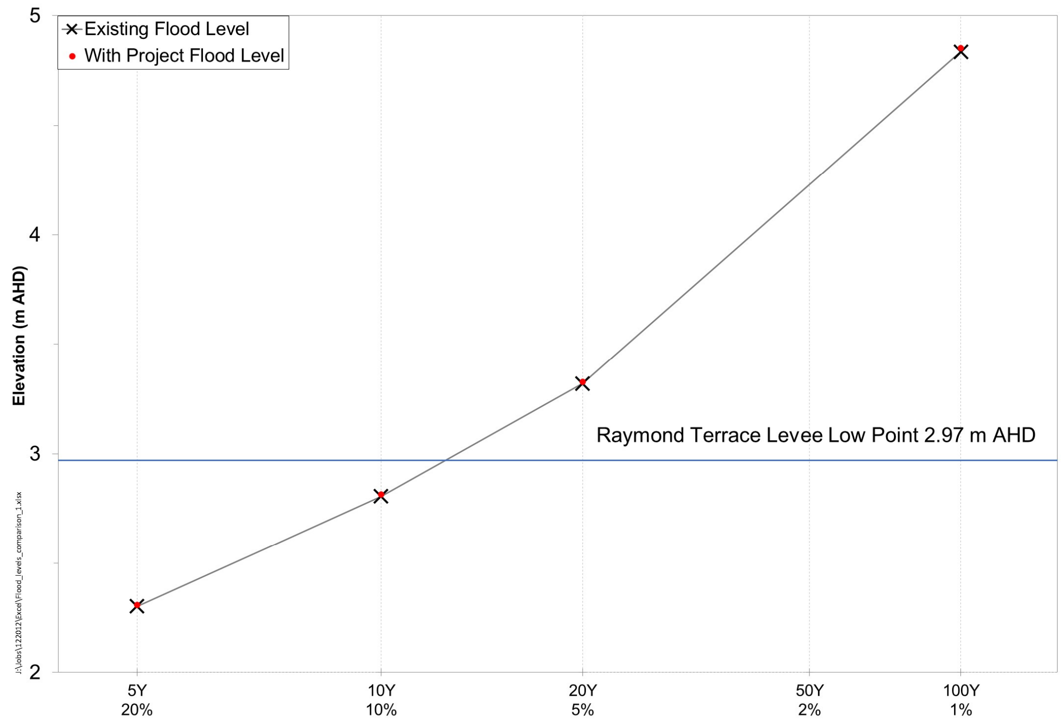

Diagram 9: Stage Frequency in Hunter River near the low point of the Raymond Terrace Levee

All other levees within the Hunter Mitigation Scheme are not affected by the Project.

6.7. Impact of flooding on the Project

The Project alignment is generally flood free up to a 1% AEP (Figure 58). North of Heatherbrae, there is a small section of the proposed road which is inundated by 12 mm in the 1% AEP. Flood levels in the 1% AEP have been checked against the bridge deck levels. This showed that there were no overtopping bridges in the 1% AEP event.

The operational footprint of the Project at the Tomago Interchange extends to Old Punt Road and Tomago Road. Within the Project footprint along Old Punt Road, the peak flood levels increase by 55 mm in a 1% AEP. Tomago Road is overtopped at its intersection with Pacific Highway in the existing scenario. The Project has minimal impacts to Tomago Road at the Tomago Interchange.

The Project involves an upgrade of Masonite Road at its intersection with the Project in the form of a fly-over. In the 1% AEP event, the flood extent along Masonite Road is reduced at the intersection however peak flood levels increase by up to 19 mm adjacent to the upgrade in the Project scenario.

In the existing 1% AEP case the northern tie in of the Project with the existing Pacific Highway at Raymond Terrace was inundated (Figure 26). The Project increases the flood level at the Pacific Highway by up to 18 mm in the 1% AEP (Figure 66).

7. Conclusion

The M1 Pacific Motorway extension to Raymond Terrace updated flood model developed as part of the current project and documented in this report was developed in response to the Ministers Condition of Approval E36. The extent of the model on the Hunter, Williams and Paterson Rivers is sufficient that the afflux impacts of the M1 to Raymond Terrace Project is contained within the model extent. The flood model is considered appropriate for assessment of the impacts of the Project on the full range of flood behaviour and characteristics as it has been shown to reproduce flood behaviour and takes into consideration the various flood mechanisms that result in the flooding of the Hunter Valley.

The Project was assessed against the quantitative design limits (refer to Section 4). Overall, the Project was found to be result in flood behaviour above the quantitative design limits at 1,044 buildings and 474 lots for the 1% AEP event. Overall, impacts above the QDLs are considered minor in nature with the largest increase in flood level at a habitable building being 23mm in the 1% AEP. In this case, the building is already flooded by up to 1.91 m in existing case. Transport will consult with all impacted landowners and receivers to further communicate and discuss specific project flood impacts.

8. References

Pilgrim DH (Editor in Chief)

Australian Rainfall and Runoff – A Guide to Flood Estimation

Institution of Engineers, Australia, 1987.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors)

Australian Rainfall and Runoff: A Guide to Flood Estimation

Commonwealth of Australia, Australia, 2019

Babister, M., Trim, A., Testoni, I. & Retallick, M

The Australian Rainfall & Runoff Datahub

37th Hydrology and Water Resources Symposium Queenstown NZ, 2016

Babister, M & Barton C (Editors)

Australian Rainfall and Runoff Revision Project 15: Two Dimensional Modelling in Urban and Rural Floodplains- Stage 1&2 Report P15/S1/009

Engineers Australia, 2012

NSW Government

Floodplain Development Manual: The management of flood liable land

April 2005

Commonwealth of Australia

Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia

AIDR 2017

WMAwater

M1 to Raymond Terrace: Technical Report – Flood Modelling

Transport for NSW, May 2024

Boyd M, Rigby T, VanDrie R, and Schymitzek I

WBNM User Guide

2007

Jacobs

M1 to Raymond Terrace Environmental Impact Statement

2022

WMAwater

Green Rocks to Branxton Flood Study

2011

BMT WBM
Williams River Flood Study
2010

NSW Public Works Department
Lower Hunter River Flood Study (Green Rocks to Newcastle)
1994

VIII. Figures 1 to 94

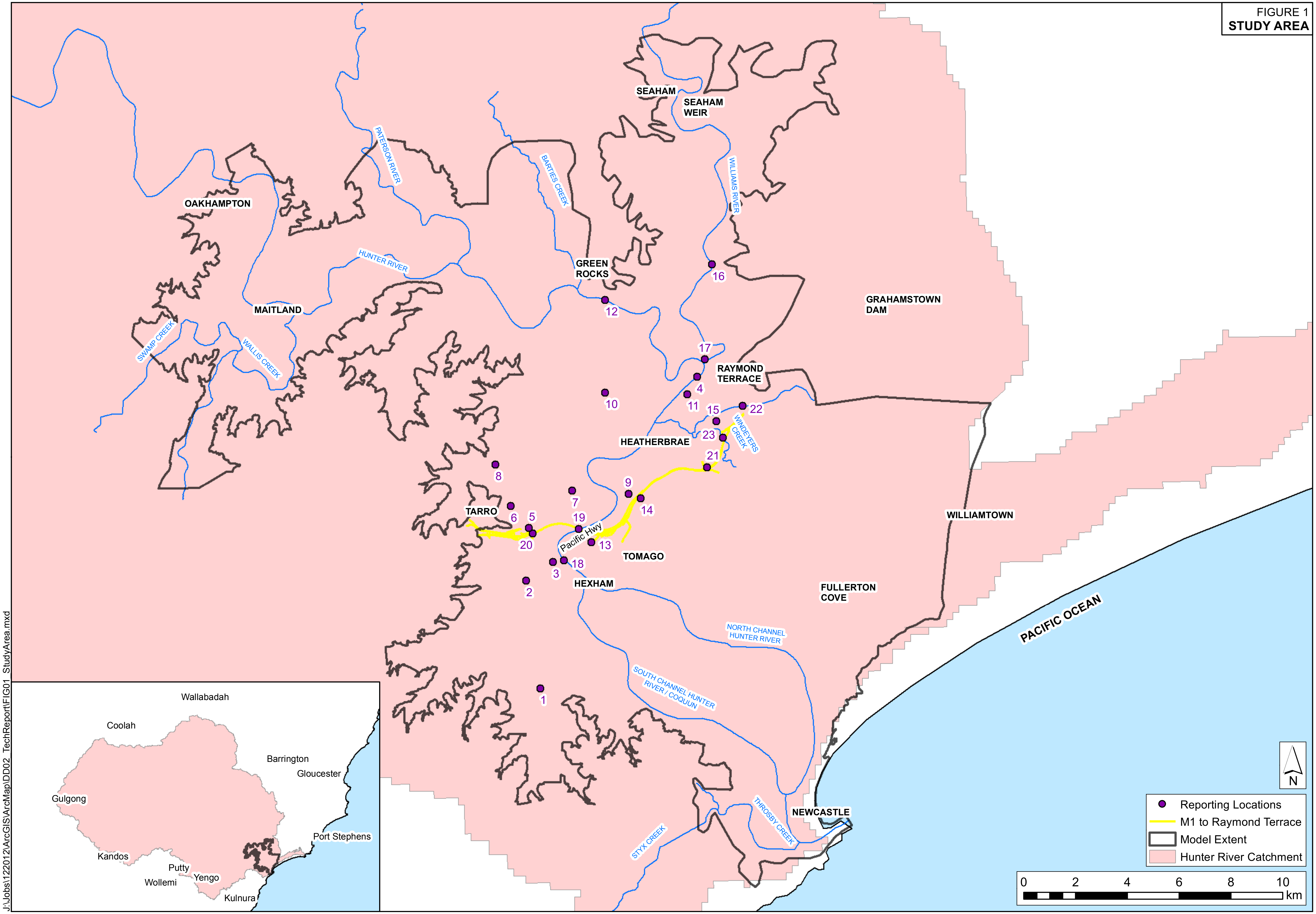
FIGURE 1
STUDY AREA
SEAHAM
SEAHAM WEIR
PATERSON RIVER
BARTIES CREEK
WILLIAMS RIVER
OAKHAMPTON
HUNTER RIVER
GREEN ROCKS
MAITLAND
SWAMP CREEK
WALLIS CREEK
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
WINDEYERS CREEK
TARRO
Pacific Hwy
TOMAGO
HEXHAM
WILLIAMTOWN
FULLERTON COVE
PACIFIC OCEAN
NORTH CHANNEL HUNTER RIVER
SOUTH CHANNEL HUNTER RIVER / COQUUN
STYX CREEK
THROSBY CREEK
NEWCASTLE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Wallabadah
Coolah
Barrington
Gloucester
Gulgong
Port Stephens
Kandos
Putty
Yengo
Wollemi
Kulnura
N
Reporting Locations
M1 to Raymond Terrace
Model Extent
Hunter River Catchment
0 2 4 6 8 10 km
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FIGURE 2
LAND ZONING

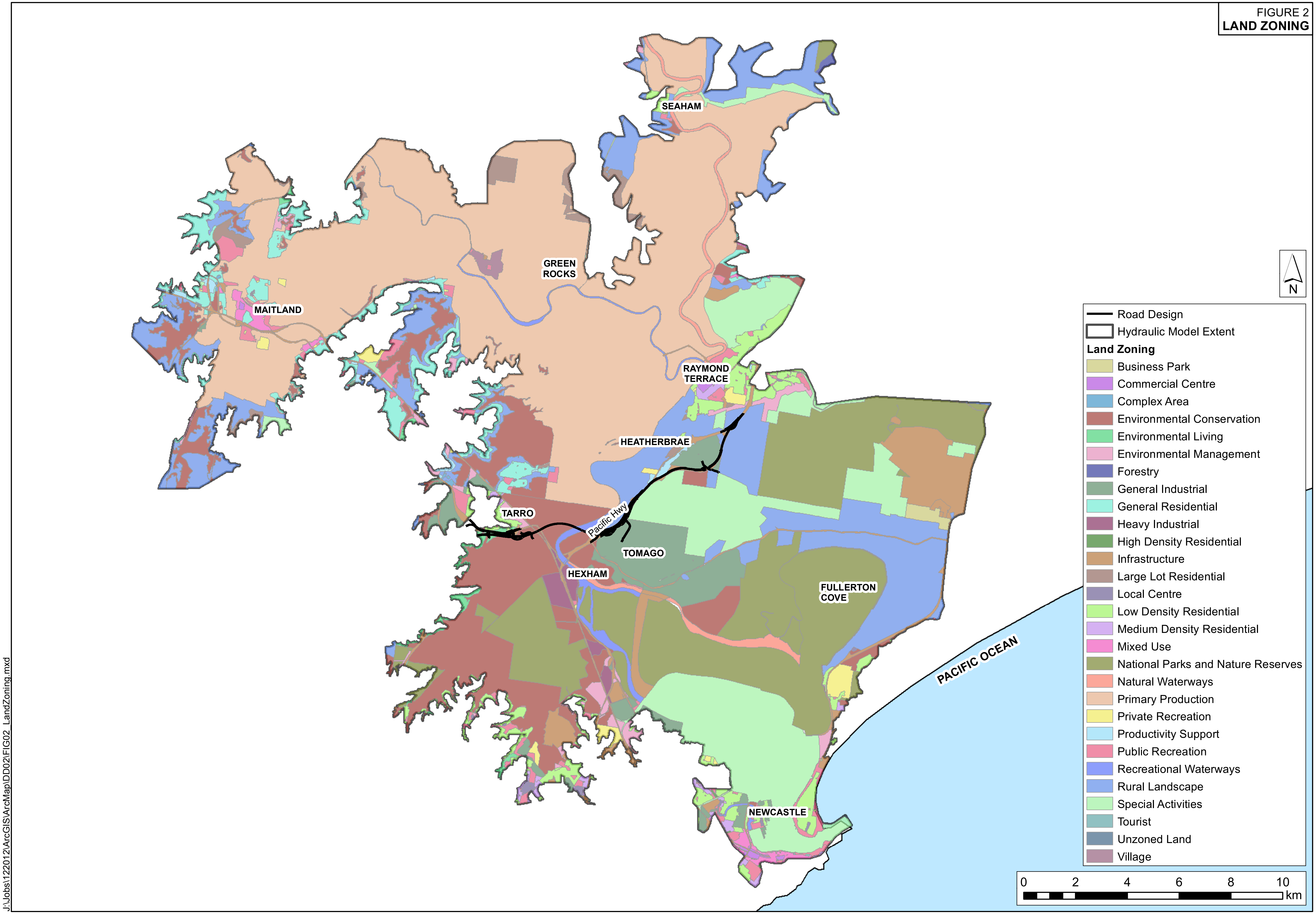

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FIGURE 3
CATEGORISED LAND ZONES FOR CONDITIONS OF APPROVAL ASSESSMENT

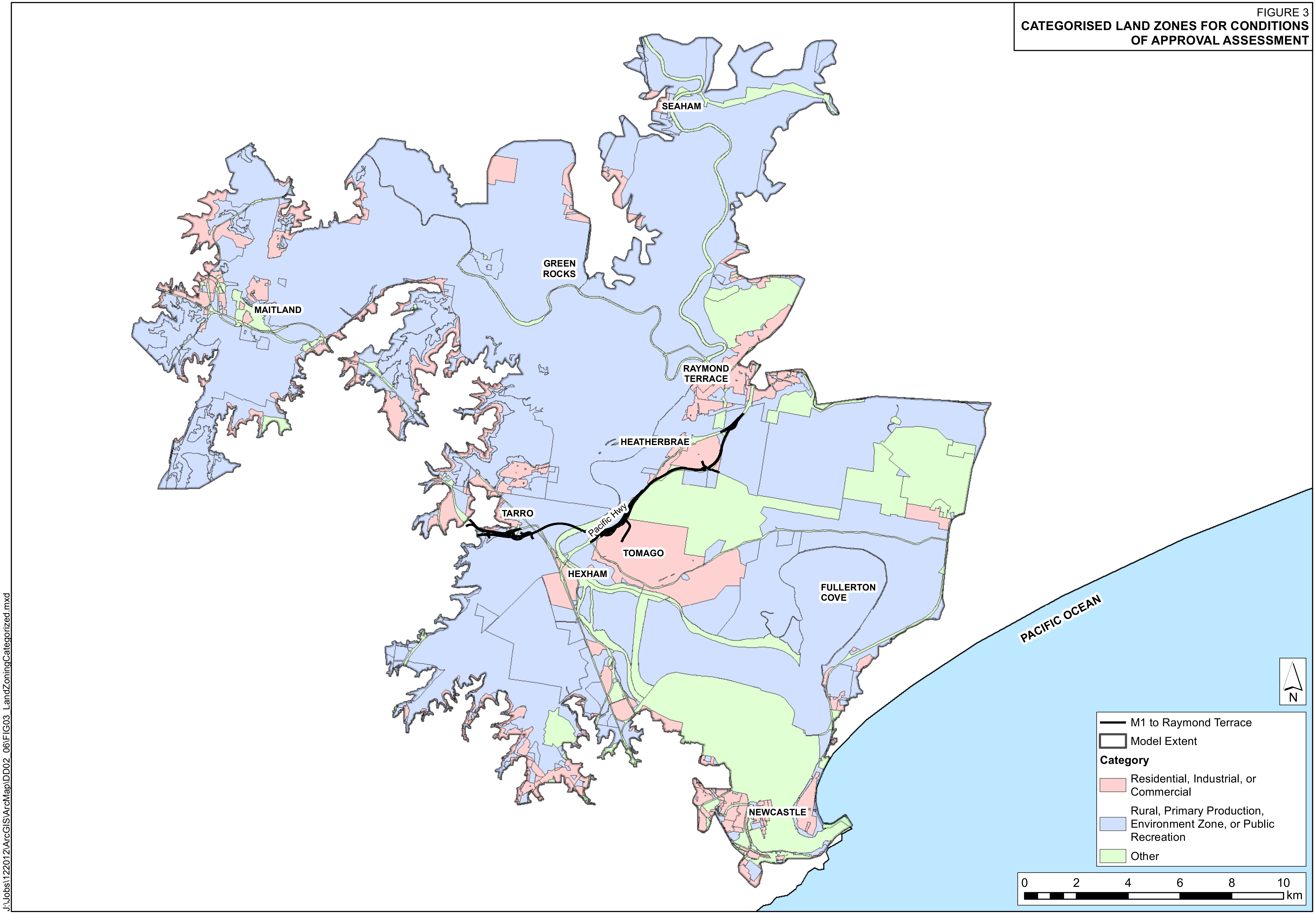

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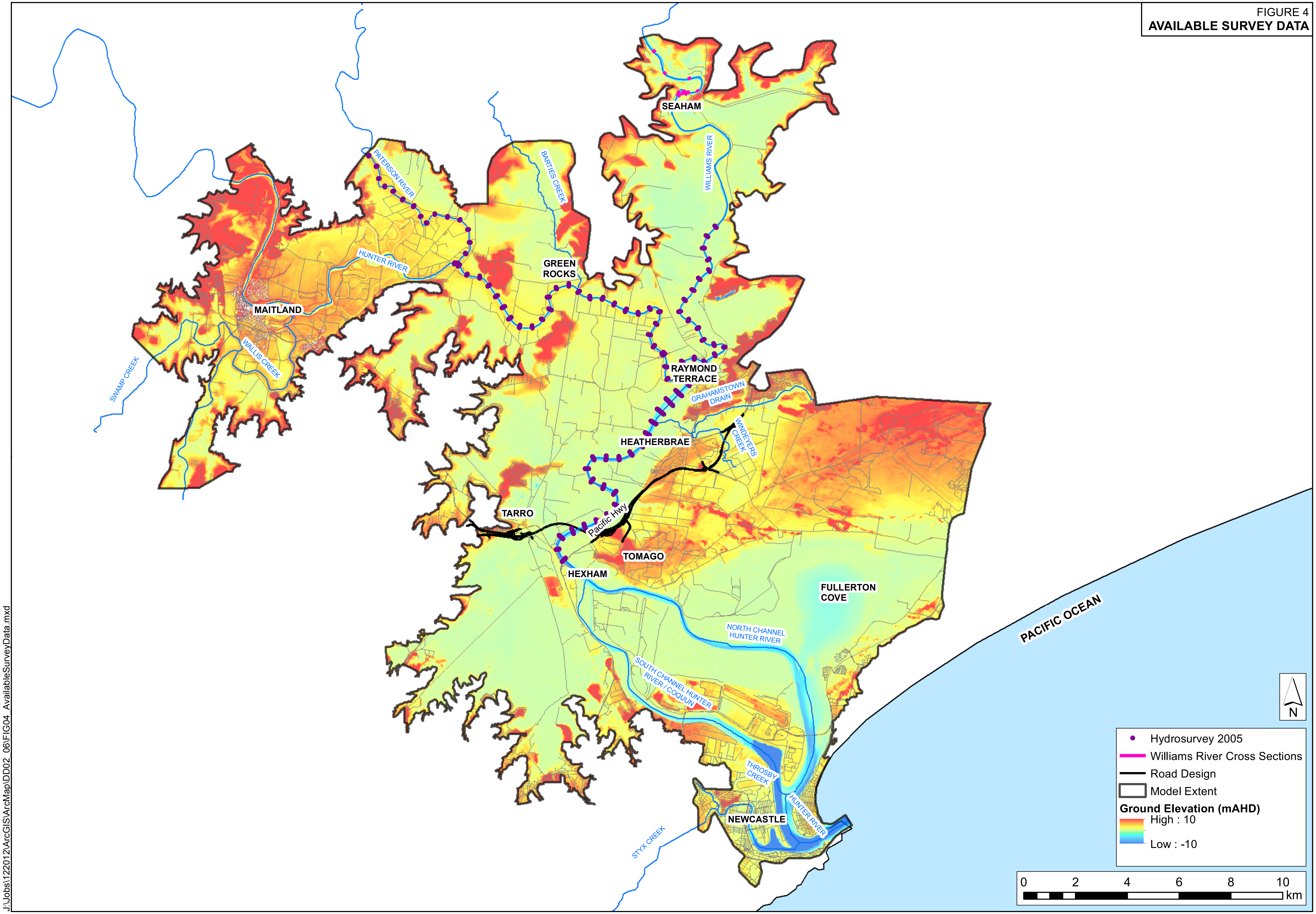
FIGURE 4
AVAILABLE SURVEY DATA



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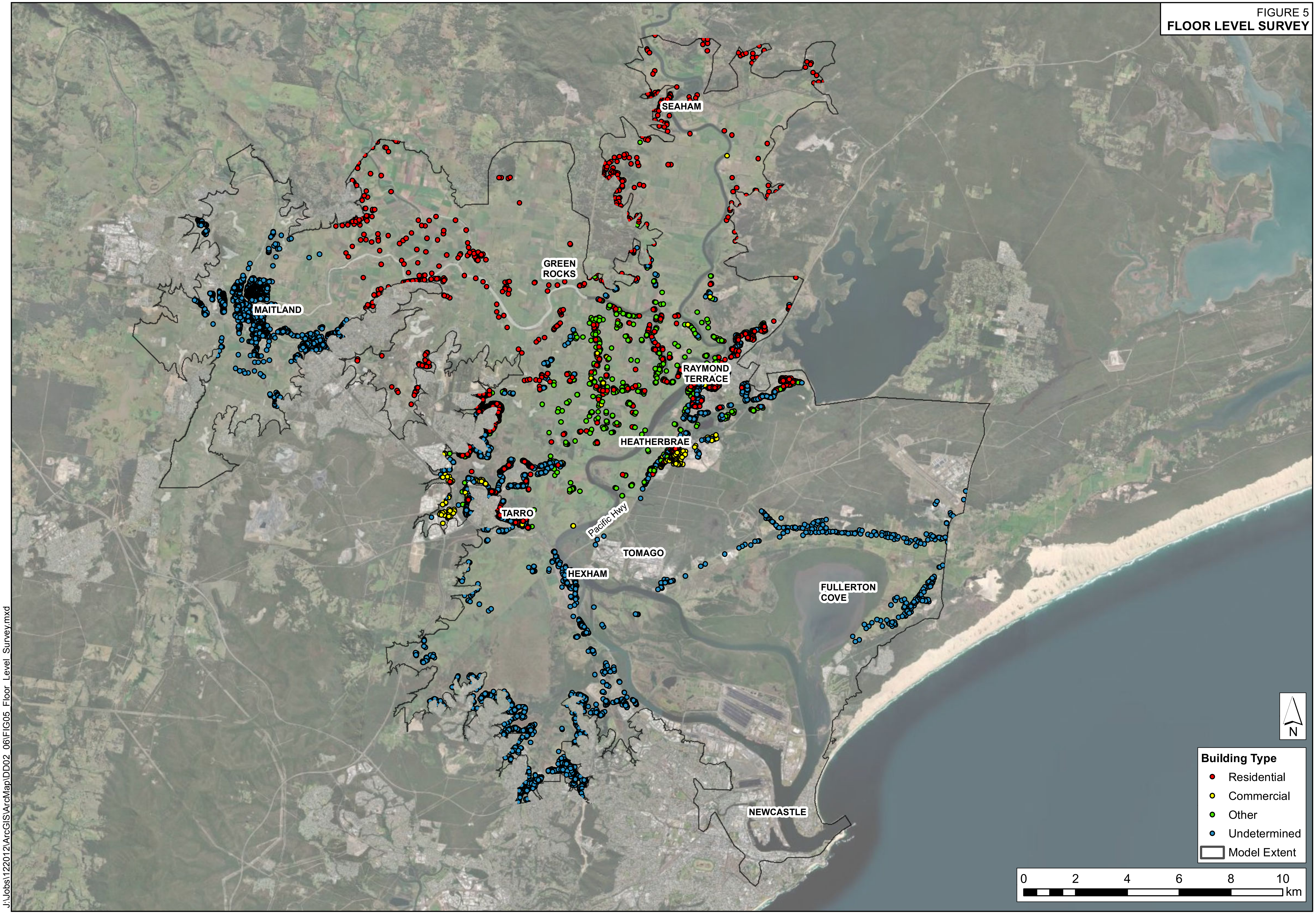
FIGURE 5
FLOOR LEVEL SURVEY
SEAHAM
GREEN ROCKS
MAITLAND
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
NEWCASTLE
N
Building Type
Residential
Commercial
Other
Undetermined
Model Extent
0
2
4
6
8
10
km
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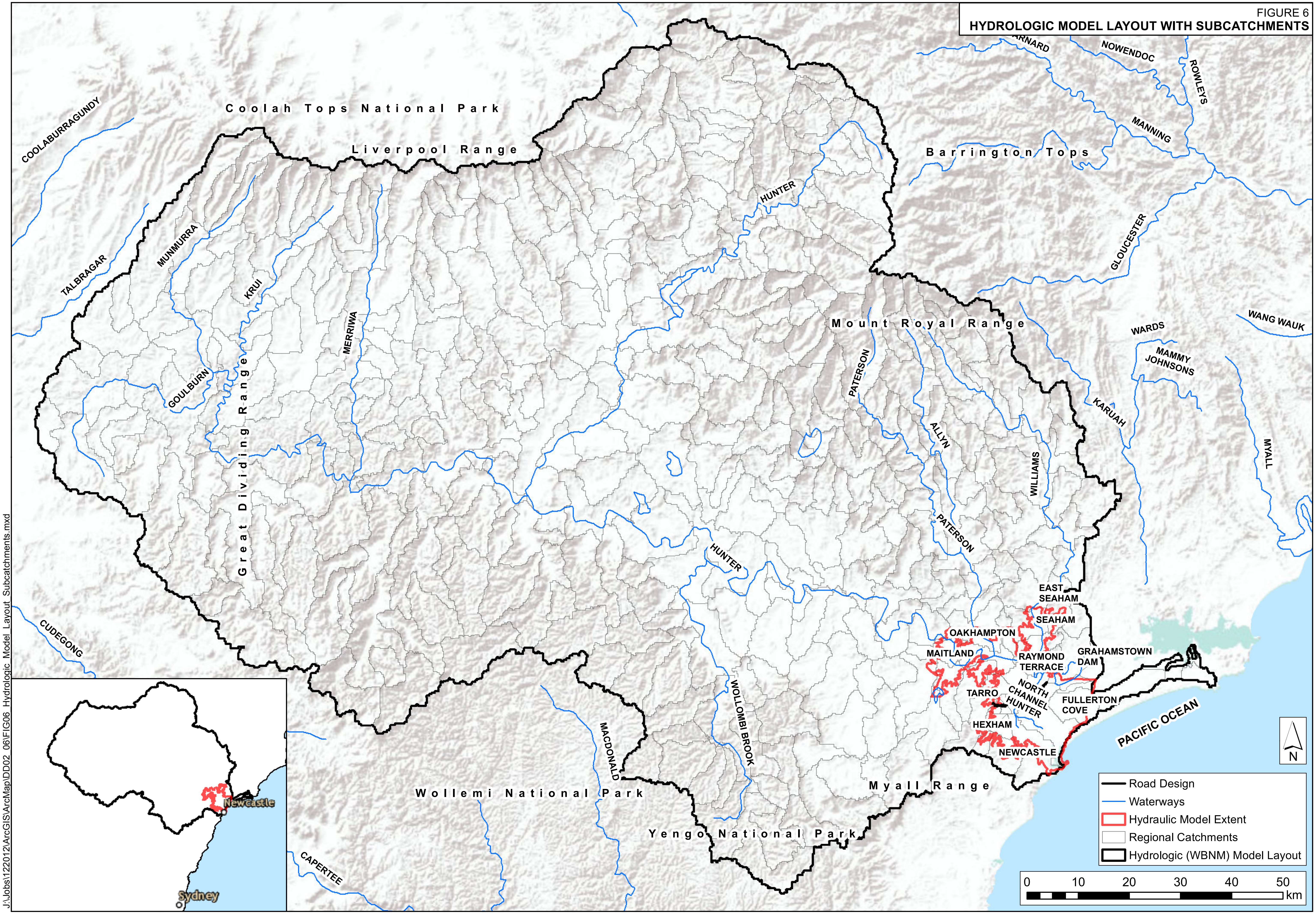
FIGURE 6

HYDROLOGIC MODEL LAYOUT WITH SUBCATCHMENTS



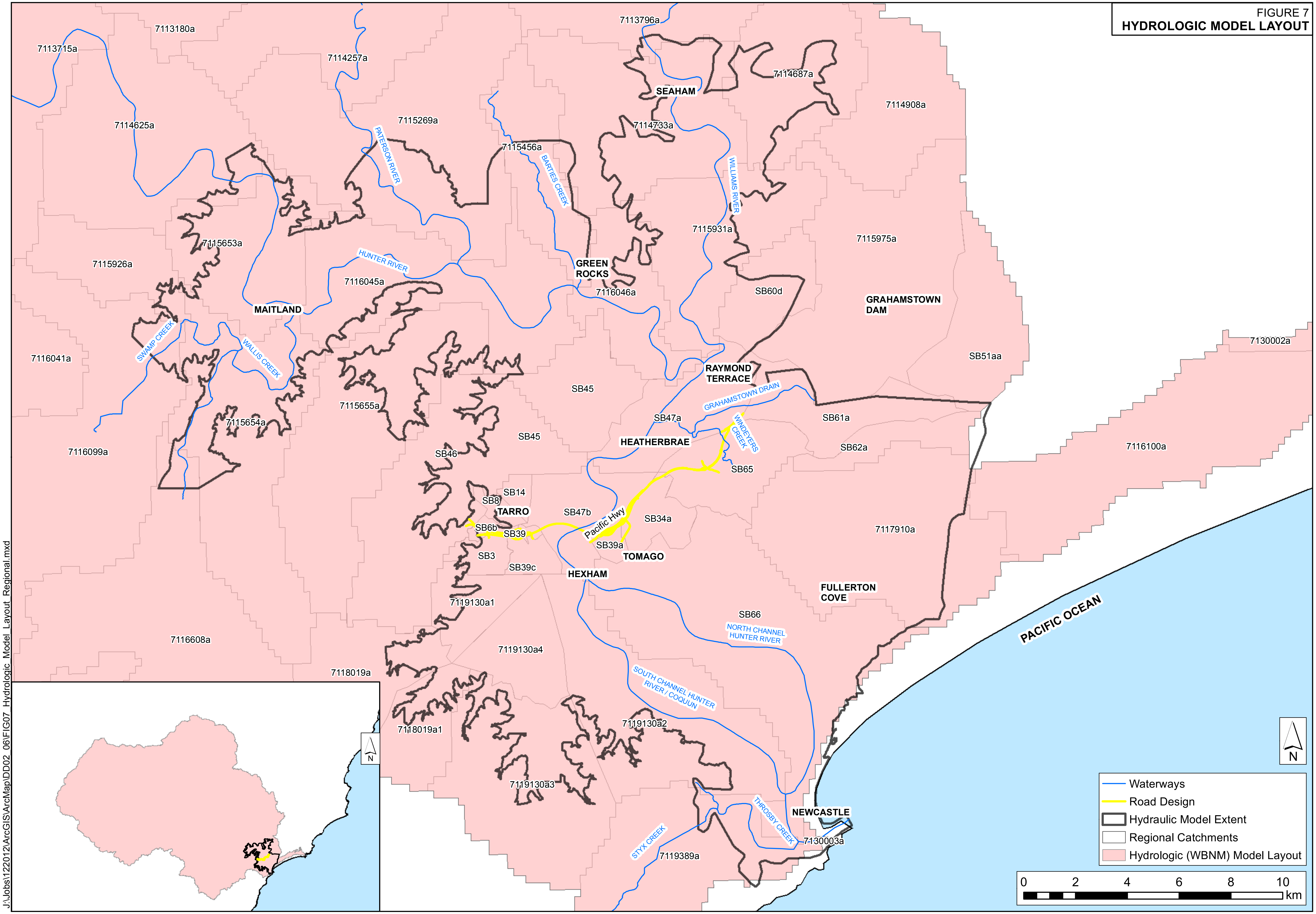


FIGURE 7
HYDROLOGIC MODEL LAYOUT

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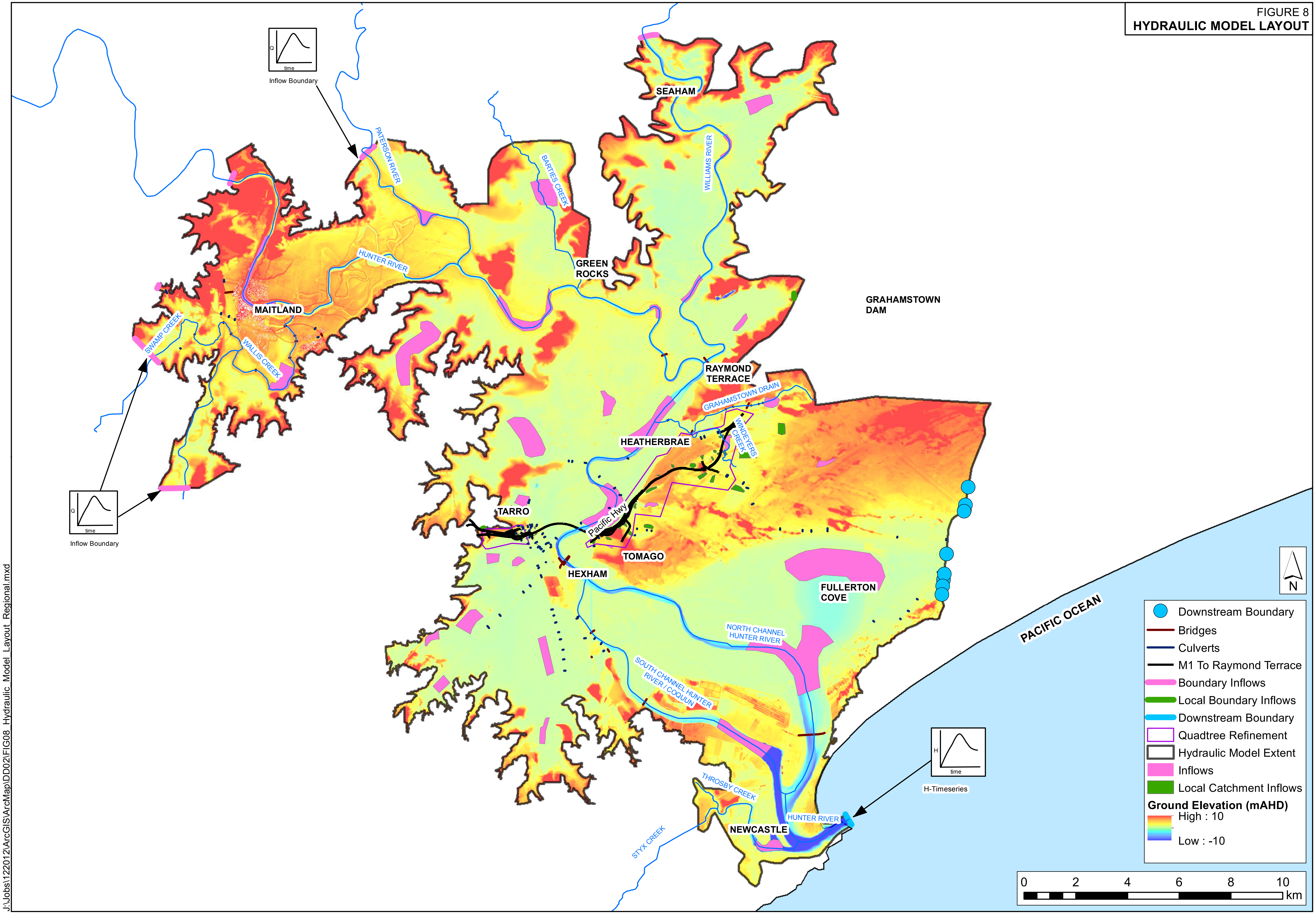
FIGURE 8
HYDRAULIC MODEL LAYOUT



J:\Jobs\122012\ArcGIS\ArcMap\DD02\FIG08_Hydraulic_Model_Layout_Regional.mxd

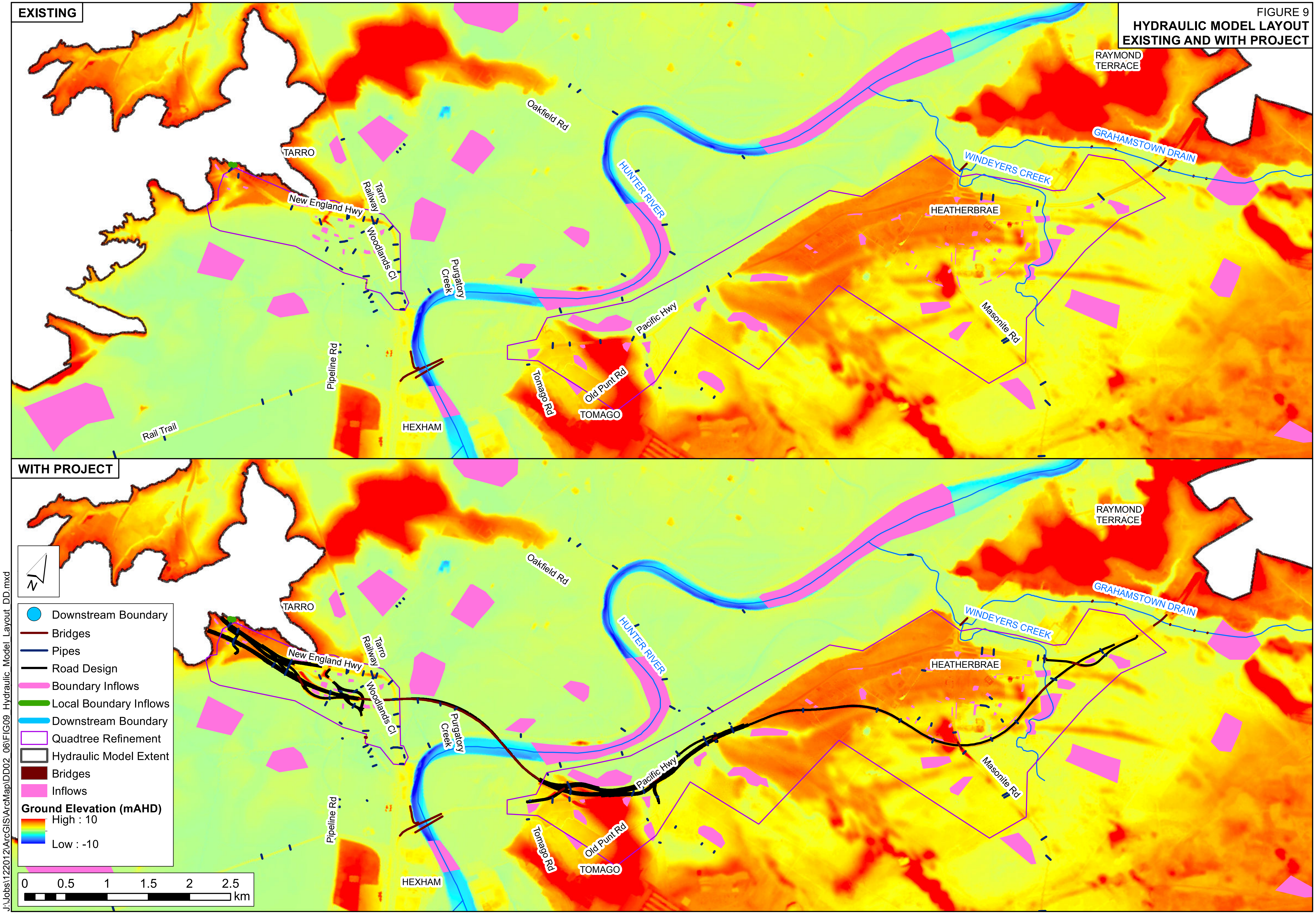
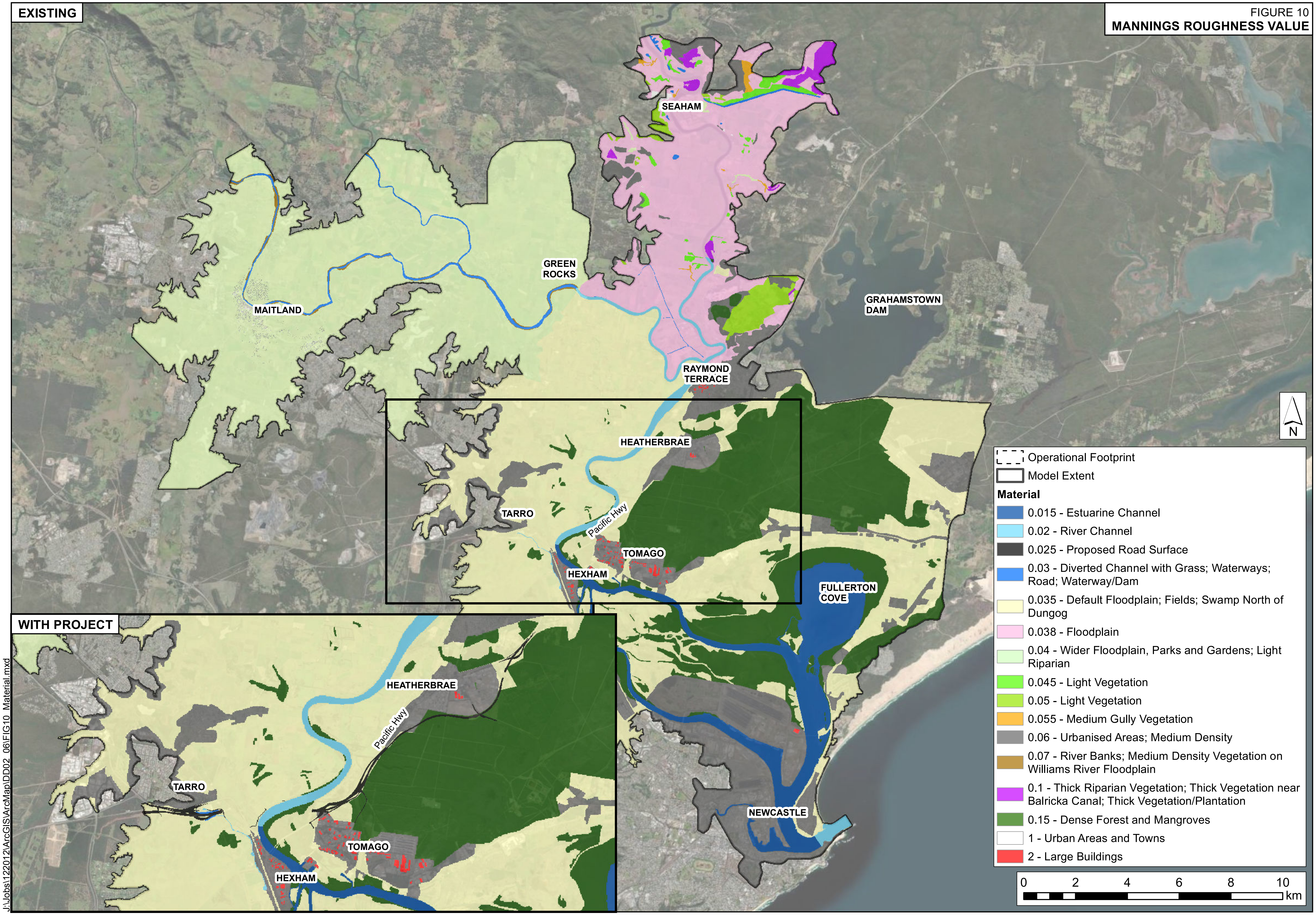


FIGURE 9
HYDRAULIC MODEL LAYOUT EXISTING AND WITH PROJECT

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG09_Hydraulic_Model_Layout_DD.mxd


EXISTING
FIGURE 10
MANNINGS ROUGHNESS VALUE
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
NEWCASTLE
WITH PROJECT
HEATHERBRAE
Pacific Hwy
TARRO
TOMAGO
HEXHAM
N
Operational Footprint
Model Extent
Material
0.015 - Estuarine Channel
0.02 - River Channel
0.025 - Proposed Road Surface
0.03 - Diverted Channel with Grass; Waterways; Road; Waterway/Dam
0.035 - Default Floodplain; Fields; Swamp North of Dungog
0.038 - Floodplain
0.04 - Wider Floodplain, Parks and Gardens; Light Riparian
0.045 - Light Vegetation
0.05 - Light Vegetation
0.055 - Medium Gully Vegetation
0.06 - Urbanised Areas; Medium Density
0.07 - River Banks; Medium Density Vegetation on Williams River Floodplain
0.1 - Thick Riparian Vegetation; Thick Vegetation near Balricka Canal; Thick Vegetation/Plantation
0.15 - Dense Forest and Mangroves
1 - Urban Areas and Towns
2 - Large Buildings
0 2 4 6 8 10 km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG10_Material.mxd

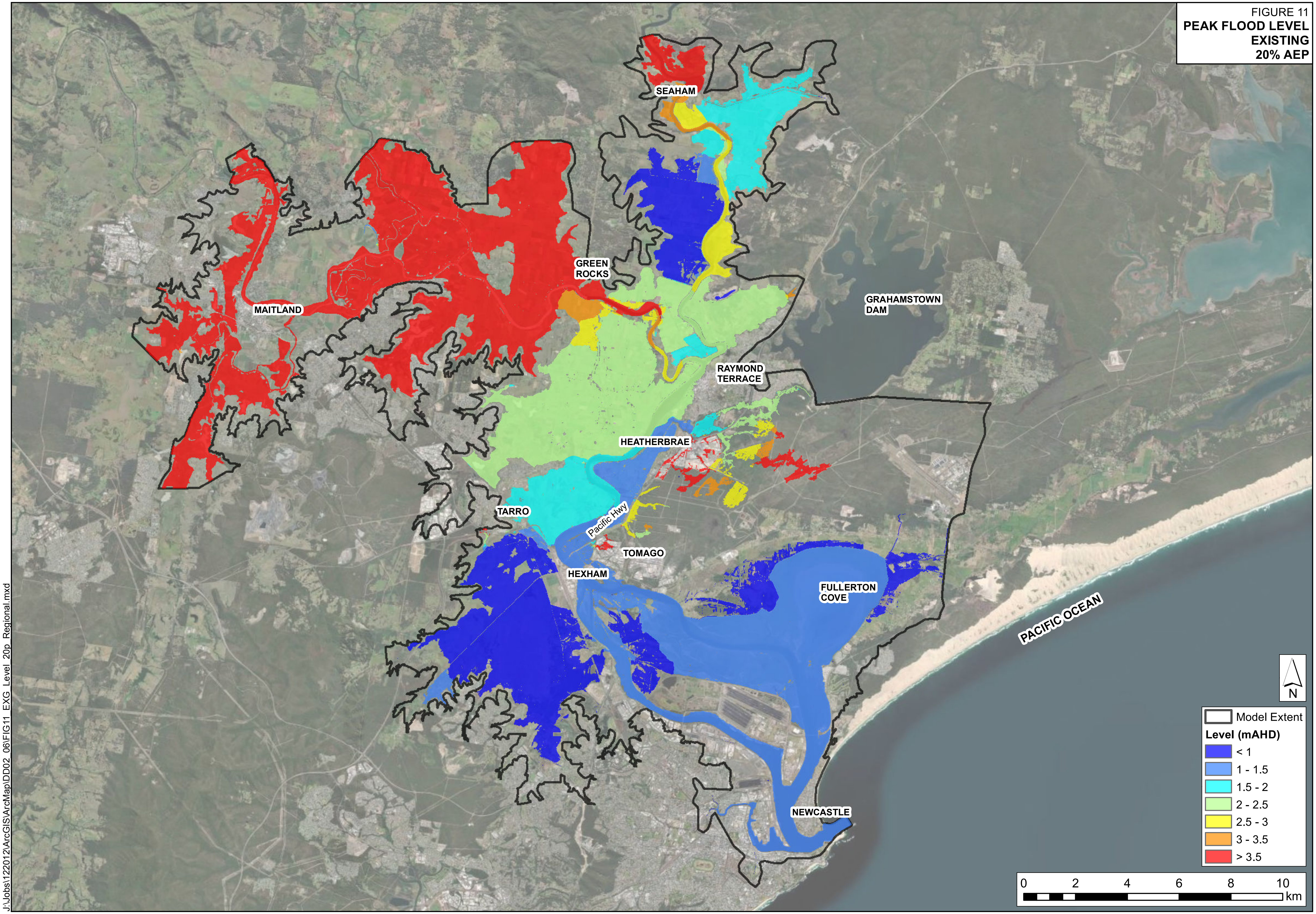


FIGURE 11
PEAK FLOOD LEVEL
EXISTING
20% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Model Extent
Level (mAHD)
< 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
> 3.5
0 2 4 6 8 10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG11_EXG_Level_20p_Regional.mxd

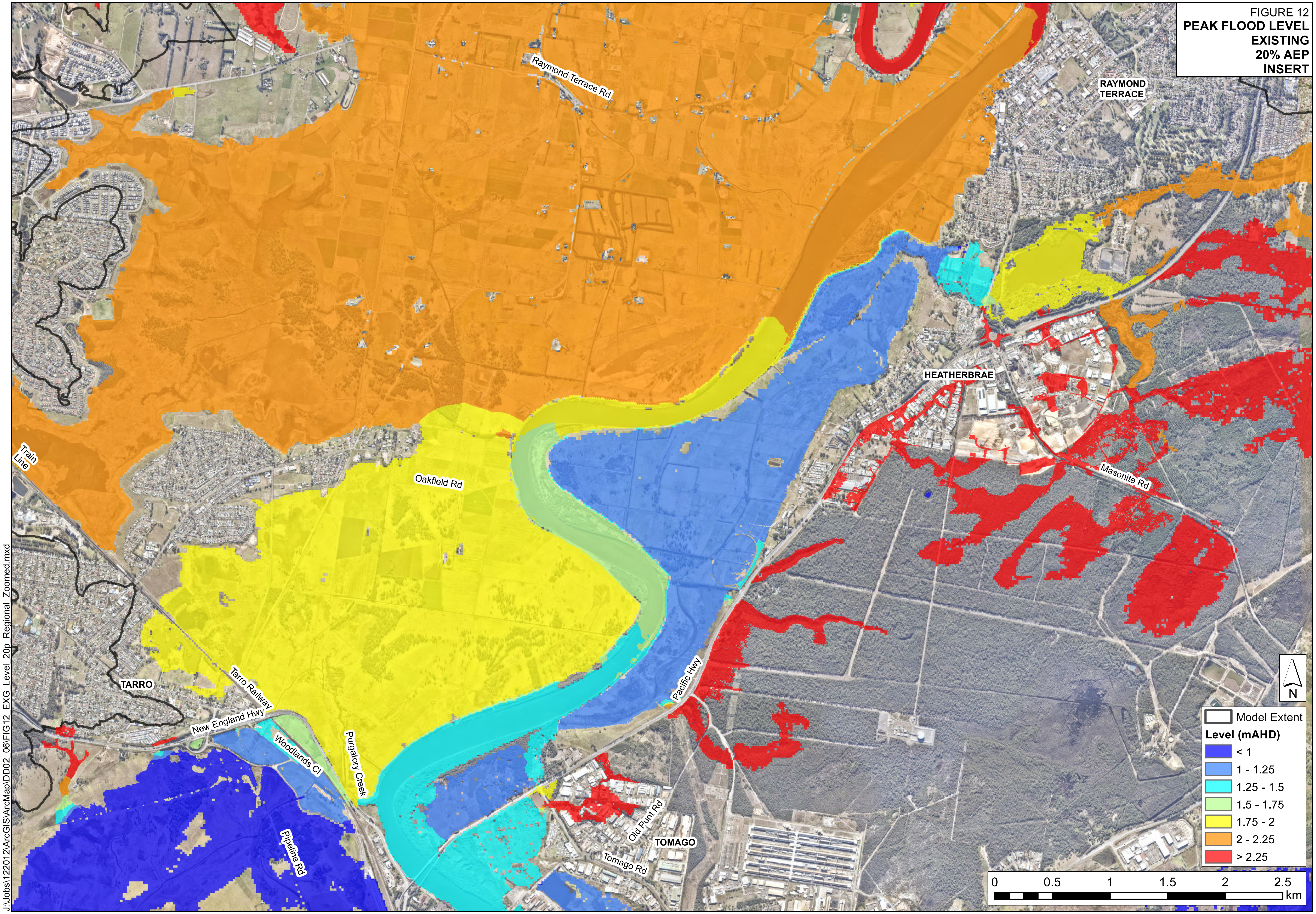
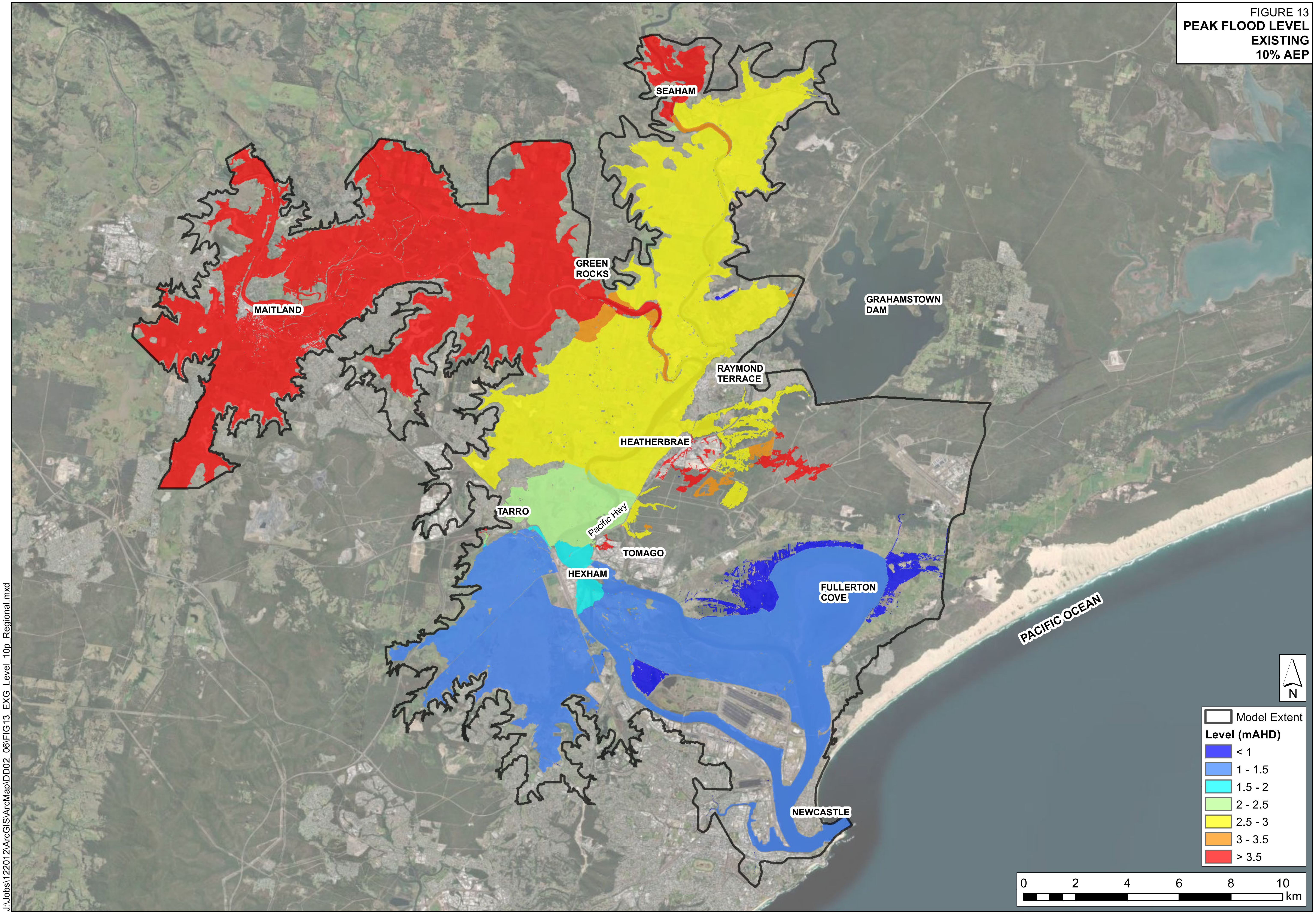
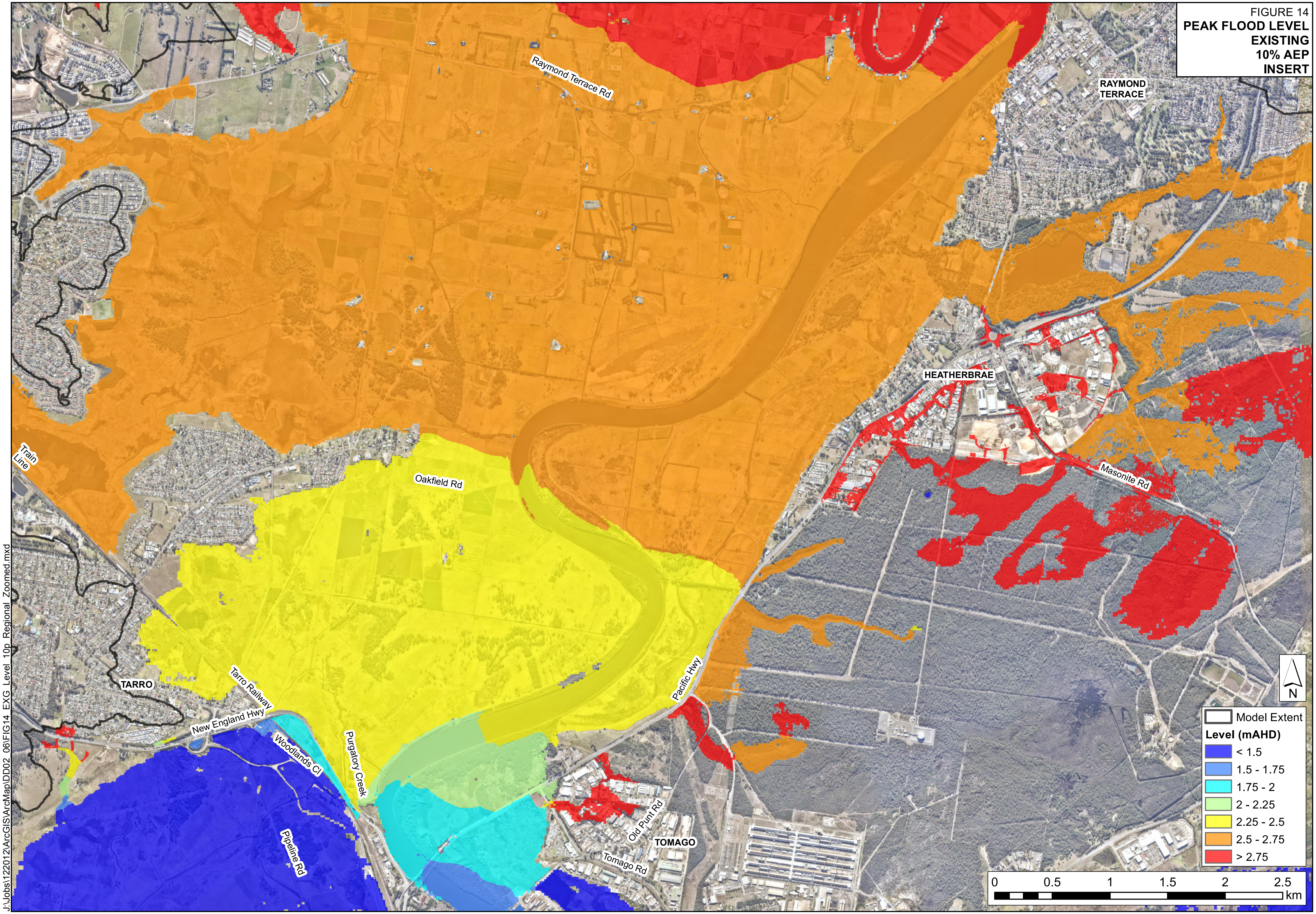


FIGURE 12
PEAK FLOOD LEVEL
EXISTING
20% AEP
INSERT
Raymond Terrace Rd
RAYMOND TERRACE
HEATHERBRAE
Masonite Rd
Train Line
Oakfield Rd
Pacific Hwy
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Old Punt Rd
TOMAGO
Tomago Rd
N
Model Extent
Level (mAHD)
< 1
1 - 1.25
1.25 - 1.5
1.5 - 1.75
1.75 - 2
2 - 2.25
> 2.25
0 0.5 1 1.5 2 2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG12_EXG_Level_20p_Regional_Zoomed.mxd

FIGURE 13
PEAK FLOOD LEVEL
EXISTING
10% AEP

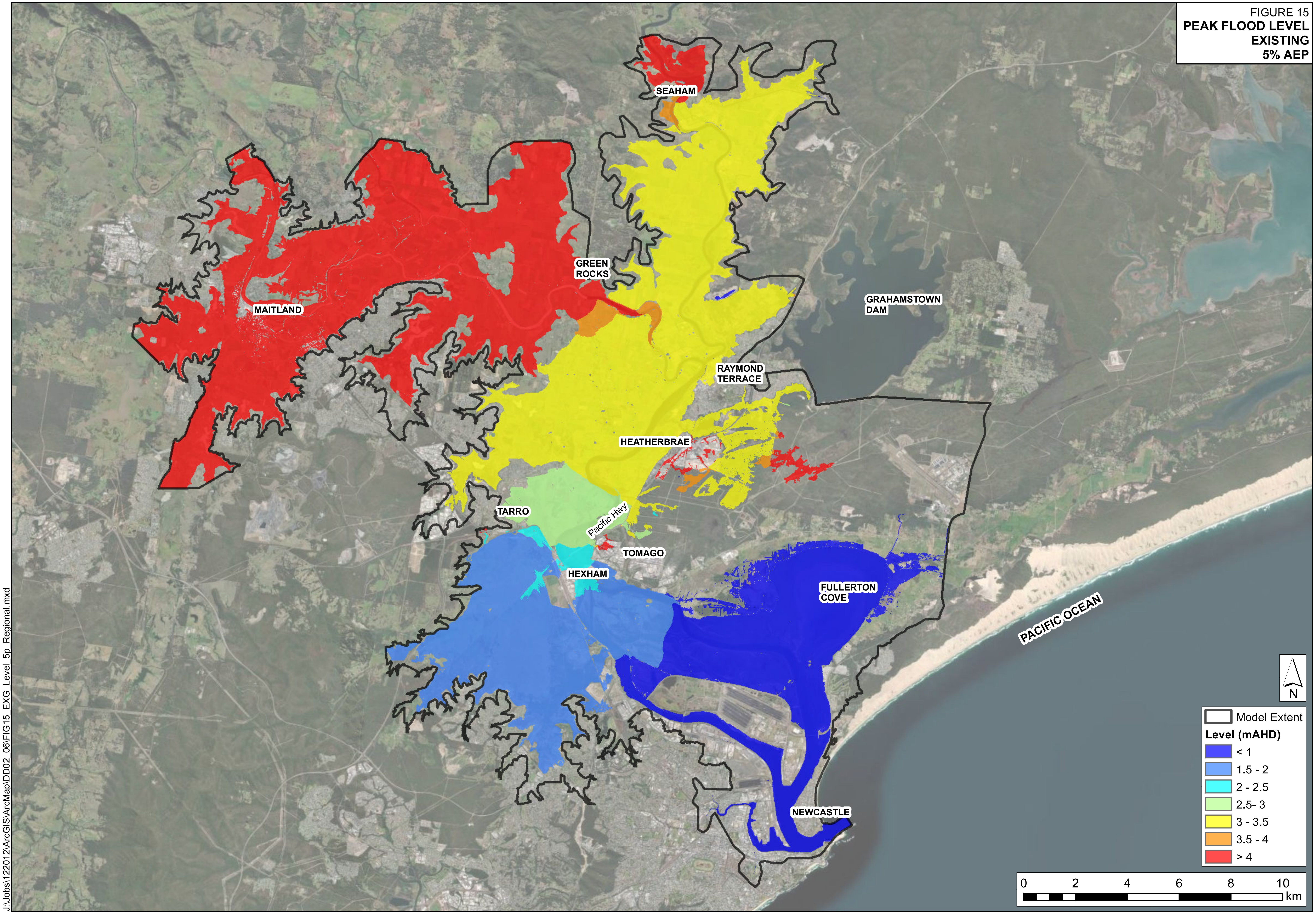


J:\Jobs\122012\ArcGIS\ArcMap\DD02 06\FIG13 EXG Level 10p Regional.mxd



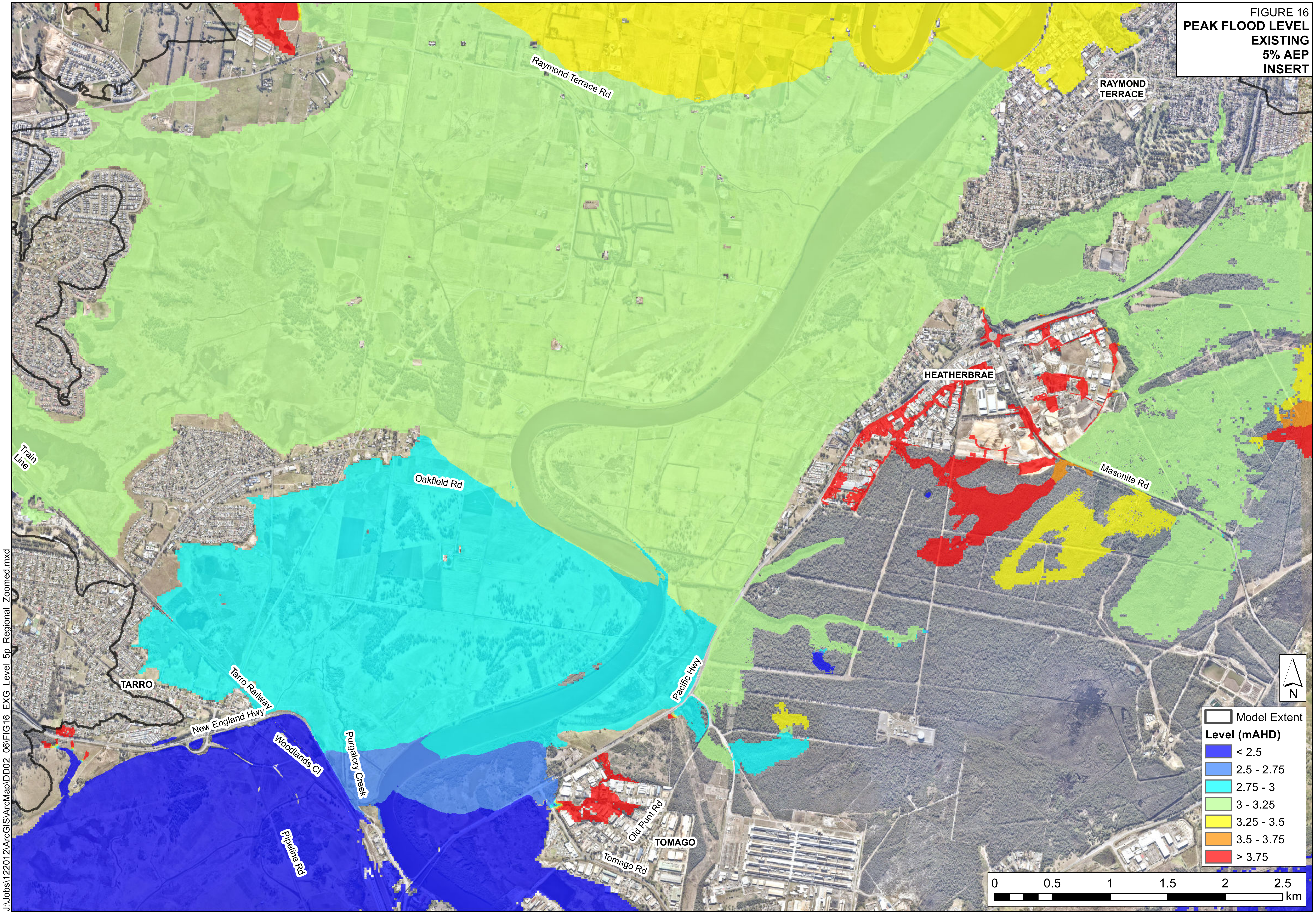
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG14_EXG_Level_10p_Regional_Zoomed.mxd

FIGURE 15
PEAK FLOOD LEVEL EXISTING 5% AEP



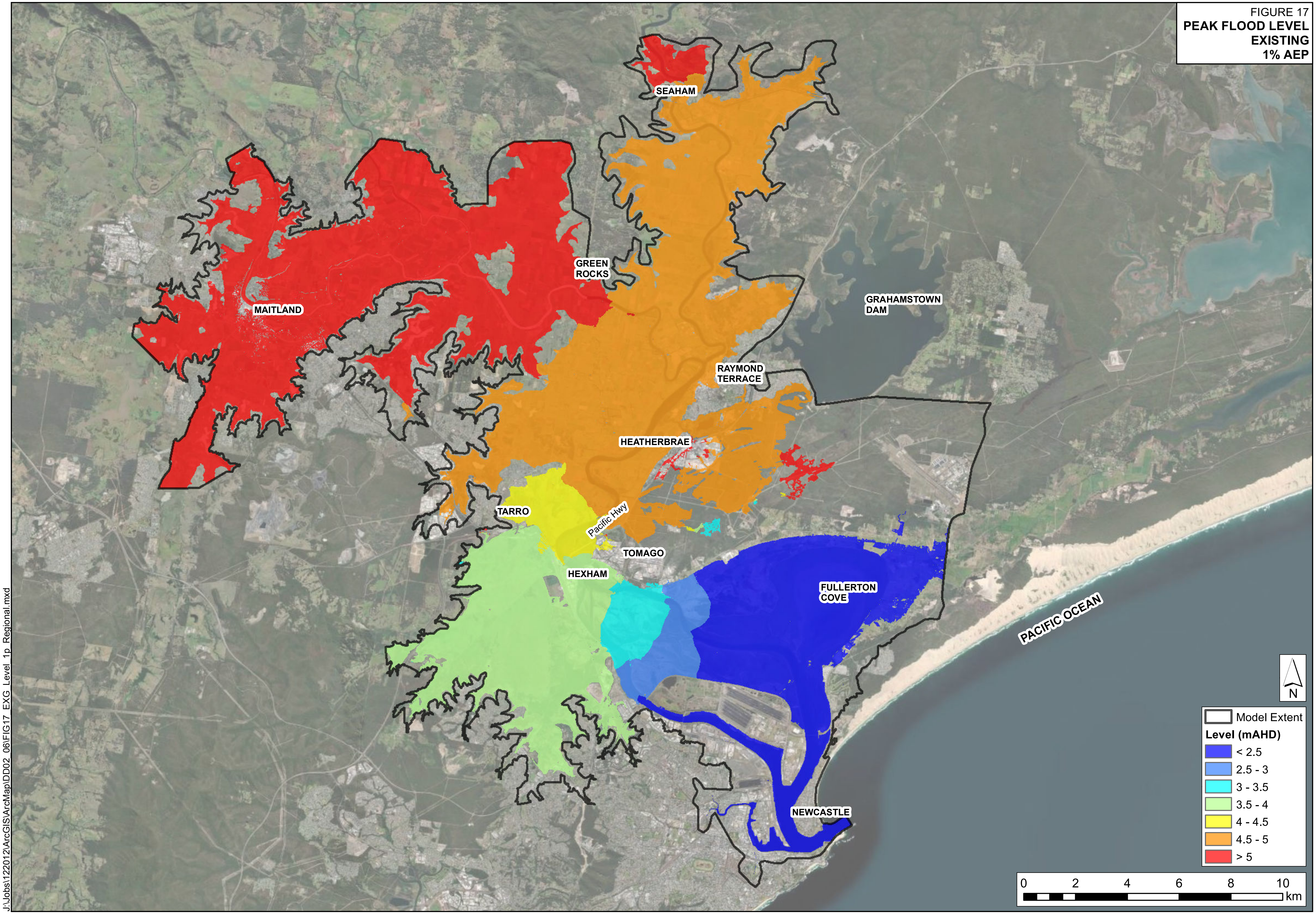
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG15_EXG_Level_5p_Regional.mxd

FIGURE 16
PEAK FLOOD LEVEL EXISTING 5% AEP INSERT



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG16_EXG_Level_5p_Regional_Zoomed.mxd

FIGURE 17
PEAK FLOOD LEVEL EXISTING 1% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG17_EXG_Level_1p_Regional.mxd

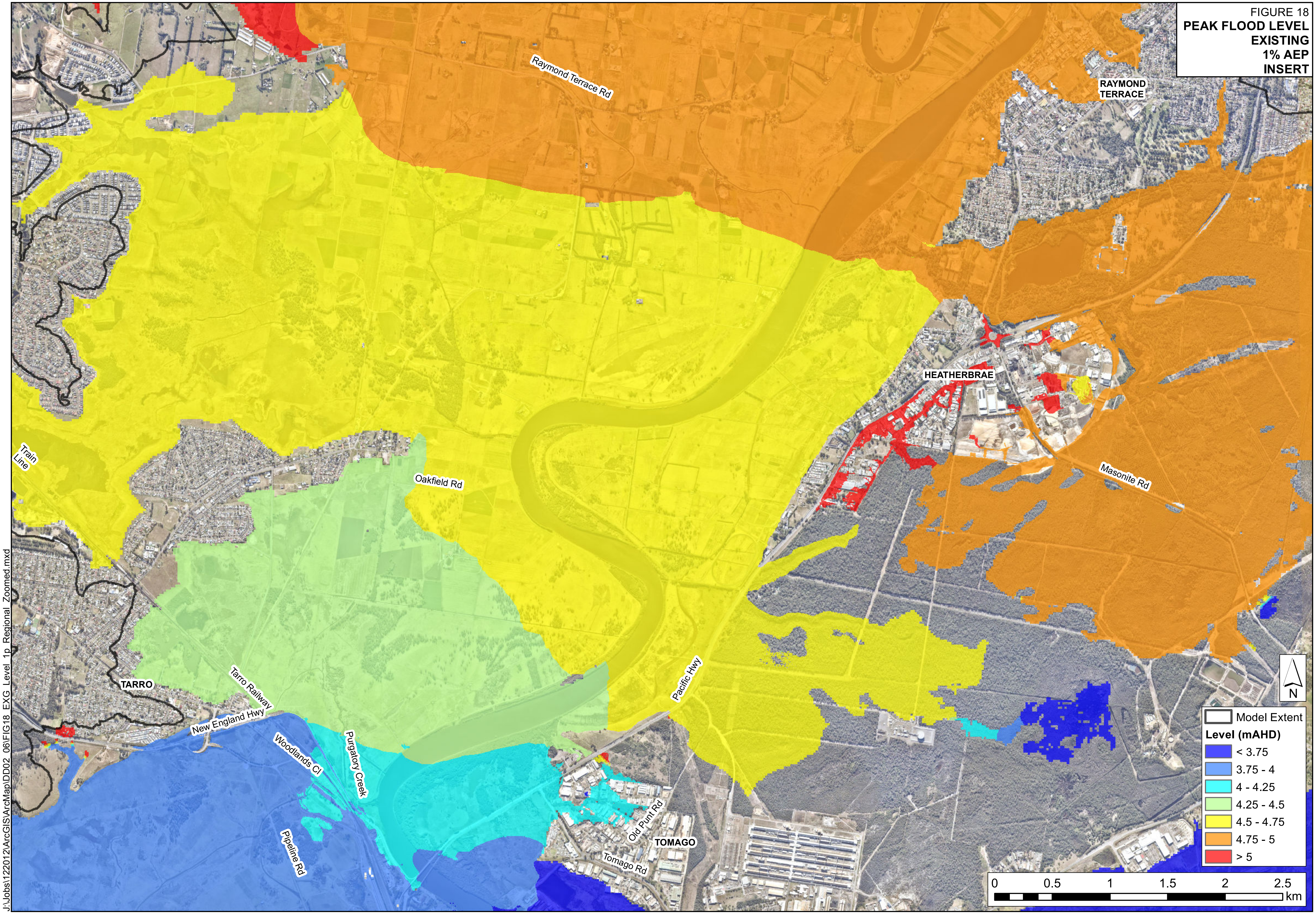


FIGURE 18
PEAK FLOOD LEVEL EXISTING 1% AEP INSERT

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG18_EXG_Level_1p_Regional_Zoomed.mxd

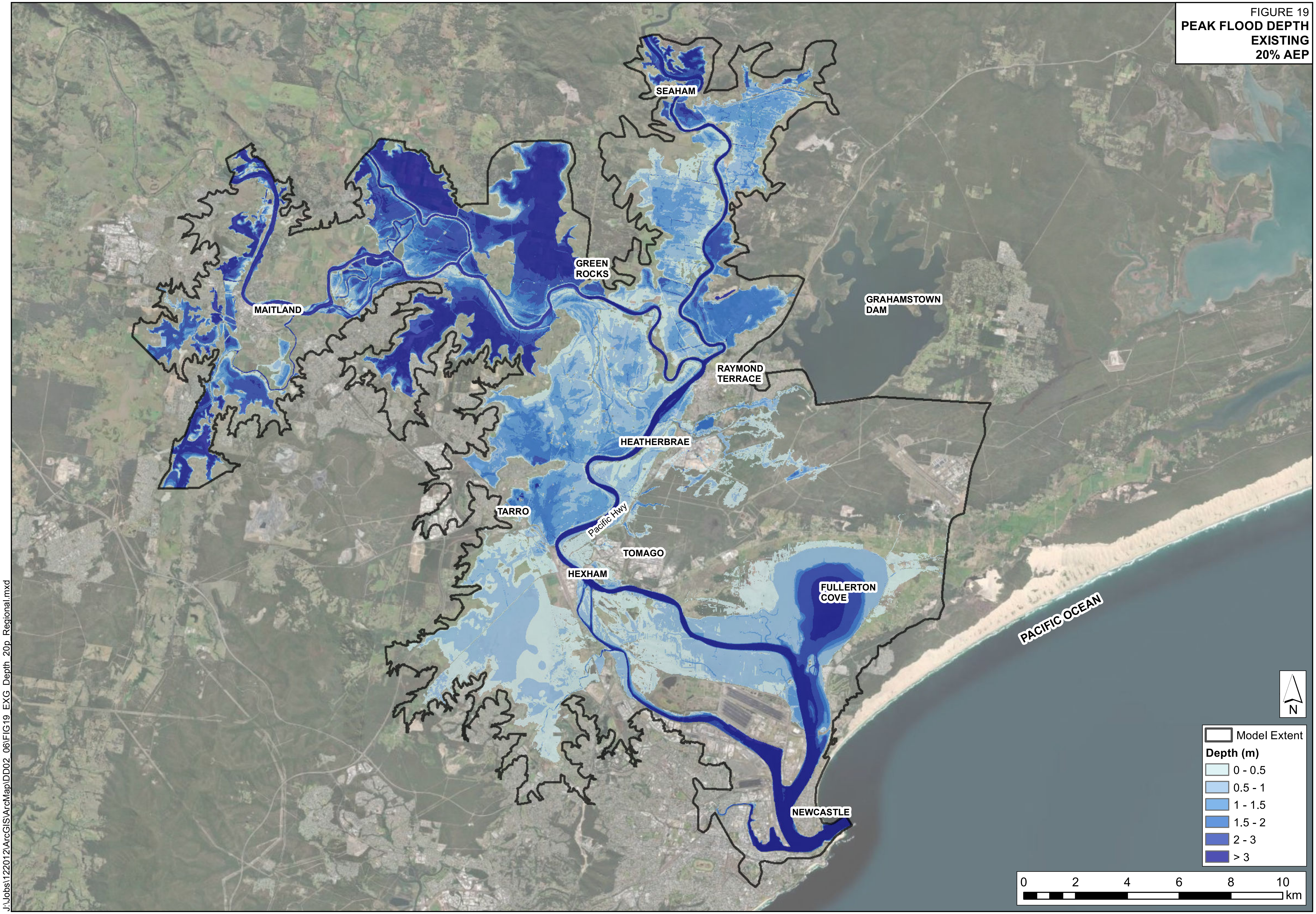
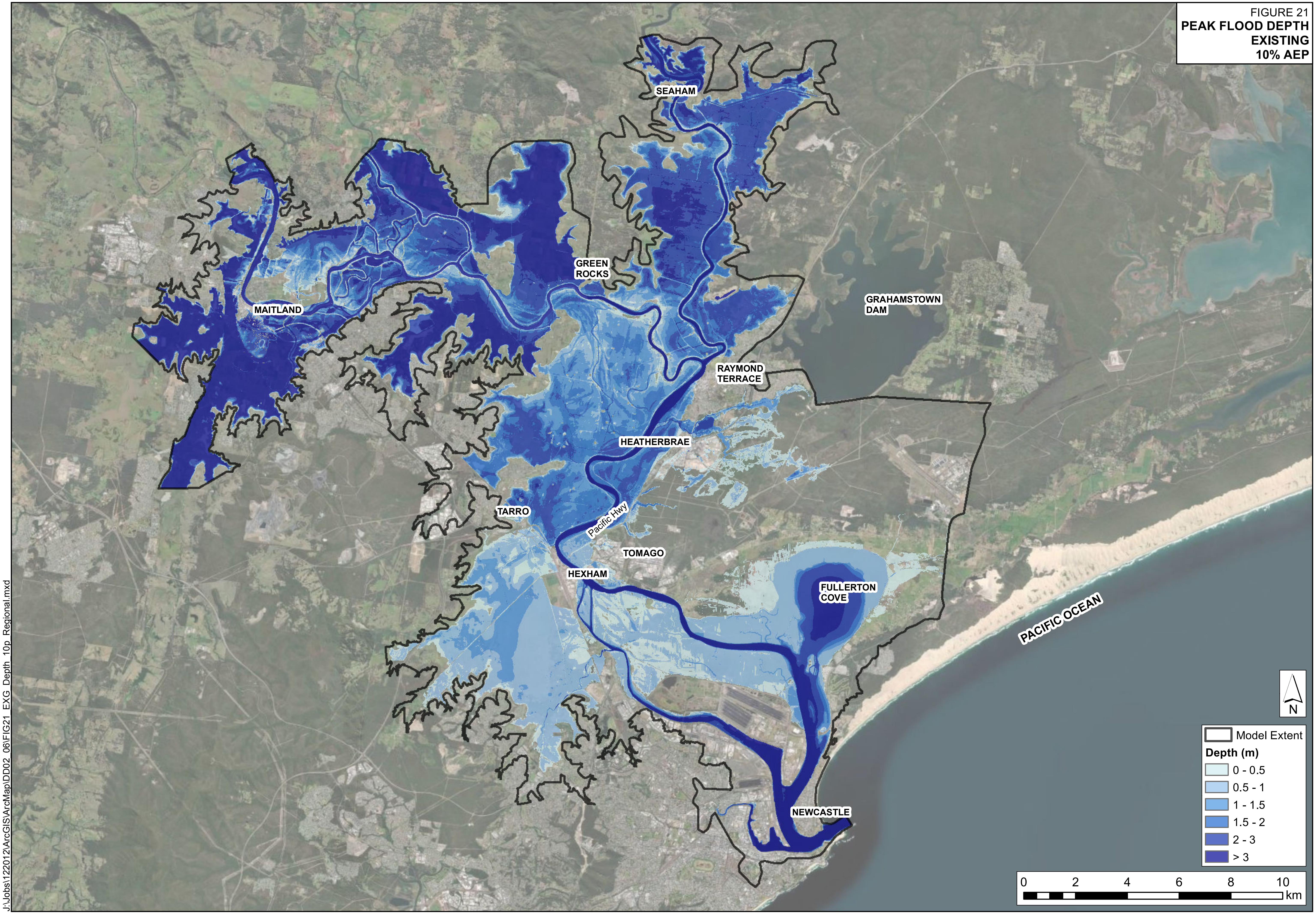


FIGURE 19
PEAK FLOOD DEPTH
EXISTING
20% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Model Extent
Depth (m)
0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 3
> 3
0
2
4
6
8
10
km
J:Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG19_EXG_Depth_20p_Regional.mxd

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG20_EXG_Depth_20p_Regional_Zoomed.mxd

FIGURE 21
PEAK FLOOD DEPTH EXISTING 10% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG21_EXG_Depth_10p_Regional.mxd

FIGURE 22
PEAK FLOOD DEPTH
EXISTING
10% AEP
INSERT
Raymond Terrace Rd
RAYMOND TERRACE
HEATHERBRAE
Masonite Rd
Train Line
Oakfield Rd
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Pacific Hwy
Old Punt Rd
TOMAGO
Tomago Rd
N
Model Extent
Depth (m)
0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 3
> 3
0 0.5 1 1.5 2 2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG22_EXG_Depth_10p_Regional_Zoomed.mxd

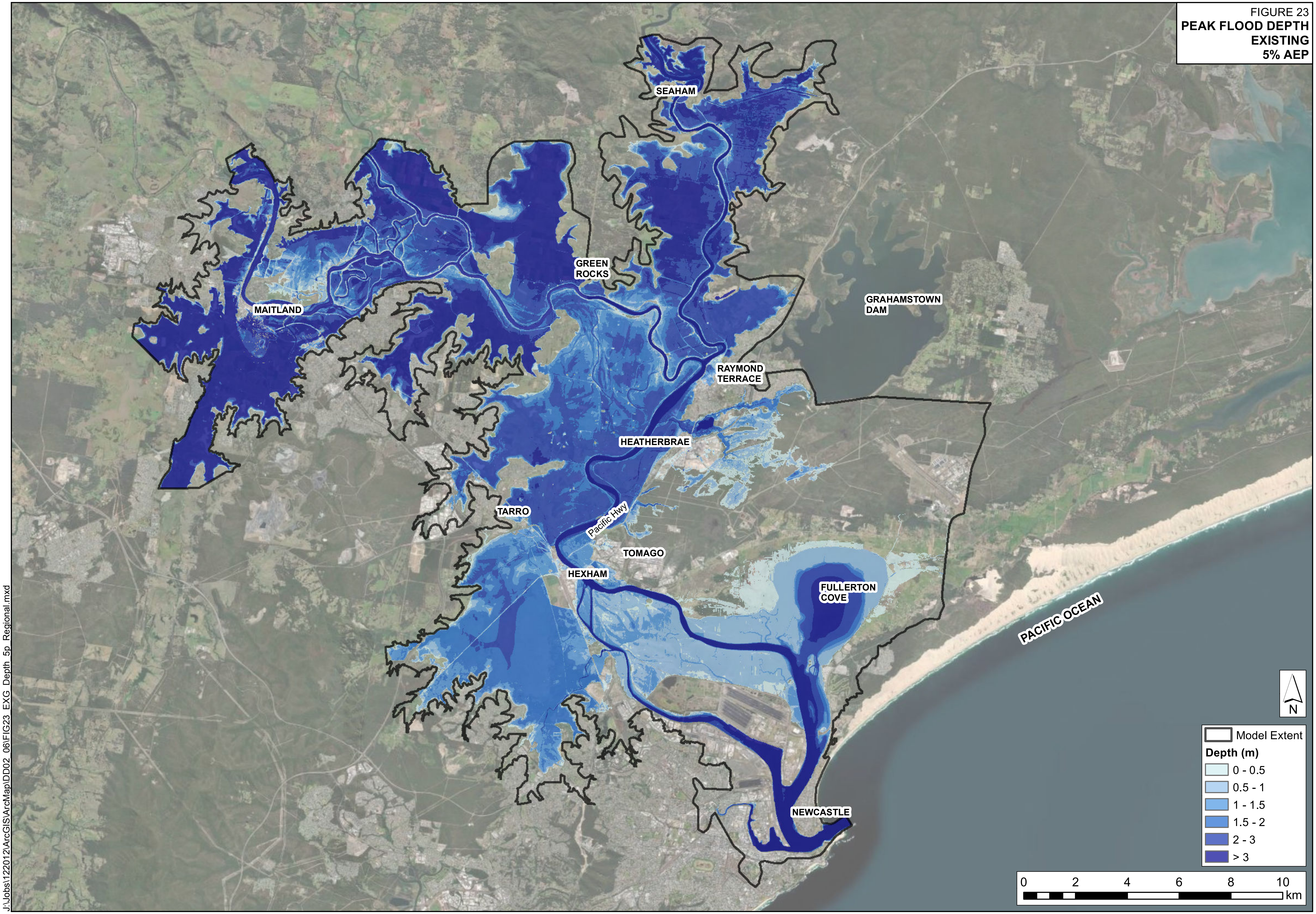


FIGURE 23
PEAK FLOOD DEPTH
EXISTING
5% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Model Extent
Depth (m)
0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 3
> 3
0 2 4 6 8 10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG23_EXG_Depth_5p_Regional.mxd

FIGURE 24
PEAK FLOOD DEPTH
EXISTING
5% AEP
INSERT

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG24_EXG_Depth_5p_Regional_Zoomed.mxd

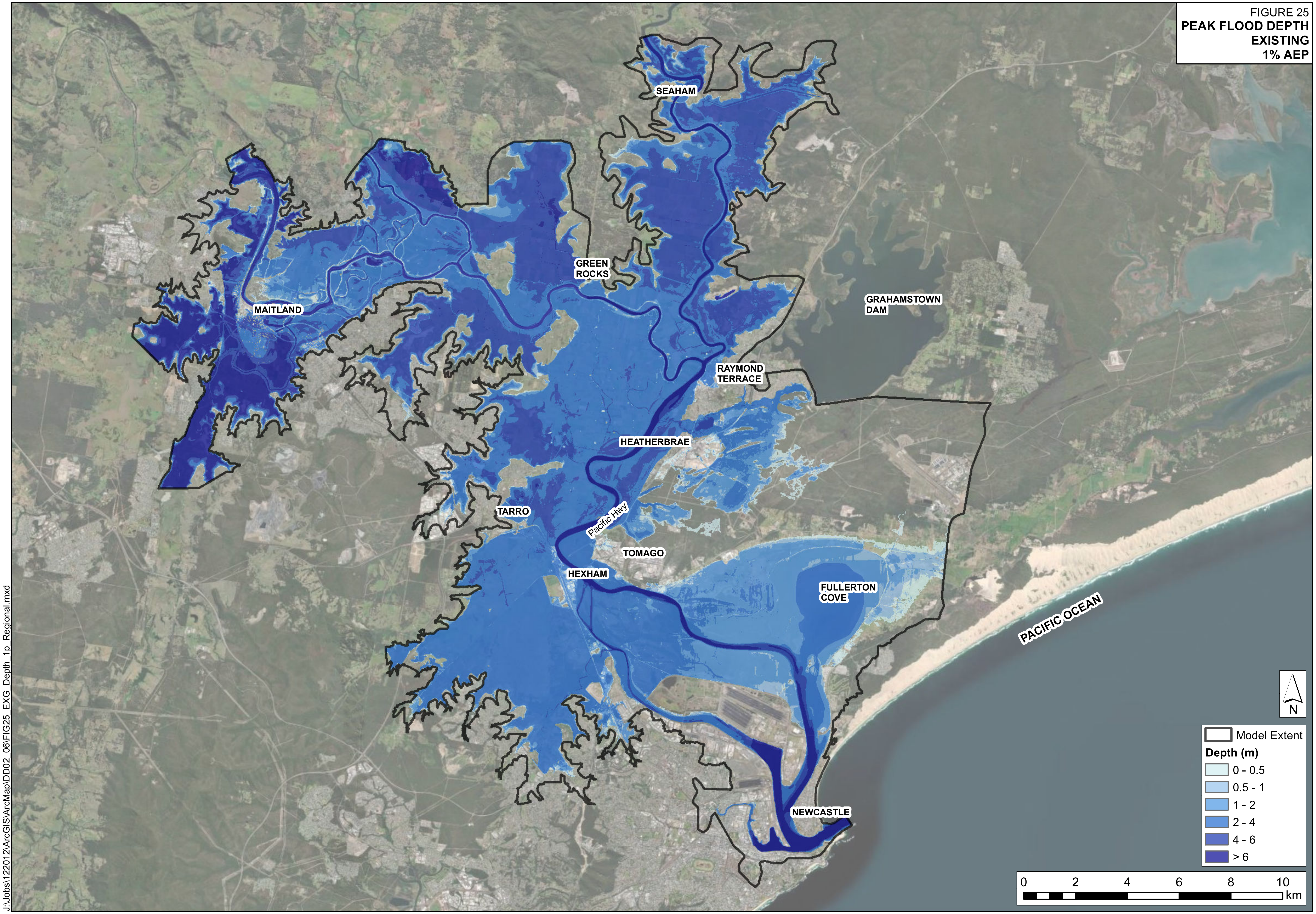


FIGURE 25
PEAK FLOOD DEPTH
EXISTING
1% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Model Extent
Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 6
> 6
0 2 4 6 8 10 km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG25_EXG_Depth_1p_Regional.mxd


FIGURE 26
PEAK FLOOD DEPTH
EXISTING
1% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Oakfield Rd
Train Line
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pacific Hwy
Pipeline Rd
Old Punt Rd
TOMAGO
Tomago Rd
N
Model Extent
Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 6
> 6
0
0.5
1
1.5
2
2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG26_EXG_Depth_1p_Regional_Zoomed.mxd

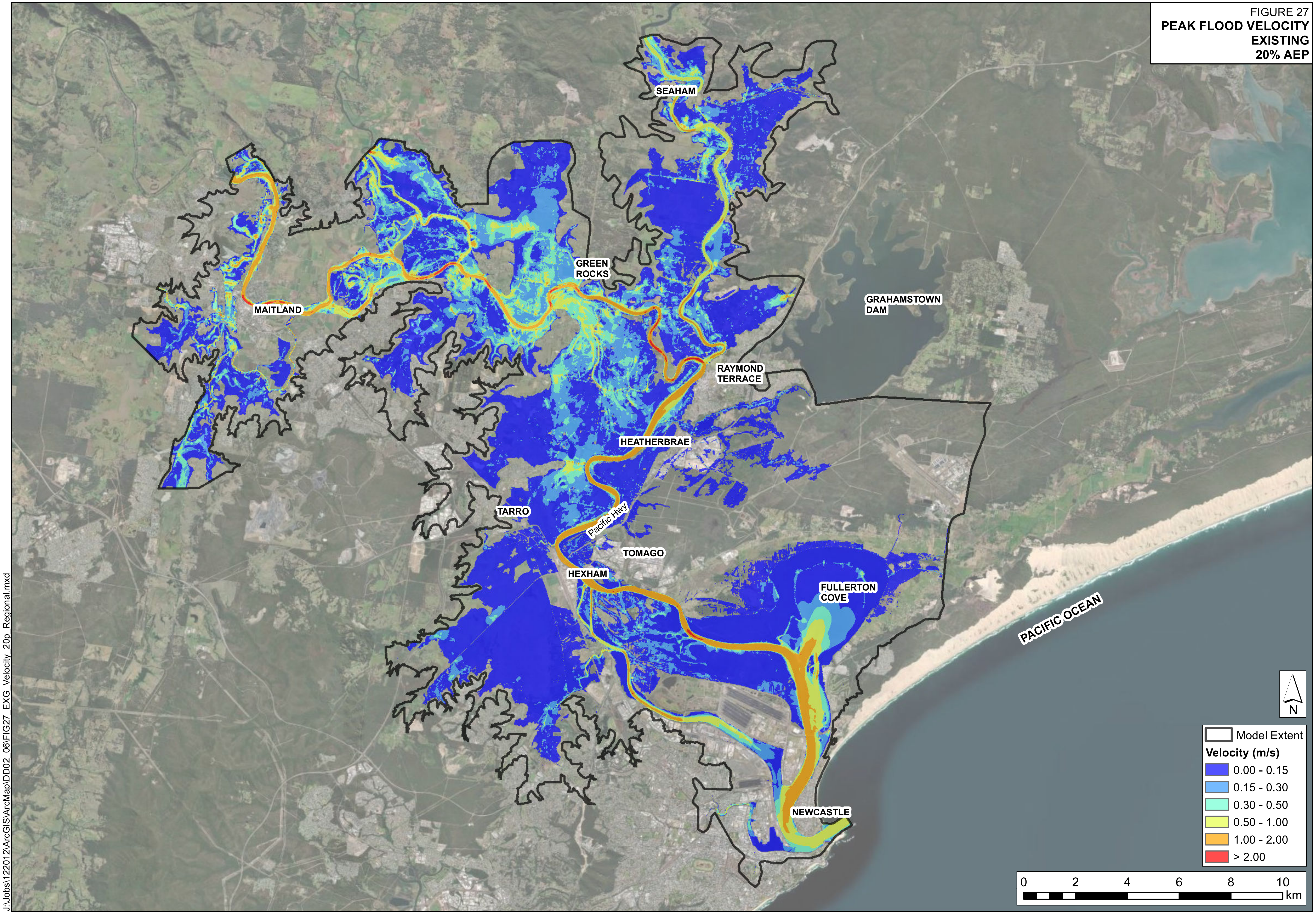


FIGURE 27
PEAK FLOOD VELOCITY
EXISTING
20% AEP
SEAHAM
GREEN
ROCKS
MAITLAND
GRAHAMSTOWN
DAM
RAYMOND
TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON
COVE
PACIFIC OCEAN
NEWCASTLE
N
Model Extent
Velocity (m/s)
0.00 - 0.15
0.15 - 0.30
0.30 - 0.50
0.50 - 1.00
1.00 - 2.00
> 2.00
0
2
4
6
8
10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG27_EXG_Velocity_20p_Regional.mxd

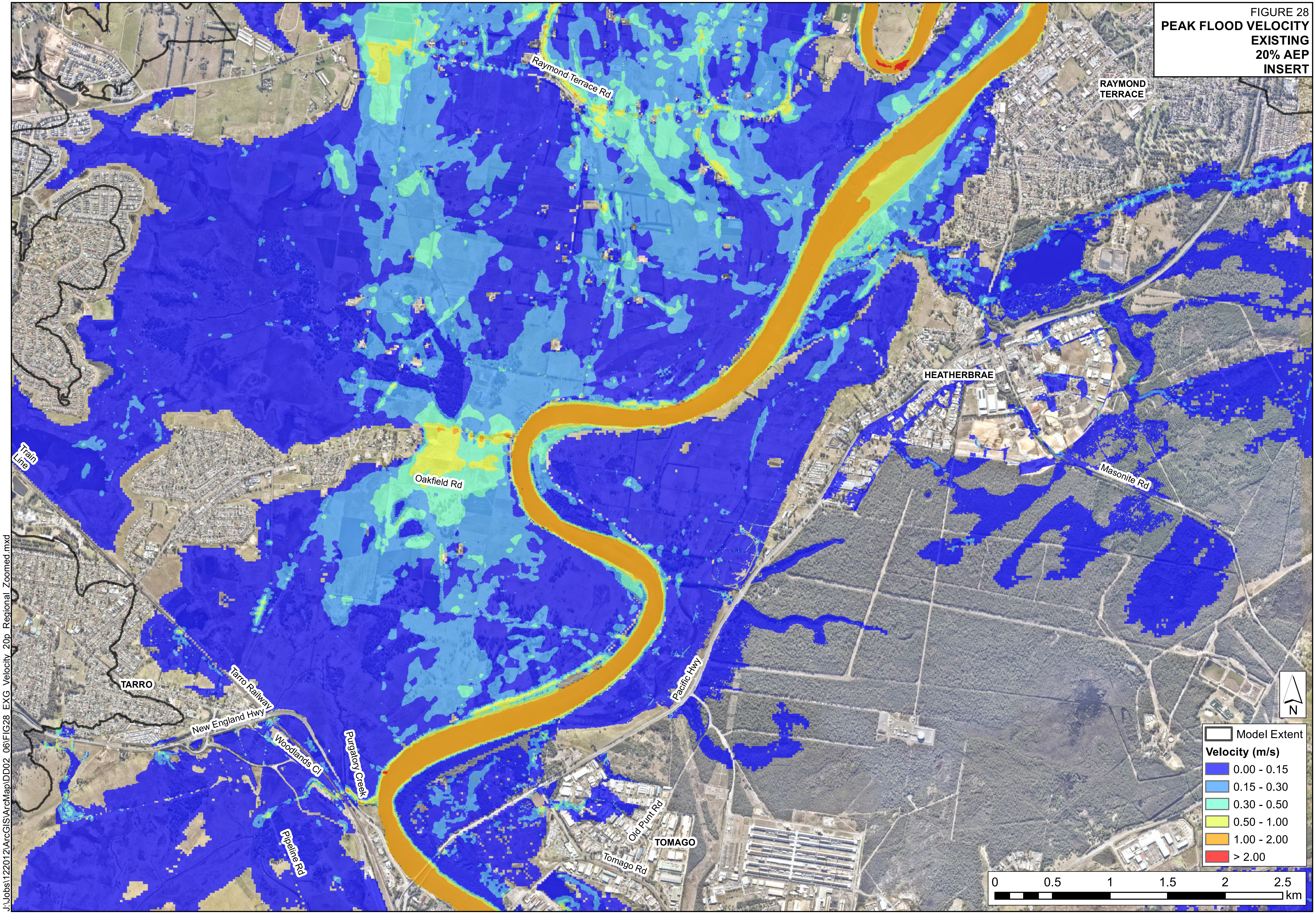


FIGURE 28
PEAK FLOOD VELOCITY
EXISTING
20% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Train Line
Oakfield Rd
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Pacific Hwy
Old Punt Rd
TOMAGO
Tomago Rd
N
Model Extent
Velocity (m/s)
0.00 - 0.15
0.15 - 0.30
0.30 - 0.50
0.50 - 1.00
1.00 - 2.00
> 2.00
0 0.5 1 1.5 2 2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG28_EXG_Velocity_20p_Regional_Zoomed.mxd

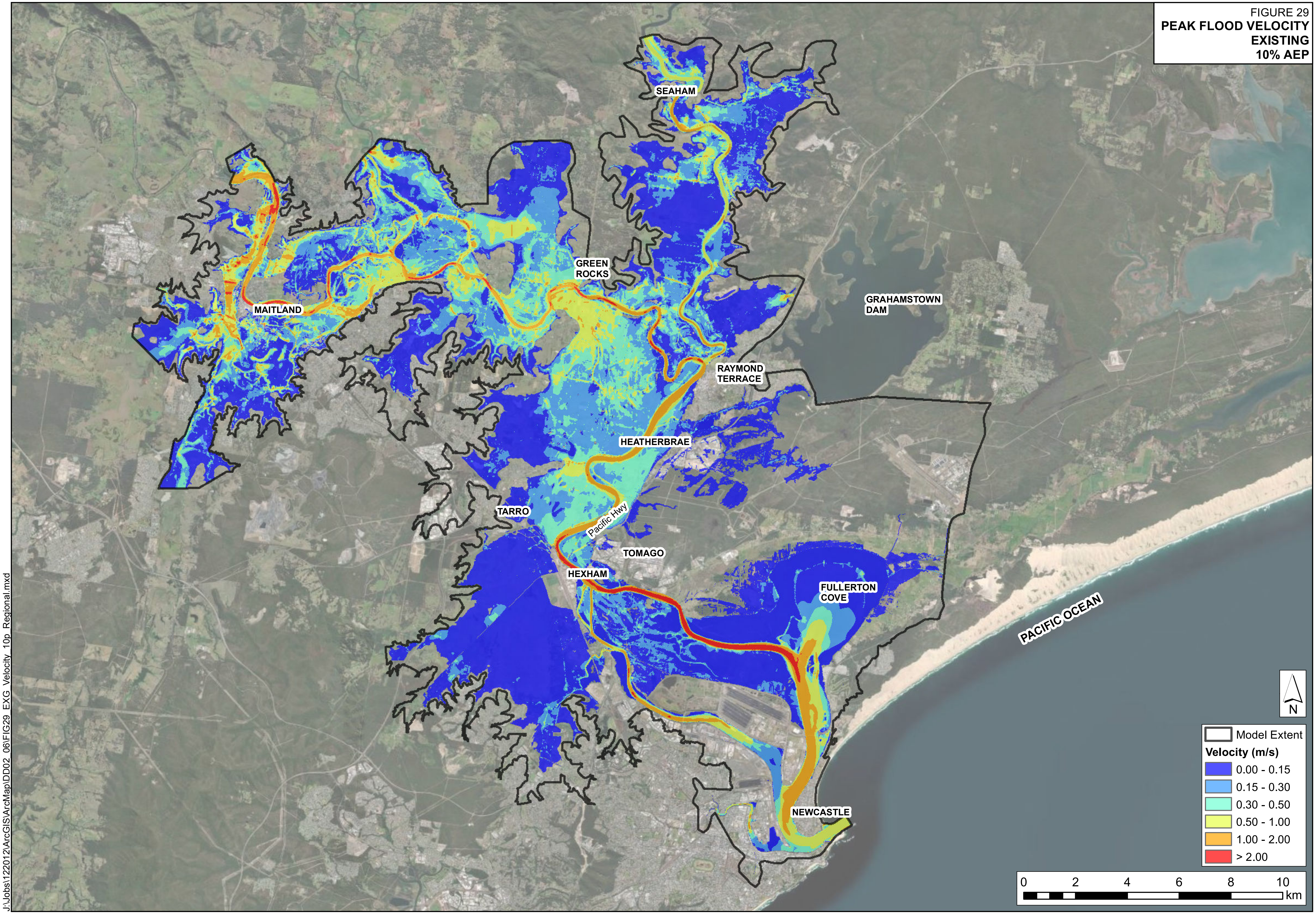


FIGURE 29
PEAK FLOOD VELOCITY
EXISTING
10% AEP

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG29_EXG_Velocity_10p_Regional.mxd

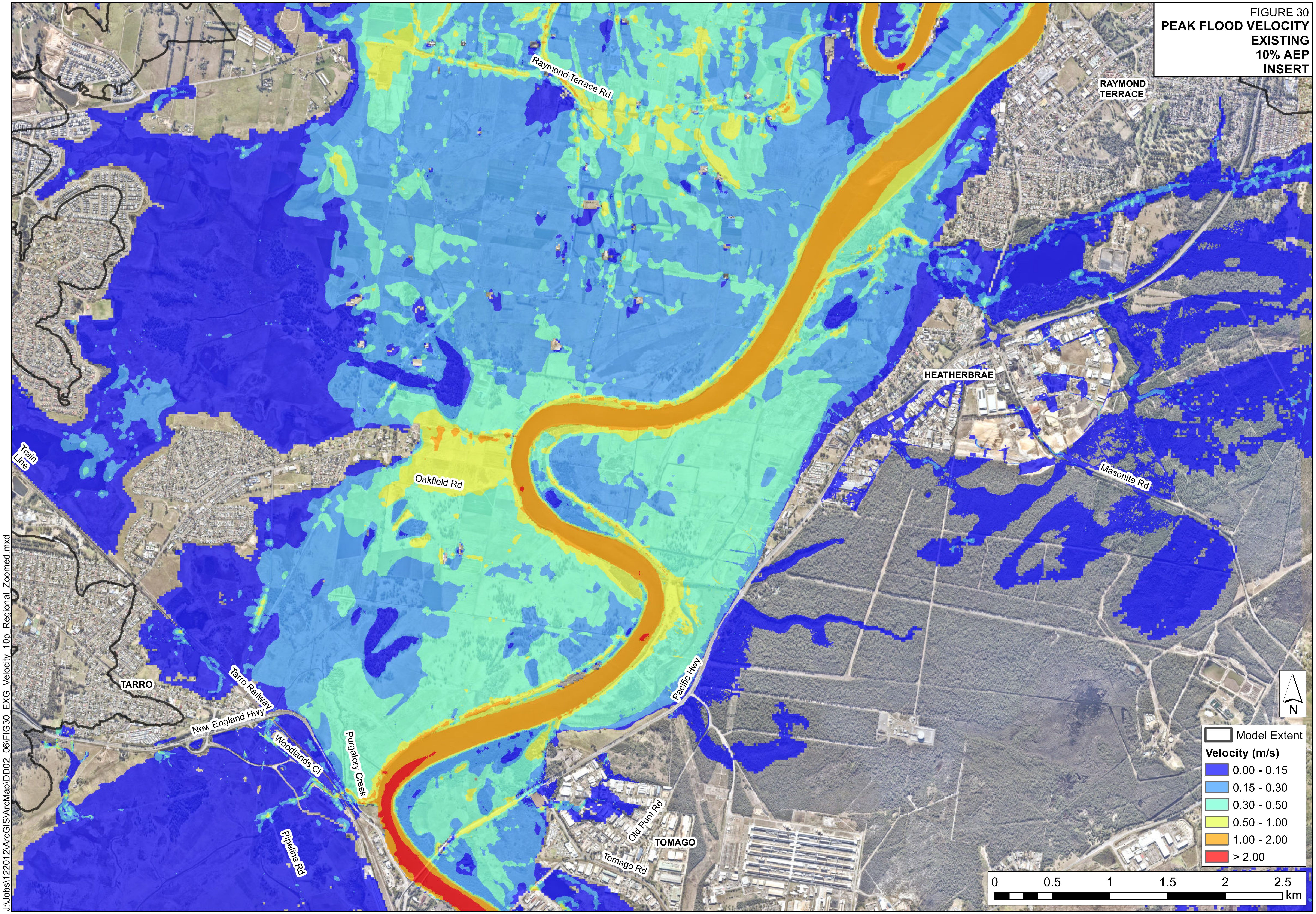
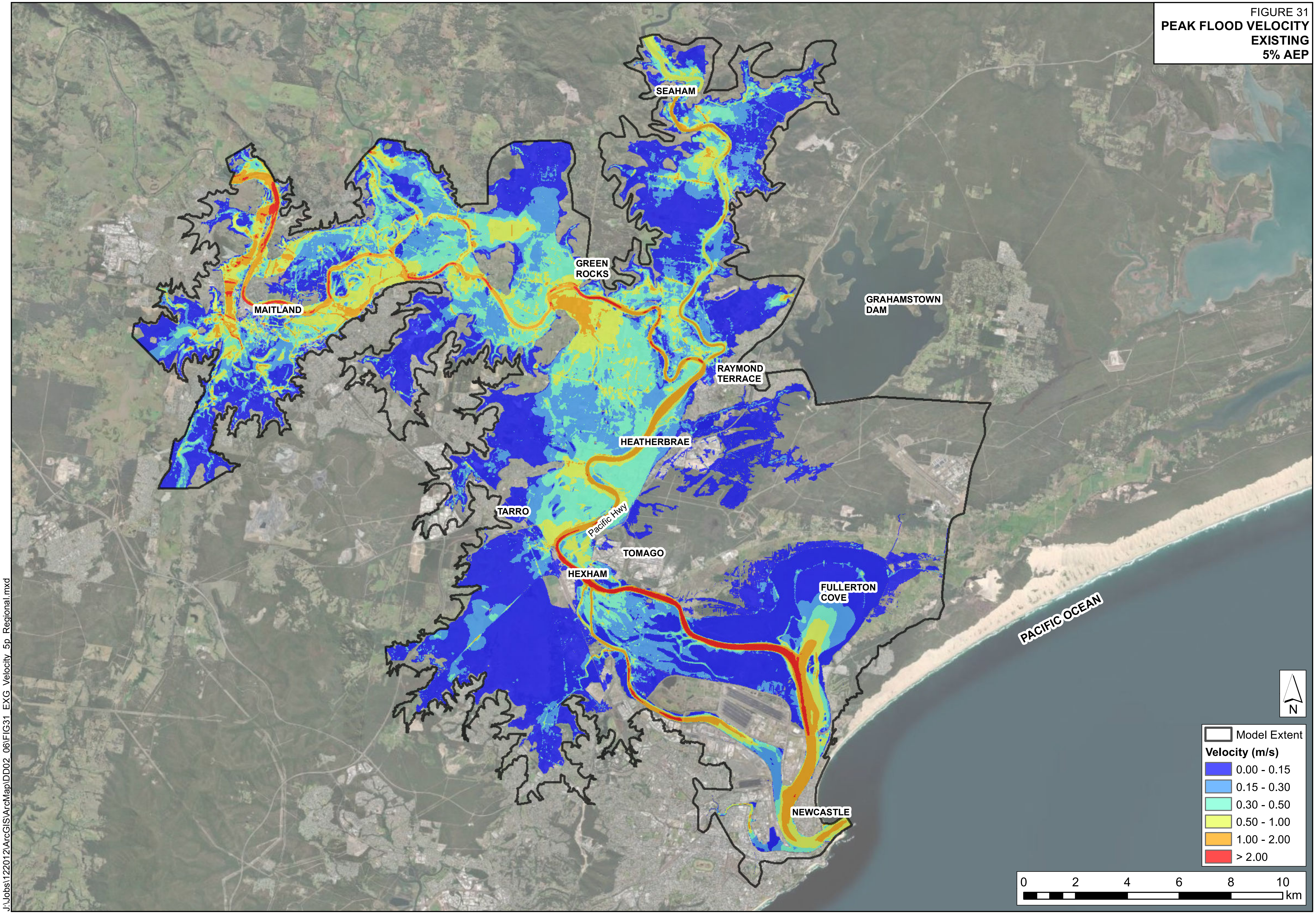


FIGURE 30
PEAK FLOOD VELOCITY
EXISTING
10% AEP
INSERT

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG30_EXG_Velocity_10p_Regional_Zoomed.mxd

PEAK FLOOD VELOCITY EXISTING 5% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG31_EXG_Velocity_5p_Regional.mxd

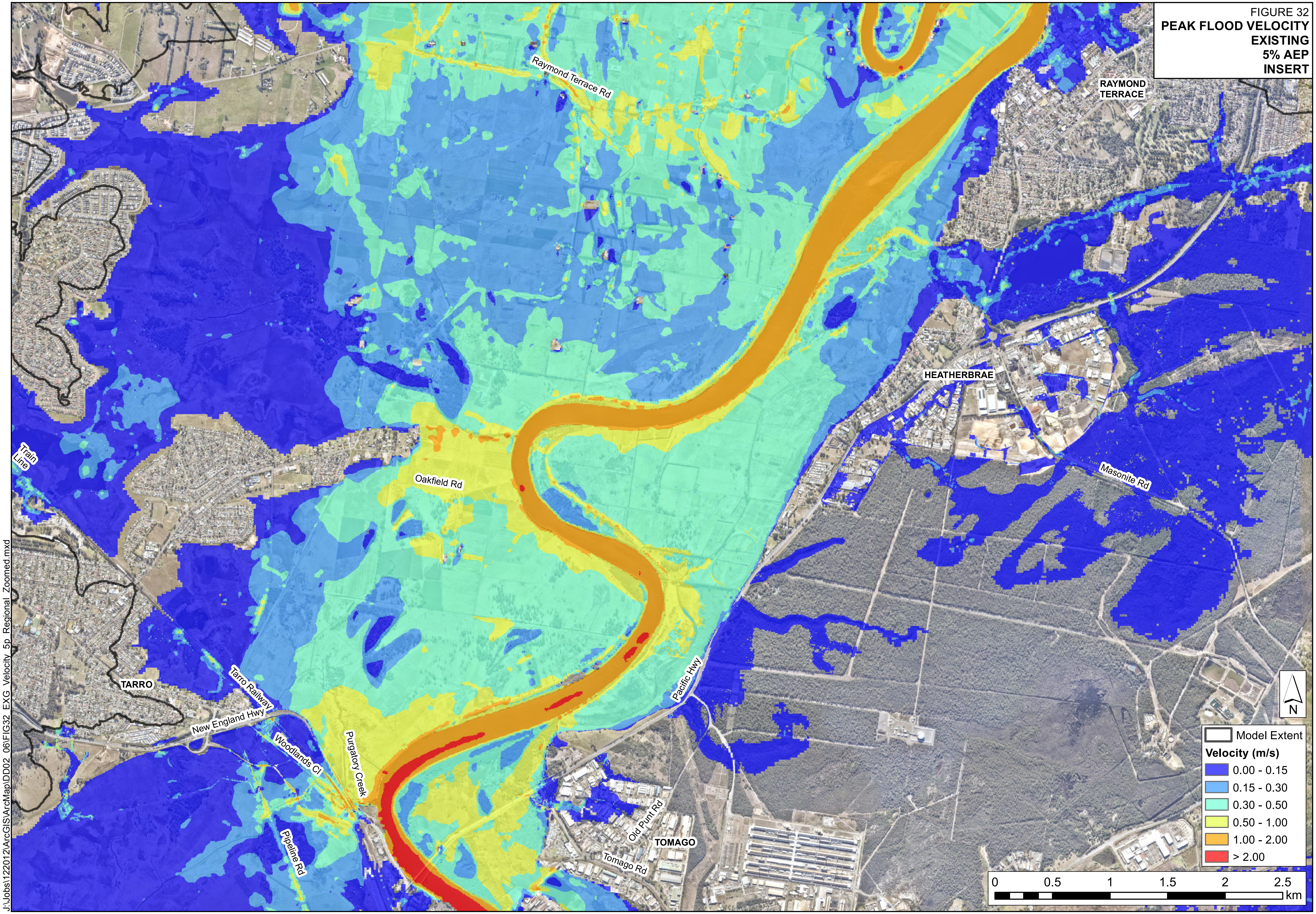


FIGURE 32
PEAK FLOOD VELOCITY
EXISTING
5% AEP
INSERT
Raymond Terrace Rd
RAYMOND TERRACE
HEATHERBRAE
Masonite Rd
Train Line
Oakfield Rd
Pacific Hwy
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Old Punt Rd
TOMAGO
Tomago Rd
N
Model Extent
Velocity (m/s)
0.00 - 0.15
0.15 - 0.30
0.30 - 0.50
0.50 - 1.00
1.00 - 2.00
> 2.00
0
0.5
1
1.5
2
2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG32_EXG_Velocity_5p_Regional_Zoomed.mxd

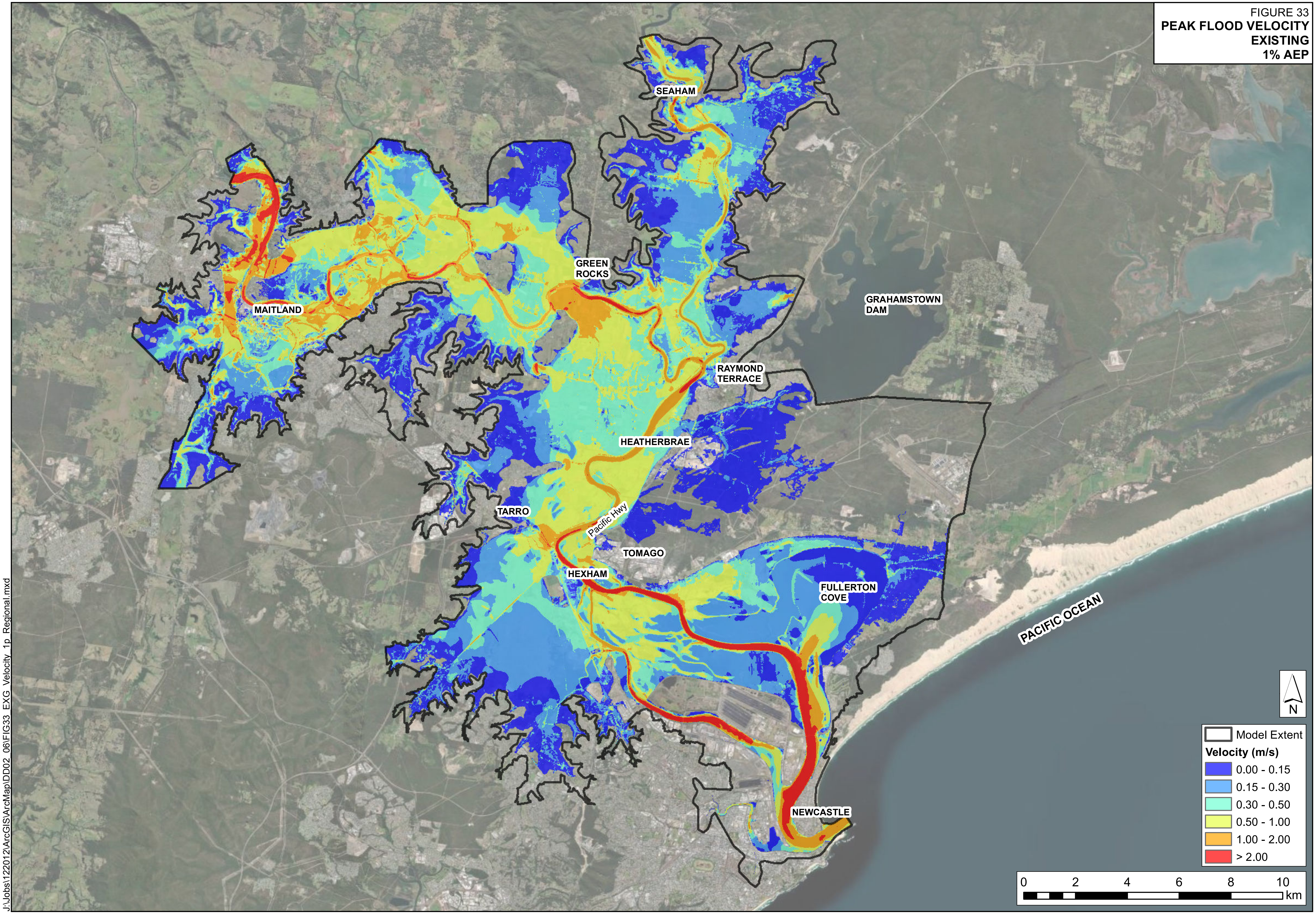
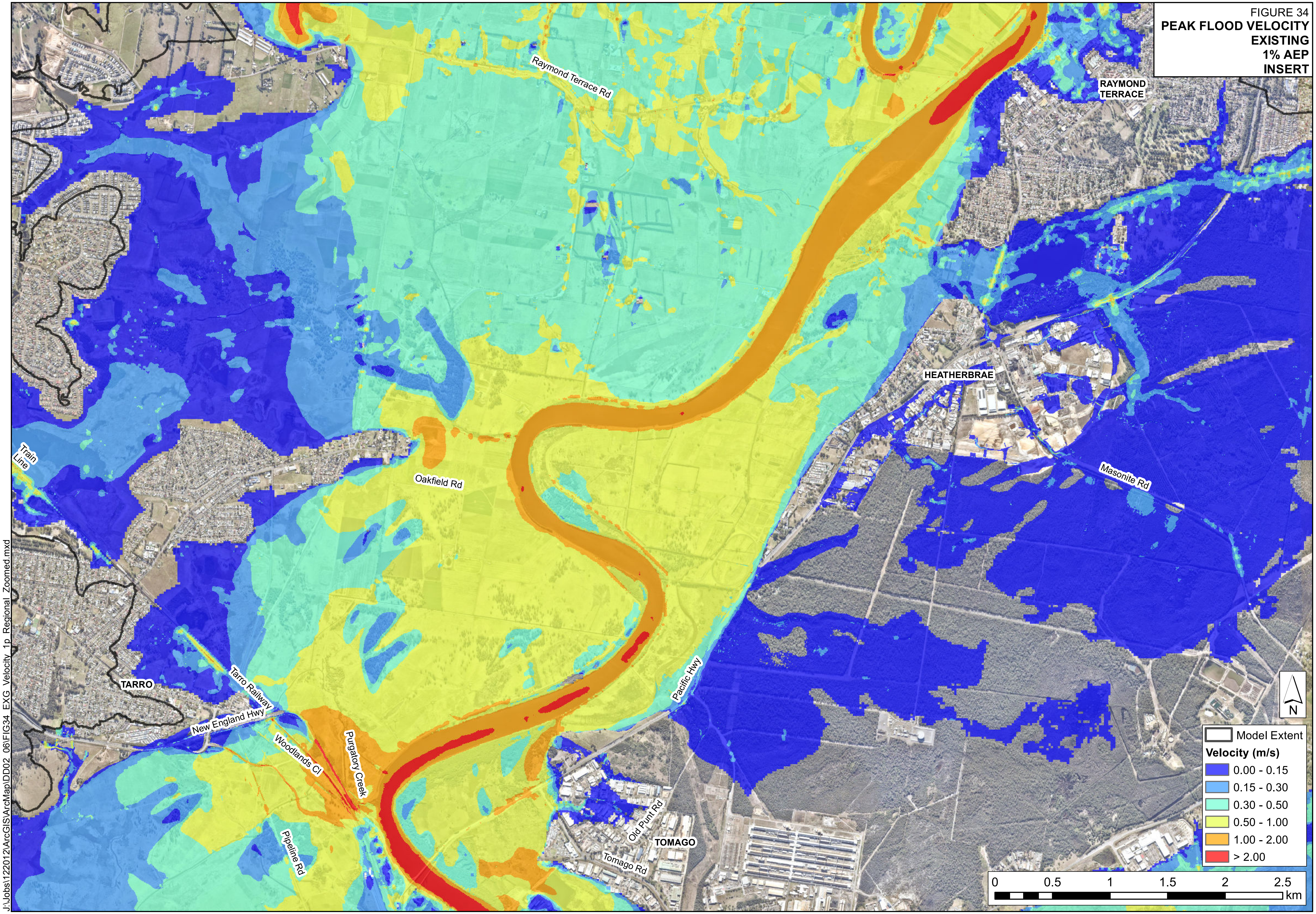


FIGURE 33
PEAK FLOOD VELOCITY
EXISTING
1% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Model Extent
Velocity (m/s)
0.00 - 0.15
0.15 - 0.30
0.30 - 0.50
0.50 - 1.00
1.00 - 2.00
> 2.00
0
2
4
6
8
10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG33_EXG_Velocity_1p_Regional.mxd

FIGURE 34
PEAK FLOOD VELOCITY
EXISTING
1% AEP
INSERT



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG34_EXG_Velocity_1p_Regional_Zoomed.mxd

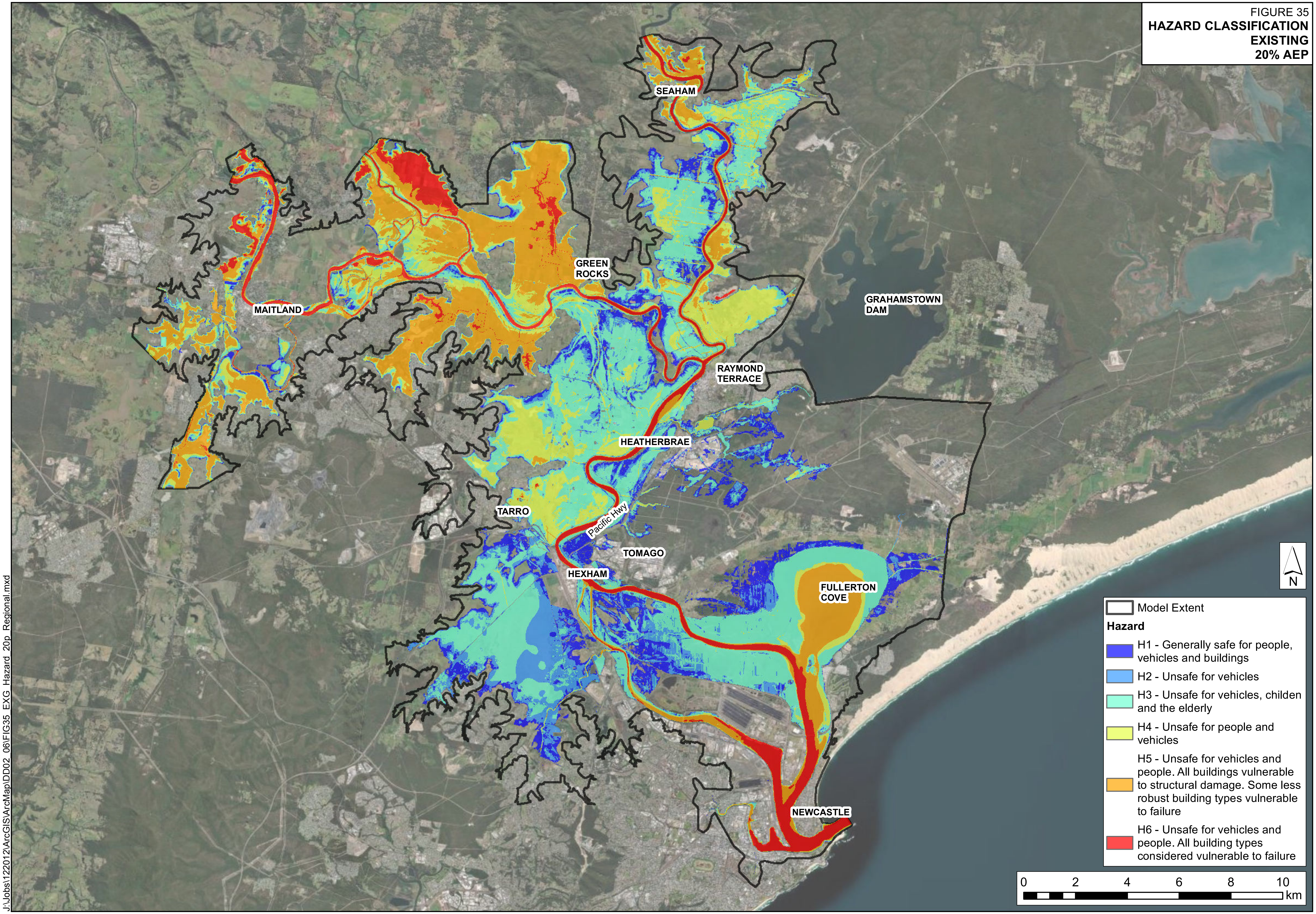


FIGURE 35
HAZARD CLASSIFICATION EXISTING 20% AEP

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG35_EXG_Hazard_20p_Regional.mxd

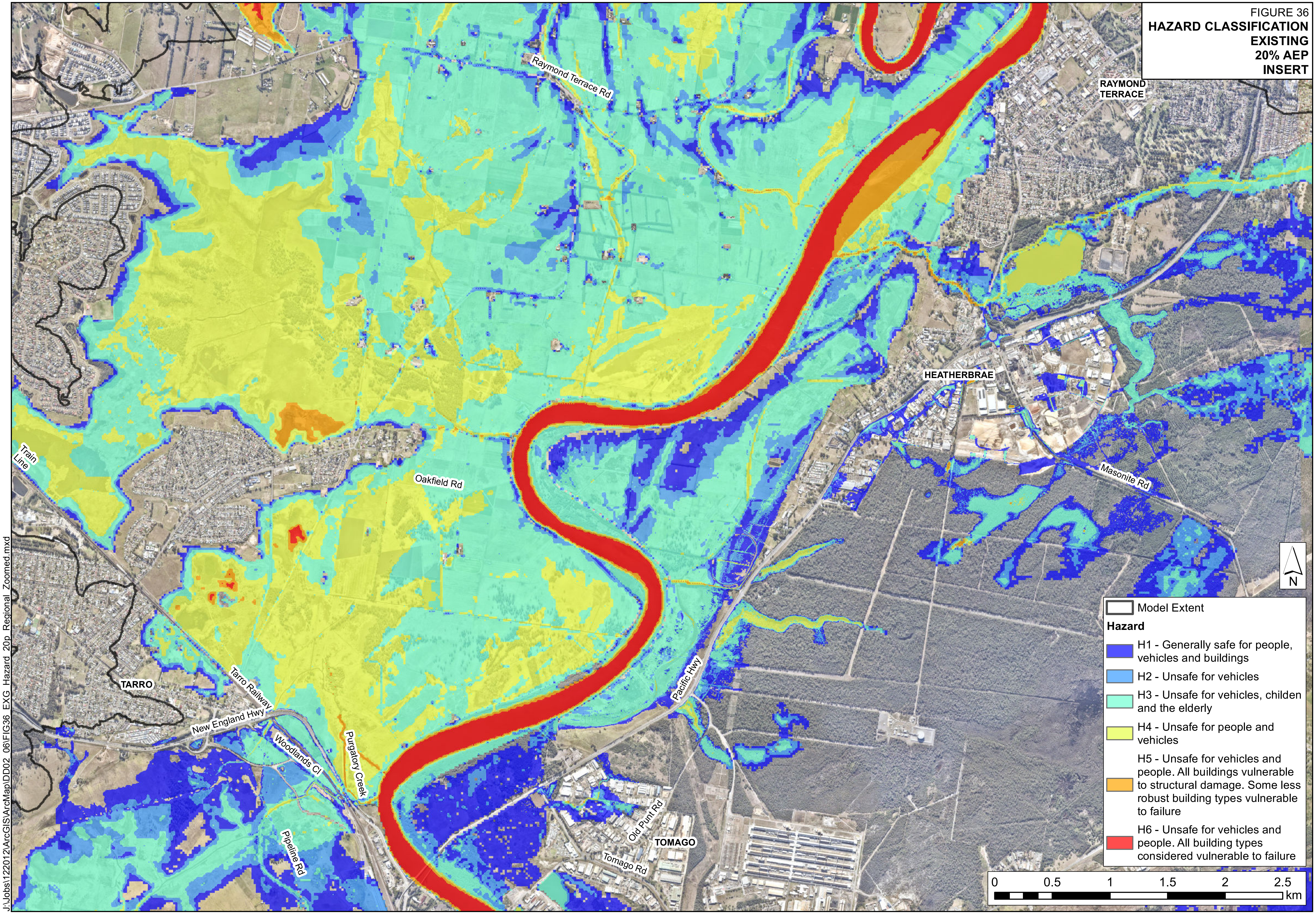


FIGURE 36
HAZARD CLASSIFICATION EXISTING 20% AEP INSERT

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG36_EXG_Hazard_20p_Regional_Zoomed.mxd

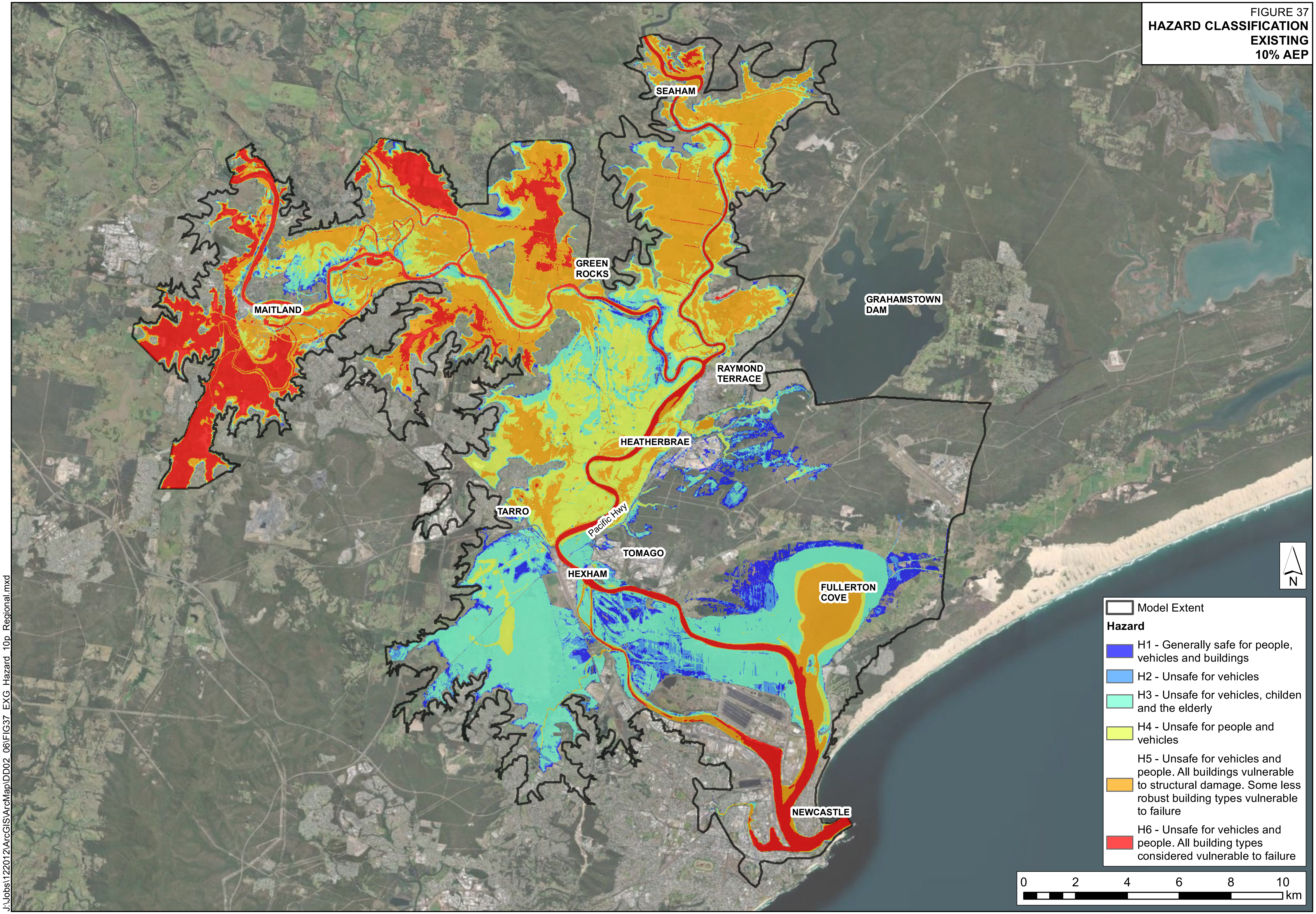


FIGURE 37
HAZARD CLASSIFICATION EXISTING 10% AEP

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG37_EXG_Hazard_10p_Regional.mxd

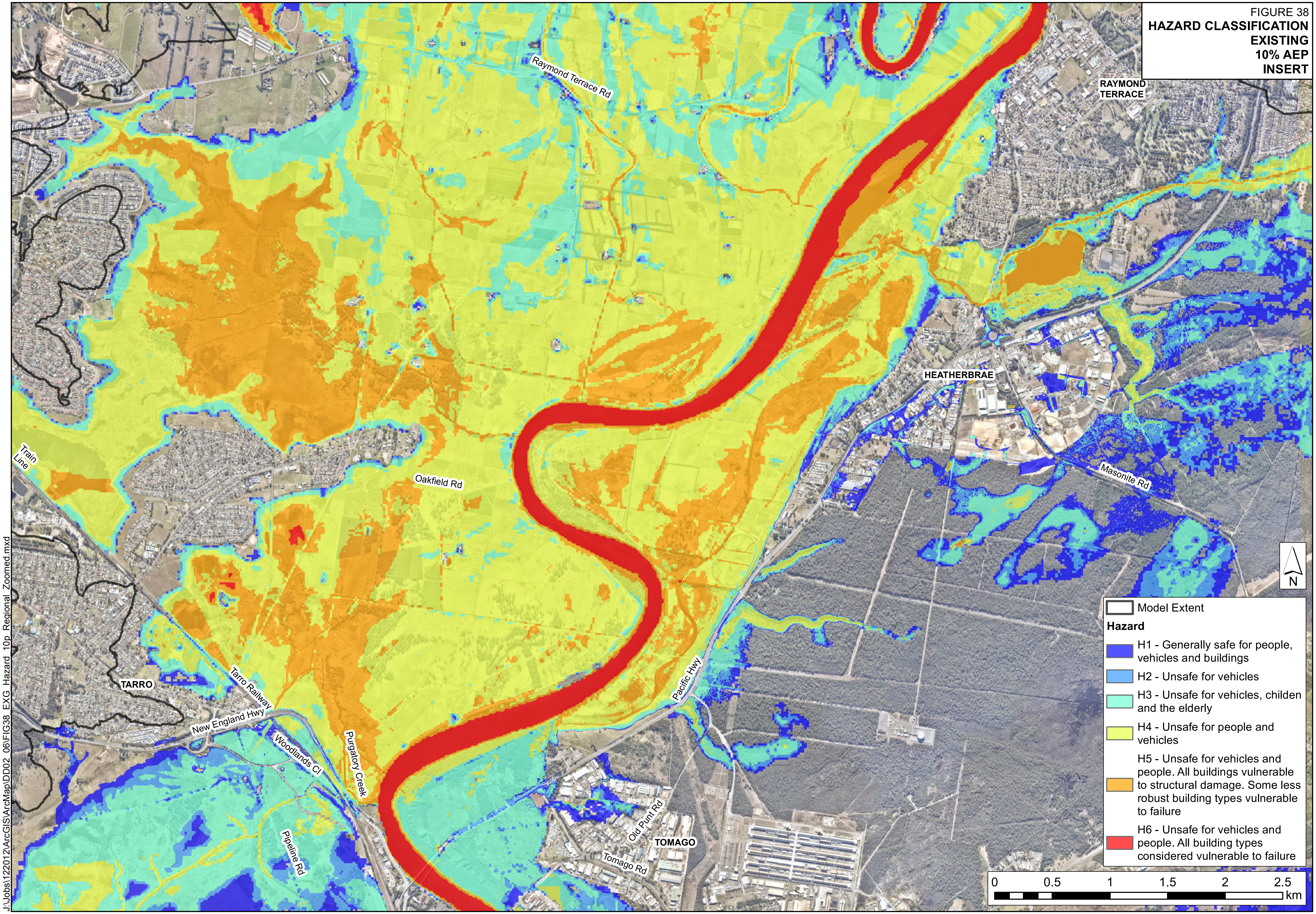


FIGURE 38
HAZARD CLASSIFICATION
EXISTING
10% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Train Line
Oakfield Rd
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Pacific Hwy
Old Punt Rd
TOMAGO
Tomago Rd
N
Model Extent
Hazard
H1 - Generally safe for people, vehicles and buildings
H2 - Unsafe for vehicles
H3 - Unsafe for vehicles, childen and the elderly
H4 - Unsafe for people and vehicles
H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure
0 0.5 1 1.5 2 2.5 km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG38_EXG_Hazard_10p_Regional_Zoomed.mxd

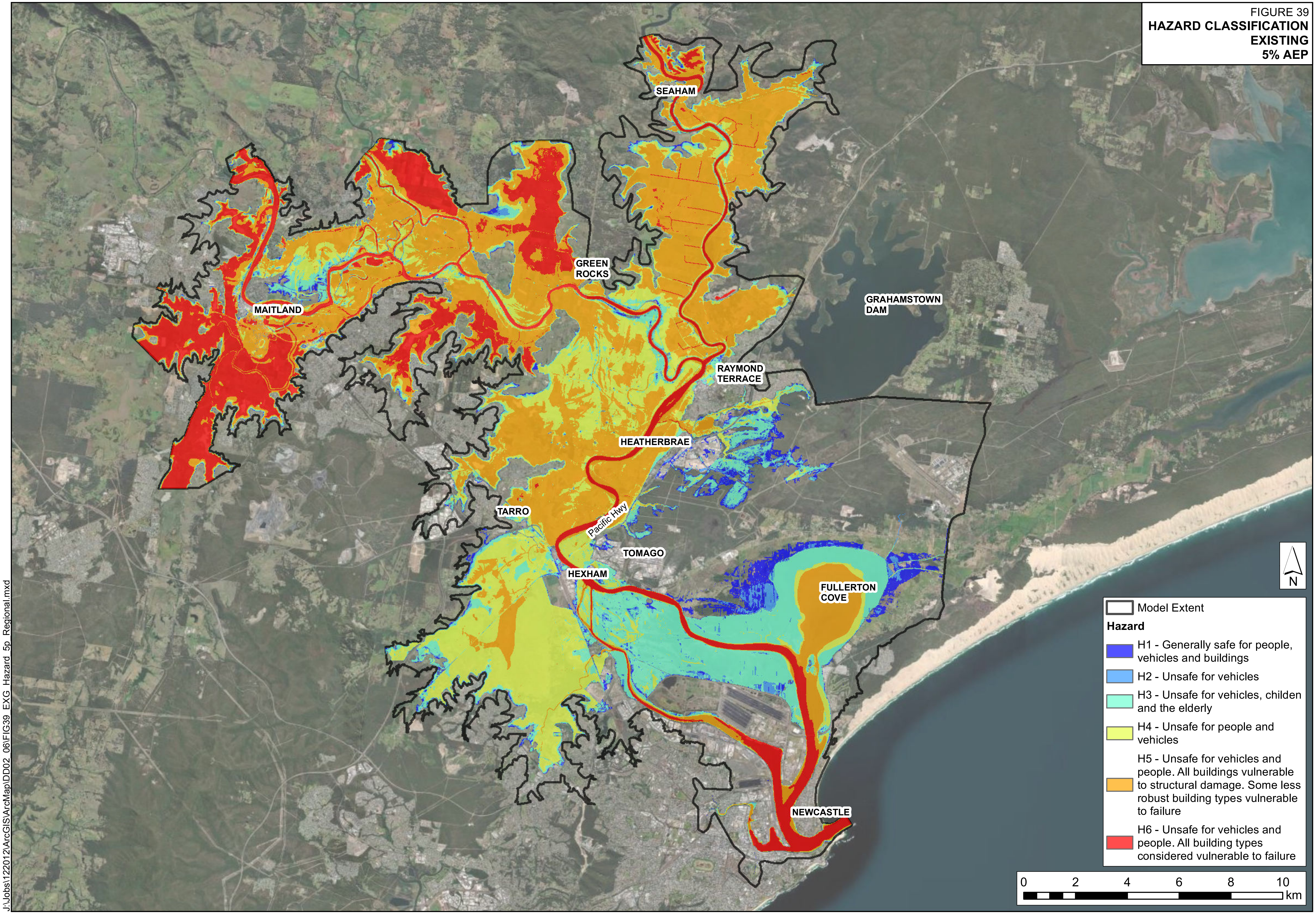
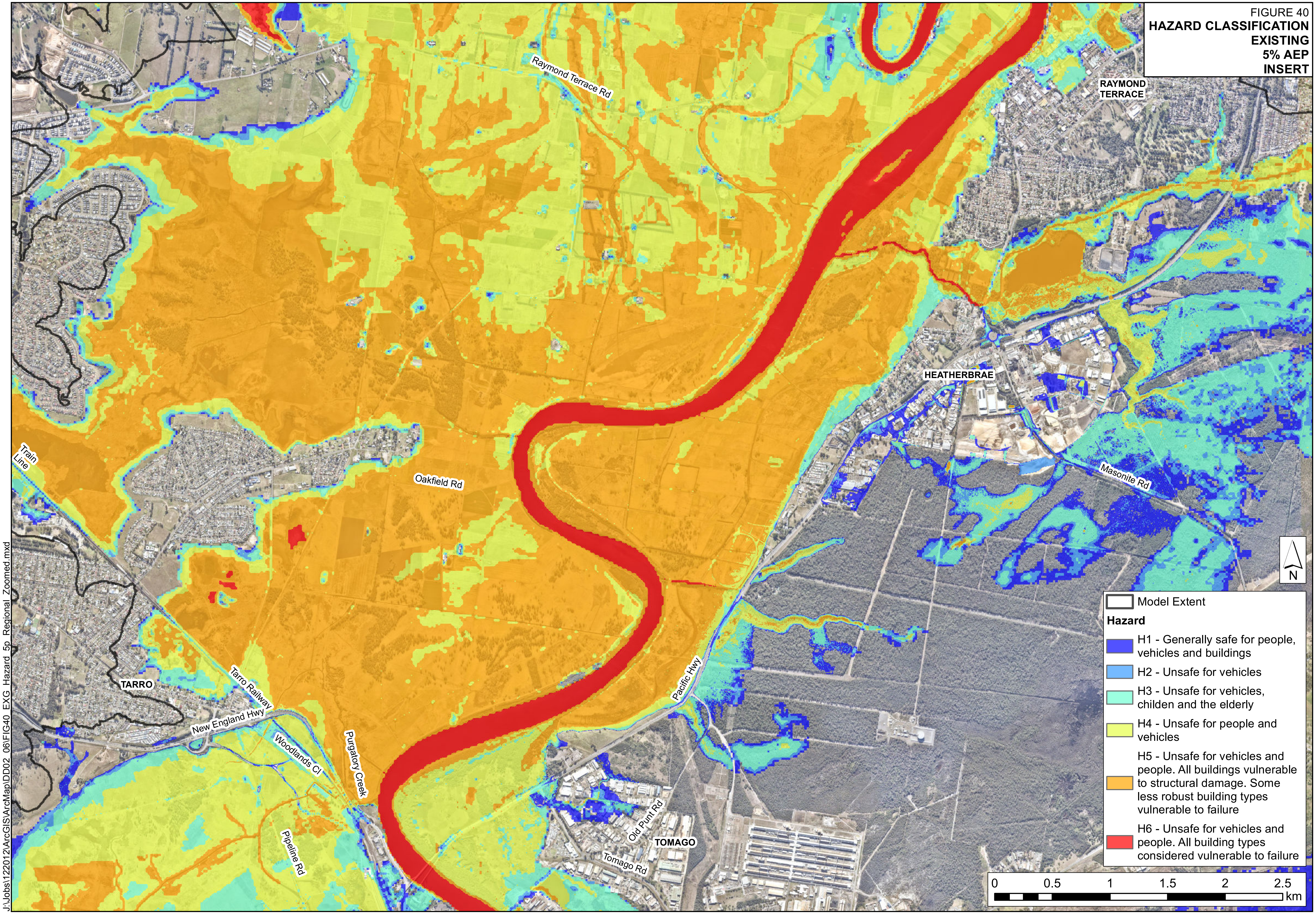


FIGURE 39
HAZARD CLASSIFICATION EXISTING 5% AEP

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG39_EXG_Hazard_5p_Regional.mxd



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG40_EXG_Hazard_5p_Regional_Zoomed.mxd

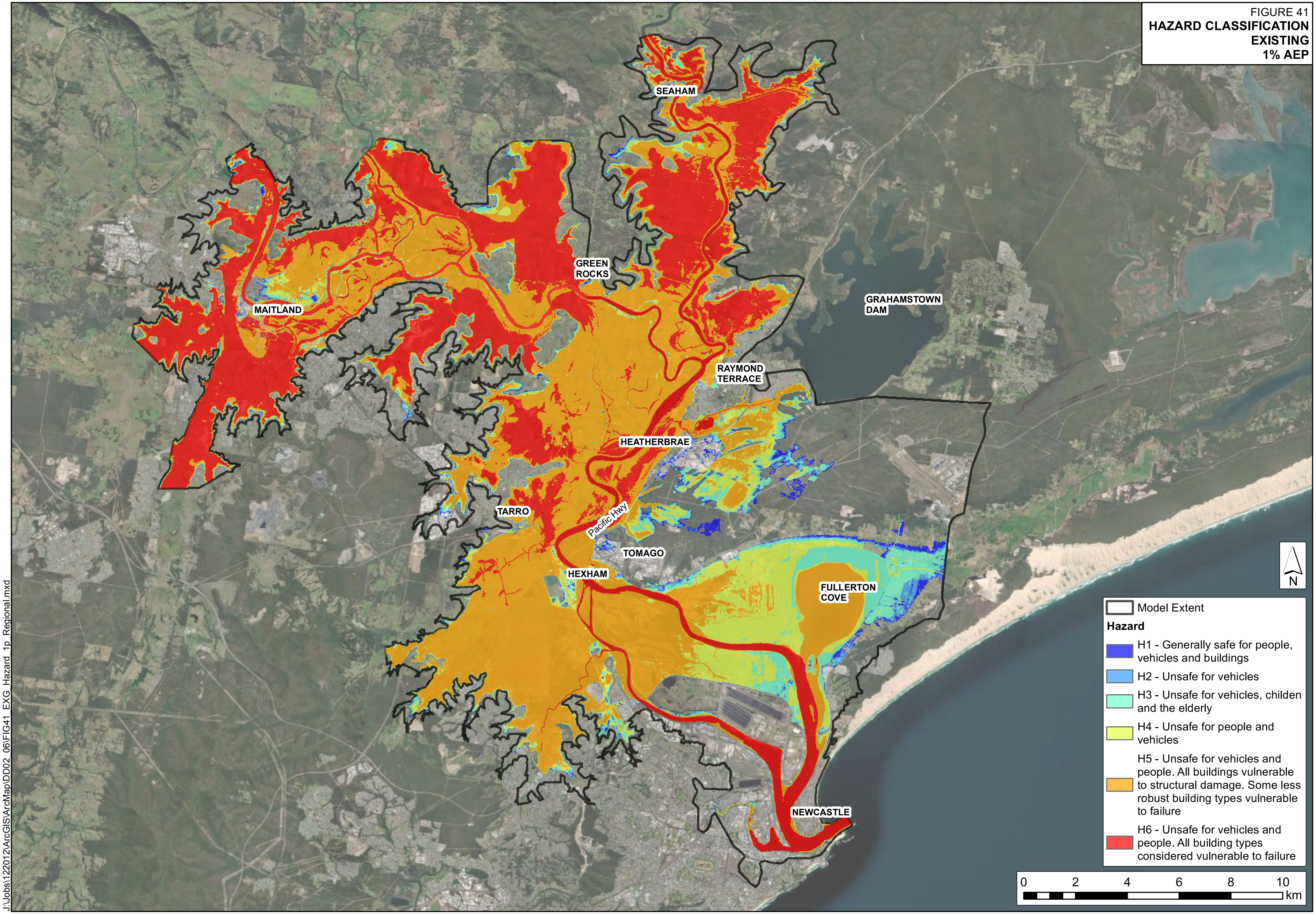


FIGURE 41
HAZARD CLASSIFICATION EXISTING 1% AEP

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG41_EXG_Hazard_1p_Regional.mxd

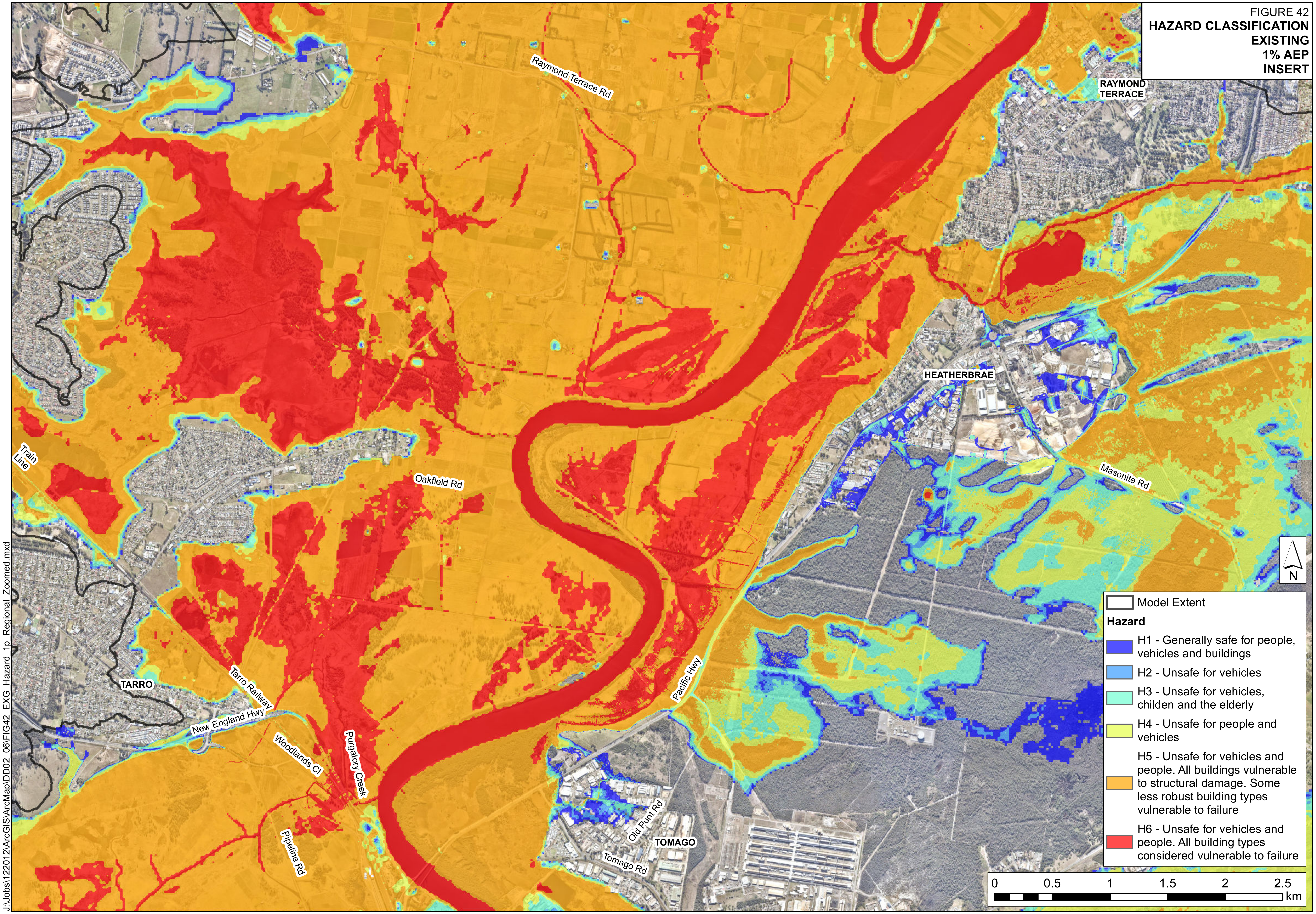


FIGURE 42
HAZARD CLASSIFICATION
EXISTING
1% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Oakfield Rd
Train Line
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Pacific Hwy
Old Punt Rd
TOMAGO
Tomago Rd
N
Model Extent
Hazard
H1 - Generally safe for people, vehicles and buildings
H2 - Unsafe for vehicles
H3 - Unsafe for vehicles, childen and the elderly
H4 - Unsafe for people and vehicles
H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure
0 0.5 1 1.5 2 2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG42_EXG_Hazard_1p_Regional_Zoomed.mxd

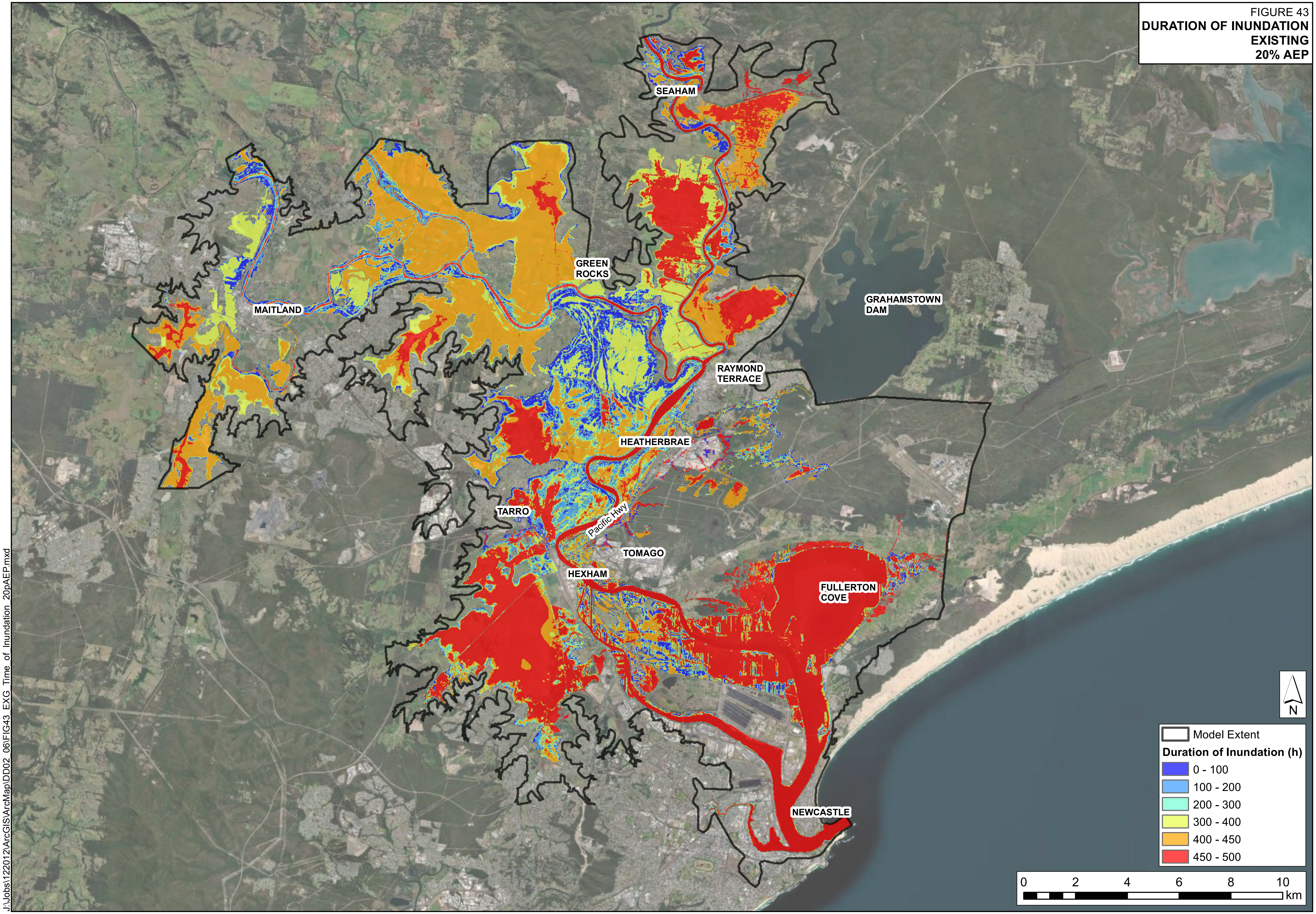
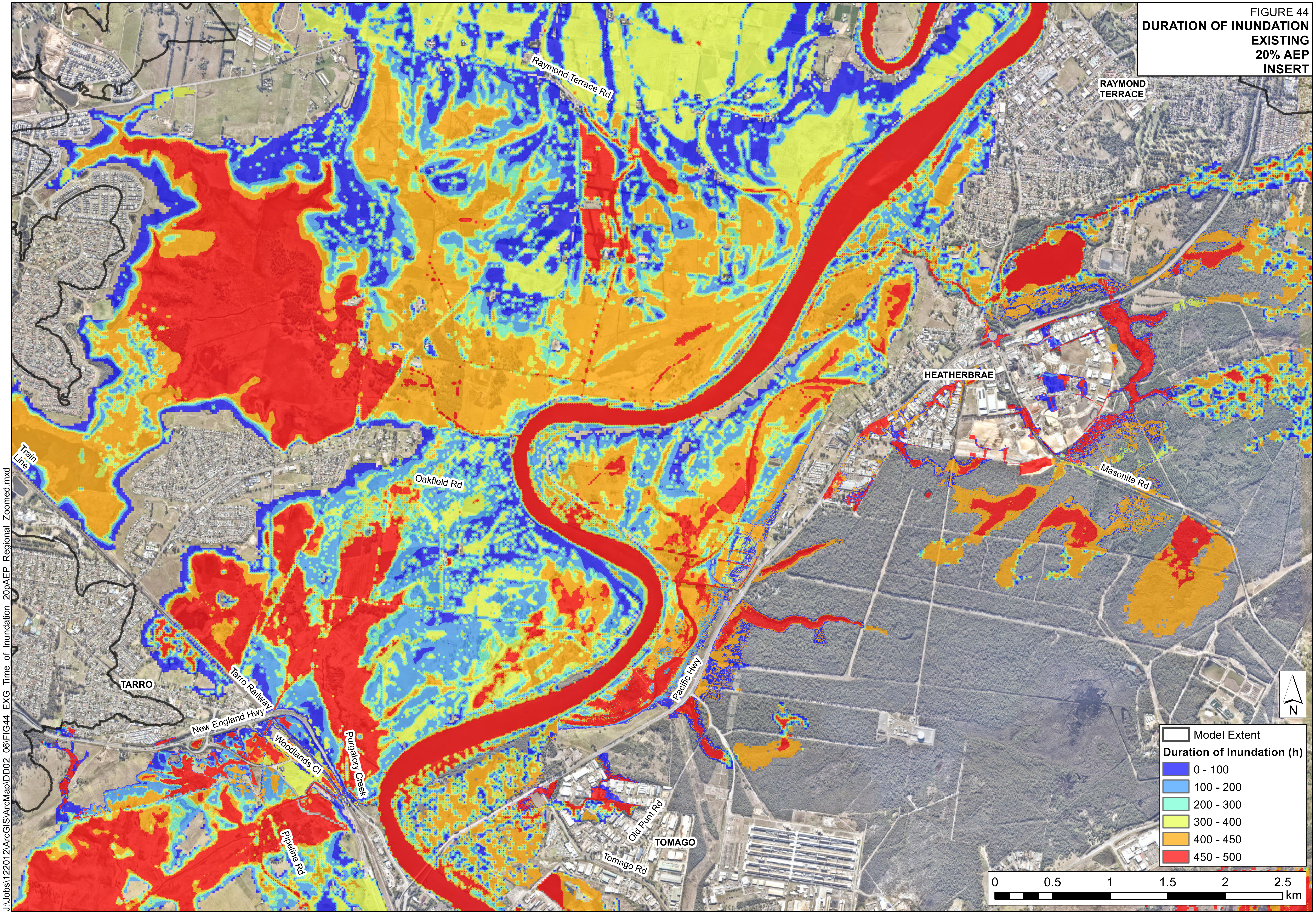


FIGURE 43
DURATION OF INUNDATION
EXISTING
20% AEP

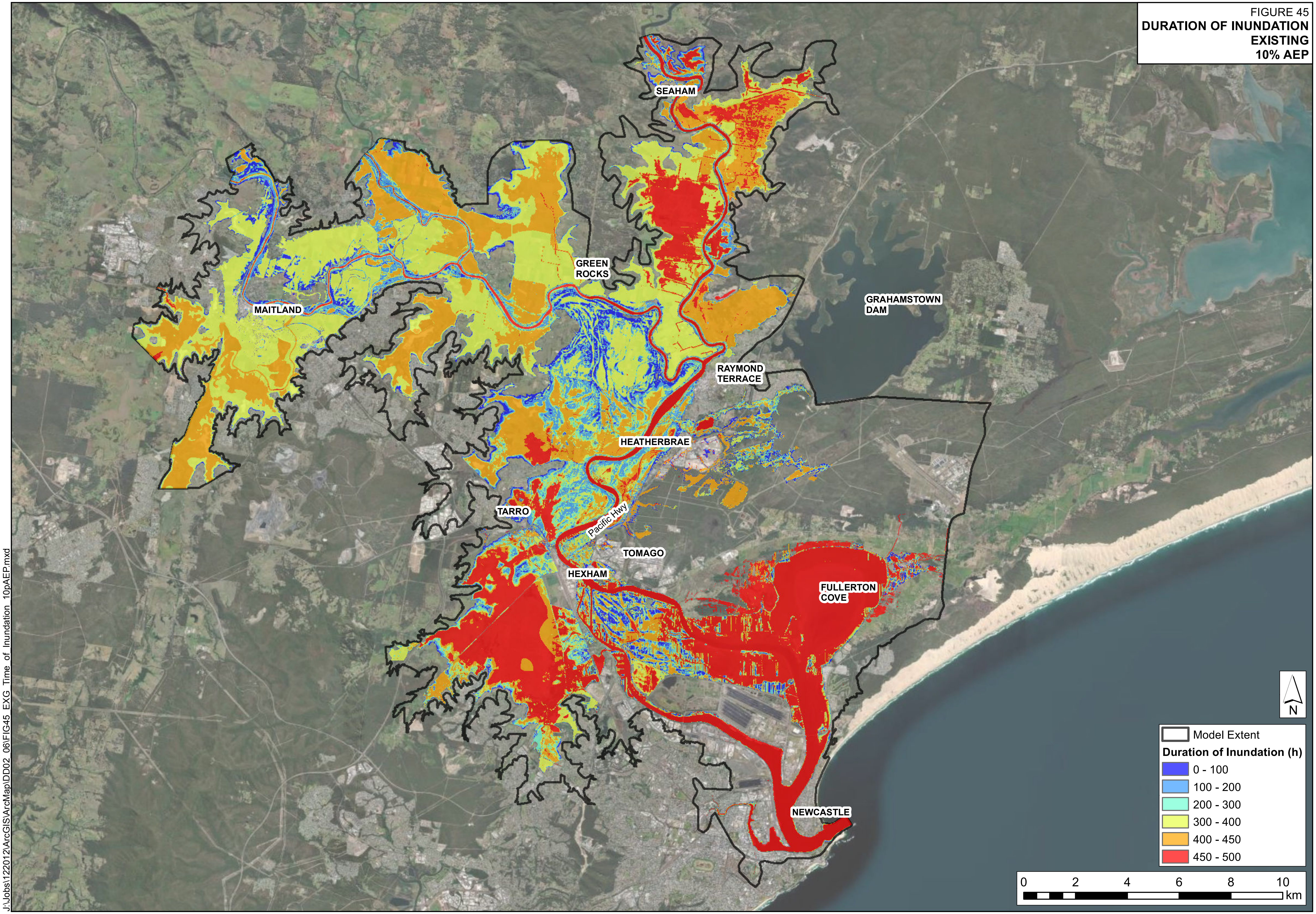
J:\Jobs\122012\ArcGIS\ArcMap\DD02 06\FIG43 EXG Time of Inundation 20pAEP.mxd

FIGURE 44
DURATION OF INUNDATION
EXISTING
20% AEP
INSERT



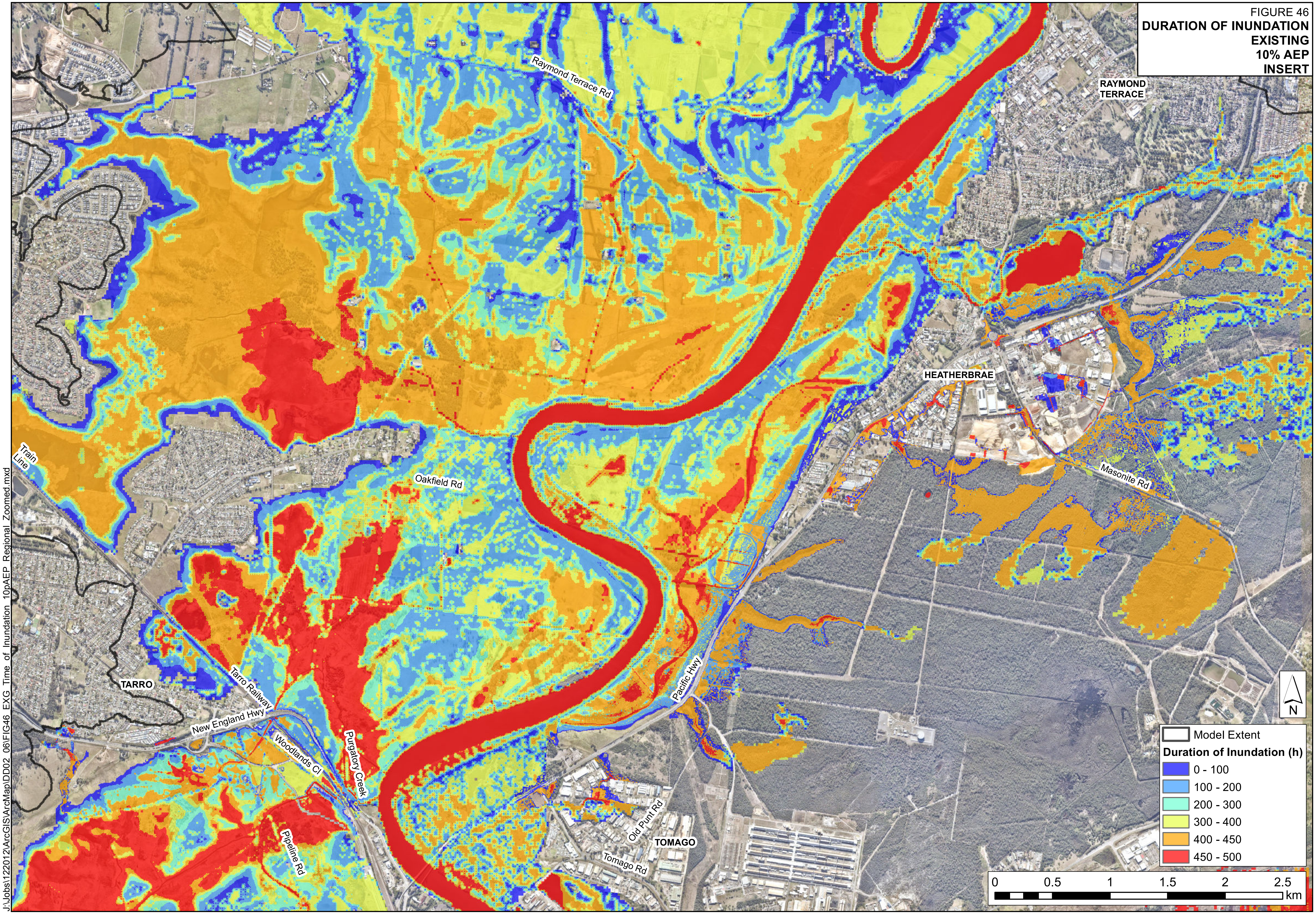
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG44_EXG_Time_of_Inundation_20pAEP_Regional_Zoomed.mxd

FIGURE 45
DURATION OF INUNDATION EXISTING 10% AEP



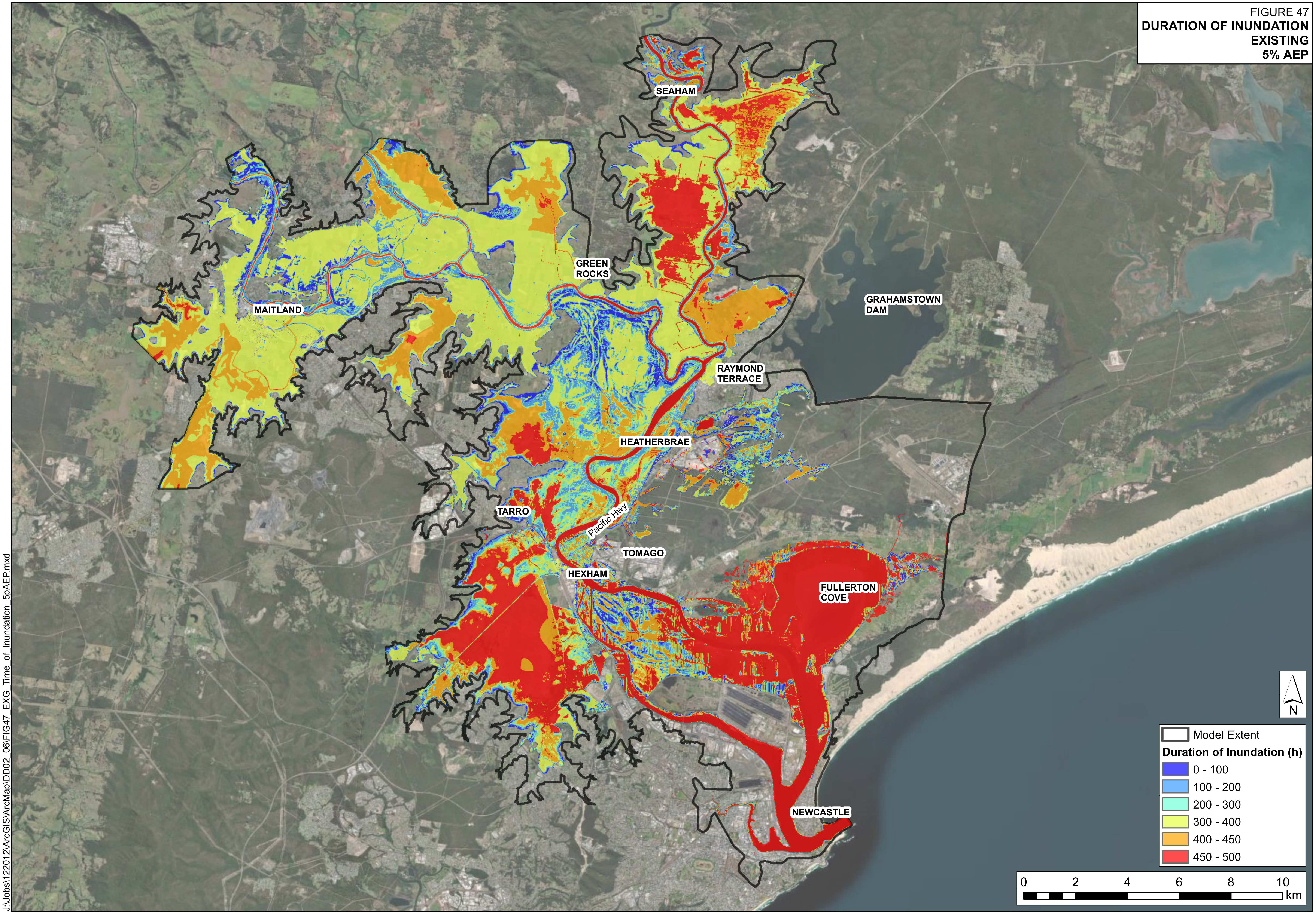
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG45_EXG_Time_of_Inundation_10pAEP.mxd

FIGURE 46
DURATION OF INUNDATION EXISTING 10% AEP INSERT



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG46_EXG_Time_of_Inundation_10pAEP_Regional_Zoomed.mxd

FIGURE 47
DURATION OF INUNDATION EXISTING 5% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG47_EXG_Time_of_Inundation_5pAEP.mxd

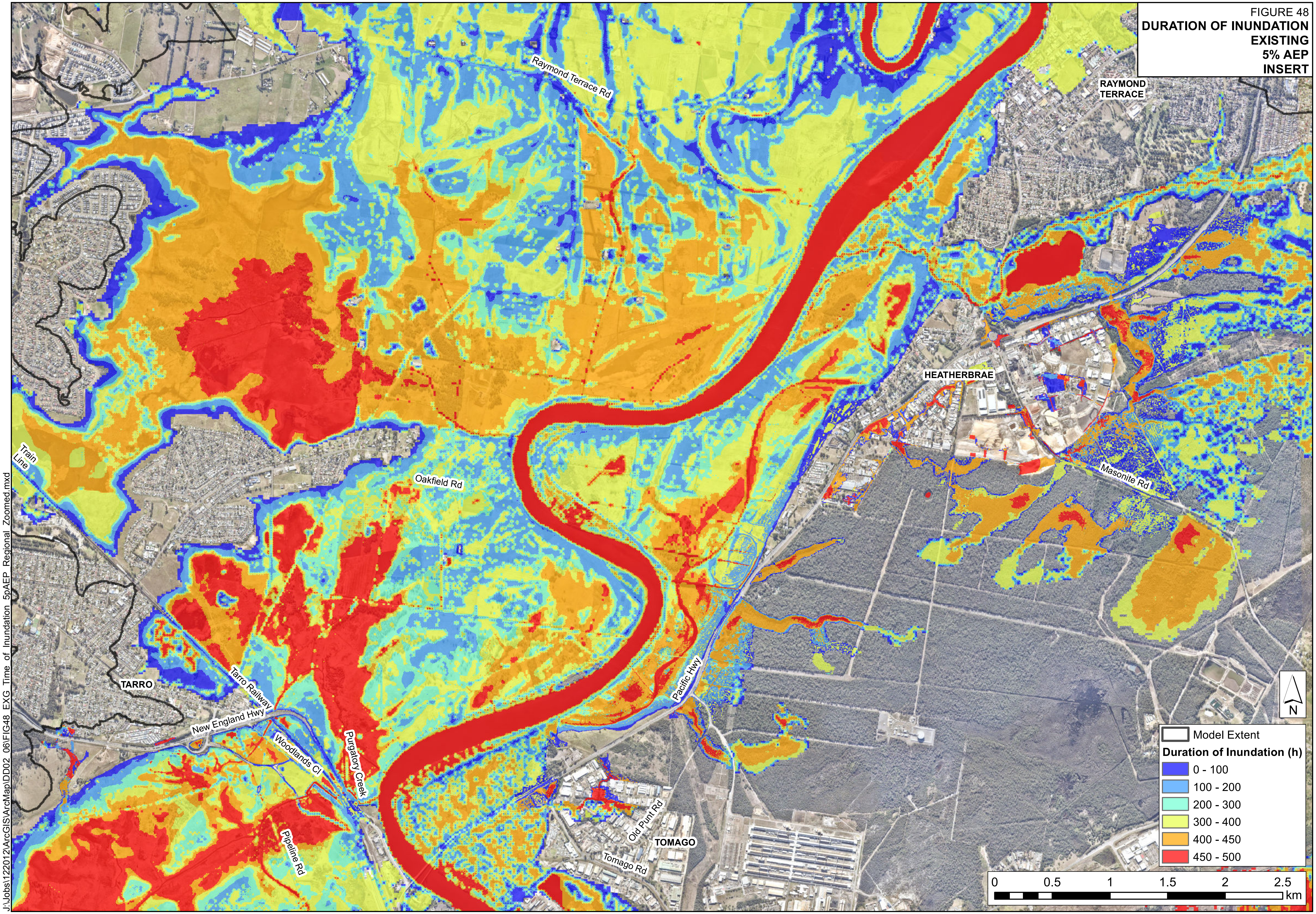


FIGURE 48
DURATION OF INUNDATION EXISTING 5% AEP INSERT

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG48_EXG_Time_of_Inundation_5pAEP_Regional_Zoomed.mxd

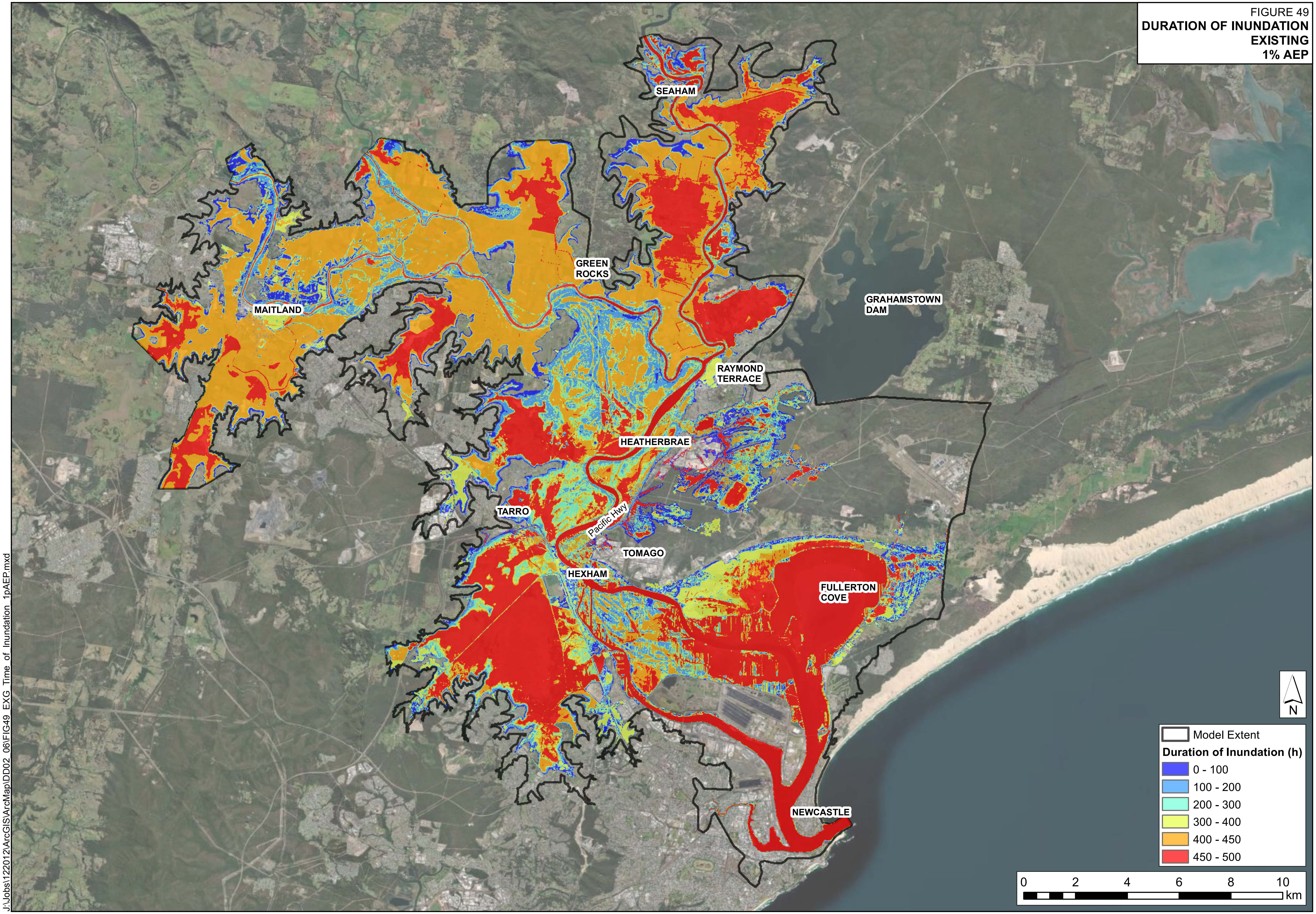


FIGURE 49
DURATION OF INUNDATION
EXISTING
1% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
NEWCASTLE
N
Model Extent
Duration of Inundation (h)
0 - 100
100 - 200
200 - 300
300 - 400
400 - 450
450 - 500
0 2 4 6 8 10 km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG49_EXG_Time_of_Inundation_1pAEP.mxd

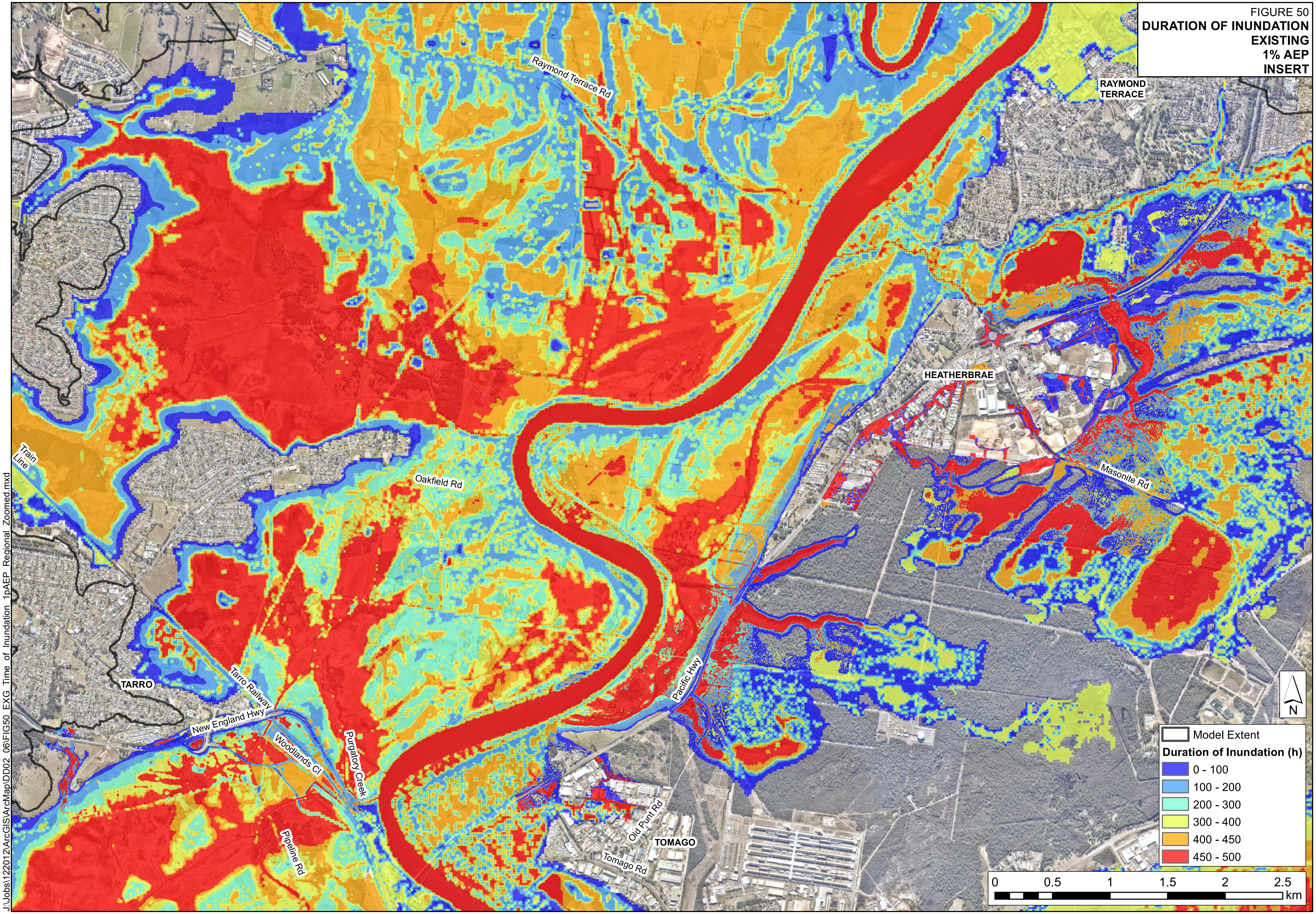
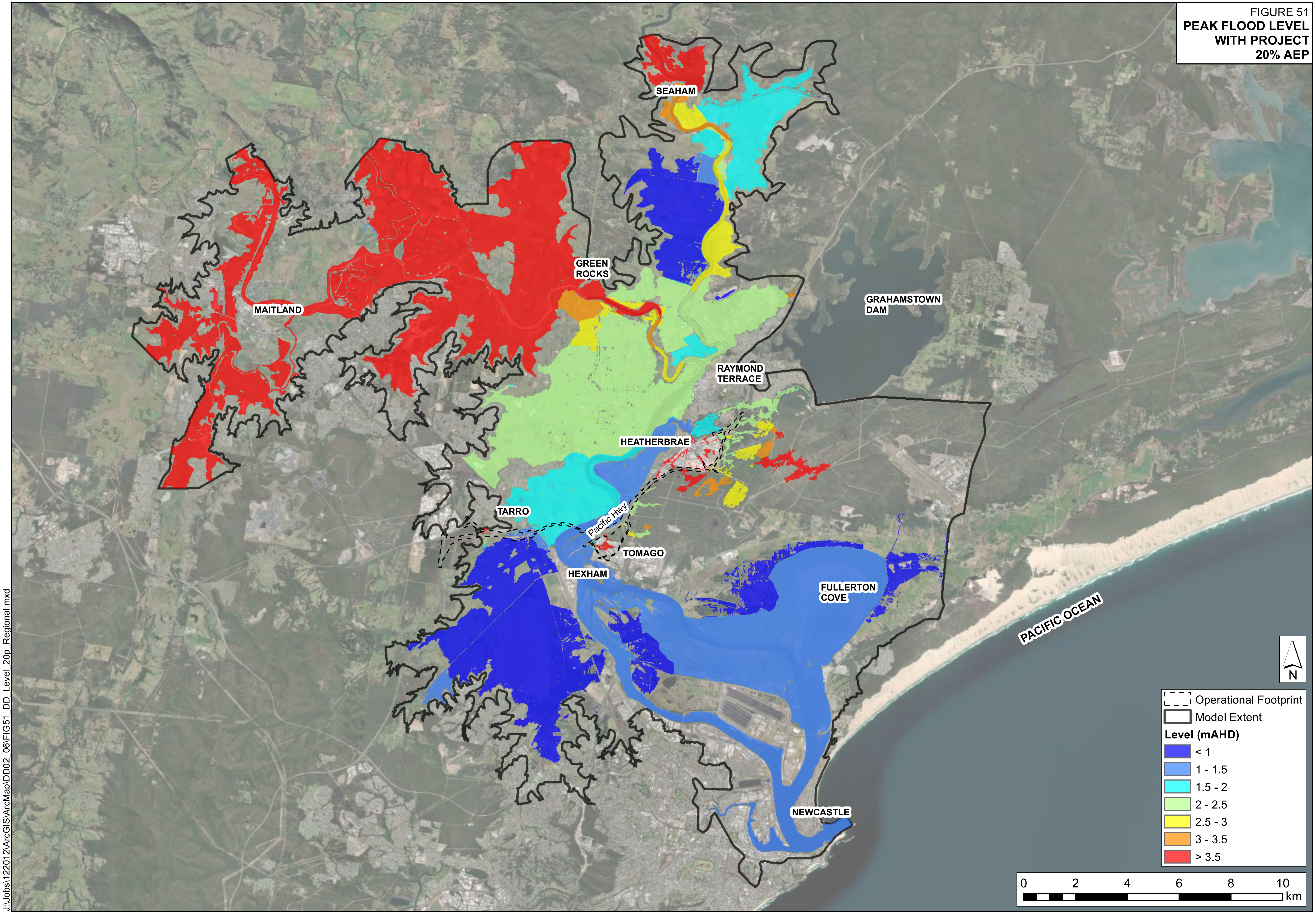
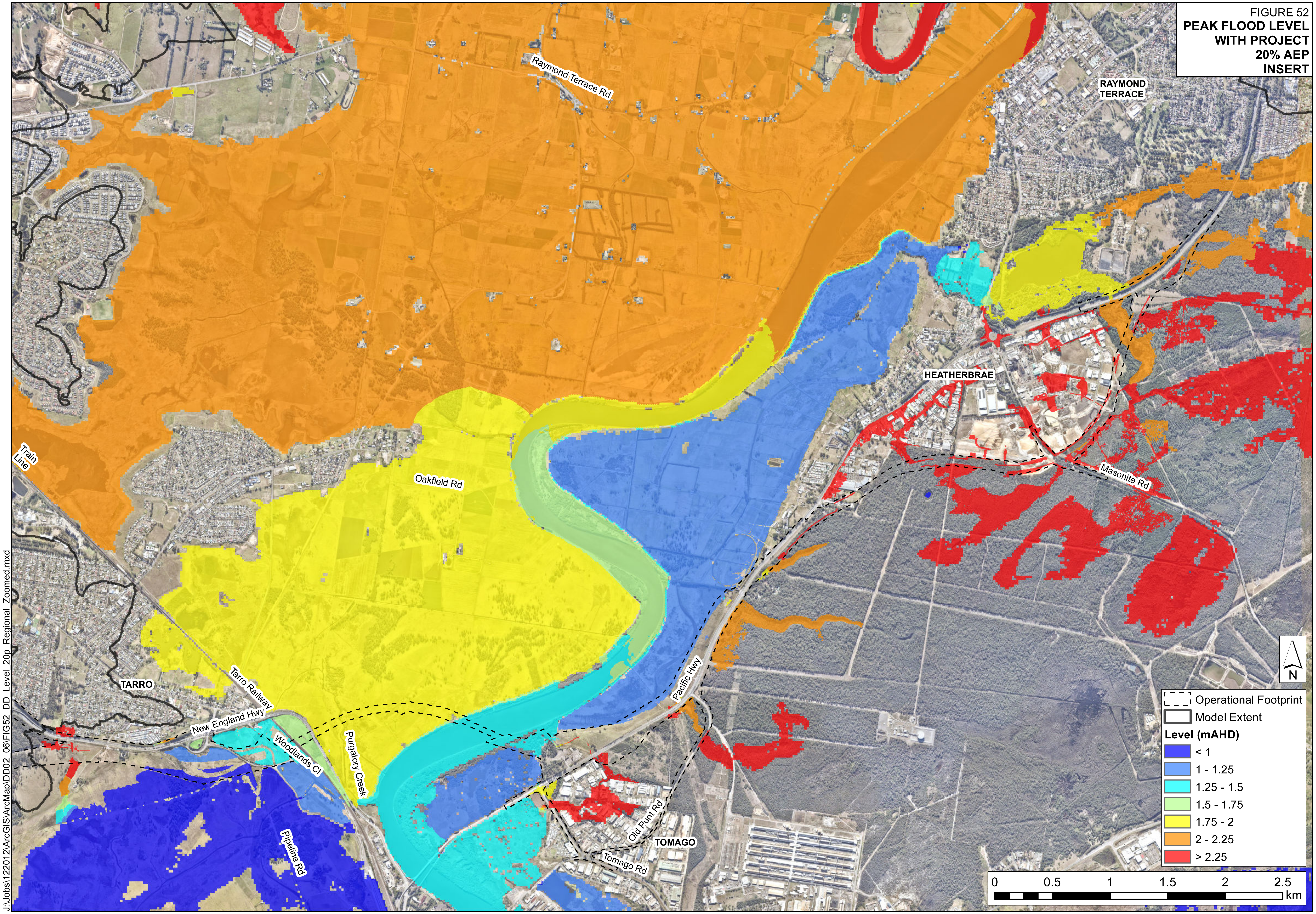


FIGURE 50
DURATION OF INUNDATION
EXISTING
1% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Oakfield Rd
Train Line
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Pacific Hwy
Old Punt Rd
TOMAGO
Tomago Rd
N
Model Extent
Duration of Inundation (h)
0 - 100
100 - 200
200 - 300
300 - 400
400 - 450
450 - 500
0
0.5
1
1.5
2
2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG50_EXG_Time_of_Inundation_1pAEP_Regional_Zoomed.mxd

FIGURE 51
PEAK FLOOD LEVEL WITH PROJECT 20% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG51_DD_Level_20p_Regional.mxd



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG52_DD_Level_20p_Regional_Zoomed.mxd

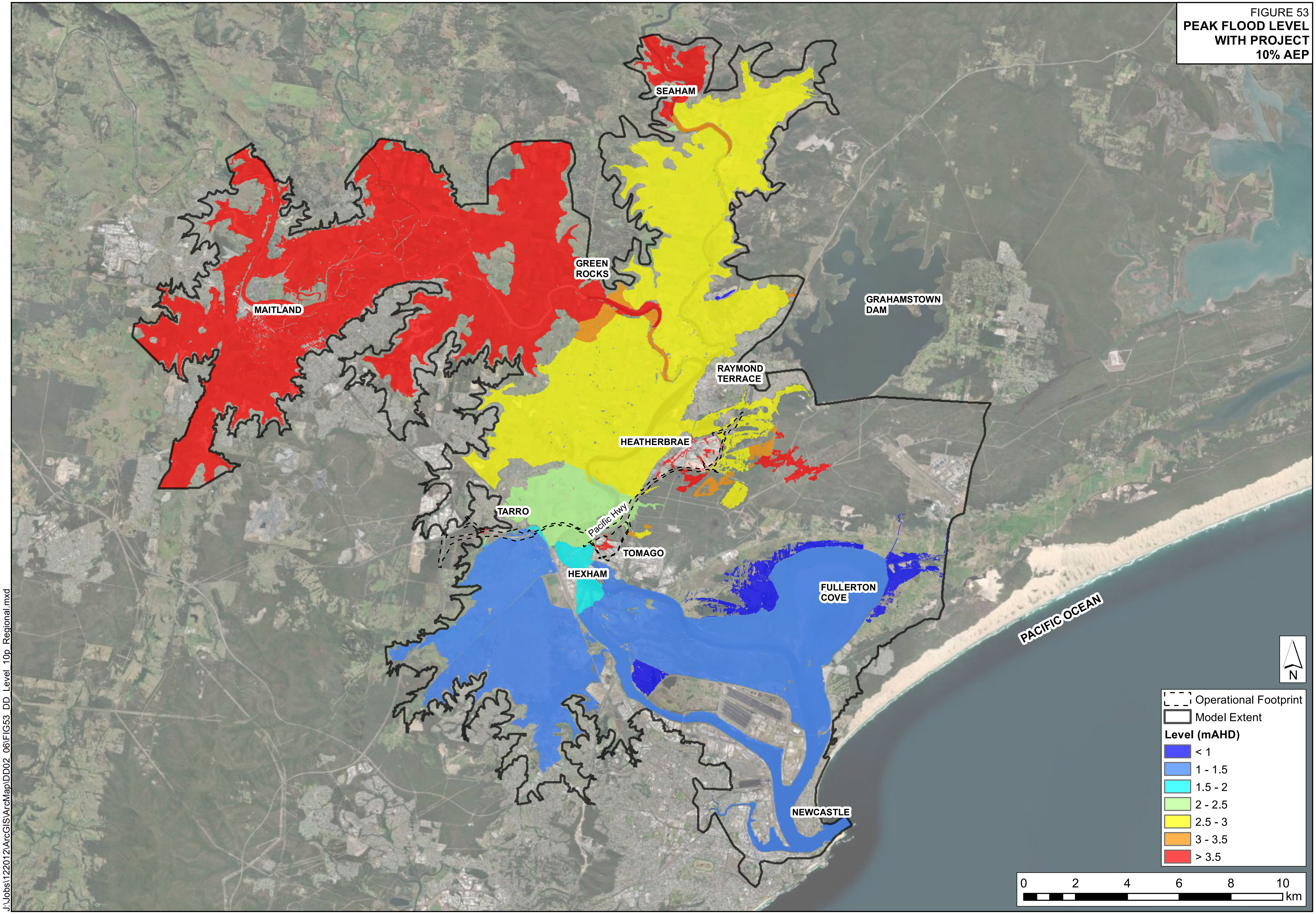
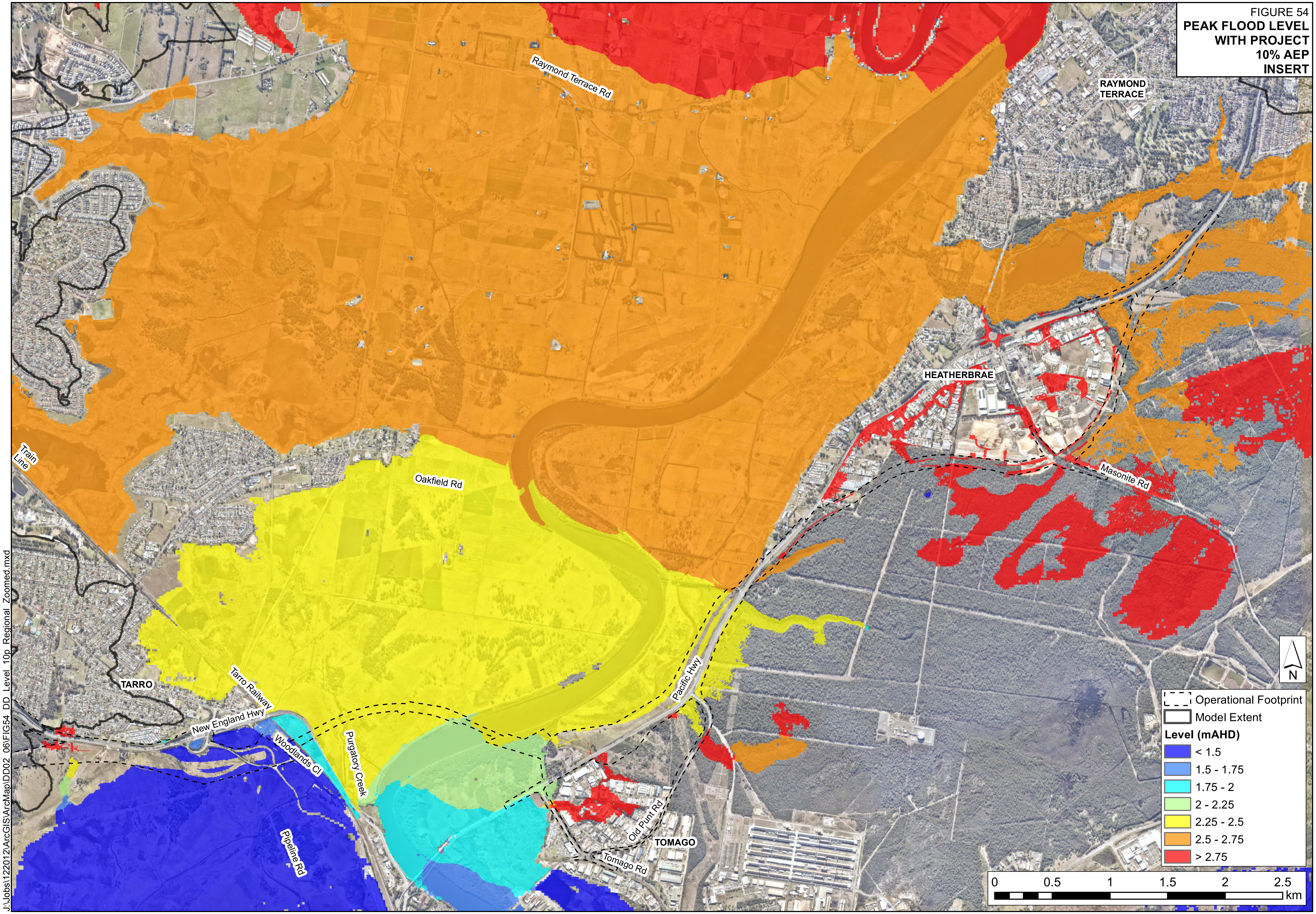


FIGURE 53
PEAK FLOOD LEVEL
WITH PROJECT
10% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Operational Footprint
Model Extent
Level (mAHD)
< 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
> 3.5
0
2
4
6
8
10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG53_DD_Level_10p_Regional.mxd

FIGURE 54
PEAK FLOOD LEVEL WITH PROJECT 10% AEP INSERT



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG54_DD_Level_10p_Regional_Zoomed.mxd

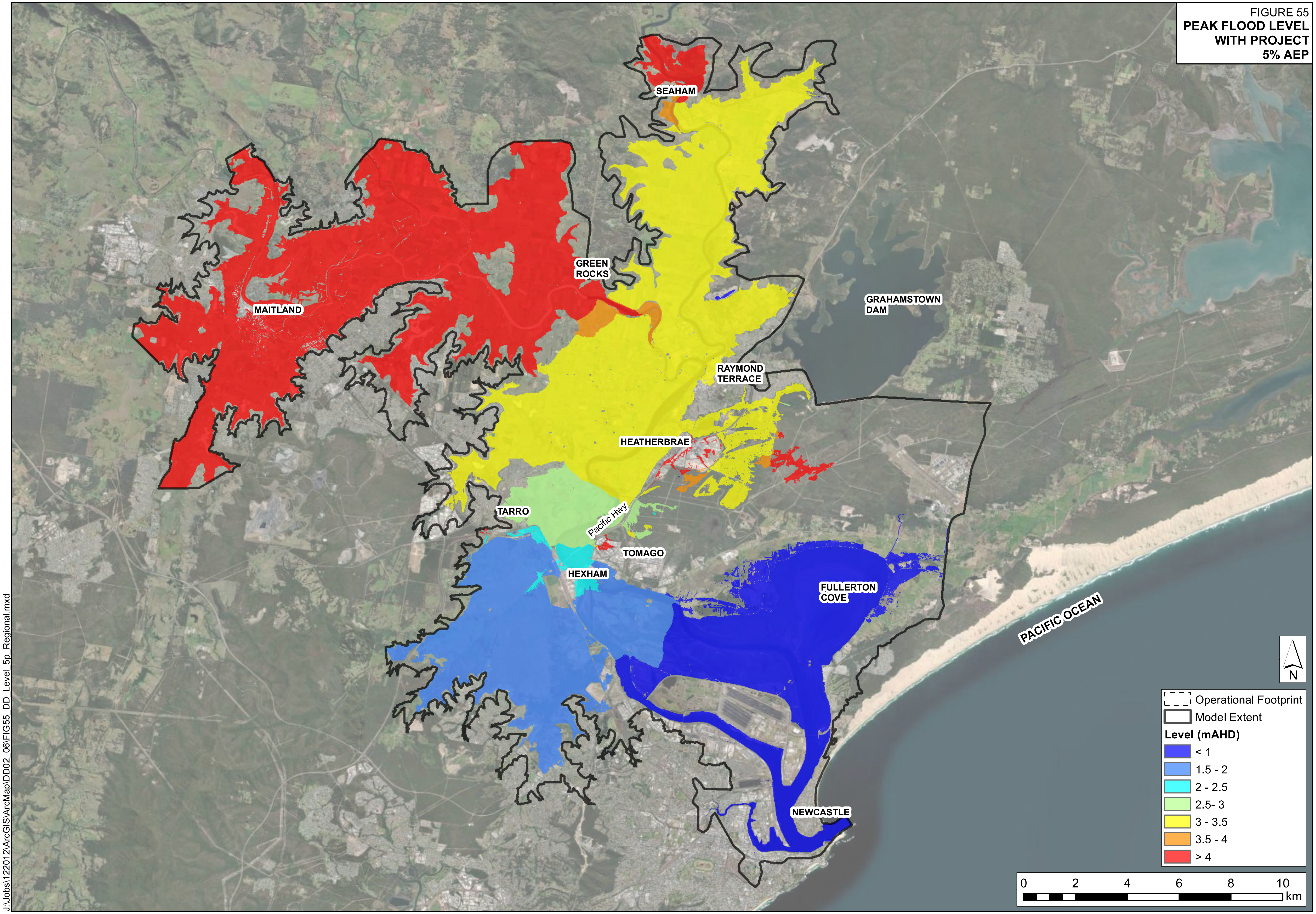


FIGURE 55
PEAK FLOOD LEVEL
WITH PROJECT
5% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Operational Footprint
Model Extent
Level (mAHD)
< 1
1.5 - 2
2 - 2.5
2.5- 3
3 - 3.5
3.5 - 4
> 4
0
2
4
6
8
10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG55_DD_Level_5p_Regional.mxd

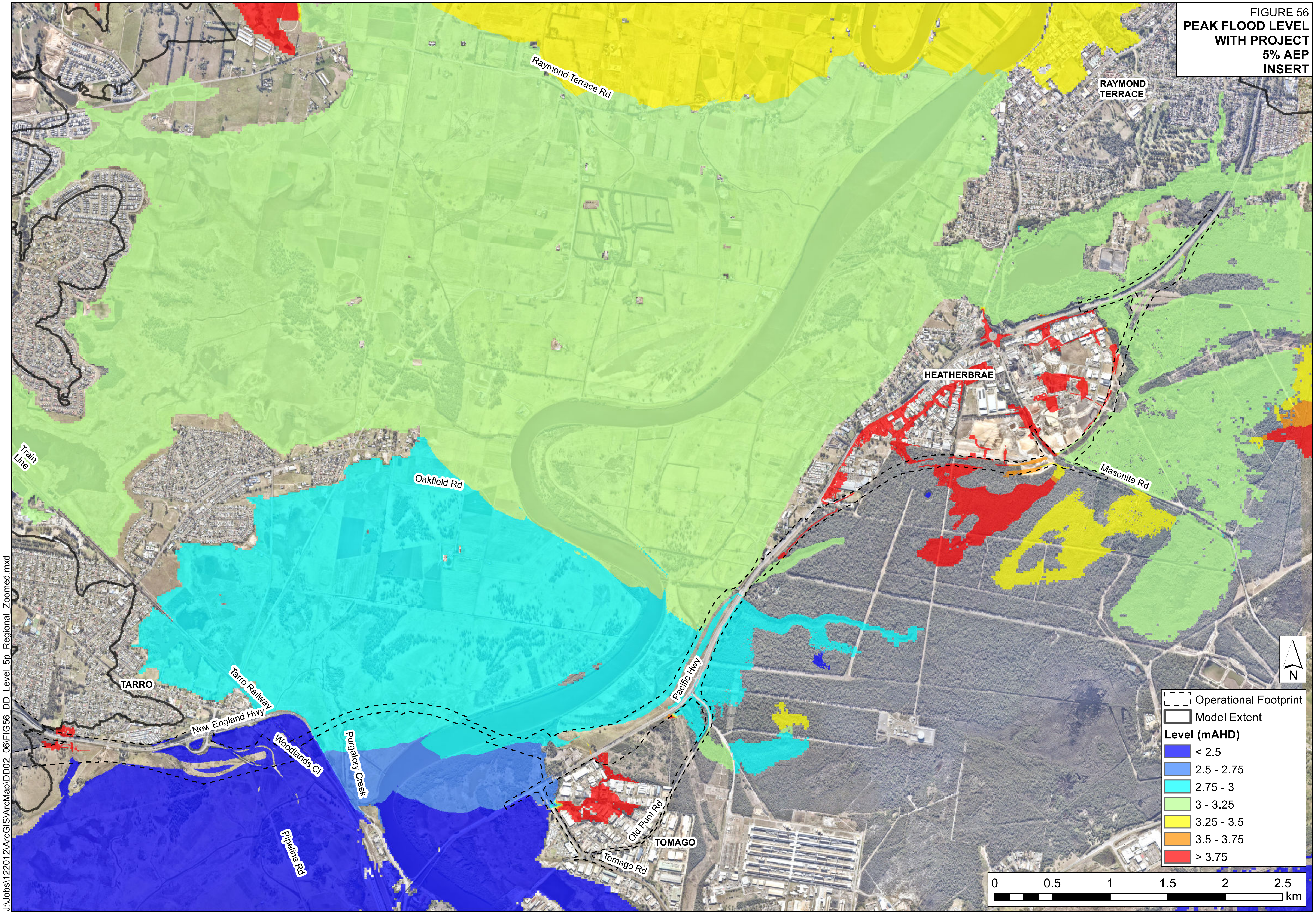


FIGURE 56
PEAK FLOOD LEVEL
WITH PROJECT
5% AEP
INSERT
Raymond Terrace Rd
RAYMOND
TERRACE
HEATHERBRAE
Train
Line
Oakfield Rd
Masonite Rd
Pacific Hwy
Tarro Railway
TARRO
New England Hwy
Woodlands Cl
Purgatory Creek
Old Punt Rd
TOMAGO
Tomago Rd
Pipeline Rd
N
Operational Footprint
Model Extent
Level (mAHD)
< 2.5
2.5 - 2.75
2.75 - 3
3 - 3.25
3.25 - 3.5
3.5 - 3.75
> 3.75
0
0.5
1
1.5
2
2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG56_DD_Level_5p_Regional_Zoomed.mxd

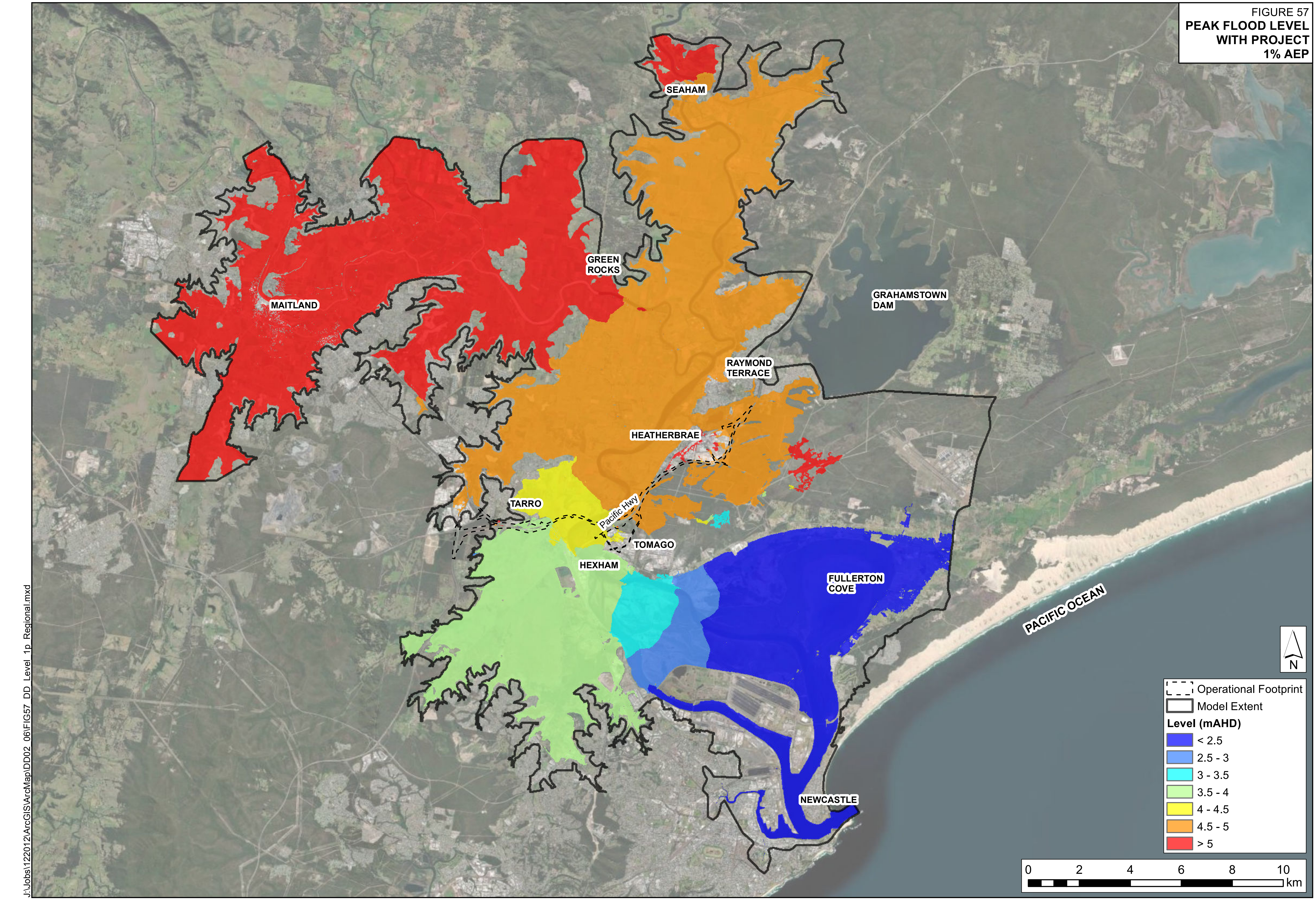


FIGURE 57
PEAK FLOOD LEVEL
WITH PROJECT
1% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Operational Footprint
Model Extent
Level (mAHD)
< 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 4.5
4.5 - 5
> 5
0 2 4 6 8 10 km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG57_DD_Level_1p_Regional.mxd

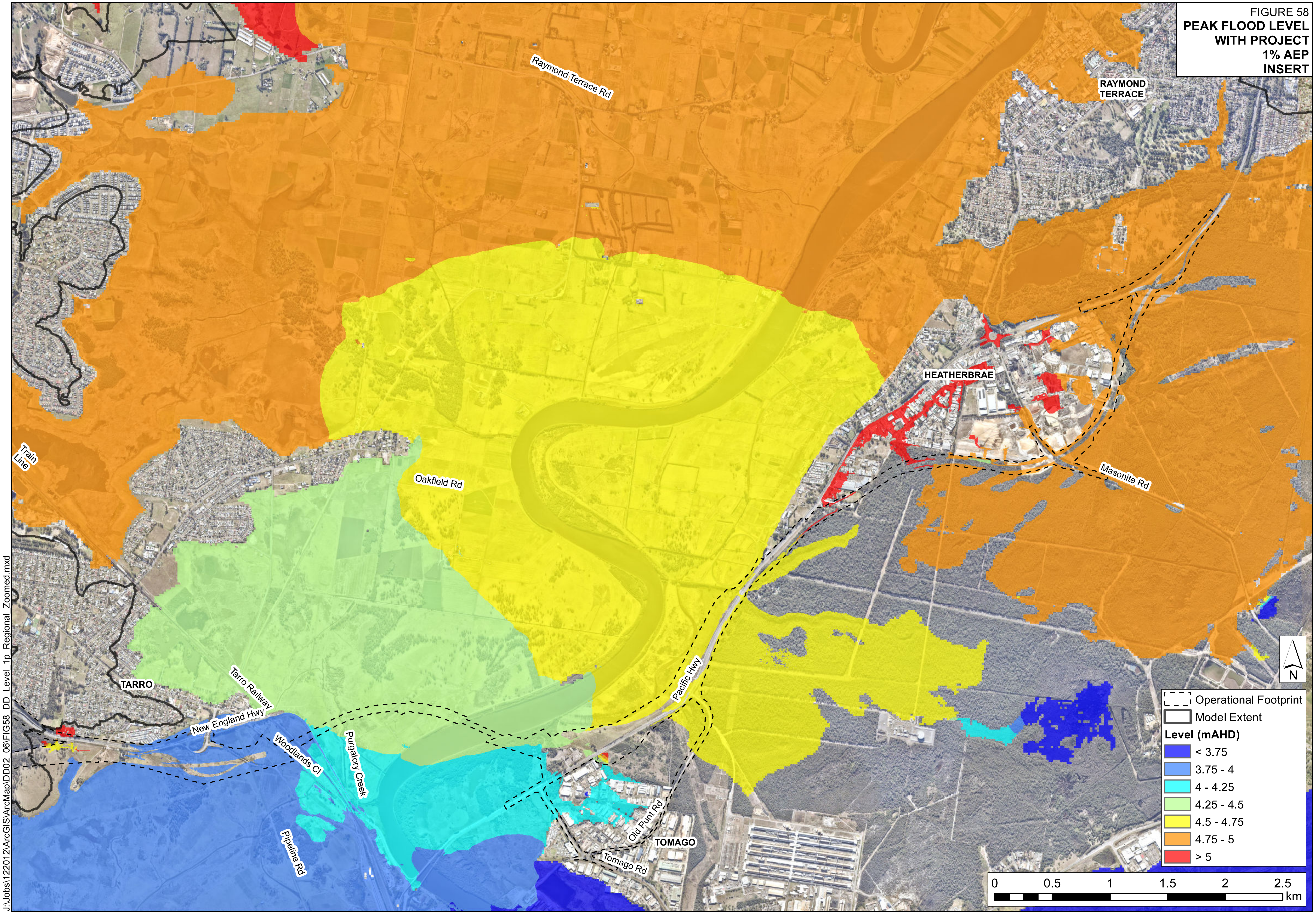


FIGURE 58
PEAK FLOOD LEVEL WITH PROJECT 1% AEP INSERT

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG58_DD_Level_1p_Regional_Zoomed.mxd

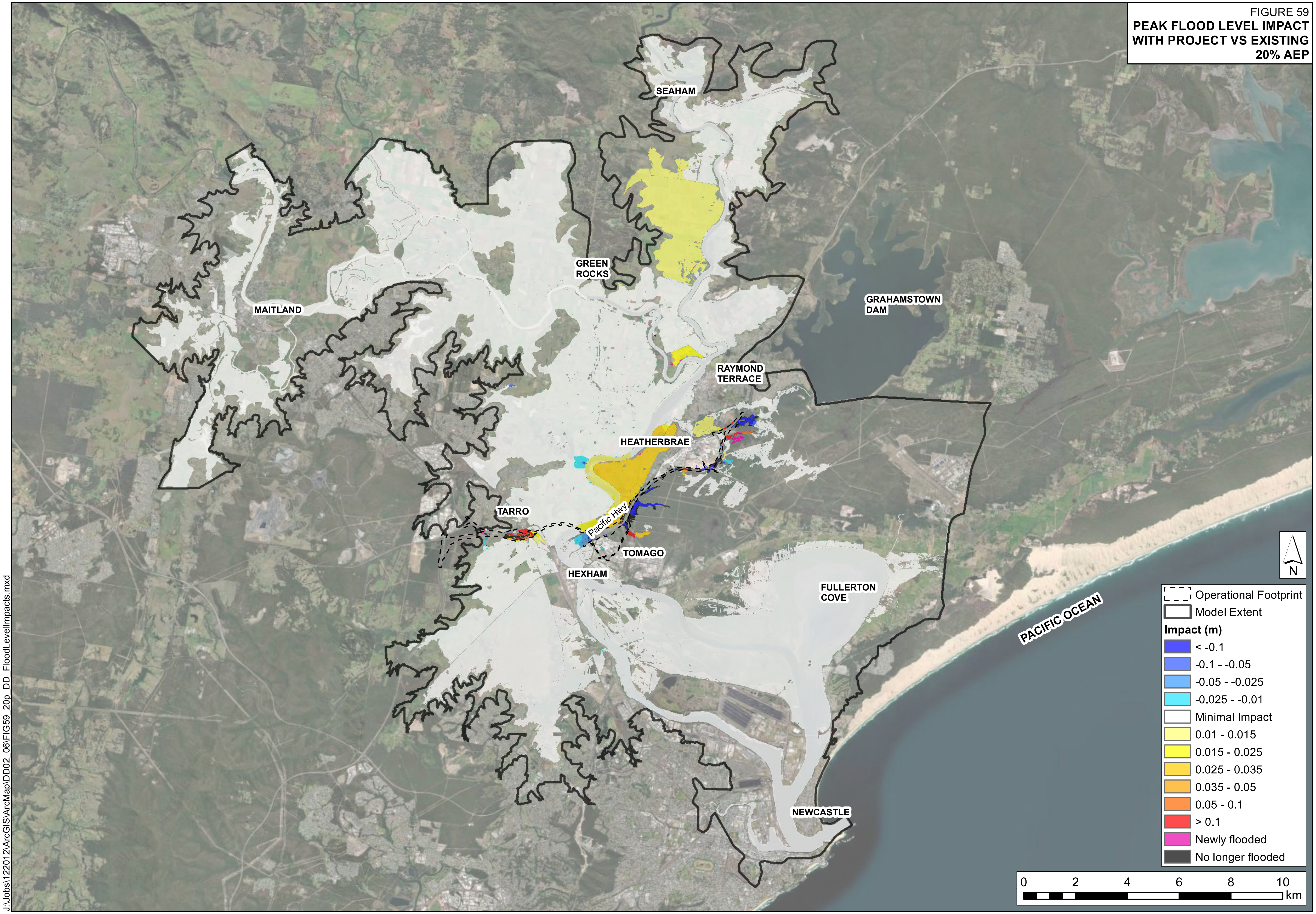


FIGURE 59
PEAK FLOOD LEVEL IMPACT
WITH PROJECT VS EXISTING
20% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Operational Footprint
Model Extent
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.025
-0.025 - -0.01
Minimal Impact
0.01 - 0.015
0.015 - 0.025
0.025 - 0.035
0.035 - 0.05
0.05 - 0.1
> 0.1
Newly flooded
No longer flooded
0 2 4 6 8 10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG59_20p_DD_FloodLevelImpacts.mxd

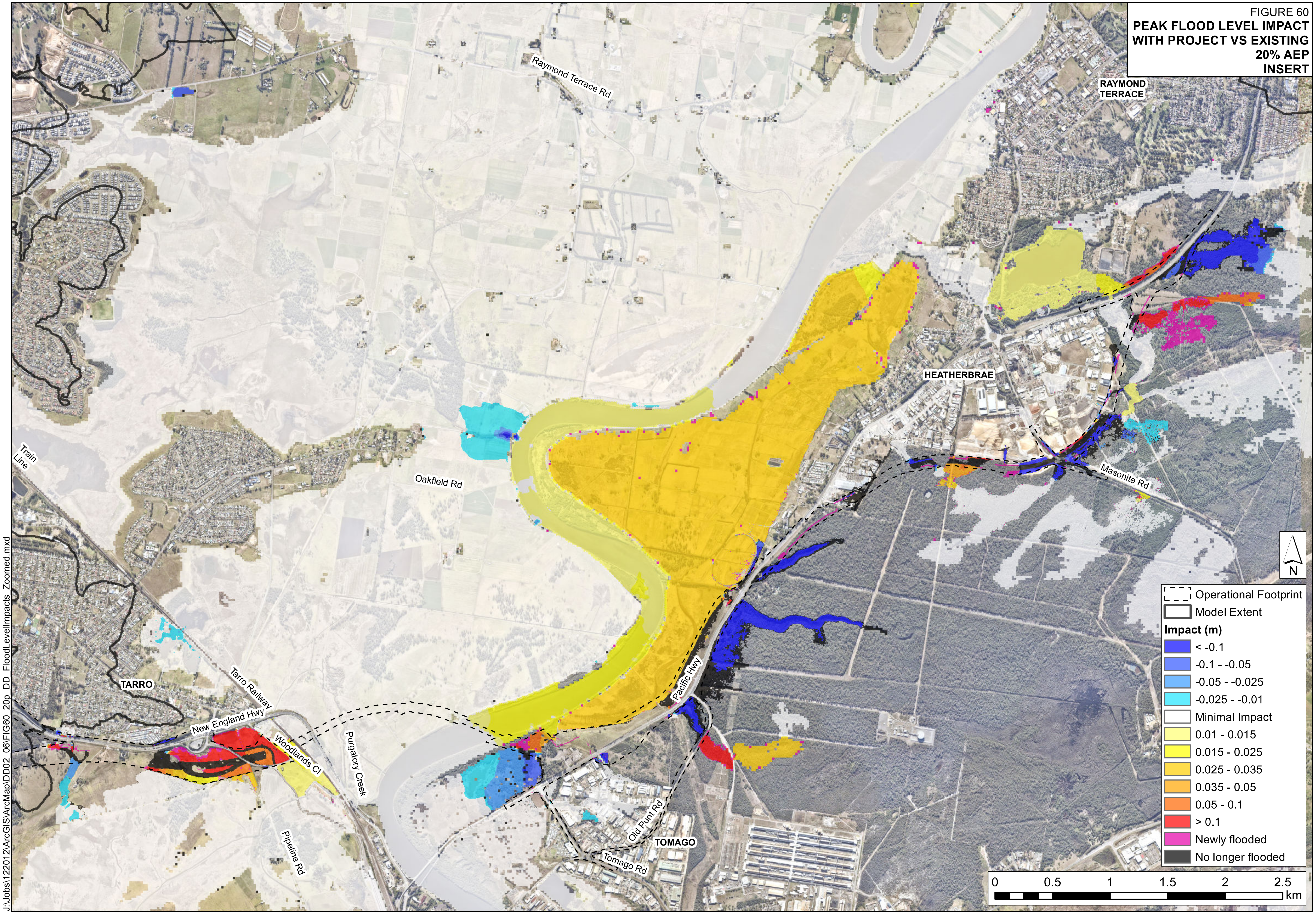
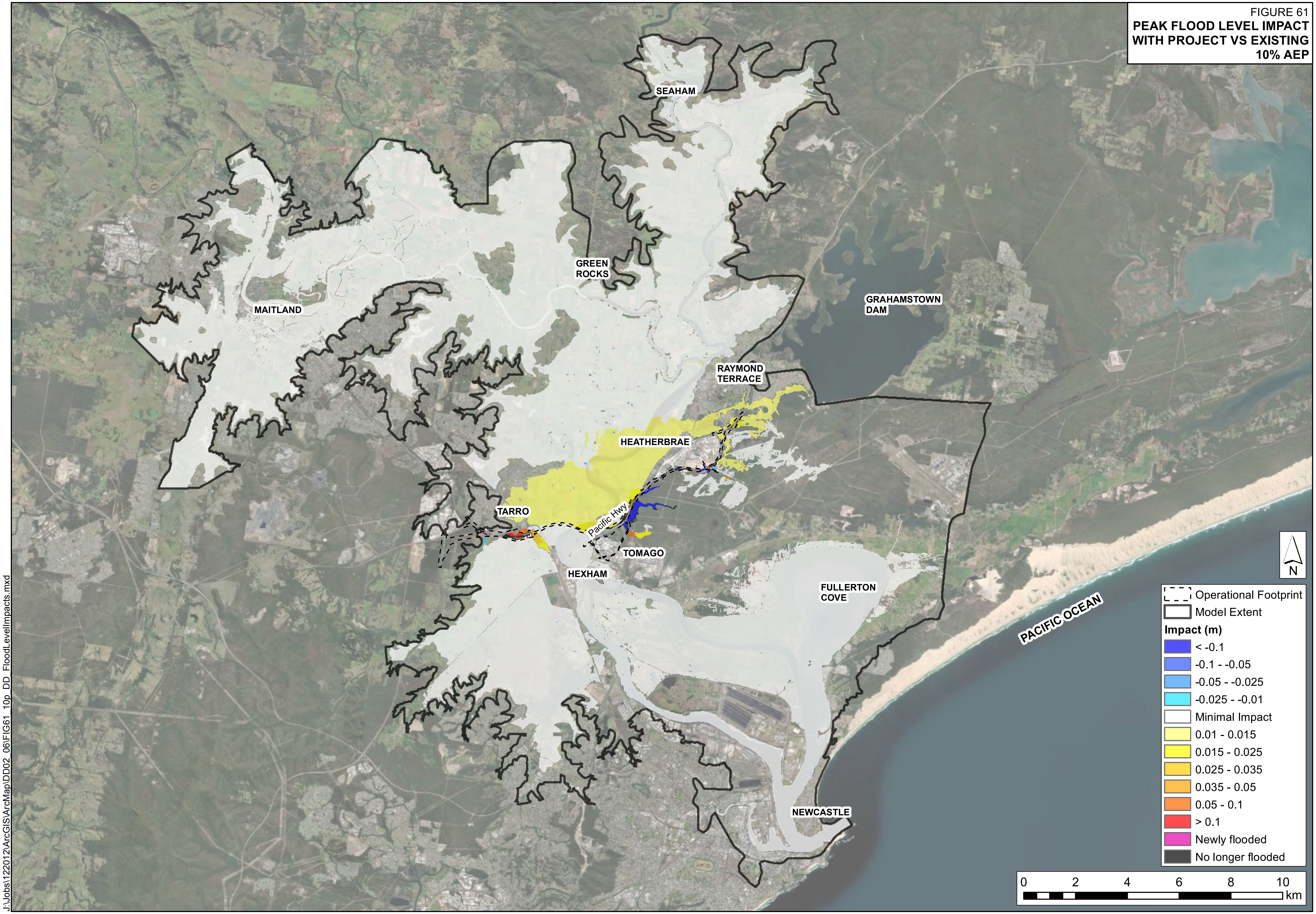


FIGURE 60
PEAK FLOOD LEVEL IMPACT
WITH PROJECT VS EXISTING
20% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Oakfield Rd
Train Line
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Pacific Hwy
Old Punt Rd
TOMAGO
Tomago Rd
N
Operational Footprint
Model Extent
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.025
-0.025 - -0.01
Minimal Impact
0.01 - 0.015
0.015 - 0.025
0.025 - 0.035
0.035 - 0.05
0.05 - 0.1
> 0.1
Newly flooded
No longer flooded
0 0.5 1 1.5 2 2.5 km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG60_20p_DD_FloodLevelImpacts_Zoomed.mxd

FIGURE 61

PEAK FLOOD LEVEL IMPACT WITH PROJECT VS EXISTING 10% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG61_10p_DD_FloodLevelImpacts.mxd

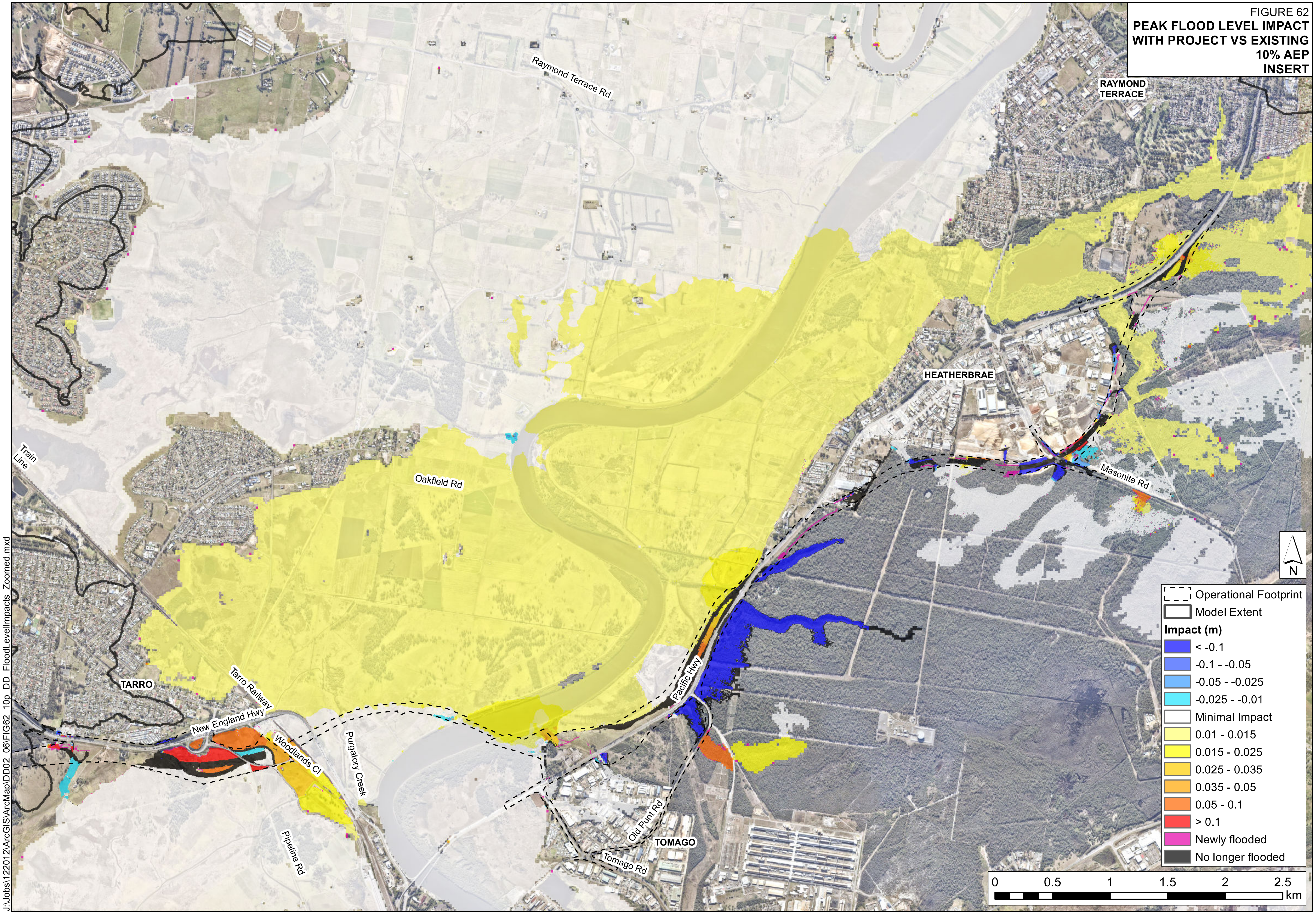


FIGURE 62
PEAK FLOOD LEVEL IMPACT
WITH PROJECT VS EXISTING
10% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Oakfield Rd
Train Line
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Pacific Hwy
Old Punt Rd
TOMAGO
Tomago Rd
N
Operational Footprint
Model Extent
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.025
-0.025 - -0.01
Minimal Impact
0.01 - 0.015
0.015 - 0.025
0.025 - 0.035
0.035 - 0.05
0.05 - 0.1
> 0.1
Newly flooded
No longer flooded
0 0.5 1 1.5 2 2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG62_10p_DD_FloodLevelImpacts_Zoomed.mxd

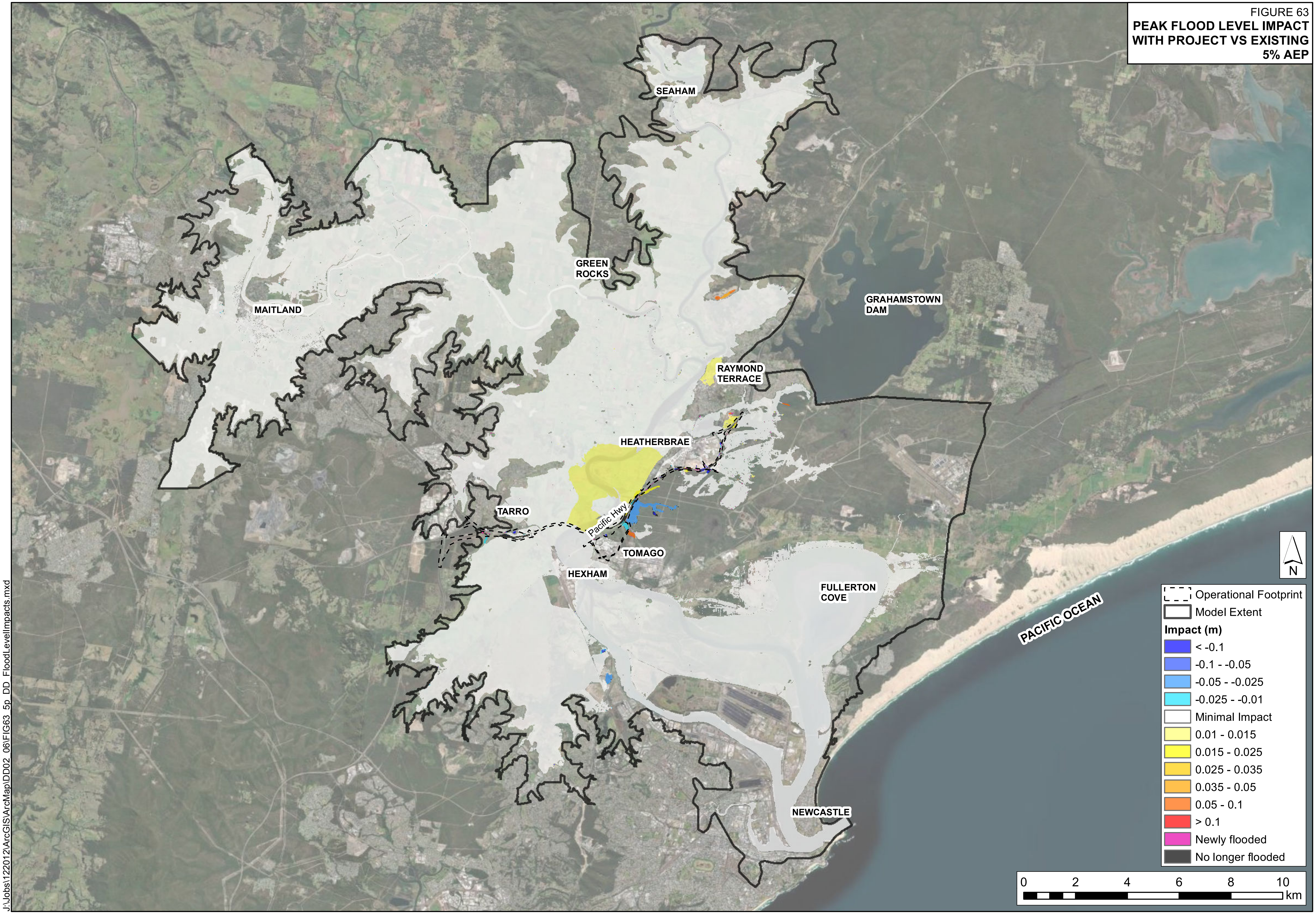


FIGURE 63
PEAK FLOOD LEVEL IMPACT
WITH PROJECT VS EXISTING
5% AEP
SEAHAM
GREEN
ROCKS
MAITLAND
GRAHAMSTOWN
DAM
RAYMOND
TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON
COVE
PACIFIC OCEAN
NEWCASTLE
N
Operational Footprint
Model Extent
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.025
-0.025 - -0.01
Minimal Impact
0.01 - 0.015
0.015 - 0.025
0.025 - 0.035
0.035 - 0.05
0.05 - 0.1
> 0.1
Newly flooded
No longer flooded
0 2 4 6 8 10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG63_5p_DD_FloodLevelImpacts.mxd

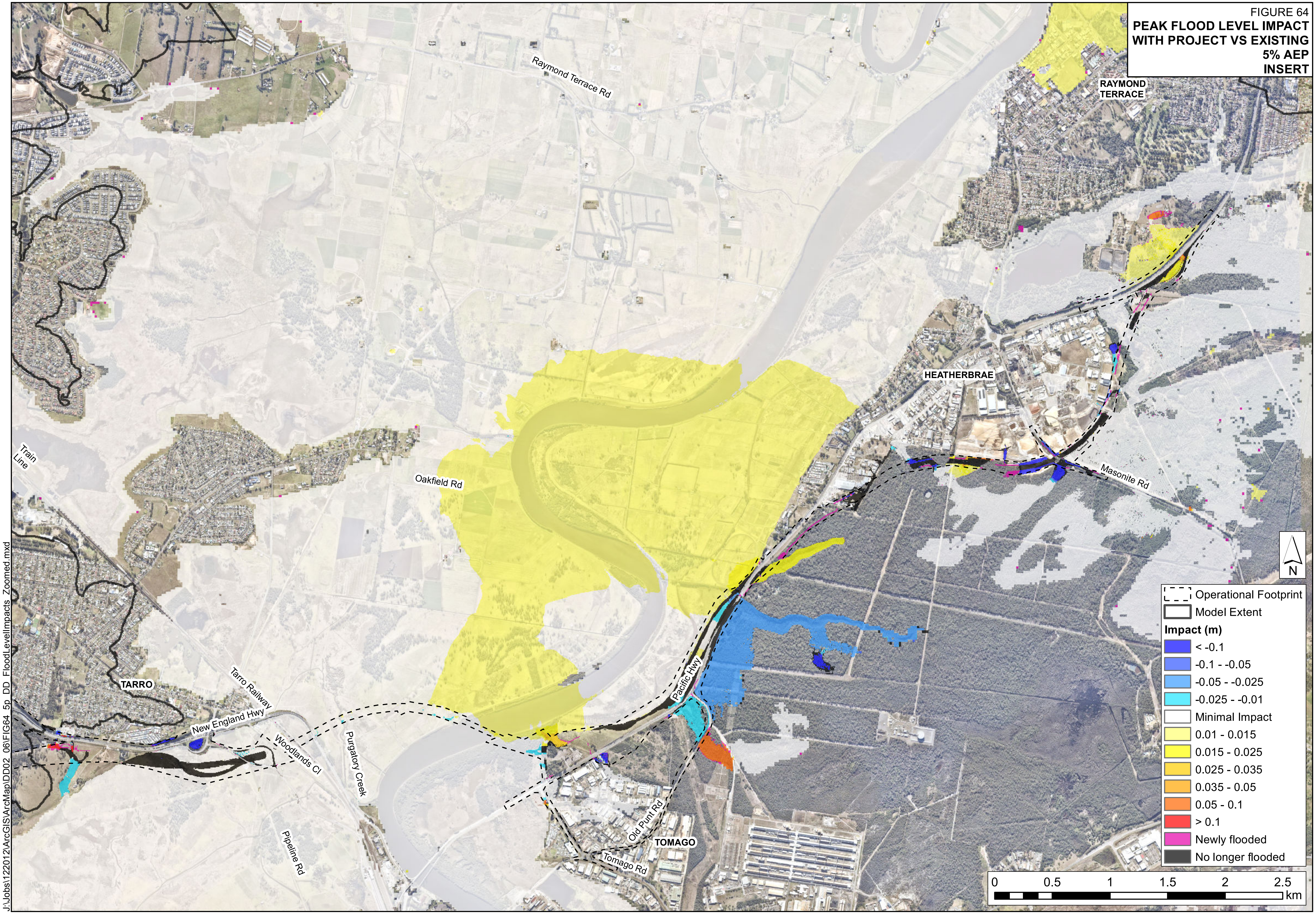


FIGURE 64
PEAK FLOOD LEVEL IMPACT
WITH PROJECT VS EXISTING
5% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Oakfield Rd
Train Line
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Pacific Hwy
Old Punt Rd
TOMAGO
Tomago Rd
N
Operational Footprint
Model Extent
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.025
-0.025 - -0.01
Minimal Impact
0.01 - 0.015
0.015 - 0.025
0.025 - 0.035
0.035 - 0.05
0.05 - 0.1
> 0.1
Newly flooded
No longer flooded
0 0.5 1 1.5 2 2.5 km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG64_5p_DD_FloodLevelImpacts_Zoomed.mxd

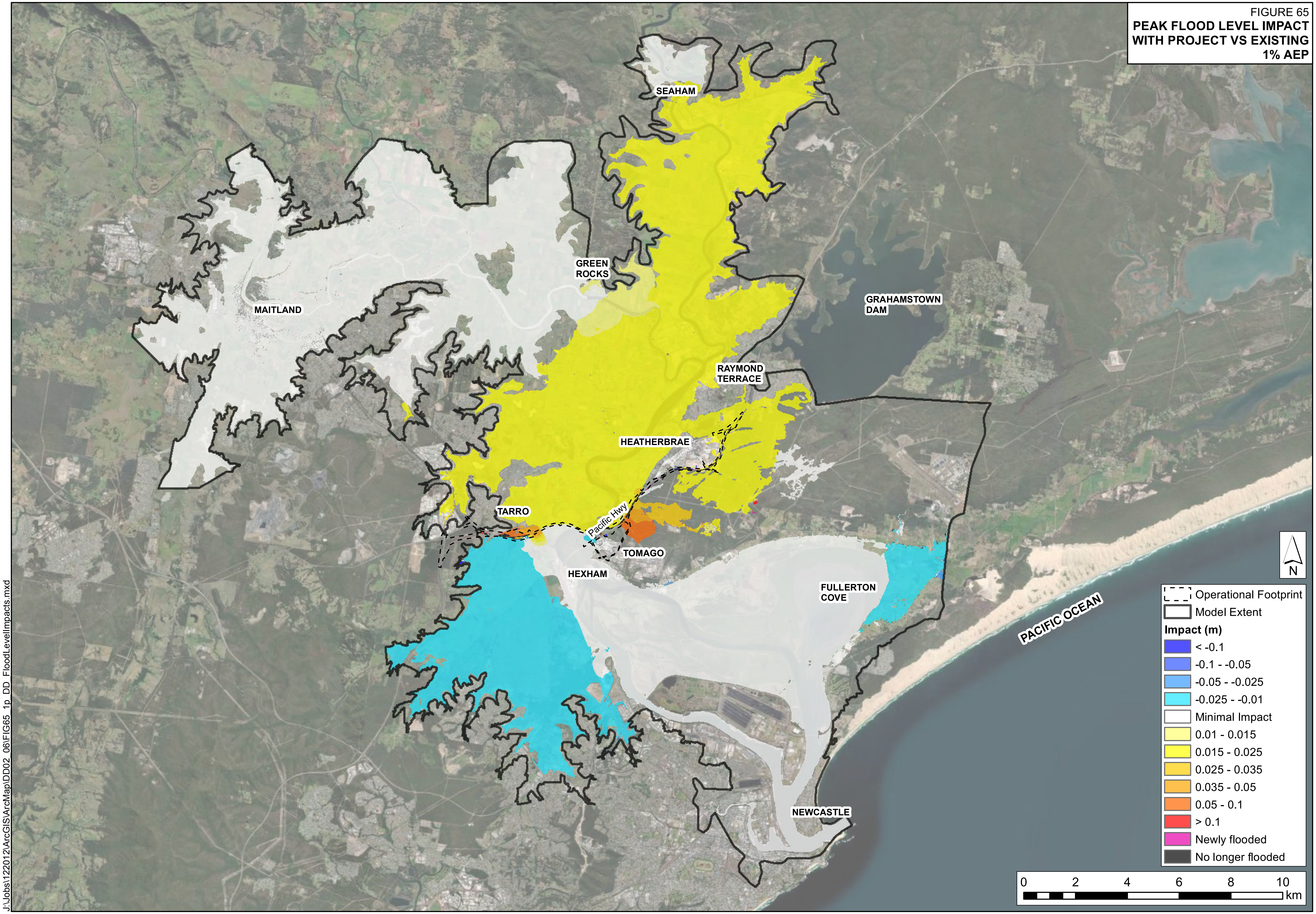


FIGURE 65
PEAK FLOOD LEVEL IMPACT
WITH PROJECT VS EXISTING
1% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Operational Footprint
Model Extent
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.025
-0.025 - -0.01
Minimal Impact
0.01 - 0.015
0.015 - 0.025
0.025 - 0.035
0.035 - 0.05
0.05 - 0.1
> 0.1
Newly flooded
No longer flooded
0 2 4 6 8 10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG65_1p_DD_FloodLevelImpacts.mxd

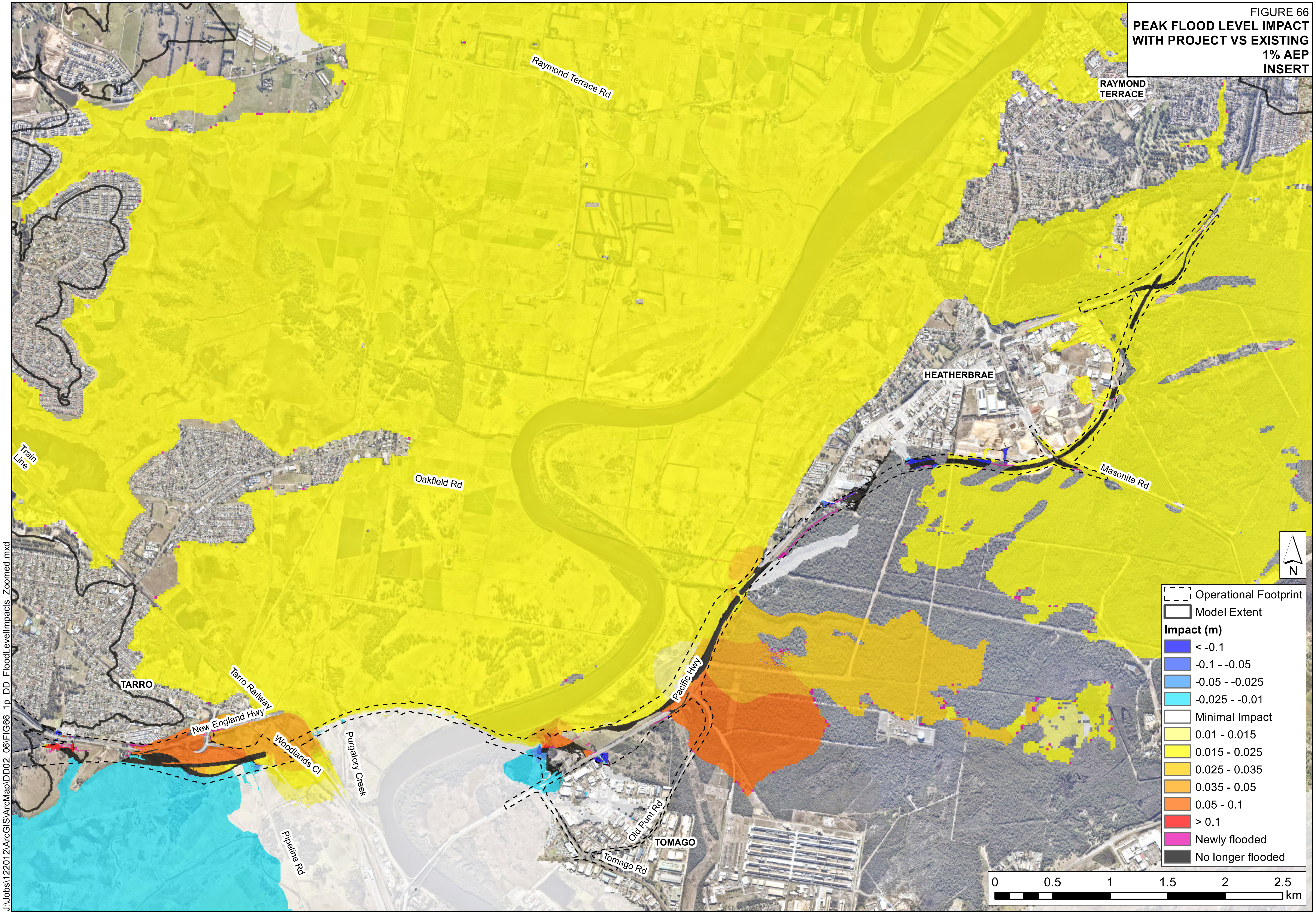


FIGURE 66
PEAK FLOOD LEVEL IMPACT WITH PROJECT VS EXISTING 1% AEP INSERT

J:\Jobs\122012\ArcGIS\ArcMap\DD02 06\FIG66 1p DD FloodLevelImpacts Zoomed.mxd

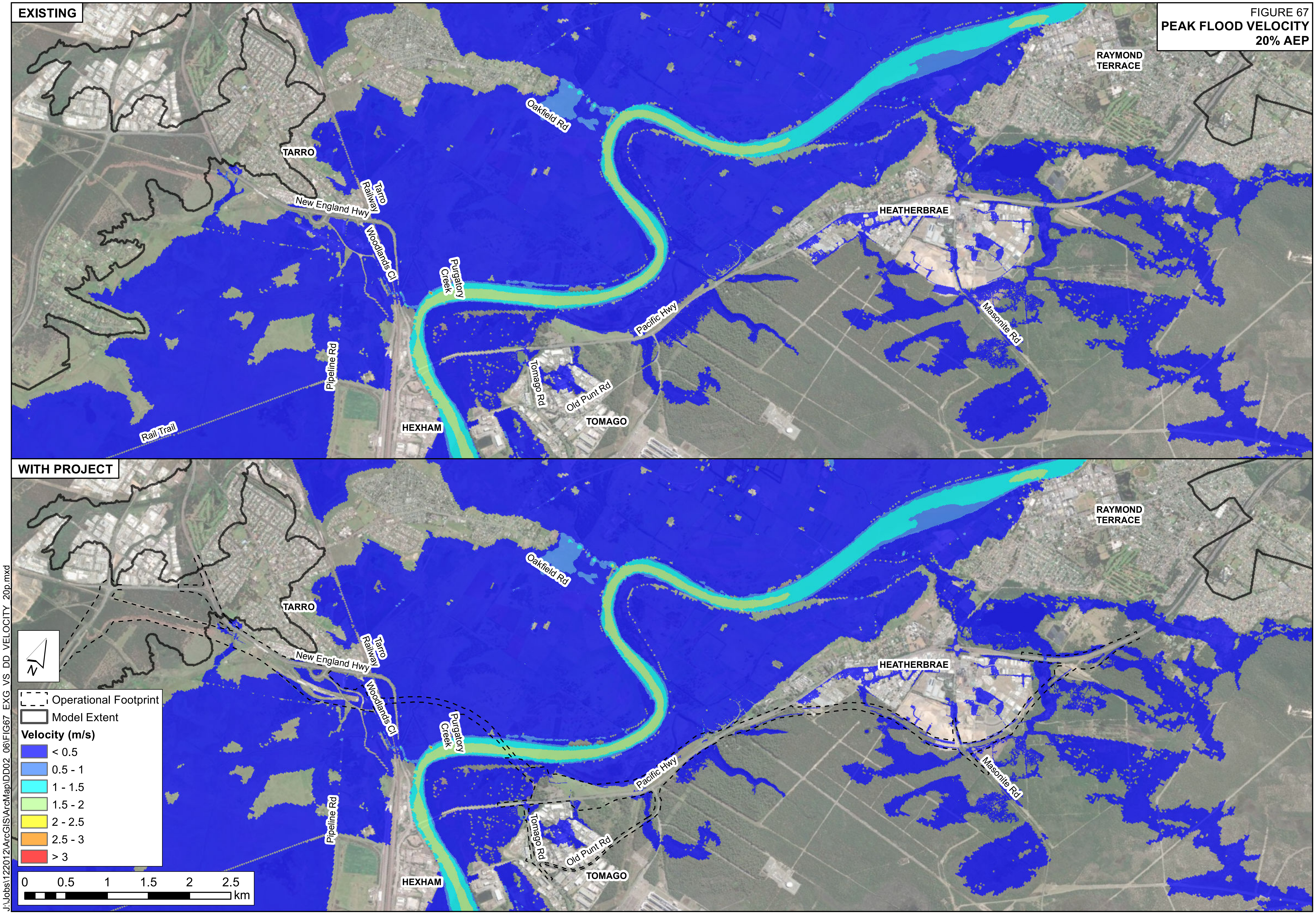
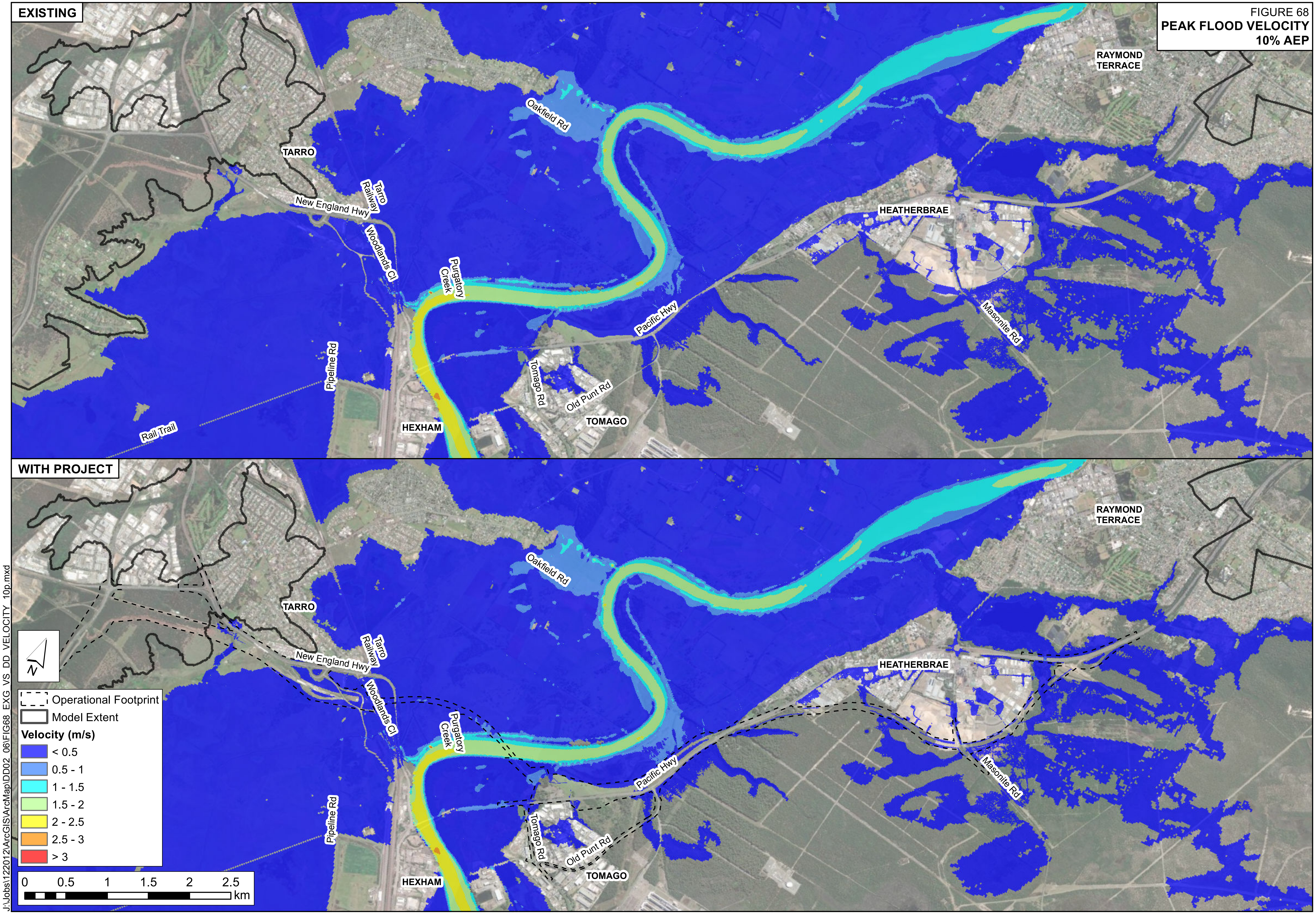
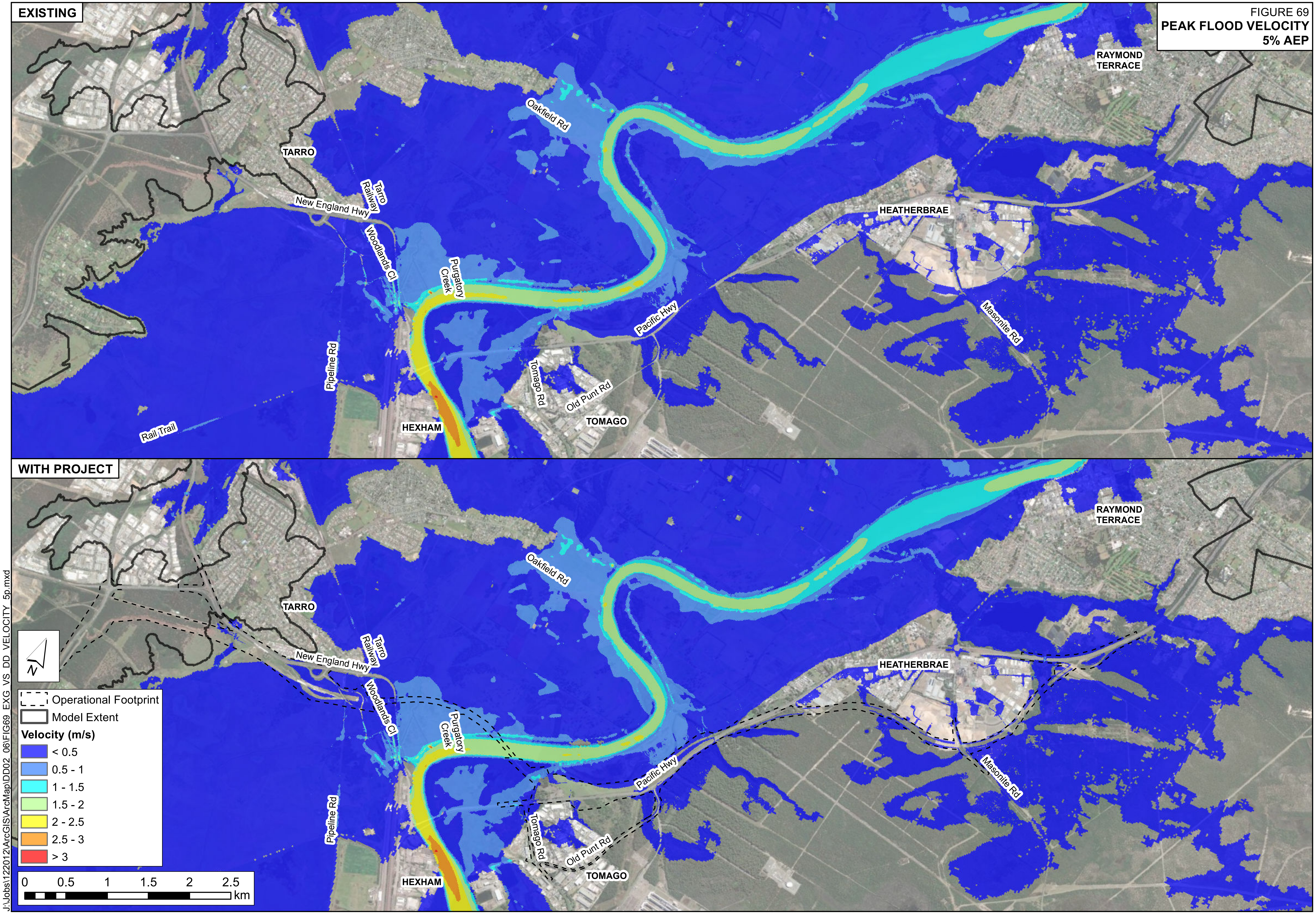


FIGURE 67
PEAK FLOOD VELOCITY
20% AEP
EXISTING
WITH PROJECT
RAYMOND TERRACE
TARRO
Oakfield Rd
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
HEATHERBRAE
Pacific Hwy
Masonite Rd
Pipeline Rd
Tomago Rd
Old Punt Rd
TOMAGO
HEXHAM
Rail Trail
N
Operational Footprint
Model Extent
Velocity (m/s)
< 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
> 3
0 0.5 1 1.5 2 2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG67_EXG_VS_DD_VELOCITY_20p.mxd



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG68_EXG_VS_DD_VELOCITY_10p.mxd

FIGURE 69
PEAK FLOOD VELOCITY
5% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG69_EXG_VS_DD_VELOCITY_5p.mxd

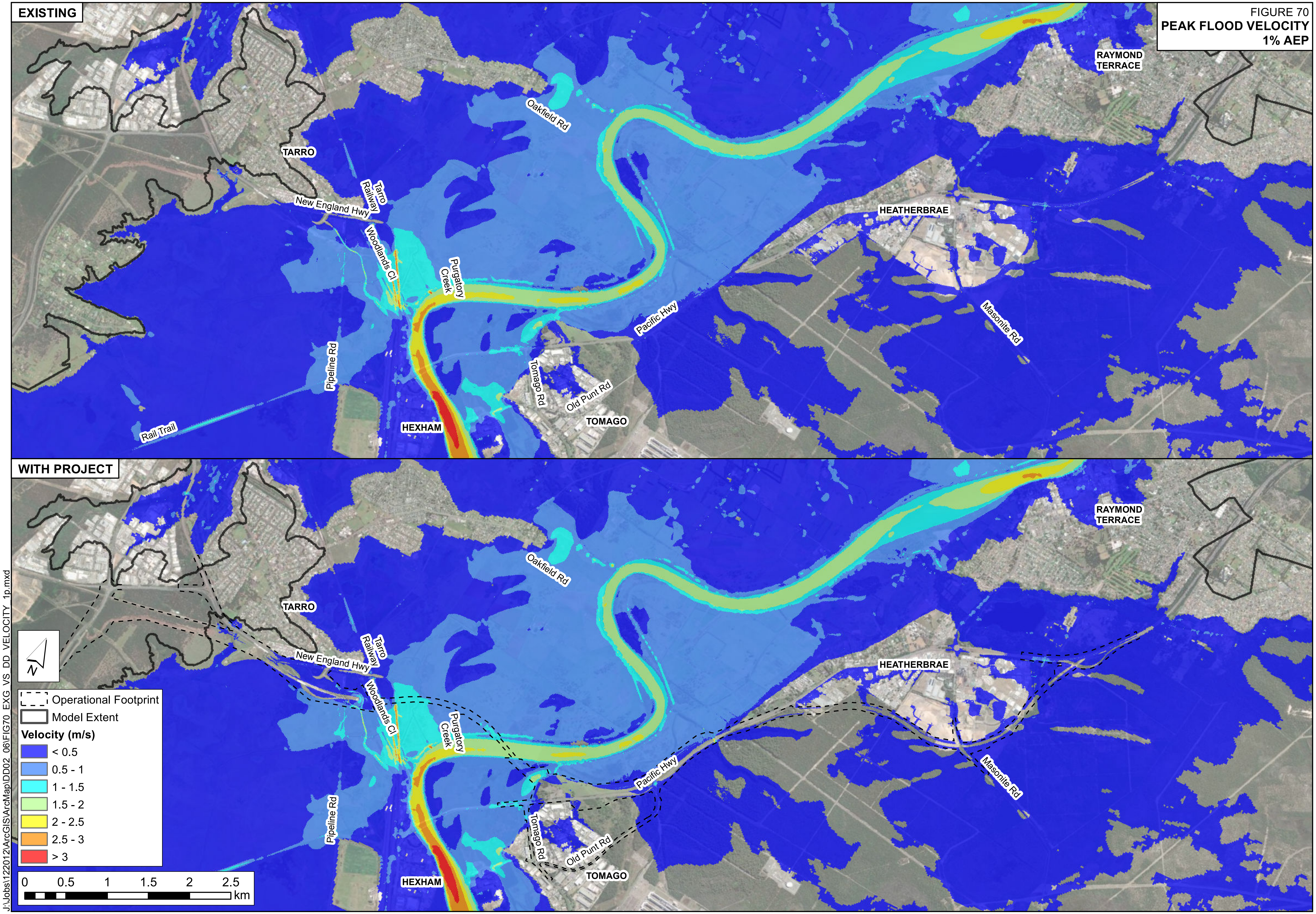
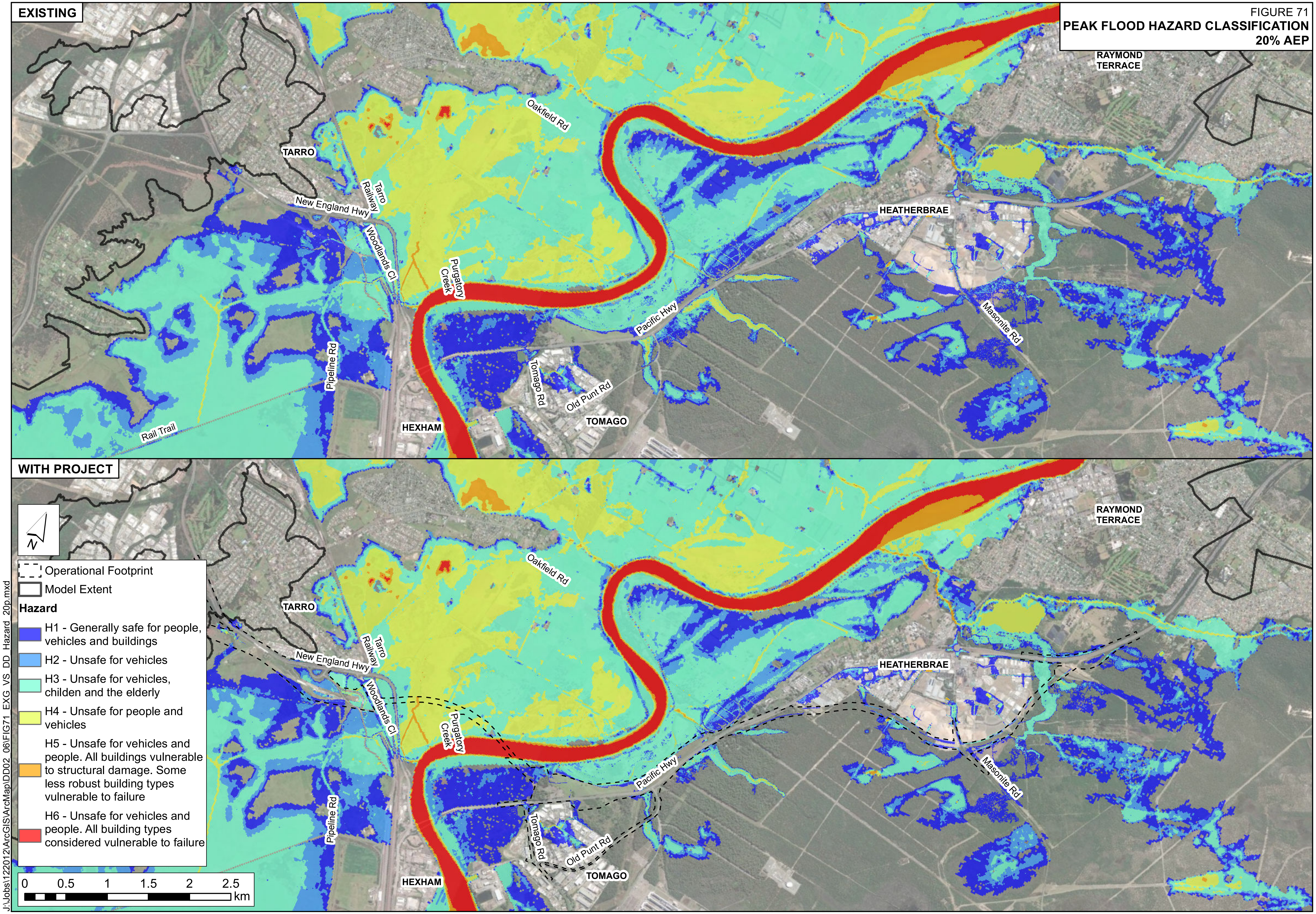


FIGURE 70
PEAK FLOOD VELOCITY
1% AEP

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG70_EXG_VS_DD_VELOCITY_1p.mxd

FIGURE 71
PEAK FLOOD HAZARD CLASSIFICATION
20% AEP



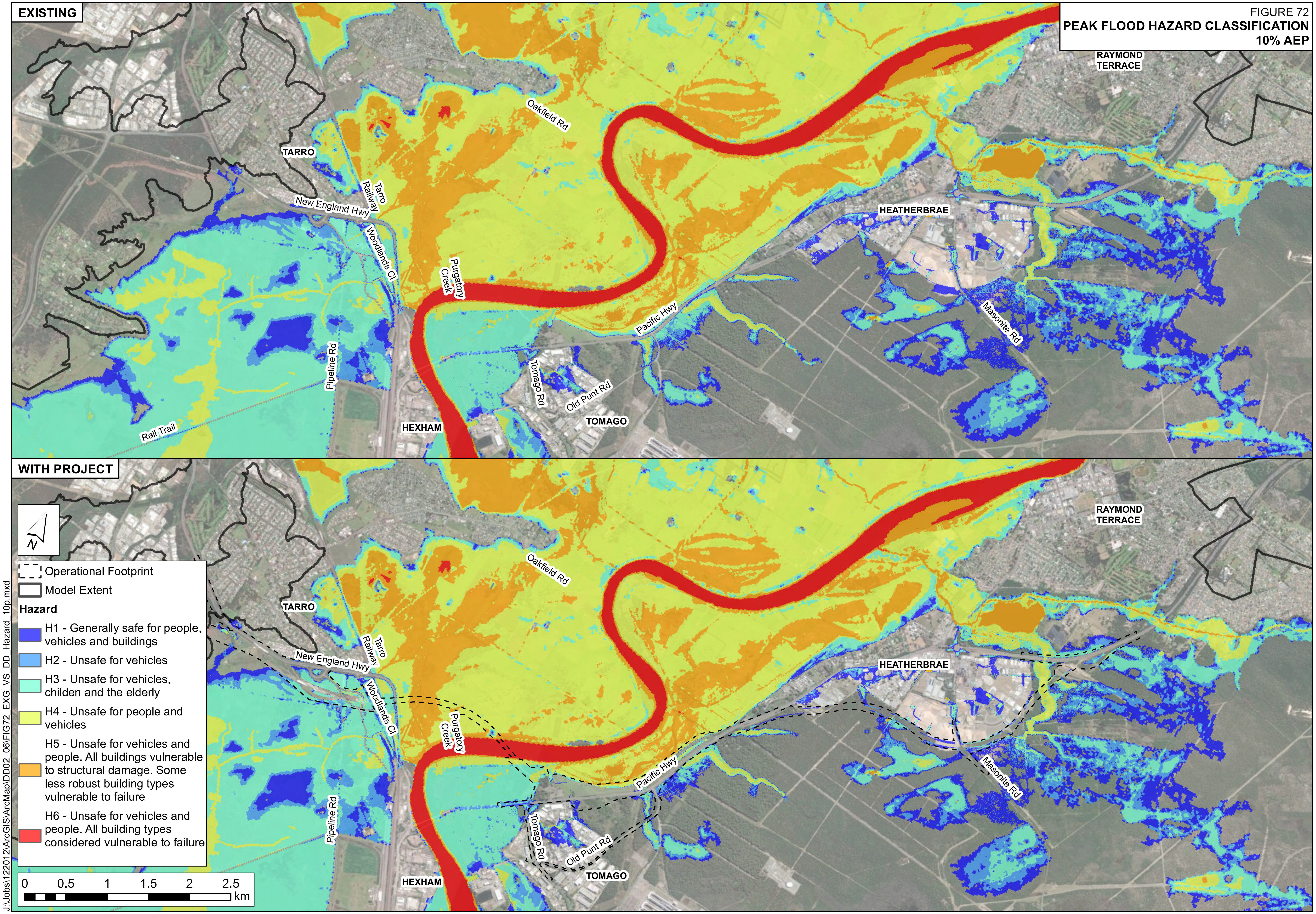


FIGURE 72
PEAK FLOOD HAZARD CLASSIFICATION
10% AEP

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG72_EXG_VS_DD_Hazard_10p.mxd

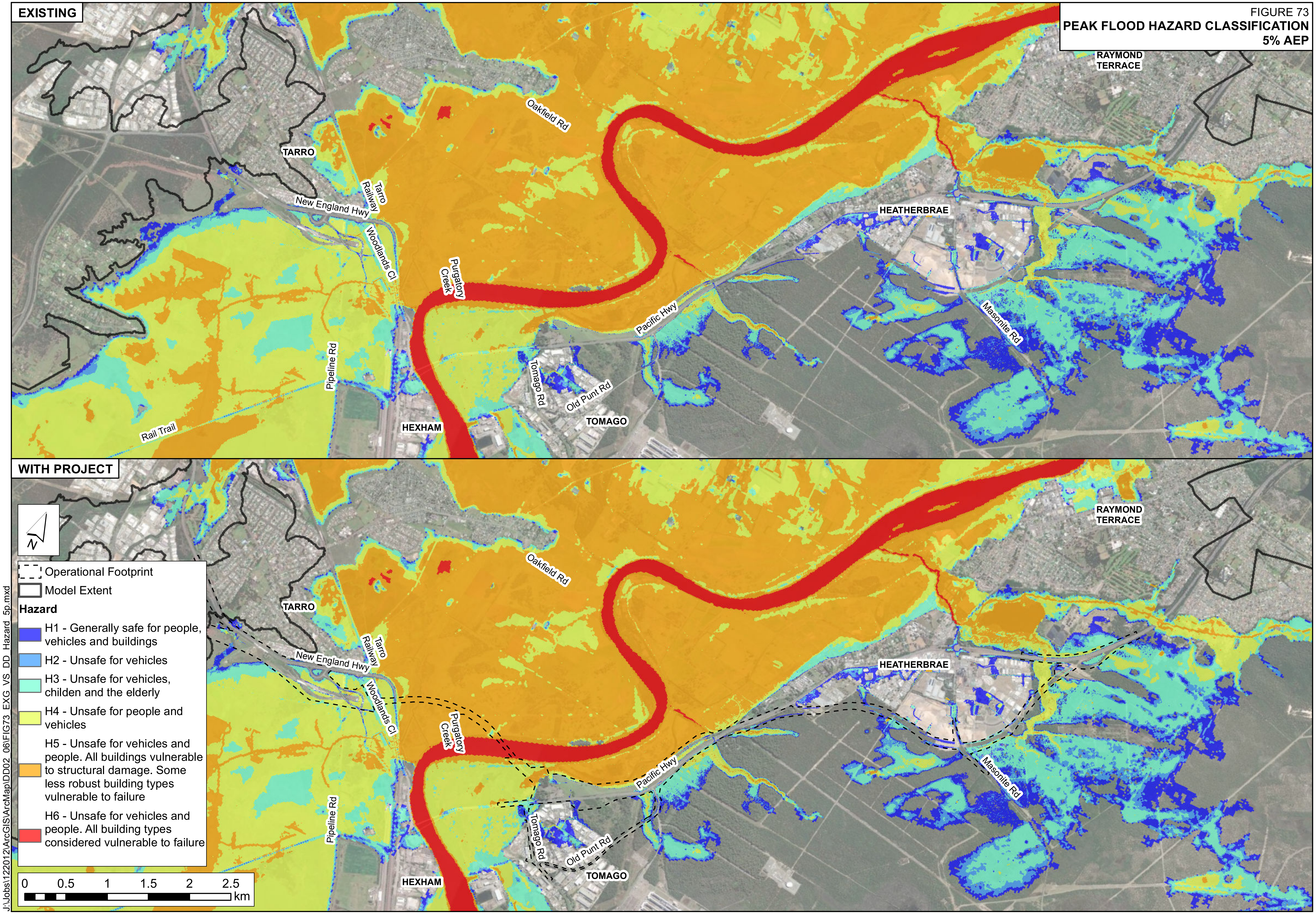
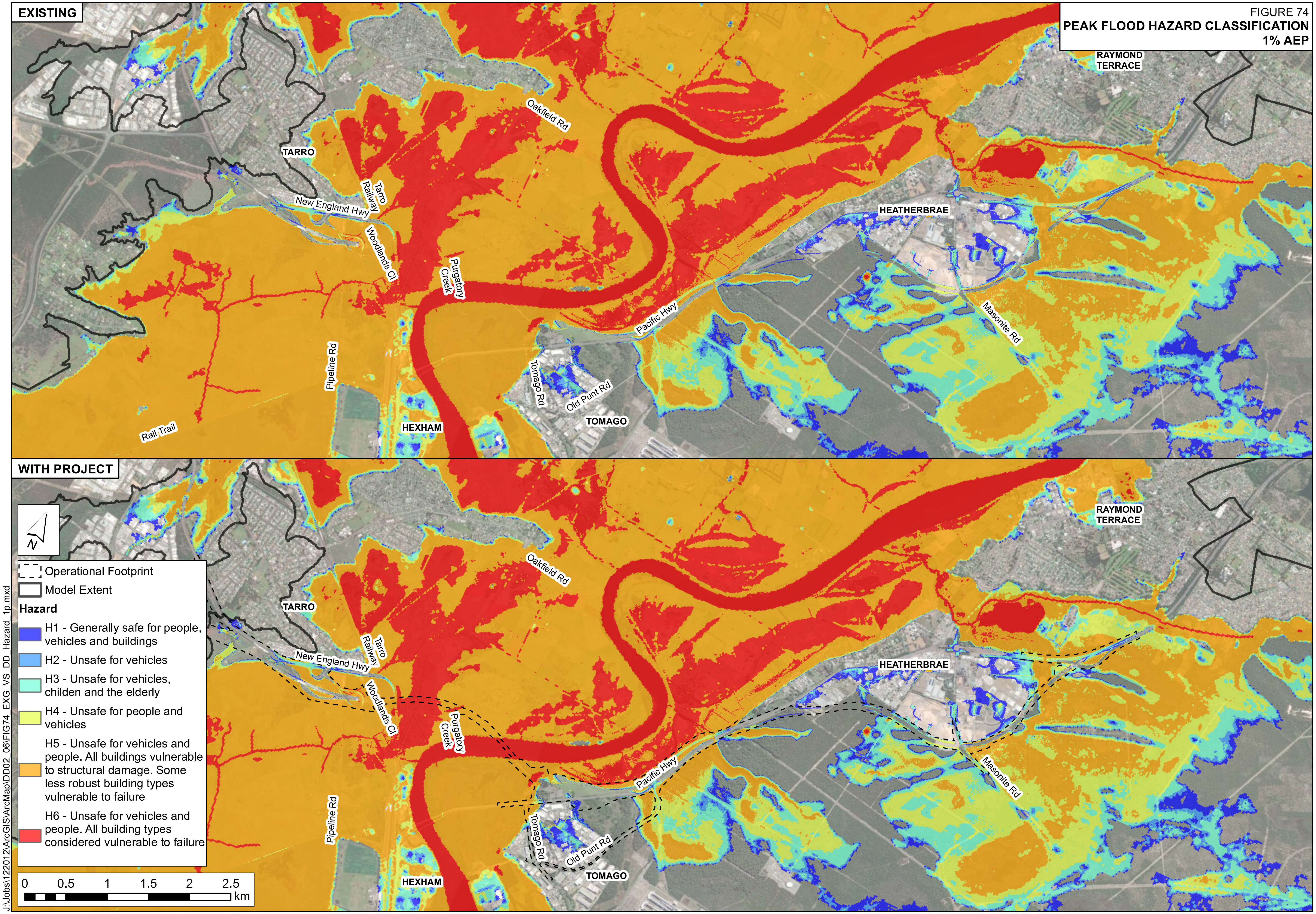


FIGURE 73
PEAK FLOOD HAZARD CLASSIFICATION
5% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG74_EXG_VS_DD_Hazard_1p.mxd

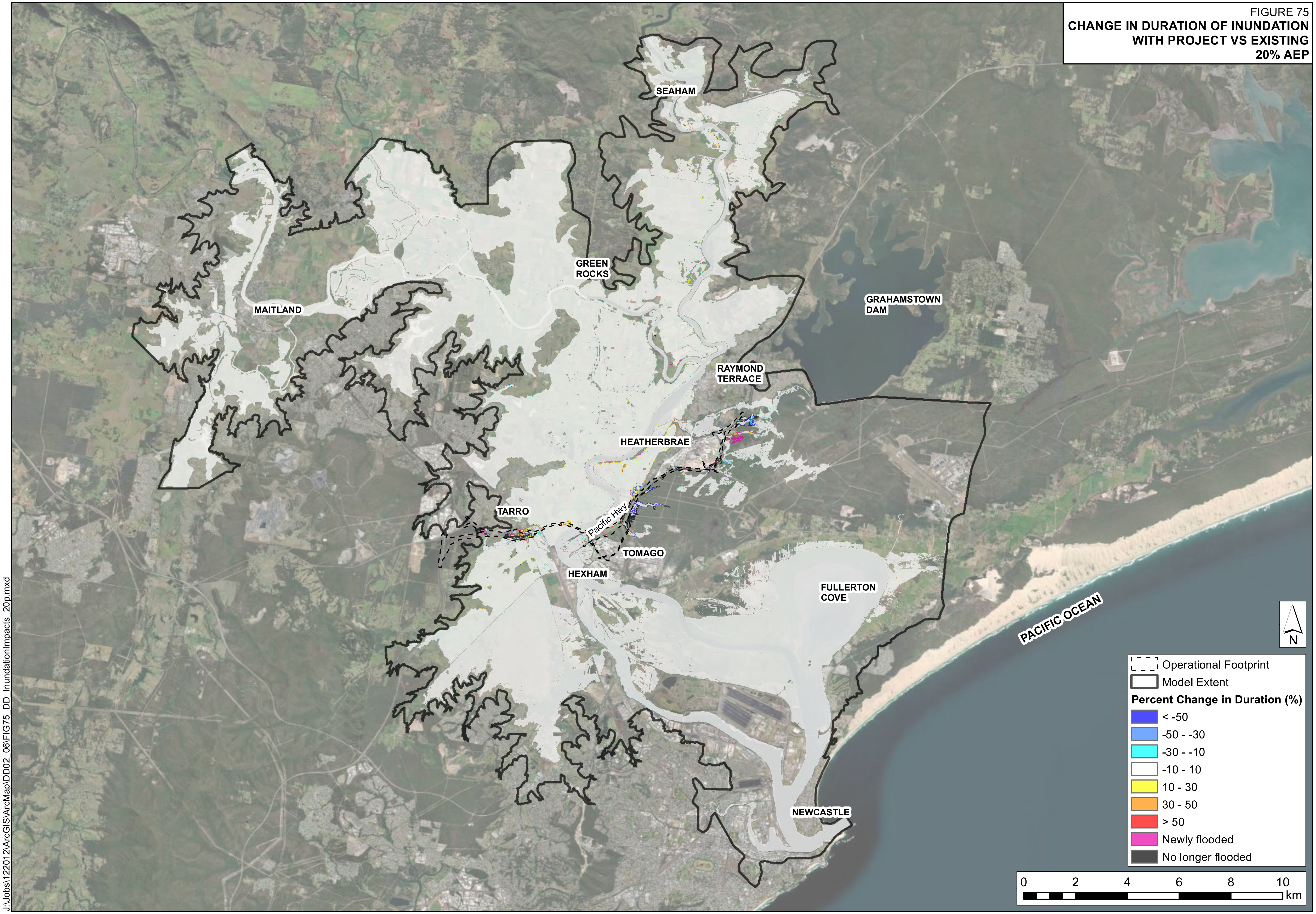


FIGURE 75
CHANGE IN DURATION OF INUNDATION WITH PROJECT VS EXISTING 20% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Operational Footprint
Model Extent
Percent Change in Duration (%)
< -50
-50 - -30
-30 - -10
-10 - 10
10 - 30
30 - 50
> 50
Newly flooded
No longer flooded
0
2
4
6
8
10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG75_DD_InundationImpacts_20p.mxd

FIGURE 76
CHANGE IN DURATION OF INUNDATION WITH PROJECT VS EXISTING 10% AEP

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06FIG76_DD_InundationImpacts_10p.mxd


FIGURE 77
CHANGE IN DURATION OF INUNDATION
WITH PROJECT VS EXISTING
5% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Operational Footprint
Model Extent
Percent Change in Duration (%)
< -50
-50 - -30
-30 - -10
-10 - 10
10 - 30
30 - 50
> 50
Newly flooded
No longer flooded
0 2 4 6 8 10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG77_DD_InundationImpacts_5p.mxd

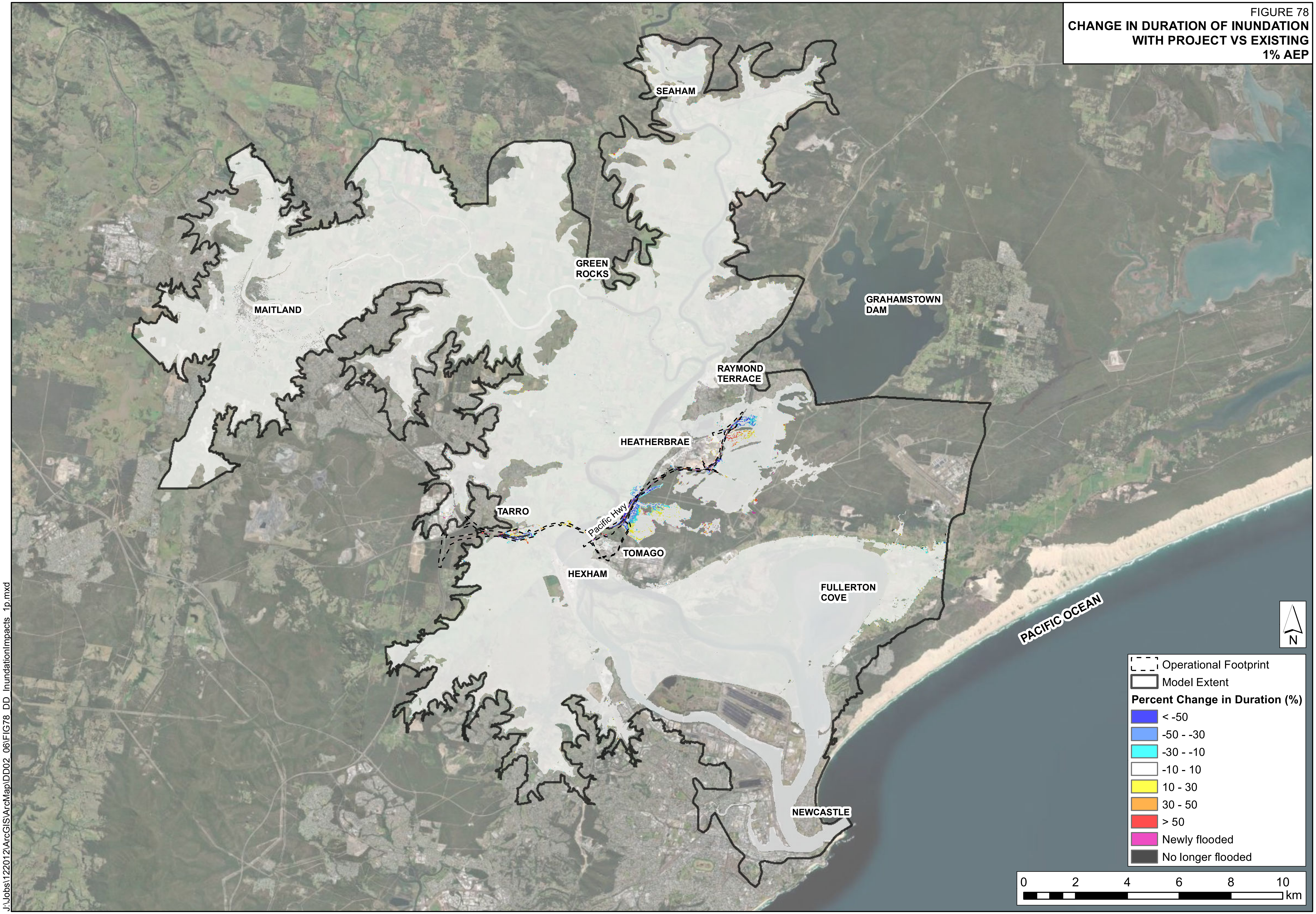
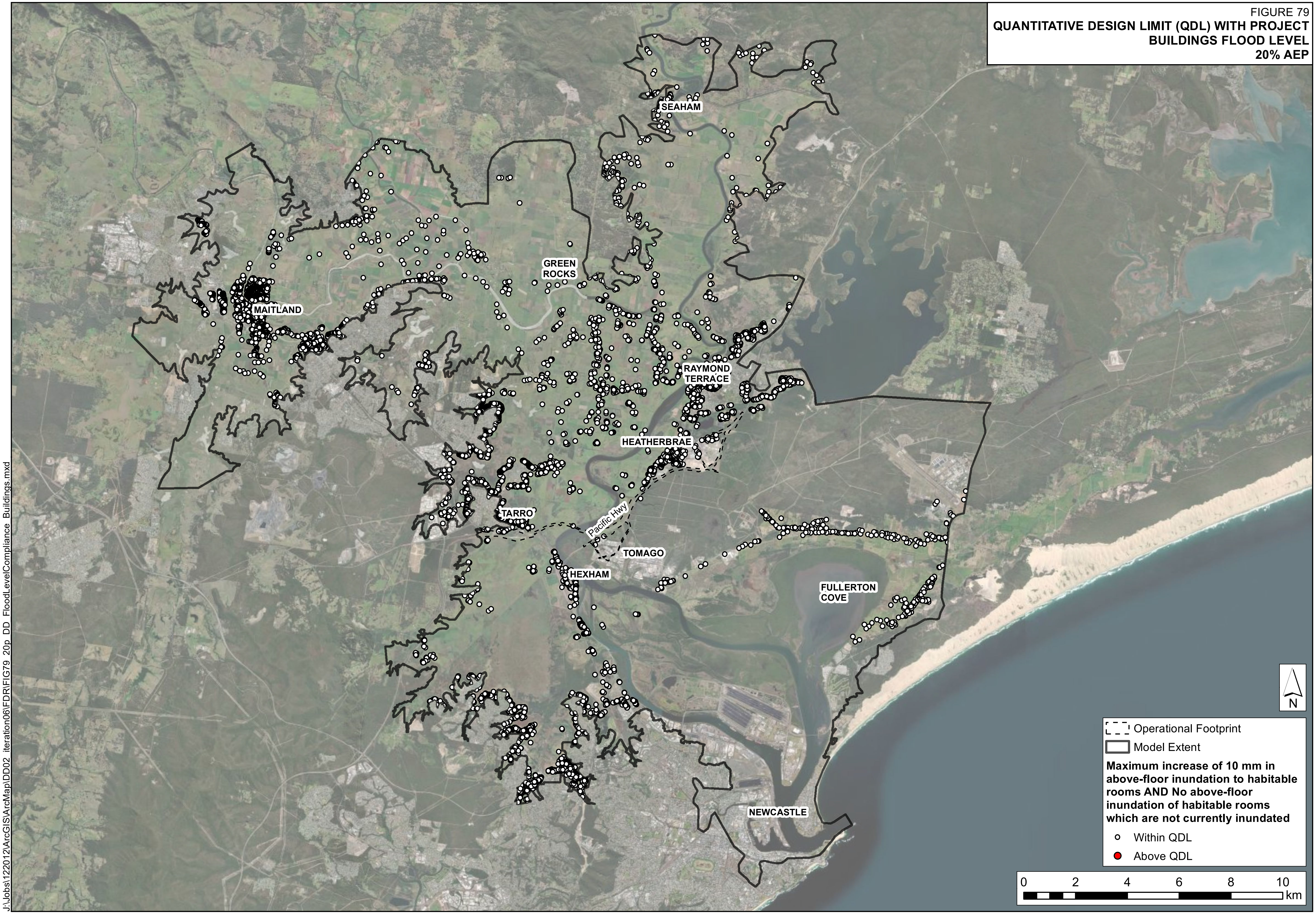


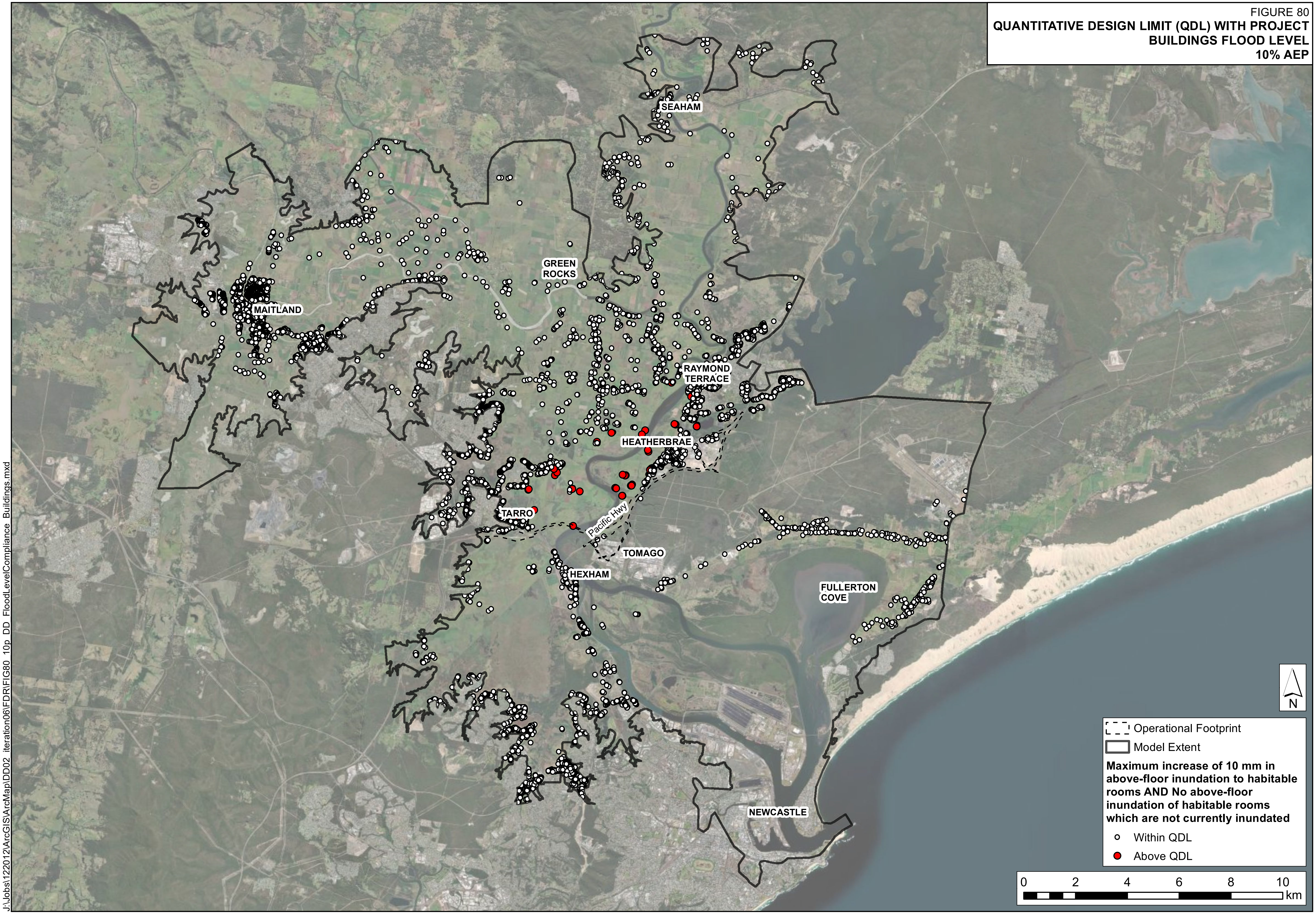
FIGURE 78
CHANGE IN DURATION OF INUNDATION
WITH PROJECT VS EXISTING
1% AEP
SEAHAM
GREEN ROCKS
MAITLAND
GRAHAMSTOWN DAM
RAYMOND TERRACE
HEATHERBRAE
TARRO
Pacific Hwy
TOMAGO
HEXHAM
FULLERTON COVE
PACIFIC OCEAN
NEWCASTLE
N
Operational Footprint
Model Extent
Percent Change in Duration (%)
< -50
-50 - -30
-30 - -10
-10 - 10
10 - 30
30 - 50
> 50
Newly flooded
No longer flooded
0
2
4
6
8
10
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG78_DD_InundationImpacts_1p.mxd

FIGURE 79
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT BUILDINGS FLOOD LEVEL 20% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_iteration06\FDR\FIG79_20p_DD_FloodLevelCompliance_Buildings.mxd

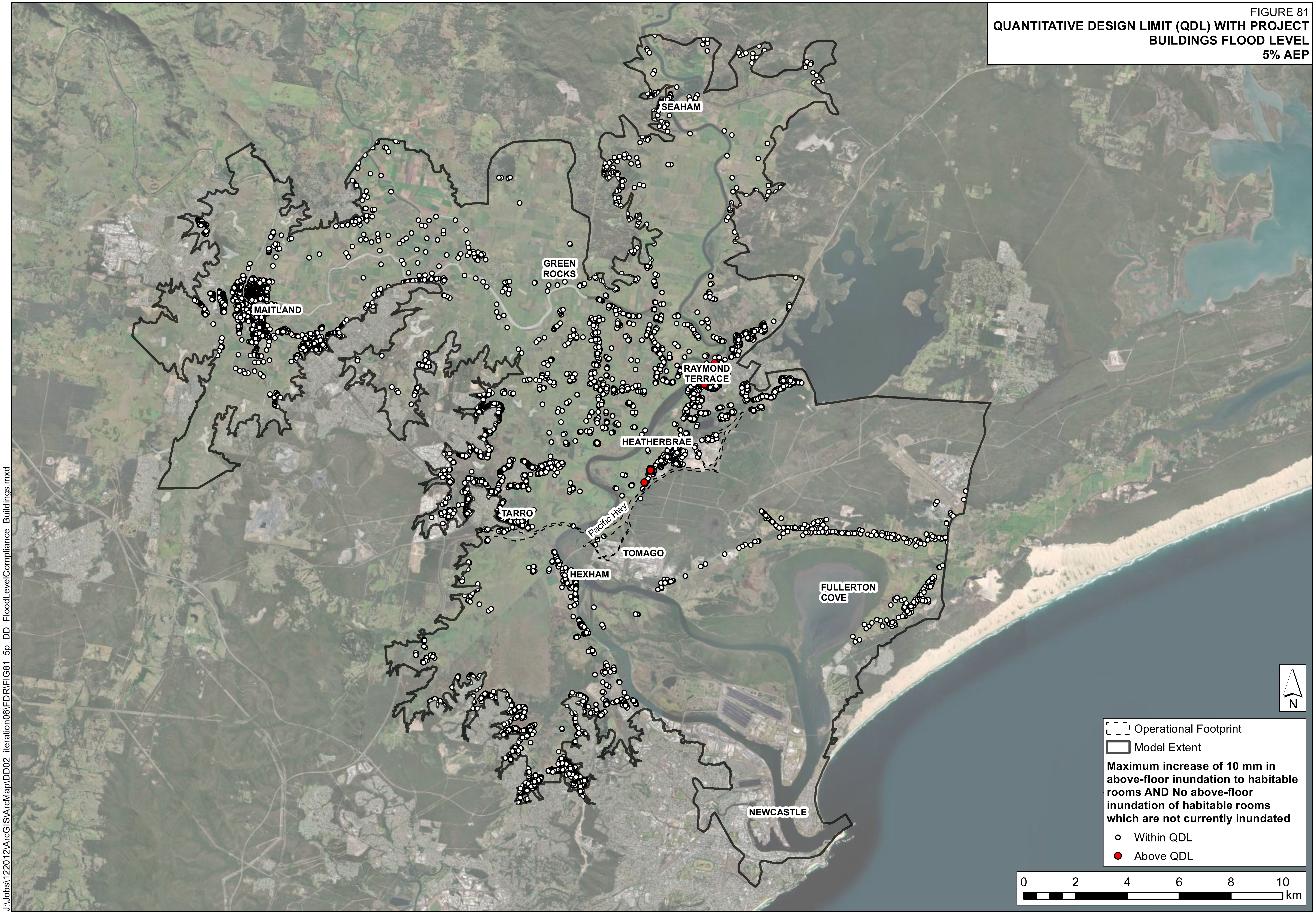
FIGURE 80
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT BUILDINGS FLOOD LEVEL 10% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_iteration06\FDR\FIG80_10p_DD_FloodLevelCompliance_Buildings.mxd

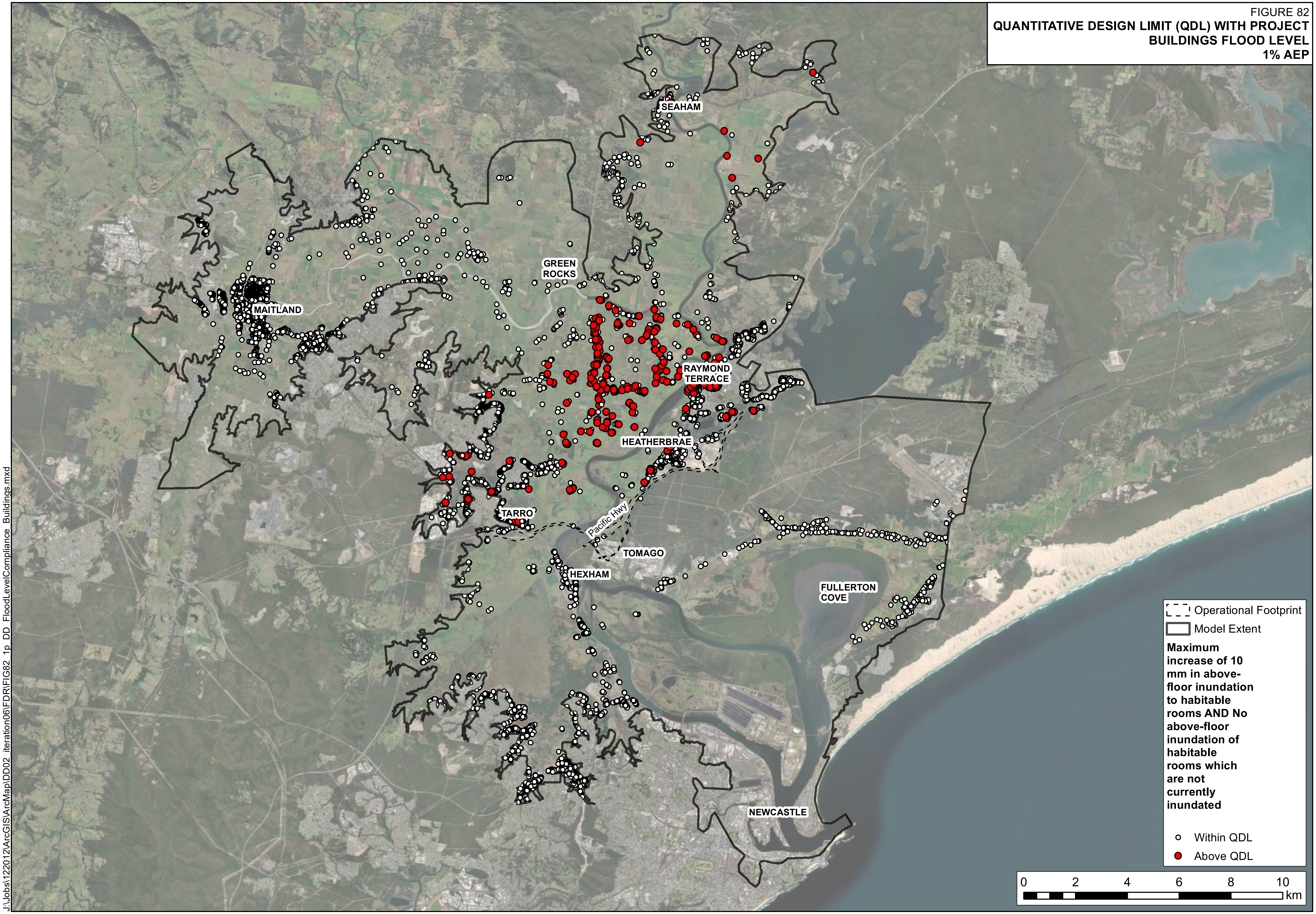
FIGURE 81

QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT BUILDINGS FLOOD LEVEL 5% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_iteration06\FDR\FIG81_5p_DD_FloodLevelCompliance_Buildings.mxd

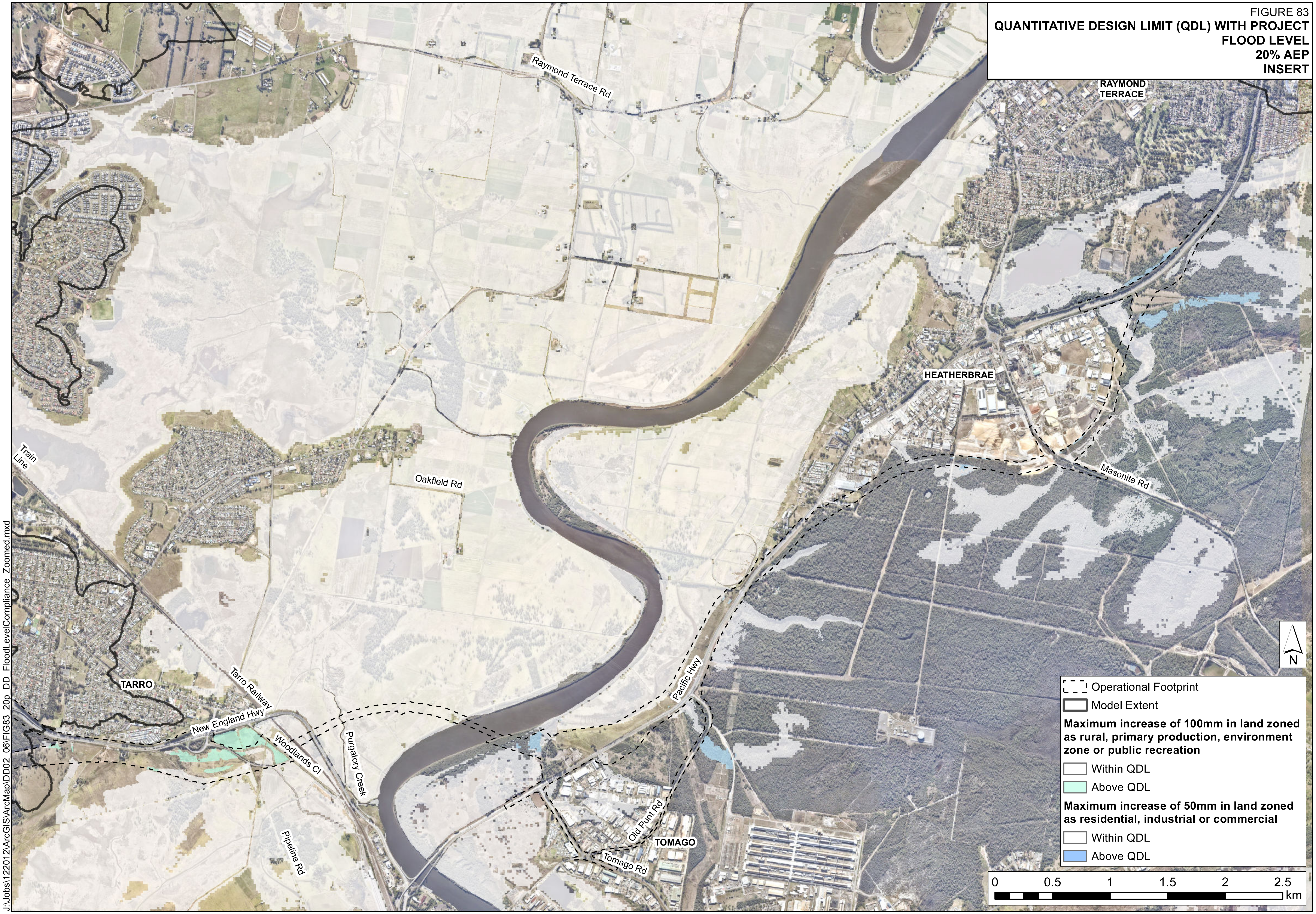
FIGURE 82
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT BUILDINGS FLOOD LEVEL 1% AEP



J:\Jobs\122012\ArcGIS\ArcMap\DD02_iteration06\FDR\FIG82_1p_DD_FloodLevelCompliance_Buildings.mxd

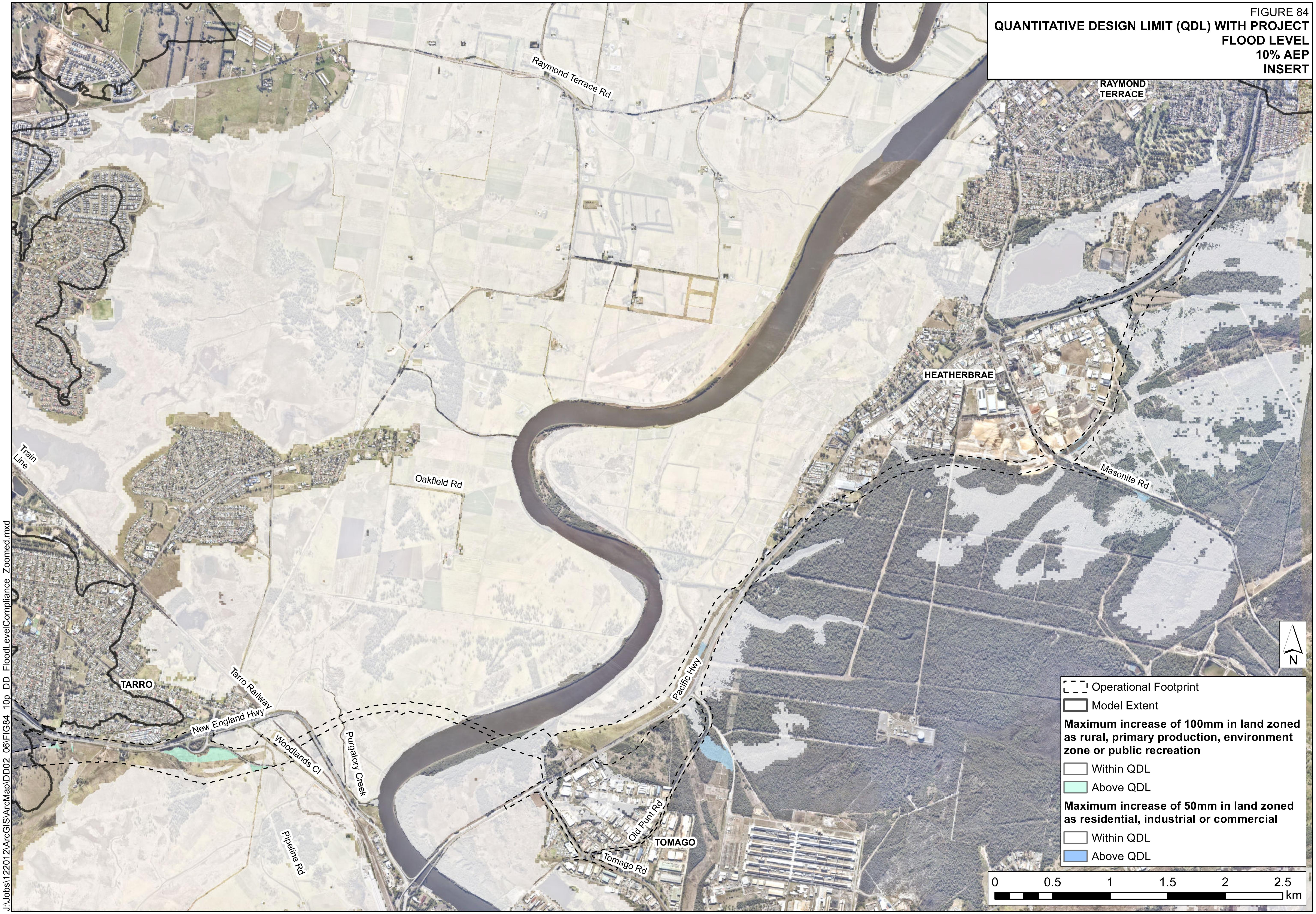
FIGURE 83

QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT FLOOD LEVEL 20% AEP INSERT



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG83_20p_DD_FloodLevelCompliance_Zoomed.mxd

FIGURE 84
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT FLOOD LEVEL 10% AEP INSERT



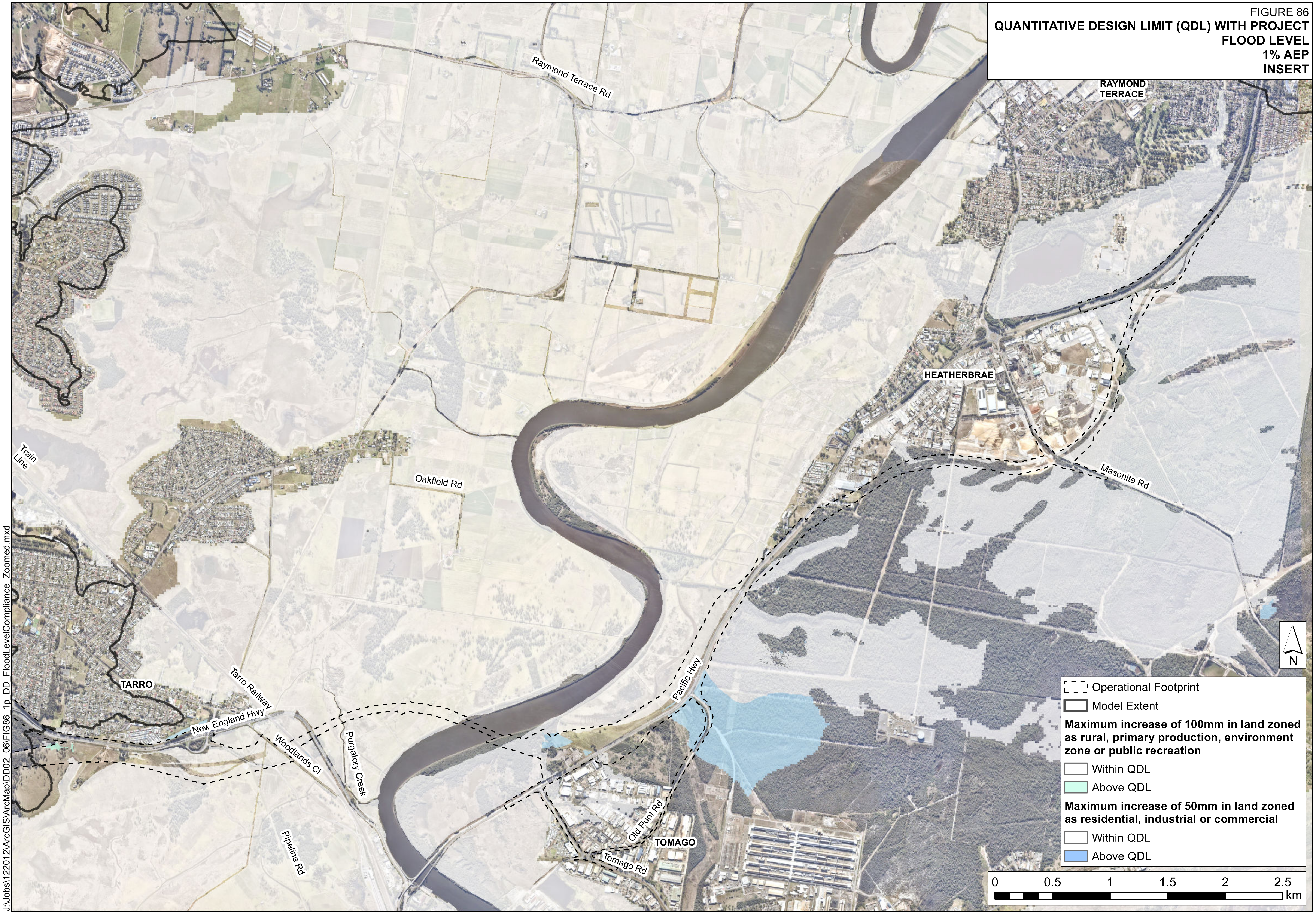
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG84_10p_DD_FloodLevelCompliance_Zoomed.mxd

FIGURE 85
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT FLOOD LEVEL 5% AEP INSERT

Operational Footprint
Model Extent
Maximum increase of 100mm in land zoned as rural, primary production, environment zone or public recreation
Within QDL
Above QDL
Maximum increase of 50mm in land zoned as residential, industrial or commercial
Within QDL
Above QDL

FIGURE 86

QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT FLOOD LEVEL 1% AEP INSERT



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG86_1p_DD_FloodLevelCompliance_Zoomed.mxd


FIGURE 87
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT
FLOOD VELOCITY
20% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Oakfield Rd
Train Line
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pipeline Rd
Pacific Hwy
Old Punt Rd
TOMAGO
Tomago Rd
N
Operational Footprint
Model Extent
Maximum increase of 10% where the resulting velocity is greater than 1m/s
Wihin QDL
Above QDL
0
0.5
1
1.5
2
2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG87_20p_FloodVelocityCompliance_Zoomed.mxd

FIGURE 88

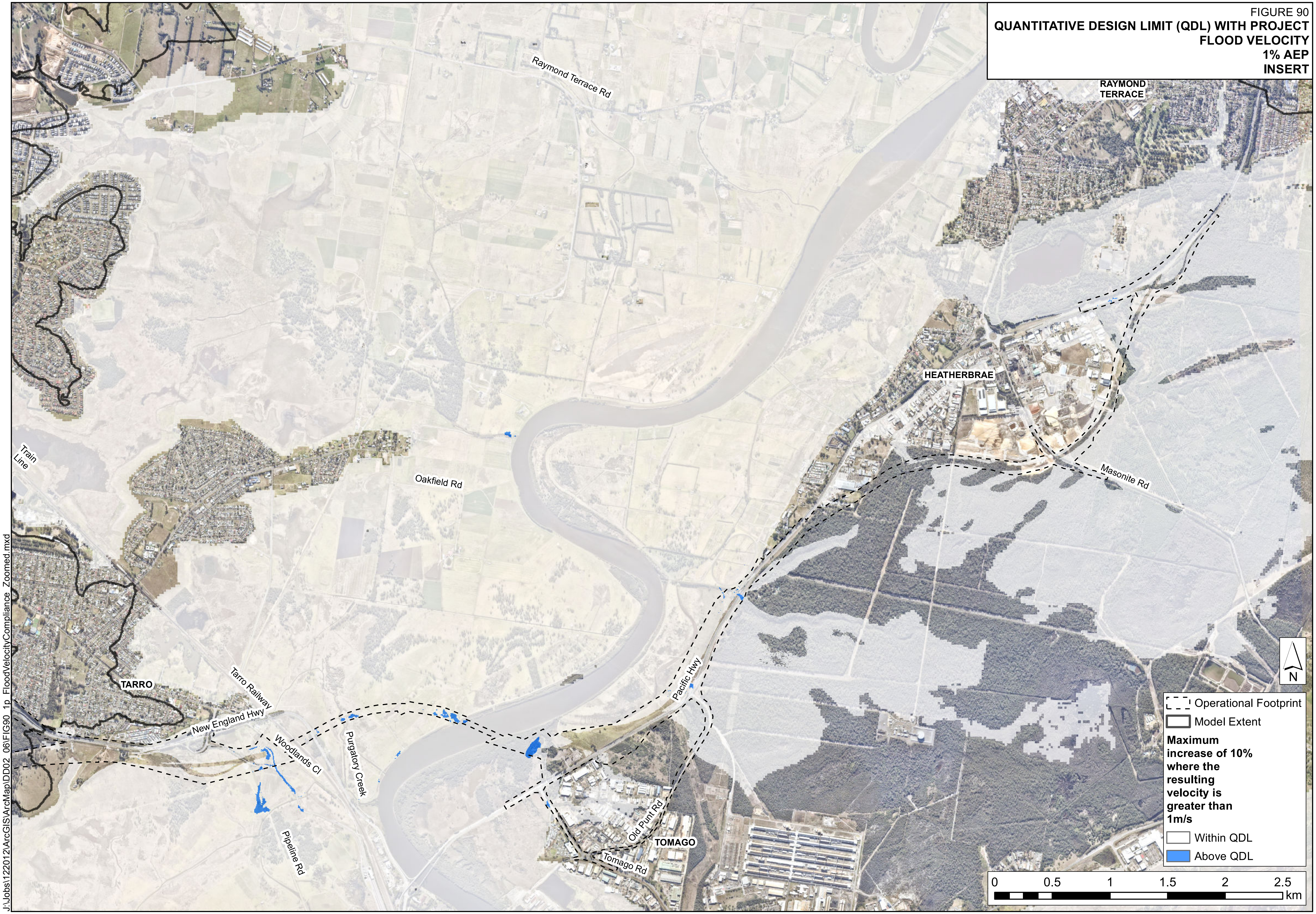
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT FLOOD VELOCITY 10% AEP INSERT

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG88_10p_FloodVelocityCompliance_Zoomed.mxd

FIGURE 89

QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT FLOOD VELOCITY 5% AEP INSERT

J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG89_5p_FloodVelocityCompliance_Zoomed.mxd



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG90_1p_FloodVelocityCompliance_Zoomed.mxd

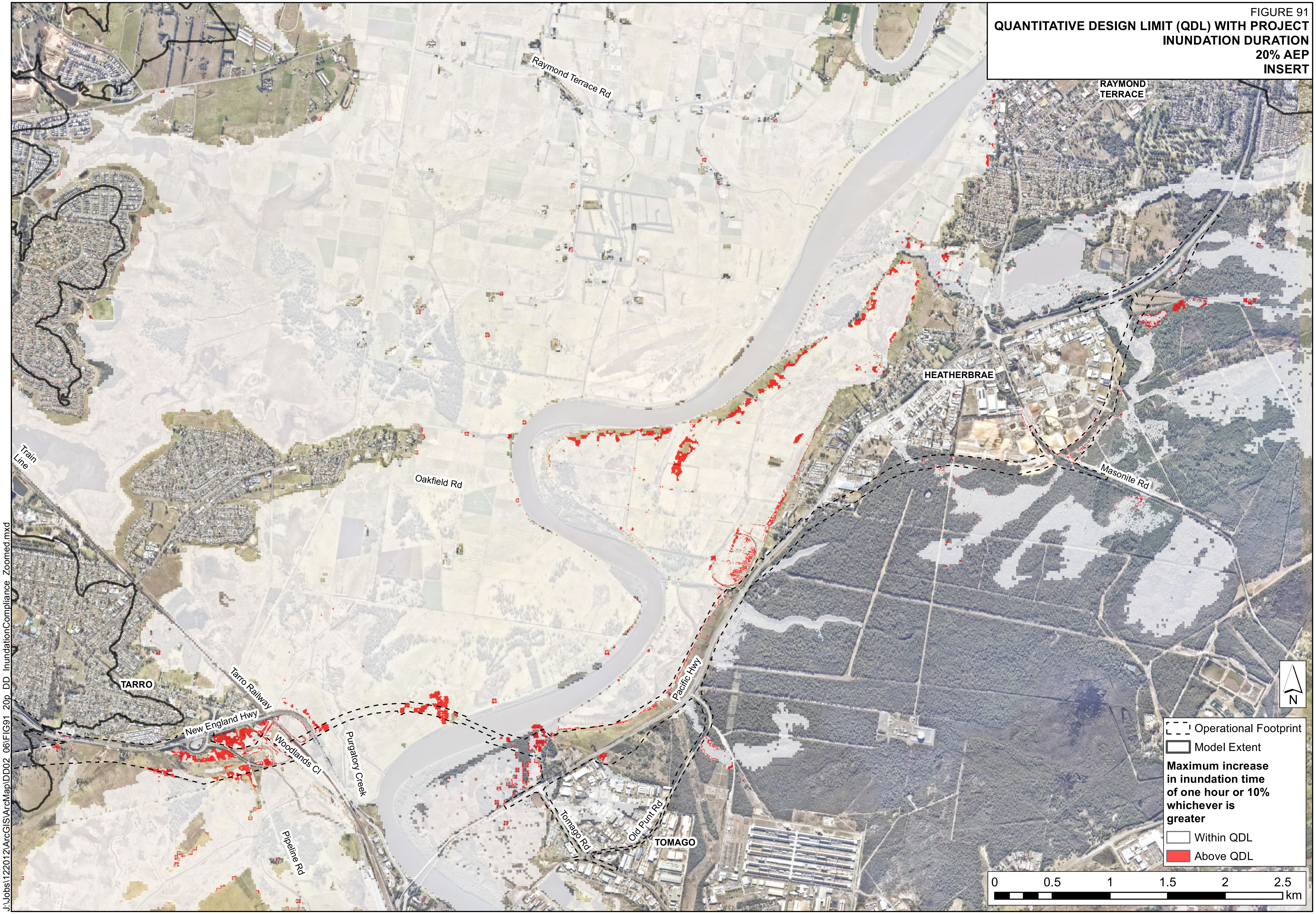
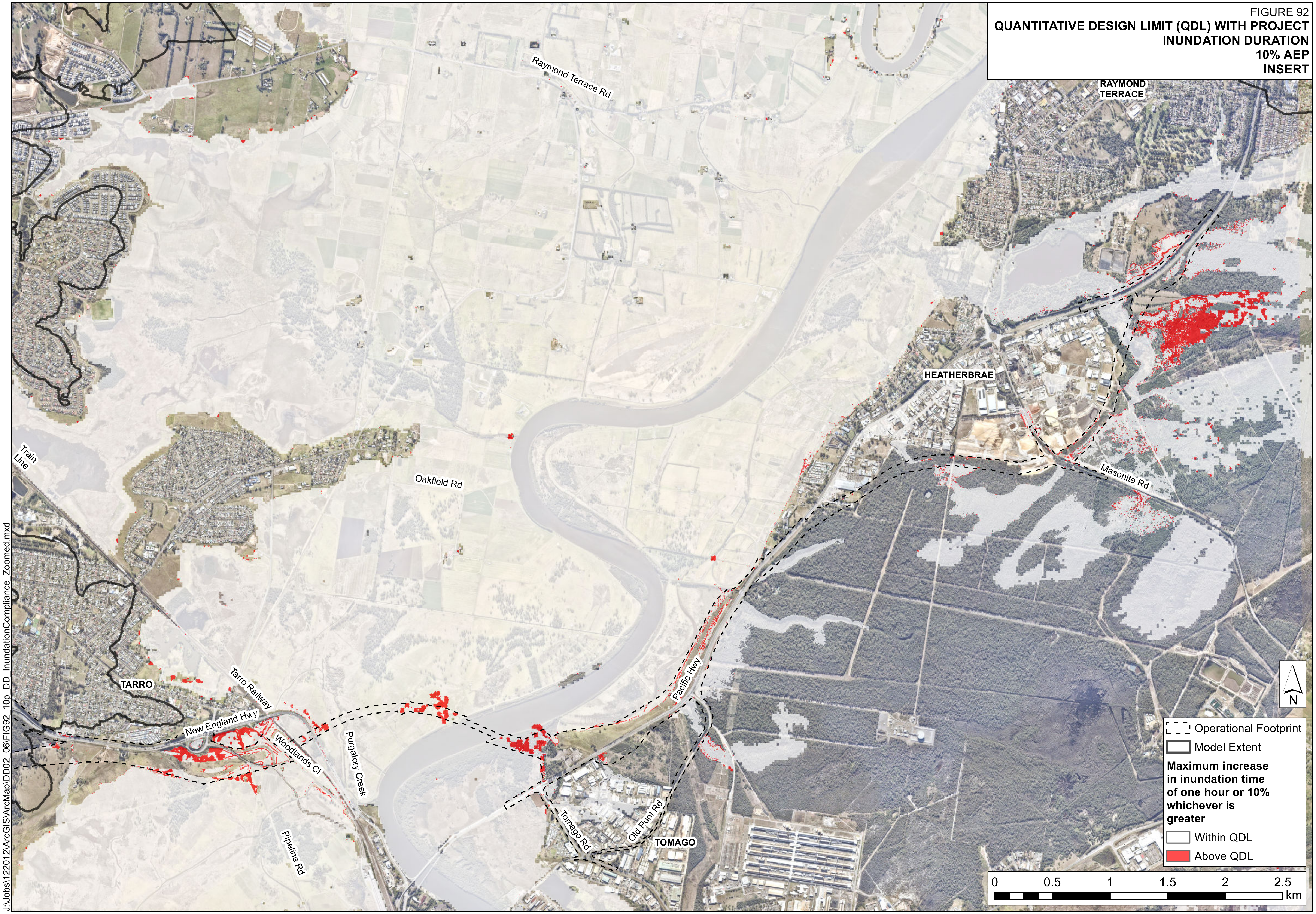


FIGURE 91
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT
INUNDATION DURATION
20% AEP
INSERT
RAYMOND TERRACE
Raymond Terrace Rd
HEATHERBRAE
Masonite Rd
Oakfield Rd
Train Line
TARRO
Tarro Railway
New England Hwy
Woodlands Cl
Purgatory Creek
Pacific Hwy
Tomago Rd
Old Punt Rd
TOMAGO
Pipeline Rd
N
Operational Footprint
Model Extent
Maximum increase in inundation time of one hour or 10% whichever is greater
Within QDL
Above QDL
0
0.5
1
1.5
2
2.5
km
J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG91_20p_DD_InundationCompliance_Zoomed.mxd

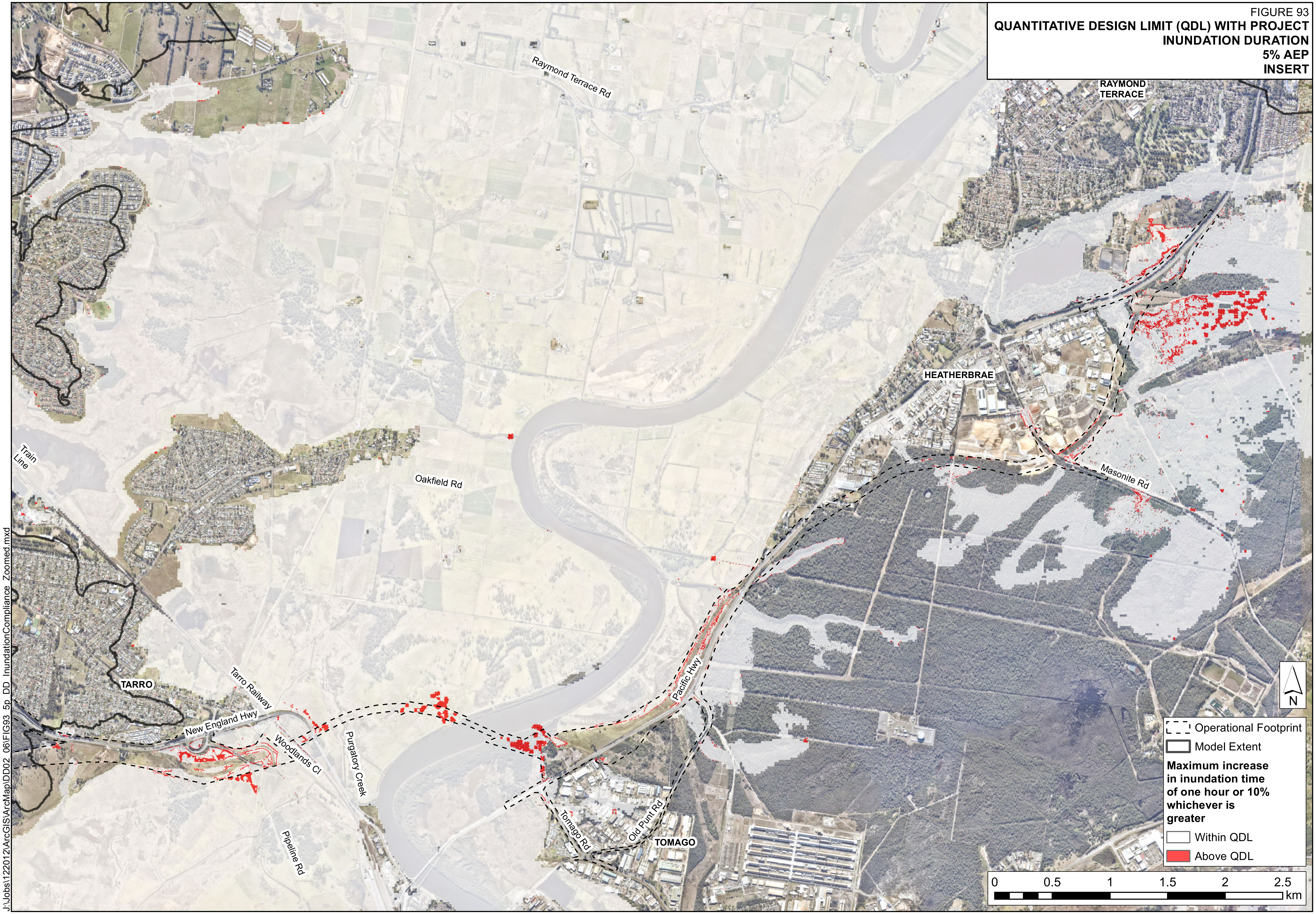
FIGURE 92
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT INUNDATION DURATION 10% AEP INSERT



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG92_10p_DD_InundationCompliance_Zoomed.mxd

FIGURE 93

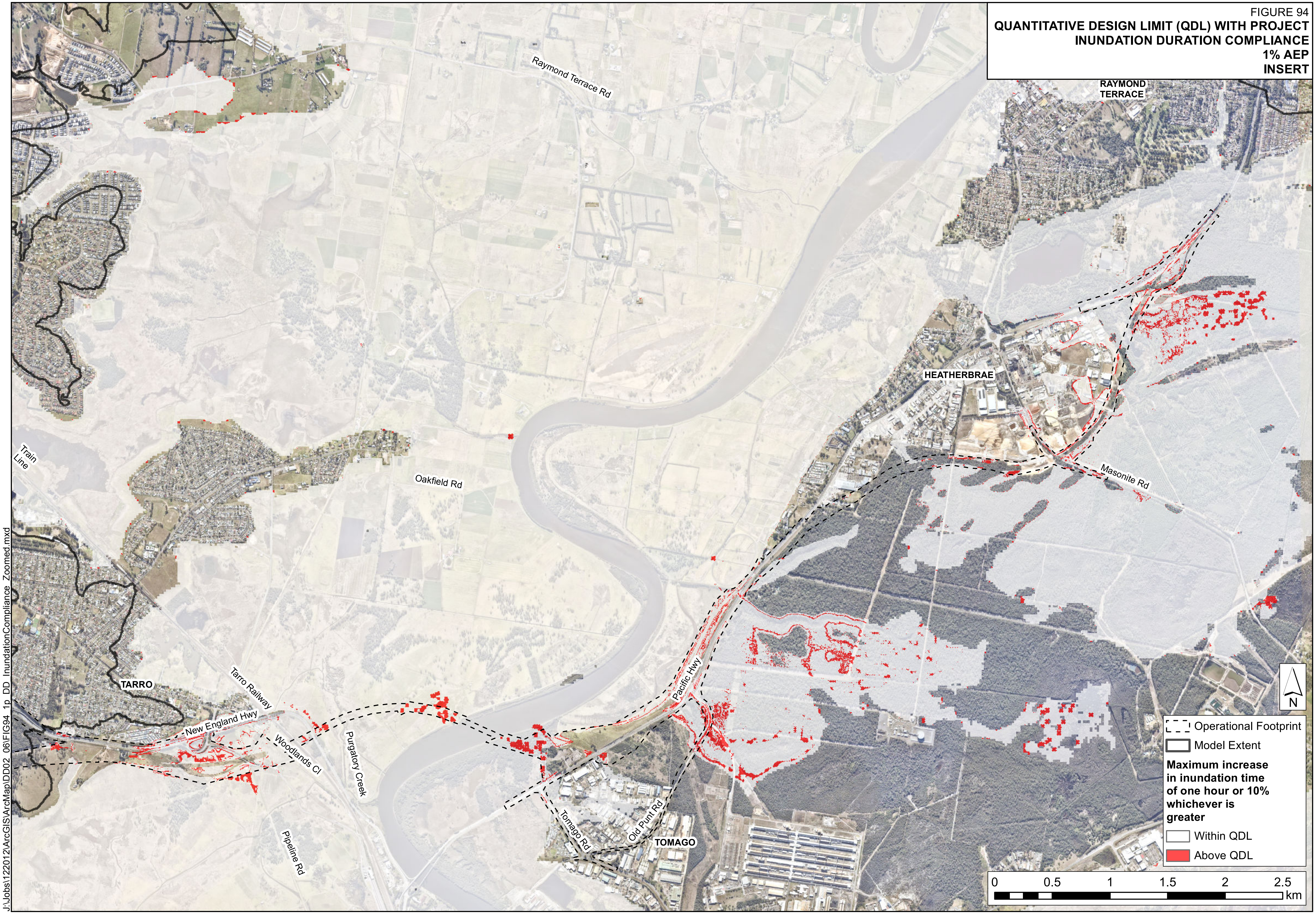
QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT INUNDATION DURATION 5% AEP INSERT



J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG93_5p_DD_InundationCompliance_Zoomed.mxd

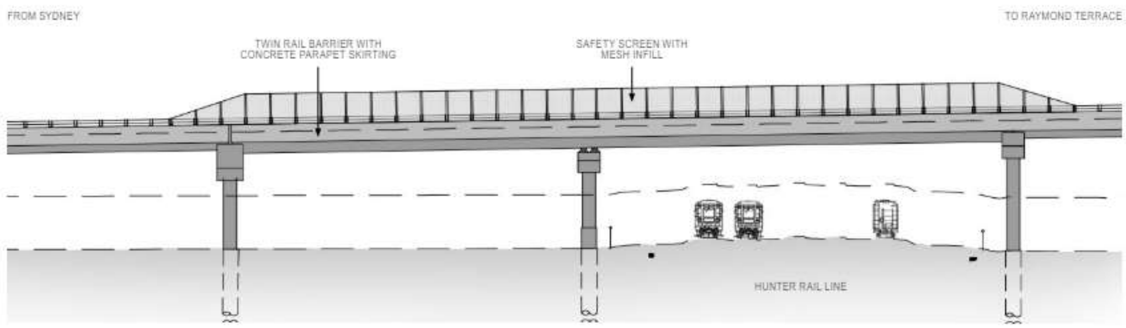
FIGURE 94

QUANTITATIVE DESIGN LIMIT (QDL) WITH PROJECT INUNDATION DURATION COMPLIANCE 1% AEP INSERT

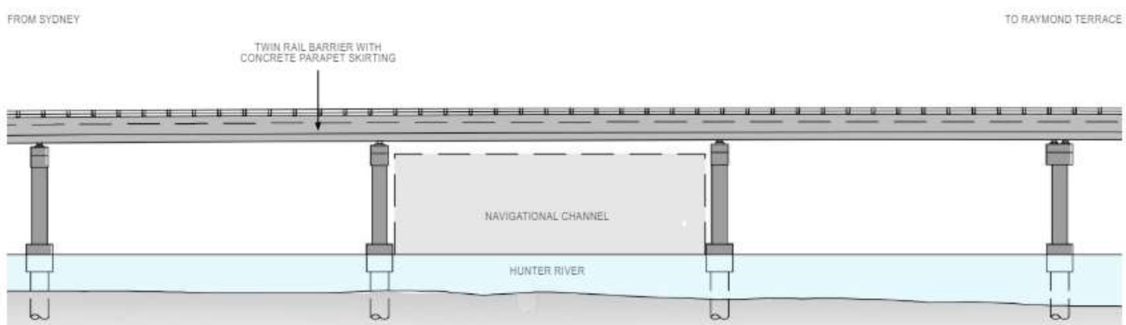


J:\Jobs\122012\ArcGIS\ArcMap\DD02_06\FIG94_1p_DD_InundationCompliance_Zoomed.mxd

IX. Appendix A



BR05 - TYPICAL ELEVATION SHOWING SAFETY SCREEN



BR05 - TYPICAL ELEVATION OVER WATER

Diagram A 1: Typical Plan view of the new bridge

Diagram A 2: River view looking north

Diagram A 3: River view of bridge - looking west

Diagram A 4: Aerial view of the Project - looking east

X. Glossary

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.
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.
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).
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major

	drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defied.
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).
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the A tandard 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.
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.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

stage — Equivalent to Awater level@. Both are measured with reference to a specified datum.

stage hydrograph — A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.

survey plan — A plan prepared by a registered surveyor.

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